Life Science

Introduction to Life Science

Introduction

What does it mean to be alive?

Scientifically, there is an actual definition of living. Living organisms must have certain characteristics. If they do not have these characteristics, are they living? This butterfly, like all other insects, animals, plants, and every other living organism, shares common characteristics with all life. What exactly does it mean to be alive? This chapter will answer this question. These concepts will serve as an introduction to life science, discussing the basics of studying the life sciences and addressing the question, "What is a living organism?"

Section 1

Scientific Ways of Thinking

Scientific Ways of Thinking

•Describe the role of a scientist.
•Describe what is meant by "thinking like a scientist."

What was that noise?

If you let your emotions rule your thinking, you might think a thumping noise was a ghost. If you think like a scientist, however, you ask questions and make observations. You'd observe the shutters are loose and blowing in the wind.

Scientific Ways of Thinking

Modern science is a way of understanding the physical world, based on observable evidence, reasoning, and repeated testing. That means scientists explain the world based on their own observations. If they develop new ideas about the way the world works, they set up a way to test these new ideas.

Thinking Like a Scientist

How can you think like a scientist? Thinking like a scientist is based on asking and answering questions. Though you may not know it, you do this all day long. Scientists ask questions, and then make detailed observations to try to ask more specific questions and develop a **hypothesis** . They may design and perform an **experiment** to try to answer their question. From the results of their experiment, scientists draw **conclusions** .

•**Scientists ask questions** : The key to being a great scientist is to ask questions. Imagine you are a scientist in the African Congo. While in the field, you observe one group of healthy chimpanzees on the north side of the jungle. On the other side of the jungle, you find a group of chimpanzees that are mysteriously dying. What questions might you ask? A good scientist might ask the following two questions:
1."What differs between the two environments where the chimpanzees live?"
2."Are there differences in behavior between the two groups of chimpanzees?"

•**Scientists make detailed observations** : To **observe** means to watch and study attentively. A person untrained in the sciences may only observe, "The chimps on one side of the jungle are dying, while chimps on the other side of the jungle are healthy." A scientist, however, will make more detailed observations. Can you think of ways to make this observation more detailed? What about the number of chimps? Are they male or female? Young or old? What do they eat? A good scientist may observe, "While all seven adult females and three adult males on the north side of the jungle are healthy and show normal behavior, four female and five male chimps under the age of five on the south side have died." Detailed observations can ultimately help scientists design their experiments and answer their questions. From these observations, a scientist will develop a hypothesis to explain the observations. A hypothesis is the scientist's proposed explanation for his observations. The scientist's hypothesis may be that "Young chimps on the south side die due to a lack of nutrients in their diet."

Figure 1.1

An adult and infant chimpanzee (*Pan troglodytes*).

•**Scientists find answers using tests** : When scientists want to answer a question, they search for evidence using experiments. An experiment is a test to see if their explanation is right or wrong. **Evidence** is made up of the observations a scientist makes during an experiment. To study the cause of death in the chimpanzees, scientists may give the chimps nutrients in the form of nuts, berries, and vitamins to see if they are dying from a lack of food. This test is the experiment. If fewer chimps die, then the experiment

shows that the chimps may have died from not having enough food. This is the evidence.
•**Scientists question the answers** : Good scientists are skeptical. Scientists never use only one piece of evidence to form a conclusion. For example, the chimpanzees in the experiment may have died from a lack of food, but can you think of another explanation for their death? They may have died from a virus, or from another less obvious cause. More experiments need to be completed before scientists can be sure. Good scientists constantly question their own conclusions. They also find other scientists to confirm or disagree with their evidence.

Summary

•Modern science is a way of understanding the physical world, based on observable evidence, reasoning, and repeated testing.
•To think like a scientist, you must ask questions, make detailed observations, develop a hypothesis, find answers using tests, and question your answers.

Explore More

Use the resource below to answer the questions that follow.

•**Understanding Science** at http://undsci.berkeley.edu/article/scienceflowchart
1.Once an experiment has been conducted and the results analyzed, what 4 possible responses are there when interpreting the data?
2.How does "peer review" fit into the scientific process? Why is it so important?
3.In the flowchart, what 5 processes are involved in "Exploration and Discovery"? Do you think any one of these processes is more important than the others? Explain your reasoning.

Review

1.What is modern science?
2.How do you think scientifically?
3.What does it mean "to observe"?
4.What is a hypothesis?

Section 2

Fields in the Life Sciences

Fields in the Life Sciences

- Define life science.
- Describe the major fields within the life sciences.
- Explain what is studied in cell biology, genetics, and evolution.

What kind of scientist studies dolphins?

Dolphins are living organisms, so studying them is part of the life sciences. The life sciences, however, are broken down into many fields. Scientists that study dolphins and other life in the ocean are called marine biologists.

Fields in the Life Sciences

The **life sciences** are the study of living organisms. They deal with every aspect of living organisms, from the biology of **cells** , to the biology of individual organisms, to how these organisms interact with other organisms and their environment.

The life sciences are so complex that most scientists focus on just one or two subspecialties. If you want to study insects, what would you be called? An entomologist. If you want to study the tiny things that give us the flu, then you need to enter the field of **virology** , the study of viruses. If you want to study the nervous system, which life science field is right for you (**Table** below , **Table** below , and **Table** below)?

Field	Focus
Botany	Plants
Zoology	Animals
Marine biology	Organisms living in oceans
Freshwater biology	Organisms living in and around freshwater lakes, streams, rivers, ponds, etc.
Microbiology	Microorganisms

Field	Focus
Cell biology	Cells and their structures/functions
Anatomy	Structures of animals
Morphology	Form and structure of living organisms
Physiology	Physical and chemical functions of tissues and organs
Immunology	Mechanisms inside organisms that protect them from disease and infection
Neuroscience	The nervous system
Developmental biology and embryology	Growth and development of plants and animals
Genetics	Genetic makeup of living organisms and heredity
Biochemistry	Chemistry of living organisms
Molecular biology	Nucleic acids and proteins
Epidemiology	How diseases arise and spread
Evolution	The changing of species over time

Field	Focus
Ecology	How various organisms interact with their environments
Biogeography	Distribution of living organisms
Population biology	The biodiversity, evolution, and environmental biology of populations of organisms

During the study of the life sciences, you will study **cell biology** , **genetics** , **molecular biology** , **botany** , **microbiology** , **zoology** , **evolution** , **ecology** , and **physiology** . Cell biology is the study of cellular structure and function (**Figure** below). Genetics is the study of **heredity** , which is the passing of traits from one generation to the next. Molecular biology is the study of molecules, such as DNA and proteins. What will you study with the other subspecialties?

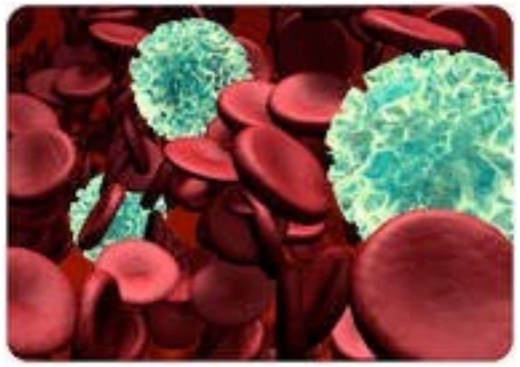


Figure 1.2

This illustration shows a virus among red blood cells. Which fields study red blood cells and viruses? (Keep in mind that viruses are actually much smaller than cells.)

Figure 1.3

Other life science subspecialties include biogeography, which is the study of where organisms live and at what abundance.

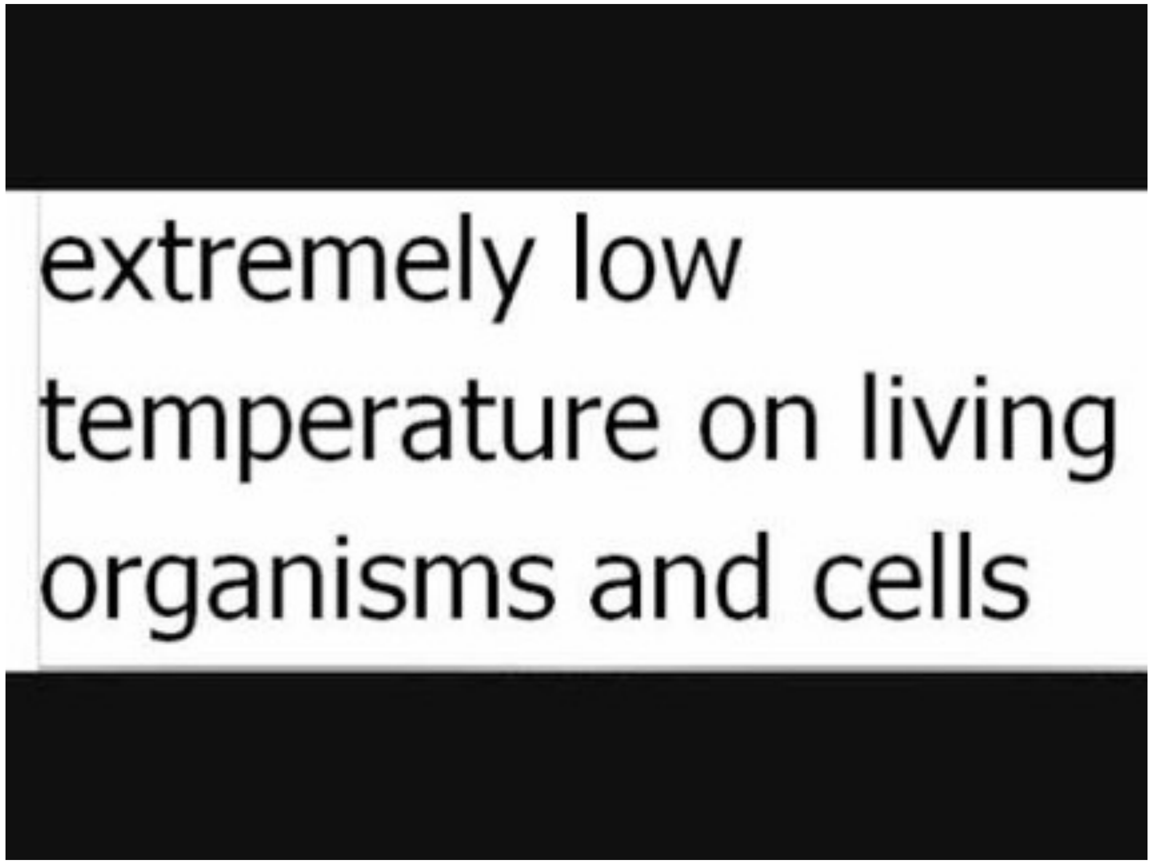
Summary

- There are several subspecialties within the life sciences that focus on one type of organism, such as virology and bacteriology.
- There are several fields of the life sciences that examine interactions between organisms and their environments, such as ecology.

Explore More

Use the resource below to answer the questions that follow.

- **Branches of Biology** at http://www.youtube.com/watch?v=OrlOOJ0Tm_E (3:28)



Click on the image above for more content

1. What is the study of reptiles and amphibians?
2. What is the study of prehistoric life by means of fossils?
3. What is the study of mollusks?
4. What is the study of cells?
5. What is the study of fungi?
6. What is ecology?

Review

1. What is name of the field of the life sciences that studies insects?

2.What is name of the field of the life sciences that studies the nervous system?
3.What are cell biology, genetics, and molecular biology?

Section 3

Scientific Theories

Scientific Theories

•Explain the concepts of a hypothesis and scientific evidence.
•Distinguish between a scientific theory and a scientific law.

What causes disease?

Today most people realize that microorganisms, such as bacteria or viruses, are the cause of disease. This concept is known as the germ theory of disease, one of the few scientific theories in the field of the life sciences. Although it seems obvious now, people did not always understand the cause of disease. How does a theory such as this become established?

Scientific Evidence and Theories

One goal of a scientist is to find answers to scientific questions. To do this, scientists first develop a **hypothesis** , which is a proposed explanation that tries to explain an observation. To collect **evidence** to support (or disprove) their hypothesis, scientists must do **experiments.** Evidence is:

1. A direct, physical observation of something or a process over time.
2. Usually something measurable or "quantifiable."
3. The data resulting from an experiment.

For example, an apple falling to the ground is evidence in support of the law of gravity. A bear skeleton in the woods would be evidence of the presence of bears.

Looking at the image below might be confusing at first because this evidence seems to defy the law of gravity (**Figure** below). Of course water cannot be poured out of bottle and flow upward. The law of gravity is a **scientific law** , which is a statement describing what always happens under certain conditions in nature. Scientific laws are developed from lots of collected information.

Figure 1.4

Water going upward against gravity.

If many experiments are performed, and lots of evidence is collected in support of a general hypothesis, a scientific theory can be developed. **Scientific theories** are well established explanations of evidence. Theories are usually tested and confirmed by many different people. Scientific theories usually have a lot of evidence in support of the theory, and no evidence disproving the theory. Scientific theories produce information that helps us understand our world. For example, the idea that matter is made up of atoms is a scientific theory. Scientists accept this theory as a fundamental principle of basic science. However, when scientists find new evidence, they can change their theories. In addition to the germ theory of disease, other scientific theories are the cell theory and the theory of evolution.

Summary

- Evidence is a direct, physical observation of something or a process.
- Scientific theories are explanations of some aspect of the natural world based on repeated observations.

Explore More

Use the resource below to answer the questions that follow.

- **Scientific Theories** at http://www.youtube.com/watch?v=-M1hxGj5bMg (4:43)

Click on the image above for more content

1. What happens to scientific ideas that do not match the natural world?

2. In science, what is meant by a fact, a hypothesis, a theory, and a law?
3. How do scientists' views of theories differ from the everyday use of these words?

Review

1. What is evidence?
2. What is a scientific theory?
3. What is a scientific law?

Section 4

Scientific Investigation

Scientific Investigation

- •Define and describe the scientific method.
- •Summarize the characteristics of a scientific hypothesis.
- •Develop a scientific hypothesis.
- •Explain the importance of communicating results.

How do scientists obtain new knowledge?

All the information in textbooks had to come from somewhere. In the sciences, new information about the natural world is a result of scientific investigations. These investigations are shaped by the scientific method.

Scientific Method

The **scientific method** is a process used to investigate the unknown (**Figure** below). It is the general process of a **scientific investigation** . This process uses evidence and testing. Scientists use the scientific method so they can find information. A common method allows all scientists to answer questions in a similar way. Scientists who use this method can reproduce another scientist's experiments.

Almost all versions of the scientific method include the following steps, although some scientists do use slight variations.

1. Make observations.
2. Identify a question you would like to answer based on the observation.
3. Find out what is already known about your observation (research).
4. Form a hypothesis.
5. Test the hypothesis.
6. Analyze your results and draw conclusions.
7. Communicate your results.

Figure 1.5

Steps of a Scientific Investigation. A scientific investigation typically has these steps.

Making Observations

Imagine that you are a scientist. While collecting water samples at a local pond, you notice a frog with five legs instead of four (**Figure** below). As you start to look around, you discover that many of the frogs have extra limbs, extra eyes, or no eyes. One frog even has limbs coming out of its mouth. These are your **observations** , or things you notice about an environment using your five senses.

Figure 1.6

A frog with an extra leg.

Identify a Question Based on Your Observations

The next step is to ask a question about the frogs. You may ask, "Why are so many frogs deformed?" Or, "Is there something in their environment causing these defects, like water pollution?" Yet, you do not know if this large number of deformities is "normal" for frogs. What if many of the frogs found in ponds and lakes all over the world have similar deformities? Before you look for causes, you need to find out if the number and kind of deformities is unusual. So besides finding out *why* the frogs are deformed, you should also ask: "Is the percentage of deformed frogs in this pond greater than the percentage of deformed frogs in other places?"

Figure 1.7

A pond with frogs.

Research Existing Knowledge About the Topic

No matter what you observe, you need to find out what is already known about your questions. For example, is anyone else doing research on deformed frogs? If yes, what did they find out? Do you think that you should repeat their research to see if it can be duplicated? During your research, you might learn something that convinces you to change or refine your question. From this, you will construct your hypothesis.

Construct a Hypothesis

A **hypothesis** is a proposed explanation that tries to explain an observation. A good hypothesis allows you to make more predictions. For example, you might hypothesize that a pesticide from a nearby farm is running into the pond and causing frogs to have extra legs. If that's true, then you can predict that the water in a pond of non-deformed frogs will have lower levels of that pesticide. That's a prediction you can test by measuring pesticide levels in two sets of ponds, those with deformed frogs and those with nothing but healthy frogs. Every hypothesis needs to be written in a way that it can:

1. Be tested using evidence.
2. Be proven wrong.
3. Provide measurable results.
4. Provide yes or no answers.

For example, do you think the following hypothesis meets the four criteria above? Let's see. Hypothesis: "The number of deformed frogs in five ponds that are polluted with chemical X is higher than the number of deformed frogs in five ponds without chemical X." Of course, next you will have to test your hypothesis.

Test Your Hypothesis

To test the hypothesis, an **experiment** will be done. You would count the healthy and deformed frogs and measure the amount of chemical X in all of the ponds. The hypothesis will be either true or false. Doing an experiment will test most hypotheses. The experiment may generate evidence in support of the hypothesis. The experiment may also generate evidence proving the hypothesis false. Once you collect your data, it will need to be analyzed.

Analyze Data and Draw a Conclusion

If a hypothesis and experiment are well designed, the experiment will produce results that you can measure, collect, and analyze. The analysis should tell you if the hypothesis is true or false. Refer to the table for the experimental results (**Table** below).

Polluted Pond	Number of Deformed Frogs	Non-Polluted Pond	Number of Deformed Frogs
1	20	1	23
2	23	2	25
3	25	3	30
4	26	4	16
5	21	5	20
Average:	23	Average:	22.8

Your results show that pesticide levels in the two sets of ponds are different, but the average number of deformed frogs is almost the same. Your results demonstrate that your hypothesis is false. The situation may be more complicated than you thought. This gives you new information that will help you decide what to do next. Even if the results supported your hypothesis, you would probably ask a new question to try to better understand what is happening to the frogs and why.

Drawing Conclusions and Communicating Results

If a hypothesis and experiment are well designed, the results will indicate whether your hypothesis is true or false. If a hypothesis is true, scientists will often continue testing the hypothesis in new ways to learn more. If a hypothesis is false, the results may be used to come up with and test a new hypothesis. A scientist will then communicate the results to the scientific community. This will allow others to review the information and extend the studies. The scientific community can also use the information for related studies. Scientists communicate their results in a number of ways. For example, they may talk to small groups of scientists and give talks at large scientific meetings. They will also write articles for scientific journals. Their findings may also be communicated to journalists.

If you conclude that frogs are deformed due to a pesticide not previously measured, you would publish an article and give talks about your research. Your conclusion could eventually help find solutions to this problem.

Discovering the Scientific Method

A summery video of the scientific method, using the identification of DNA structure as an example, is shown in this video by MIT students: https://www.youtube.com/watch?v=5eDNgeEUtMg .

Summary

- To study new problems, scientists use the scientific method; this includes making observations, forming a hypothesis, designing an experiment, and drawing conclusions.

Explore More

Use the resource below to answer the questions that follow.

- **Control Variables** at http://www.youtube.com/watch?v=hjCvIbYoi-w (7:05)

Click on the image above for more content

1. What is the difference between a dependent and an independent variable?
2. How many dependent variables do you want in an experiment?
3. What are control variables?
4. Why are control variables important?

Review

1. What steps are usually included in the scientific method?
2. What are the features of a good hypothesis?
3. Why is it important for a scientist to communicate the results and conclusions of a study?

Section 5

Basic and Applied Science

Basic and Applied Science

- •Define basic science and applied science.
- •Distinguish between basic science and applied science.

Why should we study the rainforest?

Some scientists study problems that seem to have very little impact on our lives. For example, scientists are working to describe every type of plant and animal in the rainforest. What is the purpose? Many of our medicines come from plants and animals of the rainforest. So what medicines have not yet been discovered? There might be new cures to diseases yet to be identified. This is an example of how science can be applied to our lives.

Basic and Applied Science

Science can be "basic" or "applied." The goal of **basic science** is to understand how things work—whether it is a single **cell** , an organism made of trillions of cells, or a whole **ecosystem** . Scientists working on basic science questions are simply looking to increase human knowledge of nature and the world around us. The knowledge obtained through the study of the subspecialties of the life sciences is mostly basic science. Basic science is the source of most **scientific theories** . For example, a scientist that tries to figure out how the body makes cholesterol is performing basic science. This is also known as basic research.

The study of the cell (cell biology), the study of inheritance (genetics), the study of molecules (molecular biology), the study of microorganisms and viruses (microbiology and virology), the study of tissues and organs (physiology) have all generated lots of information that is applied to humans and human health. **Applied science** is using scientific discoveries to solve practical problems. For example, medicine, and all that is known about how to treat patients, is applied science based on basic research (**Figure** below). A doctor administering a drug to lower a person's cholesterol is an example of applied science. Applied science also creates new technologies based on basic science. For example, designing windmills to capture wind energy is applied science (**Figure** below). This technology relies, however, on basic science. Studies of wind patterns and bird migration routes help determine the best placement for the windmills.

Figure 1.8

Surgeons operating on a person, an example of applied science.

Figure 1.9

Windmills capturing energy, an example of applied science.

Summary

- Basic science, such as understanding how cells work, is research aimed at understanding fundamental problems.
- Applied science, such as the medical field, is the application of basic scientific knowledge to solve practical problems.
- Applied science uses and applies information obtained through basic science.

Explore More

Use the resources below to answer the questions that follow.

Explore More I

- **Basic vs. Applied Research** at http://www.sjsu.edu/people/fred.prochaska/courses/ScWk170/s0/Basic%20vs.%20Applied%20Research.pdf

1. What is basic research? Give two examples of basic research.
2. What is applied research? Give two examples of applied research.
3. What is the relationship between basic research and applied science?
4. Why do some scientists believe more emphasis needs to be placed on applied science?

Explore More II

•**Reinvesting in Basic Research** at http://www.youtube.com/watch?v=NHjrMtECVo0 (3:58)

Click on the image above for more content

1. How could basic biomedical research lead to better physicians?
2. What is BMPER? Did its discovery come from basic or applied research? Explain your resoning fully.

Review

1. What is the difference between basic and applied science?
2. What is an example of applied science?

Section 6

Microscopes

Microscopes

•Describe how microscopes are used in the life sciences.
•Identify how cells were first identified.

How can we see the details of bacteria?

With the naked eye, bacteria just look like a slimy smear on a petri dish. How can we study them in more detail? The invention of the microscope has allowed us to see bacteria, cells, and other things too small to be seen with the naked eye.

The Microscope

Microscopes, tools that you may get to use in your class, are some of the most important tools in biology (**Figure** below). A **microscope** is a tool used to make things that are too small to be seen by the human eye look bigger. **Microscopy** is the study of small objects using microscopes. Look at your fingertips. Before microscopes were invented in 1595, the smallest things you could see on yourself were the tiny lines in your skin. But what else is hidden in your skin?

Figure 1.10

Basic light microscopes opened up a new world to curious people.

Invention of the Microscope

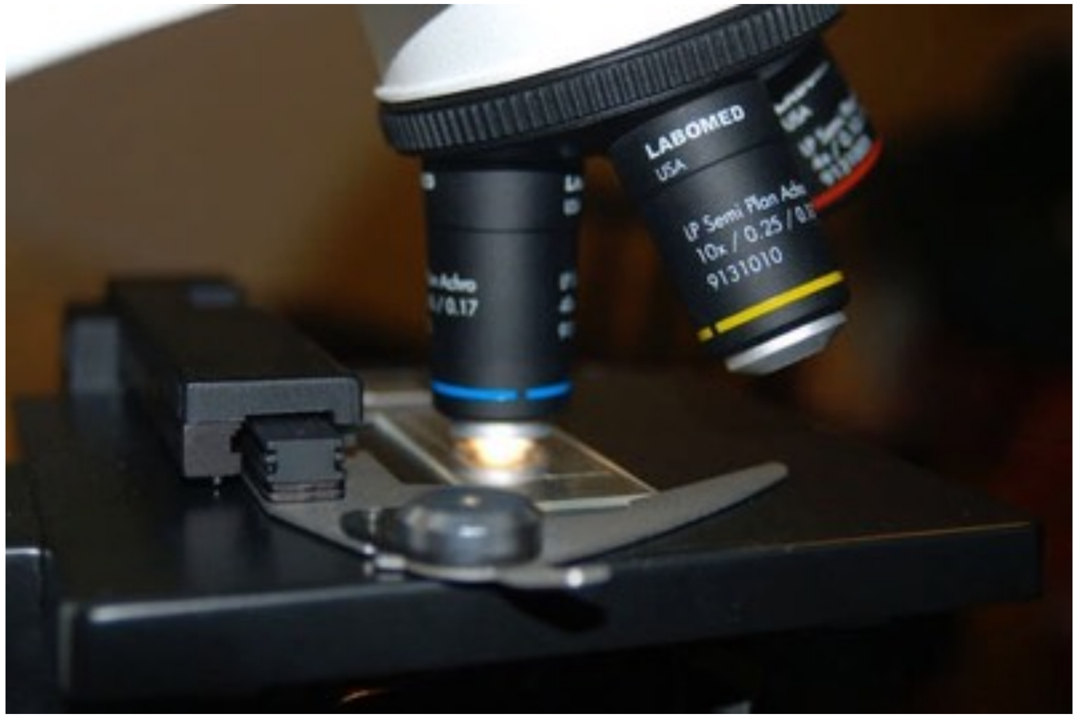
Over four hundred years ago, two Dutch spectacle makers, Zaccharias Janssen and his son Hans, were experimenting with several lenses in a tube. They discovered that nearby objects appeared greatly enlarged, or **magnified** . This was the forerunner of the compound microscope and of the telescope. Later, the father of microscopy, Dutch scientist Antoine van Leeuwenhoek (**Figure** below) taught himself to make one of the first microscopes. In one of his early experiments, van Leeuwenhoek took a sample of scum from his own teeth and used his microscope to discover **bacteria** , the smallest living organism on the planet. Using microscopes, van Leeuwenhoek also discovered one-celled **protists** and sperm cells.

In 1665, Robert Hooke, an English natural scientist, used a microscope to zoom in on a piece of cork—the stuff that makes up the stoppers in wine bottles, which is made from tree bark. Inside of cork, he discovered tiny structures, which he called **cells** . It turns out that cells are the smallest structural unit of living organisms. This finding eventually led to the development of the theory that *all living things are made up of cells.* Without microscopes, this theory would not have been developed.

Figure 1.11

Antoine van Leeuwenhoek, a Dutch cloth merchant with a passion for microscopy.

Types of Microscopes



Some modern microscopes use light, as Hooke's and van Leeuwenhoek's did. Others may use electron beams or sound waves. Researchers now use these four types of microscopes:

1. **Light microscopes** allow biologists to see small details of a specimen. Most of the microscopes used in schools and laboratories are light microscopes. Light microscopes use lenses, typically made of glass or plastic, to focus light either into the eye, a camera, or some other light detector. The most powerful light microscopes can make images up to 2,000 times larger.
2. **Transmission electron microscopes (TEM)** focus a beam of electrons through an object and can make an image up to two million times bigger, with a very clear image.
3. **Scanning electron microscopes (SEM)** allow scientists to find the shape and surface texture of extremely small objects, including a paperclip, a bedbug, or even an atom. These microscopes slide a beam of electrons across the surface of a specimen, producing detailed maps of the surface of objects. Magnification in a SEM can be controlled over a range from about 10 to 500,000 times.
4. **Scanning acoustic microscopes** use sound waves to scan a specimen. These microscopes are useful in biology and medical research.

Figure 1.12

A scanning electron microscope.

Summary

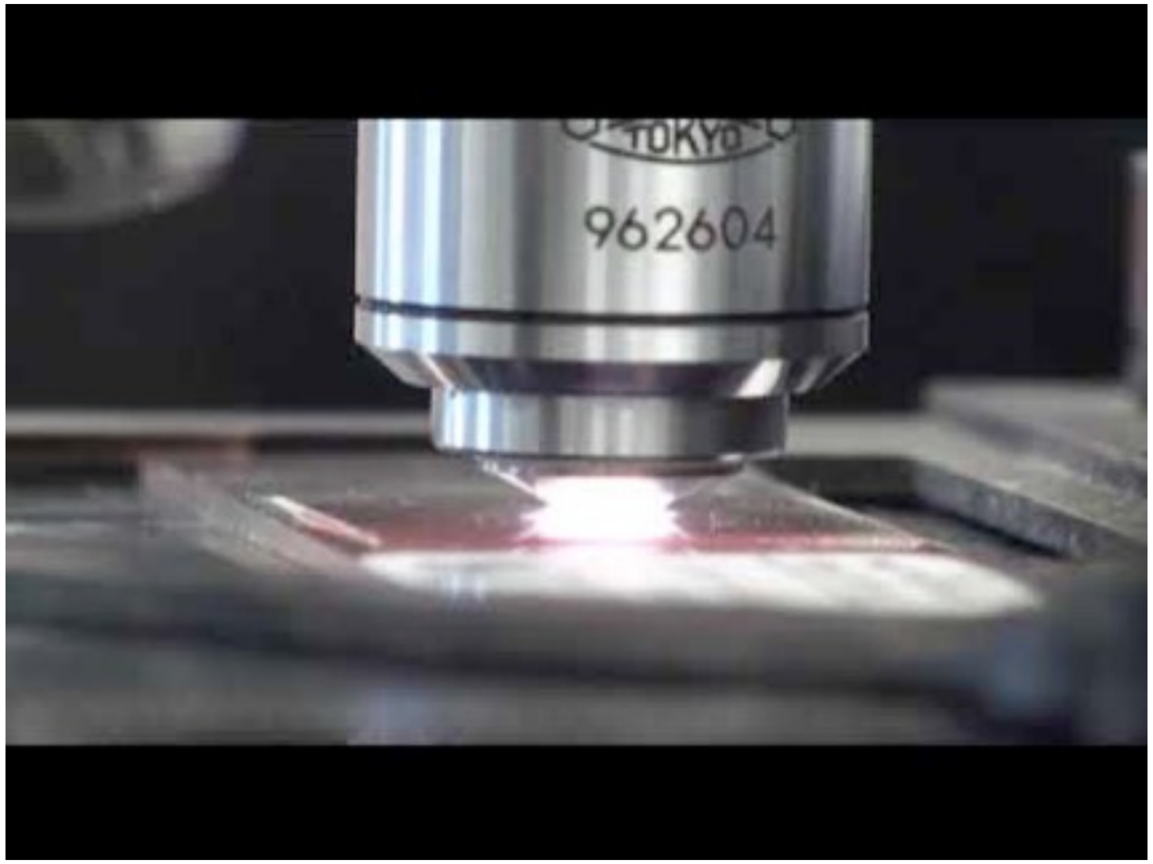
- A microscope is a tool used to make things that are too small to be seen by the naked eye look bigger.
- Types of microscopes include light microscopes, transmission electron microscopes (TEM), scanning electron microscopes (SEM), and scanning acoustic microscopes.

Explore More

Use the resources below to answer the questions that follow.

Explore More I

- **Using a microscope** at http://www.youtube.com/watch?v=bGBgABLEV4g (4:01)



Click on the image above for more content

1. How should you carry a compound optical microscope?
2. What procedure should you use when seeking to use the most powerful optical lenses?

Explore More II

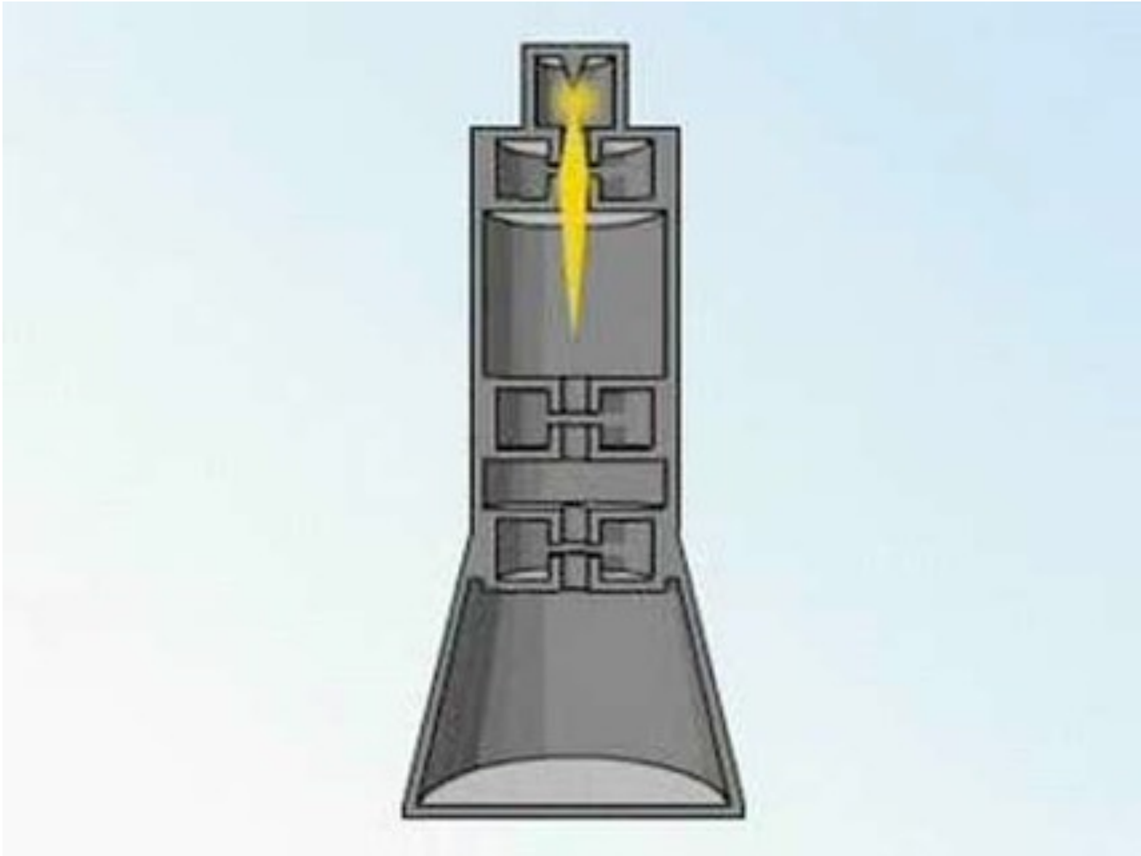
•**Dissecting Microscope** at http://www.youtube.com/watch?v=JoqOwzLyMIA (5:05)

Click on the image above for more content

1. What light sources can you use with a dissecting microscope?
2. Why is it important to have a fixed ocular lens and an adjustable ocular lens?
3. What happens to your field of view as you increase magnification? Can you explain why this happens?

Explore More III

•**Structure and Function of the Electron Microscope** at http://www.youtube.com/watch?v=fToTFjwUc5M (1:49)

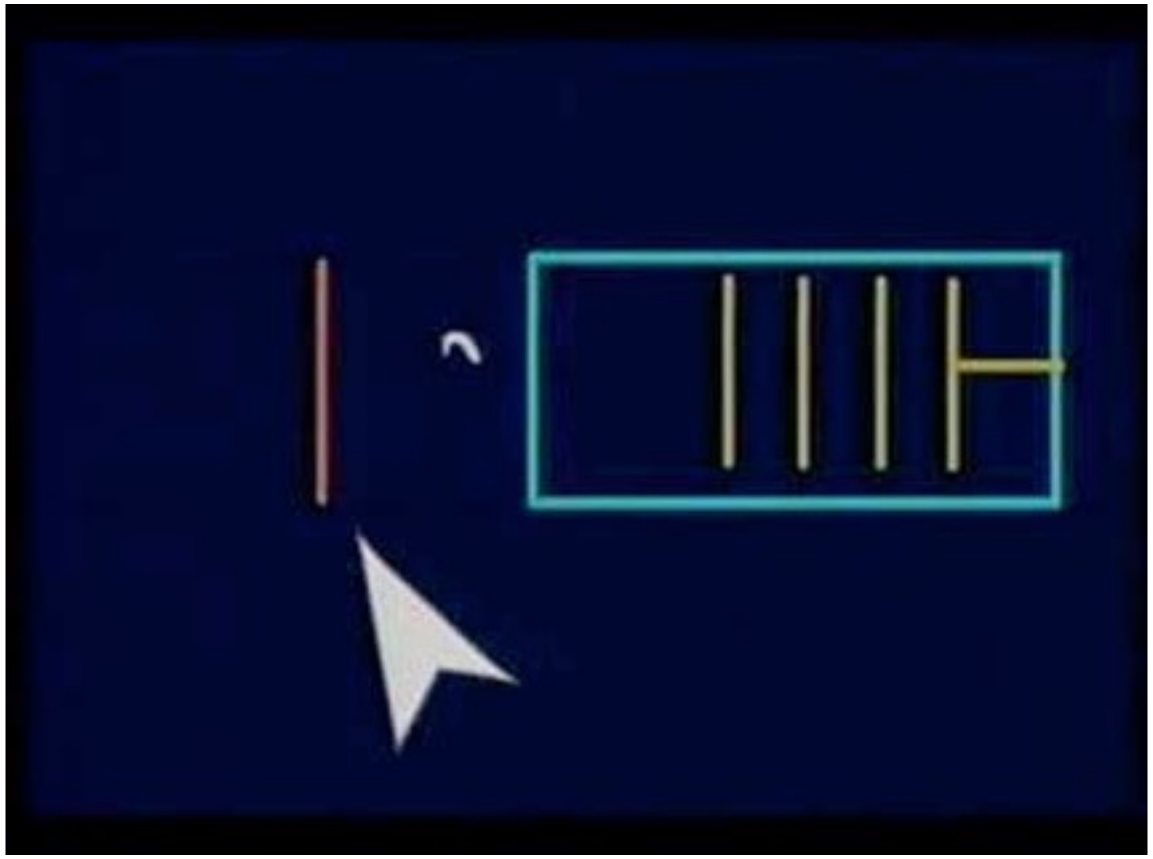


Click on the image above for more content

1. How does an electron microscope differ from a light microscope? List all the differences you can think of.
2. How should you carry an electron microscope?

Explore More IV

•**Scanning Electron Microscope** at http://www.youtube.com/watch?v=lrXMIghANbg (5:04)



Click on the image above for more content

1. How is the electron beam focused?
2. What part of a specimen does a scanning electron microscope look at?
3. Why is it important that a specimen for an electron microscope be placed in a vacuum? Why is this step unnecessary for a light microscope?

Review

1. What is the purpose of a microscope?
2. What were the findings of Hooke and van Leeuwenhoek?
3. What are the differences between a light microscope and a scanning electron microscope?

Section 7

Safety in the Life Sciences

Safety in the Life Sciences

- •Recognize the types of hazards that a scientist faces.
- •Describe laboratory safety guidelines that minimize potential risks.

What does this sign mean?

If a substance is corrosive, it can eat through objects. Many scientists have to work with chemicals that are corrosive or otherwise dangerous. That's one reason that following safety precautions in the laboratory or field is very important.

Safety in the Life Sciences

There can be some very serious safety risks in scientific research. If researchers are not careful, they could poison themselves or contract a deadly illness. The kinds of risks that scientists face depend on the kind of research they perform. For example, a scientist working with bacteria in a laboratory faces different risks than a scientist studying the behavior of lions in Africa, but both scientists must still follow safety guidelines. Safety practices must be followed when working with the hazardous things such as parasites, radiation and radioactive materials, toxins, and wild animals. Also, **carcinogens** , which are chemical that cause cancer, **pathogens** , which are disease-causing virus, bacteria or fungi, and **teratogens** , which are chemical that cause deformities in developing embryos, are extremely hazardous, and extreme care must be used when working with these items as well. For example, scientists studying dangerous organisms such as *Yersinia pestis* , the cause of bubonic plague, use special equipment that helps keep the organism from escaping the lab.

A **biohazard** is any biological material that could make someone sick, including disease-causing organisms. Therefore, a used needle is a biohazard because it could harbor blood contaminated with a disease-causing organism. Bacteria grown in a laboratory are also biohazards if they could potentially cause disease.

Figure 1.13

Science laboratory safety and chemical hazard signs.

Laboratory Safety

If you perform an experiment in your classroom, your teacher will explain how to be safe. Professional scientists follow safety rules as well, especially for the study of dangerous organisms like the bacteria that cause bubonic plague (**Figure** below).

Sharp objects, chemicals, heat, and electricity are all used at times in laboratories. Below is a list of safety guidelines that you should follow when in the laboratory:

- Be sure to obey all safety guidelines given in lab instructions and by your teacher.
- Follow directions carefully.
- Tie back long hair.
- Wear closed toe shoes with flat heels and shirts with no hanging sleeves, hoods, or drawstrings.
- Use gloves, goggles, or safety aprons when instructed to do so.
- Broken glass should only be cleaned up with a dust pan and broom. Never touch broken glass with your bare hands.
- Never eat or drink anything in the science lab. Table tops and counters could have dangerous substances on them.
- Be sure to completely clean materials like test tubes and beakers. Leftover substances could interact with other substances in future experiments.
- If you are using flames or heat plates, be careful when you reach. Be sure your arms and hair are kept far away from heat.
- Alert your teacher immediately if anything out of the ordinary occurs. An accident report may be required if someone is hurt. Also, the teacher must know if any materials are damaged or discarded.

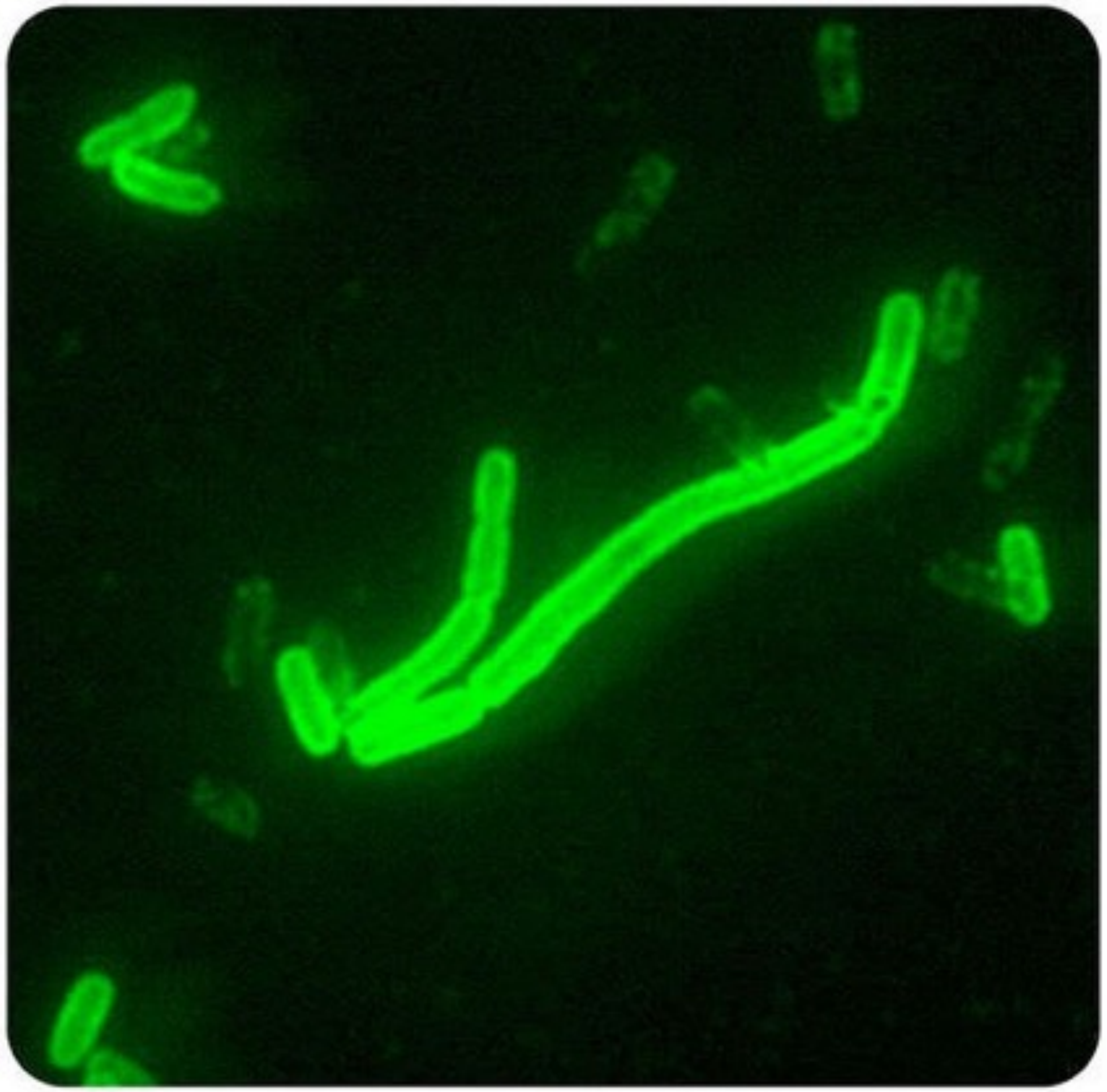


Figure 1.14

Scientists studying dangerous organisms such as *Yersinia pestis* , the cause of bubonic plague, use special equipment that helps keep the organism from escaping the lab.

Field Research Safety

Scientists who work outdoors, called **field scientists** , are also required to follow safety regulations. These safety regulations are designed to prevent harm to themselves, other humans, animals, and the environment. If scientists work outside the country, they are required to learn about and follow the laws and restrictions of the country in which they are doing research. For example, entomologists following monarch butterfly (**Figure** below) migrations between the United States and Mexico must follow regulations in both countries. Before biologists can study protected wildlife or plant species, they must apply for permission to do so. This is important to protect these fragile species. For example, if scientists collect rare butterflies, they must first get a permit. They must also be careful to not disturb the habitat.

Figure 1.15

A monarch butterfly.

Summary

- There are serious risks in scientific research, including carcinogens, biohazards, and toxins.
- You need to carefully follow all safety rules while working in the laboratory.

Explore More

Use the resources below to answer the questions that follow.

Explore More I

- **FSU Chemistry Lab Safety** at http://www.youtube.com/watch?v=hv9imJzZWrY (6:51)

Click on the image above for more content

1. Is applying cosmetics in a lab allowed?
2. What should you do if there is an accident?
3. How should you dispose of waste?

Explore More II

- **Science Lab Safety Rules** at http://www.youtube.com/watch?v=yclOrqEv7kw (2:24)

Click on the image above for more content

1. List five lab safety rules covered in the video.
2. What kind of clothing should you wear in a science lab?
3. What should you wear in a science lab that you would not wear usually outside a science lab?

Review

1. What is a biohazard?
2. List three hazards found in scientific research.
3. List three safety guidelines that you should follow in the laboratory.

Section 8

Characteristics of Life

Characteristics of Life

•Define what it means to be living.
•Know the five characteristics of living organisms.
•Describe the five characteristics shared by all living organisms.
•Identify the role of the five characteristics shared by all living organisms.
•Summarize in detail the role of each characteristic in life.

Is fire alive?

Fire can grow. Fire needs fuel and oxygen. But fire is not a form of life, although it shares a few traits with some living things. How can you distinguish between non-living and living things?

The Characteristics of Life

How do you define a living thing? What do mushrooms, daisies, cats, and bacteria have in common? All of these are living things, or **organisms** . It might seem hard to think of similarities among such different organisms, but they actually have many properties in common. Living organisms are similar to each other because all organisms evolved from the same common ancestor that lived billions of years ago.

All living organisms:

1. Need energy to carry out life processes.
2. Are composed of one or more cells.
3. Respond to their environment.
4. Grow and reproduce.
5. Maintain a stable internal environment.

Living Things Need Resources and Energy

Why do you eat everyday? To get energy. **Energy** is the ability to do work. Without energy, you could not do any "work." Though not doing any "work" may sound nice, the "work" fueled by energy includes everyday activities, such as walking, writing, and thinking. But you are not the only one who needs energy. In order to grow and reproduce and carry out the other process of life, all living organisms need energy. But where does this energy come from?

The source of energy differs for each type of living thing. In your body, the source of energy is the food you eat. Here is how animals, plants, and fungi obtain their energy:

- All animals must eat in order to obtain energy. Animals also eat to obtain building materials.
- Plants don't eat. Instead, they use energy from the sun to make their "food" through the process of **photosynthesis** .
- Mushrooms and other fungi obtain energy from other organisms. That's why you often see fungi growing on a fallen tree; the rotting tree is their source of energy (**Figure** below).

Since plants harvest energy from the sun and other organisms get their energy from plants, nearly all the energy of living things initially comes from the sun.

Figure 1.16

Orange bracket fungi on a rotting log in the Oak Openings Preserve in Ohio. Fungi obtain energy from breaking down dead organisms, such as this rotting log.

Living Things Are Made of Cells

If you zoom in very close on a leaf of a plant, or on the skin on your hand, or a drop of blood, you will find cells, you will find cells (**Figure** below). **Cells** are the smallest structural and functional unit of living organisms. Most cells are so small that they are usually visible only through a microscope. Some organisms, like bacteria, plankton that live in the ocean, or the *Paramecium* shown in **Figure** below are made of just one cell. Other organisms have millions, billions, or trillions of cells.

All cells share at least some structures. The **nucleus** is clearly visible in the blood cells (**Figure** below). The nucleus can be described as the "information center," containing the instructions (**DNA**) for making all the **proteins** in a cell, as well as how much of each protein to make. The nucleus is also the main distinguishing feature between the two general categories of cell. Although the cells of different organisms are built differently, they all have certain general functions. Every cell must get energy from food, be able to grow and divide, and respond to its environment. More about cell structure and function will be discussed in additional concepts.

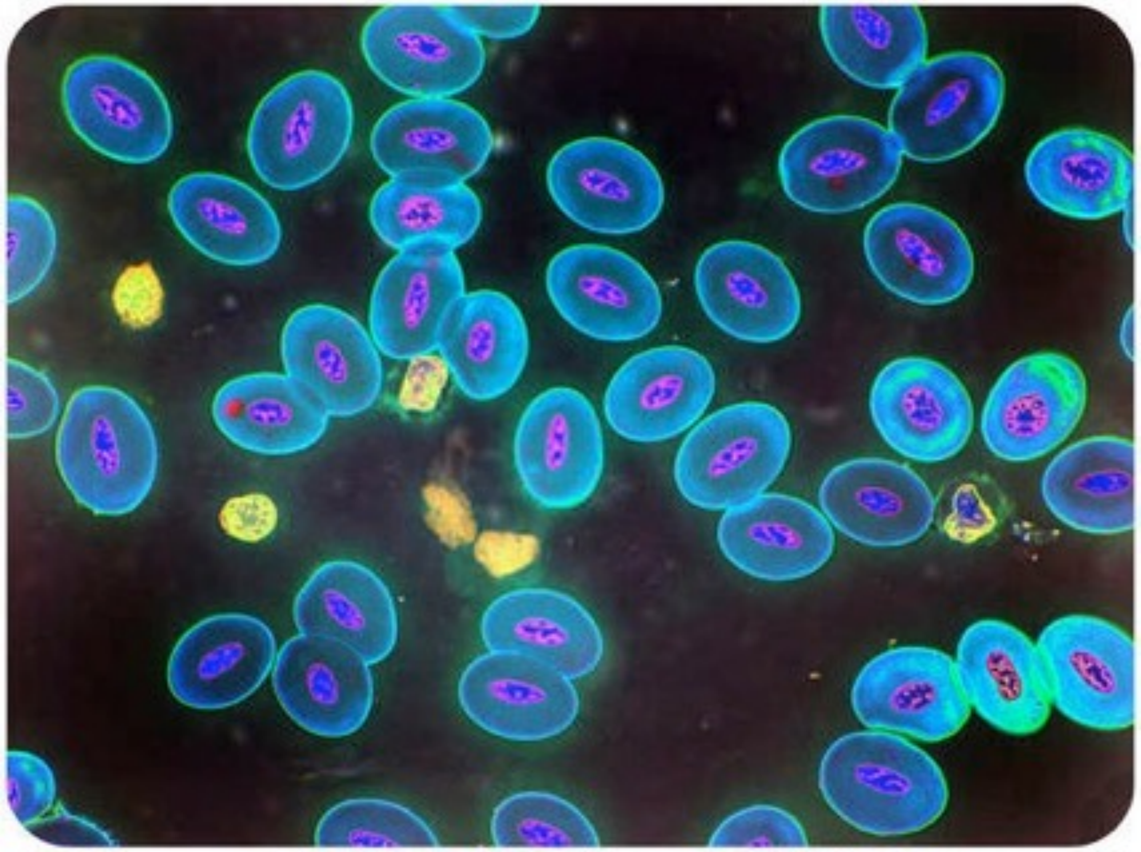


Figure 1.17

These cells show the characteristic nucleus. A few smaller cells are also visible. This image has been magnified 1000 times its real size.

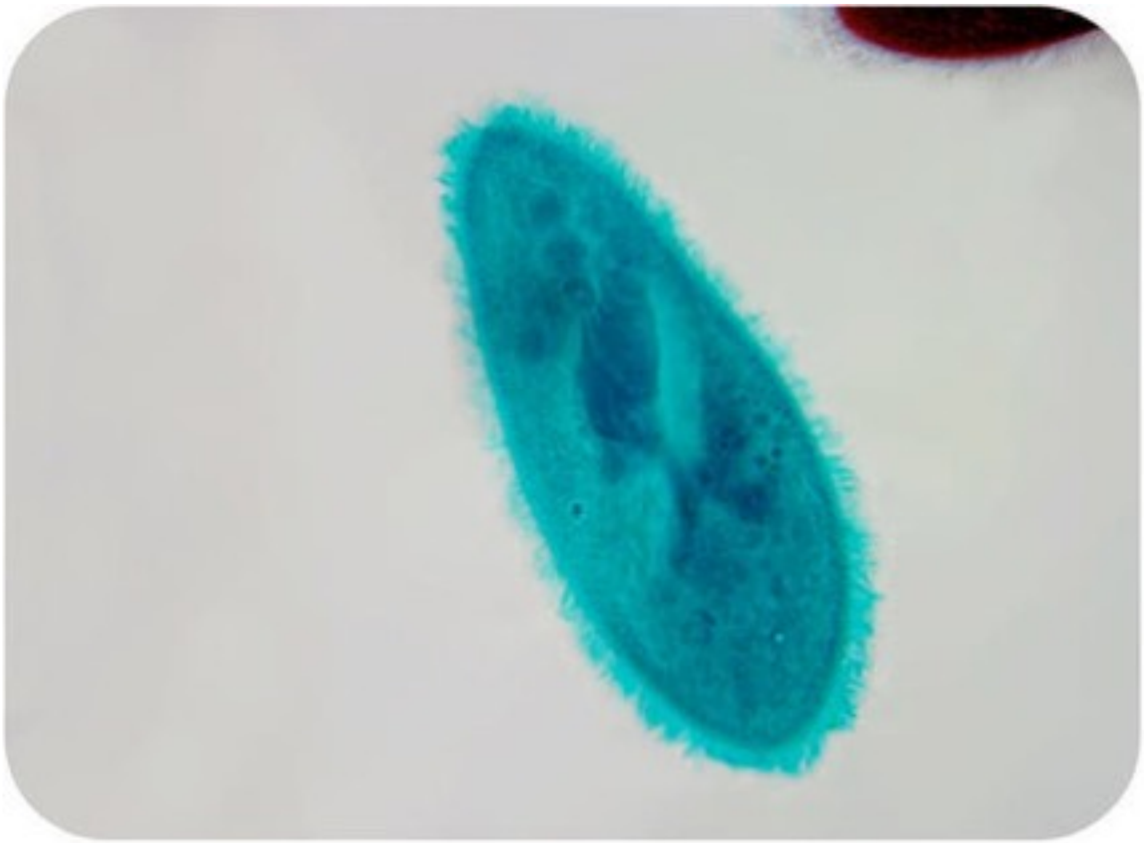


Figure 1.18

This *Paramecium* is a single-celled organism.

Living Organisms Respond to their Environment

All living organisms are able to react to something important or interesting in their external environment. For example, living organisms constantly respond to their environment. They respond to changes in light, heat, sound, and chemical and mechanical contact. Organisms have means for receiving information, such as eyes, ears, taste buds, or other structures.

Living Things Grow and Reproduce

All living things **reproduce** to make the next generation. Organisms that do not reproduce will go extinct. As a result, there are no species that do not reproduce (**Figure** below). Some organisms reproduce asexually (**asexual reproduction**), especially single-celled organisms, and make identical copies of themselves. Other organisms reproduce sexually (**sexual reproduction**), combining genetic information from two parents to make genetically unique offspring.

Figure 1.19

Like all living things, cats reproduce to make a new generation of cats.

Living Things Maintain Stable Internal Conditions

When you are cold, what does your body do to keep warm? You shiver to warm up your body. When you are too warm, you sweat to release heat. When any living organism gets thrown off balance, its body or cells help it return to normal. In other words, living organisms have the ability to keep a stable internal environment. Maintaining a balance inside the body or cells of organisms is known as **homeostasis** . Like us, many animals have evolved behaviors that control their internal temperature. A lizard may stretch out on a sunny rock to increase its internal temperature, and a bird may fluff its feathers to stay warm (**Figure** below).

Figure 1.20

A bird fluffs its feathers to stay warm and to maintain homeostasis.

Summary

- Living things are called organisms.
- All living organisms need energy to carry out life processes, are composed of one or more cells, respond to their environment, grow, reproduce, and maintain a stable internal environment.

Explore More

Use the resource below to answer the questions that follow.

- **Characteristics of Life** at http://www.youtube.com/watch?v=gJd65_Xrxs4 (3:15)

1. What are cell products? Do you think they should be included in characteristics of life? Why or why not?
2. Are all responses to the environment immediately obvious? Be specific and explain your reasoning.
3. Explain the concept of homeostasis. Give an example.
4. At what level does life evolve?

Review

1. Is a crystal alive? Why or why not?
2. What is a cell?
3. What is homeostasis?
4. What are the two forms of reproduction? Describe the examples in your response.

Section 9

Chemistry of Life

Chemistry of Life

What's happening in this beaker?

The bubbles indicate that vapor is being formed, which lets you know that a chemical reaction is taking place. Many chemical reactions are going on constantly inside your body. In fact, there are probably thousands of chemical reactions occurring every second in every one of your cells. And as all living things are comprised of chemicals, understanding how chemicals work is essential to understanding how living things work.

Chemicals of Life

The Elements

If you pull a flower petal from a plant and break it in half, and then take that piece and break it in half again, and take the next piece and break it half, and so on, and so on, until you cannot even see the flower anymore, what do you think you will find? We know that the flower petal is made of **cells** , but what are cells made of? Scientists have broken down **matter** , or anything that takes up space and has mass—like a cell—into the smallest pieces that cannot be broken down anymore. Rocks, animals, flowers, and your body are all made up of matter.

Matter is made up of a mixture of things called elements. **Elements** are substances that cannot be broken down into simpler substances. There are more than 100 known elements, and 92 occur naturally around us. The others have been made only in the laboratory.

Inside of elements, you will find identical atoms. An **atom** is the simplest and smallest particle of matter that still has chemical properties of the element. Atoms are the building block of all of the elements that make up the matter in your body or any other living or non-living thing. Atoms are so small that only the most powerful microscopes can see them.

Atoms themselves are composed of even smaller particles, including positively charged **protons** , uncharged **neutrons** , and negatively charged **electrons** . Protons and neutrons are located in the center of the atom, or the nucleus, and the electrons move around the nucleus. How many protons an atom has determines what element it is. For example, helium (He) always has two protons (**Figure** below), while sodium (Na) always has 11. All the atoms of a particular element have the exact same number of protons, and the number of protons is that element's **atomic number** . An atom usually has the same number of protons and electrons, but sometimes an atom may gain or lose an electron, giving the atom a positive or negative charge. These atoms are known as **ions** and are depicted with a "+" or "-" sign. Ions, such as H^+, Na^+, K^+, or Cl^- have significant biological roles.

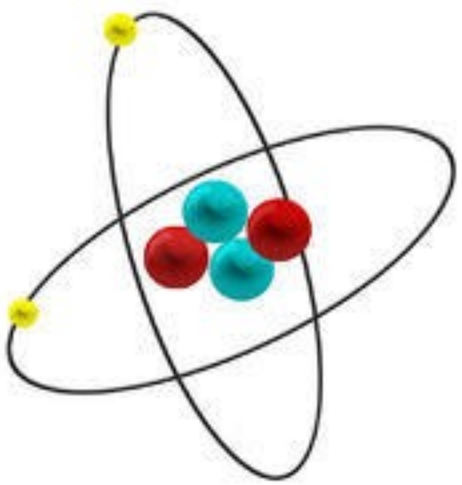


Figure 1.21

An atom of Helium (He) contains two positively charged protons (red), two uncharged neutrons (blue), and two negatively charged electrons (yellow).

The Periodic Table

In 1869, a Russian scientist named Dmitri Mendeleev created the **periodic table** , which is a way of organizing elements according to their unique characteristics, like atomic number, density, boiling point, and other values (**Figure** below). Each element is represented by a one or two letter symbol. For example, H stands for hydrogen, and Au stands for gold. The vertical columns in the periodic table are known as groups, and elements in groups tend to have very similar properties. The table is also divided into rows, known as periods.

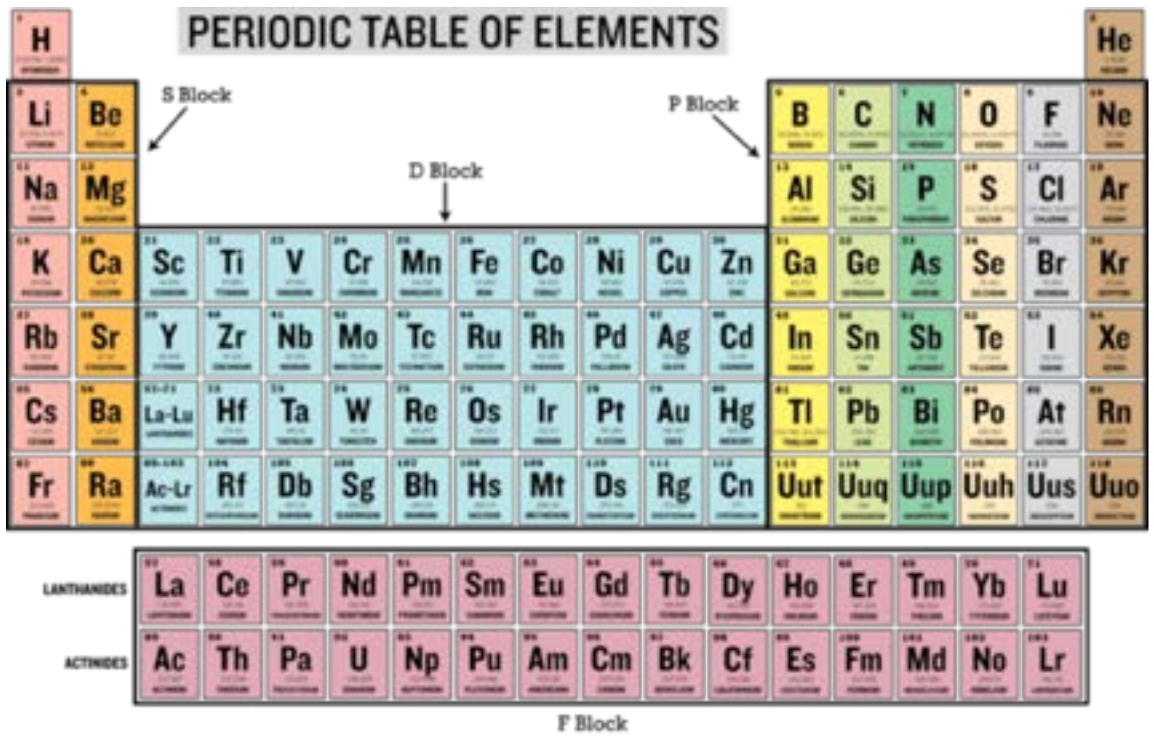


Figure 1.22

The periodic table groups the elements based on their properties.

Chemical Reactions

A **molecule** is any combination of two or more atoms. The oxygen in the air we breathe is two oxygen atoms connected by a chemical bond to form O_2, or molecular oxygen. A carbon dioxide molecule is a combination of one carbon atom and two oxygen atoms, CO_2. Because carbon dioxide includes two different elements, it is a compound as well as a molecule.

A **compound** is any combination of two or more elements. A compound has different properties from the elements that it contains. Elements and combinations of elements (compounds) make up all the many types of matter in the Universe. A **chemical reaction** is a process that breaks or forms the bonds between atoms of molecules and compounds. For example, two hydrogens and one oxygen bind together to form water, H_2O. The molecules that come together to start a chemical reaction are the **reactants** . So hydrogen and oxygen are the reactants. The **product** is the end result of a reaction. In this example, water is the product.

Atoms also come together to form compounds much larger than water. It is some of these large compounds that come together to form the basis of the cell. So essentially, your cells are made out of compounds, which are made out of atoms.

Summary

- Elements are substances that cannot be broken down into simpler substances with different properties.
- Elements have been organized by their properties to form the periodic table.
- Two or more atoms can combine to form a molecule.
- Molecules consisting of more than one element are called compounds.
- Reactants can combine through chemical reactions to form products.

Explore More

Use the resource below to answer the following questions.

- **Periodic table** at http://www.webelements.com/

1. What is the atomic number of nitrogen? When and where was it identified? In what state of matter does nitrogen exist at room temperature?
2. What is the atomic number of oxygen? When and where was it identified? In what state of matter does oxygen exist at room temperature?
3. What is the atomic number of carbon? When and where was it identified? In what state of matter does it exist at room temperature?
4. What is the atomic number of phosphorus? From what was phosphorus originally isolated? In what state of matter does it exist at room temperature?

Review

1. What is an element?
2. What is the difference between the terms molecule and compound?

3.Describe the composition of an atom.
4.Who is credited with developing the periodic table?

Section 10

Organic Compounds

Organic Compounds

•Define proteins, carbohydrates, lipids, nucleic acids.
•Recognize the basic structure of organic compounds and explain their basic functions.
•Distinguish the categories of organic compounds, compare and contrast their roles, and analyze the components of each category.
•Summarize in detail the structure and function of the organic compounds, emphasizing the relationship between structure and function.

What makes up a healthy diet?

A healthy diet includes protein, fats, and carbohydrates. Why? Because these compounds are three of the main building blocks that make up your body. You obtain these building blocks from the food that you eat, and you use these building blocks to make the organic compounds necessary for life.

Organic Compounds

The main chemical components of living organisms are known as **organic compounds** . Organic compounds are molecules built around the element carbon (C). Living things are made up of very large molecules. These large molecules are called **macromolecules** because "macro" means large; they are made by smaller molecules bonding together. Our body gets these smaller molecules, the "building blocks" or **monomers** , of organic molecules from the food we eat. Which organic molecules do you recognize from the list below?

The four main types of macromolecules found in living organisms, shown in **Table** below , are:

1. Proteins.
2. Carbohydrates.
3. Lipids.
4. Nucleic Acids.

	Proteins	**Carbohydrates**	**Lipids**	**Nucleic Acids**
Elements	C, H, O, N, S	C, H, O	C, H, O, P	C, H, O, P, N

Carbohydrates

Carbohydrates are sugars, or long chains of sugars. An important role of carbohydrates is to store energy. **Glucose** (**Figure** below) is an important simple sugar molecule with the chemical formula $C_6H_{12}O_6$. Simple sugars are known as **monosaccharides** . Carbohydrates also include long chains of connected sugar molecules. These long chains often consist of hundreds or thousands of monosaccharides bonded together to form **polysaccharides** . Plants store sugar in polysaccharides called **starch** . Animals store sugar in polysaccharides called **glycogen** . You get the carbohydrates you need for energy from eating carbohydrate-rich foods, including fruits and vegetables, as well as grains, such as bread, rice, or corn.

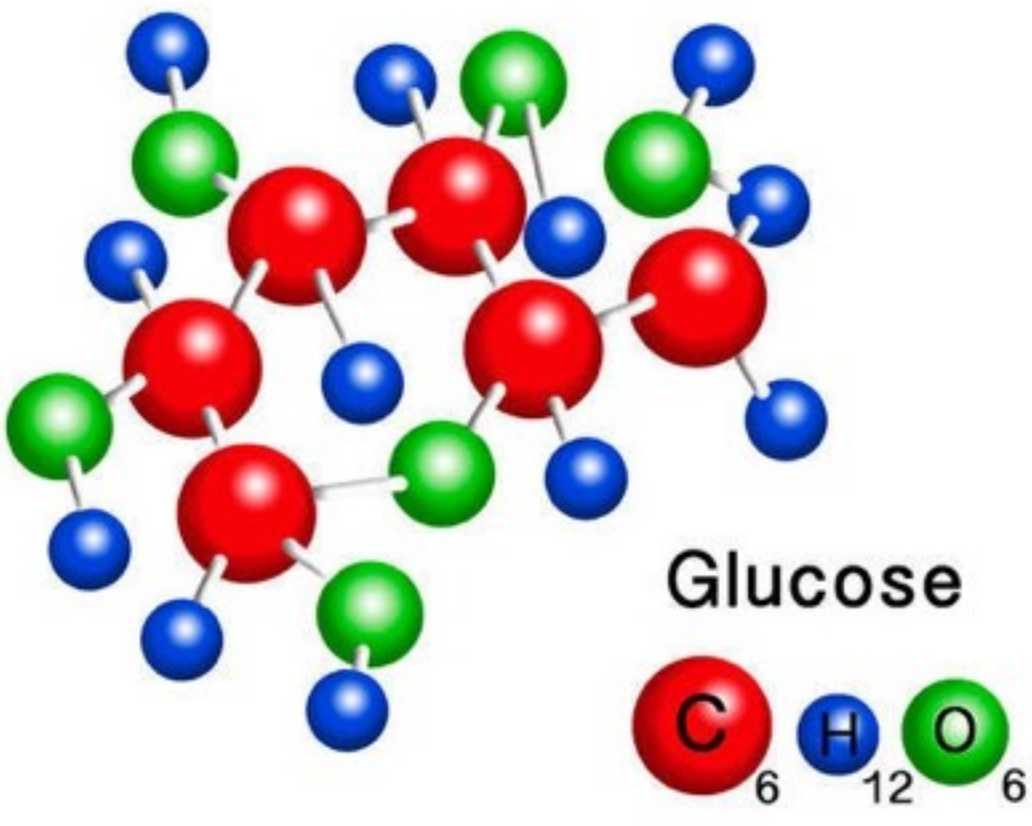


Figure 1.23

A molecule of glucose, a type of carbohydrate.

Proteins

Proteins are molecules that have many different functions in living things. All proteins are made of monomers called **amino acids** (**Figure** below) that connect together like beads on a necklace (**Figure** below). There are only 20 common amino acids needed to build proteins. These amino acids form in thousands of different combinations, making about 100,000 or more unique proteins in humans. Proteins can differ in both the number and order of amino acids. It is the number and order of amino acids that determines the shape of the protein, and it is the shape (structure) of the protein that determines the unique function of the protein. Small proteins have just a few hundred amino acids. The largest proteins have more than 25,000 amino acids.

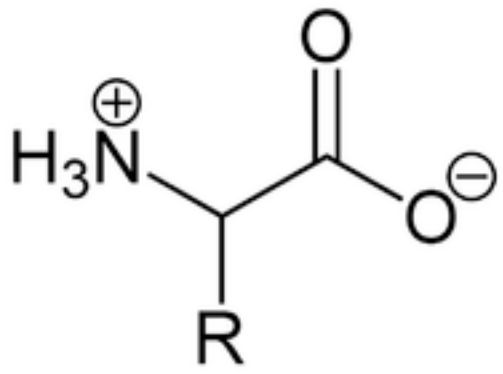


Figure 1.24

This model shows the general structure of all amino acids. Only the side chain, R, varies from one amino acid to another. KEY: H = hydrogen, N = nitrogen, C = carbon, O = oxygen, R = variable side chain.

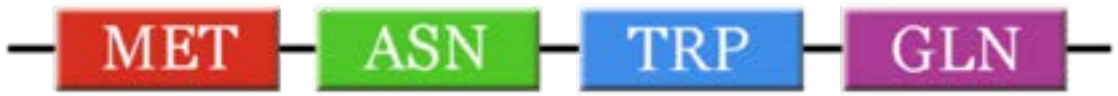


Figure 1.25

Amino acids connect together like beads on a necklace. MET, ASN, TRP, and GLN refer to four different amino acids.

Many important molecules in your body are proteins. Examples include enzymes, antibodies, and muscle fiber. **Enzymes** are a type of protein that speed up chemical reactions. They are known as "biological catalysts." For example, your stomach would not be able to break down food if it did not have special enzymes to speed up the rate of digestion. **Antibodies** that protect you against disease are proteins. Muscle fiber is mostly protein (**Figure** below).

Figure 1.26

Muscle fibers are made mostly of protein.

It's important for you and other animals to eat food with protein, because we cannot make certain amino acids on our own. You can get proteins from plant sources, such as beans, and from animal sources, like milk or meat. When you eat food with protein, your body breaks the proteins down into individual amino acids and uses them to build new proteins. You really are what you eat!

Lipids

Have you ever tried to put oil in water? They don't mix. Oil is a type of lipid. **Lipids** are molecules such as fats, oils, and waxes. The most common lipids in your diet are probably fats and oils. Fats are solid at room temperature, whereas oils are fluid. Animals use fats for long-term energy storage and to keep warm. Plants use oils for long-term energy storage. When preparing food, we often use animal fats, such as butter, or plant oils, such as olive oil or canola oil. There are many more type of lipids that are important to life. One of the most important are the **phospholipids** that make up the protective outer membrane of all cells (**Figure** below).

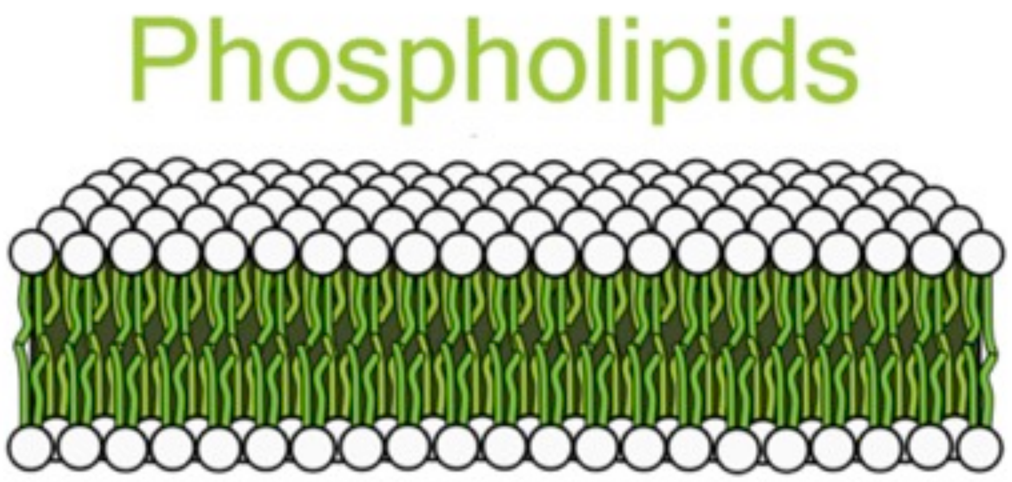


Figure 1.27

Phospholipids in a membrane, shown as two layers (a bilayer) of phospholipids facing each other.

Nucleic acids

Nucleic acids are long chains of nucleotides. Nucleotides are made of a sugar, a nitrogen-containing base, and a phosphate group. **Deoxyribonucleic acid (DNA)** and **ribonucleic acid (RNA)** are the two main nucleic acids. DNA is a double-stranded nucleic acid. DNA is the molecule that stores our genetic information (**Figure** below). The single-stranded RNA is involved in making proteins. **ATP (adenosine triphosphate)** , known as the "energy currency" of the cell, is also a nucleic acid.

Figure 1.28

A model representing DNA, a nucleic acid.

Summary

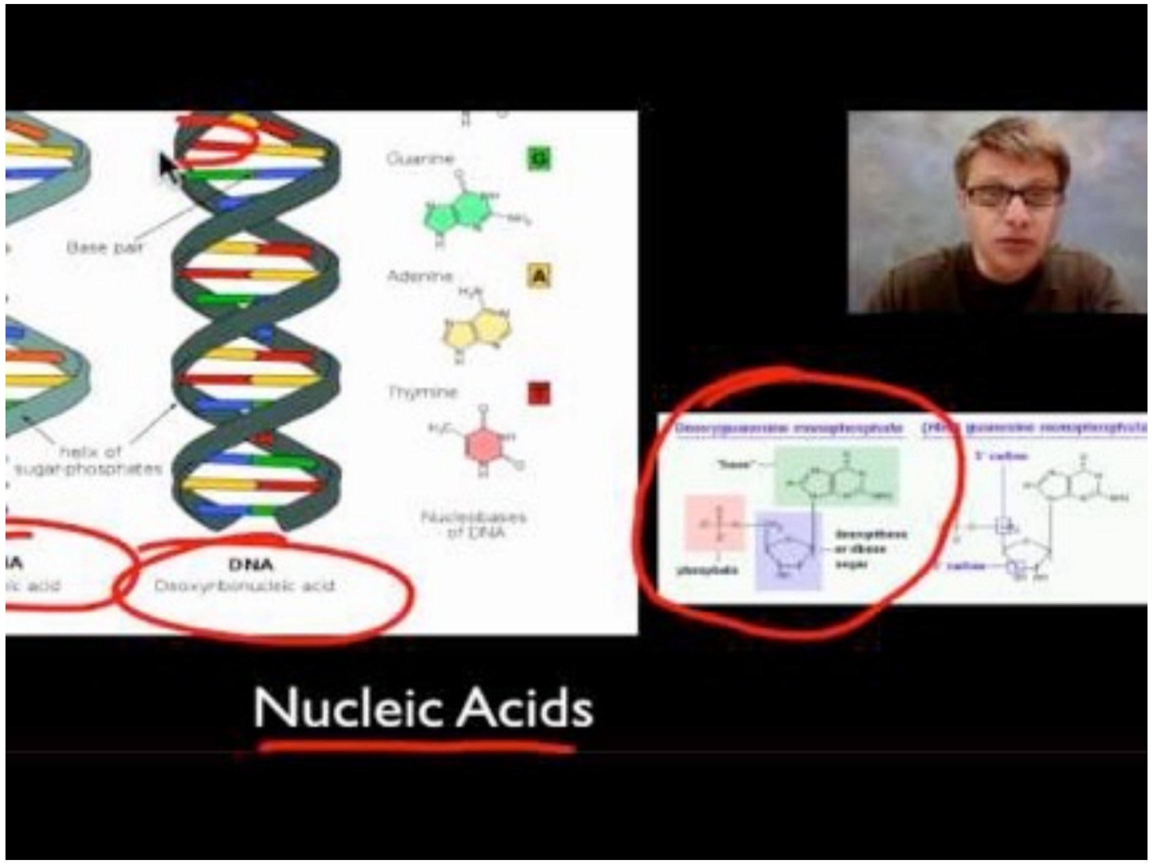
- •Living organisms are comprised of organic compounds, molecules built around the element carbon.
- •Living things are made of just four classes of organic compounds: proteins, carbohydrates, lipids, and nucleic acids.

Explore More

Use the resources below to answer the questions that follow.

Explore More I

•**Molecules of Life** at http://www.youtube.com/watch?v=QWf2jcznLsY (10:47)

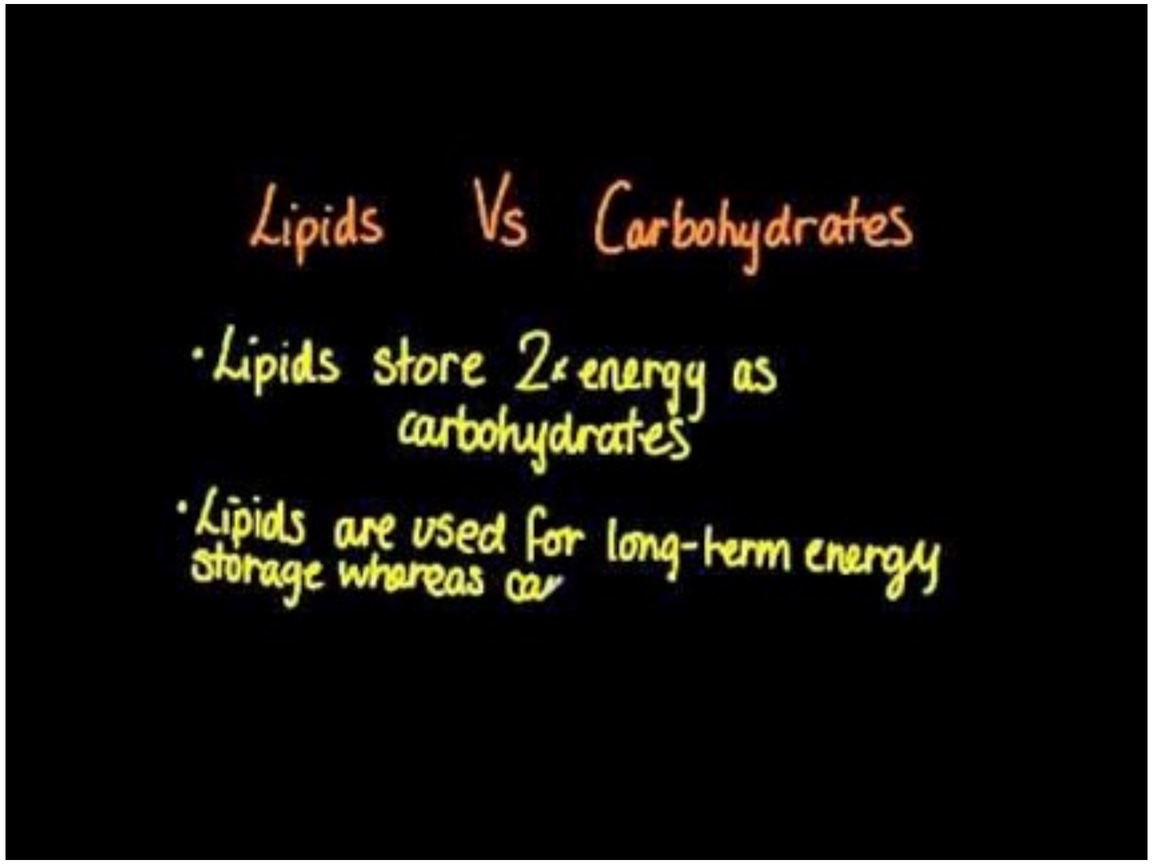


Click on the image above for more content

1. What four categories of macromolecules make up cells?
2. What about carbon makes it valuable to organisms?
3. What do functional groups do? How are they important to organisms?
4. What smaller units can proteins be broken down into?
5. What two nucleic acids are used by organisms?
6. What are three different types of carbohydrates?

Explore More II

•**Lipids vs. Carbohydrates** at http://www.youtube.com/watch?v=zTUCEY6CpVI (0:43)



Click on the image above for more content

1. What function do both lipids and carbohydrates share? How do they differ in this regard?
2. How is the solubility of lipids different than the solubility of carbohydrates?

Review

1. What are the four main types of organic compounds that make up living things?

2.What are the monomers used to make carbohydrates, proteins, and nucleic acids?
3.What are examples of lipids?
4.What are examples of proteins?

Section 11

Organization of Living

Organization of Living Things

- Explain the main contribution of Carolus (Carl) Linnaeus.
- Define binomial nomenclature.
- Summarize modern classification of living organisms.
- Define a species.

How would you classify a horse?

It's easy enough to classify the horse in the animal kingdom. That's one level of classification. But what other groups does the horse belong to? Horses also belong to a class—the mammals. These animals all have fur and nurse their young.

Classification of Life

When you see an organism that you have never seen before, you probably put it into a group without even thinking. If it is green and leafy, you probably call it a plant. If it is long and slithers, you probably call it as a snake. How do you make these decisions? You look at the physical features of the organism and think about what it has in common with other organisms.

Scientists do the same thing when they **classify** , or put into categories, living things. Scientists classify organisms not only by their physical features, but also by how closely related they are. Lions and tigers look like each other more than they look like bears, but are lions and tigers related? Evolutionarily speaking, yes. **Evolution** is the change in a species over time. Lions and tigers both evolved from a common ancestor. So it turns out that the two cats are actually more closely related to each other than to bears. How an organism looks and how it is related to other organisms determines how it is classified.

Linnaean System of Classification

People have been concerned with classifying organisms for thousands of years. Over 2,000 years ago, the Greek philosopher Aristotle developed a classification system that divided living things into several groups that we still use today, including mammals, insects, and reptiles.

Carolus (Carl) Linnaeus (1707-1778) (**Figure** below) built on Aristotle's work to create his own classification system. He invented the way we name organisms today, with each organism having a two word name. Linnaeus is considered the inventor of modern **taxonomy** , the science of naming and grouping organisms.

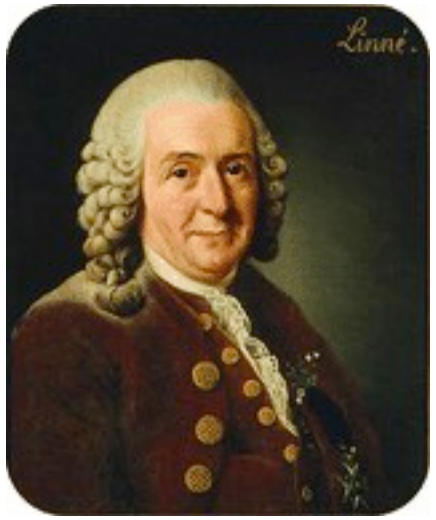


Figure 1.29

In the 18th century, Carl Linnaeus invented the two-name system of naming organisms (genus and species) and introduced the most complete classification system then known.

Linnaeus developed **binomial nomenclature** , a way to give a scientific name to every organism. In this system, each organism receives a two-part name in which the first word is the **genus** (a group of species), and the second word refers to one species in that genus. For example, a coyote's species name is *Canis latrans* . *Latrans* is the species and *Canis* is the genus, a larger group that includes dogs, wolves, and other dog-like animals. Here is another example: the red maple, *Acer rubra* , and the sugar maple, *Acer saccharum* , are both in the same genus and they look similar (**Figure** below). Notice that the genus is capitalized and the species is not, and that the whole scientific name is in italics. The names may seem strange, but the names are written in a language called Latin.

Figure 1.30

These leaves are from two different species of trees in the *Acer* , or maple, genus. The green leaf (*far left*) is from the sugar maple, and the red leaf (*center*) are from the red maple. One of the characteristics of the maple genus is winged seeds (*far right*).

Modern Classification

Modern taxonomists have reordered many groups of organisms since Linnaeus. The main categories that biologists use are listed here from the most specific to the least specific category (**Figure** below). All organisms can be classified into one of three **domains** , the least specific grouping. The three domains are Bacteria, Archaea, and Eukarya. The Kingdom is the next category after the Domain. All life is divided among six kingdoms: Kingdom Bacteria, Kingdom Archaea, Kingdom Protista, Kingdom Plantae, Kingdom Fungi, and Kingdom Animalia.

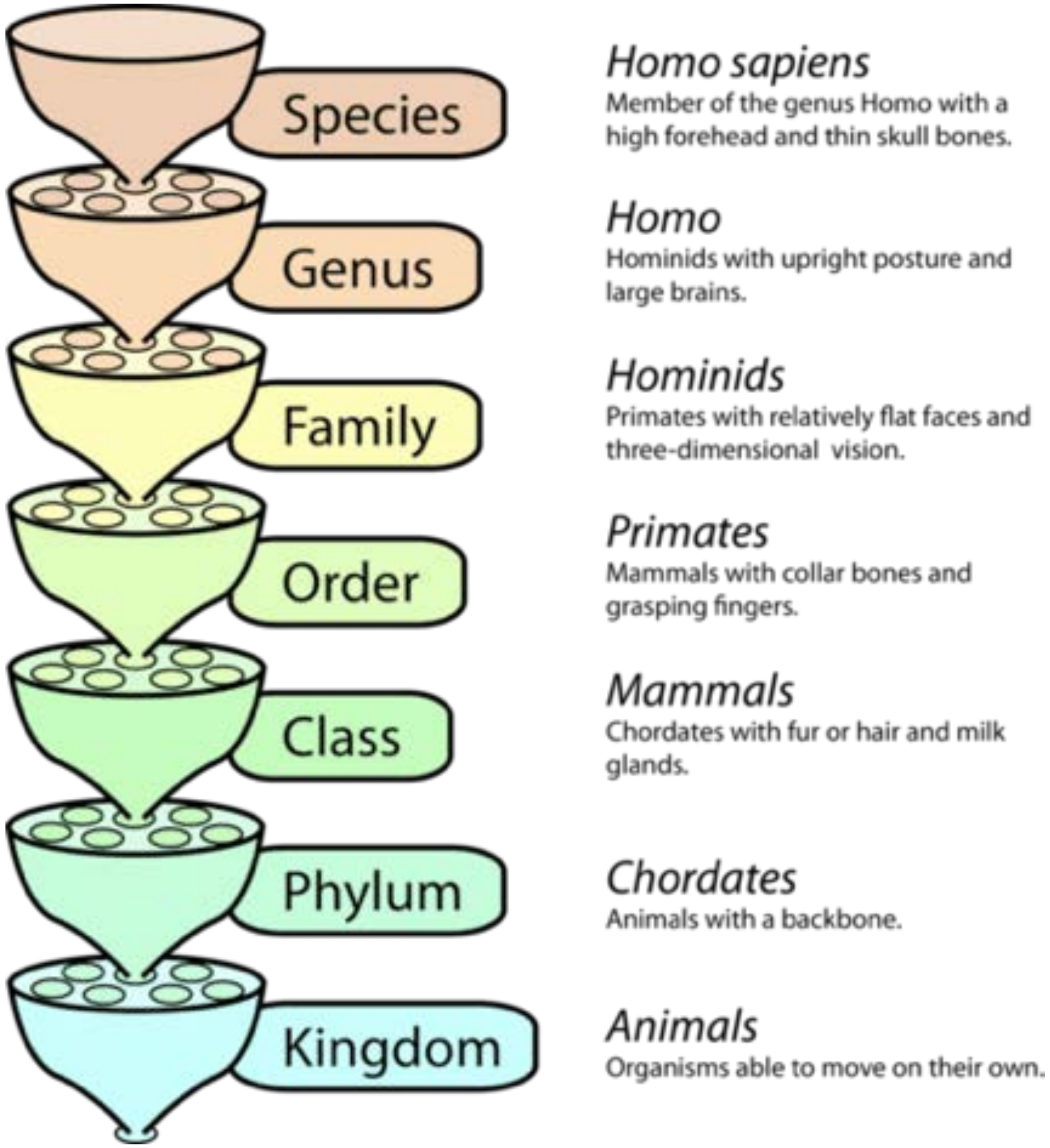


Figure 1.31

This diagram illustrates the classification categories for organisms, with the broadest category (kingdom) at the bottom, and the most specific category (species) at the top. We are *Homo sapiens. Homo* is the genus of great apes that includes modern humans and closely related species, and *sapiens* is the only living species of the genus.

Defining a Species

Even though naming species is straightforward, deciding if two organisms are the same species can sometimes be difficult. Linnaeus defined each species by the distinctive physical characteristics shared by these organisms. But two members of the same species may look quite different. For example, people from different parts of the world sometimes look very different, but we are all the same species (**Figure** below).

So how is a species defined? A **species** is defined as a group of similar individuals that can interbreed with one another and produce fertile offspring. A species does not produce fertile offspring with other species.

Figure 1.32

These children are all members of the same species, *Homo sapiens* .

Summary

- Scientists have defined several major categories for classifying organisms: domain, kingdom, phylum, class, order, family, genus, and species.
- The scientific name of an organism consists of its genus and species.

Explore More

Use the resources below to answer the following questions.

Explore More I

- **Taxonomy - Shape of Life** at http://shapeoflife.org/video/other-topics/taxonomy (2:52)

Click on the image above for more content

1. What do taxonomists study? How does their work help other scientists?
2. Who was the first person we know of who developed a system to categorize things? How was this done? Is his system still used today?

3. What contribution to taxonomy did Carolus Linnaeus make?

Explore More II

Use the below activity to see specific examples of how organisms are categorized. Make sure you go through all three types of organisms so you can gain a good understanding of the level at which different types of organisms separate from each other.

- **Nova: Classifying Life** at http://www.pbs.org/wgbh/nova/nature/classifying-life.html

Review

1. Who is the inventor of the modern classification system?
2. List the classification categories for organisms from the broadest category to the most specific.
3. What is meant by binomial nomenclature?
4. Define a species.

Section 12

Domains of Life

Domains of Life

•Distinguish between the three domains of life.
•List the four Eukarya kingdoms.

What do you have in common with pond scum?

Humans are in the same domain as trees and algae, which makes up the "pond scum" you see here. What could they possibly have in common? It is the location of their DNA inside their cells. Their cells all have a nucleus that is home to their genetic material.

The Domains of Life

Let's explore the **domain** , the least specific category of classification.

All of life can be divided into three domains, based on the type of cell of the organism:

1. **Bacteria** : cells do not contain a nucleus.
2. **Archaea** : cells do not contain a nucleus; they have a different cell wall from bacteria.
3. **Eukarya** : cells do contain a nucleus.

Archaea and Bacteria

The Archaea and Bacteria domains (**Figure** below) are both entirely composed of small, single-celled organisms and seem very similar, but they also have significant differences. Both are composed of **prokaryotic cells** , which are cells without a nucleus. In addition, both domains are composed of species that reproduce asexually (**asexual reproduction**) by dividing in two. Both domains also have species with cells surrounded by a **cell wall** , however, the cell walls are made of different materials. Bacterial cell walls contain the polysaccharide **peptidoglycan** . Lastly, Archaea often live in extreme environments including hot springs, geysers, and salt flats. Bacteria do not live in these environments.

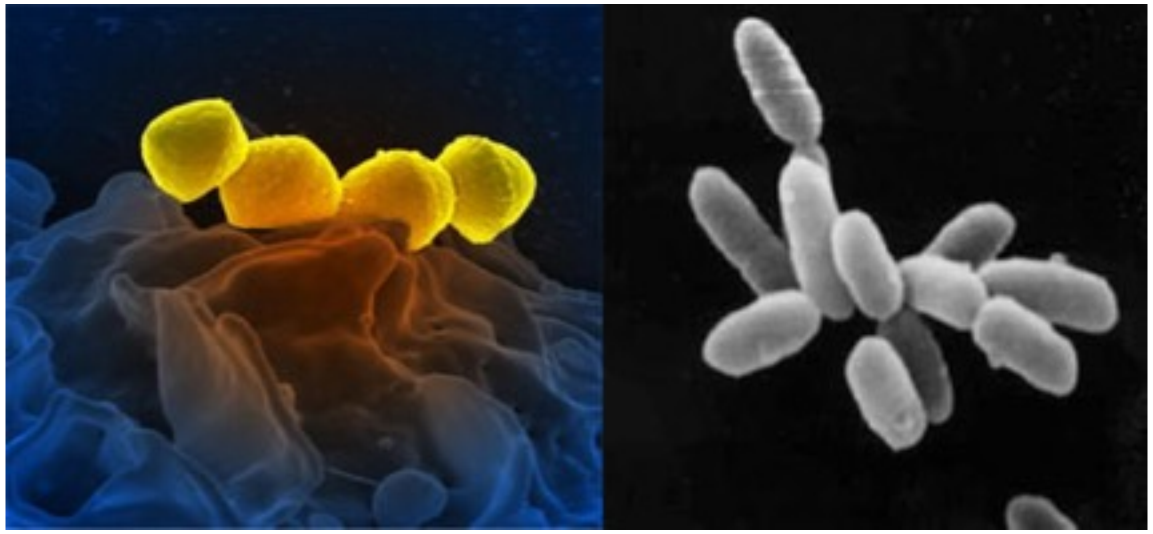


Figure 1.33

The Group A *Streptococcus* organism (*left*) is in the domain Bacteria, one of the three domains of life. The *Halobacterium* (*right*) is in the domain Archaea, another one of the three domains.

Eukarya

All of the cells in the domain Eukarya keep their genetic material, or **DNA** , inside the **nucleus** . The domain Eukarya is made up of four kingdoms:

1. Plantae: Plants, such as trees and grasses, survive by capturing energy from the sun, a process called **photosynthesis** .
2. Fungi: Fungi, such as mushrooms and molds, survive by "eating" other organisms or the remains of other organisms. These organisms absorb their nutrients from other organisms.
3. Animalia: Animals also survive by eating other organisms or the remains of other organisms. Animals range from tiny ants to the largest whales, and include arthropods, fish, amphibians, reptiles, and mammals (**Figure** below).
4. Protista: Protists are not all descended from a single common ancestor in the way that plants, animals, and fungi are. Protists are all the eukaryotic organisms that do not fit into one of the other three kingdoms. They include many kinds of microscopic one-celled organisms, such as algae and plankton, but also giant seaweeds that can grow to be 200 feet long.

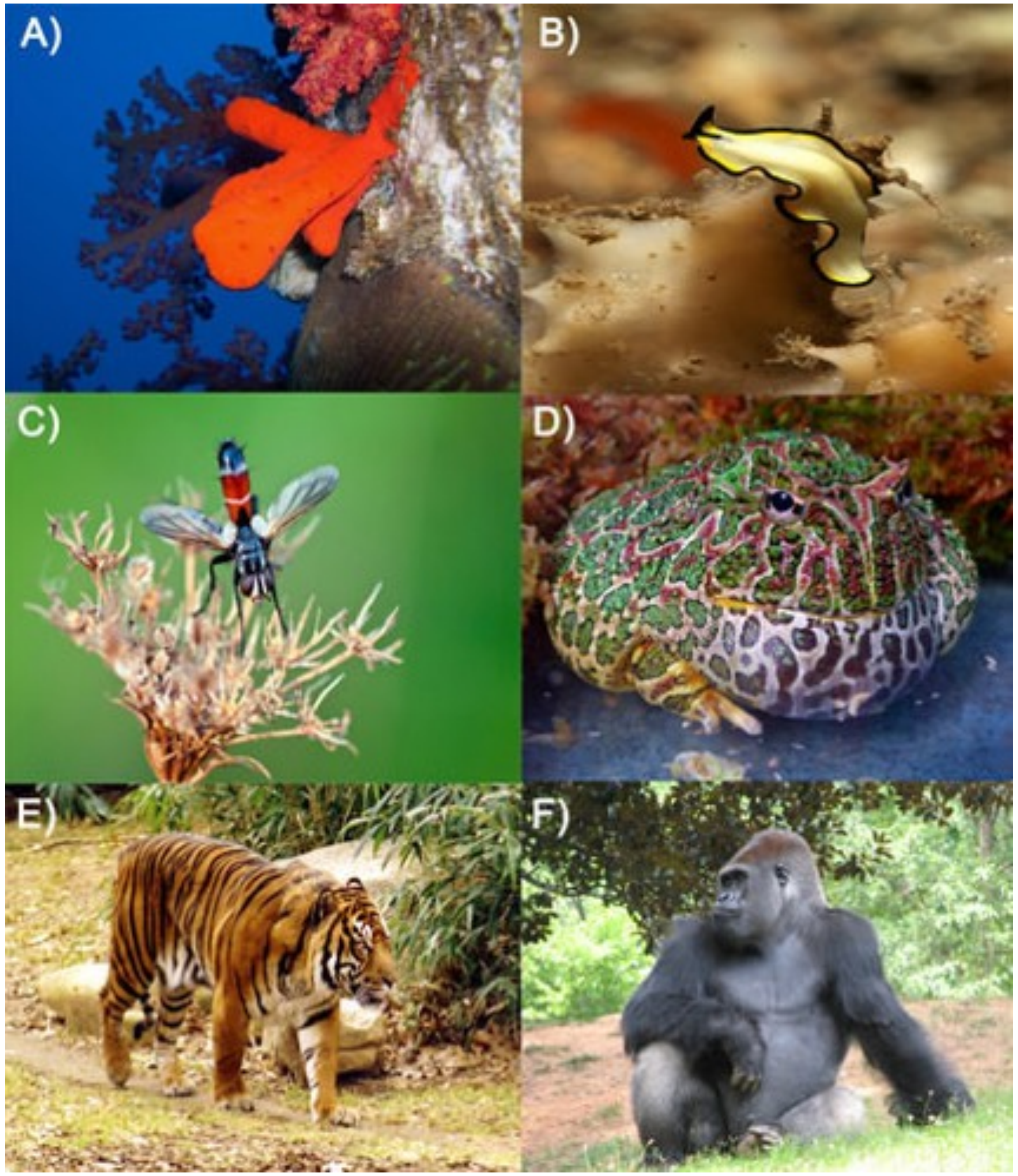


Figure 1.34

Diversity of Animals. These photos give just an inkling of the diversity of organisms that belong to the animal kingdom. (A) Sponge, (B) Flatworm, (C) Flying Insect, (D) Frog, (E) Tiger, (F) Gorilla.

Plants, animals, fungi, and protists might seem very different, but remember that if you look through a microscope, you will find similar cells with a membrane-bound nucleus in all of them. These are **eukaryotic cells** . These cells also have membrane-bound **organelles** , which prokaryotic cells lack. The main characteristics of the three domains of life are summarized in **Table** below .

	Archaea	Bacteria	Eukarya
Multicelluar	No	No	Often, but not always.
Cell wall	Yes, without peptidoglycan	Yes, with peptidoglycan	Varies. Plants and fungi have a cell wall; animals do not.
Nucleus (Membrane-Enclosed DNA)	No	No	Yes
Membrane-Bound Organelles	No	No	Yes

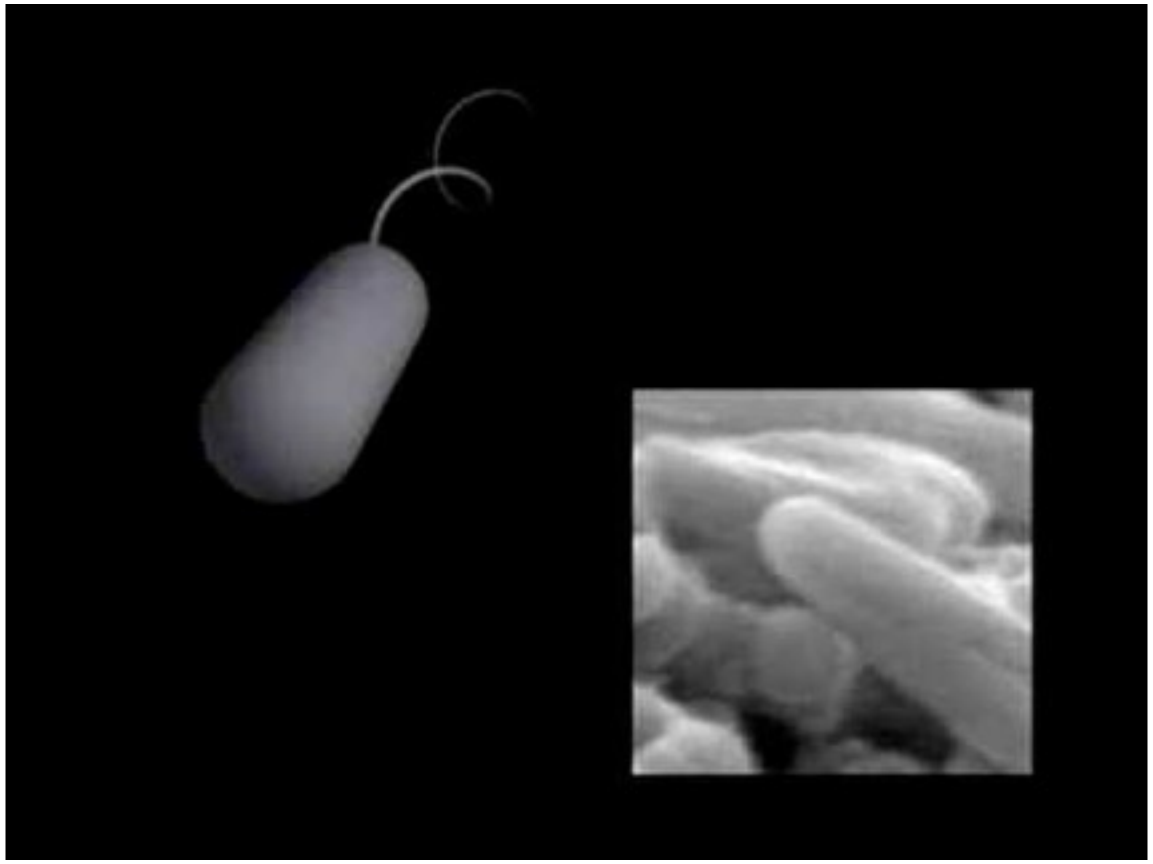
Summary

- All life can be classified into three domains: Bacteria, Archaea, and Eukarya.
- Organisms in the domain Eukarya keep their genetic material in a nucleus and include the plants, animals, fungi, and protists.

Explore More

Use the resource below to answer the questions that follow.

- **Exploring Deep-Subsurface: Life Domains** at http://www.youtube.com/watch?v=UI7Yvu4McDU (8:02)



Click on the image above for more content

1. What are the three domains of life?
2. What category do the individual organisms that we can see with our naked eye fall into?
3. What is an extremophile? What domain is known for these organisms? (Note: recent work has shown that extremophiles are not the only members of this domain.)
4. How do Archaea and Bacteria differ? How are they the same?
5. Which domain of life seems to be absent for deep-subsurface communities?

Review

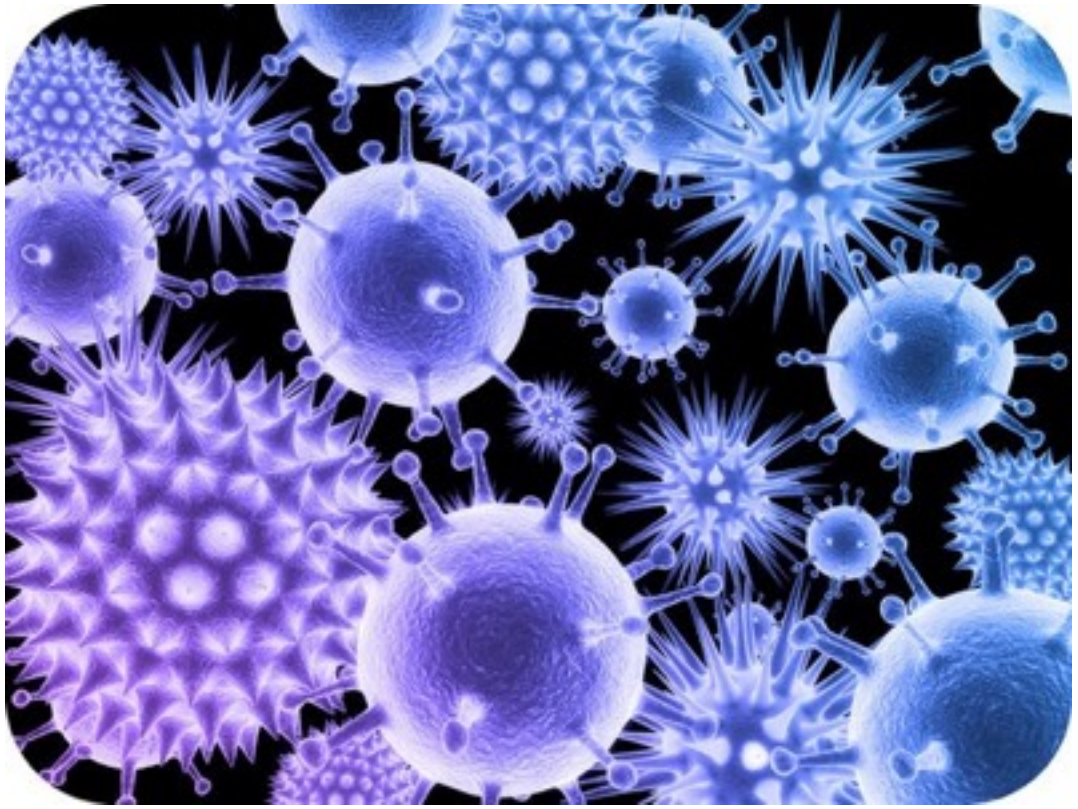
1. Compare and contrast the domains Archaea and Bacteria.
2. What are the four kingdoms that make up the domain Eukarya?
3. Name three different examples of organisms in the domain Eukarya.

Section 13

Viruses

Viruses

•Explain why viruses are not considered living.
•Describe the features and list examples of viruses.



What causes the common cold?

That miserable cough and runny nose is caused by one villain: a virus. Viruses come in many different shapes, including the prickly balls you see here. They are so tiny that they can only be seen with a very powerful microscope.

What is a Virus?

We have all heard of viruses. The flu, the common cold, and many other diseases are caused by viruses. But what is a virus? Do you think viruses are living? Which domain do they belong to? Bacteria? Archaea? Eukarya?

Are Viruses Alive?

The answer is actually “no.” A **virus** is essentially DNA or RNA surrounded by a coat of protein (**Figure** below). It is not made of a **cell** , and cannot maintain a stable internal environment (**homeostasis**). Recall that a cell is the basic unit of living organisms. So if a virus is not made of at least one cell, can it be living? Viruses also cannot reproduce on their own—they need to infect a **host cell** to reproduce. So a virus is very different from any of the organisms that fall into the three domains of life.

Though viruses are not considered living, they share two important traits with living organisms. They have **genetic material** like all cells do, and they can evolve. As the process of **evolution** has resulted in all life on the planet today, the classification of viruses has been controversial. It calls into question the very definition of life.

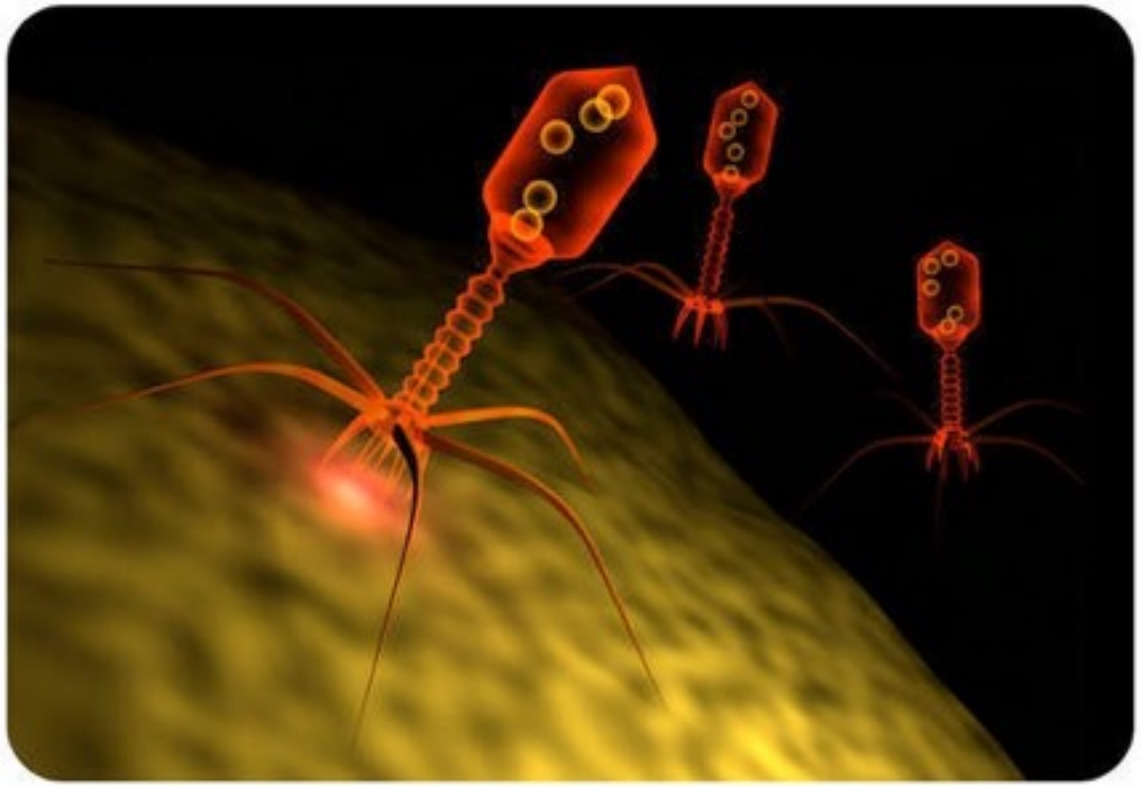


Figure 1.35

These little "alien" looking creatures are viruses, and these specific viruses infect *Escherichia coli* bacteria. Shown is a representation of viruses infecting a cell. The virus lands on the outside of the cell and injects its genetic material into the cell.

Replication

Viruses infect a variety of organisms, including plants, animals, and bacteria. Once inside the host cell, they use the cell's own **ATP** (energy), **ribosomes** , **enzymes** , and other cellular parts to make copies of themselves. The host cell makes a copy of the viral DNA and produces viral proteins. These are then packaged into new viruses. So viruses cannot **replicate** or reproduce on their own; they rely on a host cell to make additional viruses.

Viruses and Human Disease

Viruses cause many human diseases. In addition to the flu and the common cold, viruses cause rabies, diarrheal diseases, **AIDS** , cold sores, and many other diseases (**Figure** below). Viral diseases range from mild to fatal.

Figure 1.36

Cold sores are caused by a herpes virus.

Summary

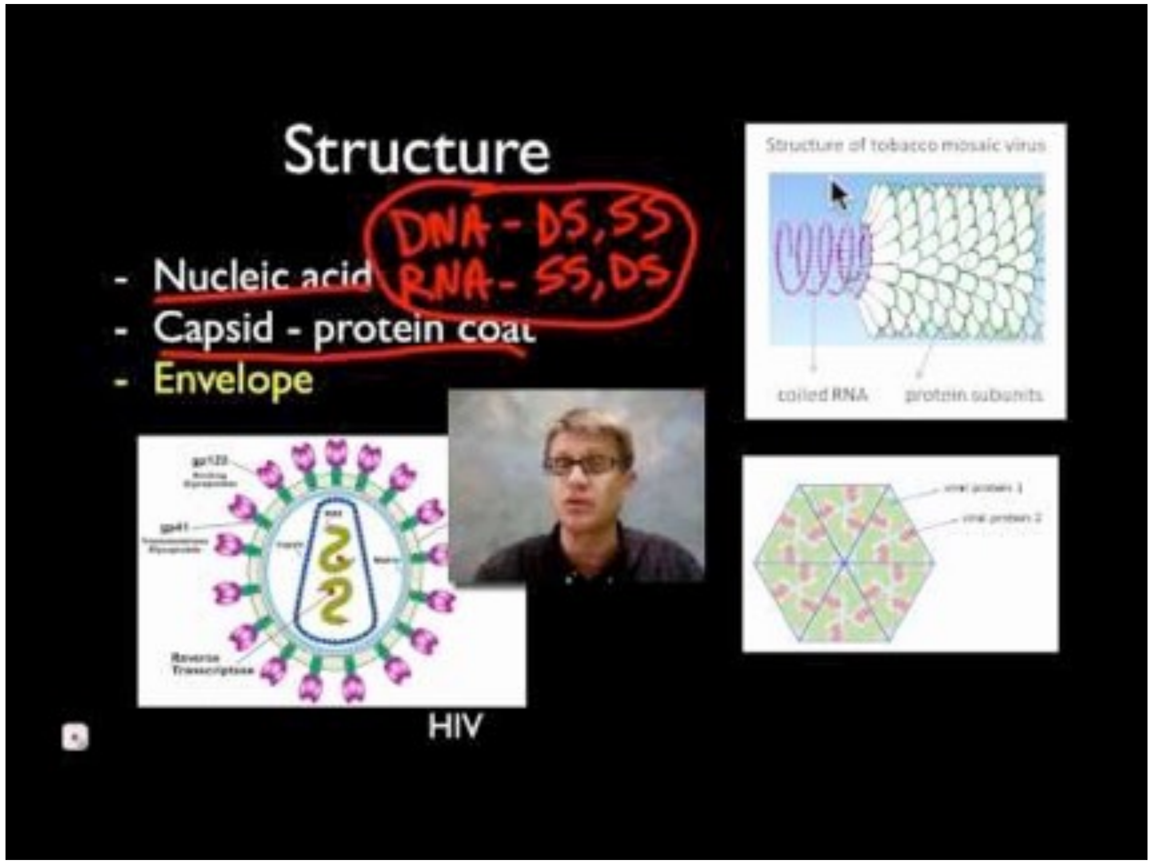
•A virus is composed of DNA or RNA surrounded by a coat of protein.
•Viruses are not considered living things because they cannot reproduce on their own, and they are not comprised of cells.

Explore More

Use the resources below to answer the questions that follow.

Explore More I

•**Viruses** at http://www.youtube.com/watch?v=L8oHs7G_syI (8:06)



Click on the image above for more content

1.How do viruses reproduce? How does this differ from other organisms?
2.What kinds of nucleic acids can viruses have?
3.Explain one of the theories as to how viruses came to be.
4.What is the importance of the "envelope" to a virus? What is the envelope made of?
5.What is a difference between the lytic cycle of a virus and the lysogenic cycle?

Explore More II

•**How Flu Viruses Attack** at http://www.youtube.com/watch?v=TVLo2CtB3GA (3:48)

Click on the image above for more content

1. What is one way a flu virus can kill a human?
2. Do mutations make viruses more deadly? Why or why not?

Review

1. Is a virus a living thing? Why or why not?
2. Name four examples of human diseases caused by a virus.

Summary

Biology is the study of life, so the Life Sciences are essentially, the study of biology. The scientific method is the process by which biological information, like that of all other sciences, has been identified. This has resulted in a number of important biological scientific theories, including the cell theory and the theory of evolution. All life is built around the element carbon, and four categories of organic compounds: carbohydrates, lipids, proteins, and nucleic acids. One particular type of protein, enzymes, are biological catalysts, allowing biochemical reactions to proceed at the rate necessary to maintain life. All life can be classified into three domains. All members of these domains share characteristics in common. Viruses do not share all of the characteristics of life, and so many scientists do not consider viruses to be living.

References

1. Derek Keats. An adult and infant chimapanzee . CC BY 2.0
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Cell Biology

Introduction

What is a cell?

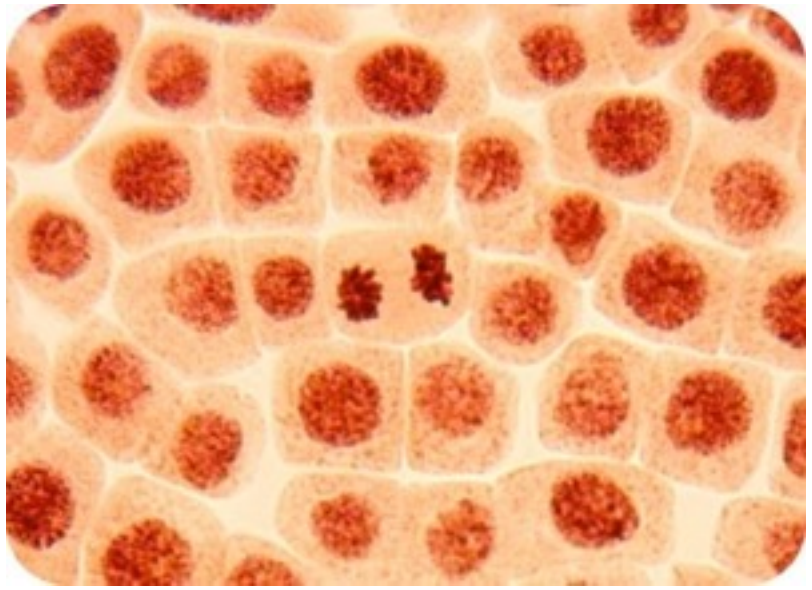
It could easily be said that a cell is the fundamental unit of life, the smallest unit capable of life or the structural and functional unit necessary for life. But whatever it is, a cell is necessary for life. And as shown above, a cell may be filled with all sorts of structures, each with its own specific function. This concept will discuss some of the fundamental properties of the cell, with lessons that include the cell structure, transport in and out of the cell, energy metabolism, and cell division and reproduction.

Section 1

Cell Biology

Cell Biology

•Explain how cells are observed.
•Define cell. Describe the general role of a cell.
•State the three main parts of the cell theory.
•Summarize the structure-function relationship of a cell.
•Explain the levels of organization in an organism.



What are you made of?

Cells make up all living things, including your own body. This picture shows a typical group of cells. But not all cells look alike. Cells can differ in shape and sizes. And the different shapes usually means different functions.

Introduction to Cells

A **cell** is the smallest structural and functional unit of an organism. Some organisms, like bacteria, consist of only one cell. Big organisms, like humans, consist of trillions of cells. Compare a human to a banana. On the outside, they look very different, but if you look close enough you'll see that their cells are actually very similar.

Observing Cells

Most cells are so small that you cannot see them without the help of a **microscope** . It was not until 1665 that English scientist Robert Hooke invented a basic light microscope and observed cells for the first time. You may use light microscopes in the classroom. You can use a light microscope to see cells (**Figure** below). But many structures in the cell are too small to see with a light microscope. So, what do you do if you want to see the tiny structures inside of cells?

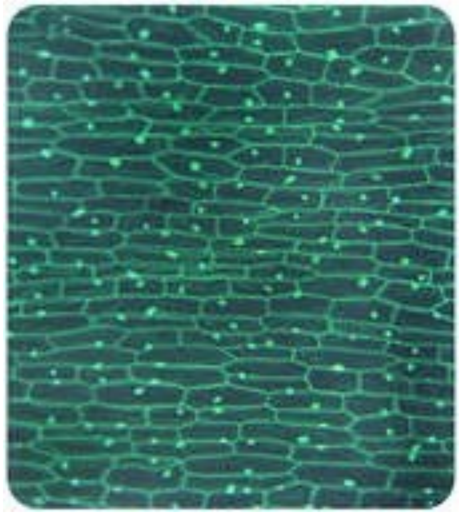


Figure 2.1

The outline of onion cells are visible under a light microscope.

In the 1950s, scientists developed more powerful microscopes. A light microscope sends a beam of light through a specimen, or the object you are studying. A more powerful microscope, called an **electron microscope** , passes a beam of electrons through the specimen. Sending electrons through a cell allows us to see its smallest parts, even the parts inside the cell (**Figure** below). Without electron microscopes, we would not know what the inside of a cell looked like.

Figure 2.2

An electron microscope allows scientists to see much more detail than a light microscope, as with this sample of pollen.

Cell Theory

In 1858, after using microscopes much better than Hooke's first microscope, Rudolf Virchow developed the hypothesis that cells only come from other cells. For example, bacteria, which are single-celled organisms, divide in half (after they grow some) to make new bacteria. In the same way, your body makes new cells by dividing the cells you already have. In all cases, cells only come from cells that have existed before. This idea led to the development of one of the most important theories in biology, the **cell theory** .

Cell theory states that:

1. All organisms are composed of cells.
2. Cells are alive and the basic living units of organization in all organisms.
3. All cells come from other cells.

As with other scientific theories, many hundreds, if not thousands, of experiments support the cell theory. Since Virchow created the theory, no evidence has ever been identified to contradict it.

Specialized Cells

Although cells share many of the same features and structures, they also can be very different (**Figure** below). Each cell in your body is designed for a specific task. In other words, the cell's function is partly based on the cell's structure. For example:

- Red blood cells are shaped with a pocket that traps oxygen and brings it to other body cells.
- Nerve cells are long and stringy in order to form a line of communication with other nerve cells, like a wire. Because of this shape, they can quickly send signals, such as the feeling of touching a hot stove, to your brain.
- Skin cells are flat and fit tightly together to protect your body.

As you can see, cells are shaped in ways that help them do their jobs. Multicellular (many-celled) organisms have many types of specialized cells in their bodies.

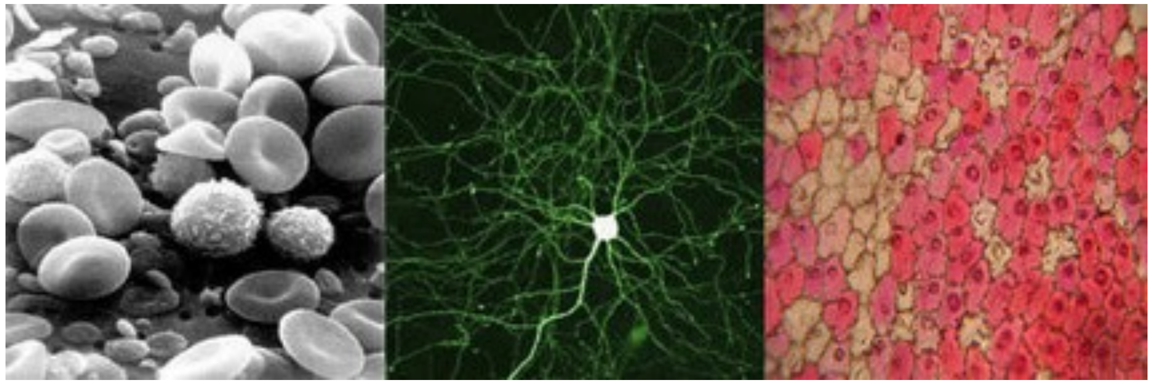


Figure 2.3

Red blood cells (*left*) are specialized to carry oxygen in the blood. Neurons (*center*) are shaped to conduct electrical impulses to many other nerve cells. These epidermal cells (*right*) make up the “skin” of plants. Note how the cells fit tightly together.

Levels of Organization

While cells are the basic units of an organism, groups of cells can perform a job together. These cells are called specialized because they have a special job. Specialized cells can be organized into **tissues** . For example, your liver cells are organized into liver tissue. Your liver tissue is further organized into an organ, your liver. **Organs** are formed from two or more specialized tissues working together to perform a job. All organs, from your heart to your liver, are made up of an organized group of tissues.

These organs are part of a larger system, the **organ systems** . For example, your brain works together with your spinal cord and other nerves to form the nervous system. This organ system must be organized with other organ systems, such as the circulatory system and the digestive system, for your body to work. Organ systems work together to form the entire organism. There are many levels of organization in living things (**Figure** below).

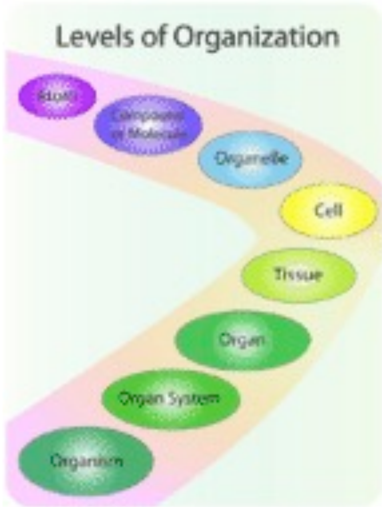


Figure 2.4

Levels of organization, from the atom (smallest) to the organism (largest).

Summary

- Cells were first observed under a light microscope, but today's electron microscopes allow scientists to take a closer look at the inside of cells.
- Cell theory says that:
    - All organisms are composed of cells.

    ◦Cells are alive and the basic living units of organization in all organisms.
    ◦All cells come from other cells.
- Cells are organized into tissues, which are organized into organs, which are organized into organ systems, which are organized to create the whole organism.

Explore More

Use the sliding bar to zoom in on this animation to get an idea of the relative sizes of your cells.

- **Cell Size and Scale - The University of Utah** at http://learn.genetics.utah.edu/content/begin/cells/scale/

1. What is the average size of a grain of salt?
2. How big is an amoeba proteus? How big is a paramecium? (Remember this relationship for when you study amoeba.)
3. How big is a skin cell? How big is a red blood cell? Can you think of any problems that might exist if this relationship was reversed? Explain your thinking fully.
4. How big is an *E. coli* bacterium? How big is a mitochondrion? (Remember this relationship for when you study endosymbiosis.)
5. Are all cells the same size?

Review

1. What type of microscope would be best for studying the structures found inside of cells?
2. What are the three basic parts of the cell theory?
3. According the cell theory, can you create a cell by combining molecules in a laboratory? Why or why not?
4. Give an example of a specialized cell.
5. What is a tissue?
6. What is the relationship between tissues and organs?

Section 2

Prokaryotic and Eukaryotic

Prokaryotic and Eukaryotic Cells

- •Distinguish between eukaryotic and prokaryotic cells.
- •Define an organelle.
- •Describe the main role of the nucleus

Are bacteria cells like our cells?

Yes and no. Bacteria cells are similar to our cells in some ways. Like our cells, bacteria cells have DNA and a plasma membrane. But bacteria are unique in other ways. They are called prokaryotic cells because of these differences.

Prokaryotic and Eukaryotic

There are two basic types of cells, **prokaryotic cells** and **eukaryotic cells** . The main difference between eukaryotic and prokaryotic cells is that eukaryotic cells have a **nucleus** . The nucleus is where cells store their **DNA** , which is the genetic material. The nucleus is surrounded by a membrane. Prokaryotic cells do not have a nucleus. Instead, their DNA floats around inside the cell. Organisms with prokaryotic cells are called **prokaryotes** . All prokaryotes are single-celled organisms. Bacteria and Archaea are the only prokaryotes. Organisms with eukaryotic cells are called **eukaryotes** . Animals, plants, fungi, and protists are eukaryotes. All multicellular organisms are eukaryotes. Eukaryotes may also be single-celled.

Both prokaryotic and eukaryotic cells have structures in common. All cells have a plasma membrane, ribosomes, cytoplasm, and DNA. The **plasma membrane** , or cell membrane, is the phospholipid layer that surrounds the cell and protects it from the outside environment. **Ribosomes** are the non-membrane bound organelles where proteins are made, a process called **protein synthesis.** The **cytoplasm** is all the contents of the cell inside the cell membrane, not including the nucleus.

Eukaryotic Cells

Eukaryotic cells usually have multiple **chromosomes** , composed of DNA and protein. Some eukaryotic species have just a few chromosomes, others have close to 100 or more. These chromosomes are protected within the nucleus. In addition to a nucleus, eukaryotic cells include other membrane-bound structures called **organelles** . Organelles allow eukaryotic cells to be more specialized than prokaryotic cells. Pictured below are the organelles of eukaryotic cells (**Figure** below), including the **mitochondria** , **endoplasmic reticulum** , and **Golgi apparatus** . These will be discussed in additional concepts.

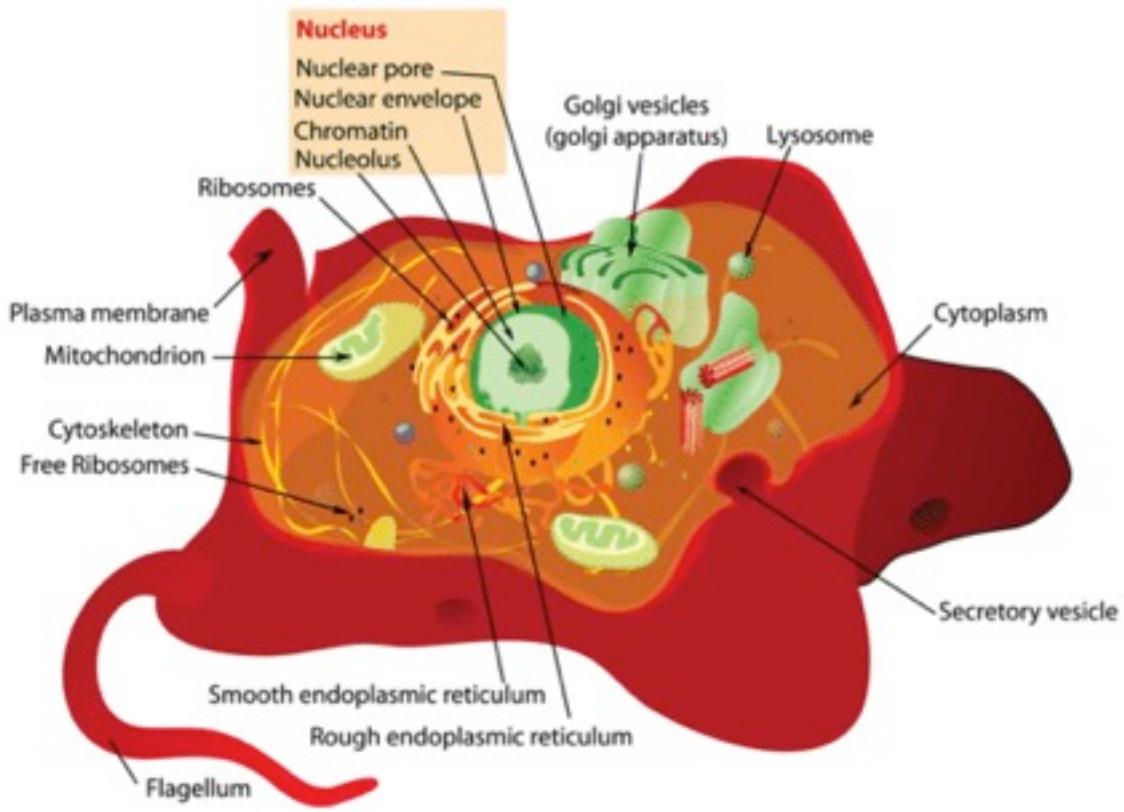


Figure 2.5

Eukaryotic cells contain a nucleus and various other special compartments surrounded by membranes, called organelles. The nucleus is where the DNA (chromatin) is stored.

Prokaryotic Cells

Prokaryotic cells (**Figure** below) are usually smaller and simpler than eukaryotic cells. They do not have a nucleus or other membrane-bound organelles. In prokaryotic cells, the DNA, or genetic material, forms a single large circle that coils up on itself. The DNA is located in the main part of the cell.

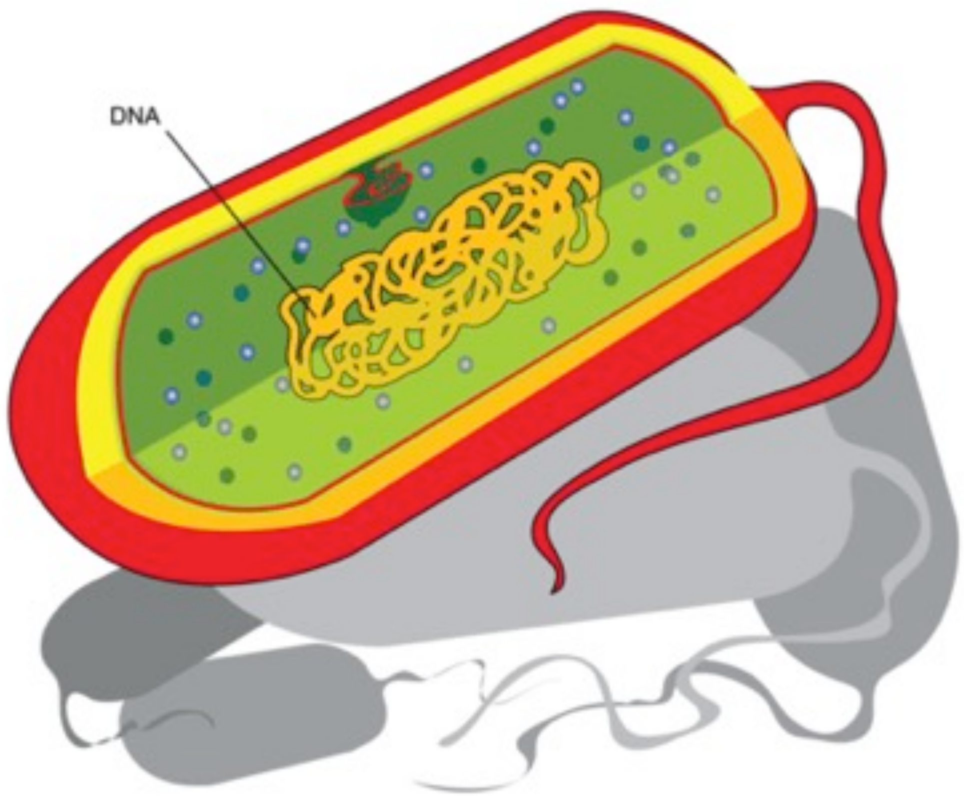


Figure 2.6

Prokaryotes do not have a nucleus. Instead, their genetic material is located in the main part of the cell.

	Prokaryotic Cells	**Eukaryotic Cells**
Nucleus	No	Yes

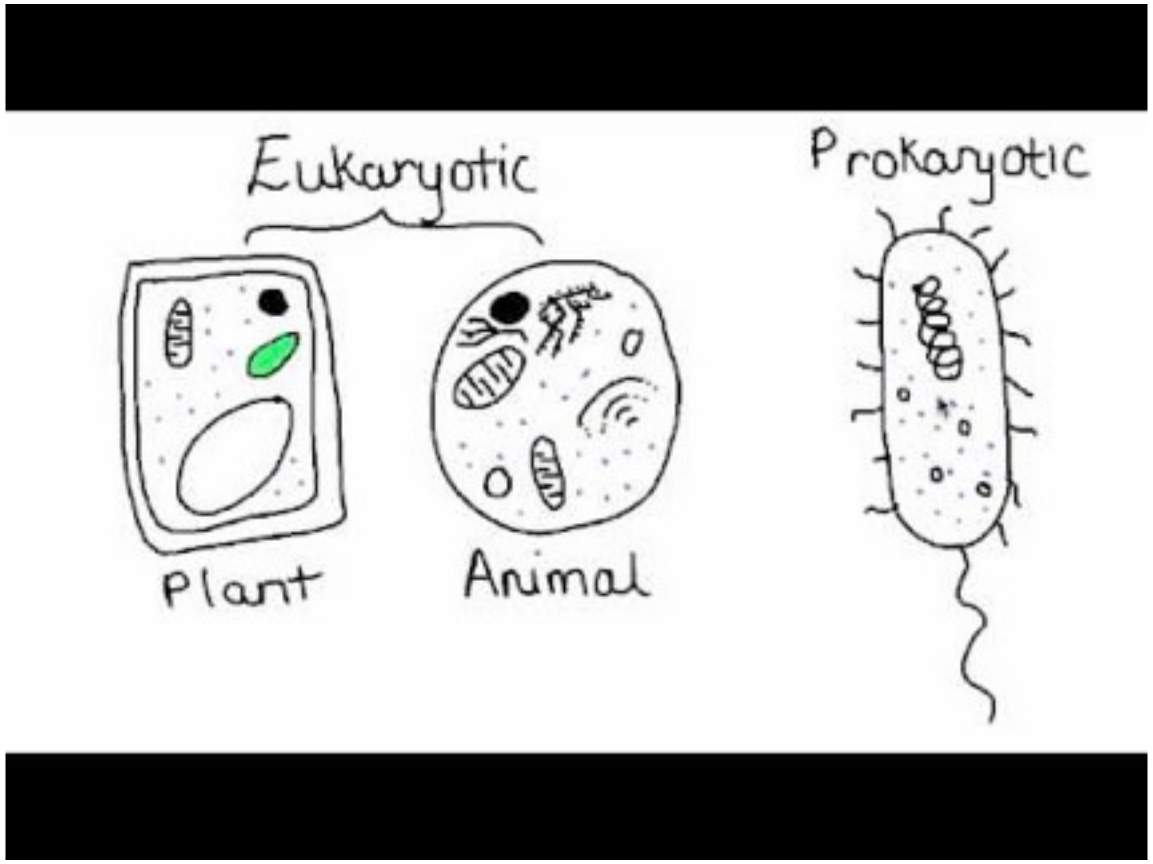
Summary

- All cells have a plasma membrane, ribosomes, cytoplasm, and DNA.
- Prokaryotic cells lack a nucleus and membrane-bound structures.
- Eukaryotic cells have a nucleus and membrane-bound structures called organelles.

Explore More

Use the resource below to answer the questions that follow.

- **Compare Prokaryotic and Eukaryotic Cells** at http://www.youtube.com/watch?v=QON4z9vo7Ag (1:55)



Click on the image above for more content

1. What does "naked" DNA mean? What kinds of organisms have "naked" DNA?
2. Where do you find membrane bound organelles? Are plasmids membrane bound organelles?
3. What is the function of mitochondria in prokaryotes?

Review

1. What do all cells have in common?
2. What are organelles?
3. Compare the location of the genetic material of eukaryotic cells and prokaryotic cells.
4. What are ribosomes?

5.What are the only prokaryotes?
6.Which prokaryotes are multicellular?

Section 3

Cell Membrane

Cell Membrane

•Describe the roles of the plasma membrane and cytosol.
•Explain the concept of semipermeability.
•Summarize how the plasma membrane separates the cytosol from the outside environment.

Who guards your cells?

Not everything can make it into your cells. Your cells have a plasma membrane that helps to guard your cells from unwanted intruders.

The Plasma Membrane and Cytosol

If the outside environment of a cell is water-based, and the inside of the cell is also mostly water, something has to make sure the cell stays intact in this environment. What would happen if a cell dissolved in water, like sugar does? Obviously, the cell could not survive in such an environment. So something must protect the cell and allow it to survive in its water-based environment. All cells have a barrier around them that separates them from the environment and from other cells. This barrier is called the **plasma membrane** , or cell membrane.

The Plasma Membrane

The plasma membrane (**Figure** below) is made of a double layer of special lipids, known as **phospholipids** . The phospholipid is a lipid molecule with a hydrophilic ("water-loving") head and two hydrophobic ("water-hating") tails. Because of the hydrophilic and hydrophobic nature of the phospholipid, the molecule must be arranged in a specific pattern as only certain parts of the molecule can physically be in contact with water. Remember that there is water outside the cell, and the **cytoplasm** inside the cell is mostly water as well. So the phospholipids are arranged in a double layer (a bilayer) to keep the cell separate from its environment. Lipids do not mix with water (recall that oil is a lipid), so the phospholipid bilayer of the cell membrane acts as a barrier, keeping water out of the cell, and keeping the cytoplasm inside the cell. The cell membrane allows the cell to stay structurally intact in its water-based environment.

The function of the plasma membrane is to control what goes in and out of the cell. Some molecules can go through the cell membrane to enter and leave the cell, but some cannot. The cell is therefore not completely permeable. "Permeable" means that anything can cross a barrier. An open door is completely permeable to anything that wants to enter or exit through the door. The plasma membrane is **semipermeable** , meaning that some things can enter the cell, and some things cannot.

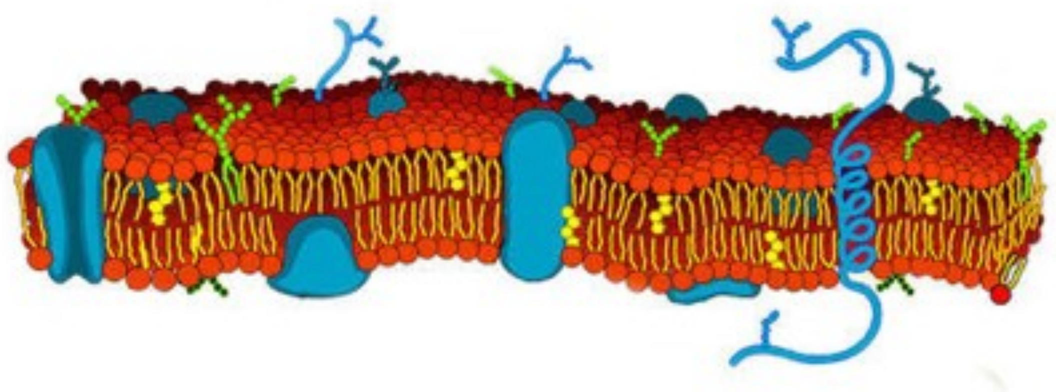


Figure 2.7

Plasma membranes are primarily made up of phospholipids (orange). The hydrophilic ("water-loving") head and two hydrophobic ("water-hating") tails are shown. The phospholipids form a bilayer (two layers). The middle of the bilayer is an area without water. There can be water on either side of the bilayer. There are many proteins throughout the membrane.

Cytosol

The inside of all cells also contain a jelly-like substance called **cytosol** . Cytosol is composed of water and other molecules, including **enzymes** , which are proteins that speed up the cell's chemical reactions. Everything in the cell sits in the cytosol, like fruit in a Jell-o mold. The term cytoplasm refers to the cytosol and all of the organelles, the specialized compartments of the cell. The cytoplasm does not include the nucleus. As a prokaryotic cell does not have a nucleus, the DNA is in the cytoplasm.

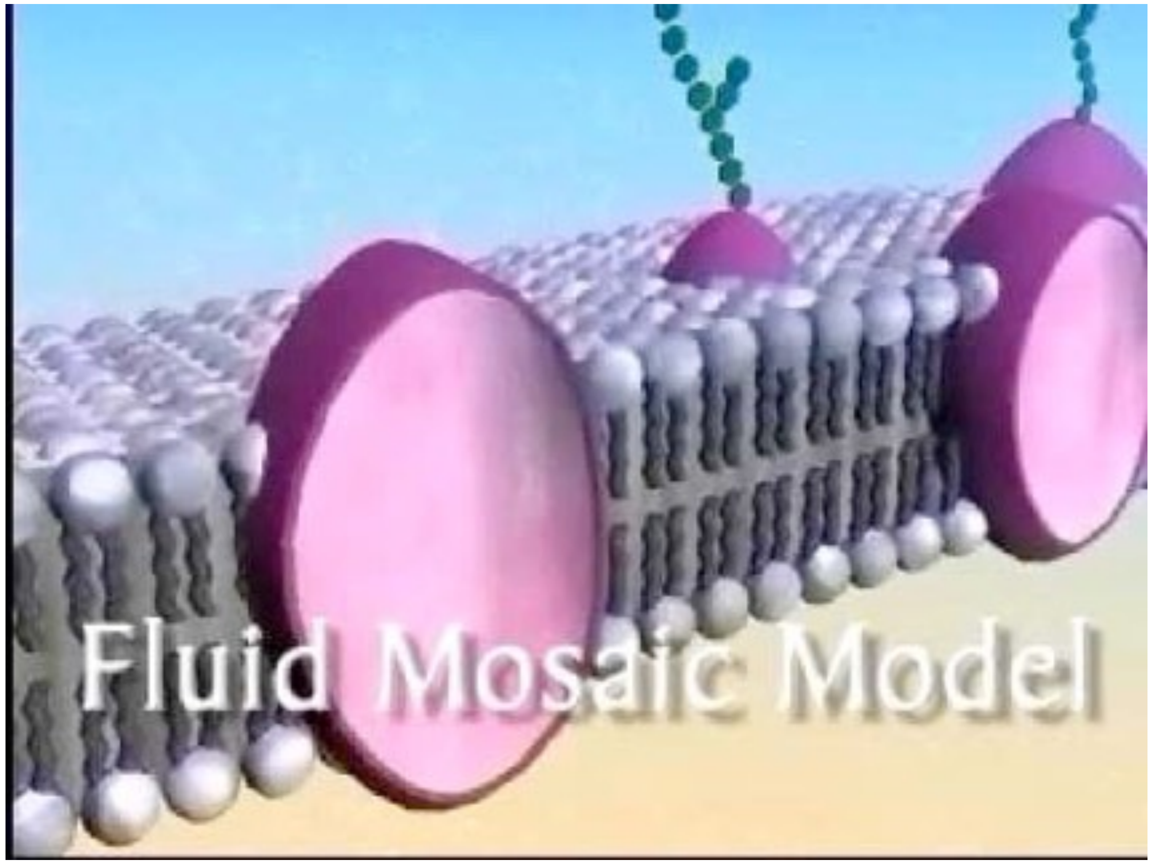
Summary

- •The plasma membrane is formed by a phospholipid bilayer.
- •The plasma membrane controls what moves inside and outside the cell.
- •The cytosol is the jelly-like material in which the contents of the cell are suspended.

Explore More

Use the resource below to answer the following questions.

- •**The Plasma Membrane** at http://www.youtube.com/watch?v=moPJkCbKjBs (5:16)



Click on the image above for more content

1. What makes up the "head" region of a phospholipid? Is it hydrophobic or hyrdrophilic?
2. What makes up the "tail" region of a phospholipid? Is it hydrophobic or hyrdrophilic?
3. What happens when you drop a phospholipid in water?
4. How are phospholipids arranged in a plasma membrane?
5. What is a glycoprotein? What is one of the uses of glycoproteins?
6. What is "Brownian movement"? How is this movement related to the cell membrane?

Review

1. What is the plasma membrane?
2. Describe a phospholipid.
3. What are the components of the cytosol?
4. What is meant by the description of the plasma membrane as “semipermeable”?
5. What is the difference between the cytosol and the cytoplasm?

Section 4

Cell Nucleus

Cell Nucleus

- •Describe the features and function of the cell's nucleus.
- •Define chromosome.
- •Explain the role of the nucleolus.

Where is your DNA?

You may know that a criminal can easily leave DNA at a crime scene. How? DNA is found in every cell of your body. In each cell there is a nucleus, which is home to your DNA. So if a criminal has a cut, and blood is left at the crime scene, or a hair falls out and is left behind, then DNA will also be left at the scene.

The Nucleus

The **nucleus** is only found in eukaryotic cells. It contains most of the genetic material (the **DNA**) of the cell. The genetic material of the nucleus is like a set of instructions. These instructions tell the cell how to build molecules needed for the cell to function properly. That is, the DNA tells the cell how to build molecules needed for life. The nucleus is surrounded by the **nuclear envelope** , a double membrane (two bilayers) that controls what goes in and out of the nucleus. The nucleus also has holes embedded in the nuclear envelope. These holes are nuclear pores, and they allow things to flow in and out of the nucleus.

Chromosomes

Inside of the nucleus, you will find the **chromosomes** . Chromosomes are strands of DNA wrapped around proteins. They contain **genes** , or small units of genetic material. Human cells have 46 chromosomes.

Nucleolus

The nucleus of many cells also contains a central region called the **nucleolus** . The job of the nucleolus is to build ribosomes. These ribosomes flow out the nuclear pores into the cytoplasm. **Ribosomes** are organelles that make proteins in the cytoplasm. See the composition of the nucleus pictured below (**Figure** below).

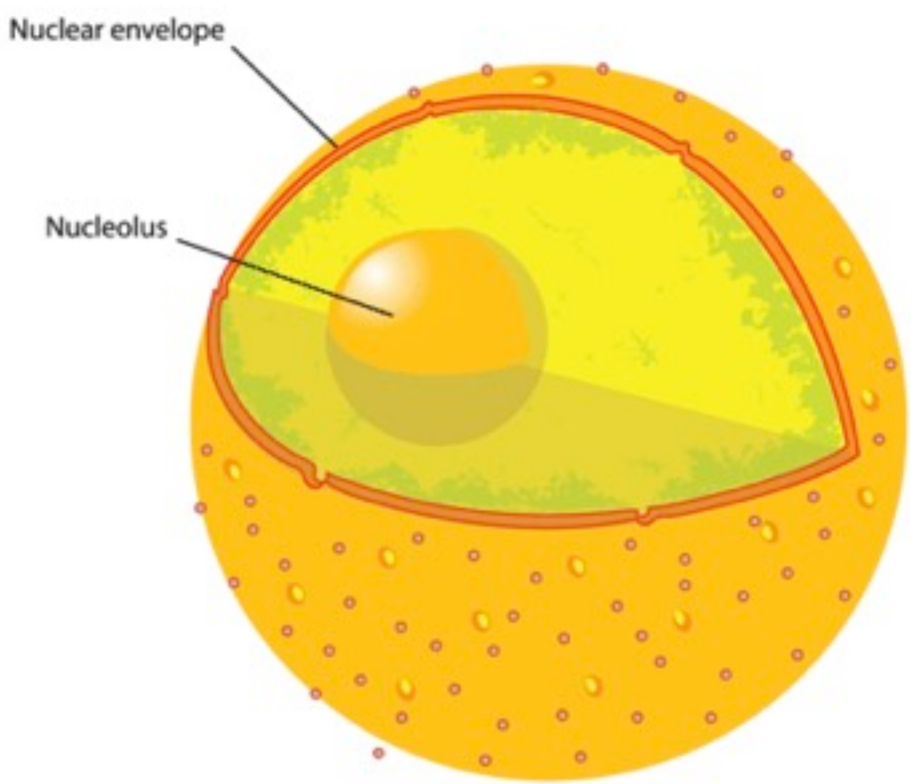


Figure 2.8

In eukaryotic cells, the DNA is kept in the nucleus. The nucleus is surrounded by a double membrane called the nuclear envelope. Within the nucleus is the nucleolus.

Summary

- The nucleus contains the genetic material of the cell.
- The genetic material of the cell is found in chromosomes, DNA wrapped around proteins.
- The nucleolus, which makes ribosomes, is also within the nucleus.

Explore More

Use the resources below to answer the following questions.

- **Nucleus** at http://www.youtube.com/watch?v=DMd3mr6rQ2o (2:25)

1. What is chromatin? What molecules make up chromatin?
2. What is the nuclear membrane? What kind of membrane is this membrane?
3. What is the nucleolus? What molecules do you find there?
4. How is the inside of the nucleus connected to the cytosol? Why is this connection vital for the cell?

Review

1. What is contained in the nucleus of a cell?
2. What is a chromosome? Where are chromosomes located?
3. How many chromosomes do humans have?
4. What is the function of the nucleolus?

Section 5

Organelles

Organelles

•List the main organelles found in an eukaryotic cell.
•Define the role of a ribosome.
•Describe the functions of the mitochondria, endoplasmic reticulum, and Golgi apparatus.
•Explain the function of a vesicle, a vacuole, and a lysosome.

Do brain cells have the same internal structures as your other cells?

Yes. Although brain cells look quite different from your other cells, they have the same internal structures as other cells. They need the same structures because they need to perform the same tasks, such as making proteins and obtaining energy.

Organelles

Eukaryotic cells have many specific functions, so it can be said that a cell is like a factory. A factory has many machines and people, and each has a specific role. Just like a factory, the cell is made up of many different parts. Each part has a special role. The different parts of the cell are called **organelles** , which means "small organs." All organelles are found in eukaryotic cells. Prokaryotic cells are "simpler" than eukaryotic cells. Though prokaryotic cells still have many functions, they are not as specialized as eukaryotic cells. Thus, most organelles are NOT found in prokaryotic cells.

Below are the main organelles found in eukaryotic cells (**Figure** below):

1.The **nucleus** of a cell is like a safe containing the factory's trade secrets. The nucleus contains the genetic material-the information about how to build thousands of proteins.
2.The **mitochondria** are the powerhouses of the cell; they provide the energy needed to power chemical reactions. This energy is in the form of ATP (adenosine triphosphate). Cells that use a lot of energy may have thousands of mitochondria.

3.**Vesicles** are small membrane bound sacs that transport materials around the cell and to the cell membrane.
4.The **vacuoles** are like storage centers. Plant cells have larger vacuoles than animal cells. Plants store water and nutrients in their large central vacuoles.
5.**Lysosomes** are like the recycling trucks that carry waste away from the factory. Lysosomes have digestive enzymes that break down old molecules into parts that can be recycled.
6.In both eukaryotes and prokaryotes, **ribosomes** are the non-membrane bound organelles where proteins are made. Ribosomes are like the machines in the factory that produce the factory's main product. Proteins are the main product of the cell.
7.Some ribosomes can be found on folded membranes called the **endoplasmic reticulum** (ER), others float freely in the cytoplasm. If the ER is covered with ribosomes, it looks bumpy like sandpaper, and is called the rough endoplasmic reticulum. If the ER does not contain ribosomes, it is smooth and called the smooth endoplasmic reticulum. Many proteins are made on the ribosomes on the rough ER. These proteins immediately enter the ER, where they are modified, packaged into vesicles and sent to the Golgi apparatus. Lipids are made in the smooth ER.
8.The **Golgi apparatus** works like a mail room. The Golgi apparatus receives proteins from the rough ER and puts "shipping addresses" on them. The Golgi then packages the proteins into vesicles and sends them to the right place in the cell or to the cell membrane. Some of these proteins are secreted from the cell (they exit the cell); others are placed into the cell membrane.

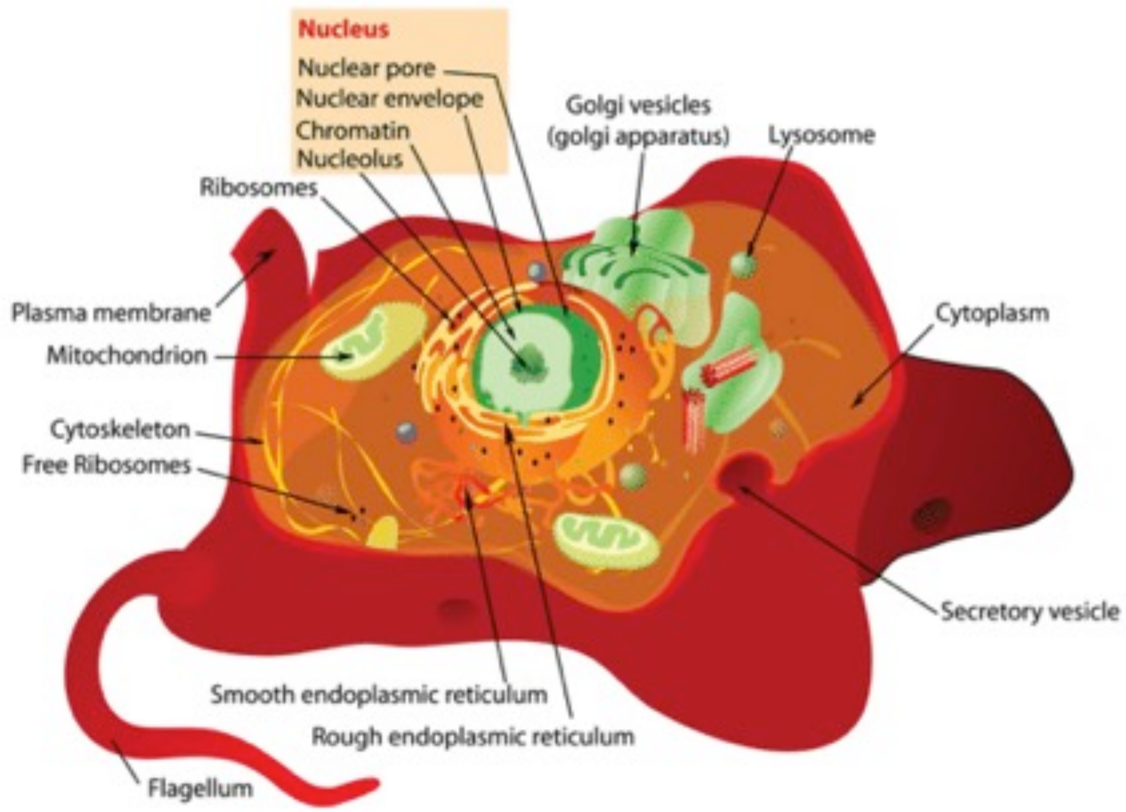


Figure 2.9

Eukaryotic cells contain special compartments surrounded by membranes, called organelles. For example, notice in this image the mitochondria, lysosomes, and Golgi apparatus.

Also, the **cytoskeleton** gives the cell its shape, and the **flagella** helps the cell to move. Prokaryotic cells may also have flagella.

Summary

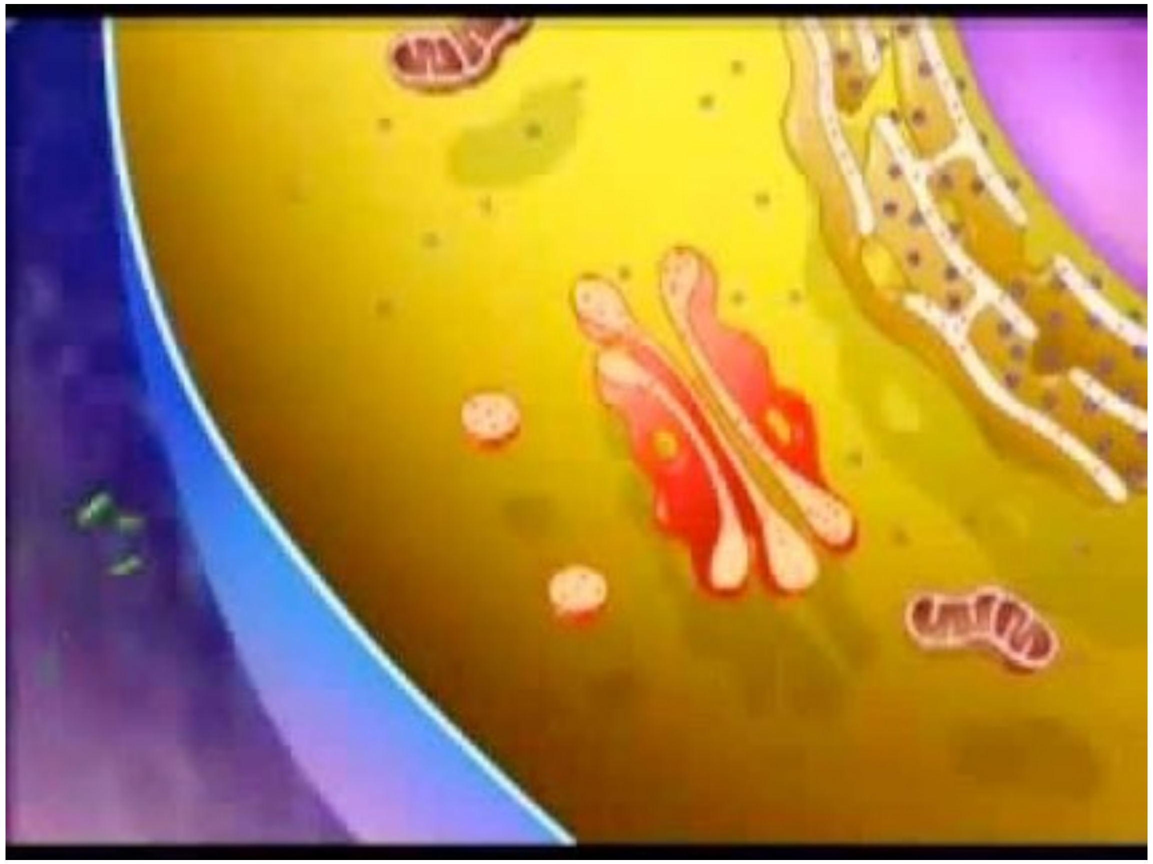
•The nucleus stores the genetic information.
•The vacuoles are needed for storage.
•The lysosomes recycle waste.
•The cytoskeleton provides the shape of the cell.
•The ribosomes produce proteins.
•The rough ER is covered with ribosomes and makes proteins, while the smooth ER makes lipids.
•The Golgi apparatus packages proteins.

Explore More

Use the resources below to answer the following questions.

Explore More I

•**Organelles** at http://www.youtube.com/watch?v=fKEaTt9heNM (6:25)



Click on the image above for more content

1. What are the functions of the endoplasmic reticulum? What gives the rough endoplasmic reticulum its "rough" appearance?
2. What are the most abundant organelles in a cell? Where do they occur? What is there function?
3. What is the appearance of the Golgi apparatus? What is the function of the Golgi apparatus?
4. What are lysosomes? What are their functions?
5. What is the function of mitochondria? Do all cells have the same number of mitochondria? How can this situation be explained?

Explore More II

•**Cell Models** at http://www.cellsalive.com/cells/cell_model.htm . Go to this site and click on "animal cell."

1.What is cytosol? How does this differ from cytoplasm?
2.What are the primary types of protein filaments that make up the cytoskeleton?
3.What is the function of a peroxisome?
4.What is a secretory vesicle? Where are they made? What is their function?

Review

1.What is the purpose of the Golgi apparatus?
2.What is the purpose of the mitochondria?
3.How is the smooth ER different from the rough ER?
4.What is a lysosome?

Section 6

Plant Cell Structures

Plant Cell Structures

•Distinguish plant cells from animal cells.
•Explain the roles of the chloroplast and central vacuole.
•Summarize the function of the cell wall.

Do plants have cells like yours?

Yes, your cells are actually very similar to a plant's cells. For example, they are both eukaryotic cells, both contain DNA in a nucleus, and both make proteins in ribosomes. However, plant cells also differ in some crucial ways from your own cells.

Plant Cells

Even though plants and animals are both eukaryotes, plant cells differ in some ways from animal cells (**Figure** below). Plant cells have a large central vacuole, are surrounded by a cell wall, and have chloroplasts, which are the organelles of **photosynthesis** .

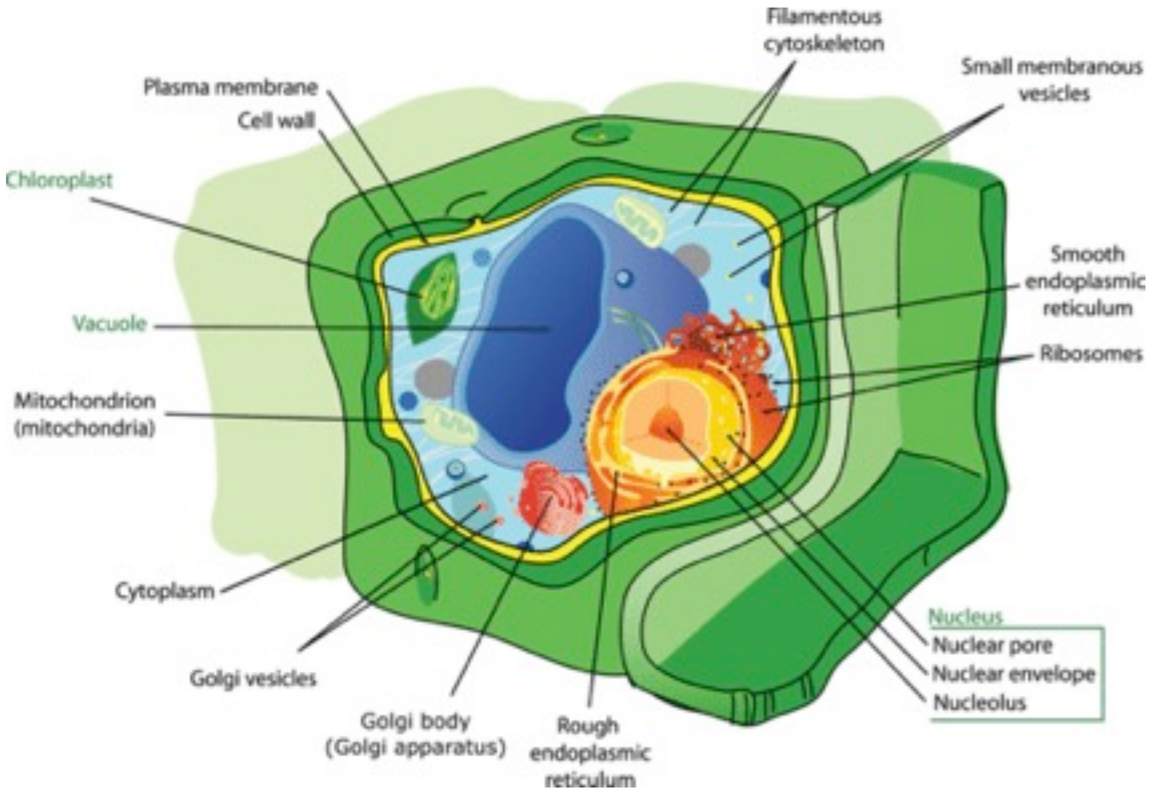


Figure 2.10

A plant cell has several features that make it different from an animal cell, including a cell wall, huge vacuoles, and chloroplasts, which photosynthesize.

Vacuoles

First, plant cells have a large central **vacuole** that holds a mixture of water, nutrients, and wastes. A plant cell's vacuole can make up 90% of the cell's volume. The large central vacuole essentially stores water. What happens when a plant does not get enough water? In animal cells, vacuoles are much smaller.

Cell Wall

Second, plant cells have a **cell wall** , while animal cells do not (**Figure** below). The cell wall surrounds the plasma membrane but does not keep substances from entering or leaving the cell. A cell wall gives the plant cell strength and protection.

Figure 2.11

In this photo of plant cells taken with a light microscope, you can see green chloroplasts, as well as a cell wall around each cell.

Plastids

A third difference between plant and animal cells is that plants have several kinds of organelles called **plastids** . And there are several different kinds of plastids in plant cells. For example, **Chloroplasts** are needed for photosynthesis, leucoplasts can store starch or oil, and brightly colored chromoplasts give some flowers and fruits their yellow, orange, or red color. It is the presence of chloroplasts and the ability to photosynthesize, that is one of the defining features of a plant. No animal or fungi can photosynthesize, and only some protists are able to. The photosynthetic protists are the plant-like protists, represented mainly by the unicellular algae.

Summary

- Plant and animal cells differ in that plants have a large central vacuole, while animals have smaller vacuoles.
- Plant cells also have cell walls and plastids, while animal cells do not.

Explore More

Use the resource below to answer the following questions.

- **Plant and Animal Cell Animation - Cells alive** at http://www.cellsalive.com/cells/cell_model.htm

1. Compare and contrast the vacuoles of plant cells and the vacuoles of animal cells.
2. How is the appearance of thylakoids similar to the appearance of the Golgi apparatus?
3. What kind of membrane do chloroplasts have? What other organelle has a similar type of membrane?
4. What features do plant cells have in common with animal cells?

Review

1. What are three structures that are found in plant cells but not in animal cells?
2. What is the role of the chloroplast?
3. What is the main role of the plant vacuole?

Section 7

Cell Transport

Cell Transport

- •Describe the structure and properties of a phospholipid and a phospholipid bilayer.
- •Distinguish between hydrophilic and hydrophobic.

How is a cell membrane like a castle wall?

The walls of a castle, like the cell membrane, are designed to keep out dangerous things. Whether you're concerned about an enemy army or a disease-causing bacteria, you don't want to allow everything to enter! However, in order to survive, there are some things that the cell (or the castle) does need to let in.

Introduction to Cell Transport

Cells are found in all different types of environments, and these environments are constantly changing. For example, one-celled organisms, like bacteria, can be found on your skin, in the ground, or in all different types of water. Therefore, cells need a way to protect themselves. This job is done by the **cell membrane** , which is also known as the plasma membrane.

Controlling the Cell Contents

The cell membrane is **semipermeable** , or selectively permeable, which means that only some molecules can pass through the membrane. If the cell membrane were completely permeable, the inside of the cell would be the same as the outside of the cell. It would be impossible for the cell to maintain **homeostasis** . Homeostasis means maintaining a stable internal environment. For example, if your body cells have a temperature of 98.6°F, and it is freezing outside, your cells will maintain homeostasis if the temperature of the cells stays the same and does not drop with the outside temperature.

How does the cell ensure it is semipermeable? How does the cell control what molecules enter and leave the cell? The composition of the cell membrane helps to control what can pass through it.

Composition of the Cell Membrane

Molecules in the cell membrane allow it to be semipermeable. The membrane is made of a double layer of phospholipids (a "bilayer") and proteins (**Figure** below). Recall that phospholipids, being lipids, do not mix with water. It is this quality that allows them to form the outside barrier of the cell.

A single phospholipid molecule has two parts:

1. A head that is **hydrophilic** , or water-loving.
2. A tail that is **hydrophobic** , or water-fearing.

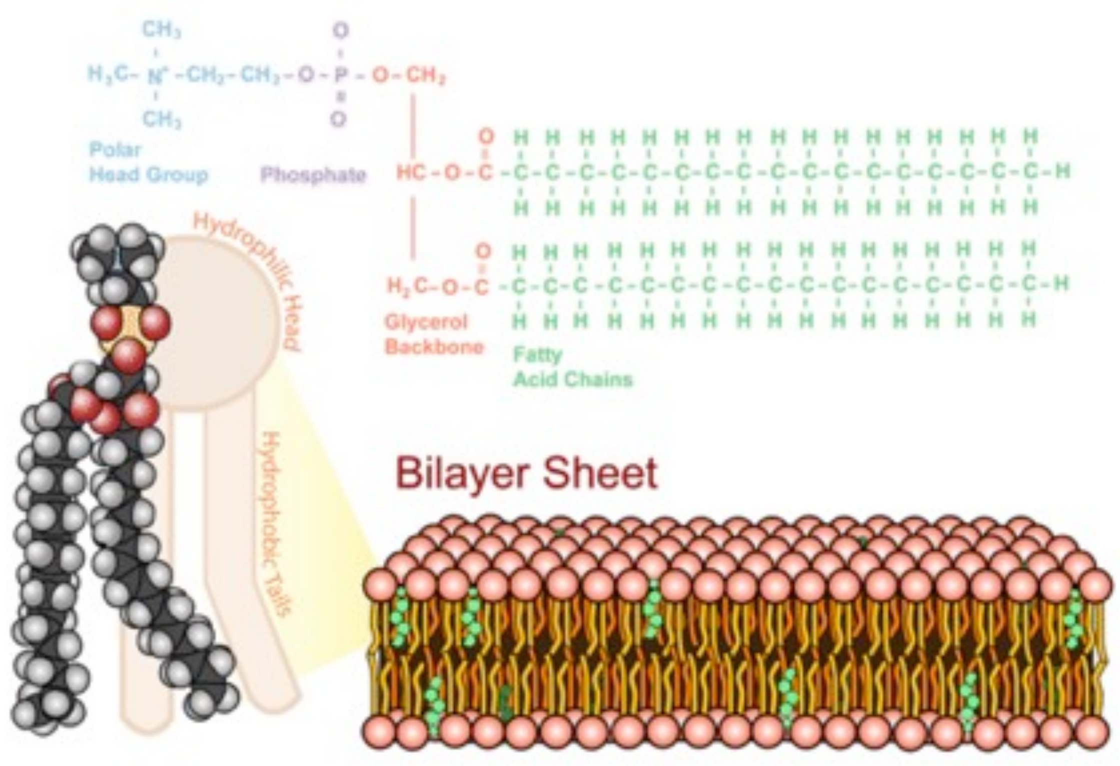


Figure 2.12

The cell membrane is made up of a phospholipid bilayer, two layers of phospholipid molecules.

There is water found on both the inside and the outside of cells. Since hydrophilic means water-loving, and they want to be near water, the heads face the inside and outside of the cell where water is found. The water-fearing, hydrophobic tails face each other in the middle of the cell membrane, because water is not found in this space. The phospholipid bilayer allows the cell to stay intact in a water-based environment.

An interesting quality of the plasma membrane is that it is very "fluid" and constantly moving, like a soap bubble. Due to the composition of the cell membrane, small molecules such as oxygen and carbon dioxide can pass freely through the membrane, but other molecules cannot easily pass through the plasma membrane. These molecules need assistance to get across the membrane. That assistance will come in the form of **transport proteins.**

Summary

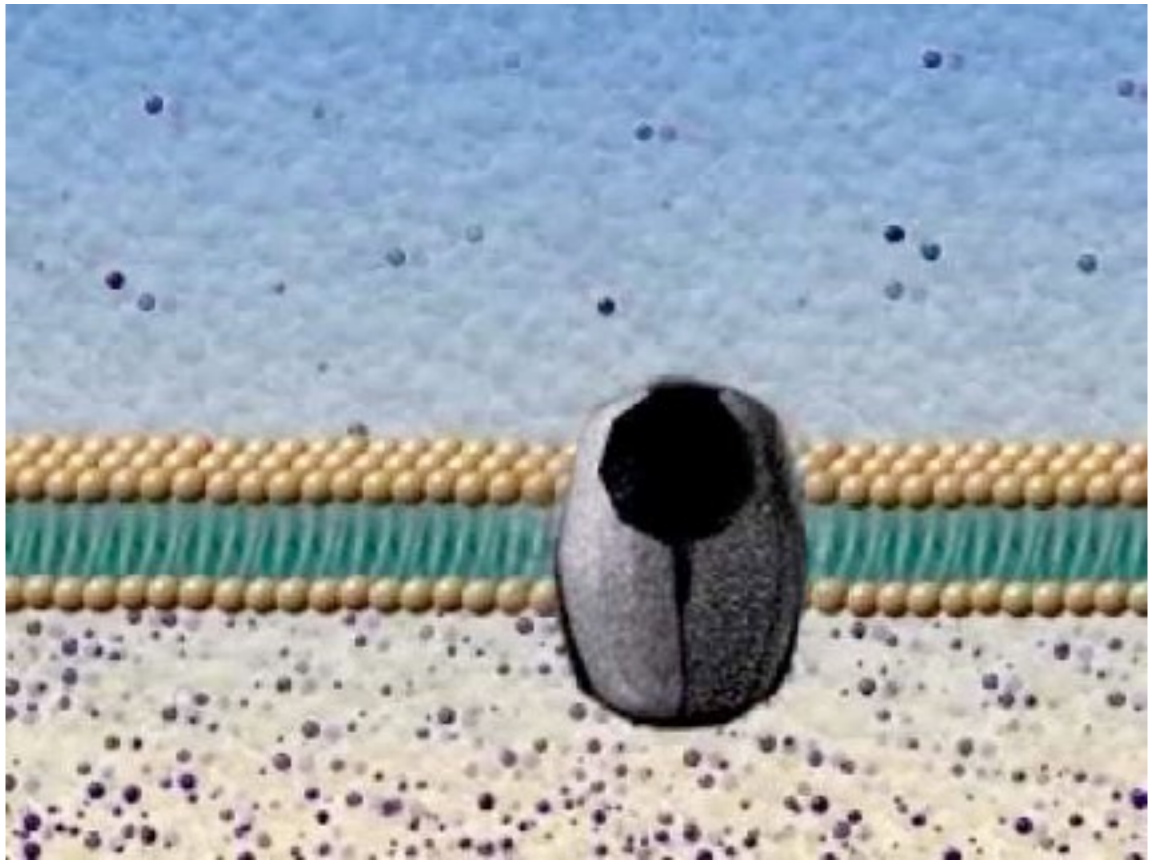
- The cell membrane is selectively permeable, meaning only some molecules can get through.
- The cell membrane is made of a double layer of phospholipids, each with a hydrophilic (water-loving) head and a hydrophobic (water-fearing) tail.

Explore More

Use the resources below to answer the following questions.

Explore More I

•**Active and Passive Transport** at http://www.youtube.com/watch?v=kfy92hdaAH0 (6:13)



Click on the image above for more content

1.How is passive transport different from active transport?
2.What are three types of passive transport? What do these all have in common?
3.What does the body use iodine for? What kind of transport is necessary to transport this molecule into a cell?
4.What happens to the receptor complex in receptor mediated endocytosis?

Explore More II

•**Membrane tutorial** at http://www.bio.davidson.edu/people/macampbell/111/memb-swf/membranes.swf
1.Can proteins in the plasma membrane move around the membrane? Why is this characteristic beneficial to the cell?
2.What are five functions of the membrane in cells?
3.What types of lipids are found in plasma membranes? What characteristics do these types of lipids share?

Review

1.Why is the plasma membrane considered selectively permeable? Why is this important?
2.Explain the composition of the cell membrane.
3.Explain the arrangement of phospholipids in the membrane.

Section 8

Diffusion

Diffusion

•Describe a concentration gradient.
•Define diffusion.
•Distinguish between diffusion and osmosis.
•Differentiate between hypertonic, hypotonic, and isotonic solutions.

What happens if you put a few drops of food coloring in water?

Over time, the molecules of color spread out through the rest of the water. When the molecules are evenly spread throughout the space, the water will become an even color. This process of molecules moving from an area where there are lots of molecules to an area where there are fewer molecules is known as diffusion.

Diffusion

Small molecules can pass through the plasma membrane through a process called diffusion. **Diffusion** is the movement of molecules from an area where there is a higher concentration (larger amount) of the substance to an area where there is a lower concentration (lower amount) of the substance (**Figure** below). The amount of a substance in relation to the total volume is the **concentration** . During diffusion, molecules are said to flow down their **concentration gradient** , flowing from an area of high concentration to an area of low concentration. This is a natural process and does not require energy. Diffusion can occur across a semipermeable membrane, such as the cell membrane, as long as a concentration gradient exists. Molecules will continue to flow in this manner until **equilibrium** is reached. At equilibrium, there is no longer an area of high concentration or low concentration.

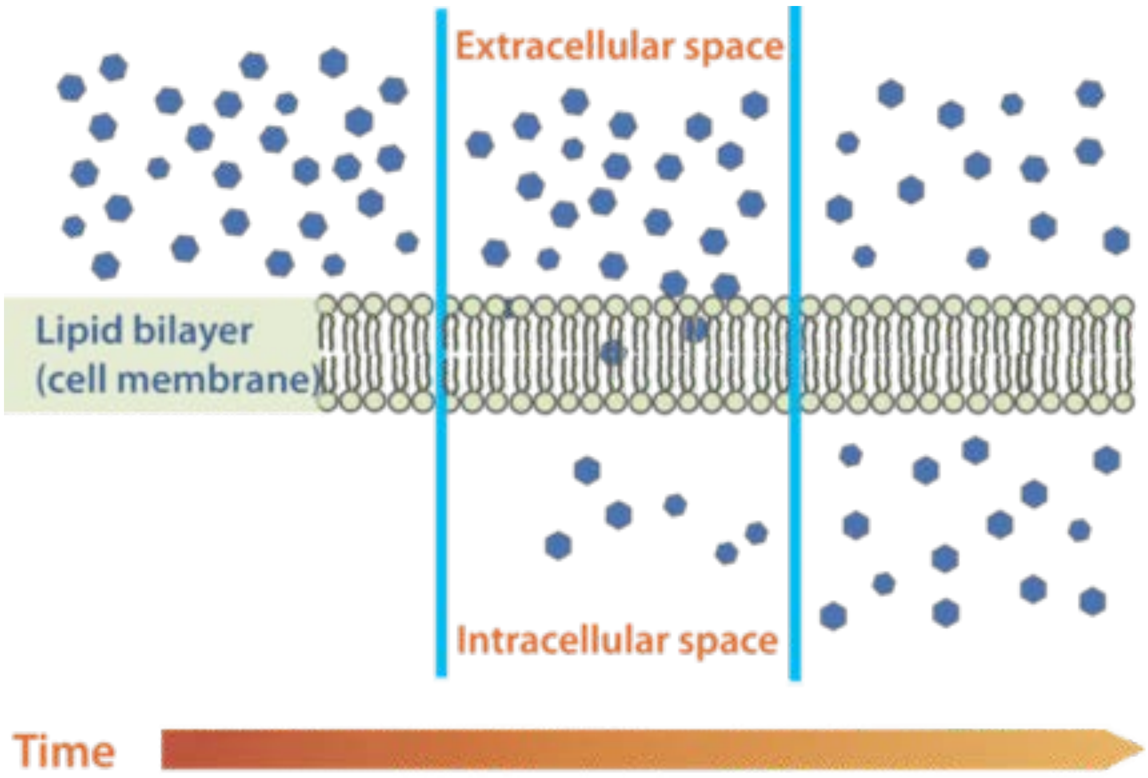


Figure 2.13

Diffusion is the movement of a substance from an area of a higher amount toward an area of lower amount. A concentration gradient initially exists across the cell membrane. Equilibrium is reached when there is an equal amount of the substance on both sides of the membrane.

Osmosis

The diffusion of water across a membrane because of a difference in concentration is called **osmosis** . Let's explore three different situations and analyze the flow of water.

1. A **hypotonic solution** means the environment outside of the cell has a lower concentration of dissolved material than the inside of the cell. If a cell is placed in a hypotonic solution, water will move into the cell. This causes the cell to swell, and it may even burst.
2. A **hypertonic solution** means the environment outside of the cell has more dissolved material than inside of the cell. If a cell is placed in a hypertonic solution, water will leave the cell. This can cause a cell to shrink and shrivel.
3. An **isotonic solution** is a solution in which the amount of dissolved material is equal both inside and outside of the cell. Water still flows in both directions, but an equal amount enters and leaves the cell.

Applications of Osmosis

How do marine animals keep their cells from shrinking? How do you keep your blood cells from bursting? Both of these questions have to do with the cell membrane and osmosis. Marine animals live in salt water, which is a hypertonic environment; there is more salt in the water than in their cells. To prevent losing too much water from their bodies, these animals intake large quantities of salt water and then secrete the excess salt. Red blood cells can be kept from bursting or shriveling if put in a solution that is isotonic to the blood cells. If the blood cells were put in pure water, the solution would be hypotonic to the blood cells, so water would enter the blood cells, and they would swell and burst (**Figure** below).

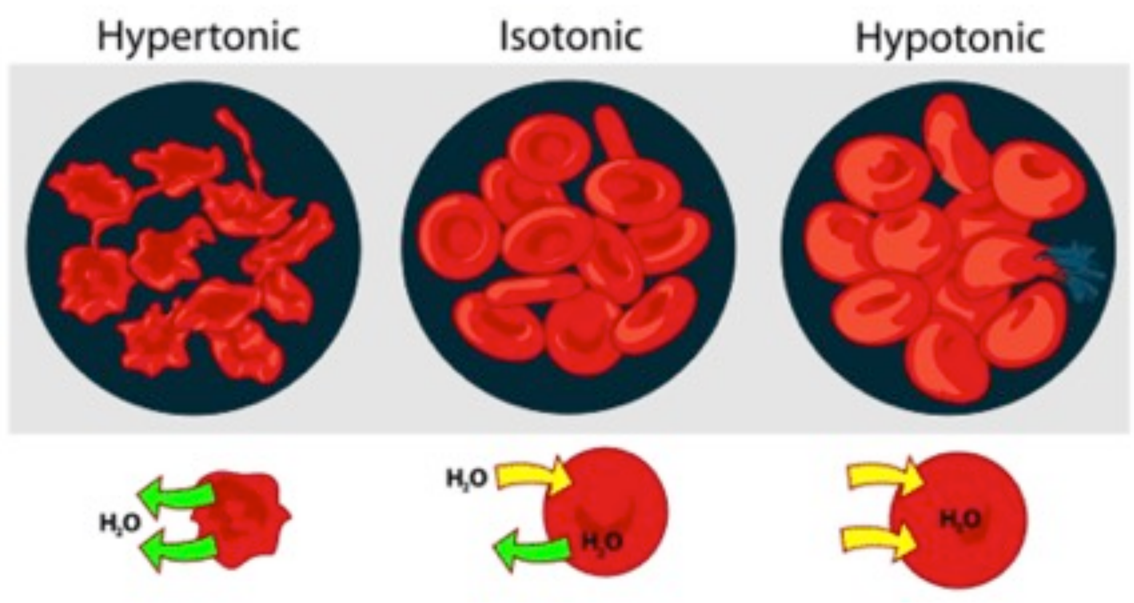


Figure 2.14

Osmosis causes these red blood cells to change shape by losing or gaining water.

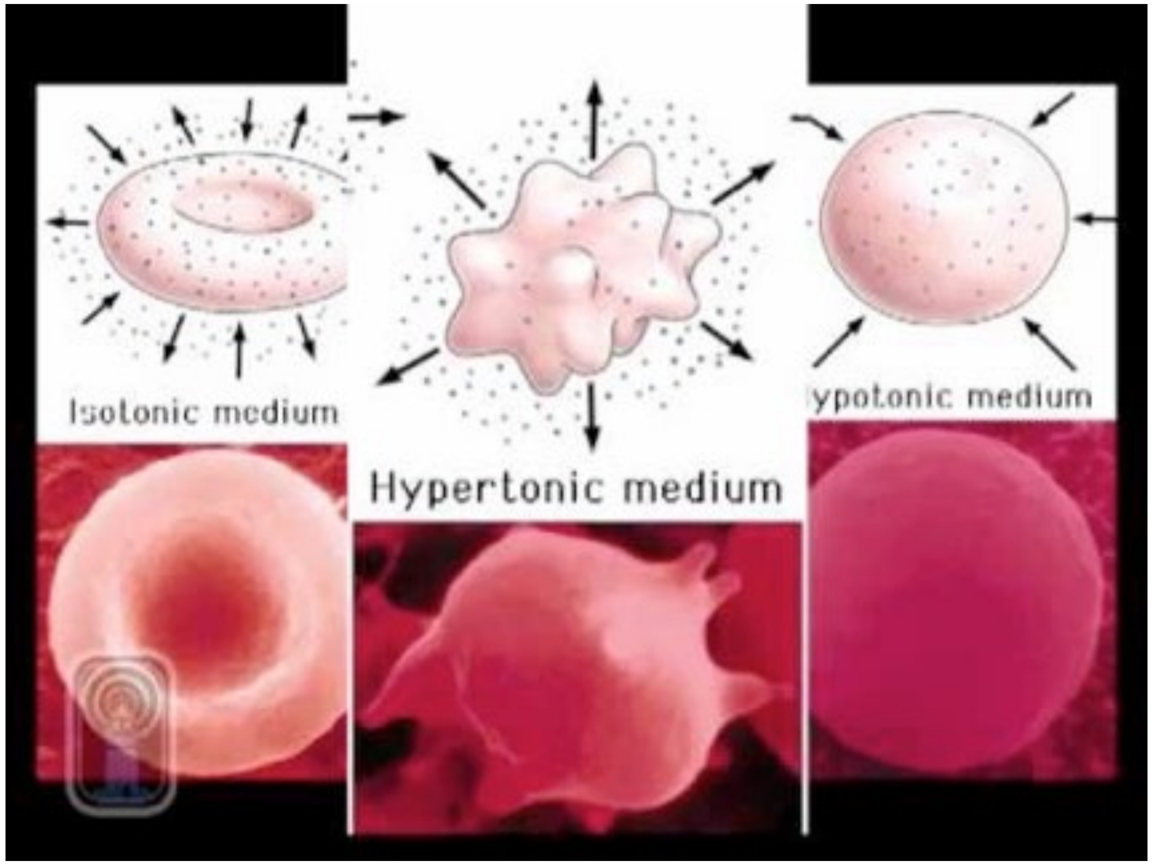
Summary

•Diffusion is the movement of molecules from an area of high concentration to an area of low concentration.
•The diffusion of water across a membrane because of a difference in concentration is called osmosis.

Explore More

Use the resource below to answer the following questions.

•**Osmosis** at http://www.youtube.com/watch?v=7-QJ-UUX0iY (5:07)



Click on the image above for more content

1.What is osmosis?
2.What is tonicity?

3. How can a hypotonic solution cause a cell to rupture? Describe this process as specifically as you can.
4. How would a hypertonic solution affect a cell? How could this affect cellular processes?
5. Do water molecules leave or enter a cell in an isotonic solution?

Review

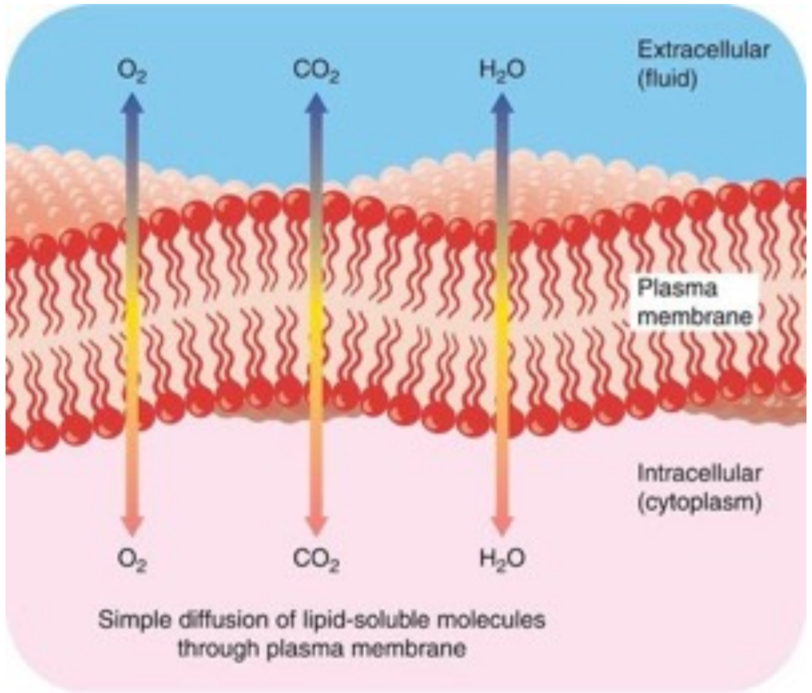
1. Describe the process of diffusion.
2. Define osmosis.
3. If a plant cell is placed in a solution and the cell shrivels up, what type of solution was it placed in? How do you know?

Section 9

Passive Transport

Passive Transport

•Define passive transport and facilitative diffusion.
•Explain the process of passive transport.
•Distinguish between a channel protein and a carrier protein.
•Summarize the functions of channel proteins and carrier proteins.



Can any molecule move freely through your cell membranes?

The cell regulates most molecules that pass through the cell membrane. If a molecule is charged or very big, it won't make it through the cell membrane on its own. However, small, non-charged molecules like oxygen, carbon dioxide, and water, can pass through the cell membrane freely.

Passive Transport

Recall that the cell membrane is semipermeable. It does not allow everything to pass through. Some molecules can pass easily through your cell membranes, while others have more difficulty. Sometimes molecules need the help of special transport proteins to move across the cell membrane. Some molecules even need an input of energy to help get them across the cell membrane. The movement of molecules across a membrane without the input of energy is known as **passive transport** . When energy is needed, the movement is known as **active transport** .

Simple Diffusion

One example of passive transport is **diffusion** , when molecules move from an area of high concentration (large amount) to an area of low concentration (low amount). Molecules are said to flow down their concentration gradient. This type of diffusion proceeds without an input of energy. In **simple diffusion** , molecules that are small and uncharged can freely diffuse across a cell membrane. They simply flow through the cell membrane. Simple diffusion does not require energy or need the assistance of a transport protein. Other larger or charged molecules that diffuse across a membrane may need assistance from a protein.

Oxygen is a molecule that can freely diffuse across a cell membrane. For example, oxygen diffuses out of the air sacs in your lungs into your bloodstream because oxygen is more concentrated in your lungs than in your blood. Oxygen moves from the high concentration of oxygen in your lungs to the low concentration of oxygen in your bloodstream.

Passive Transport using Membrane Proteins

Sometimes, molecules cannot move through the cell membrane on their own. These molecules need special transport proteins to help them move across the membrane, a process known as **facilitative diffusion** . These special proteins are called **channel proteins** or **carrier proteins** (**Figure** below), and they are attached to the cell membrane. In fact, they go through the cell membrane, from the inside of the cell to the outside. Channel proteins provide an open channel or passageway through the cell membrane for molecules to move across. Many channel proteins allow the diffusion of **ions.** Carrier proteins bind and carry the molecules across the cell membrane. These proteins bind a molecule on one side of the membrane, change shape as they carry the molecule across the membrane, and deposit the molecule on the other side of the membrane. Even though a protein is involved in both these methods of transport, neither method requires energy. Therefore these are still types of passive transport.

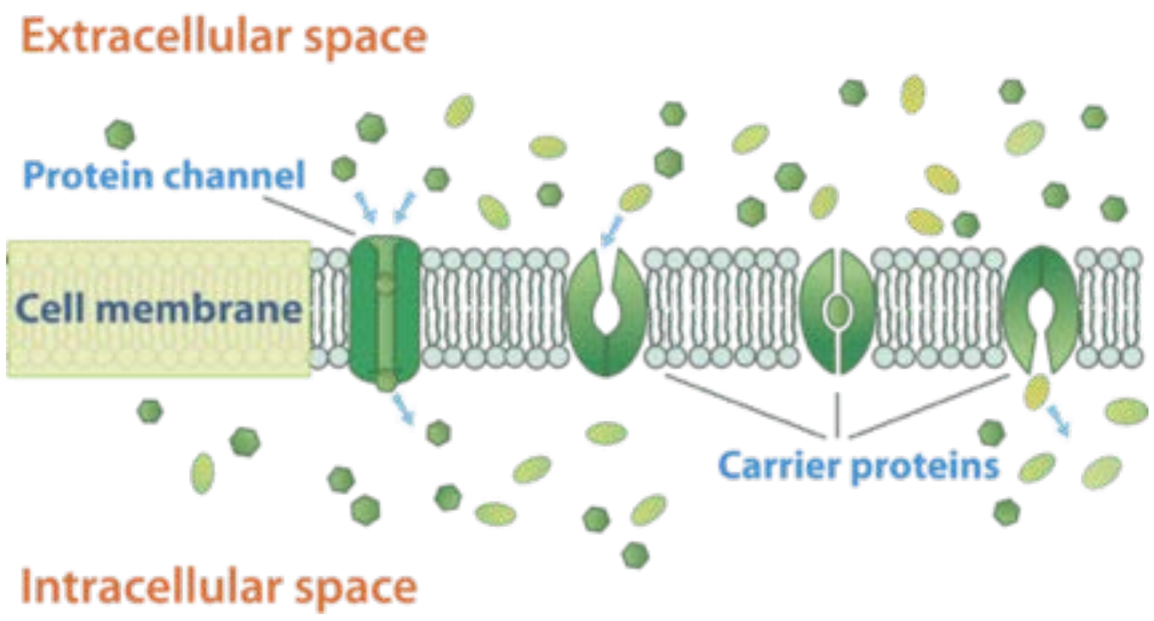


Figure 2.15

Protein channels and carrier proteins are involved in passive transport.

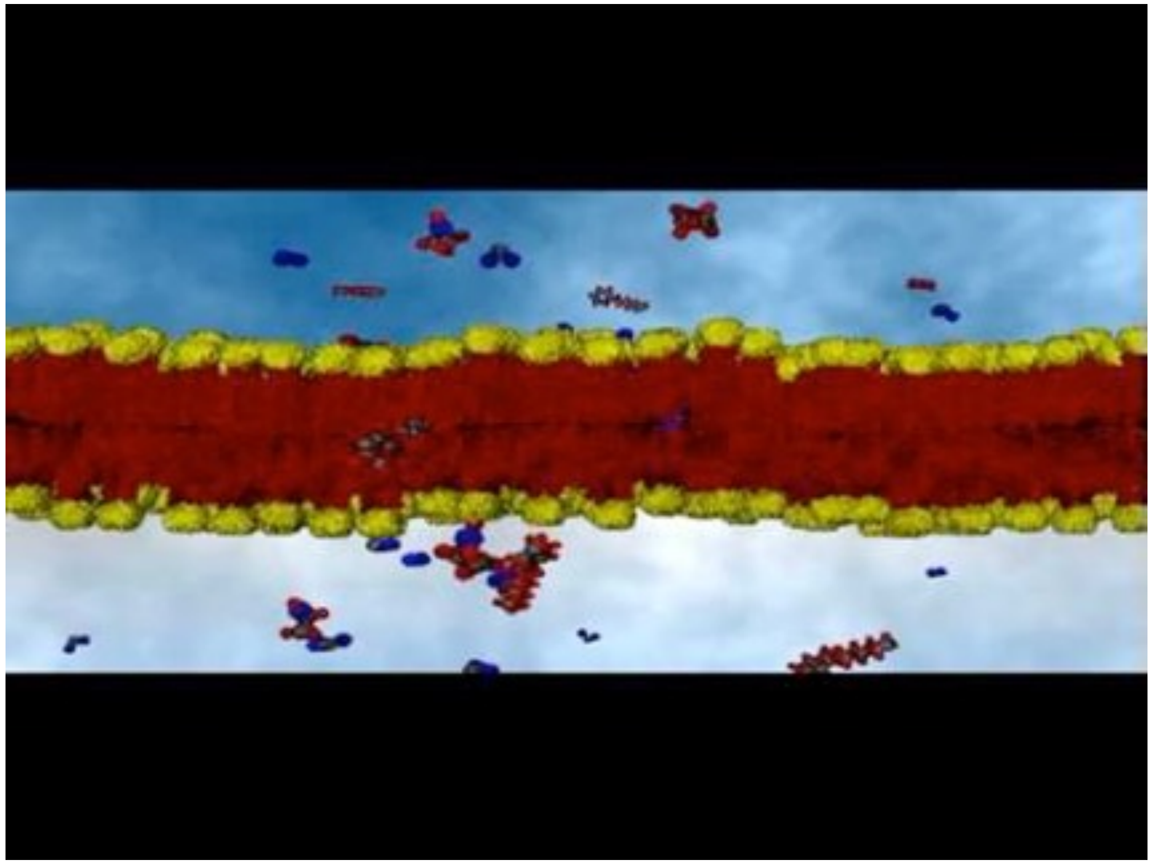
Summary

- Passive transport does not require energy input.
- An example of passive transport is diffusion, the movement of molecules from an area of high concentration to an area of low concentration.
- Carrier proteins and channel proteins are involved in facilitated diffusion.

Explore More

Use the resource below to answer the questions that follow.

- **Cell Membrane Passive Transport** at http://www.youtube.com/watch?v=JShwXBWGMyY (4:41)



Click on the image above for more content

1. What does selectively permeable mean?
2. Can a membrane control the direction of diffusion? Explain your reasoning fully.
3. Give two examples of phospholipid soluble molecules? How can these molecules move across a cell membrane? What affects the direction of their movement?
4. What is the difference between simple and facilitated diffusion? What are two types of facilitated diffusion?

Review

1. Explain two ways materials can enter the cell through passive transport.
2. Does passive transport involve an expenditure of much energy? Why or why not?
3. How does oxygen move across the membrane?

Section 10

Active Transport

Active Transport

•Define active transport.
•Describe the process of active transport.
•Summarize the role of the sodium-potassium pump.

What does it take to roll a stone uphill?

This round stone tends to roll downhill due to the force of gravity. It takes an input of energy to push it uphill. Due to diffusion, molecules tend to move from an area of high concentration (large amount) to an area of low concentration (small amount). So guess what it takes to move molecules the opposite way, from an area of low concentration to an area of high concentration? Energy, of course!

Active Transport

During **active transport,** molecules move from an area of low concentration to an area of high concentration. This is the opposite of **diffusion** , and these molecules are said to flow *against their concentration gradient.* Active transport is called "active" because this type of transport requires energy to move molecules. **ATP** is the most common source of energy for active transport.

As molecules are moving against their concentration gradients, active transport cannot occur without assistance. A **carrier protein** is always required in this process. Like facilitated diffusion, a protein in the membrane carries the molecules across the membrane, except this protein moves the molecules from a low concentration to a high concentration. These proteins are often called "pumps" because they use energy to pump the molecules across the membrane. There are many cells in your body that use pumps to move molecules. For example, your nerve cells (neurons) would not send messages to your brain unless you had protein pumps moving molecules by active transport.

The **sodium-potassium pump** (**Figure** below) is an example of an active transport pump. The sodium-potassium pump uses ATP to move three sodium (Na^+) ions and two potassium (K^+) ions to where they are already highly concentrated. Sodium ions move out of the cell, and potassium ions move into the cell.

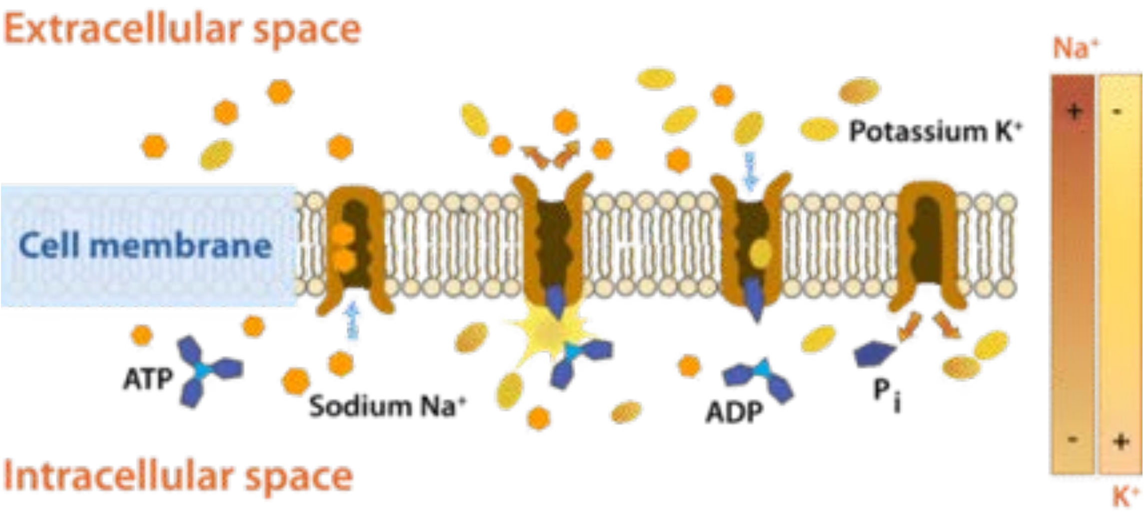


Figure 2.16

The sodium-potassium pump moves sodium ions to the outside of the cell and potassium ions to the inside of the cell. ATP is required for the protein to change shape. ATP is converted into ADP (adenosine diphosphate) during active transport.

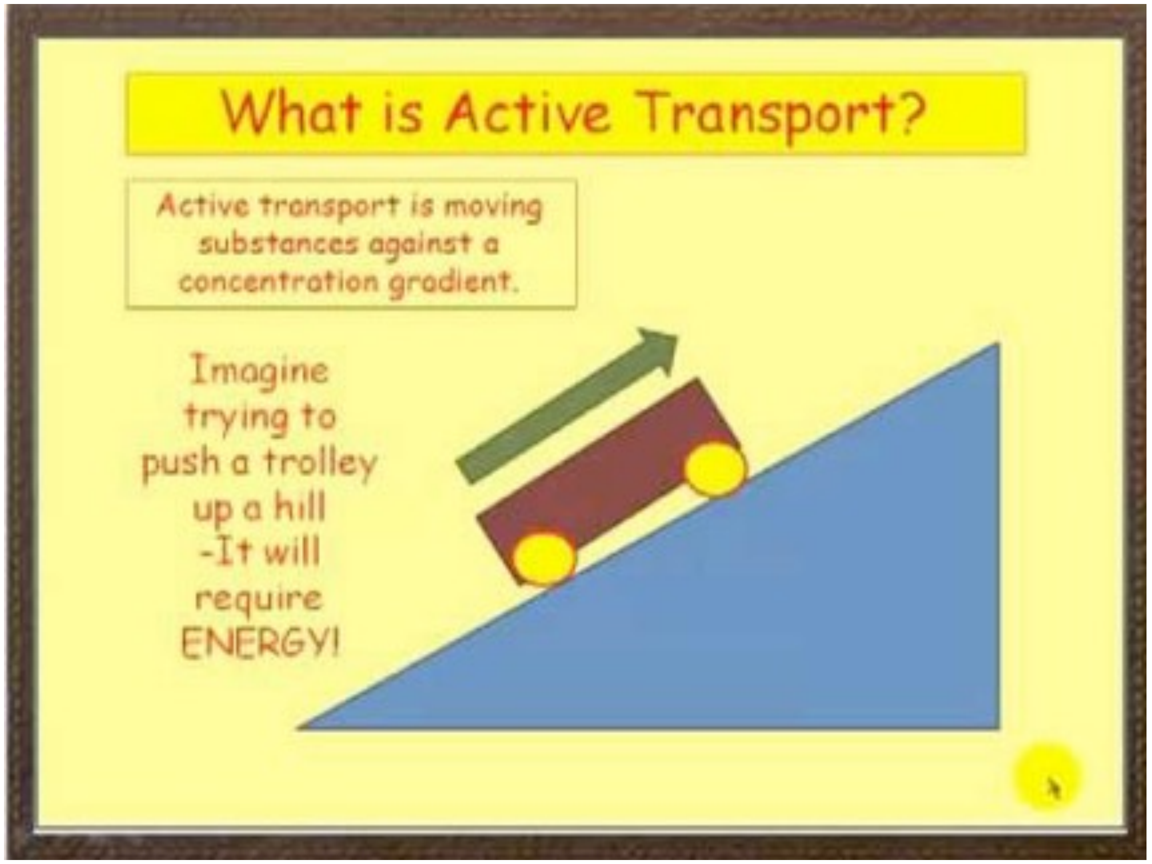
Summary

- During active transport, a protein pump uses energy, in the form of ATP, to move molecules from an area of low concentration to an area of high concentration.
- An example of active transport is the sodium-potassium pump, which moves sodium ions to the outside of the cell and potassium ions to the inside of the cell.

Explore More

Use the resource below to answer the questions that follow.

- **Osmosis and Active Transport** at http://www.youtube.com/watch?v=6tVc5gyOzO4 (8:40)



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1. What is active transport?
2. Where does a cell obtain the energy for active transport?

3.How does the body prevent the loss of sugar in urine?
4.List three factors that affect the movement of materials across a membrane. Explain how these factors affect the movement of matter.

Review

1.How is active transport different from passive transport?
2.What form of energy is usually used in active transport?
3.Give an example of active transport. Explain what occurs during this process.

Section 11

Photosynthesis

Photosynthesis

•Define photosynthesis.
•Distinguish between autotrophs and heterotrophs.
•Explain the importance of photosynthesis.

What can a tiny plant do that you can't do?

This tiny plant can use the energy of the sun to make its own food. You can't make food by just sitting in the sun. Plants are not the only organisms that can get energy from the sun, however. Some protists, such as algae, and some bacteria can also use the energy of the sun to make their own food.

What is Photosynthesis?

If a plant gets hungry, it cannot walk to a local restaurant and buy a slice of pizza. So, how does a plant get the food it needs to survive? Plants are **producers** , which means they are able to make, or produce, their own food. They also produce the "food" for other organisms. Plants are also **autotrophs.** Autotrophs are the organisms that collect the energy from the sun and turn it into organic compounds. So once again, how does a plant get the food it needs to survive?

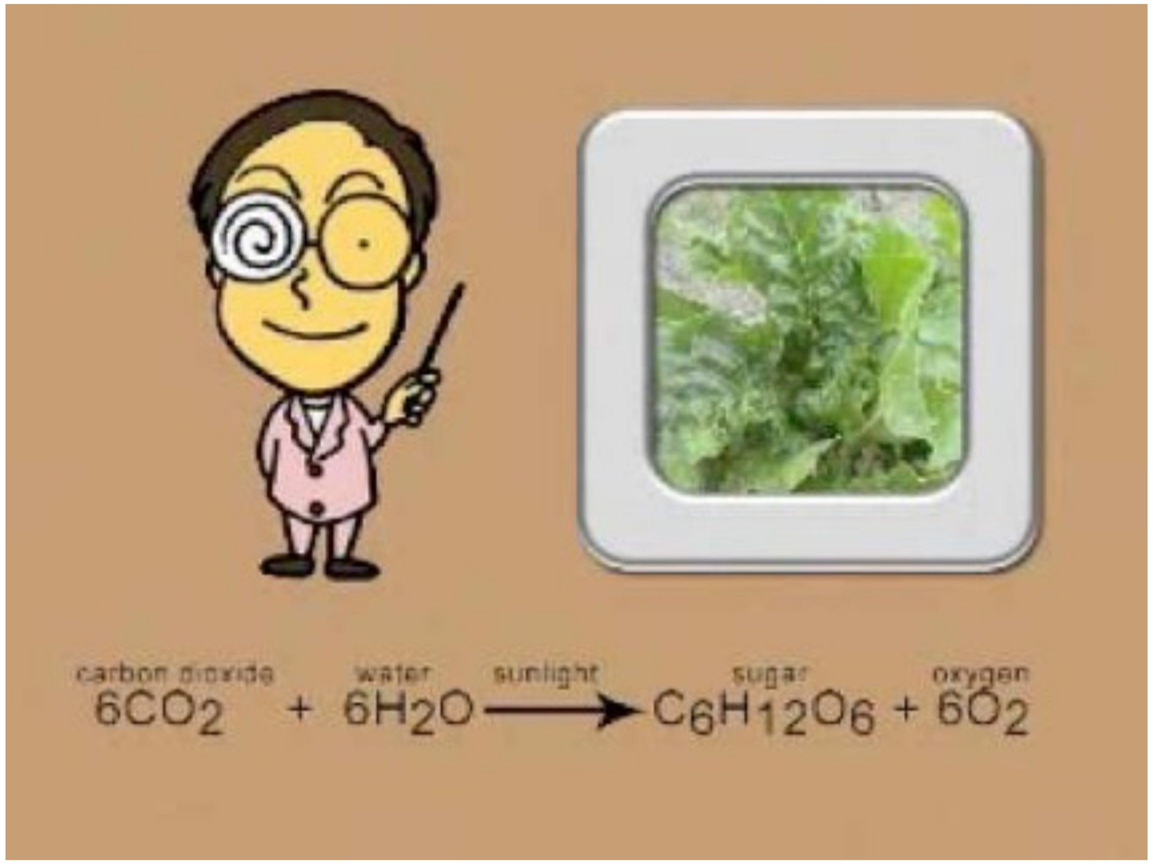
Through photosynthesis. **Photosynthesis** is the process plants use to make their own "food" from the sun's energy, carbon dioxide, and water. During photosynthesis, carbon dioxide and water combine with solar energy to create **glucose** , a carbohydrate ($C_6H_{12}O_6$), and oxygen.

The process can be summarized as: in the presence of sunlight, carbon dioxide + water → glucose + oxygen.

Glucose is a sugar that acts as the "food" source for plants. The glucose is then converted into usable chemical energy, **ATP** , during **cellular respiration** . The oxygen formed during photosynthesis, which is necessary for animal life, is essentially a waste product of the photosynthesis process.

Actually, almost all organisms obtain their energy from photosynthetic organisms. For example, if a bird eats a caterpillar, then the bird gets the energy that the caterpillar gets from the plants it eats. So the bird indirectly gets energy that began with the glucose formed through photosynthesis. Therefore, the process of photosynthesis is central to sustaining life on Earth. In eukaryotic organisms, photosynthesis occurs in **chloroplasts** . Only cells with chloroplasts—plant cells and algal (protist) cells—can perform photosynthesis. Animal cells and fungal cells do not have chloroplasts and, therefore, cannot photosynthesize. That is why these organisms, as well as the non-photosynthetic protists, rely on other organisms to obtain their energy. These organisms are **heterotrophs.**

The Photosynthesis Song explaining photosynthesis, can be heard at http://www.youtube.com/watch?v=C1_uez5WX1o (1:52).



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Time for Me to Leaf: Tree Chlorophyll Chromatography

Why do leaves change color each fall? This MIT video demonstrates an experiment about the different pigments in leaves. See the video at https://www.youtube.com/watch?v=_v6_5Zxdb68 .

Click on the image above for more content

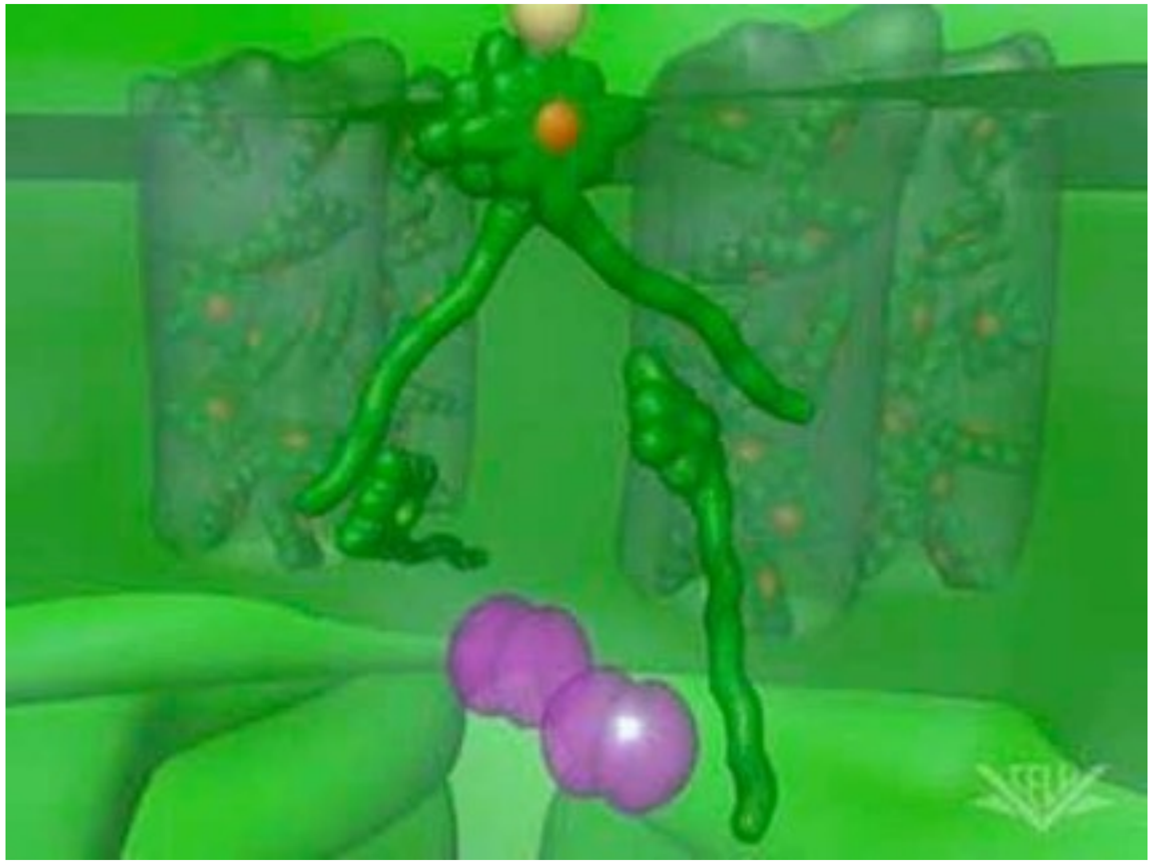
Summary

•All the energy used by living things on Earth came from the process of photosynthesis.
•During photosynthesis, carbon dioxide and water combine with solar energy to create glucose and oxygen.

Explore More

Use the resource below to answer the following questions.

•**Photosynthesis** at http://www.youtube.com/watch?v=hj_WKgnL6MI (5:04)



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1.Where does the energy for photosynthesis come from?
2.In photosynthesis, how does the movement of electrons along the electron transport chain affect hydrogen ions (H^+)? How does this compare to what happens in the mitochondria during cellular respiration?
3.Do all organisms which carry out photosynthesis have chloroplasts? Explain your answer as fully as you can.

4. What is the function of mobile electron carriers? What is their relationship to the embedded protein complexes in the membrane?

Review

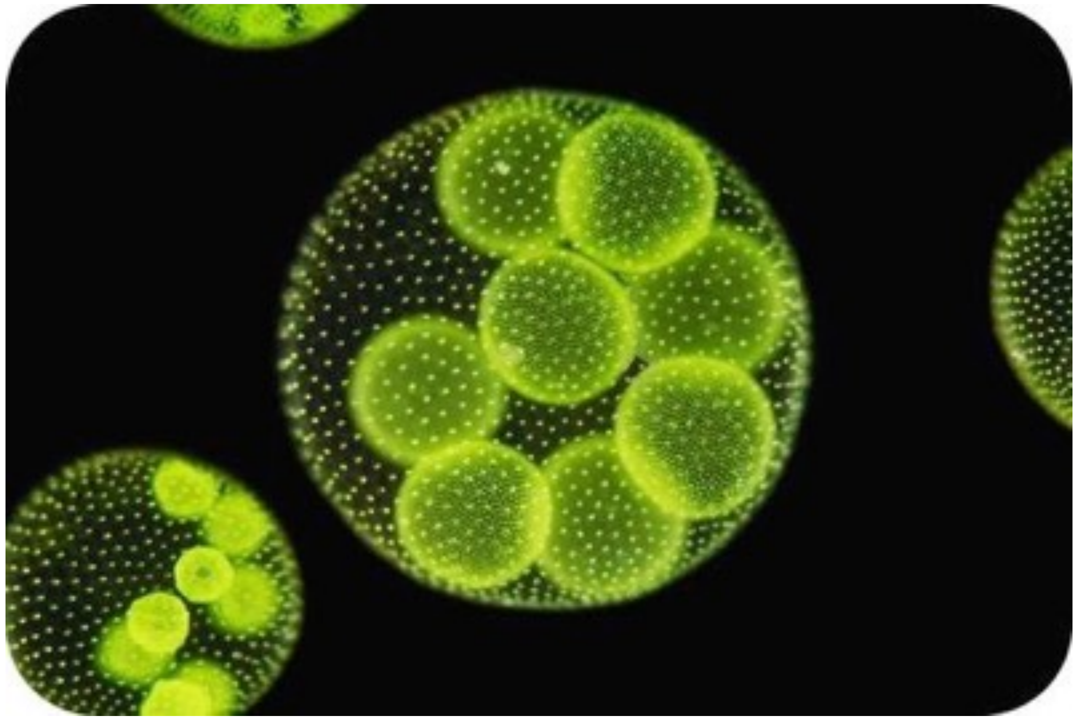
1. How is the process of photosynthesis central to sustaining life on Earth?
2. What are the two products produced by photosynthesis?
3. What two raw materials are needed by plants in order to perform photosynthesis?

Section 12

Light Reactions of Photosyn-

Light Reactions of Photosynthesis

- Describe the structure of a chloroplast.
- Write the chemical reaction of photosynthesis.
- Name the reactants and products of photosynthesis.
- Summarize the process of photosynthesis.



Are plants the only organisms that perform photosynthesis?

Although we generally discuss plants when learning about photosynthesis, keep in mind that plants are not the only organisms that can make their own food. Some bacteria and some protists, such as the algae pictured here, also perform photosynthesis. This alga has chloroplasts and photosynthesizes just like a plant.

The Process of Photosynthesis

In the Presence of Sunlight, Carbon Dioxide + Water → Glucose + Oxygen

Photosynthesis takes place in the organelle of the plant cell known as the chloroplasts. **Chloroplasts** are one of the main differences between plant and animal cells. Animal cells do not have chloroplasts, so they cannot photosynthesize. Photosynthesis occurs in two stages. During the first stage, the energy from sunlight is absorbed by the chloroplast. Water is used, and oxygen is produced during this part of the process. During the second stage, carbon dioxide is used, and glucose is produced.

Chloroplasts contain stacks of **thylakoids** , which are flattened sacs of membrane. Energy from sunlight is absorbed by the pigment **chlorophyll** in the thylakoid membrane. There are two separate parts of a chloroplast: the space inside the chloroplast itself, and the space inside the thylakoids (**Figure** below).

- The inner compartments inside the thylakoids are called the thylakoid space (or lumen). This is the site of the first part of photosynthesis.

•The interior space that surrounds the thylakoids is filled with a fluid called **stroma** . This is where carbon dioxide is used to produce glucose, the second part of photosynthesis.

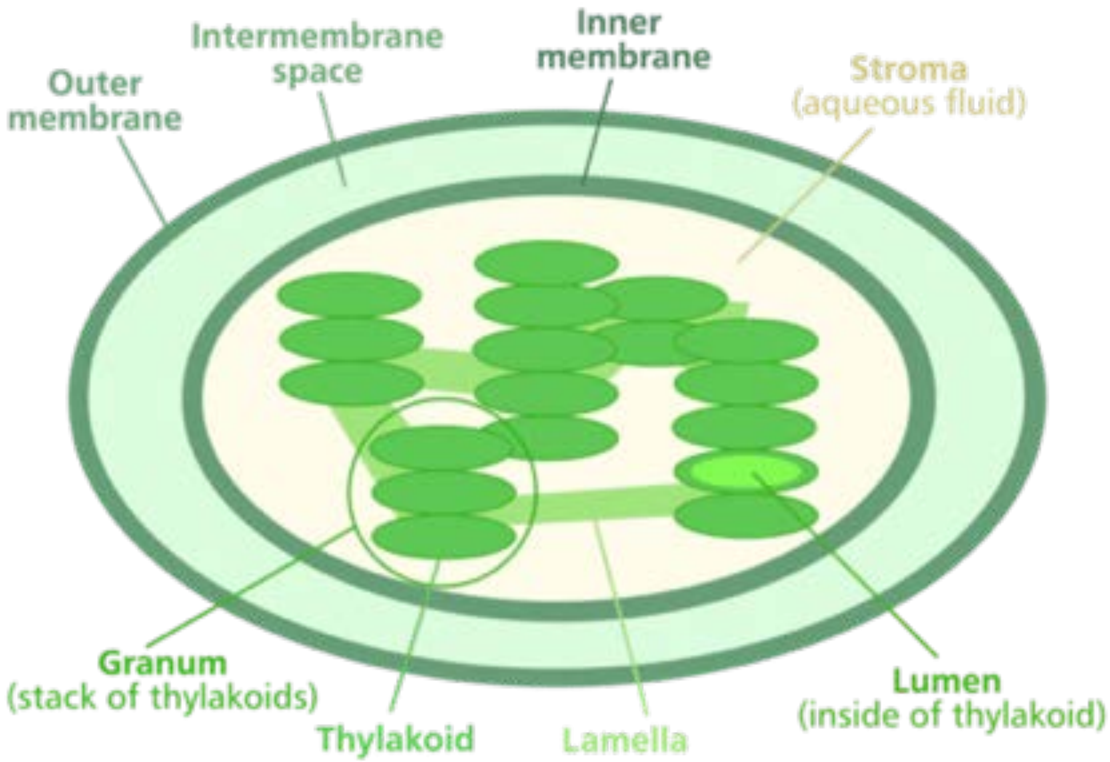


Figure 2.17

The chloroplast is the photosynthesis factory of the plant.

The Reactants

What goes into the plant cell to start photosynthesis? The **reactants** of photosynthesis are carbon dioxide and water. These are the molecules necessary to begin the process. But one more item is necessary, and that is sunlight. All three components, carbon dioxide, water, and the sun's energy are necessary for photosynthesis to occur. These three components must meet in the chloroplast of the leaf cell for photosynthesis to occur. How do these three components get to the cells in the leaf?

•Chlorophyll is the green pigment in leaves that captures energy from the sun. Chlorophyll molecules are located in the thylakoid membranes.
•The *veins* in a plant carry water from the roots to the leaves.
•Carbon dioxide enters the leaf from the air through special openings called **stomata** (**Figure** below).

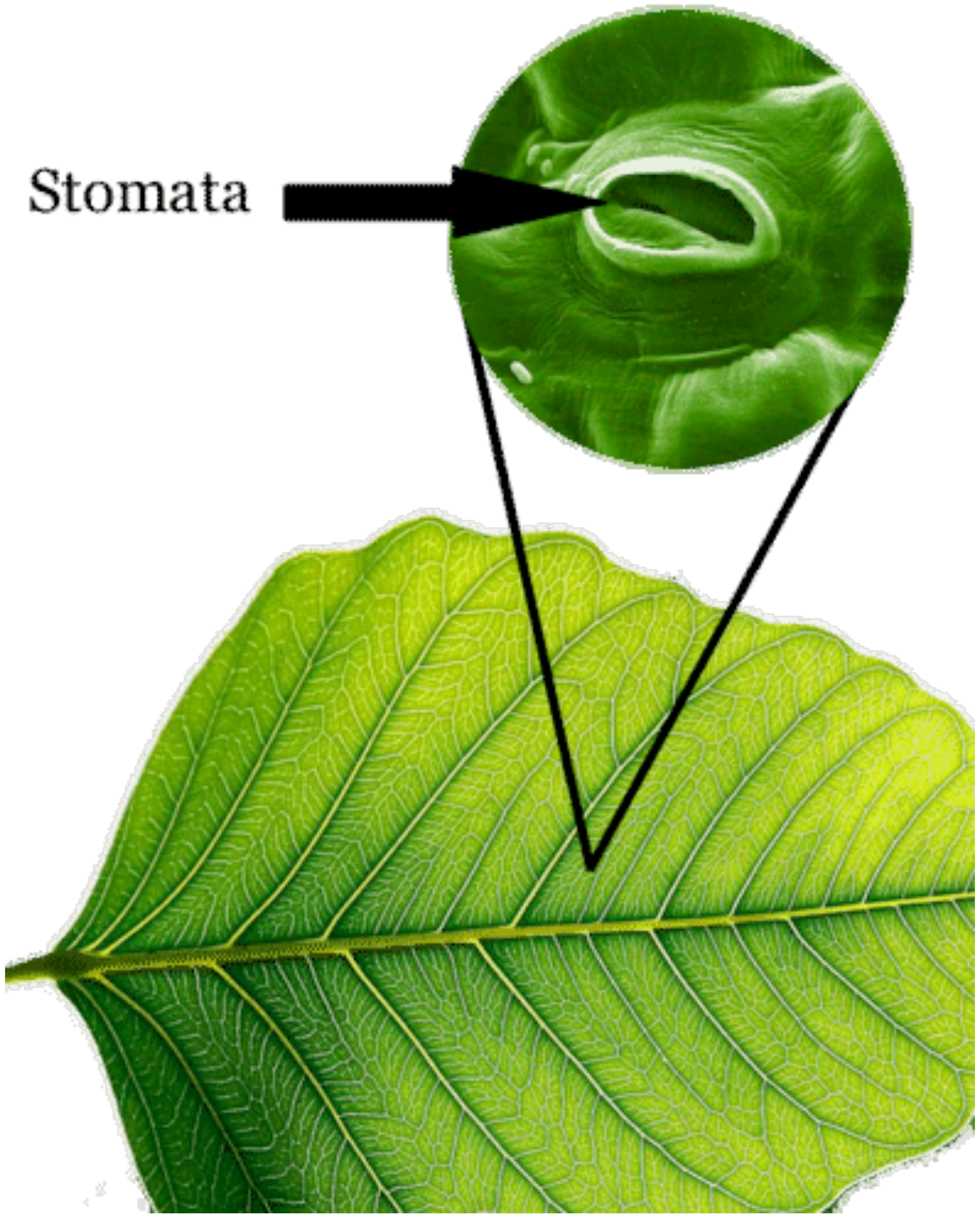


Figure 2.18

Stomata are special pores that allow gasses to enter and exit the leaf.

The Products

What is produced by the plant cell during photosynthesis? The **products** of photosynthesis are glucose and oxygen. This means they are produced at the end of photosynthesis. **Glucose** , the food of plants, can be used to store energy in the form of large carbohydrate molecules. Glucose is a simple sugar molecule which can be combined with other glucose molecules to form large carbohydrates, such as starch. Oxygen is a waste product of photosynthesis. It is released into the atmosphere through the stomata. As you know, animals need oxygen to live. Without photosynthetic organisms like plants, there would not be enough oxygen in the atmosphere for animals to survive.

The Chemical Reaction

The overall chemical reaction for photosynthesis is 6 molecules of carbon dioxide (CO_2) and 6 molecules of water (H_2O), with the addition of solar energy. This produces 1 molecule of glucose ($C_6H_{12}O_6$) and 6 molecules of oxygen (O_2). Using chemical symbols, the equation is represented as follows: $6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$. Though this equation may not seem that complicated, photosynthesis is a series of chemical reactions divided into two stages, the light reactions and the Calvin cycle.

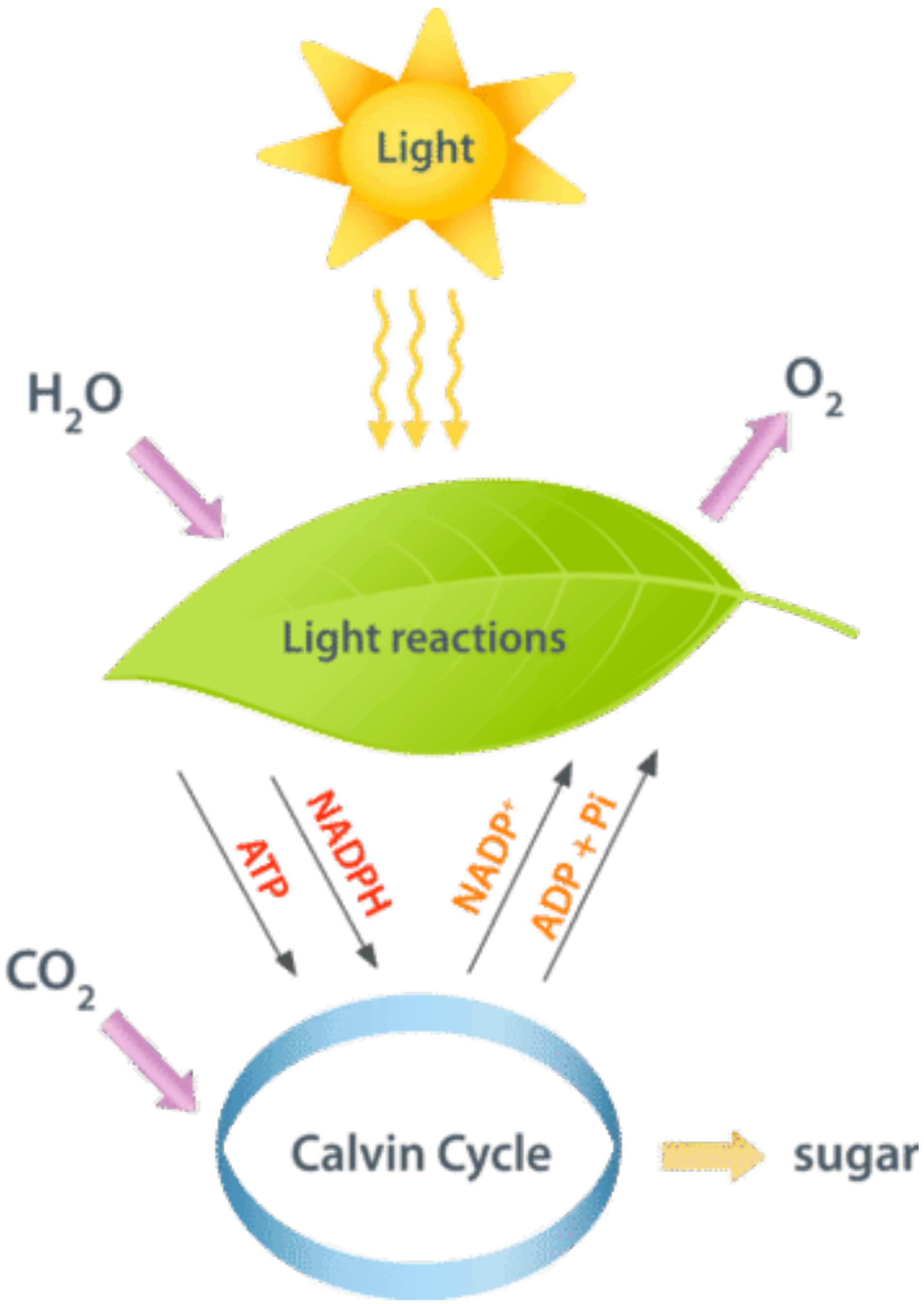


Figure 2.19

Photosynthesis is a two stage process. As is depicted here, the energy from sunlight is needed to start photosynthesis. The initial stage is called the light reactions as they occur only in the presence of light. During these initial reactions, water is used and oxygen is released. The energy from sunlight is converted into a small amount of ATP and an energy carrier called NADPH. Together with carbon dioxide, these are used to make glucose (sugar) through a process called the Calvin Cycle. NADP $^+$ and ADP (and Pi, inorganic phosphate) are regenerated to complete the process.

Summary

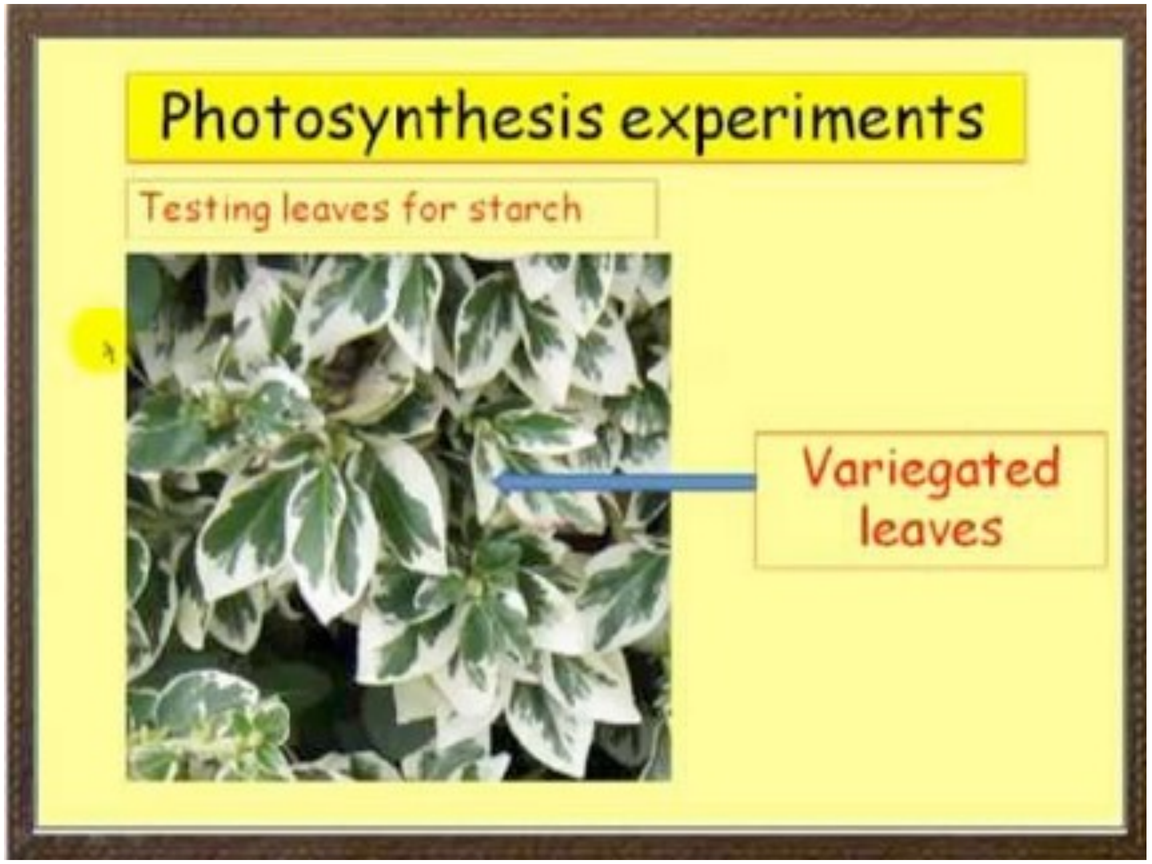
- Photosynthesis occurs in the chloroplast of the plant cell.
- Carbon dioxide, water, and the sun's energy are necessary for the chemical reactions of photosynthesis.
- The products of photosynthesis are glucose and oxygen.

Explore More

Use the resources below to answer the following questions.

Explore More I

- **Photosynthesis** at http://www.youtube.com/watch?v=RNufj-64OO0 (7:08)



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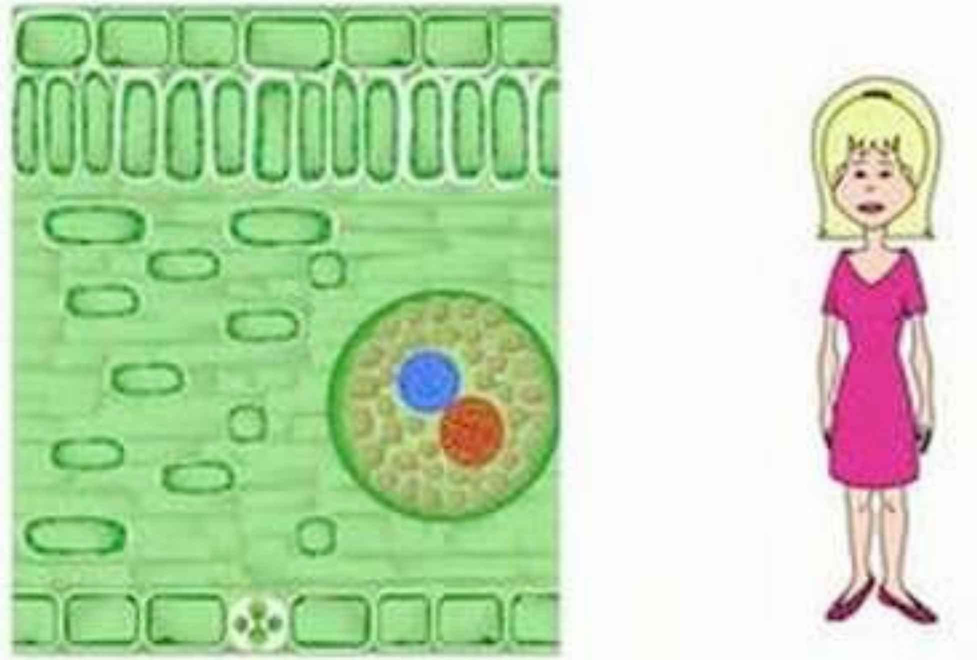
1. How do autotrophs differ from heterotrophs? How are they the same?
2. What do plants do with most of the sugar they produce during photosynthesis?
3. How do decreasing levels of CO_2 affect plants? How do you think increasing levels of CO_2 affect plants?

Explore More II

- **Photosynthesis** at http://www.youtube.com/watch?v=mpPwmvtDjWw (2:41)



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1. Where do plants get the raw materials for photosynthesis?
2. What do plants take up through their roots? Which of these substances are used for photosynthesis?
3. Where does the chemical reactions of photosynthesis take place?

Review

1. Describe the structures of the chloroplast where photosynthesis takes place.

2.What would happen if the stomata of a plant leaf were glued shut? Would that plant be able to perform photosynthesis? Why or why not?
3.What are the reactants needed to perform photosynthesis? The products?
4.What happens to the products of photosynthesis?

Section 13

Cellular Respiration

Cellular Respiration

- •Define cellular respiration.
- •Summarize the significance of ATP.

Why do you need food?

The main reason you need to eat is to get energy. Food is your body's only supply of energy. However, this energy must be converted from the apple (or any other food you eat) into an energy source that your body can use. The process of getting energy from your food is called cellular respiration.

What is Cellular Respiration?

How does the food you eat provide energy? When you need a quick boost of energy, you might reach for an apple or a candy bar. But cells do not "eat" apples or candy bars; these foods need to be broken down so that cells can use them. Through the process of **cellular respiration** , the energy in food is changed into energy that can be used by the body's cells. Initially, the sugars in the food you eat are digested into the simple sugar **glucose** , a **monosaccharide** . Recall that glucose is the sugar produced by the plant during photosynthesis. The glucose, or the **polysaccharide** made from many glucose molecules, such as **starch** , is then passed to the organism that eats the plant. This organism could be you, or it could be the organism that you eat. Either way, it is the glucose molecules that holds the energy.

ATP

Specifically, during cellular respiration, glucose is converted into ATP (**Figure** below). **ATP** , or adenosine triphosphate, is chemical energy the cell can use. It is the molecule that provides energy for your cells to perform work, such as moving your muscles as you walk down the street. But cellular respiration is slightly more complicated than just converting glucose into ATP. Cellular respiration can be described as the reverse or opposite of photosynthesis. During cellular respiration, glucose, in the presence of oxygen, is converted into carbon dioxide and water. The process can be summarized as: glucose + oxygen →

carbon dioxide + water. During this process, the energy stored in glucose is converted into ATP.

Energy is stored in the bonds between the phosphate groups (PO_4^-) of the ATP molecule. When ATP is broken down into ADP (adenosine diphosphate) and inorganic phosphate, energy is released. When ADP and inorganic phosphate are joined to form ATP, energy is stored. During cellular respiration, about 36-38 ATP molecules are produced for every glucose molecule.

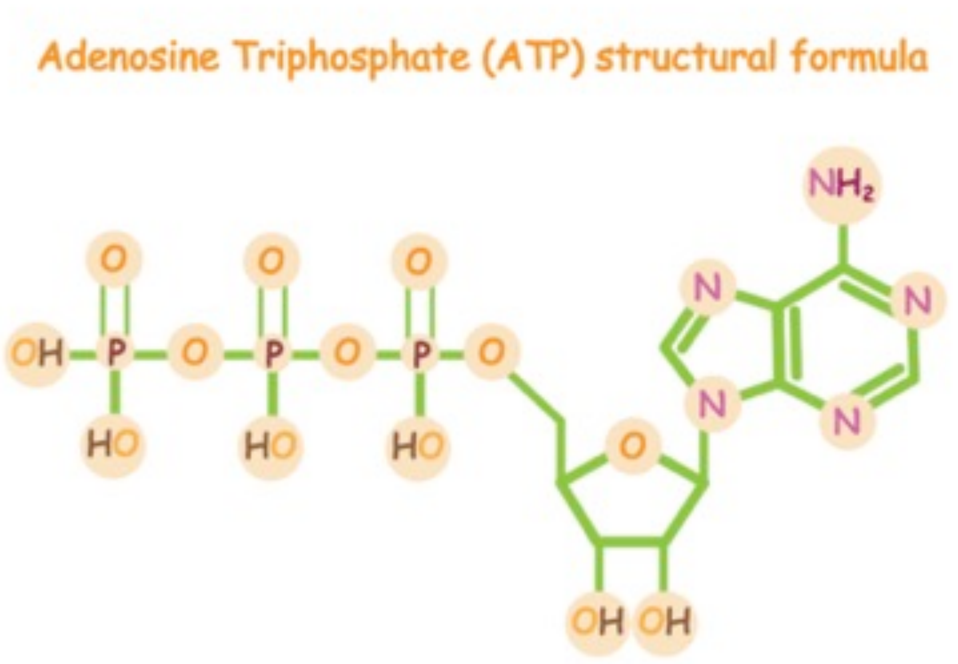


Figure 2.20

The structural formula for adenosine triphosphate (ATP). During cellular respiration, energy from the chemical bonds of the food you eat must be converted into ATP.

Summary

- Through the process of cellular respiration, the energy in food is converted into energy that can be used by the body's cells.
- During cellular respiration, glucose and oxygen are converted into ATP, carbon dioxide, and water.

Explore More

Use the resource below to answer the questions that follow.

- **Define Cellular Respiration** at http://www.youtube.com/watch?v=Sr9rYgYS1Fc (1:02)

Click on the image above for more content

1. What is cellular respiration?

2. Do plant cells respire?
3. What kinds of molecules are used for cellular respiration? Give specific examples.
4. What is the use of ATP? Give three examples of how ATP is used in the cell.

Review

1. What is the purpose of cellular respiration?
2. What is ATP?
3. How much usable energy is extracted from one glucose molecule?

Section 14

Process of Cellular Respira-

Process of Cellular Respiration

- •Describe the structure of a mitochondrion.
- •List the three steps of cellular respiration.
- •Write the chemical reaction of cellular respiration.
- •Explain the process of cellular respiration.

Why do you need to breathe?

Of course if you didn't breathe, you couldn't survive. Why do you need air to live? You need the gas oxygen to perform cellular respiration to get energy from your food.

The Process of Cellular Respiration

Cellular respiration is the process of extracting energy in the form of **ATP** from the glucose in the food you eat.

Oxygen is needed to help the process of turning glucose into ATP. The initial step releases just two molecules of ATP for each glucose. The later steps release much more ATP.

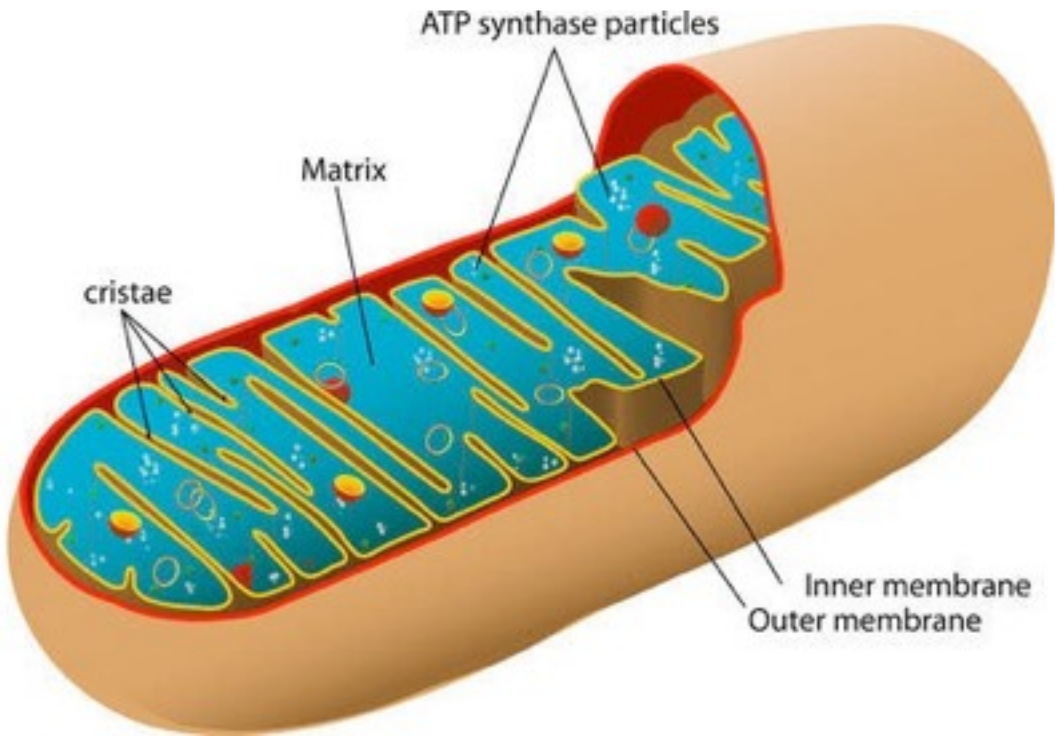


Figure 2.21

Most of the reactions of cellular respiration are carried out in the mitochondria.

The Reactants

What goes into the cell? Oxygen and glucose are both **reactants** of cellular respiration. Oxygen enters the body when an organism breathes. Glucose enters the body when an organism eats.

The Products

What does the cell produce? The **products** of cellular respiration are carbon dioxide and water. Carbon dioxide is transported from your mitochondria out of your cell, to your red blood cells, and back to your lungs to be exhaled. ATP is generated in the process. When one molecule of glucose is broken down, it can be converted to a net total of 36 or 38 molecules of ATP. This only occurs in the presence of oxygen.

The Chemical Reaction

The overall chemical reaction for cellular respiration is one molecule of glucose ($C_6H_{12}O_6$) and six molecules of oxygen (O_2) yields six molecules of carbon dioxide (CO_2) and six molecules of water (H_2O). Using chemical symbols the equation is represented as follows:

$$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$$

ATP is generated during the process. Though this equation may not seem that complicated, cellular respiration is a series of chemical reactions.

Summary

- Most of the steps of cellular respiration take place in the mitochondria.
- Oxygen and glucose are both reactants in the process of cellular respiration.
- The main product of cellular respiration is ATP; waste products include carbon dioxide and water.

Explore More

1. Which types of cells have mitochondria?
2. What is the cristae? Where does it occur? Why is this structure important?

Review

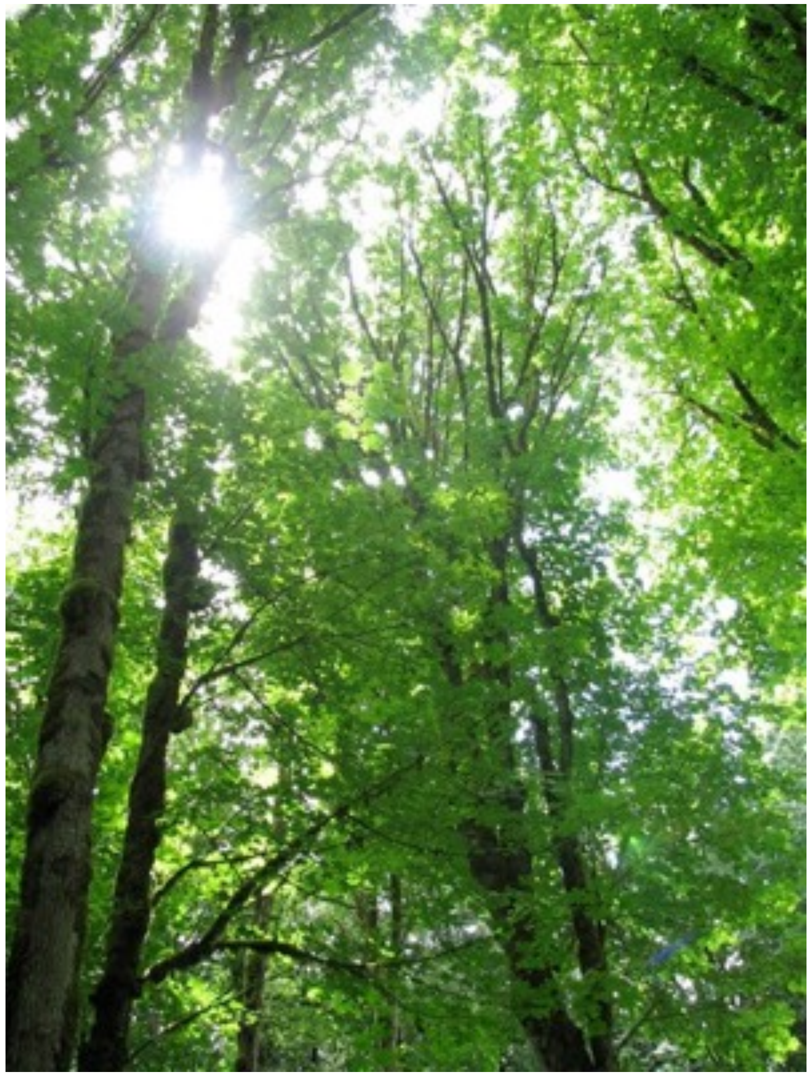
1. Where is glucose broken down to form ATP? What is this process called? Does this process need oxygen?
2. Write the chemical reaction for the overall process of cellular respiration.

Section 15

Connecting Cellular Respira-

Connecting Cellular Respiration and Photosynthesis

- •Name the products and reactants of photosynthesis and cellular respiration.
- •Explain how cellular respiration and photosynthesis are connected.



How do trees help you breathe?

Recall that trees release oxygen as a byproduct of photosynthesis. And you need oxygen to breathe. Do you know why? So your cells can perform cellular respiration.

Connecting Cellular Respiration and Photosynthesis

Photosynthesis and cellular respiration are connected through an important relationship. This relationship enables life to survive as we know it. The **products** of one process are the **reactants** of the other. Notice that the equation for **cellular respiration** is the direct opposite of **photosynthesis** :

- Cellular Respiration: $C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$
- Photosynthesis: $6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$

Photosynthesis makes the glucose that is used in cellular respiration to make ATP. The glucose is then turned back into carbon dioxide, which is used in photosynthesis. While water is broken down to form oxygen during photosynthesis, in cellular respiration oxygen is combined with hydrogen to form water. While photosynthesis requires carbon dioxide and releases oxygen, cellular respiration requires oxygen and releases carbon dioxide. It is the released oxygen that is used by us and most other organisms for cellular respiration. We breathe in that oxygen, which is carried through our blood to all our cells. In our cells, oxygen allows cellular respiration to proceed. Cellular respiration works best in the presence of oxygen. Without oxygen, much less ATP would be produced.

Cellular respiration and photosynthesis are important parts of the carbon cycle. The **carbon cycle** is the pathways through which carbon is recycled in the biosphere. While cellular respiration releases carbon dioxide into the environment, photosynthesis pulls carbon dioxide out of the atmosphere. The exchange of carbon dioxide and oxygen during photosynthesis (**Figure** below) and cellular respiration worldwide helps to keep atmospheric oxygen and carbon dioxide at stable levels.

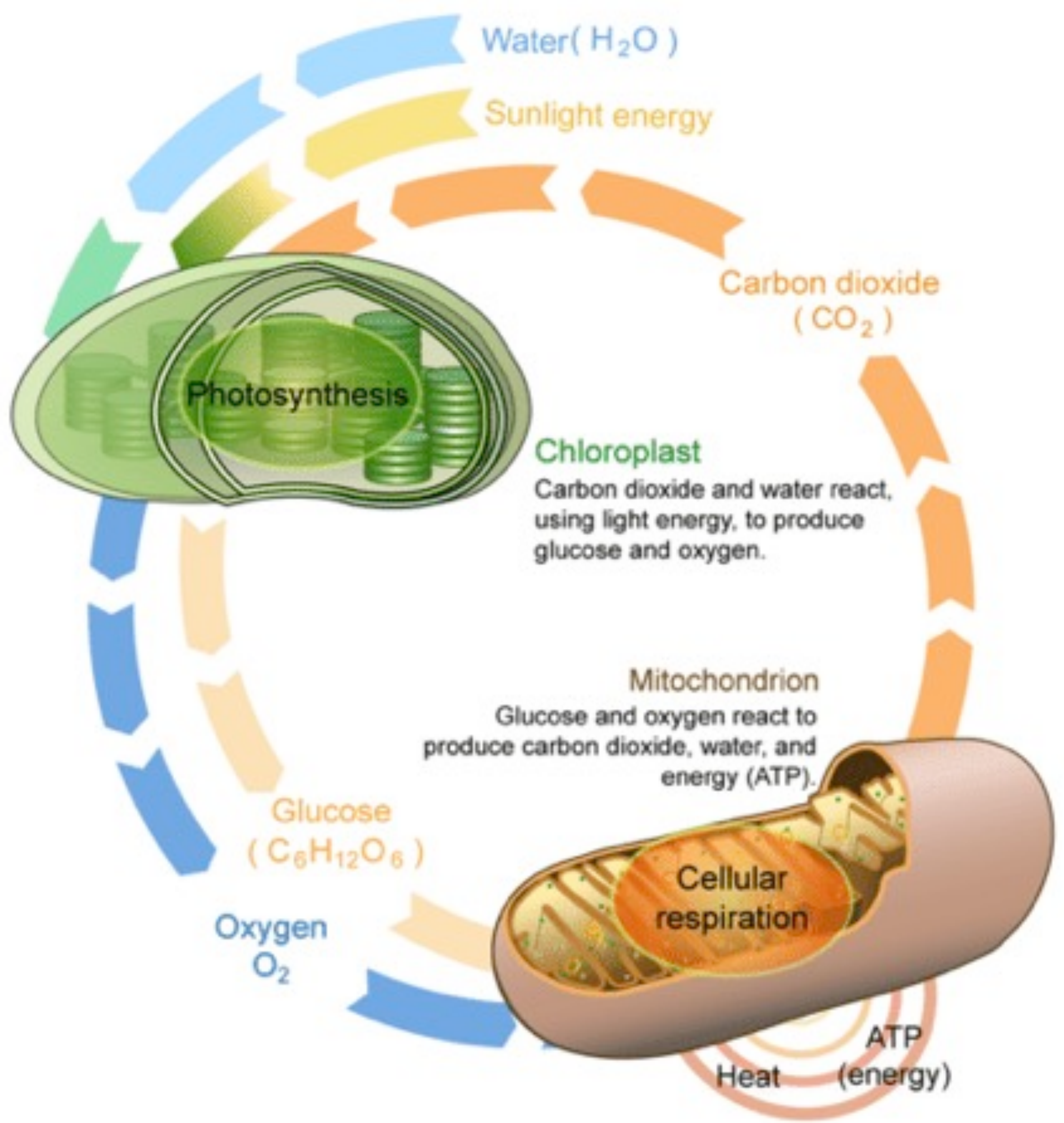


Figure 2.22

Cellular respiration and photosynthesis are direct opposite reactions. Some of the ATP made in the mitochondria is used as energy for work, and some is lost to the environment as heat.

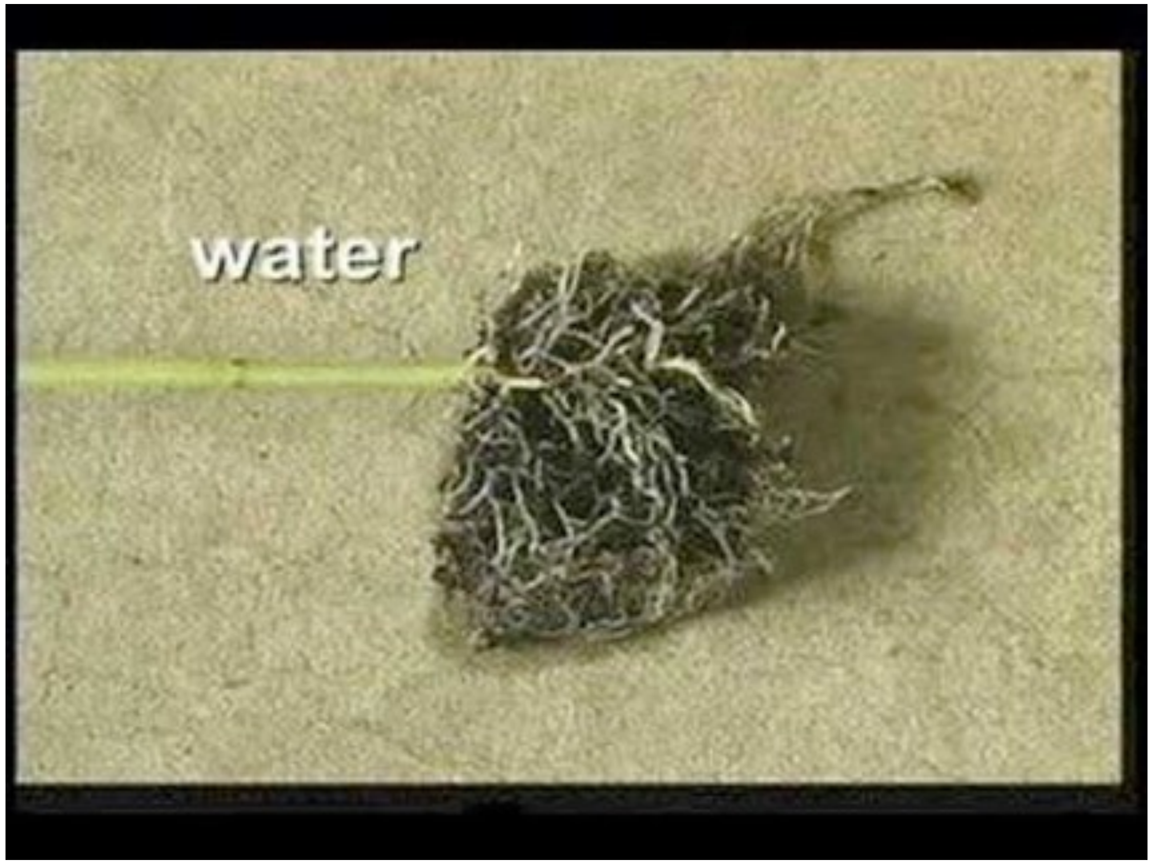
Summary

- The equation for cellular respiration is the direct opposite of photosynthesis.
- The exchange of carbon dioxide and oxygen thorough photosynthesis or cellular respiration worldwide helps to keep atmospheric oxygen and carbon dioxide at stable levels.

Explore More

Use the resource below to answer the questions that follow.

- **Photosynthesis and Respiration** at http://www.youtube.com/watch?v=JEnjph9miK4 (3:46)



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1. What is needed for photosynthesis to occur? Be specific.
2. What is needed for cellular respiration to occur?
3. What is ATP?
4. Do autotrophs need to carry out cellular respiration? Why or why not?

Review

1. How are the equations for photosynthesis and cellular respiration related?
2. What keeps atmospheric oxygen and carbon dioxide at stable levels?

Section 16

Fermentation

Fermentation

- Define fermentation.
- Differentiate between aerobic and anaerobic respiration.
- Explain the purpose of fermentation.
- Distinguish between alcoholic fermentation and lactic acid fermentation.

How is wine made?

You probably realize that grapes are needed to make wine. You might not realize, however, that yeast are also central in the process of making wine. Yeast take the sugars from the grapes and convert them into alcohol through the process of fermentation.

Fermentation

Sometimes cells need to obtain energy from sugar, but there is no oxygen present to complete cellular respiration. In this situation, cellular respiration can be **anaerobic** , occurring in the absence of oxygen. In this process, called **fermentation** , only the first step of respiration, **glycolysis** , occurs, producing two ATP; no additional ATP is produced. Therefore, the organism only obtains the two ATP molecules per glucose molecule from glycolysis. Compared to the 36-38 ATP produced under **aerobic** conditions, **anaerobic respiration** is not a very efficient process. Fermentation allows the first step of cellular respiration to continue and produce some ATP, even without oxygen.

Yeast (single-celled eukaryotic organisms) perform **alcoholic fermentation** in the absence of oxygen. The products of alcoholic fermentation are ethyl alcohol (drinking alcohol) and carbon dioxide. This process is used to make common food and drinks. For example, alcoholic fermentation is used to bake bread. The carbon dioxide bubbles allow the bread to rise and become fluffy. Meanwhile, the alcohol evaporates. In wine making, the sugars of grapes are fermented to produce wine.

Animals and some bacteria and fungi carry out **lactic acid fermentation.** Lactic acid is a waste product of this process. Our muscles perform lactic acid fermentation during strenuous exercise, since oxygen cannot be delivered to the muscles quickly enough. The buildup of lactic acid is believed to make your muscles sore after exercise. Bacteria that produce lactic acid are used to make cheese and yogurt. The lactic acid causes the proteins in milk to thicken. Lactic acid also causes tooth decay, because bacteria use the sugars in your mouth for energy.

Pictured below are some products of fermentation (**Figure** below).

Figure 2.23

Products of fermentation include cheese (lactic acid fermentation) and wine (alcoholic fermentation).

Gut Fermentation

Behind every fart is an army of gut bacteria undergoing some crazy biochemistry. These bacteria break down the remains of digested food through fermentation, creating gas in the process. Learn what these bacteria have in common with beer brewing at http://youtu.be/R1kxajH629A?list=PLzMhsCgGKd1hoofiKuifwy6qRXZs7NG6a .

Click on the image above for more content

Summary

- Fermentation happens in the absence of oxygen.
- Only the two ATP from glycolysis are produced under anaerobic conditions.
- Alcoholic fermentation and lactic acid fermentation are the two types of fermentation.

Explore More

Use the resource below to answer the questions that follow.

- **Anaerobic Respiration** at http://www.youtube.com/watch?v=s3MhJ7buOeA (2:01)

Click on the image above for more content

1. Where in the cell does anaerobic respiration take place?
2. What happens to pyruvate during anaerobic respiration? How does yeast differ from other organisms regarding the fate of pyruvate?
3. How can glycolysis participate in anaerobic repiration?
4. How much ATP is produced by the breakdown of pyruvate? How much ATP is produced overall by fermentation? Where does this ATP come from?

Review

1. What is the difference between alcoholic fermentation and lactic acid fermentation?
2. If an organism could make ATP from sugars with or without the presence of oxygen, which would be preferred and why?

Section 17

Cell Division

Cell Division

- •Define cell division.
- •Explain why cells must divide.

Do cells get worn out?

Yes, just like this car, cells cannot last forever. Cells do eventually wear out. At that point, they need to be replaced. This is one reason that your cells divide. New cells that result after cells divide are also used for growth and to repair cuts.

Why Cells Divide

Imagine the first stages of life. In humans and other animals, a sperm fertilizes an egg, forming the first cell. But humans are made up of trillions of cells, so where do the new cells come from? Remember that according to the **cell theory** , all cells come from existing cells. From that first cell, called a **zygote** , an entire baby will develop. And each cell in that baby will be genetically identical, meaning that each cell will have exactly the same DNA.

How does a new life go from one cell to so many? The cell divides in half, creating two cells. Then those two cells divide, for a total of four cells. The new cells continue to divide and divide. One cell becomes two, then four, then eight, and so on (**Figure** below). This continual process of a cell dividing and creating two new cells is known as **cell division.** Cell division is part of a cycle of cellular growth and division known as the cell cycle—cells must grow before they divide. The **cell cycle** describes the "life" of a eukayrotic cell.

Most cell division produces genetically identical cells, meaning they have the same DNA. The process of **mitosis** ensures that each cell has the same DNA. A special form of cell division, called **meiosis** , produces cells with half as much DNA as the parent cell. These cells are used for reproduction. In prokaryotic organisms, cell division is how those organisms reproduce.

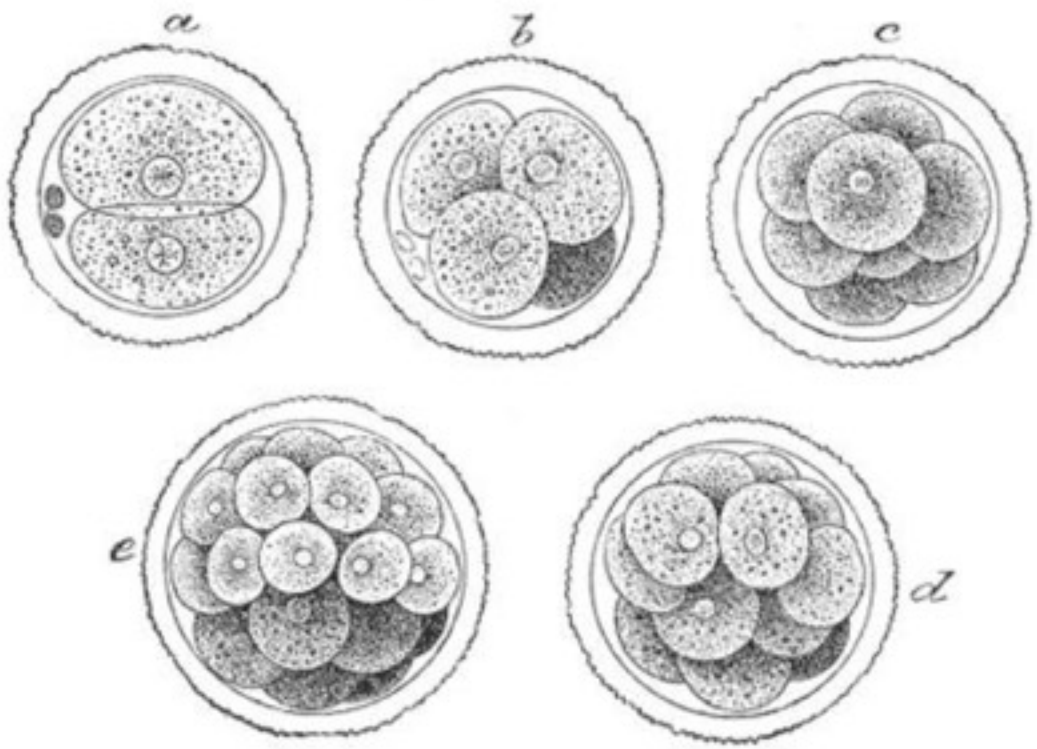


Figure 2.24

Cells divide repeatedly to produce an embryo. Previously the one-celled zygote (the first cell of a new organism) divided to make two cells (a). Each of the two cells divides to yield four cells (b), then the four cells divide to make eight cells (c), and so on. Through cell division, an entire embryo forms from one initial cell.

Besides the development of a baby, there are many other reasons that cell division is necessary for life:

1. To grow and develop, you must form new cells. Imagine how often your cells must divide during a growth spurt. Growing just an inch requires countless cell divisions. Your body must produce new bone cells, new skin cells, new cells in your blood vessels and so on.
2. Cell division is also necessary to repair damaged cells. Imagine you cut your finger. After the scab forms, it will eventually disappear and new skin cells will grow to repair the wound. Where do these cells come from? Some of your existing skin cells divide and produce new cells.
3. Your cells can also simply wear out. Over time you must replace old and worn-out cells. Cell division is essential to this process.

Summary

- Cells must divide repeatedly for an embryo to develop or for you to grow.
- Cells also divide in order to replace damaged or worn-out cells.

Explore More

Use the resources below to answer the questions that follow.

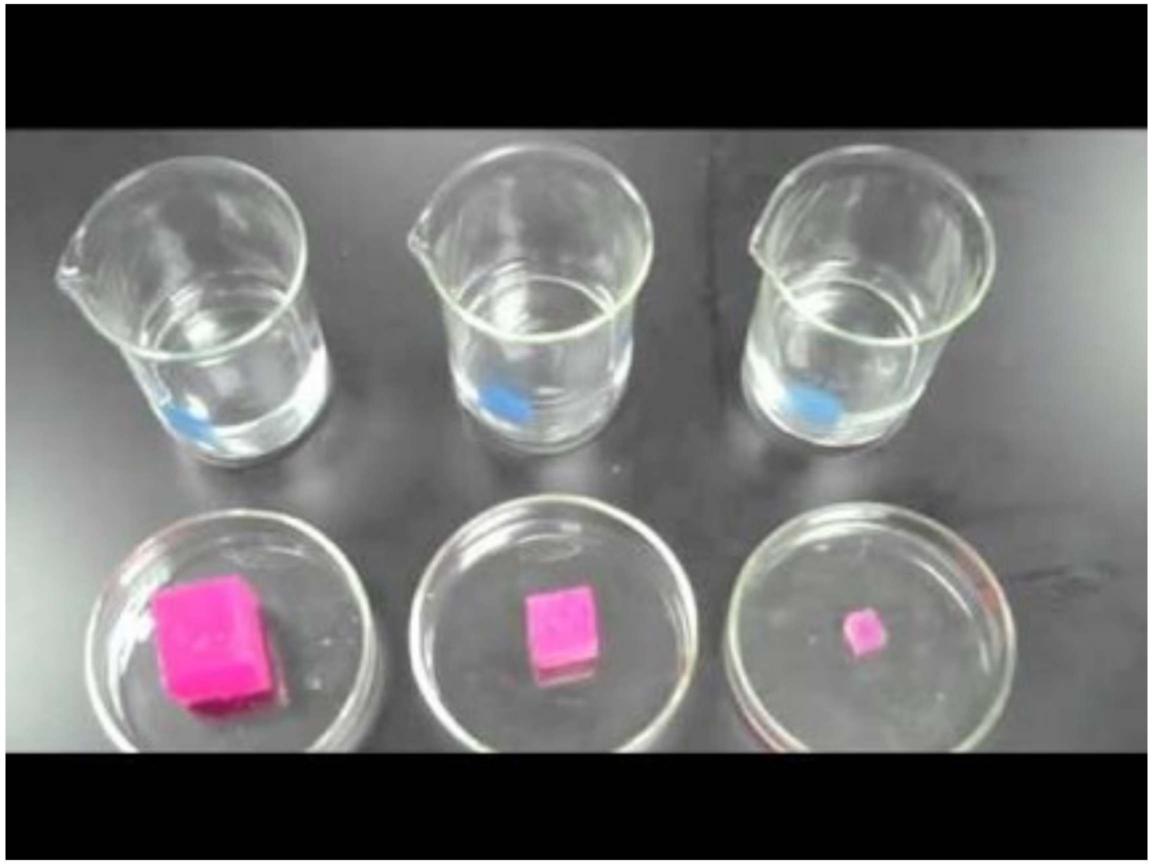
Explore More I

- **Why Must A Cell Divide** at http://plaza.ufl.edu/alallen/pgl/modules/rio/stingarees/module/why.html

1. What limits the size a cell can become? Be as specific as you can.
2. If you double the size of a cube, how does this affect the surface to volume ratio?

Explore More II

- **Surface Area to Volume Ratios** at http://www.youtube.com/watch?v=xuG4ZZ1GbzI (2:45)



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1. Does the rate at which materials diffuse into a cell vary with the size of the cell?
2. What does this mean for large cells?

Review

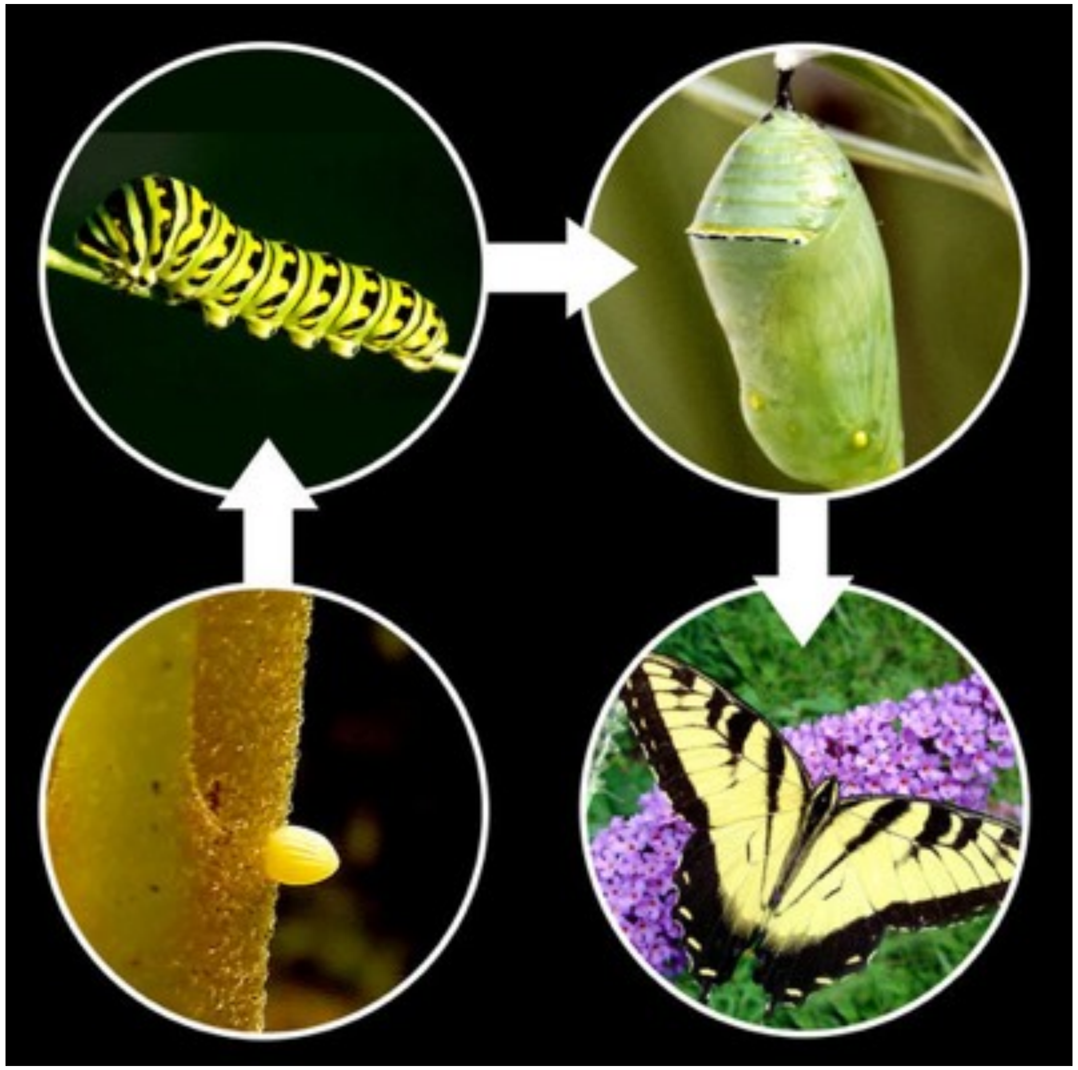
1. Define cell division.
2. How does an embryo develop from a fertilized egg?
3. List two reasons that cells must divide.

Section 18

Cell Cycle

Cell Cycle

•Describe the cell cycle.
•Explain the phases of the cell cycle.



Do cells have a life cycle?

Yes, just like a butterfly passes through different phases, such as caterpillar, chrysalis, and adult butterfly, there are a series of phases in a cell's life as it gets ready to divide. The sequence of phases leading up to cell division and then ending with cell division itself is called the cell cycle.

Cell Cycle

The process of cell division in eukaryotic cells is carefully controlled. The **cell cycle** (**Figure** below) is the life cycle of a cell, with cell division at the end of the cycle. Like a human life cycle, which is made up of different phases, like childhood, adolescence, and adulthood, the cell cycle also occurs in a series of phases.

These steps can be divided into two main components: interphase and the mitotic phase. **Interphase** is the stage when the cell mostly performs its “everyday” functions. For example, it is when a kidney cell does what a kidney cell is supposed to do. The cell also gets ready to divide during this time. The cell divides during the mitotic phase, which consists of mitosis and cytokinesis.

Most of the cell cycle consists of interphase, the time between cell divisions. Interphase can be divided into three stages:

1. The first growth phase (G1): During the G1 stage, the cell doubles in size and doubles the number of organelles.
2. The synthesis phase (S): The DNA is replicated during this phase. In other words, an identical copy of

all the cell's DNA is made. This ensures that each new cell has a set of genetic material identical to that of the parental cell. This process is called **DNA replication** .
3.The second growth phase (G2): Proteins are synthesized that will help the cell divide. At the end of interphase, the cell is ready to enter mitosis.

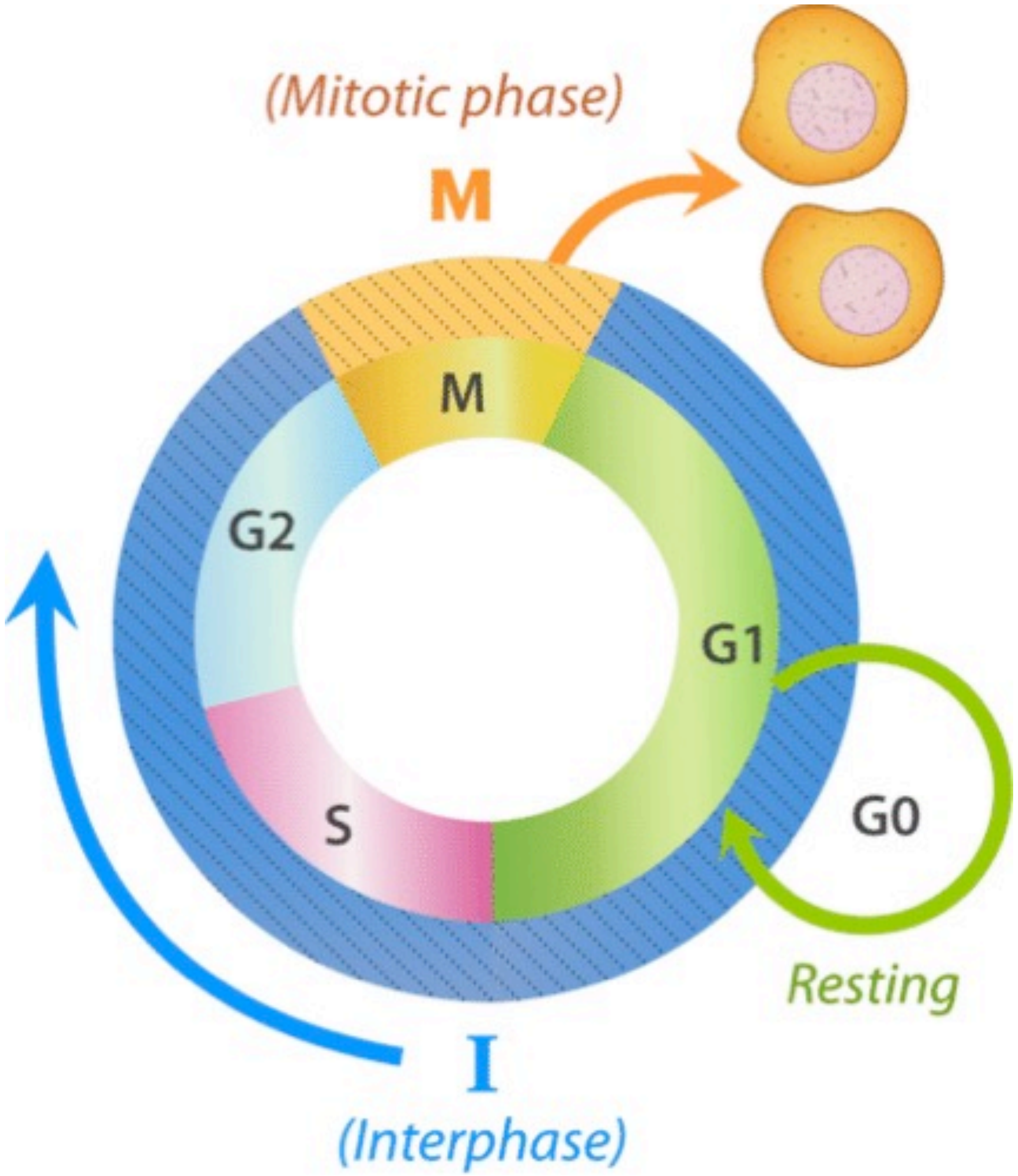


Figure 2.25

Notice that most of the cell cycle is spent in interphase (G1, S, and G2).

During **mitosis** , the nucleus divides. One nucleus becomes two nuclei, each with an identical set of **chromosomes** . Mitosis is followed by **cytokinesis** , when the cytoplasm divides, resulting in two cells. After cytokinesis, cell division is complete. The one parent cell (the dividing cell) forms two genetically identical daughter cells (the cells that divide from the parent cell). The term "genetically identical" means that each cell has an identical set of DNA, and this DNA is also identical to that of the parent cell. If the cell cycle is not carefully controlled, it can cause a disease called **cancer** in which the cells divide out of control. A tumor can result from this kind of growth.

Summary

- The cell cycle describes the "life" of a cell.
- Interphase, the stage of the cell cycle when the cell, preparing to divide, is divided into the G1, S, and G2 stages.
- The nucleus divides during mitosis, and the cytoplasm divides during cytokinesis.

Explore More

Use the resource below to answer the questions that follow.

- **Cell Division and Cell Cycle** at http://vimeo.com/9536315 (5:34)

Click on the image above for more content

1. What are the major phases of the cell cycle?
2. Why do you think it is important for a cell to grow before it replicates its DNA? Be as specific as you can in your answer.
3. What happens during the S phase of the cell cycle?
4. What happens during mitosis?
5. What is the function of spindle fibers? Where do they attach?
6. What is the function of meiosis?

Review

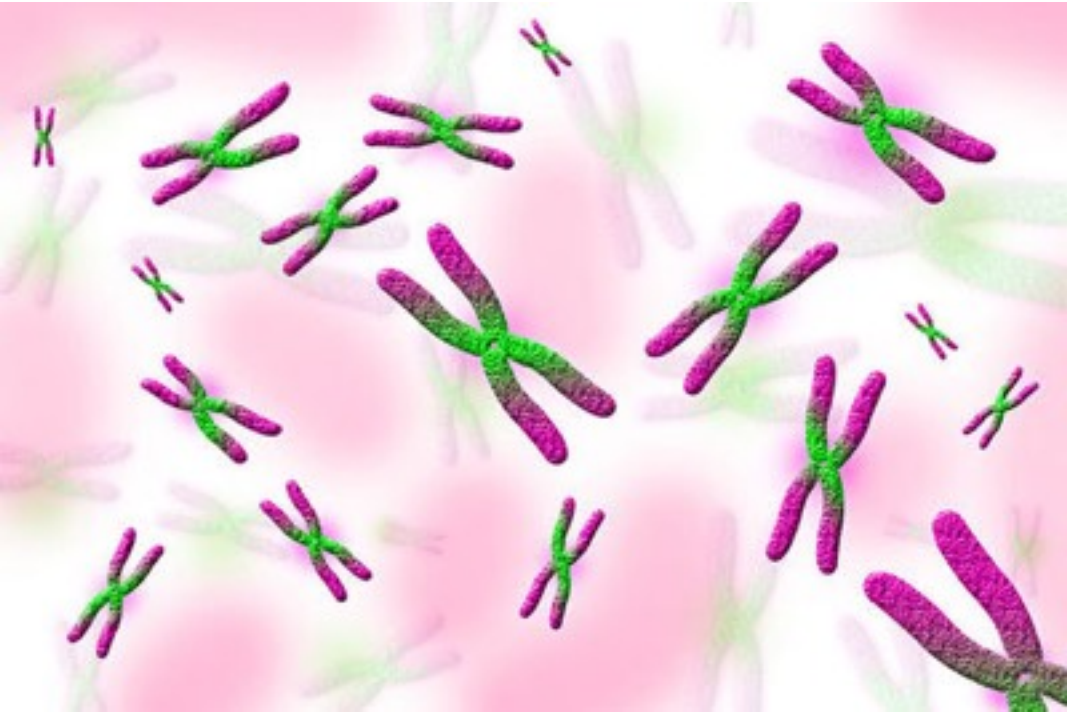
1. What is the cell cycle?
2. What are the two main components of the cell cycle?
3. What occurs during interphase?
4. What are the three stages of interphase?
5. What is the main purpose of the S phase?
6. Describe the main events of the mitotic phase.
7. Define cancer.

Section 19

Mitosis and Cytokinesis

Mitosis and Cytokinesis

- •Explain the importance of mitosis.
- •Explain chromosome structure.
- •Define sister chromatids.
- •List the phases of mitosis.
- •Summarize the phases of mitosis.



How is your DNA organized?

Your DNA is organized into chromosomes, the pink structures pictured above. Your DNA doesn't always look so pretty, though. It only winds tightly into chromosomes when the cell is getting ready to divide. If your DNA wasn't organized into chromosomes, your DNA would look like a mass of strings and would be difficult to divide up!

Mitosis and Chromosomes

The genetic information of the cell, or DNA, is stored in the **nucleus** . During **mitosis** , two nuclei (plural for nucleus) must form, so that one nucleus can be in each of the new cells after the cell divides. In order to create two genetically identical nuclei, DNA inside of the nucleus must be copied or replicated. This occurs during the S phase of the cell cycle. During mitosis, the copied DNA is divided into two complete sets, so that after **cytokinesis** , each cell has a complete set of genetic instructions.

Chromosomes

To begin mitosis, the DNA in the nucleus wraps around proteins to form **chromosomes** . Each organism has a unique number of chromosomes. In human cells, our DNA is divided up into 23 pairs of chromosomes. Replicated DNA forms a chromosome made from two identical **sister chromatids** , forming an "X" shaped molecule (**Figure** below). The two chromatids are held together on the chromosome by the **centromere** . The centromere is also where spindle fiber microtubules attach during mitosis. The **spindles** separate sister chromatids from each other.

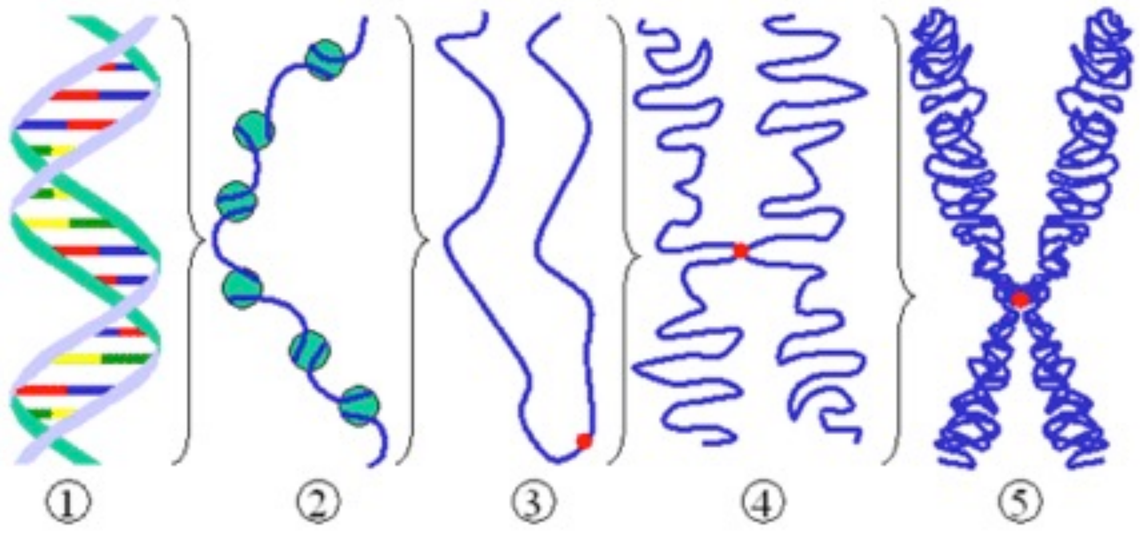


Figure 2.26

The DNA double helix wraps around proteins (2) and tightly coils a number of times to form a chromosome (5). This figure shows the complexity of the coiling process. The red dot shows the location of the centromere, which holds the sister chromatids together and is where the spindle microtubules attach during mitosis and meiosis. Notice that a chromosome resembles an "X."

Four Phases of Mitosis

During mitosis, the two sister chromatids must be divided. This is a precise process that has four individual phases to it. After the sister chromatids separate, each separate chromatid is now known as a chromosome. Each resulting chromosome is made of DNA from just one chromatid. So: each chromosome after this separation is made of "1/2 of the X." Through this process, each daughter cell receives one copy of each chromosome. The four phases of mitosis are prophase, metaphase, anaphase and telophase (**Figure** below).

1. **Prophase** : The chromosomes "condense," or become so tightly wound that you can see them under a microscope. The membrane around the nucleus, called the nuclear envelope, disappears. Spindles also form and attach to chromosomes to help them move.
2. **Metaphase** : The chromosomes line up in the center, or the equator, of the cell. The chromosomes line up in a row, one on top of the next.
3. **Anaphase** : The two sister chromatids of each chromosome separate as the spindles pull the chromatids apart, resulting in two sets of identical chromosomes.
4. **Telophase** : The spindle dissolves and nuclear envelopes form around the chromosomes in both cells.

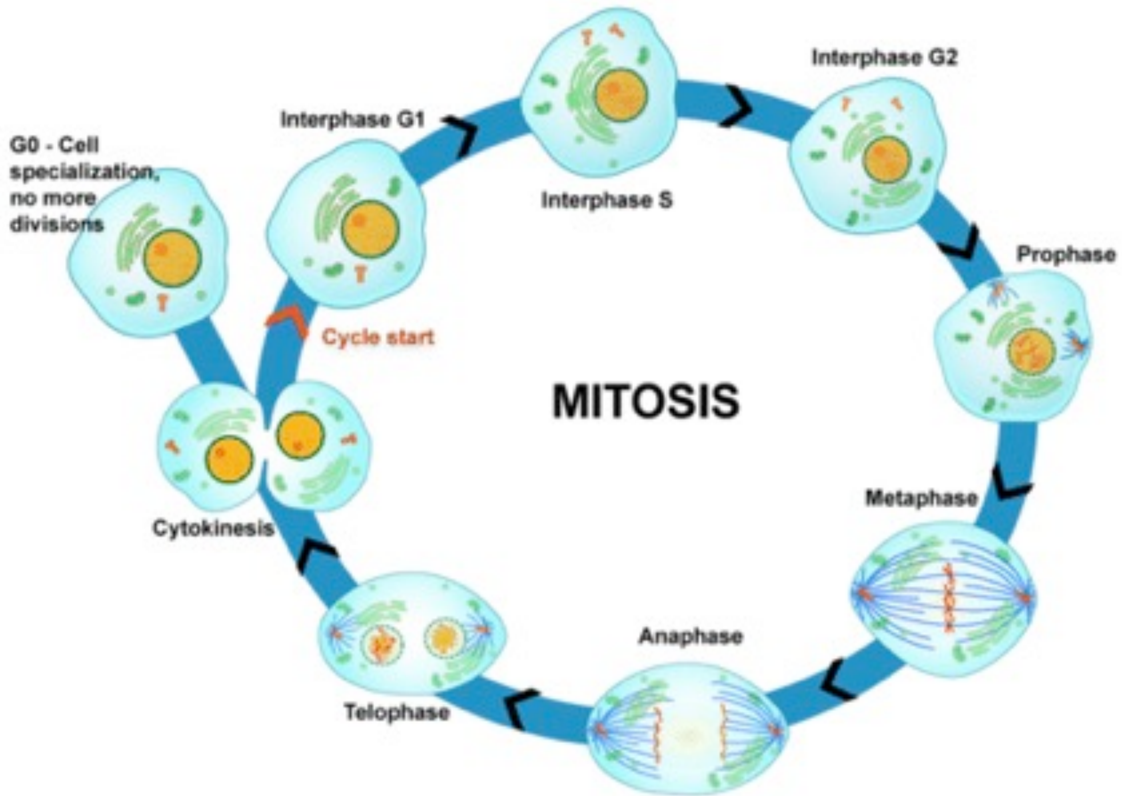


Figure 2.27

An overview of the cell cycle and mitosis: during prophase the chromosomes condense, during metaphase the chromosomes line up, during anaphase the sister chromatids are pulled to opposite sides of the cell, and during telophase the nuclear envelope forms.

After telophase, each new nucleus contains the exact same number and type of chromosomes as the original cell. The cell is now ready for cytokinesis, which literally means "cell movement." During cytokinesis, the cytoplasm divides and the parent cell separates, producing two genetically identical cells, each with its own nucleus. A new cell membrane forms and in plant cells, a cell wall forms as well. Below is a representation of dividing plant cells (**Figure** below).

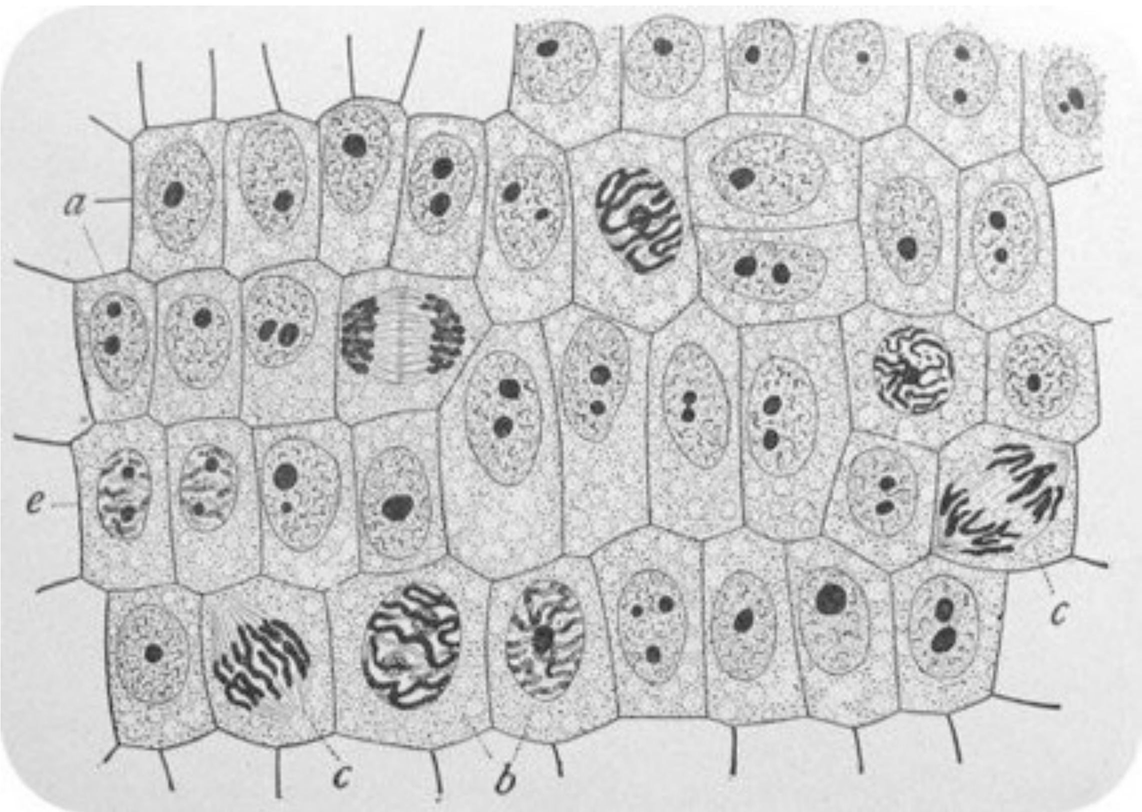


Figure 2.28

This is a representation of dividing plant cells. Cell division in plant cells differs slightly from animal cells as a cell wall must form. Note that most of the cells are in interphase. Can you find examples of the different stages of mitosis?

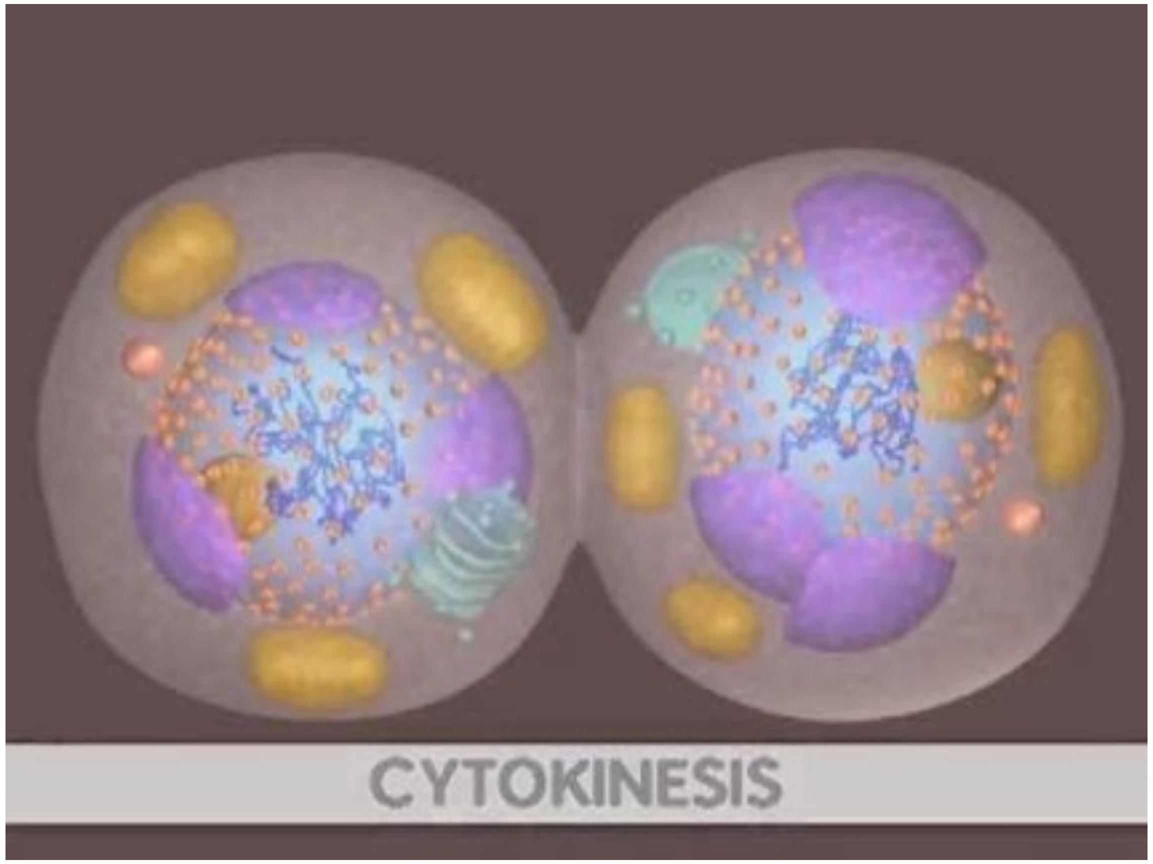
Summary

- The DNA in the nucleus wraps around proteins to form chromosomes.
- During mitosis, the newly duplicated chromosomes are divided into two daughter nuclei.
- Mitosis occurs in four phases, called prophase, metaphase, anaphase, and telophase.

Explore More

Use the resource below to answer the questions that follow.

- **Mitosis** by NDSU VCell Productions at http://www.youtube.com/watch?v=C6hn3sA0ip0 (6:10)



Click on the image above for more content

1. When does the "classic" chromosome structure of DNA appear during mitosis?
2. What problems do you think might arise if the chromosomes did not align during metaphase?
3. When do the nuclear envelopes reform? What problems might arise if a cell started forming the nuclear envelopes earlier?
4. In what stage do cells spend most of their "life"?
5. How long does mitosis take in the typical eukaryotic cell?

Review

1. What are chromosomes?
2. What are the four phases of mitosis, in the correct order?
3. In what phase of mitosis are chromosomes moving toward opposite sides of the cell?
4. Compare the two nuclei that form as a result of mitosis?
5. What is cytokinesis, and when does it occur?

Section 20

Asexual vs. Sexual Repro-

Asexual vs. Sexual Reproduction

•Distinguish between sexual and asexual reproduction.
•Describe the types of asexual reproduction.
•Explain how plants and animals reproduce sexually.

Do animals always have two parents?

No, not all animals have two parents. When necessary, some animals can be produced from just one parent. Some reptiles, such as this Komodo dragon, have only one parent. The process of creating offspring from just one individual is called asexual reproduction.

Reproduction

Animals and other organisms cannot live forever. They must reproduce if their species is to survive. But what does it mean to reproduce? **Reproduction** is the ability to make the next generation, and it is one of the basic characteristics of life. Two methods of reproduction are:

1. **Asexual reproduction** , the process of forming a new individual from a single parent.
2. **Sexual reproduction** , the process of forming a new individual from two parents.

There are advantages and disadvantages to each method, but the result is always the same: a new life begins.

Asexual Reproduction

When humans reproduce, there are two parents involved. DNA must be passed from both the mother and father to the child. Humans cannot reproduce with just one parent; humans can only reproduce sexually. But having just one parent is possible in other eukaryotic organisms, including some insects, fish, and reptiles. These organisms can reproduce asexually, meaning the offspring ("children") have a single parent and share the exact same genetic material as the parent. This is very different from reproduction in humans. Bacteria, being a prokaryotic, single-celled organism, must reproduce asexually.

The advantage of asexual reproduction is that it can be very quick and does not require the meeting of a male and female organism. The disadvantage of asexual reproduction is that organisms do not receive a mix of traits from both parents. An organism that is born through asexual reproduction only has the DNA from the one parent. In fact, the offspring is genetically an exact copy of the parent. This can cause problems for the individual. For example, if the parent has a gene that causes a particular disease, the offspring will also have the gene that causes that disease. Organisms produced sexually may or may not inherit the disease gene because they receive a mix of their parents' genes.

Types of organisms that reproduce asexually include:

1. Prokaryotic organisms, like bacteria. Bacteria reproduce through **binary fission** , where they grow and divide in half (**Figure** below). First, their chromosome replicates and the cell enlarges. The cell then divides into two cells as new membranes form to separate the two cells. After cell division, the two new cells each have one identical chromosome. This simple process allows bacteria to reproduce very rapidly.
2. Flatworms, an invertebrate animal species. Flatworms divide in two, then each half regenerates into a new flatworm identical to the original, a process called **fragmentation** .
3. Different types of insects, fish, and lizards. These organisms can reproduce asexually through a process called parthenogenesis. **Parthenogenesis** happens when an unfertilized egg cell grows into a new organism. The resulting organism has half the amount of genetic material of the parent. Parthenogenesis is common in honeybees. In a hive, the sexually produced eggs become workers, while the asexually produced eggs become drones.

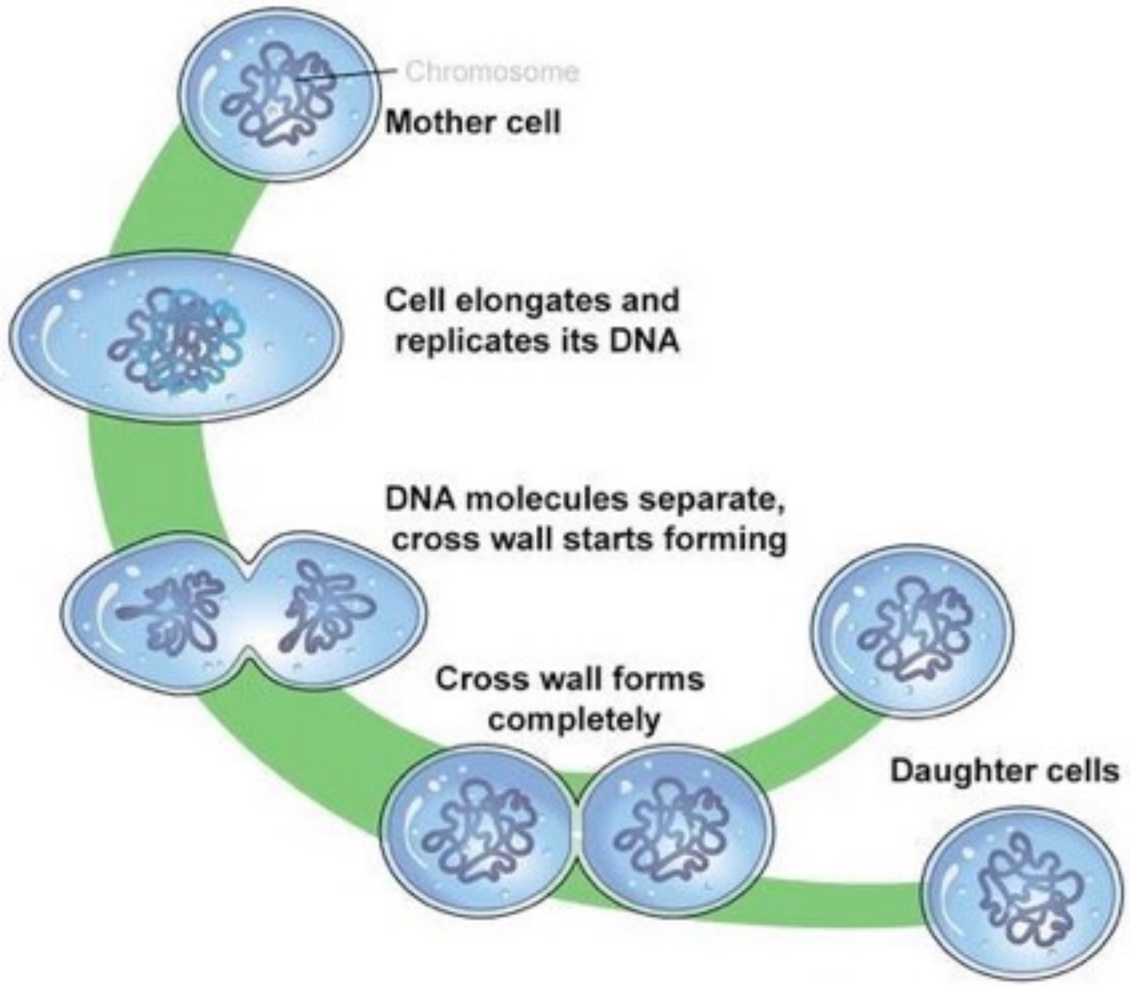


Figure 2.29

Bacteria reproduce by binary fission. Shown is one bacterium reproducing and becoming two bacteria.

Sexual Reproduction

During sexual reproduction, two parents are involved. Most animals are **dioecious** , meaning there is a separate male and female sex, with the male producing sperm and the female producing eggs. When a sperm and egg meet during **fertilization** , a **zygote** , the first cell of a new organism, is formed (**Figure** below). This process combines the genetic material from both parents. The resulting organism will be genetically unique. The zygote will divide by mitosis and grow into the embryo.

Figure 2.30

During sexual reproduction, a sperm fertilizes an egg.

Let's explore how animals, plants, and fungi reproduce sexually:

Animals often have **gonads** , organs that produce eggs or sperm. The male gonads are the **testes** , and the female gonads are the **ovaries** . Testes produce sperm; ovaries produce eggs. Sperm and egg, the two sex cells, are known as **gametes** , and can combine two different ways, both of which combine the genetic material from the two parents. Gametes have half the amount of the genetic material of a regular body cell. In humans, gametes have one set of 23 chromosomes. Gametes are produced through a special type of cell division known as **meiosis** .

Fish and other aquatic animals release their gametes in the water, which is called **external fertilization** (**Figure** below). These gametes will combine by chance. Animals that live on land (reptiles, birds, and mammals) reproduce by **internal fertilization** . Typically males have a penis that deposits sperm into the vagina of the female. Birds do not have penises, but they do have a chamber called the cloaca that they place close to another bird's cloaca to deposit sperm. Amphibians must live close to water as they must lay their eggs in a moist or wet environment prior to external fertilization.

Figure 2.31

This fish guards her eggs, which will be fertilized externally.

- Plants can also reproduce sexually, but their reproductive organs are different from animals' gonads. Plants that have flowers have their reproductive parts in the flower. The sperm is contained in the pollen, while the egg is contained in the ovary, deep within the flower. The sperm can reach the egg two different ways:

1. In **self-pollination** , the egg is fertilized by the pollen of the same flower.
2. In **cross-pollination** , sperm from the pollen of one flower fertilizes the egg of another flower. Like other types of sexual reproduction, cross-pollination allows

new combinations of traits. Cross-pollination occurs when pollen is carried by the wind to another flower. It can also occur when animal pollinators, like honeybees or butterflies (**Figure** below), carry the pollen from flower to flower.

Figure 2.32

Butterflies receive nectar when they deposit pollen into flowers, resulting in cross-pollination.

- Fungi can also reproduce sexually, but instead of female and male sexes, they have (+) and (-) strains. When the filaments of a (+) and (-) fungi meet, the zygote is formed. Just like in plants and animals, each zygote receives DNA from two parent strains.

Summary

- Types of asexual reproduction, when a new individual is formed from a single parent, include binary fission in bacteria and parthenogenesis in some animals.
- During sexual reproduction in animals, fertilization can be internal or external.
- Cross-pollination allows sexual reproduction in plants.

Explore More

Use the resource below to answer the questions that follow.

- **Plant reproduction: Asexual Reproduction** at http://www.youtube.com/watch?v=drcnTg7ZCoc (2:57)

Click on the image above for more content

1. How does the production of bulbs benefit plants?
2. How can an organism benefit from asexual reproduction?
3. What can be a negative effect of asexual reproduction? Is this more applicable to the individual or the population?

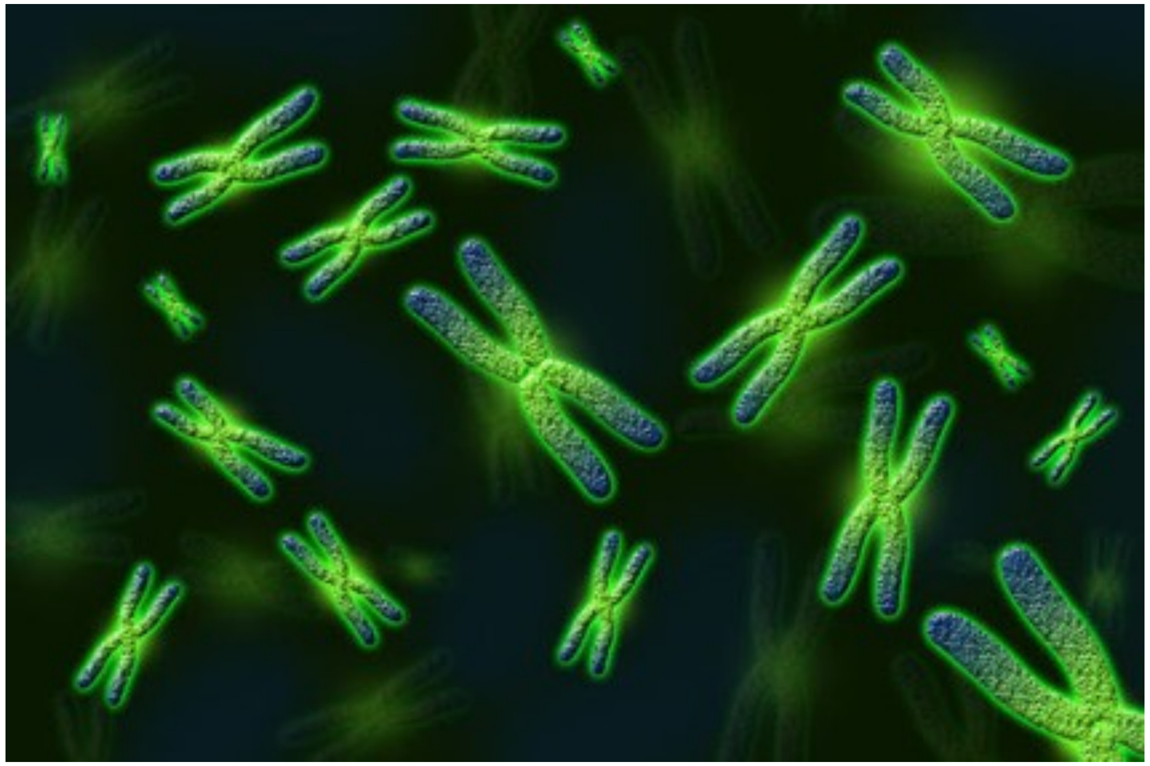
Review

1. What is asexual reproduction?
2. What is the advantage of sexual reproduction?
3. Describe two types of asexual reproduction.
4. What is a zygote?
5. How many chromosomes are in a human zygote? How many chromosomes are in a human gamete?

Section 21
Meiosis

Meiosis

•Explain the importance of meiosis.
•Distinguish between haploid and diploid.
•List the stages of meiosis.
•Summarize the steps of meiosis.
•Define crossing-over and explain its significance.



Do you have ALL your parents' chromosomes?

No, you only received half of your mother's chromosomes and half of your father's chromosomes. If you inherited them all, you would have twice the number of chromosomes that you're supposed to have. Humans typically have 23 pairs of chromosomes. If you received all your parents' chromosomes, you would have 46 pairs!

Introduction to Meiosis

Sexual reproduction combines gametes from two parents. **Gametes** are reproductive cells, such as sperm and egg. As gametes are produced, the number of chromosomes must be reduced by half. Why? The **zygote** must contain genetic information from the mother and from the father, so the gametes must contain half of the chromosomes found in normal body cells. When two gametes come together at fertilization, the normal amount of chromosomes results. Gametes are produced by a special type of cell division known as **meiosis** . Meiosis contains two rounds of cell division without DNA replication in between. This process reduces the number of chromosomes by half.

Human cells have 23 pairs of chromosomes, and each chromosome within a pair is called a **homologous chromosome** . For each of the 23 chromosome pairs, you received one chromosome from your father and one chromosome from your mother. **Alleles** are alternate forms of genes found on chromosomes. Homologous chromosomes have the same genes, though they may have different alleles. So, though homologous chromosomes are very similar, they are not identical. The homologous chromosomes are separated when gametes are formed. Therefore, gametes have only 23 chromosomes, not 23 pairs.

Haploid vs. Diploid

A cell with two sets of chromosomes is **diploid** , referred to as *2n* , where *n* is the number of sets of chromosomes. Most of the cells in a human body are diploid. A cell with one set of chromosomes, such as a gamete, is **haploid** , referred to as *n* . Sex cells are haploid. When a haploid sperm (*n*) and a haploid egg (*n*) combine, a diploid zygote will be formed (*2n*). In short, when a diploid zygote is formed, half of the DNA comes from each parent.

Overview of Meiosis

Before meiosis begins, DNA replication occurs, so each chromosome contains two sister chromatids that are identical to the original chromosome. Meiosis (**Figure** below) is divided into two divisions: Meiosis I and Meiosis II. Each division can be divided into the same phases: prophase, metaphase, anaphase, and telophase. Cytokinesis follows telophase each time. Between the two cell divisions, DNA replication does not occur. Through this process, one diploid cell will divide into four haploid cells.

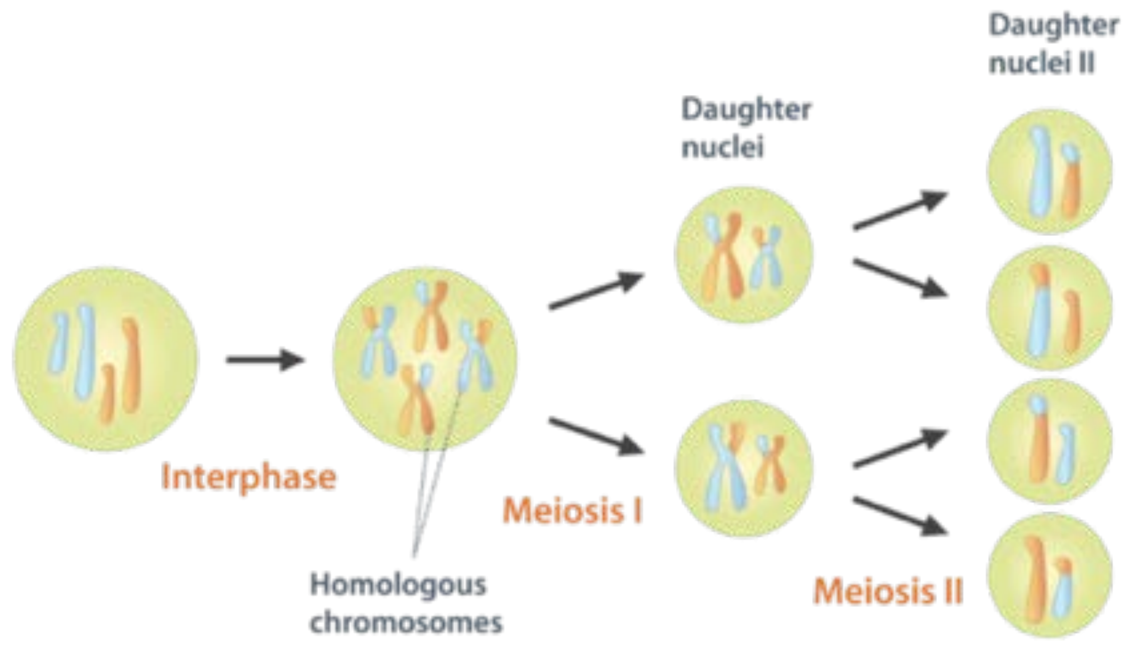


Figure 2.33

Overview of Meiosis. During meiosis, four haploid cells are created from one diploid parent cell.

Meiosis I

During meiosis I, the pairs of homologous chromosomes are separated from each other. This requires that they line up in their homologous paris during metaphase I. The steps are outlined below:

1.Prophase I: The homologous chromosomes line up together. During this time, a process that only happens in meiosis can occur. This process is called **crossing-over** (**Figure** below), which is the exchange of DNA between homologous chromosomes. Crossing-over forms new combinations of alleles on the resulting chromosome. Without crossing-over, the offspring would always inherit all of the alleles on one of the homologous chromosomes. Also during prophase I, the **spindle** forms, the chromosomes condense as they coil up tightly, and the nuclear envelope disappears.

2. Metaphase I: The homologous chromosomes line up in their pairs in the middle of the cell. Chromosomes from the mother or from the father can each attach to either side of the spindle. Their attachment is random, so all of the chromosomes from the mother or father do not end up in the same gamete. The gamete will contain some chromosomes from the mother and some chromosomes from the father.
3. Anaphase I: The homologous chromosomes are separated as the spindle shortens, and begin to move to opposite sides of the cell.
4. Telophase I: The spindle fibers dissolves, but a new nuclear envelope does not need to form. This is because, after cytokinesis, the nucleus will immediately begin to divide again. No DNA replication occurs between meiosis I and meiosis II because the chromosomes are already duplicated. After cytokinesis, two haploid cells result, each with chromosomes made of sister chromatids.

Since the separation of chromosomes into gametes is random during meiosis I, this process results in different combinations of chromosomes (and alleles) in each gamete. With 23 pairs of chromosomes, there is a possibility of over 8 million different combinations of chromosomes (2^{23}) in a human gamete.

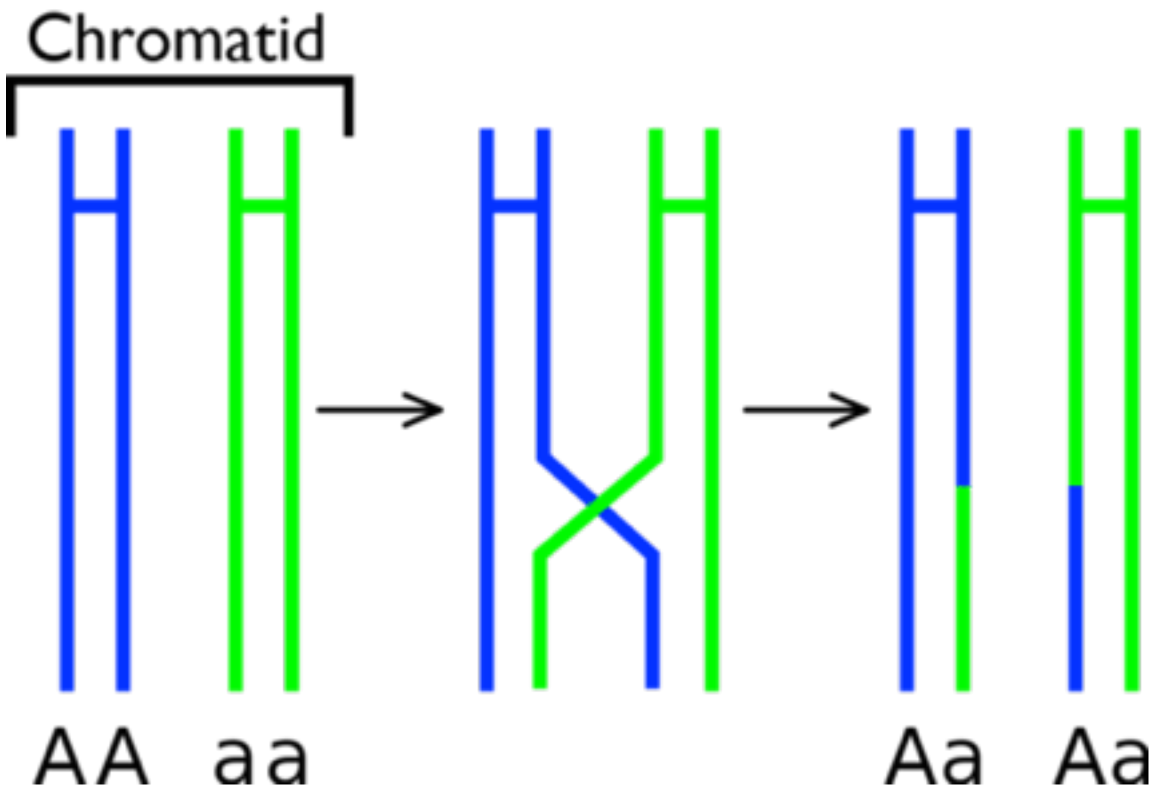


Figure 2.34

During crossing-over, segments of DNA are exchanged between non-sister chromatids of homologous chromosomes. Notice how this can result in an allele (A) on one chromatid being moved onto the other non-sister chromatid.

Meiosis II

During meiosis II, the sister chromatids are separated and the gametes are generated. This cell division is similar to that of **mitosis** , but results in four genetically unique haploid cells. The steps are outlined below:

1. Prophase II: The chromosomes condense.

2.Metaphase II: The chromosomes line up one on top of each other along the middle of the cell, similar to how they line up in mitosis. The spindle is attached to the centromere of each chromosome.
3.Anaphase II: The sister chromatids separate as the spindle shortens and move to opposite ends of the cell.
4.Telophase II: A nuclear envelope forms around the chromosomes in all four cells. This is followed by cytokinesis.

After cytokinesis, each cell has divided again. Therefore, meiosis results in four haploid genetically unique daughter cells, each with half the DNA of the parent cell (**Figure** below). In human cells, the parent cell has 46 chromosomes, so the cells produced by meiosis have 23 chromosomes. These cells will become gametes.

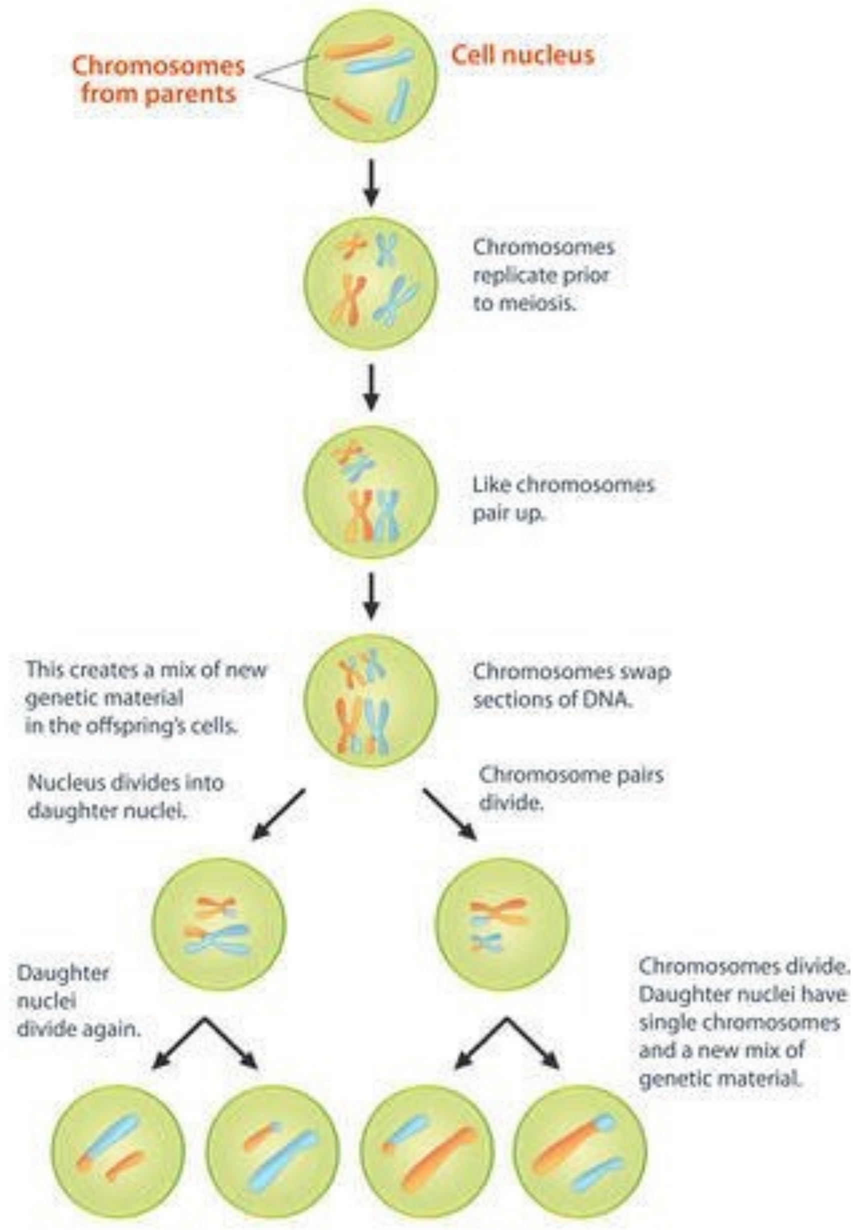


Figure 2.35

An overview of meiosis.

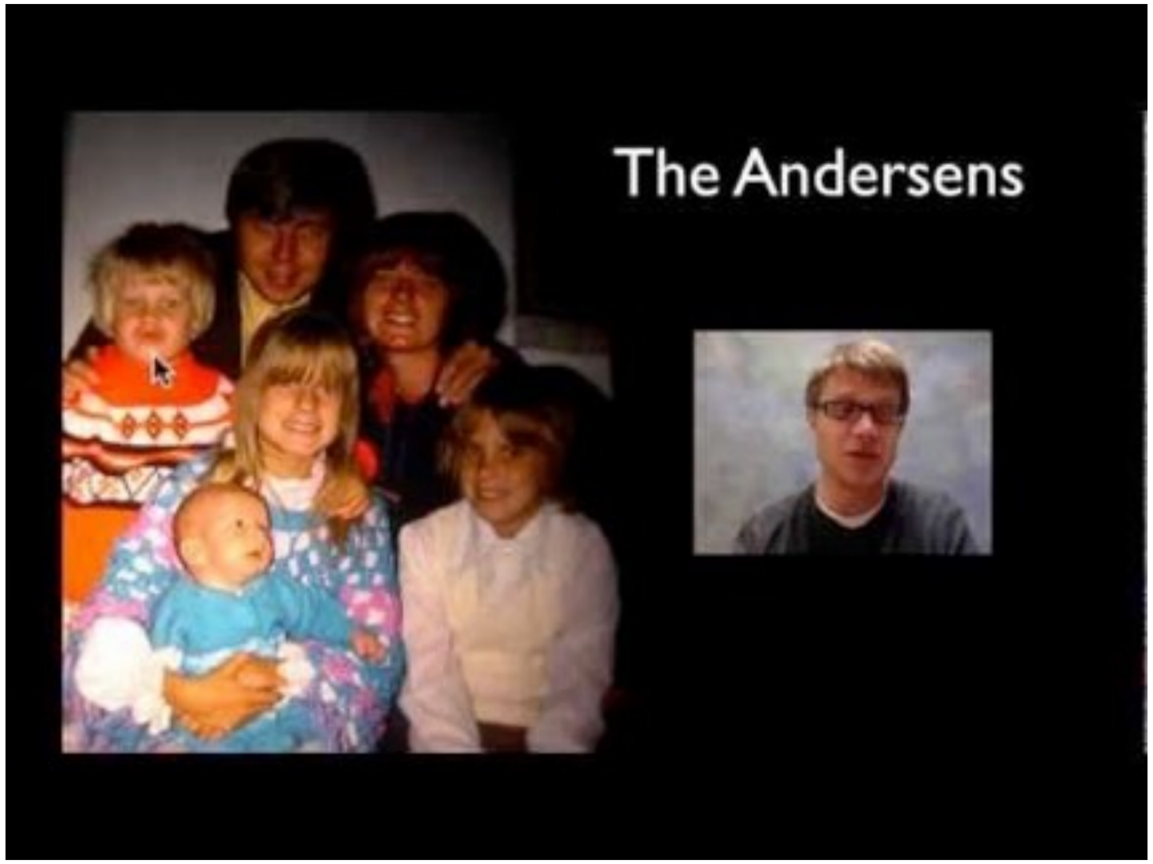
Summary

•Meiosis is a process of cell division that reduces the chromosome number by half and produces sex cells, or gametes.
•Meiosis is divided into two parts: Meiosis I and Meiosis II. Each part is similar to mitosis and can be divided into the same phases: prophase, metaphase, anaphase, and telophase.
•Crossing-over occurs only during prophase I.
•Four genetically unique haploid cells result from meiosis.

Explore More

Use the resource below to answer the questions that follow.

•**Meiosis** on YouTube at http://www.youtube.com/watch?v=rB_8dTuh73c (9:15)



Click on the image above for more content

1. What is meiosis?
2. What is diploid? How many chromosomes are in a diploid human cell?
3. What is a zygote? How does the zygote form the organism?
4. What is the result of crossing-over?
5. How many cell divisions occur during meiosis?
6. Why are you genetically distinct?

Review

1. Define meiosis.

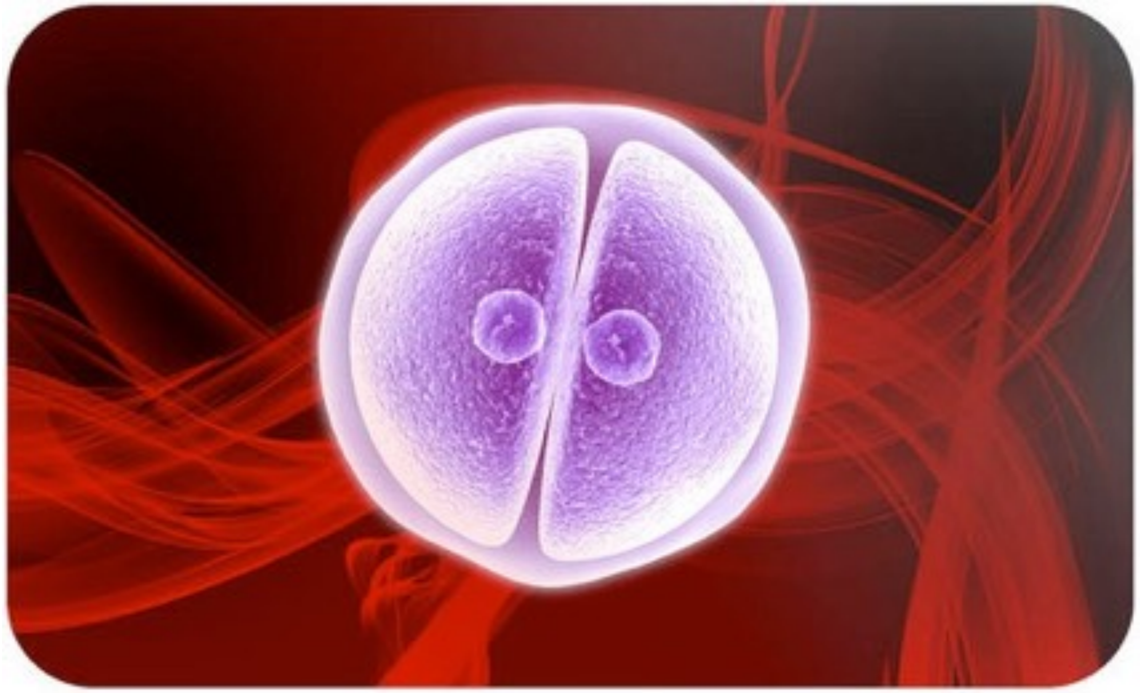
2.What is the difference between a haploid cell and a diploid cell?
3.Describe the steps of Meiosis I and Meiosis II.
4.Describe crossing-over. When does crossing-over occur?
5.What is the outcome of meiosis?

Section 22

Mitosis vs. Meiosis

Mitosis vs. Meiosis

- Distinguish between mitosis and meiosis.
- Summarize the necessity for mitosis and meiosis.

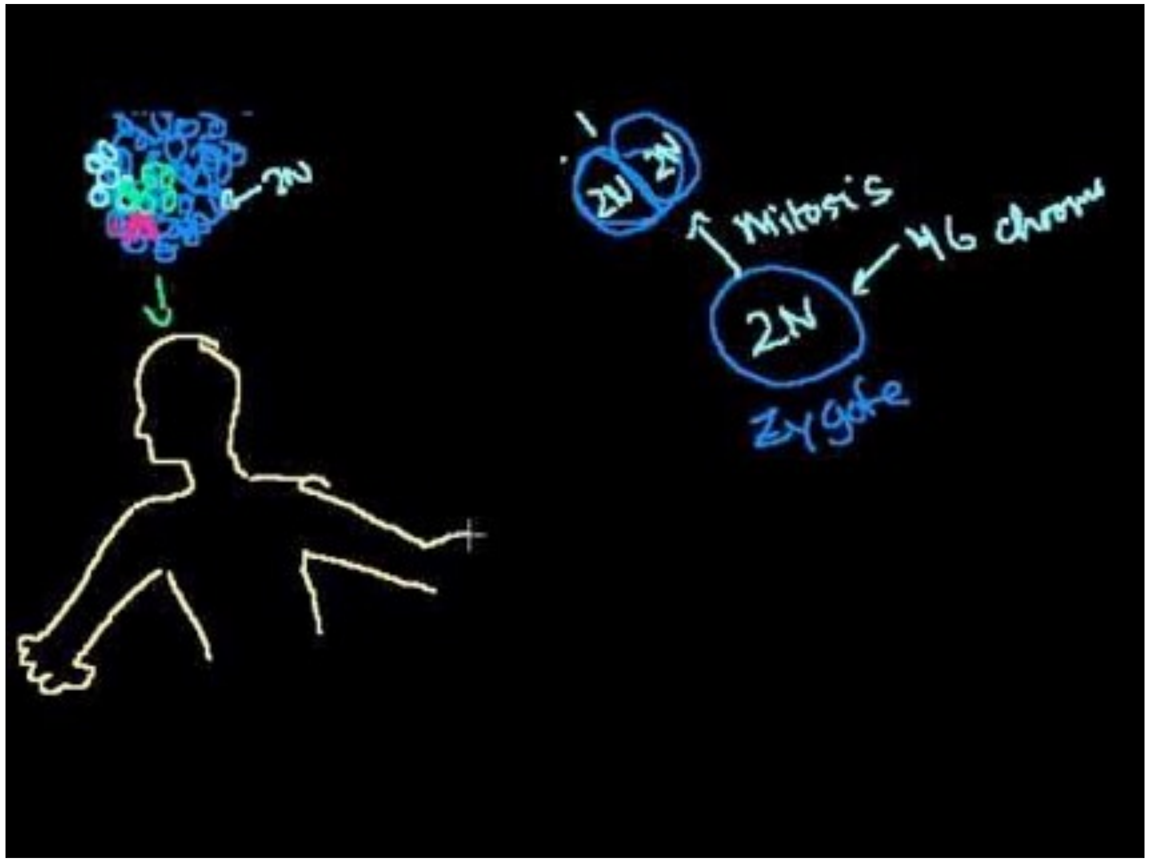


Mitosis or Meiosis?

This represents a tiny embryo just beginning to form. Once an egg is fertilized, the resulting single cell must divide many, many times to develop a fetus. Both mitosis and meiosis involve cell division; is this type of cell division an example of mitosis or meiosis? The answer is mitosis. With each division you are making a genetically exact copy of the parent cell, which only happens through mitosis.

Mitosis vs. Meiosis

Mitosis, meiosis, and sexual reproduction are discussed at http://www.youtube.com/watch?v=kaSIjIzAtYA (18:23).



Click on the image above for more content

Both **mitosis** and **meiosis** result in eukaryotic cells dividing. So what is the difference between mitosis and meiosis? The primary difference is the differing goals of each process. The goal of mitosis is to produce two **daughter cells** that are genetically identical to the parent cell, meaning the new cells have exactly the same DNA as the parent cell. Mitosis happens when you want to grow, for example. You want all your new cells to have the same DNA as the previous cells. The goal of meiosis, however, is to produce sperm or eggs, also known as **gametes** . The resulting gametes are not genetically identical to the parent cell. Gametes are **haploid** cells, with only half the DNA present in the **diploid** parent cell. This is necessary so that when a sperm and an egg combine at **fertilization** , the resulting **zygote** has the correct amount of DNA—not twice as much as the parents. The zygote then begins to divide through mitosis.

Pictured below is a comparison between **binary fission** (**Figure** below), which is cell division of prokaryotic organisms, mitosis, and meiosis. Mitosis and meiosis are also compared in the table that follows (**Table** below).

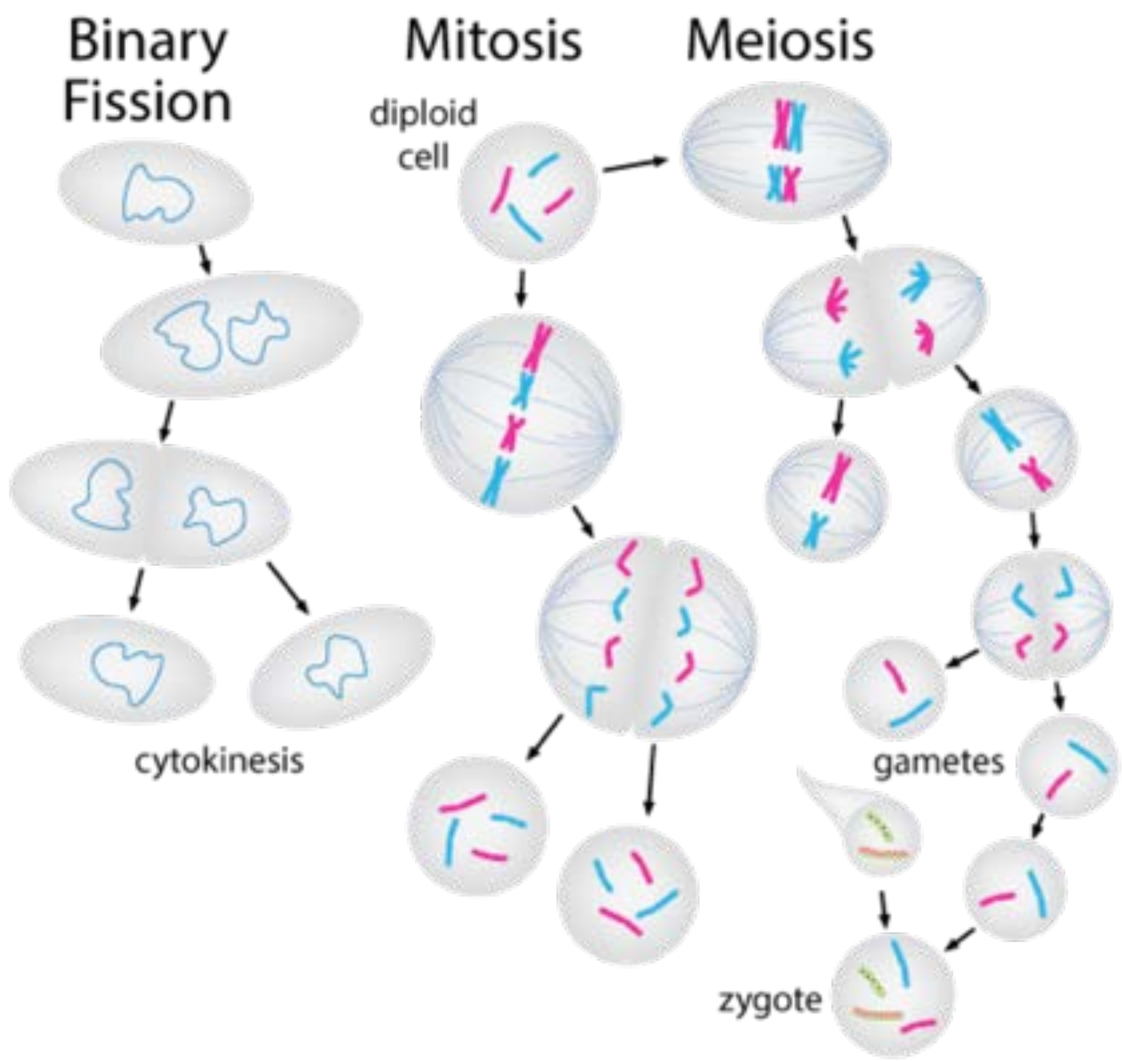


Figure 2.36

A comparison between binary fission, mitosis, and meiosis.

	Mitosis	**Meiosis**
Purpose	To produce new cells	To produce gametes
Number of Cells Produced	2	4
Rounds of Cell Division	1	2
Haploid or Diploid	Diploid	Haploid

Summary

- The goal of mitosis is to produce a new cell that is identical to the parent cell.
- The goal of meiosis is to produce gametes that have half the DNA of the parent cell.

Explore More

Use the resources below to answer the questions that follow.

Explore More I

- **Mitosis and Meiosis Simulation** at http://www.youtube.com/watch?v=zGVBAHAsjJM (11:53)

Click on the image above for more content

1. What are homologous chromosomes?
2. How do the location of specific genes compare between homologous chromosomes?
3. What is the outcome from mitosis?
4. What is a tetrad? Why are they an important feature of meiosis?
5. How does meiosis differ between females and males?

Explore More II

- **How Cells Divide** at http://www.pbs.org/wgbh/nova/body/how-cells-divide.html

1.How many daughter cells arise from mitosis? How many daughter cells are produced in meiosis?
2.How does the attachment of spindle fibers differ between mitosis and meiosis I?
3.Is anaphase I or anaphase II in meiosis more analogous to anaphase in mitosis? Explain your reasoning.
4.How many steps are there in mitosis? How many steps are there in meiosis?
5.How does interphase I of meiosis differ from interphase II of meiosis?

Review

1.What is the goal of mitosis? Of meiosis?
2.How many cells are created from cytokinesis following mitosis? Following meiosis?
3.Which process, mitosis to meiosis, creates genetically identical cells?
4."Gametes are haploid cells." What does this sentence mean?

Summary

The cell is the smallest unit of structure and function of all living organisms. But this smallest of units still performs some very complex processes. In fact, for some organisms, just one cell must do everything necessary for life.

Cell Biology focuses on significant aspects of the cell from its structure to its division. Some organisms contain just one cell, and others contain trillions. Some have a nucleus with DNA, others do not. Some have many organelles, others do not. But all cells are surrounded by a cell membrane. And it is this semipermeable membrane that determines what can enter and leave the cell. All cells need energy, and for many organisms, this energy comes from the processes of photosynthesis and cellular respiration. All cells come from preexisting cells through the process of cell division, which can produce a new prokaryotic organism. The cell cycle, which includes mitosis, defines the life of the eukaryotic cell.

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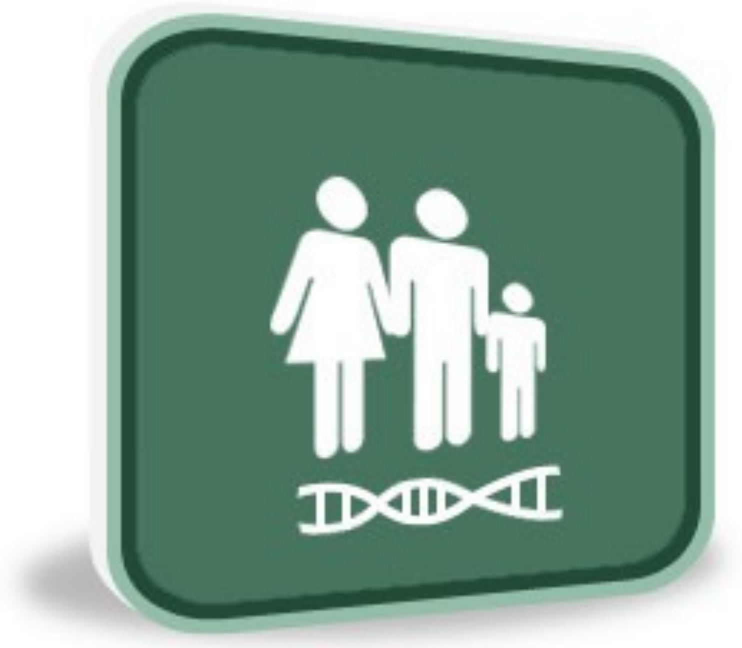
Molecular Biology and Genetics

Molecular Biology and Genetics

Introduction



Why is heredity so important?

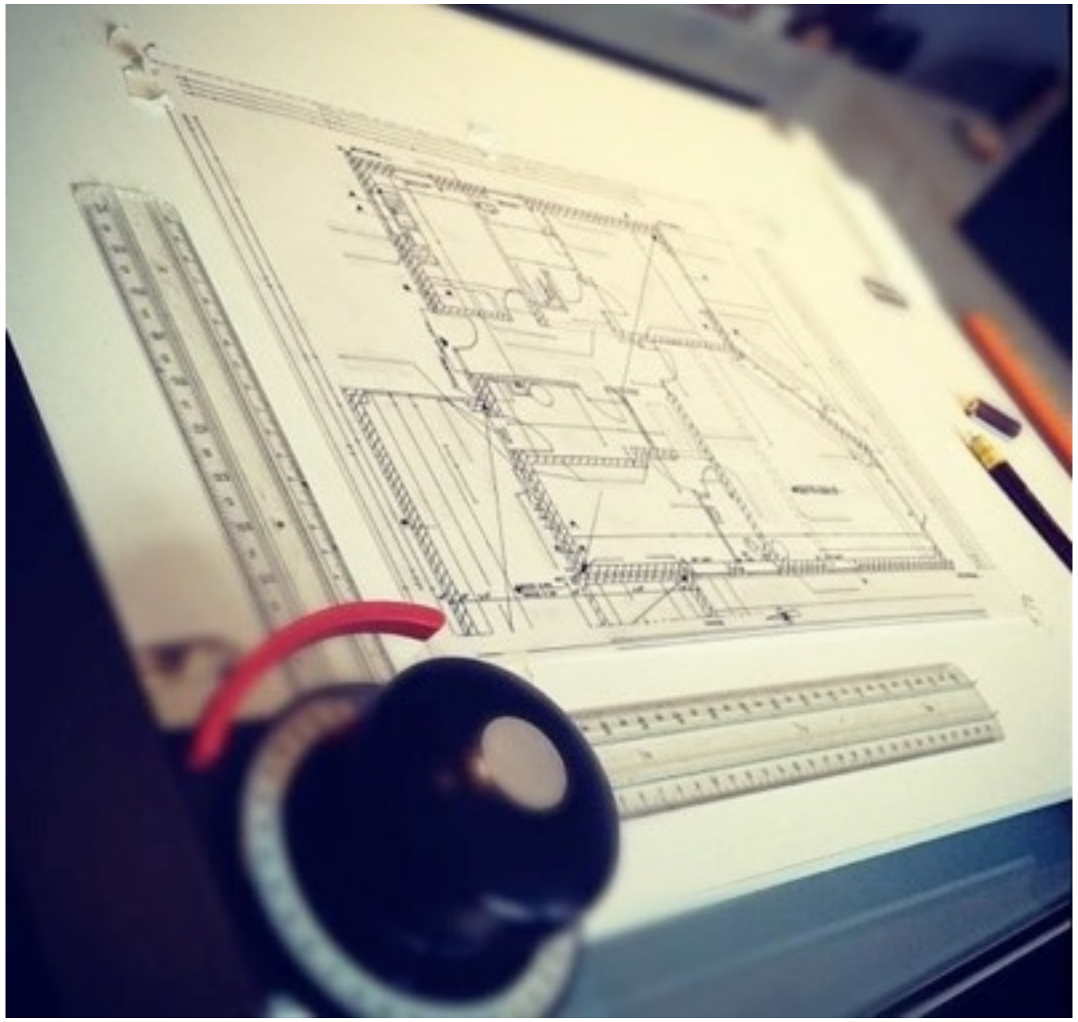
Genetics is the study of inheritance. Inheritance is the passing of traits from parents to offspring. How are these traits "passed"? Through DNA, which is the genetic material of all organisms. This concept will focus on genetics, inheritance, and DNA.

Section 1

DNA, the Genetic Material

DNA, the Genetic Material

- •Explain the importance of DNA.
- •Define and describe a nucleotide.
- •Describe the shape of DNA.
- •Summarize the base-pairing rules.



Where's the instructions?

How do your cells know what to do? Just like builders have blueprints to tell them how to build a house, your cells also have instructions. Your cells' instructions are molecules of DNA.

What is DNA?

DNA is the material that makes up our chromosomes and stores our genetic information. When you build a house, you need a blueprint, a set of instructions that tells you how to build. The DNA is like the blueprint for living organisms. The genetic information is a set of instructions that tell your cells what to do.

DNA is an abbreviation for **deoxyribonucleic acid** . As you may recall, **nucleic acids** are a type of macromolecule that store information. The *deoxyribo* part of the name refers to the name of the sugar that is contained in DNA, deoxyribose. DNA may provide the instructions to make up all living things, but it is actually a very simple molecule. DNA is made of a very long chain of nucleotides. In fact, in you, the smallest DNA molecule has well over 20 million nucleotides.

Nucleotides

Nucleotides are composed of three main parts:

1. a phosphate group.
2. a 5-carbon sugar (deoxyribose in DNA).
3. a nitrogen-containing base.

The only difference between each nucleotide is the identity of the base. There are only four possible bases that make up each DNA nucleotide: adenine (A), guanine (G), thymine (T), and cytosine (C).

The Genetic Code

The various sequences of the four nucleotide bases make up the genetic code of your cells. It may seem strange that there are only four letters in the “alphabet” of DNA. But since your **chromosomes** contain millions of nucleotides, there are many, many different combinations possible with those four letters.

But how do all these pieces fit together? James Watson and Francis Crick won the Nobel Prize in 1962 for piecing together the structure of DNA. Together with the work of Rosalind Franklin and Maurice Wilkins, they determined that DNA is made of two strands of nucleotides formed into a **double helix** , or a two-stranded spiral, with the sugar and phosphate groups on the outside, and the paired bases connecting the two strands on the inside of the helix (**Figure** below).

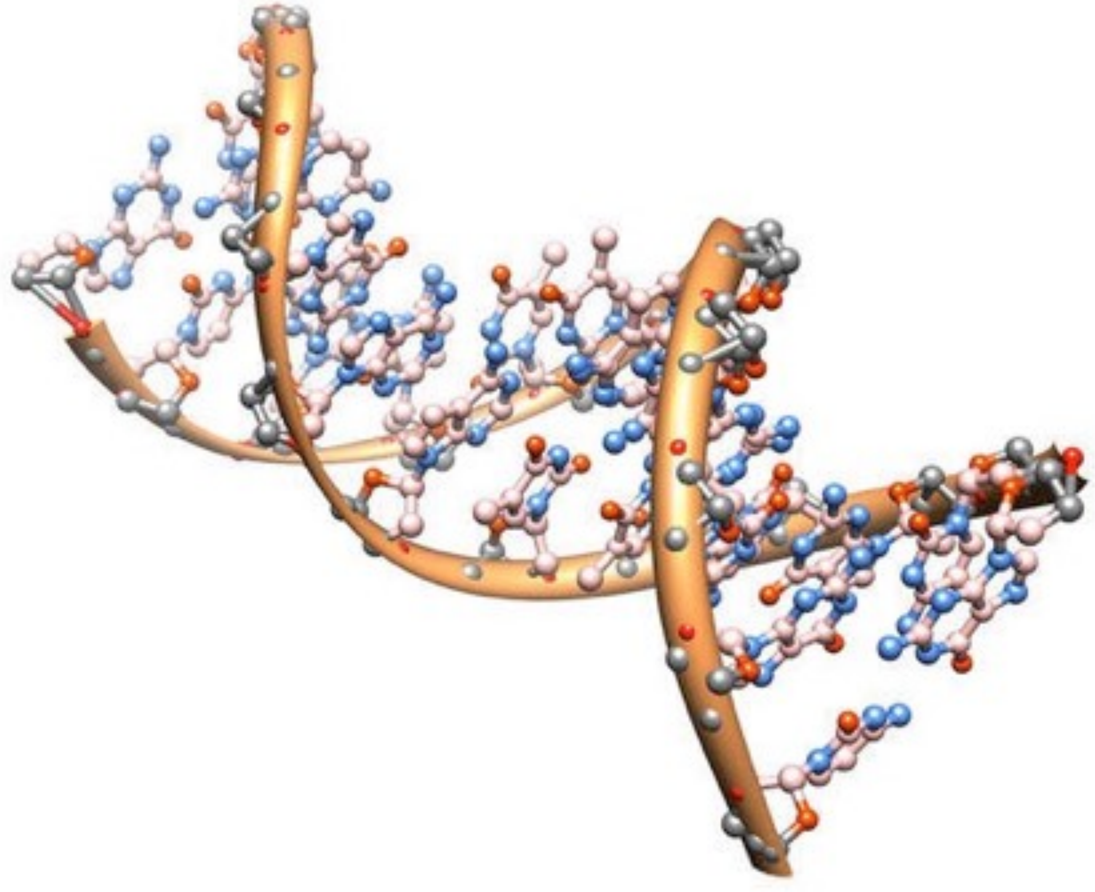


Figure 3.1

DNA’s three-dimensional structure is a double helix. The hydrogen bonds between the bases at the center of the helix hold the helix together.

Base-Pairing

The bases in DNA do not pair randomly. When Erwin Chargaff looked closely at the bases in DNA, he noticed that the percentage of adenine (A) in the DNA always equaled the percentage of thymine (T), and the percentage of guanine (G) always equaled the percentage of cytosine (C). Watson and Crick’s model explained this result by suggesting that A always pairs with T, and G always pairs with C in the DNA helix. Therefore A and T, and G and C, are "complementary bases," or bases that always pair together, known as a **base-pair** . The base-pairing rules state that A will always bind to T, and G will always bind to C (**Figure** below). For example, if one DNA strand reads ATGCCAGT, the other strand will be made up of the complementary bases: TACGGTCA.

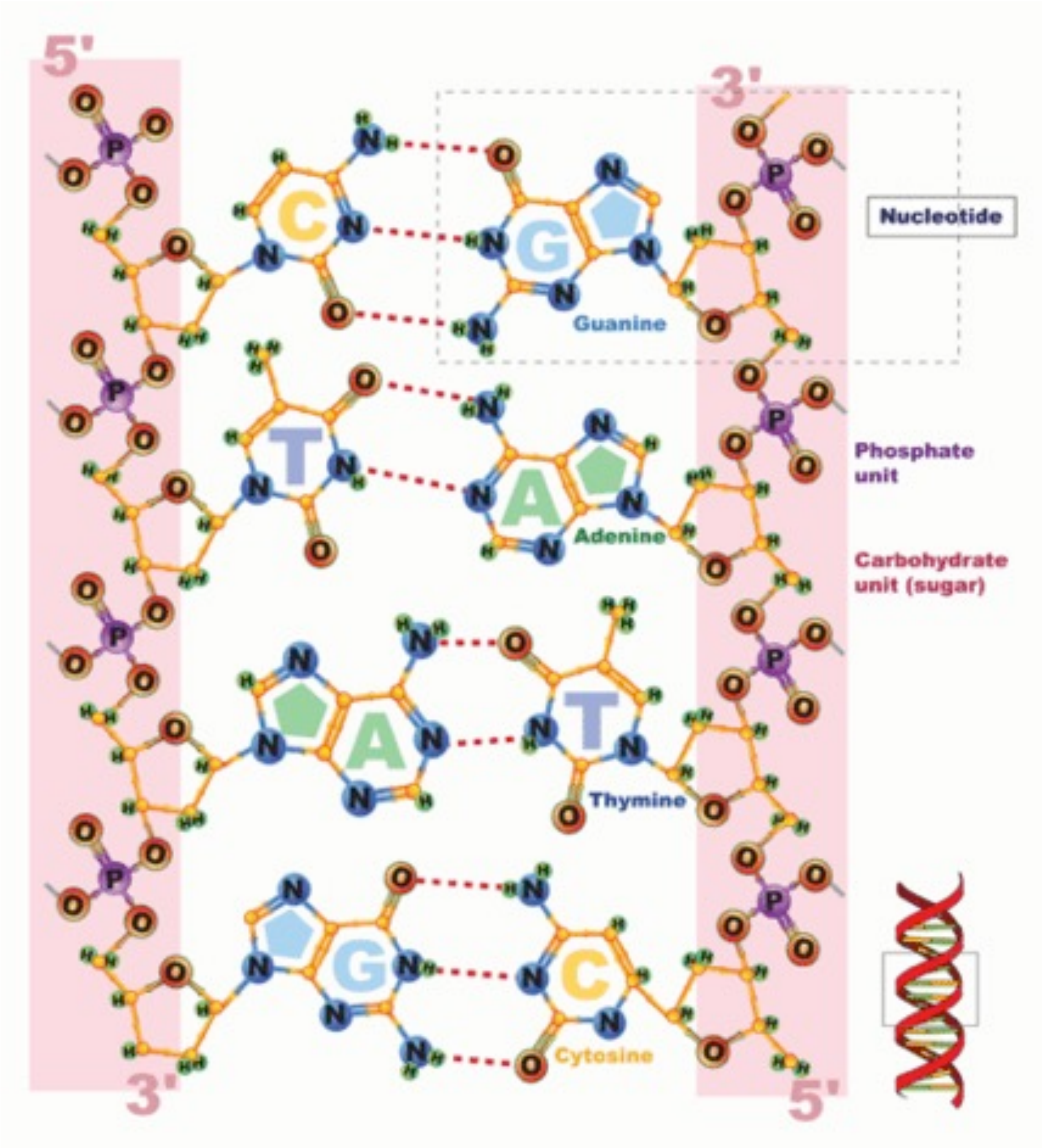


Figure 3.2

The chemical structure of DNA includes a chain of nucleotides consisting of a 5-carbon sugar, a phosphate group, and a nitrogen base. Notice how the sugar and phosphate form the backbone of DNA (strands highlighted in pink), with the hydrogen bonds between the bases joining the two strands.

Summary

- DNA stores the genetic information of the cell in the sequence of its 4 bases: adenine, thymine, guanine, and cytosine.
- DNA is made of a long chain of nucleotides consisting of a 5-carbon sugar, a phosphate group, and nitrogen-containing base.

Explore More

Use the resources below to answer the questions that follow.

Explore More I

- **What Is DNA?** at http://learn.genetics.utah.edu/content/begin/dna/ . Click on the box "What Is DNA?" on the left side of the page.

1. Where is nuclear DNA located in a eukaryotic organism?
2. Describe the structure of DNA.
3. What is another name for the "sentences" that DNA encodes?

4. What to genes tell a cell to do?

Explore More II

•Go to this link to build a DNA molecule: http://learn.genetics.utah.edu/content/begin/dna/builddna/ .

1. How long does it take a human cell to copy the DNA in its nucleus before it divides?
2. How many new cells does your body produce every day?
3. How many hydrogen bonds form between guanine and cytosine? How many hydrogen bonds form between adenine and thymine? Do you think this relationship helps minimize errors? Explain your reasoning.
4. What steps does the cell take to speed the rate of DNBA replication?

Review

1. Describe the structure of DNA.
2. What does a nucleotide consist of?
3. What are the base-pairing rules?
4. If one DNA strand reads CCGTAATGCAT, what will be the sequence of the complimentary strand?

Section 2

DNA Structure and Replica-

DNA Structure and Replication

- Explain why DNA must replicate itself.
- Describe the process of DNA replication.
- Explain the meaning of semiconservative replication.

Does DNA copy itself?

Yes, your DNA needs to copy itself every time a new cell is created. The new cell needs to have DNA exactly like the rest of your cells. Otherwise, that cell might malfunction. That's why it's important that the process of copying DNA, called DNA replication, is very accurate.

DNA Replication

DNA must replicate (copy) itself so that each resulting cell after mitosis and cell division has the same DNA as the parent cell. **DNA replication** occurs during the S phase of the cell cycle, before mitosis and cell division. The base pairing rules are crucial for the process of replication. DNA replication occurs when DNA is copied to form an identical molecule of DNA.

The general steps involved in DNA replication are as follows:

1. The DNA helix unwinds like a zipper as the bonds between the base pairs are broken. The enzyme DNA Helicase is involved in breaking these bonds.
2. The two single strands of DNA then each serve as a template for a new stand to be created. Using DNA as a template means that on the new strand, the bases are placed in the correct order because of the base pairing rules. As a template strand is read, the new strand is created. If ATGCCA is on the "template strand," then TACGGT will be on the new DNA strand. The enzyme DNA Polymerase reads the template and builds the new strand of DNA.
3. The new set of nucleotides then join together to form a new strand of DNA. The process results in two DNA molecules, each with one old strand and one new strand of DNA.

This process is known as **semiconservative replication** because one strand is conserved (kept the same) in each new DNA molecule (**Figure** below).

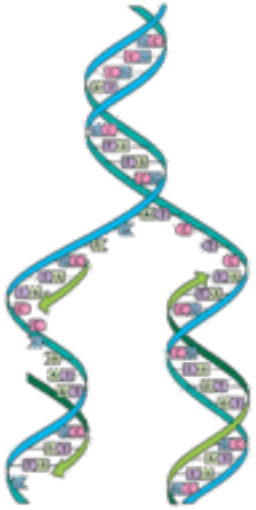


Figure 3.3

DNA replication occurs when the DNA strands "unzip," and the original strands of DNA serve as a template for new nucleotides to join and form a new strand.

Summary

- During DNA replication, the DNA helix unwinds and the two single strands of DNA then each serve as a template for a new stand to be created.
- DNA replication is semi-conservative: the new DNA molecule consists of half of the parent DNA molecule.

Explore More

Use the resource below to answer the questions that follow.

- **DNA replication** at http://www.youtube.com/watch?v=yqESR7E4b_8 (7:47)

Click on the image above for more content

1. What protein molecules does DNA wrap around to form a nucleosome?
2. What makes up chromatin?
3. When can you see chromosomes in a cell?
4. Are both strands of DNA copied continuously during replication? Explain your answer.

Review

1. Describe how DNA is replicated.

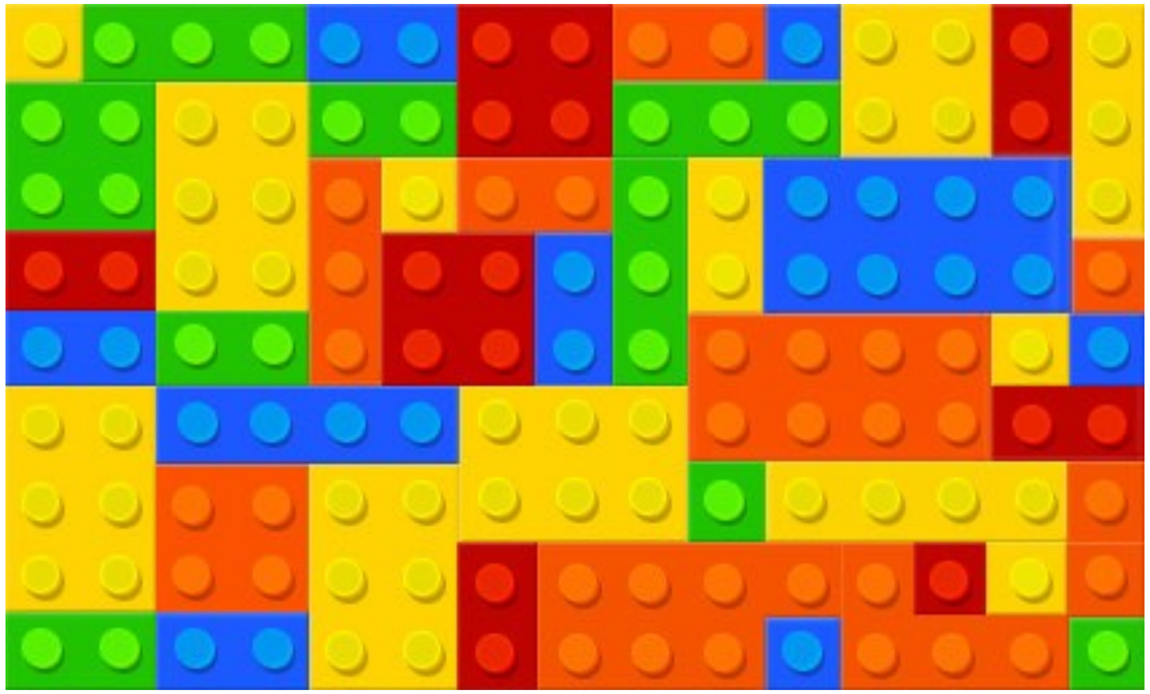
2.Explain why DNA replication is sometimes called semiconservative.

Section 3

Protein Synthesis and Gene

Protein Synthesis and Gene Expression

•Define gene.
•Describe the purpose of protein synthesis.
•Explain the meaning of gene expression.
•Summarize the relationship between DNA, amino acids, and proteins.



How do you build a protein?

Your body needs proteins to create muscles, regulate chemical reactions, transport oxygen, and perform other important tasks in your body. But how are these proteins built? They are made up of units called amino acids. Just like there are only a few types of blocks in a set, there are a limited number of amino acids. But there are many different ways in which they can be combined.

Introduction to Protein Synthesis

The DNA sequence contains the instructions to place units called **amino acids** into a specific order. When these amino acid are assembled in that specific order, proteins are made, a process called **protein synthesis.** In short, DNA contains the instructions to create proteins. Each strand of DNA has many separate sequences that code for a specific protein. Insulin is an example of a protein made by your cells (**Figure** below). Units of DNA that contain code for the creation of a protein are called **genes** .

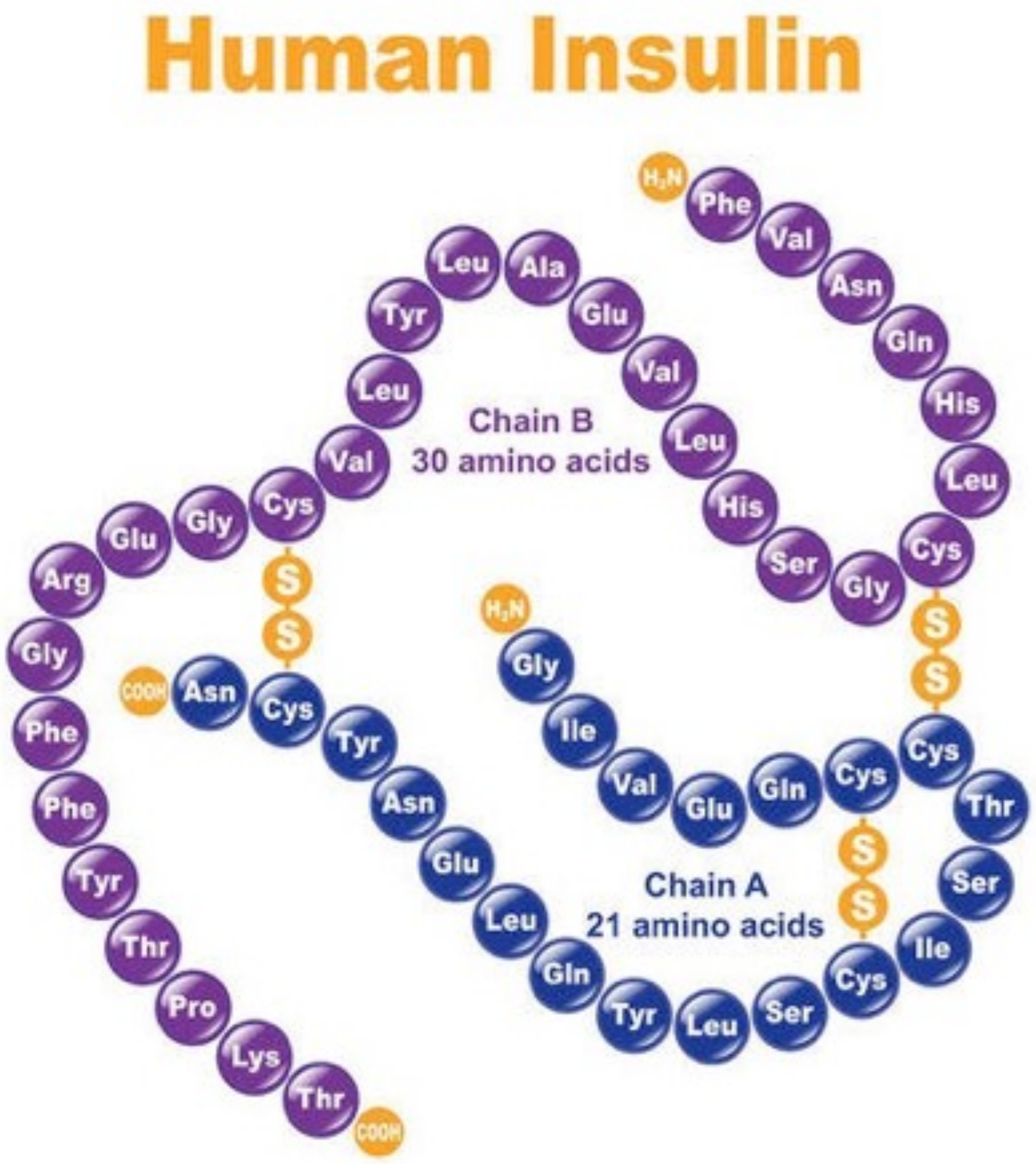


Figure 3.4

Insulin. Each blue or purple bead represents a different amino acid. Just 20 different amino acids are arranged in many different combinations to make thousands of proteins.

Cells Can Turn Genes On or Off

There are about 22,000 genes in every human cell. Does every human cell have the same genes? Yes. Does every human cell make the same proteins? No. In a multicellular organism, such as us, cells have specific functions because they have different proteins. They have different proteins because different genes are expressed in different cell types (which is known as **gene expression**).

Imagine that all of your genes are "turned off." Each cell type only "turns on" (or expresses) the genes that have the code for the proteins it needs to use. So different cell types "turn on" different genes, allowing different proteins to be made. This gives different cell types different functions.

Summary

- •DNA contains the instructions to assemble amino acids in a specific order to make protein.
- •Each cell type only "turns on" (or expresses) the genes that have the code for the proteins it needs to use.

Explore More

Use the resource below to answer the questions that follow.

•**Protein Synthesis** at http://www.biostudio.com/demo_freeman_protein_synthesis.htm

1. What is the cell structure used in the assembly of proteins?
2. What is the molecule that delivers the amino acids?
3. What ends protein synthesis?

Review

1. What is a gene?
2. What is an amino acid?
3. If every human cell has the same genes, how can they look and function so differently?
4. What is the relationship between DNA and proteins?

Section 4

RNA

RNA

- •Distinguish between DNA and RNA.
- •Name the three types of RNA.
- •Explain the functions of each type of RNA.

How does your DNA send a message?

DNA is the blueprint that provides the directions on how to build all the proteins your body needs to function. However, DNA is confined to the nucleus and, therefore, isn't involved directly in the process of actually making the proteins. So how does DNA tell the rest of the cell what to do? It sends a message! The messengers consist of a special type of RNA.

Three RNAs

DNA contains the instructions to create proteins, but it does not make proteins itself. DNA is located in the nucleus, which it never leaves, while proteins are made on ribosomes in the cytoplasm. So DNA needs a messenger to bring its instructions to a ribosome located outside of the nucleus. DNA sends out a message, in the form of **RNA** (ribonucleic acid), describing how to make the protein.

There are three types of RNA directly involved in protein synthesis:

- •Messenger RNA (**mRNA**) carries the instructions from the nucleus to the cytoplasm.
- •The other two forms of RNA, ribosomal RNA (**rRNA**) and transfer RNA (**tRNA**), are involved in the process of ordering the amino acids to make the protein. rRNA becomes part of the ribosome, which is the site of protein synthesis, and tRNA brings an amino acid to the ribosome so it can be added to a growing chain during protein synthesis. There are numerous tRNAs, as each tRNA is specific for an amino acid. The amino acid actually attaches to the tRNA during this process. More about RNAs will be discussed during the *Transcription* and *Translation* Concepts.

All three RNAs are nucleic acids, made of nucleotides, similar to DNA (**Figure** [below](#)). The RNA nucleotide is different from the DNA nucleotide in the following ways:

- •RNA contains a different kind of sugar, called ribose.
- •In RNA, the base uracil (U) replaces the thymine (T) found in DNA.
- •RNA is a single strand molecule.

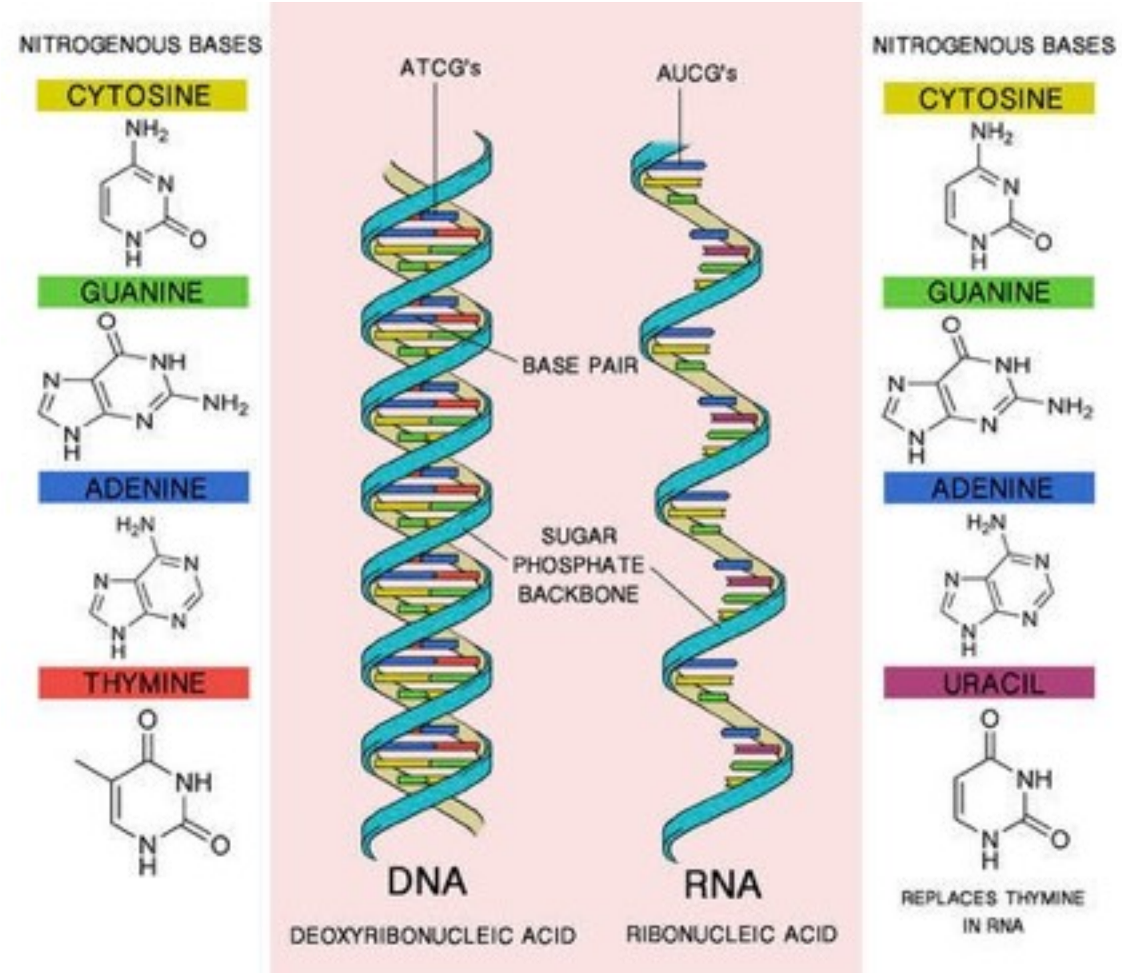


Figure 3.5

A comparison of DNA and RNA, with the bases of each shown. Notice that in RNA, uracil replaces thymine.

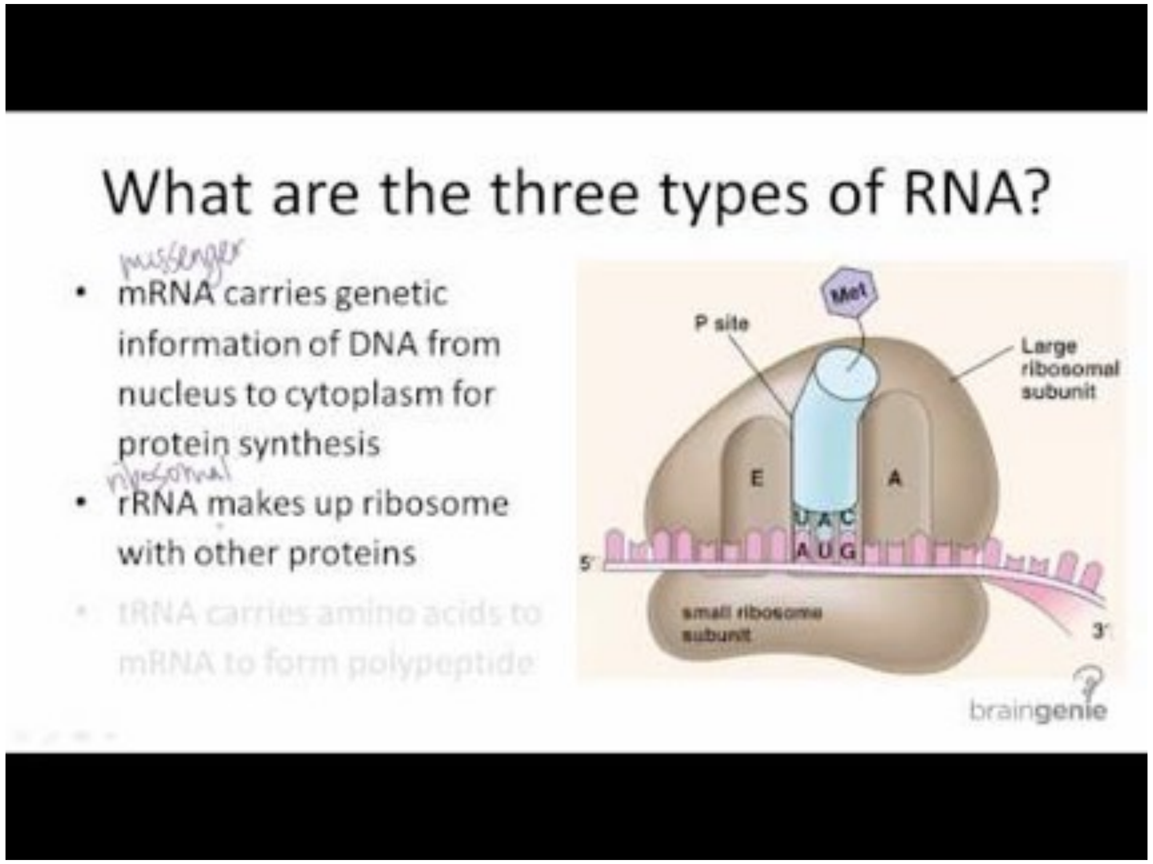
Summary

- •Messenger RNA (mRNA) carries the instructions from the nucleus to the cytoplasm.
- •The other two forms of RNA, ribosomal RNA (rRNA) and transfer RNA (tRNA), are involved in the process of ordering the amino acids to make proteins.
- •RNA is a nucleic acid, like DNA, but differs slightly in its structure.

Explore More

Use the resource below to answer the questions that follow.

- •**Three types of RNA** at http://www.youtube.com/watch?v=Kf5NeG97-38 (1:13)



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1. What does mRNA do? Where does it do this?
2. What does tRNA do? Where does it do this?
3. What does rRNA do? Where does it do this?
4. Describe the structure of the ribosome.

Review

1. What is the role of the mRNA in the cell?
2. Compare and contrast the composition of DNA and RNA.
3. What are the roles of tRNA and rRNA?

Section 5

Transcription of DNA to RNA

Transcription of DNA to RNA

- Define transcription.
- Explain the relationship between a codon and the mRNA.
- Describe how mRNA is created from DNA.

How does DNA write its message?

The process of DNA sending a message to the cytoplasm is called transcription. Transcription means "a written copy." However, DNA can't get out a pen and write a message. It creates an mRNA molecule to carry the message.

Transcription

DNA is located in the nucleus. Proteins are made on ribosomes in the cytoplasm. Remember that information in a **gene** is converted into **mRNA** , which carries the information to the ribosome. In the nucleus, mRNA is created by using the DNA in a gene as a template. A **template** is a model provided for others to copy.

The process of constructing an mRNA molecule from DNA is known as **transcription** (**Figure** below and **Figure** below). The double helix of DNA unwinds and an enzyme, RNA Polymerase, builds the mRNA using the DNA as a template. The nucleotides follow basically the same base pairing rules as in DNA to form the correct sequence in the mRNA. This time, however, uracil (U) pairs with each adenine (A) in the DNA. For example, a DNA sequence ACGGGTAAGG will be transcribed into the mRNA sequence UGCCCAUUCC. In this manner, the information of the DNA is passed on to the mRNA. The mRNA will carry this code to the ribosomes to tell them how to make a protein.

As not all genes are used in every cell, a gene must be "turned on" or expressed when the gene product is needed by the cell. Only the information in a gene that is being expressed is transcribed into an mRNA.

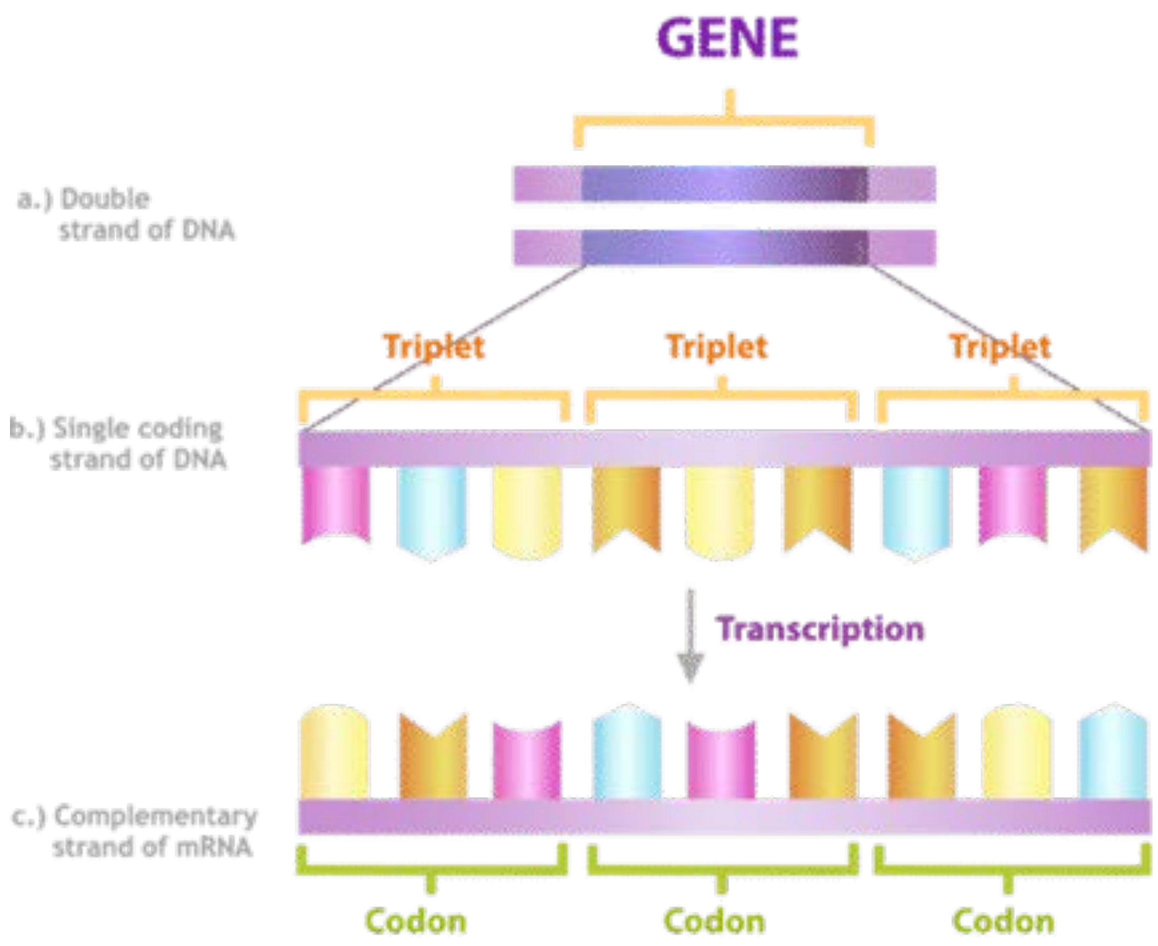


Figure 3.6

Each gene (a) contains triplets of bases (b) that are transcribed into RNA (c). Every triplet, or **codon** , encodes for a unique amino acid.

Figure 3.7

Base-pairing ensures the accuracy of transcription. Notice how the helix must unwind for transcription to take place. The new mRNA is shown in green.

Summary

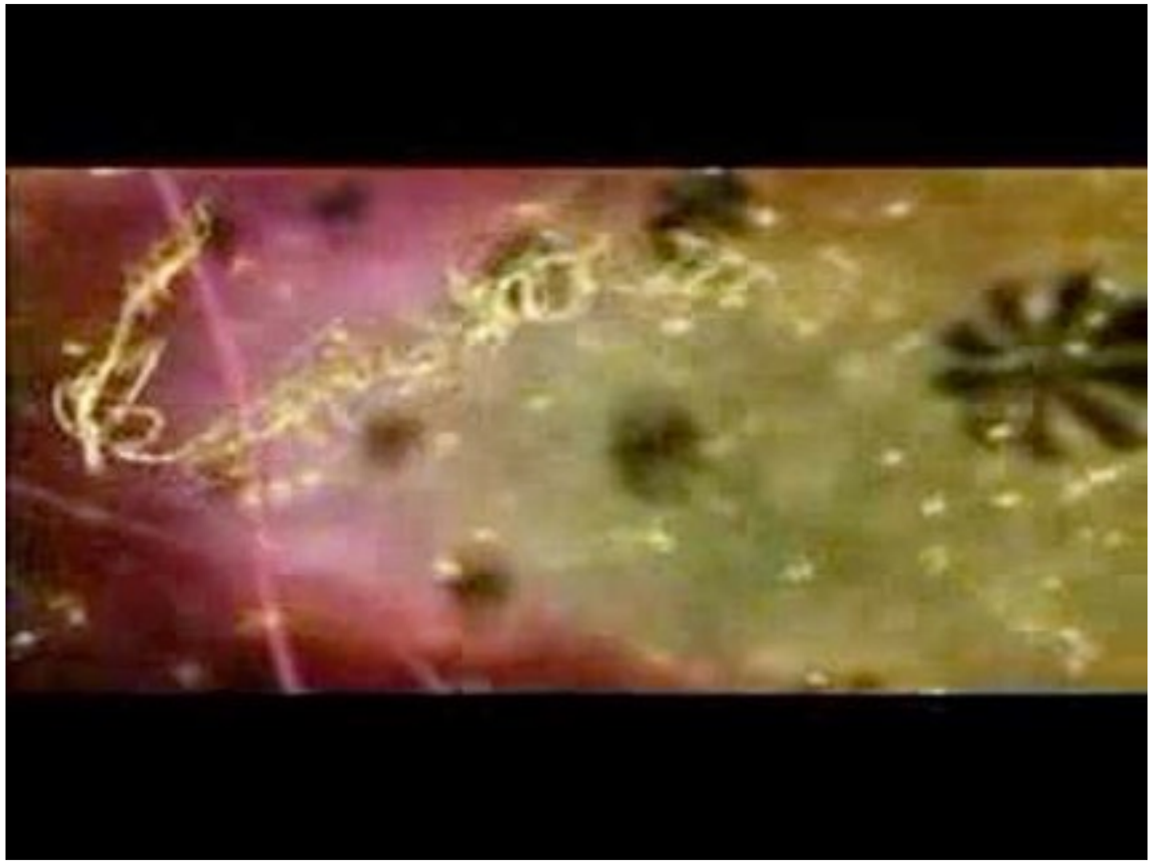
- •The process of constructing an mRNA molecule from DNA is known as transcription.
- •The base pairing rules ensure that the DNA code is conserved in the sequence in the mRNA.

Explore More

Use the resources below to answer the questions that follow.

Explore More I

- **Transcription and Translation** at http://www.youtube.com/watch?v=41_Ne5mS2ls (4:06)



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1. How is RNA different from DNA? Do you think this difference is important? Why?
2. Where is the mRNA made?
3. Where does the mRNA go after it is produced?

Explore More II

- **Cell Transcription** at http://www.pbslearningmedia.org/asset/lsps07_int_celltrans/

1. How many regions of a gene are there? What are they called? What is the function of each region?
2. Imagine one of these three regions was deleted by a mutation. What would happen during transcription? Explain your answer for each separate region.
3. What is the function of RNA polymerase? What kind of molecule is RNA polymerase?

Review

1. What is the final product of transcription?
2. How does the genetic code in the DNA get passed on to the mRNA?
3. What will be the mRNA sequence transcribed from a TTAAACGGCCTA template?

Section 6

Translation of RNA to Pro-

Translation of RNA to Protein

- •Define translation.
- •Explain the relationship between the tRNA, anticodon, codon, and mRNA.
- •Describe the process of translation.
- •Explain the role of the genetic code.

How does the cell translate a message?

The mRNA is the message sent from the nucleus to the ribosome. Like a foreign language, the genetic code of the mRNA message must then be translated so that the ribosomes make the correct protein. The process of reading the code of a mRNA to make a protein is called translation.

Translation

The mRNA, which is transcribed from the DNA in the nucleus, carries the directions for the protein-making process. mRNA tells the **ribosome** (**Figure** below) how to create a specific protein.

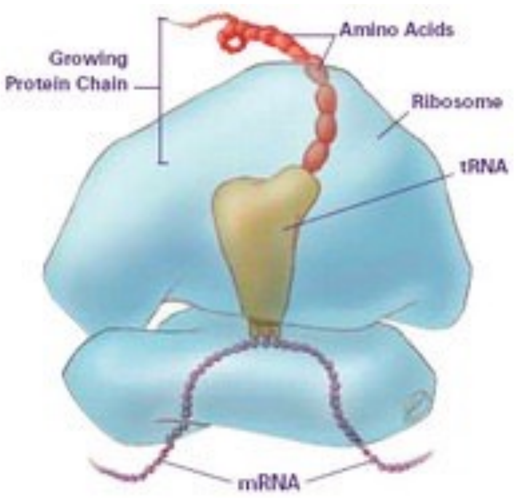


Figure 3.8

Ribosomes translate RNA into a protein with a specific amino acid sequence. The tRNA binds and brings to the ribosome the amino acid encoded by the mRNA.

The process of reading the mRNA code in the ribosome to make a protein is called **translation** (**Figure** below): the mRNA is translated from the language of nucleic acids (nucleotides) to the language of proteins (amino acids). Sets of three bases, called **codons** , are read in the ribosome, the organelle responsible for making proteins.

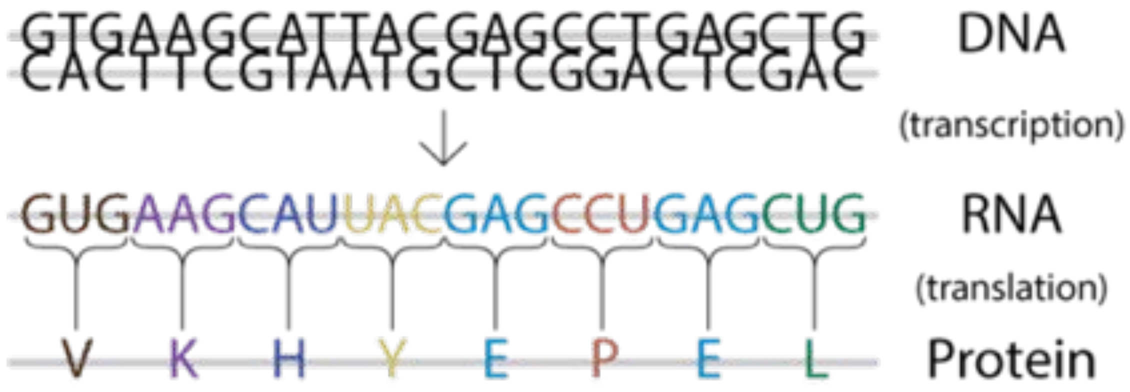


Figure 3.9

This summary of how genes are expressed shows that DNA is transcribed into RNA, which is translated, in turn, to protein. The one letter code represents amino acids.

The following are the steps involved in translation:

•mRNA travels to the ribosome from the nucleus.

The following steps occur in the ribosome:

•The base code in the mRNA determines the order of the amino acids in the protein. The genetic code in mRNA is read in “words” of three letters (triplets), called codons. There are 20 amino acids used to make proteins, and different codons code for different amino acids. For example, GGU codes for the amino acid glycine, while GUC codes for valine.
•tRNA reads the mRNA code and brings a specific amino acid to attach to the growing chain of amino acids. The **anticodon** on the tRNA binds to the codon on the mRNA. Each tRNA carries only one type of amino acid and only recognizes one specific codon.
•tRNA is released from the amino acid.

- Three codons, UGA, UAA, and UAG, indicate that the protein should stop adding amino acids. They are called **stop codons** and do not code for an amino acid. Once tRNA comes to a stop codon, the protein is set free from the ribosome.

The following chart (**Figure** below) is used to determine which amino acids correspond to which codons.

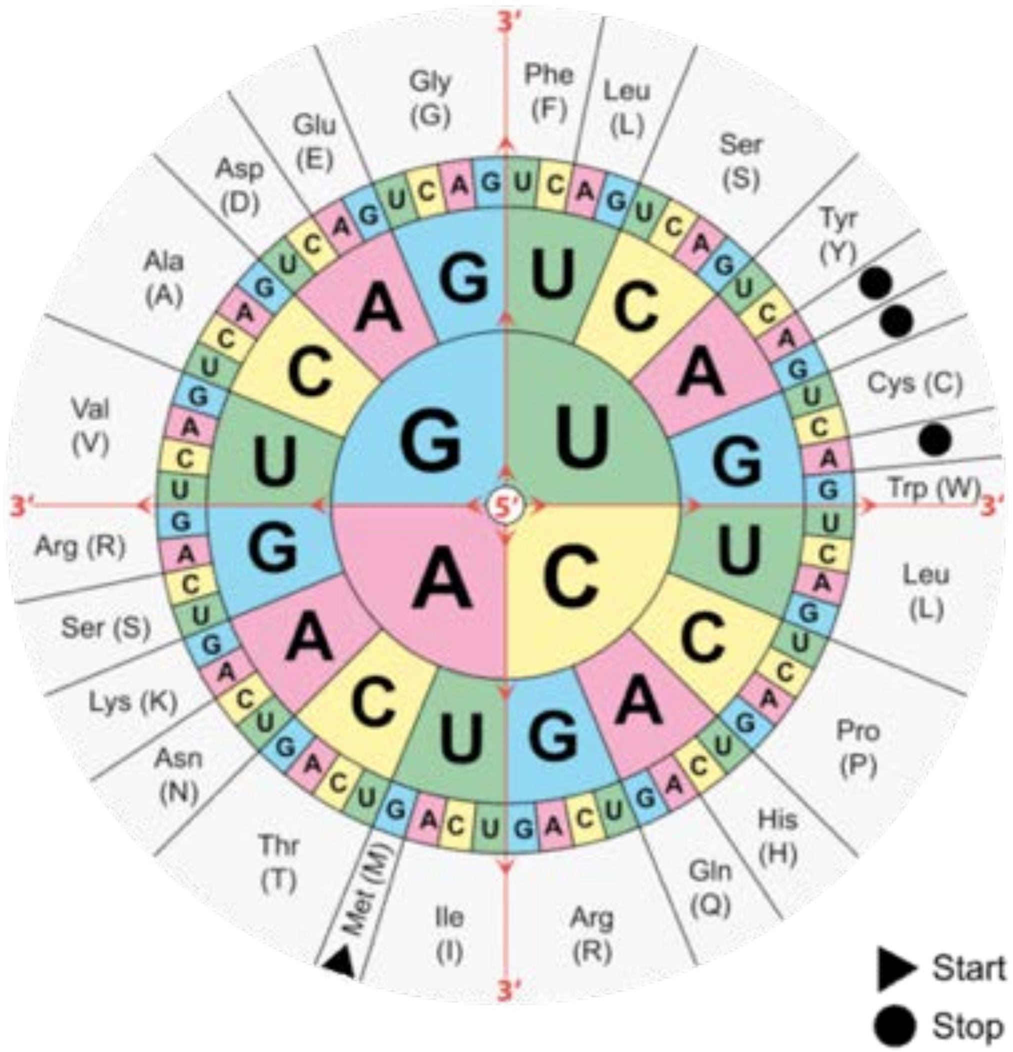


Figure 3.10

This chart shows the genetic code used by all organisms. For example, an RNA codon reading GUU would encode for a valine (Val) according to this chart. Start at the center for the first base of the three base codon, and work your way out. Notice that more than one codon may encode for a single amino acid. For example, glycine (Gly) is encoded by a GGG, GGA, GGC, and GGU.

Summary

- Translation is the process of reading the mRNA code in the ribosome to make a protein.
- Sets of three bases on the mRNA, called codons, are read in order to select the correct amino acid for building a protein.

Explore More

Use the resources below to answer the following questions.

Explore More I

- **Cell Translation** at http://www.pbslearningmedia.org/asset/lsps07_int_celltrans/

1. What reads the sequence of the mRNA? What are three nucleotides that code for an amino acid called?
2. What brings amino acids to the translation site?
3. What is an anticodon? Where are they found? What is their function?
4. About how many amino acids are present in your average protein?

5. How many ribosomes read a single mRNA molecule at the same time? How is this beneficial to the organism?

Explore More II

- **Transcribe and Translate a Gene** at http://learn.genetics.utah.edu/content/begin/dna/transcribe/

Go to this site to make a protein. Practice and see how fast you can transcribe DNA and translate mRNA.

1. What is the start code for translating an mRNA molecule?
2. How many stop codes are there from translating mRNA? What are they?
3. How many different amino acids are used to make proteins?

Review

1. What is translation?
2. What is a codon?
3. What is a stop codon?
4. What would happen if the stop codon was mutated to encode for another amino acid?
5. Given the DNA sequence, ATGTTAGCCGTATGC, what is the mRNA sequence? What is the amino acid sequence?

Section 7

Mutations

Mutations

•Define mutation.
•Distinguish between point mutations and chromosomal mutations.
•Explain the outcome from a frameshift mutation.
•Describe the types of chromosomal mutations.
•Explain how mutations occur.

Would a mutation make you a superhero?

In the comic books, a mutation can give a person superpowers. Do you think this really happens? In real life, a mutation can be beneficial, or it can harm an organism. For example, beneficial mutations lead to evolution, and harmful mutations can lead to diseases like cancer. A mutation, however, is not going to turn you into a superhero!

Mutations

The process of DNA replication is not always 100% accurate. Sometimes the wrong base is inserted in the new strand of DNA. This wrong base could become permanent. A permanent change in the sequence of DNA is known as a **mutation** . Small changes in the DNA sequence are usually **point mutations** , which is a change in a single nucleotide.

A mutation may have no effect. However, sometimes a mutation can cause a protein to be made incorrectly. A defect in the protein can affect how well the protein works, or whether it works at all. Usually the loss of a protein function is detrimental to the organism.

In rare circumstances, though, the mutation can be beneficial. For example, suppose a mutation in an animal's DNA causes the loss of an enzyme that makes a dark pigment in the animal's skin. If the population of animals has moved to a light colored environment, the animals with the mutant gene would have a lighter skin color and be better camouflaged. So in this case, the mutation is beneficial.

Point Mutations

If a single base is deleted (called a point mutation), there can be huge effects on the organism because this may cause a **frameshift mutation** . Remember that the bases in the mRNA are read in groups of three by the tRNA. If the reading frame is off by even one base, the resulting sequence will consist of an entirely different set of codons. The reading of an mRNA is like reading three-letter words of a sentence. Imagine the sentence: "The big dog ate the red cat." If you take out the second letter from "big," the frame will be shifted so now it will read: "The bgd oga tet her edc at." One single deletion makes the whole "sentence" impossible to read.

Chromosomal Mutations

Mutations may also occur in chromosomes (**Figure** below). These mutations are going to be fairly large mutations, possible affecting many genes. Possible types of mutations in chromosomes include:

1. Deletion: When a segment of DNA is lost, so there is a missing segment in the chromosome. These usually result in many genes missing from the chromosome.
2. Duplication: When a segment of DNA is repeated, creating a longer chromosome. These usually result in multiple copies of genes in the chromosome.
3. Inversion: When a segment of DNA is flipped and then reattached to the same chromosome.
4. Insertion: When a segment of DNA from one chromosome is added to another, unrelated chromosome.
5. Translocation: When two segments from different chromosomes change positions.

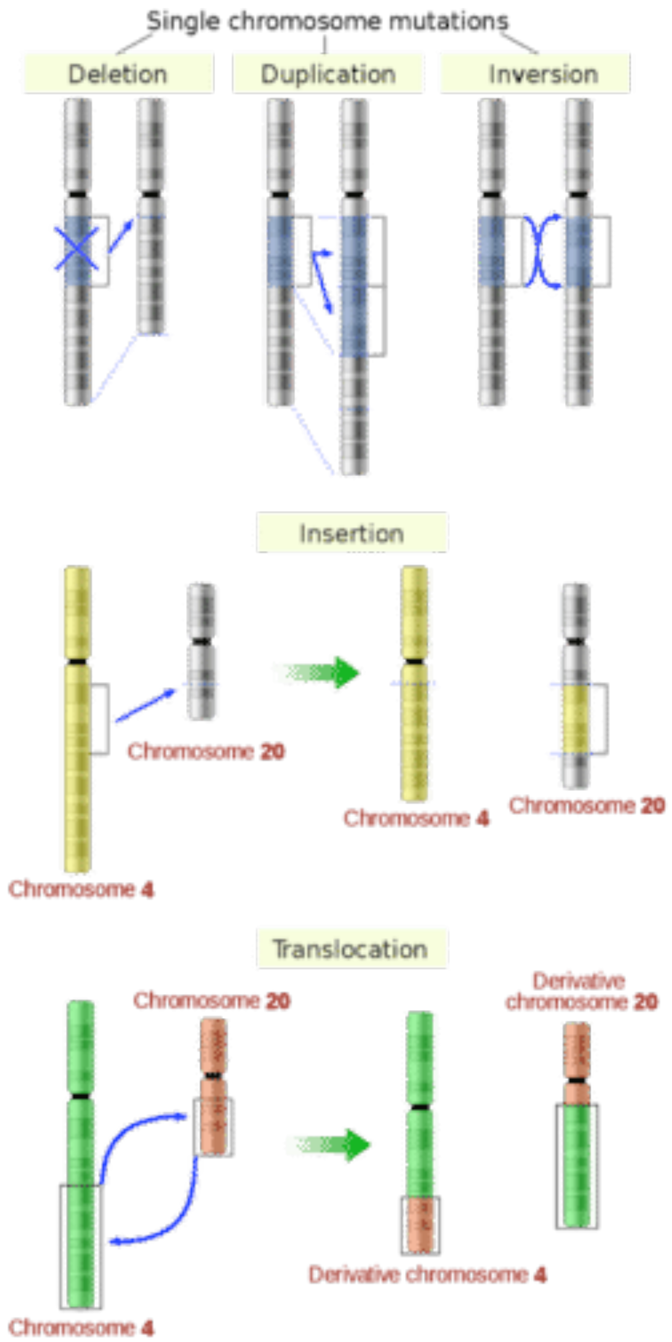


Figure 3.11

Mutations can arise in DNA through deletion, duplication, inversion, insertion, and translocation within the chromosome.

Causes of Mutations

Many mutations are not caused by errors in replication. Mutations can happen spontaneously, and they can be caused by **mutagens** in the environment. Some chemicals, such as those found in tobacco smoke, can be mutagens. Sometimes mutagens can also cause cancer. Tobacco smoke, for example, is often linked to lung cancer.

Summary

- •A mutation is a permanent change in the sequence of bases in DNA.
- •Mutations occur in the DNA through deletion, duplication, inversion, insertion, and translocation within the chromosome.
- •Mutations can occur due to errors during replication or mutagens in the environment.

Explore More

Use the resources below to answer the questions that follow.

Explore More I

•**Types of Mutations** at Understanding Evolution
http://evolution.berkeley.edu/evolibrary/article/mutations_03

1. What is an example of a genetic disorder caused by a substitution mutation?
2. How can a substitution mutation change a protein?
3. Explain a frameshift mutation.

4. What can cause a frameshift mutation?

Explore More II

- **Gene Regulation** at http://www.teachersdomain.org/asset/novat10_int_evodevo/

Go to this link to see how mutations affect gene regulation. Make sure you make more than one animal and see the effects of more than one mutation occurring at a time.

1. How do mutations in a part of DNA not associated with a gene generally affect the expression of that gene?
2. What do transcription factor proteins do in an organism?

Review

1. Are mutations typically beneficial to the organism?
2. What can cause DNA to mutate?
3. What is a frameshift mutation?
4. Describe two types of chromosomal mutations.

Section 8

Mendel's Pea Plants

Mendel's Pea Plants

- •Summarize the importance of Gregor Mendel to genetics.
- •Distinguish between self-pollination and cross-pollination.
- •Describe Mendel's first genetics experiments.

Why do you look like your family?

For a long time people understood that traits are passed down through families. The rules of how this worked were unclear, however. The work of Gregor Mendel was crucial in explaining how traits are passed down to each generation.

Mendel's Experiments

What does the word "inherit" mean? You may have inherited something of value from a grandparent or another family member. To **inherit** is to receive something from someone who came before you. You can inherit objects, but you can also inherit traits. For example, you can inherit a parent's eye color, hair color, or even the shape of your nose and ears!

Genetics is the study of inheritance. The field of genetics seeks to explain how traits are passed on from one generation to the next.

In the late 1850s, an Austrian monk named Gregor Mendel (**Figure** below) performed the first genetics experiments.

Figure 3.12

Gregor Mendel, the "father" of genetics.

To study genetics, Mendel chose to work with pea plants because they have easily identifiable traits (**Figure** below). For example, pea plants are either tall or short, which is an easy trait to observe. Furthermore, pea plants grow quickly, so he could complete many experiments in a short period of time.

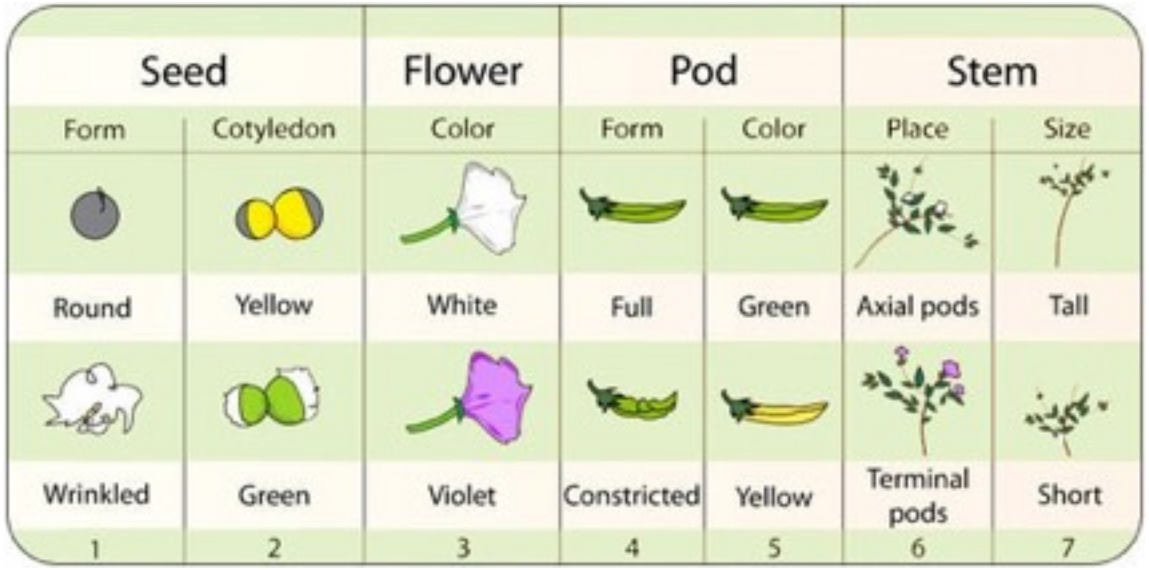


Figure 3.13

Characteristics of pea plants.

Mendel also used pea plants because they can either **self-pollinate** or be **cross-pollinated** . Self-pollination means that only one flower is involved; the flower's own pollen lands on the female sex organs. Cross pollination is done by hand by moving pollen from one flower to the stigma of another. As a result, one plant's sex cells combine with another plant's sex cells. This is called a "cross." These crosses produce **offspring** (or "children"), just like when male and female animals mate. Since Mendel could move pollen between plants, he could carefully control and then observe the results of crosses between two different types of plants.

He studied the inheritance patterns for many different traits in peas, including round seeds versus wrinkled seeds, white flowers versus purple flowers, and tall plants versus short plants. Because of his work, Mendel is considered the "Father of Genetics."

Mendel's First Experiment

In one of Mendel's early experiments, he crossed a short plant and a tall plant. What do you predict the offspring of these plants were? Medium-sized plants? Most people during Mendel's time would have said medium-sized. But an unexpected result occurred. Mendel observed that the offspring of this cross (called the **F1 generation**) were all tall plants!

Next, Mendel let the F1 generation self-pollinate. That means the tall plant offspring were crossed with each other. He found that 75% of their offspring (the **F2 generation**) were tall, while 25% were short. Shortness skipped a generation. But why? In all, Mendel studied seven characteristics, with almost 20,000 F2 plants analyzed. All of his results were similar to the first experiment—about three out of every four plants had one trait, while just one out of every four plants had the other.

For example, he crossed purple flowered-plants and white flowered-plants. Do you think the colors blended? No, they did not. Just like the previous experiment, all offspring in this cross (the F1 generation) were one color: purple. In the F2 generation, 75% of plants had purple flowers and 25% had white flowers (**Figure** below). There was no blending of traits in any of Mendel's experiments.

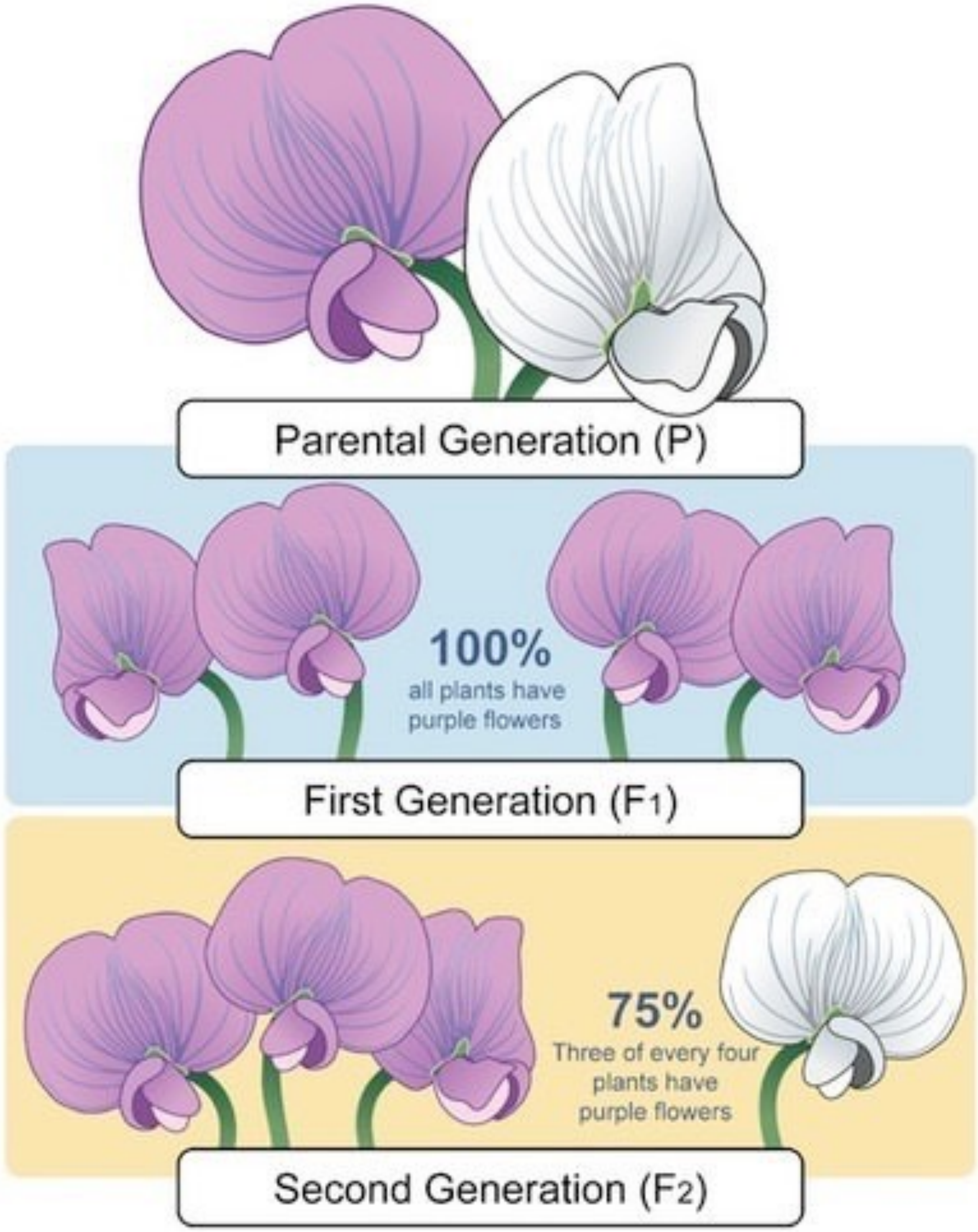


Figure 3.14

The results of Mendel's experiment with purple flowered and white flowered-plants numerically matched the results of his experiments with other pea plant traits.

Summary

- Gregor Mendel was the father of the field of genetics, which seeks to explain how traits are passed on from one generation to the next.
- To study genetics, Mendel chose to work with pea plants because they have easily identifiable traits.

Explore More

Use the resource below to answer the questions that follow.

- **Pea experiment** at http://www.sonic.net/~nbs/projects/anthro201/exper/

1. What is a "simple" trait?
2. What is a heterozygote? How is this different than a homozygote?
3. You breed a plant with yellow wrinkled peas with a plant with yellow smooth peas. Both individuals are homozygous for both traits. What will the peas of the next generation look like?
4. You breed plants with the same traits as in question 3, but this time the smooth trait is heterozygous in the second individual. What will the peas of the next generation look like?
5. You breed two green wrinkled plants. Will will the next generation look like?

Review

1.What is genetics?
2.Why did Mendel choose to study pea plants?
3.How did Mendel's experiments disprove the idea that we are simply a "blend" of our parents' traits?
4.What were the results Mendel consistently identified in his experiments?

Section 9

Mendel's Laws and Genet-

Mendel's Laws and Genetics

- •Distinguish between dominant and recessive traits.
- •Explain the law of segregation.

What does it mean to be dominant?

The most powerful or influential individual in a group is sometimes called dominant. In genetics, a dominant trait means nearly the same thing. A dominant trait is the most influential trait and masks the other trait.

Dominance

Do you remember what happened when Mendel crossed purple flowered-plants and white flowered-plants? All the offspring had purple flowers. There was no blending of traits in any of Mendel's experiments. Mendel had to come up with a theory of inheritance to explain his results. He developed a theory called the **law of segregation** .

The Law of Segregation

Mendel proposed that each pea plant had two hereditary factors for each trait. There were two possibilities for each hereditary factor, such as a purple factor or white factor. One factor is **dominant** to the other. The other trait that is masked is called the **recessive** factor, meaning that when both factors are present, only the effects of the dominant factor are noticeable (**Figure** below). Although you have two hereditary factors for each trait, each parent can only pass on one of these factors to the offspring. When the sex cells, or **gametes** (sperm or egg), form, the heredity factors must separate, so there is only one factor per gamete. In other words, the factors are "segregated" in each gamete. Mendel's law of segregation states that the two hereditary factors separate when gametes are formed. When fertilization occurs, the offspring receive one hereditary factor from each gamete, so the resulting offspring have two factors.

Figure 3.15

In peas, purple flowers are dominant to white. If one of these purple flowers is crossed with a white flower, all the offspring will have purple flowers.

Example Cross

This law explains what Mendel had seen in the F1 generation when a tall plant was crossed with a short plant. The two heredity factors in this case were the short and tall factors. Each individual in the F1 would have one of each factor, and as the tall factor is dominant to the short factor (the recessive factor), all the plants appeared tall.

In describing genetic crosses, letters are used. The dominant factor is represented with a capital letter (*T* for tall) while the recessive factor is represented by a lowercase letter (*t*). For the *T* and *t* factors, three combinations are possible: *TT* , *Tt* , and *tt* . *TT* plants will be tall, while plants with *tt* will be short. Since *T* is dominant to *t* , plants that are *Tt* will be tall because the dominant factor masks the recessive factor.

In this example, we are crossing a *TT* tall plant with a *tt* short plant. As each parent gives one factor to the F1 generation, all of the F1 generation will be *Tt* tall plants.

When the F1 generation (*Tt*) is allowed to self-pollinate, each parent will give one factor (*T* or *t*) to the F2 generation. So the F2 offspring will have four possible combinations of factors: *TT* , *Tt* , *tT* , or *tt* . According to the laws of probability, 25% of the offspring would be *tt* , so they would appear short. And 75% would have at least one *T* factor and would be tall.

Summary

- One hereditary factor is dominant to the other. The dominant trait masks the recessive factor, so that when both factors are present, only the effects of the dominant factor are noticeable.
- According to Mendel's law of segregation, there are two hereditary factors for each trait that must segregate during gamete (egg and sperm) production. As a result, offspring receive one factor from each parent, resulting in two factors for each trait in the offspring.

Explore More

Use the resource below to answer the questions that follow.

•**Mendel's Experiment** at http://www.sumanasinc.com/webcontent/animations/content/mendel/mendel.html

1. In Mendel's experiments, did it matter if the dominant trait came from the seed plant or the pollen plant?
2. Yellow is a dominant trait in peas. You breed two plants with yellow peas, and some of the offspring's peas are green? How can this be? Explain your answer fully.
3. For some of his experiments Mendel saw a 9:3:3:1 ratio, consisting of 9 yellow/smooth, 3 yellow/wrinkled, 3 green/smooth, and 1 green/wrinkled. What did he conclude from this ratio? Explain where these ratios came from.

Review

1. What is the difference between a dominant trait and a recessive trait?
2. Explain the law of segregation.
3. When Mendel crossed a *TT* tall plant with a *tt* short plant, what did he observe in the F1 generation? Why?
4. If *PP* purple plants are crossed with *pp* white plants, what will be the possible combinations of factors if the F1 generation is allowed to self-pollinate?

Section 10

Punnett Squares

Punnett Squares

- •Explain the relationship between probability and genetics.
- •Use a Punnett square to make predictions about the traits of the offspring of a genetic cross.

What's the chance of the coin landing on heads?

There is always a 50-50 chance that a coin will land on heads. Half the time it will land on heads and half the time it will land on tails. What is the chance of it landing heads twice in a row? Or three times? These rules of probability also apply to genetics. If a parent has one dominant and one recessive factor for a trait, then, on average, half the time the dominant factor will be passed on, and half the time the recessive factor will be passed on.

Probability and Punnett Squares

A **Punnett square** is a special tool derived from the laws of probability. It is used to predict the offspring from a cross, or mating between two parents.

An example of a Punnett square (**Figure** below) shows the results of a cross between two purple flowers that each have one dominant factor and one recessive factor (*Bb*).

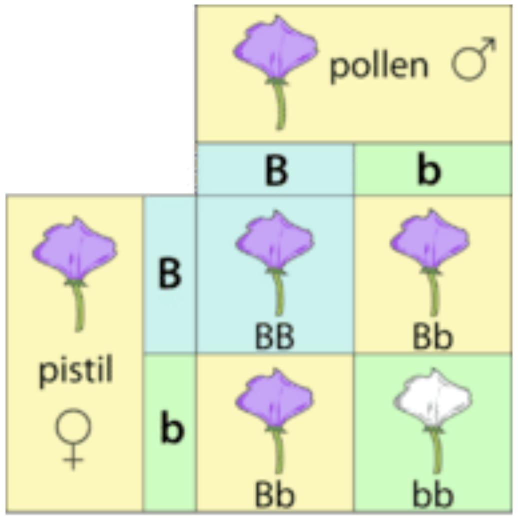


Figure 3.16

The Punnett square of a cross between two purple flowers (*Bb*).

To create a Punnett square, perform the following steps:

1. Take the factors from the first parent and place them at the top of the square (*B* and *b*).
2. Take the factors from the second parent and line them up on the left side of the square (*B* and *b*).
3. Pull the factors from the top into the boxes below.
4. Pull the factors from the side into the boxes next to them.

The possible offspring are represented by the letters in the boxes, with one factor coming from each parent.

Results:

- Top left box: *BB* , or purple flowers
- Top right box: *Bb* , or purple flowers
- Lower left box: *Bb* , or purple flowers
- Lower right box: *bb* , or white flowers

Only one of the plants out of the four, or 25% of the plants, has white flowers (*bb*). The other 75% have purple flowers (*BB* , *Bb*), because the purple factor (*B*) is the dominant factor. This shows that the color purple is the **dominant trait** in pea plants.

Now imagine you cross one of the white flowers (*bb*) with a purple flower that has both a dominant and recessive factor (*Bb*). The only possible gamete in the white flower is recessive (*b*), while the purple flower can have gametes with either dominant (*B*) or recessive (*b*).

Practice using a Punnett square with this cross (see **Table** below).

	b	**b**
B	**B b**	**B b**
b	**b b**	**b b**

Did you find that 50% of the offspring will be purple, and 50% of the offspring will be white?

Summary

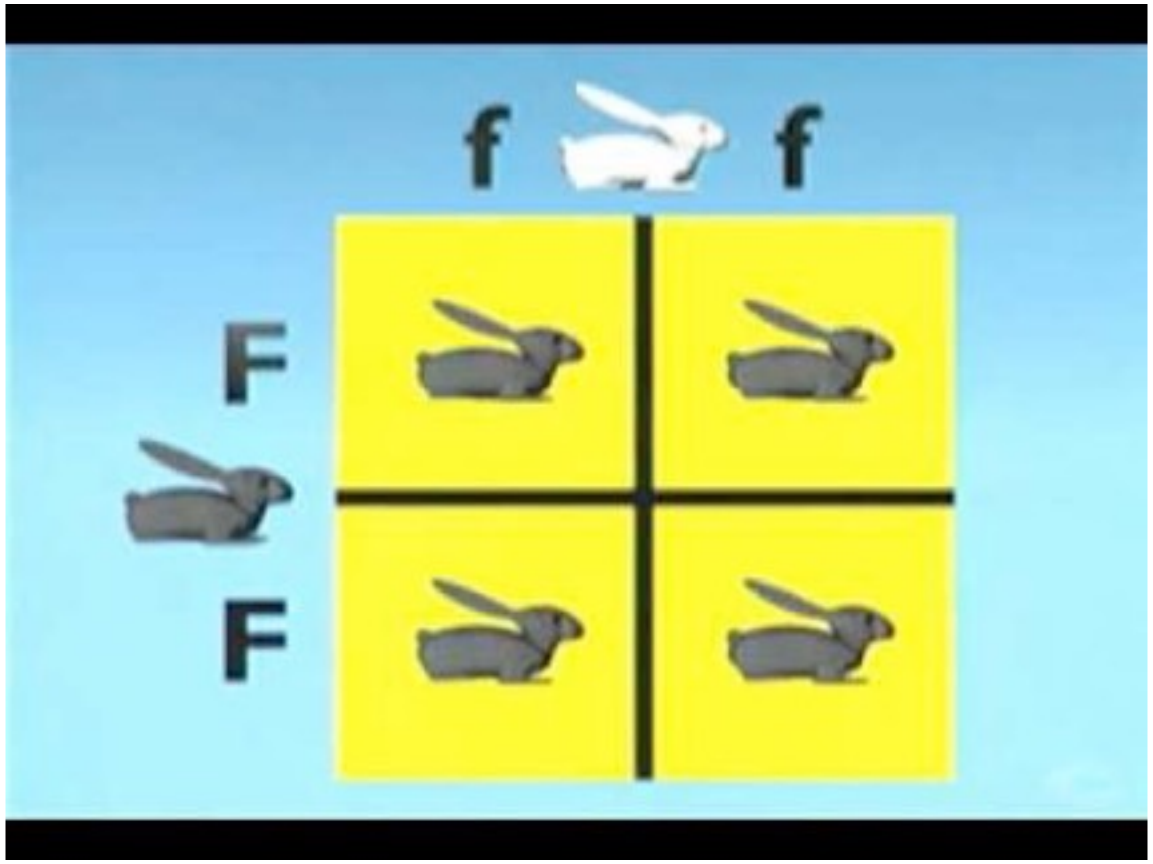
- A Punnett square is a special tool used to predict the offspring from a cross, or mating between two parents.
- In a Punnett square, the possible offspring are represented by the letters in the boxes, with one factor coming from each parent.

Explore More

Use the resources below to answer the questions that follow.

Explore More I

- **Gregor Mendel's Punnett Square** at http://www.youtube.com/watch?v=d4izVAkhMPQ (5:03)



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1. What are Mendel's two rules of heredity?
2. If a pure bred black rabbit and a white rabbit mate, what sill their potential offspring look like?
3. If two hybrid *Ff* rabbits mate, what will the offspring look like?

Explore More II

•**Punnett Square Calculator** at http://scienceprimer.com/punnett-square-calculator
1. If you cross an *Aa* individual with another *Aa* individual, what will the genotype ratio be in the next generation? What will be the phenotype ratio?
2. If you cross an *AABb* individual with an *Aabb* individual, what will the genotype ratio be in the next generation? What will be the phenotype ratio?
3. If you cross an *AAbb* individual with an *aabb* individual, what will the genotype ratio be in the next generation? What will be the phenotype ratio?

Review

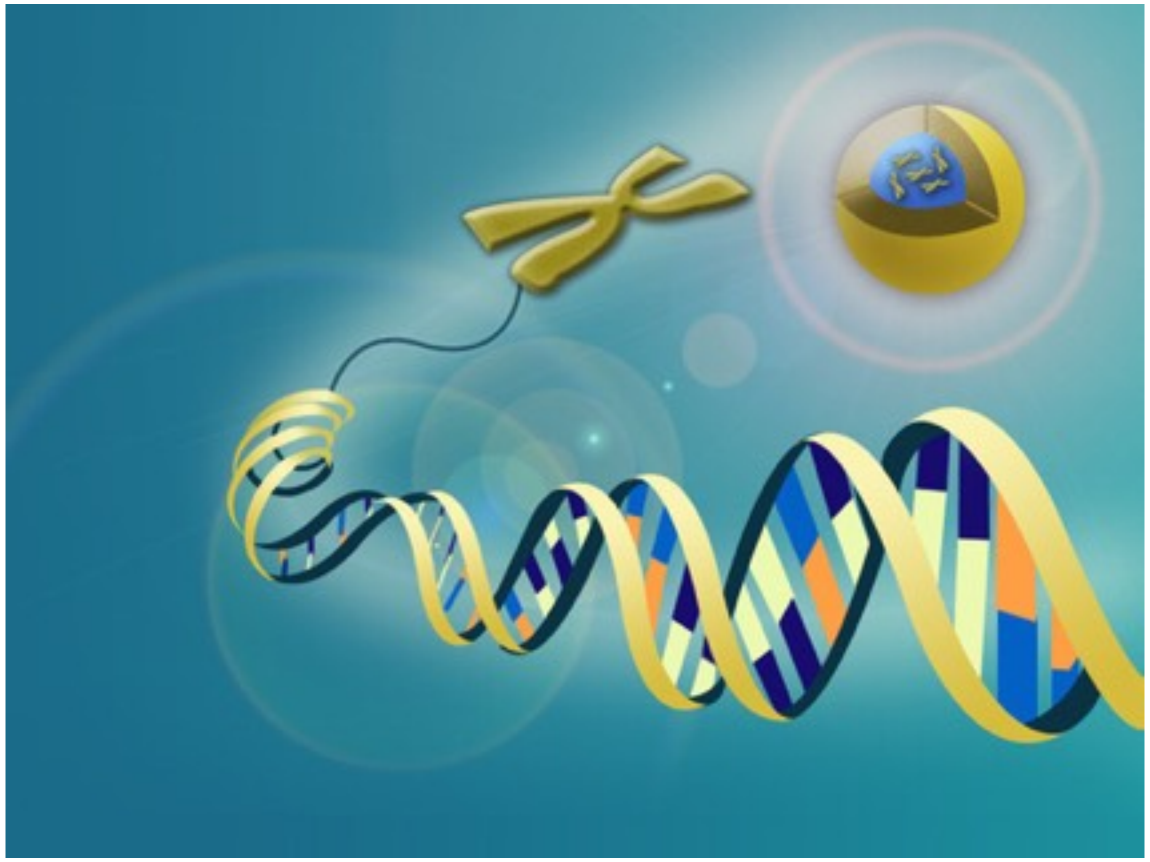
1. In peas, yellow seeds (*Y*) are dominant over green seeds (*y*). If a *yy* plant is crossed with a *YY* plant, what ratio of plants in the offspring would you predict?
2. What ratio of plants in the offspring would you predict from a *Yy* x *Yy* cross?
3. In guinea pigs, smooth coat (*S*) is dominant over rough coat (*s*). If an *SS* guinea pig is crossed with an *ss* guinea pig, what ratio of guinea pigs in the offspring would you predict?
4. What ratio of guinea pigs in the offspring would you predict from a *Ss* x *ss* cross?

Section 11

Modern Genetics

Modern Genetics

- •Define allele.
- •Compare heterozygous to homozygous.
- •Distinguish genotype from phenotype.
- •Compare Mendel's laws with the modern understanding of chromosomes.



Did Mendel know about DNA?

No, people did not understand that DNA is our hereditary material until long after Mendel's time. Our modern understanding of DNA and chromosomes helped to explain how Mendel's rules worked.

Modern Genetics

Mendel laid the foundation for modern genetics, but there were still a lot of questions he left unanswered. What exactly are the dominant and recessive factors that determine how all organisms look? And how do these factors work?

Since Mendel's time, scientists have discovered the answers to these questions. Genetic material is made out of **DNA** . It is the DNA that makes up the hereditary factors that Mendel identified. By applying our modern knowledge of DNA and chromosomes, we can explain Mendel's findings and build on them. In this concept, we will explore the connections between Mendel's work and modern genetics.

Traits, Genes, and Alleles

Recall that our DNA is wound into **chromosomes** . Each of our chromosomes contains a long chain of DNA that encodes hundreds, if not thousands, of genes. Each of these genes can have slightly different versions from individual to individual. These variants of genes are called **alleles** .

For example, remember that for the height gene in pea plants there are two possible factors. These factors are alleles. There is a dominant allele for tallness (*T*) and a recessive allele for shortness (*t*).

Genotype and Phenotype

Genotype is a way to describe the combination of alleles that an individual has for a certain gene (**Table** below). For each gene, an organism has two alleles, one on each chromosome of a homologous pair of chromosomes (think of it as one allele from Mom, one allele from Dad). The genotype is represented by letter combinations, such as *TT* , *Tt* , and *tt* .

When an organism has two of the same alleles for a specific gene, it is **homozygous** (homo- means "same") for that gene. An organism can be either homozygous dominant (*TT*) or homozygous recessive (*tt*). If an organism has two different alleles (*Tt*) for a certain gene, it is known as **heterozygous** (hetero- means different).

Genotype	Definition	Example
Homozygous	Two of the same allele	*TT* or *tt*
Heterozygous	One dominant allele and one recessive allele	*Tt*
Homozygous dominant	Two dominant alleles	*TT*
Homozygous recessive	Two recessive alleles	*tt*

Phenotype is a way to describe the traits you can see. The genotype is like a recipe for a cake, while the phenotype is like the cake made from the recipe. The genotype expresses the phenotype. For example, the phenotypes of Mendel's pea plants were either tall or short, or they were purple-flowered or white-flowered.

Can organisms with different genotypes have the same phenotypes? Let's see.

What is the phenotype of a pea plant that is homozygous dominant (*TT*) for the tall trait? Tall. What is the phenotype of a pea plant that is heterozygous (*Tt*)? It is also tall. The answer is yes, two different genotypes can result in the same phenotype. Remember, the recessive phenotype will be expressed only when the dominant allele is absent, or when an individual is homozygous recessive (*tt*) (**Figure** below).

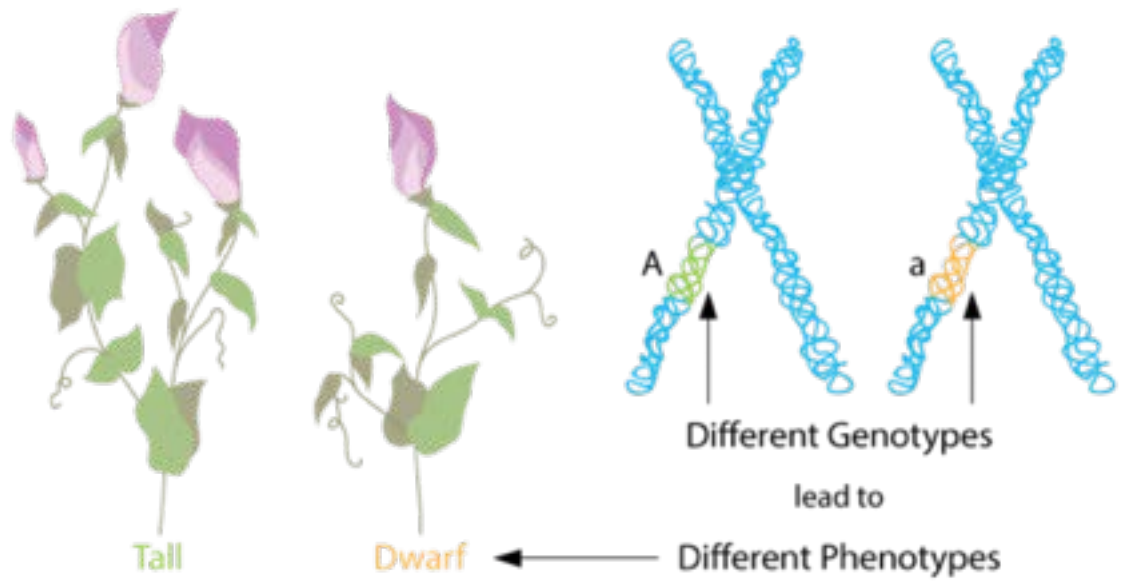


Figure 3.17

Different genotypes (*AA* , *Aa* , *aa* or *TT* , *Tt* , *tt*) will lead to different phenotypes, or different appearances of the organism.

Summary

- Mendel's hereditary "factors" are variants of genes called alleles.
- Genotype describes the combination of alleles that an individual has for a certain gene, while phenotype describes the traits that you can see.

Explore More

Use the resources below to answer the questions that follow.

Explore More I

- **Link Between Genotype and Phenotype** at http://www.sciencelearn.org.nz/Contexts/Uniquely-Me/Sci-Media/Video/Researching-the-link-between-genotype-and-phenotype

1. When geneticists look at genotype, what are they really studying?
2. Why do geneticists like to turn genes off? What question(s) do they ask?

Explore More II

- **iPlant Genotype to Phenotype** at http://www.youtube.com/watch?v=nIh0Qy_CZsU (3:49)

Click on the image above for more content

1. Do most of the complex phenotypes we observe come from a single gene?
2. What has led to the rapid analysis of DNA? Where do scientists now hope to apply these tools?
3. What are some of the phenotypic plant traits that scientists are investigating? Why do you think these traits were chosen?

Review

1. What is an allele?
2. What is the type of allele that only affects the phenotype in the homozygous condition?

3. If two individuals have a certain phenotype, does that mean they must have the same genotype?

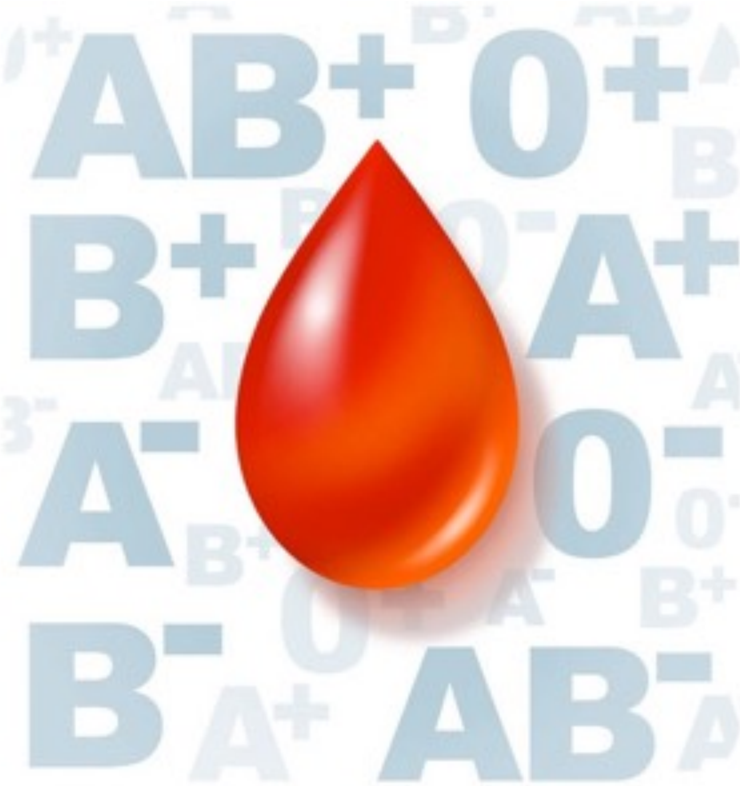
4. A tall, green plant is homozygous for each trait. If *T* is the tall allele, and *G* is the green allele, what is the genotype and the phenotype of this plant?

Section 12

Non-Mendelian Inheritance

Non-Mendelian Inheritance

- •Distinguish incomplete dominance from codominance.
- •Describe the genetics of ABO blood types in humans.



How would Mendel explain blood types?

The inheritance of traits is not always as simple as Mendel's rules. Each characteristic Mendel investigated was controlled by one gene that had only two possible alleles, one of which was completely dominant over the other. We now know that inheritance is often more complicated than this. In blood types, for example, there are actually three alleles instead of two.

Exceptions to Mendel's Rules

In all of Mendel's experiments, he worked with traits where a single gene controlled the trait. Each also had one allele that was always dominant over the recessive allele. But this is not always true.

There are exceptions to Mendel's rules, and these exceptions usually have something to do with the dominant allele. If you cross a homozygous red flower with a homozygous white flower, according to Mendel's laws, what color flower should result from the cross? Either a completely red or completely white flower, depending on which allele is dominant. But since Mendel's time, scientists have discovered this is not always the case.

Incomplete Dominance

One allele is NOT always completely dominant over another allele. Sometimes an individual has a phenotype between the two parents because one allele is not dominant over another. This pattern of inheritance is called **incomplete dominance** . For example, snapdragon flowers show incomplete dominance. One of the genes for flower color in snapdragons has two alleles, one for red flowers and one for white flowers.

A plant that is homozygous for the red allele (*RR*) will have red flowers, while a plant that is homozygous for the white allele will have white flowers (*WW*). But the heterozygote will have pink flowers (*RW*) (**Figure** below). Neither the red nor the white allele is dominant, so the phenotype of the offspring is a blend of the two parents.

Figure 3.18

Pink snapdragons are an example of incomplete dominance.

Another example of incomplete dominance is with sickle cell anemia, a disease in which a blood protein called hemoglobin is produced incorrectly. This causes the red blood cells to have a sickle shape, making it difficult for these misshapen cells to pass through the smallest blood vessels. A person that is homozygous recessive (*ss*) for the sickle cell trait will have red blood cells that all have the incorrect hemoglobin. A person who is homozygous dominant (*SS*) will have normal red blood cells.

What type of blood cells do you think a person who is heterozygous (*Ss*) for the trait will have? They will have some misshapen cells and some normal cells (**Figure** below). Both the dominant and recessive alleles are expressed, so the result is a phenotype that is a combination of the recessive and dominant traits.

Figure 3.19

Sickle cell anemia causes red blood cells to become misshapen and curved unlike normal, rounded red blood cells.

Codominance

Another exception to Mendel's laws is a phenomenon called **codominance** . For example, our blood type shows codominance. Do you know what your blood type is? Are you A? O? AB? Those letters actually represent alleles. Unlike other traits, your blood type has three alleles, instead of two!

The ABO blood types (**Figure** below) are named for the protein attached to the outside of the blood cell. In this case, two alleles are dominant and completely expressed (I^A and I^B), while one allele is recessive (*i*). The I^A allele encodes for red blood cells with the A antigen, while the I^B allele encodes for red blood cells with the B antigen. The recessive allele (*i*) does not encode for any proteins. Therefore a person with two recessive alleles (*ii*) has type O blood. As no dominant (I^A and I^B) allele is present, the person cannot have type A or type B blood.

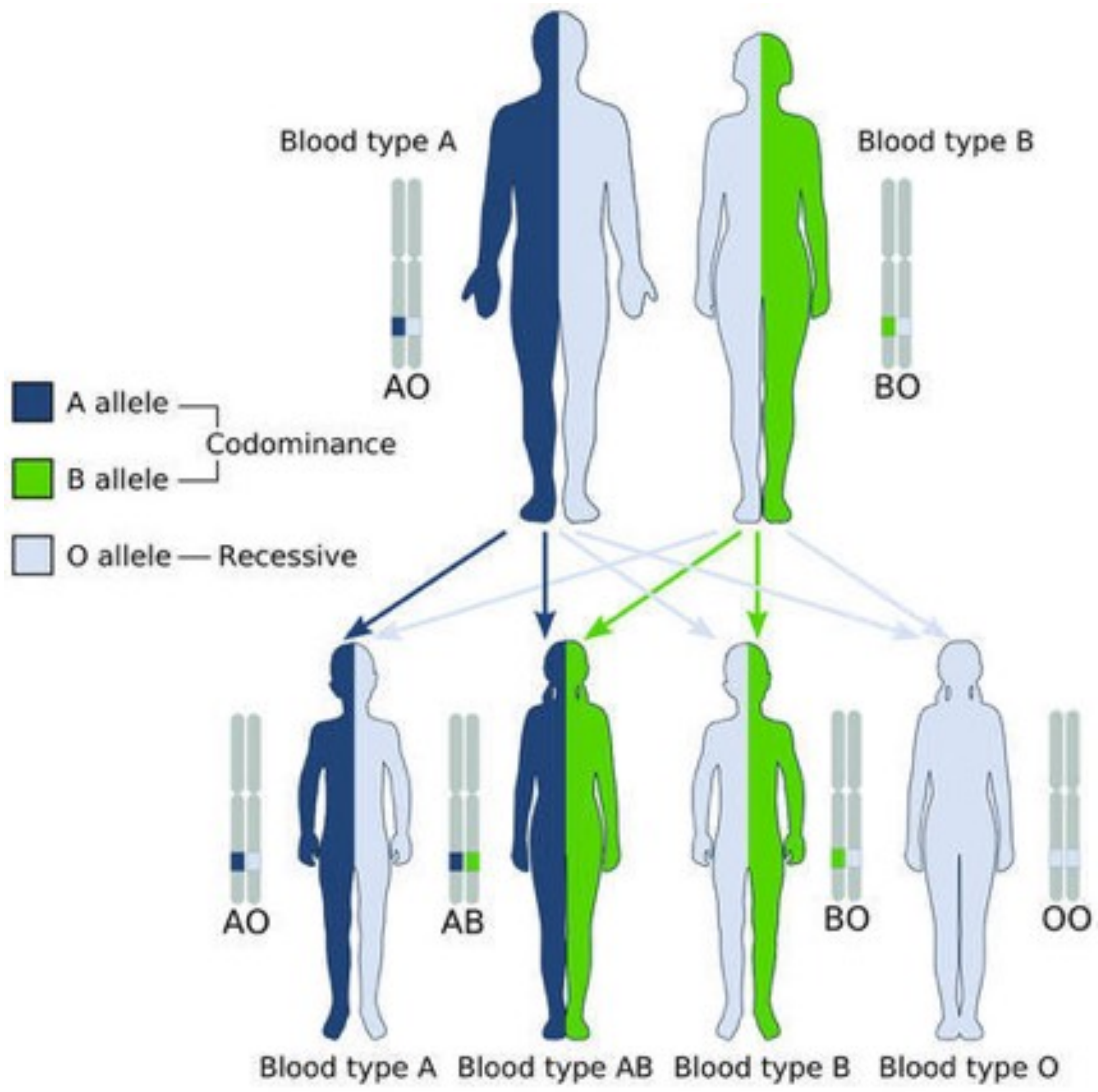


Figure 3.20

An example of codominant inheritance is ABO blood types.

There are two possible genotypes for type A blood, homozygous (I^AI^A) and heterozygous (I^Ai), and two possible genotypes for type B blood, (I^BI^B and I^Bi). If a person is heterozygous for both the I^A and I^B alleles, they will express both and have type AB blood with both proteins on each red blood cell.

This pattern of inheritance is significantly different than Mendel's rules for inheritance, because both alleles are expressed completely, and one does not mask the other.

Summary

- Incomplete dominance, as seen in sickle cell anemia, is a form of inheritance in which one allele is only partly dominant over the other allele, resulting in an intermediate phenotype.
- Codominance, as in human blood type, is a form of inheritance in which both alleles are expressed equally in the phenotype of the heterozygote.

Explore More

Use the resources below to answer the questions that follow.

Explore More I

•**Incomplete Dominance** at http://www.ksu.edu/biology/pob/genetics/incom.htm

1. A species exists with three color types, (blue, yellow and green). You breed a yellow (*bb*) individual with a blue (*BB*) individual, and all the offspring are green. Which trait is dominant? Explain your reasoning.
2. You now breed the green offspring with a yellow individual. What will their offspring look like? Explain your answer.
3. You now breed a green individual with a blue individual. What will their offspring look like? Explain your answer.

Explore More II

•**Incomplete Dominance and Codominance** at http://www2.edc.org/weblabs/incompletedom/incompletedominance.html

1. When one trait is said to cancel out another trait, what kind of relationship is said to exist?
2. What is an allele?
3. If a trait is said to show incomplete dominance, can it be a simple trait? Explain your answer fully.
4. What is found on the surface of red blood cells in humans that determines blood type?
5. Is blood type an example of incomplete dominance or codominance? Explain your reasoning and be as specific as you can.

Review

1. A dark purple flower is crossed with a white flower of the same species, and the offspring have light purple flowers. What type of inheritance does this describe? Explain.
2. What is the inheritance pattern in which both alleles are expressed?
3. What is the genotype of a person with type O blood?
4. What is the genotype(s) of a person with type AB blood?

Section 13

Polygenic Traits

Polygenic Traits

•Explain the inheritance of polygenic traits.
•Describe the phenotypic distribution of polygenic traits.

Are all people either short or tall?

Unlike Mendel's peas, people do not all fall into two categories: short or tall. Most people, in fact, are somewhere in between. Obviously, Mendel's rules are too simple to explain the inheritance of human height.

Polygenic Traits

Another exception to Mendel’s rules is **polygenic inheritance** , which occurs when a trait is controlled by more than one gene. This means that each dominant allele "adds" to the expression of the next dominant allele.

Usually, traits are polygenic when there is wide variation in the trait. For example, humans can be many different sizes. Height is a polygenic trait, controlled by at least three genes with six alleles. If you are dominant for all of the alleles for height, then you will be very tall. There is also a wide range of skin color across people. Skin color is also a polygenic trait.

Polygenic inheritance often results in a bell shaped curve when you analyze the population (**Figure** below). That means that most people fall in the middle of the phenotypic range, such as average height, while very few people are at the extremes, such as very tall or very short. At one end of the curve will be individuals who are recessive for all the alleles; at the other end will be individuals who are dominant for all the alleles. Through the middle of the curve will be individuals who have a combination of dominant and recessive alleles.

Figure 3.21

Polygenic traits tend to result in a distribution that resembles a bell-shaped curve, with few at the extremes and most in the middle. There may be 4 or 6 or more alleles involved in the phenotype. At the left extreme, individuals are completely dominant for all alleles, and at the right extreme, individuals are completely recessive for all alleles. Individuals in the middle have various combinations of recessive and dominant alleles.

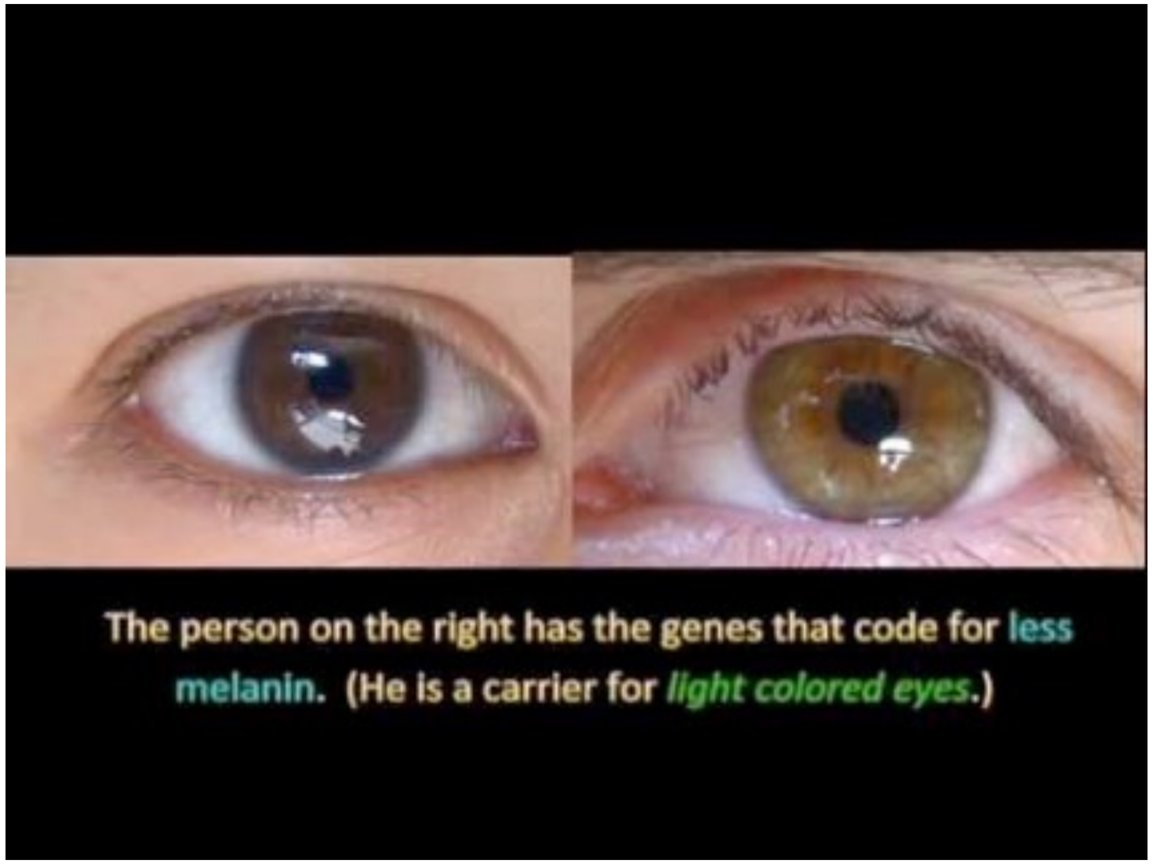
Summary

- In polygenic inheritance, a trait is controlled by more than one gene.
- Examples of polygenic inheritance include height or skin color.

Explore More

Use the resource below to answer the questions that follow.

- **Genetics and Eye Color** at http://www.youtube.com/watch?v=MjBZaed9yzM (1:49)



Click on the image above for more content

1. Is eye color a trait controlled by a single gene as it is often taught in schools?
2. Do you think skin color is a polygenic trait? Explain your reasoning, and be as specific as possible.
3. What is an albino? What kind of eyes would they definitely NOT have?

4. What is known about the melanin levels in people with blue eyes?

Review

1. How does polygenic inheritance violate Mendel's rules?
2. Give examples of traits governed by polygenic inheritance.

Section 14

Sex-linked Inheritance

Sex-linked Inheritance

•Define sex-linked trait.
•Explain the genetics of sex determination in humans.
•Explain sex-linked inheritance.

Male or female?

One of the exciting things about expecting a child is wondering if the baby will be a boy or a girl. There are many superstitions about how one might influence or predict the outcome. But what really determines if a baby is male or female? We now know that the gender of a baby is determined by a special pair of chromosomes known as the sex chromosomes.

Sex-linked Inheritance

What determines if a baby is a male or female? Recall that you have 23 pairs of chromosomes—and one of those pairs is the **sex chromosomes** . Everyone has two sex chromosomes. Your sex chromosomes can be X or Y. Females have two X chromosomes (XX), while males have one X chromosome and one Y chromosome (XY).

If a baby inherits an X chromosome from the father and an X chromosome from the mother, what will be the child's sex? The baby will have two X chromosomes, so it will be female. If the father's sperm carries the Y chromosome, the child will be male. Notice that a mother can only pass on an X chromosome, so the sex of the baby is determined by the father. The father has a 50 percent chance of passing on the Y or X chromosome, so there is a 50 percent chance that a child will be male, and there is a 50 percent chance a child will be female.

One special pattern of inheritance that doesn't fit Mendel's rules is **sex-linked inheritance** , referring to the inheritance of traits that are located on genes on the sex chromosomes. Since males and females do not have the same sex chromosomes, there will be differences between the sexes in how these **sex-linked traits** —traits linked to genes located on the sex chromosomes—are expressed.

One example of a sex-linked trait is red-green colorblindness. People with this type of colorblindness cannot tell the difference between red and green. They often see these colors as shades of brown (**Figure** below). Boys are much more likely to be colorblind than girls (**Table** below). This is because colorblindness is a sex-linked, recessive trait.

Boys only have one X chromosome, so if that chromosome carries the gene for colorblindness, they will be colorblind. As girls have two X chromosomes, a girl can have one X chromosome with the colorblind gene and one X chromosome with a normal gene for color vision. Since colorblindness is recessive, the dominant normal gene will mask the recessive colorblind gene. Females with one colorblindness allele and one normal allele are referred to as **carriers** . They carry the allele but do not express it.

How would a female become colorblind? She would have to inherit two genes for colorblindness, which is very unlikely. Many sex-linked traits are inherited in a recessive manner.

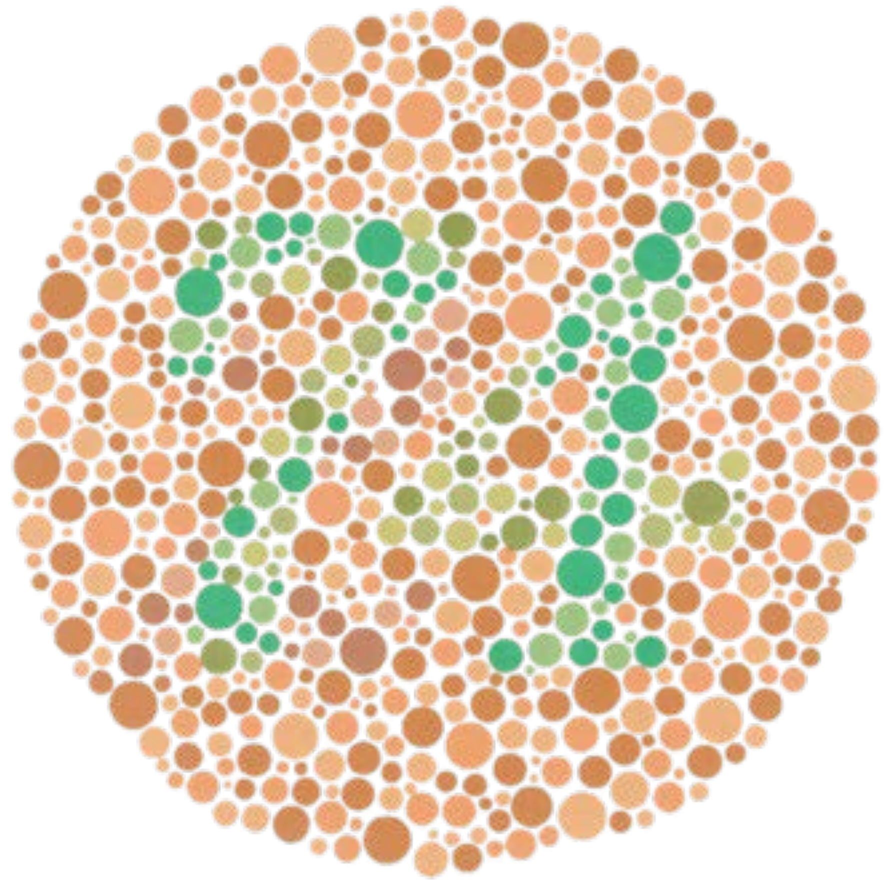


Figure 3.22

A person with red-green colorblindness would not be able to see the number.

	X^c	X
X	X^cX (carrier female)	**XX** (normal female)
Y	X^cY (colorblind male)	**XY** (normal male)

According to this Punnett square (**Table** above), the son of a woman who carries the colorblindness trait and a male with normal vision has a 50% chance of being colorblind.

Summary

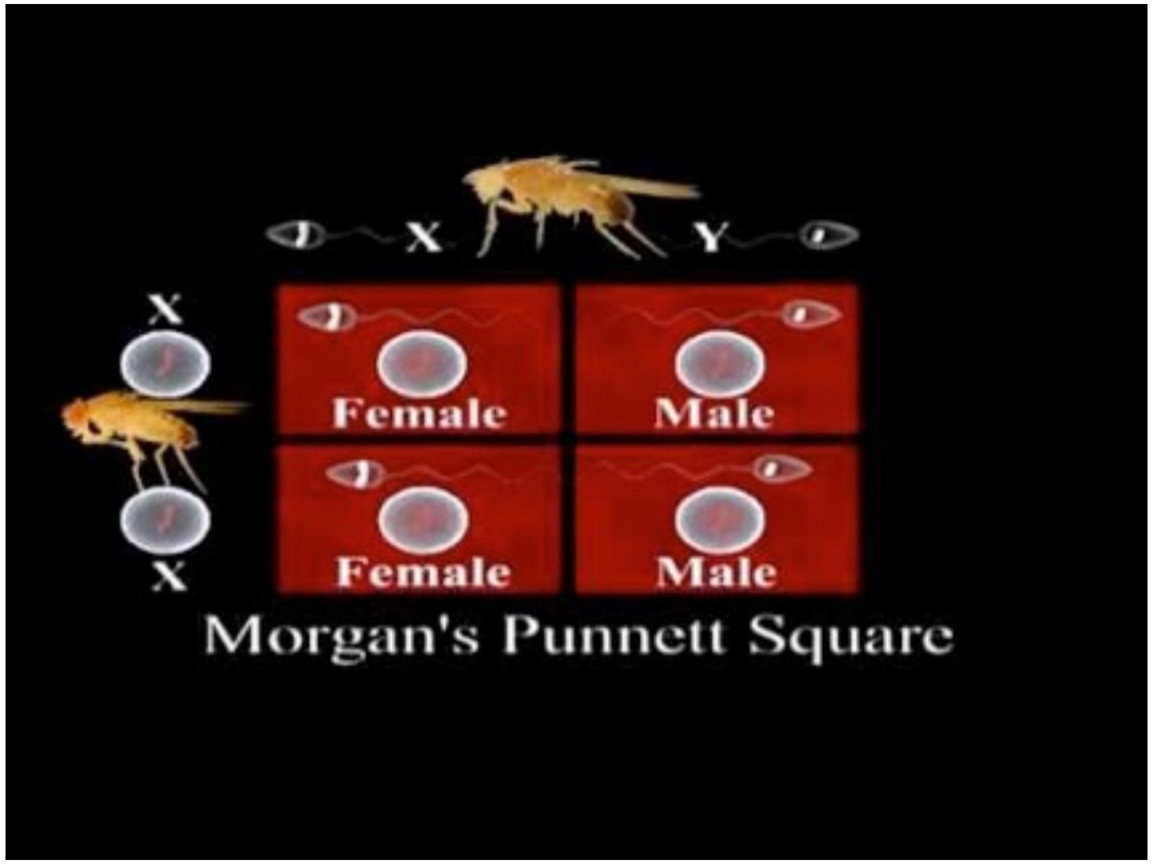
- Each individual has two sex chromosomes; females have two X chromosomes (XX), while males have one X chromosome and one Y chromosome (XY).
- Sex-linked traits are located on genes on the sex chromosomes.

Explore More

Use the resources below to answer the questions that follow.

Explore More I

- **Sex-linked Traits** at http://www.youtube.com/watch?v=H1HaR47Dqfw (5:16)



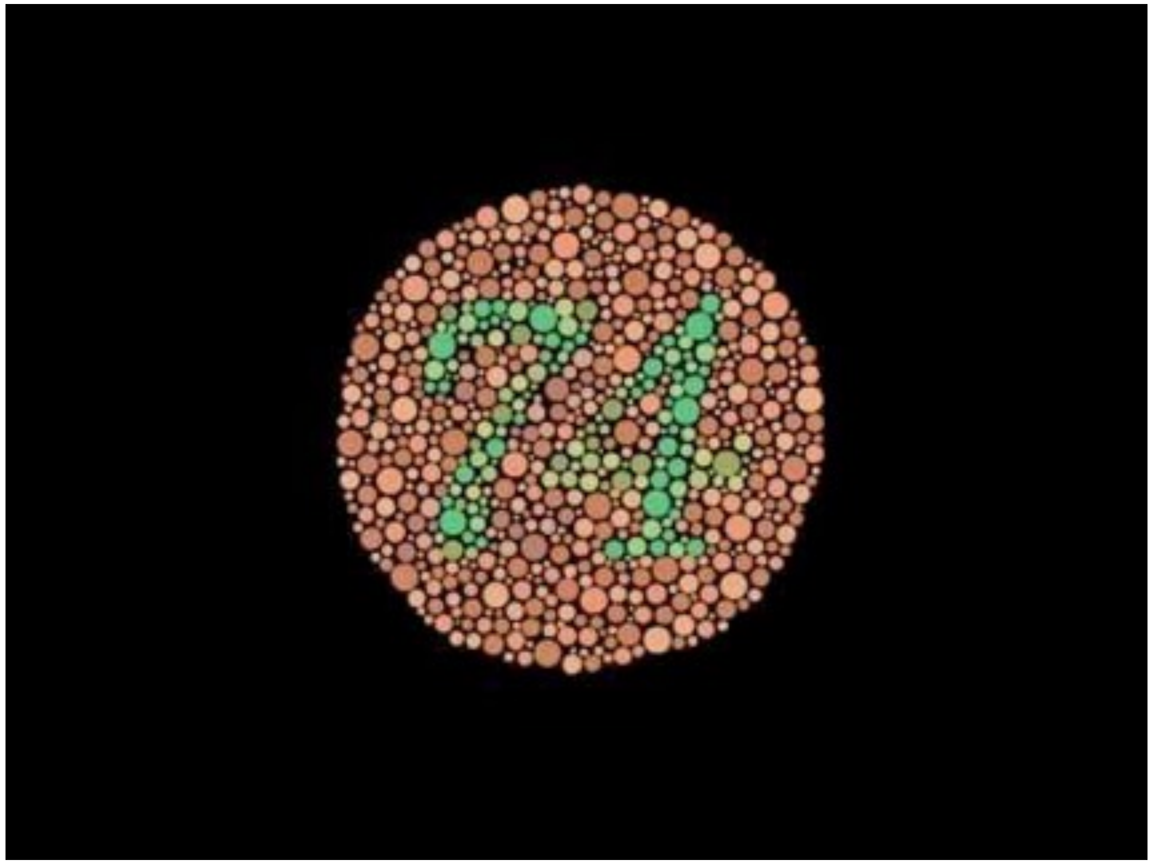
Click on the image above for more content

1. What was unusual about the F_2 generations in Morgan's crosses?
2. According to Morgan, where is the gene for eye color located?
3. How did Morgan test his hypothesis on the location of the eye color gene?
4. What are three traits that humans have that are related to genes exclusive to the X-chromosome?

The "Morgan" referred to in the above clip is Thomas Hunt Morgan. You can find out more about him and his work here: http://www.nature.com/scitable/topicpage/thomas-hunt-morgan-and-sex-linkage-452 .

Explore More II

•**Inheritance of Sex-linked Traits** at http://www.youtube.com/watch?v=lJqFk-28G08 (4:49)



Click on the image above for more content

1. What are the three types of color blindness? How are they caused?
2. What is the "Law of Dominance"?
3. Can a woman have colorblindness if her father does not? Explain your answer fully.
4. A woman is color blind but her sister isn't. What does that tell you about their parents

If you're still puzzled by sex-linked traits you can go to this site for more practice solving problems. Make sure you make good use of the "hints" on the site.

•**Sex-linked genes** at http://www.ksu.edu/biology/pob/genetics/xlinked.htm

Review

1. What are the sex chromosomes of a male and a female?
2. Explain why the father determines the sex of the child.
3. What is sex-linked inheritance?
4. A son cannot inherit colorblindness from his father. Why not?

Section 15

Genetic Disorders

Genetic Disorders

- Describe the genetics of common human genetic disorders.

When is a cold not just a cold?

At some point in your life, you're bound to catch a cold. And there are ways to prevent catching a cold. But what if you couldn't prevent an illness? What if you were born with a disease? What if having a disease was actually due to your DNA? These are genetic diseases, and they can be very serious.

Human Genetic Disorders

Some human genetic disorders are also X-linked or Y-linked, which means the faulty gene is carried on these sex chromosomes. Other genetic disorders are carried on one of the other 22 pairs of chromosomes; these chromosomes are known as **autosomes** or autosomal (non-sex) chromosomes.

Autosomal Recessive Disorders

Some genetic disorders are caused by recessive alleles of a single gene on an autosome. An example of an **autosomal recessive genetic disorder** is cystic fibrosis. Children with **cystic fibrosis** have excessively thick mucus in their lungs, which makes it difficult for them to breathe. The inheritance of this recessive allele is the same as any other recessive allele, so a Punnett square can be used to predict the probability that two **carriers** of the disease will have a child with cystic fibrosis. Recall that carriers have the recessive allele for a trait but do not express the trait. What are the possible genotypes of the offspring in the following table (**Table** below)? What are the possible phenotypes?

	F	f
F	**FF** (normal)	**Ff** (carrier)
f	**Ff** (carrier)	**ff** (affected)

According to this Punnett square, two parents that are carriers (*Ff*) of the cystic fibrosis gene have a 25% chance of having a child with cystic fibrosis (*ff*).

Automsomal Dominant Disorders

Huntington's disease is an example of an **autosomal dominant disorder** . This means that if the dominant allele is present, then the person will express the disease.

The disease causes the brain's cells to break down, leading to muscle spasms and personality changes. Unlike most other genetic disorders, the symptoms usually do not become apparent until middle age. You can use a simple Punnett square to predict the inheritance of a dominant autosomal disorder, like Huntington's disease. If one parent has Huntington's disease, what is the chance of passing it on to the children? If you draw the Punnett square, you will find that there is a 50 percent chance of the disorder being passed on to the children.

Summary

- Autosomal recessive genetic disorders, such as cystic fibrosis, are caused by recessive alleles of a single gene on an autosome.
- Autosomal dominant genetic disorders, such as Huntington's disease, are caused by dominant alleles of a single gene on an autosome.

Explore More

Use the resource below to answer the questions that follow.

- **What are Genetic Disorders?** at http://learn.genetics.utah.edu/content/disorders/

1. What are multifactorial disorders? What is an example of a multifactorial disorder?
2. What are single-gene disorders? What is an example of a single-gene disorder?
3. What causes galactosemia? How is it diagnosed? How is it treated?
4. What causes Colon Cancer? What is a tumor suppressor gene?
5. What is newborn genetic screening? How is it carried out?

Review

1. Can you be a carrier of an autosomal recessive genetic disorder?
2. Can you be a carrier of an autosomal dominant genetic disorder?
3. One parent is a carrier of the cystic fibrosis gene, while the other parent does not carry the allele. Can their child have cystic fibrosis?

Section 16

Pedigree Analysis

Pedigree Analysis

- •Define pedigree.
- •Interpret a pedigree to determine the mode of inheritance.

What's a pedigree?

When you are talking about a pedigree dog, it means the dog is purebred. Through selective breeding, the dog has all the traits of that particular breed. When talking about genetics, however, a pedigree is a chart that helps show family relationships.

Pedigree Analysis

A **pedigree** is a chart that shows the inheritance of a trait over several generations. A pedigree is commonly created for families, and it outlines the inheritance patterns of genetic disorders. Pictured below is a pedigree displaying recessive inheritance of a disorder through three generations (**Figure** below). From studying a pedigree, scientists can determine the following:

- •If the trait is **sex-linked** (on the X or Y chromosome) or **autosomal** (on a chromosome that does not determine sex).
- •If the trait is inherited in a dominant or recessive fashion.

Sometimes pedigrees can also help determine whether individuals with the trait are heterozygous or homozygous.

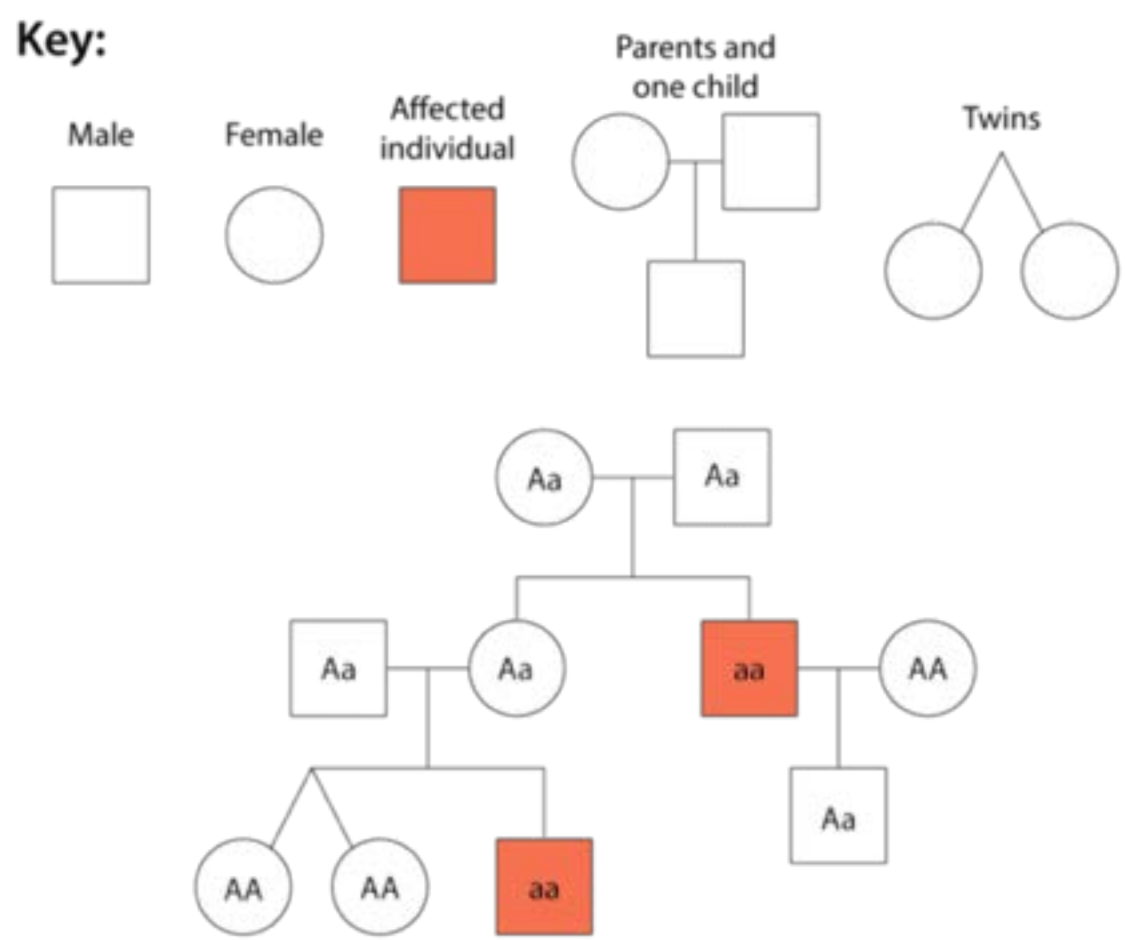


Figure 3.23

In a pedigree, squares symbolize males, and circles represent females. A horizontal line joining a male and female indicates that the couple had offspring. Vertical lines indicate offspring which are listed left to right, in order of birth. Shading of the circle or square indicates an individual who has the trait being traced. In this pedigree, the inheritance of the recessive trait is being traced. *A* is the dominant allele, and *a* is the recessive allele.

Summary

- •A pedigree is a chart which shows the inheritance of a trait over several generations.
- •From studying a pedigree, scientists can determine if a trait is sex-linked or autosomal.

Explore More

Use the resource below to answer the questions that follow.

•Find the Gene for Whirling Disorder! at http://bioserv.fiu.edu/~walterm/human_online/labs/genetics_online/find_the_gene_for_whirling_disor.htm

1.What is Whirling Disorder?
2.Is Whirling Dosorder inherited in a dominant or recessive mannor? Why?
3.Individual 5 does not have Whirling disorder, but what colored pieces does it have that potentially could have carried the gene for Whirling Disorder? From whom did he inherit these pieces.
4.Which puzzle piece (gene) is responsible for Whirling Disorder?

Review

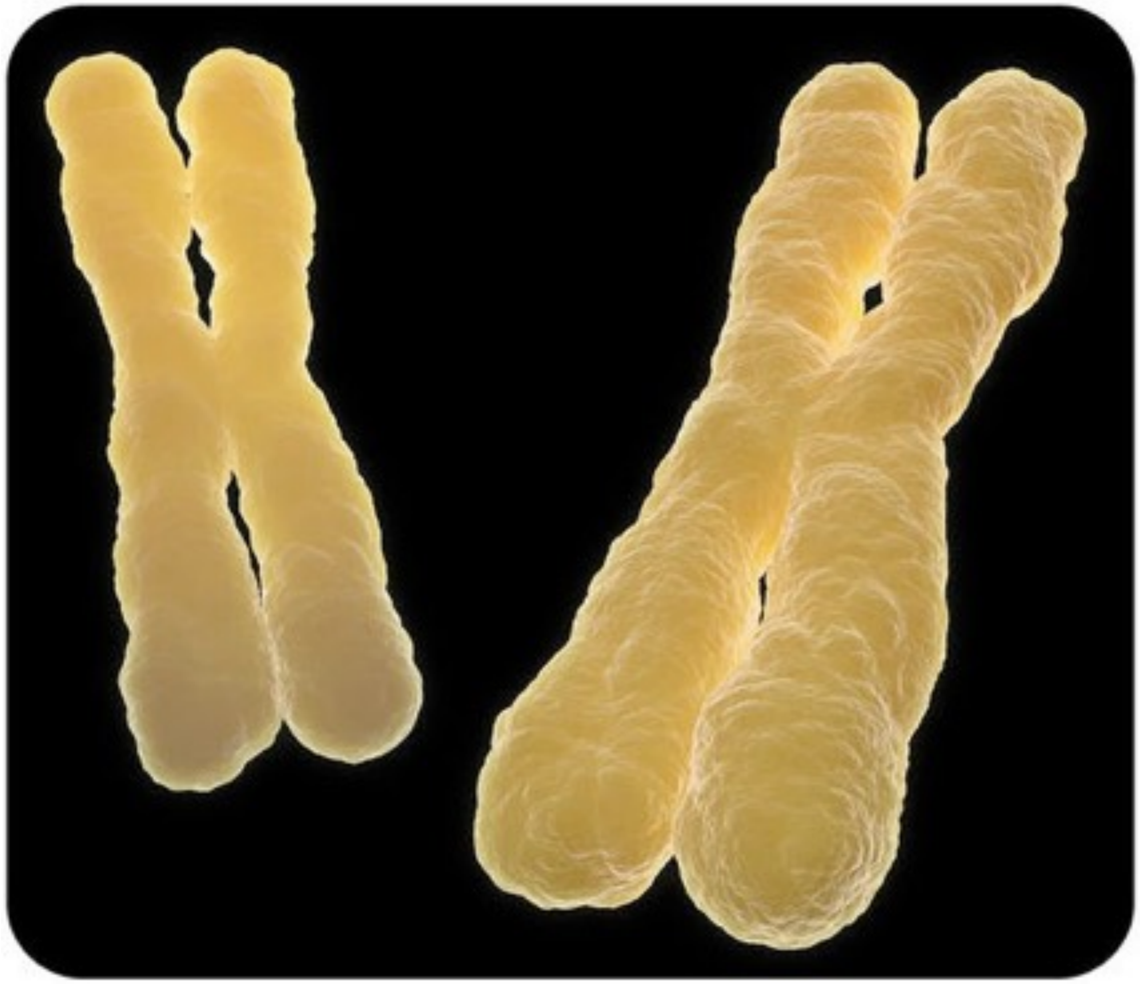
1.What is a pedigree?
2.How might a pedigree aid a scientist?

Section 17

Chromosomal Disorders

Chromosomal Disorders

- Describe the genetics of Down syndrome.
- Explain how changes in chromosomes can cause disorders in humans.



Can you have too many chromosomes?

Yes, it's not a good thing to have extra chromosomes. An extra chromosome can be fatal to an embryo, in fact. In the case of a few chromosomes, however, a baby may be born with an extra chromosome. This child will have a chromosomal disorder.

Chromosomal Disorders

Some children are born with genetic defects that are not carried by a single gene. Instead, an error in a larger part of the chromosome or even in an entire chromosome causes the disorder. Usually the error happens when the egg or sperm is forming. Having extra chromosomes or damaged chromosomes can cause disorders.

Extra Chromosomes

One common example of an extra-chromosome disorder is **Down syndrome** (**Figure** below). Children with Down syndrome are mentally disabled and also have physical deformities. Down syndrome occurs when a baby receives an extra chromosome 21 from one of his or her parents. Usually, a child will receive one chromosome 21 from the mother and one chromosome 21 from the father. In an individual with Down syndrome, however, there are three copies of chromosome 21 (**Figure** below). Therefore, Down syndrome is also known as Trisomy 21.

Figure 3.24

A child with Down syndrome.

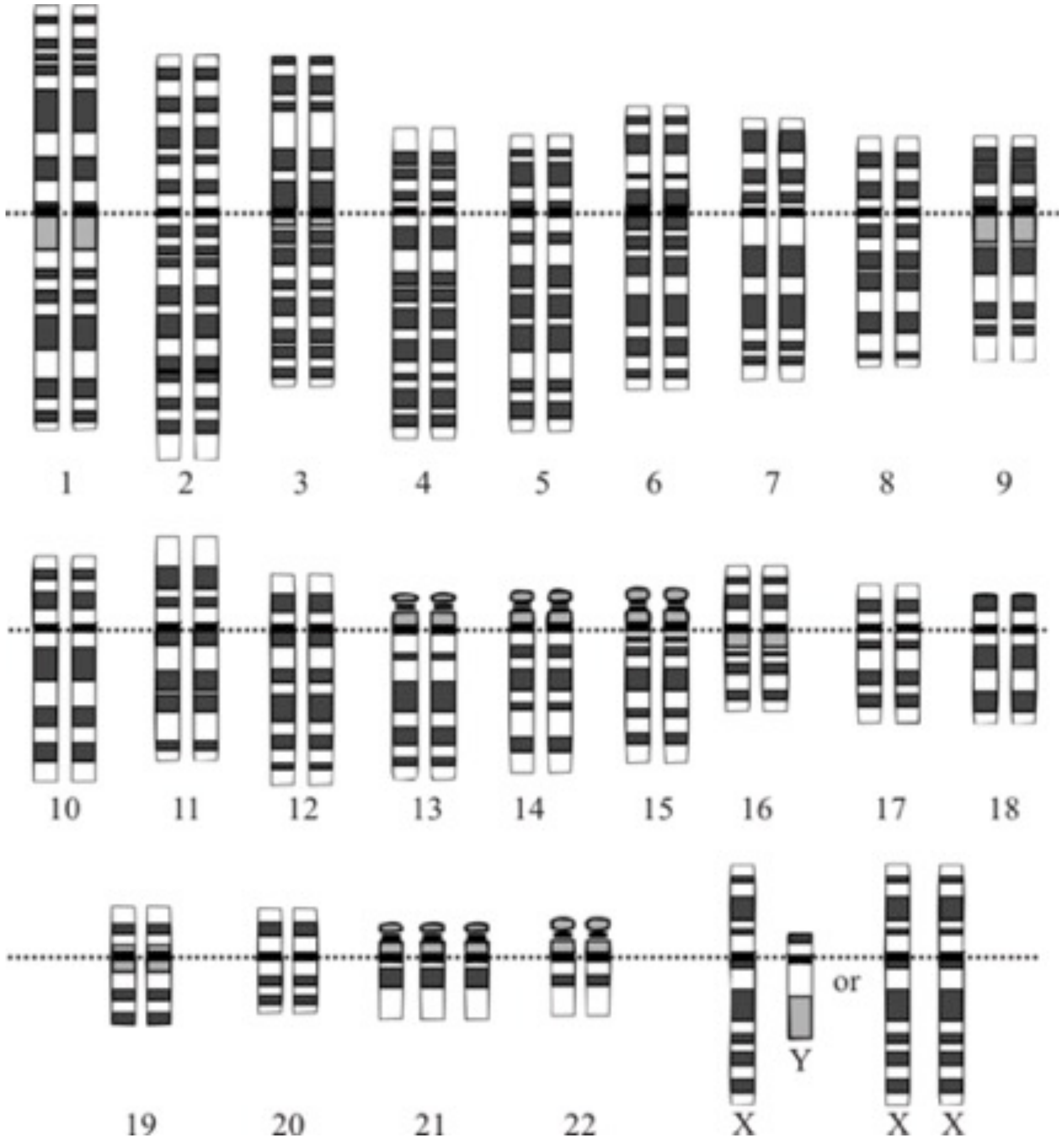


Figure 3.25

Chromosomes of a person with Down Syndrome. Notice the extra chromosome 21.

Another example of a chromosomal disorder is **Klinefelter syndrome** , in which a male inherits an extra “X” chromosome. These individuals have an XXY genotype.

They have underdeveloped sex organs and elongated limbs. They also have difficulty learning new things.

Outside of chromosome 21 and the sex chromosomes, most embryos with extra chromosomes do not usually survive. Because chromosomes carry many, many genes, a disruption of a chromosome can cause severe problems with the development of a fetus.

Damaged Chromosomes

Chromosomal disorders also occur when part of a chromosome becomes damaged. For example, if a tiny portion of chromosome 5 is missing, the individual will have *cri du chat* (cat's cry) syndrome. These individuals have misshapen facial features, and the infant's cry resembles a cat's cry.

Summary

•Changes in chromosome number can lead to disorders like Down syndrome.
•Chromosomal disorders also occur when part of a chromosome becomes damaged.

Explore More

Use the resources below to answer the questions that follow.

Explore More I

•**Down Syndrome** at http://www.ygyh.org/ds/whatisit.htm
1.Are all cases of Down Syndrome the result of inheritance?
2.Do all cases of Down Syndrome have a complete extra chromosome? Explain your answer fully.
3.How can a fetus be screened for Down syndrome?

Explore More II

•**Understanding Rare Chromosome Disorders** at http://www.youtube.com/watch?v=k4Lps1kIyR0 (8:11)

Click on the image above for more content

1. What do all people diagnosed with a chromosome disorder share?
2. What is a clinical geneticist? What are they trained to do that is different from a regular doctor?
3. What is a karyotype?
4. Do chromosomal disorders always involve extra genetic material? Explain your answer.

Review

1. What is a chromosomal disorder?
2. Explain what causes Down Syndrome.
3. When do chromosomal defects occur?
4. What happens to most embryos with extra chromosomes? Explain your answer.

Section 18

Recombinant DNA

Recombinant DNA

- Define recombinant DNA.
- Summarize the steps of gene cloning.

Can we alter DNA?

You might think that DNA is stable and unchangeable. For the most part you are right. However, there are new technologies that allow us to alter the DNA of humans and other organisms.

Recombinant DNA

Recombinant DNA is the combination of DNA from two different sources. For example, it is possible to place a human gene into bacterial DNA. Recombinant DNA technology is useful in gene cloning and in identifying the function of a gene.

Recombinant DNA technology can also be used to produce useful proteins, such as insulin. To treat diabetes, many people need insulin. Previously, insulin had been taken from animals. Through recombinant DNA technology, bacteria were created that carry the human gene which codes for the production of insulin. These bacteria become tiny factories that produce this protein. Recombinant DNA technology helps create insulin so it can be used by humans.

Recombinant DNA technology is used in gene cloning. A **clone** is an exact copy. Genes are cloned for many reasons, including use in medicine and in agriculture.

Below are the steps used to copy, or clone, a gene:

1. A gene or piece of DNA is put in a **vector** , or carrier molecule, producing a recombinant DNA molecule.
2. The vector is placed into a host cell, such as a bacterium.
3. The gene is copied (or cloned) inside of the bacterium. As the bacterial DNA is copied, so is the vector DNA. As the bacteria divide, the recombinant DNA molecules are divided between the new cells. Over a 12- to 24-hour period, millions of copies of the cloned DNA are made.

4.The cloned DNA can produce a protein (like insulin) that can be used in medicine or in research.

Plasmids

Bacteria have small rings of DNA in the cytoplasm, called **plasmids** (**Figure** below). When putting foreign DNA into a bacterium, the plasmids are often used as a vector. Viruses can also be used as vectors.

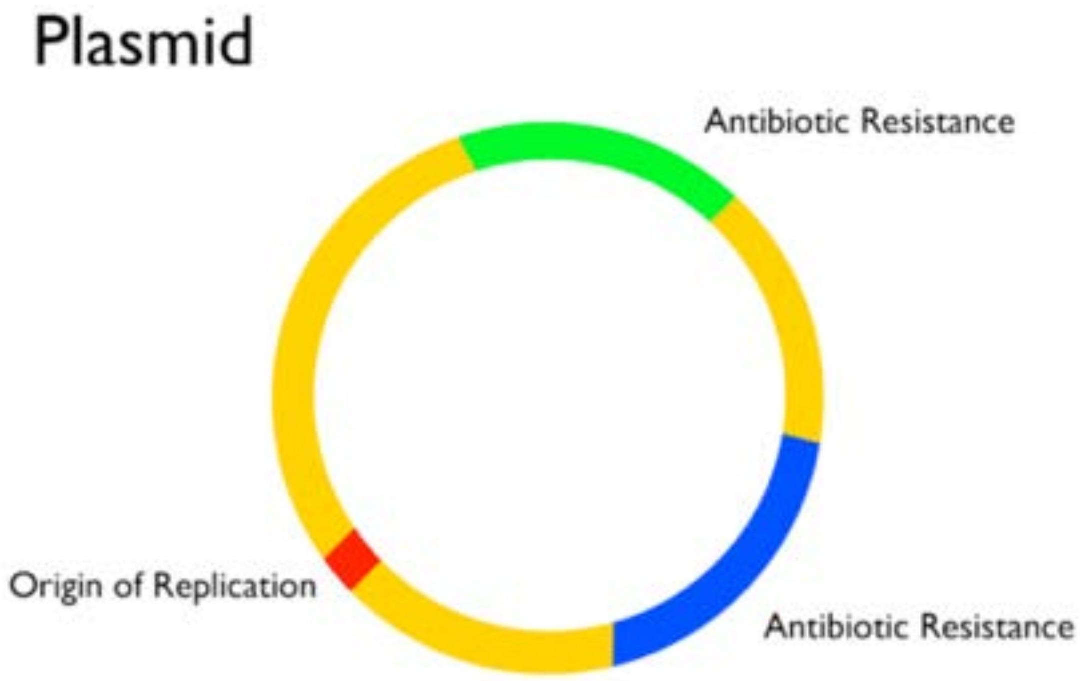


Figure 3.26

This image shows a drawing of a plasmid. The plasmid has two large segments and one small segment depicted. The two large segments (green and blue) indicate antibiotic resistances usually used in a screening procedure. The antibiotic resistance segments ensure only bacteria with the plasmid will grow. The small segment (red) indicates an origin of replication. The **origin of replication** is where DNA replication starts, copying the plasmid.

Summary

- Recombinant DNA is the combination of DNA from two different sources.
- Gene cloning is making an exact copy of a gene.

Explore More

Use the resource below to answer the questions that follow.

- **Stanley Cohen and Herbert Boyer** at http://www.dnalc.org/view/16033-Stanley-Cohen-and-Herbert-Boyer-1972.html

1.What bacteria were used to create the first recombinant DNA?
2.In the plasmid pSC101, what does the SC stand for? What gene did this plasmid carry?
3.What does DNA ligase do? How is it used in recombinant DNA technology?
4.What did Cohen and Boyer do to get a bacteria to take up the recombinant plasmid they had made?
5.Since not all of the plasmids that Cohen and Boyer created carried both genes they were seeking to transfer, how did they isolate the bacteria that had plasmids with both genes?

Review

1.What is recombinant DNA technology?
2.Explain the process of gene cloning.

Section 19

Cloning

Cloning

- Describe the process of animal cloning.
- Summarize the significance of Dolly.

Would you like to clone yourself?

Although it's illegal to clone humans in the United States, it is possible to clone many types of animals. What might be the consequences if we allowed human cloning?

Cloning

Cloning is the process of creating an exact replica of an organism. The clone's DNA is exactly the same as the parent's DNA. Bacteria and plants have long been able to clone themselves through asexual reproduction. In animals, however, cloning does not happen naturally. In 1997, that all changed when a sheep named Dolly was the first mammal ever to be successfully cloned. Other animals can now also be cloned in a laboratory.

The process of producing an animal like Dolly starts with a single cell from the animal that is going to be cloned. Below are the steps involved in the process of cloning:

1. In the case of Dolly, cells from the mammary glands were taken from the adult that was to be cloned. But other somatic cells can be used. **Somatic cells** come from the body and are not gametes like sperm or egg.
2. The nucleus is removed from this cell.
3. The nucleus is placed in a donor egg that has had its nucleus removed.
4. The new cell is stimulated with an electric shock and embryo development begins, as if it were a normal **zygote** .
5. The resulting embryo is implanted into a mother sheep, where it continue its development (**Figure** below).

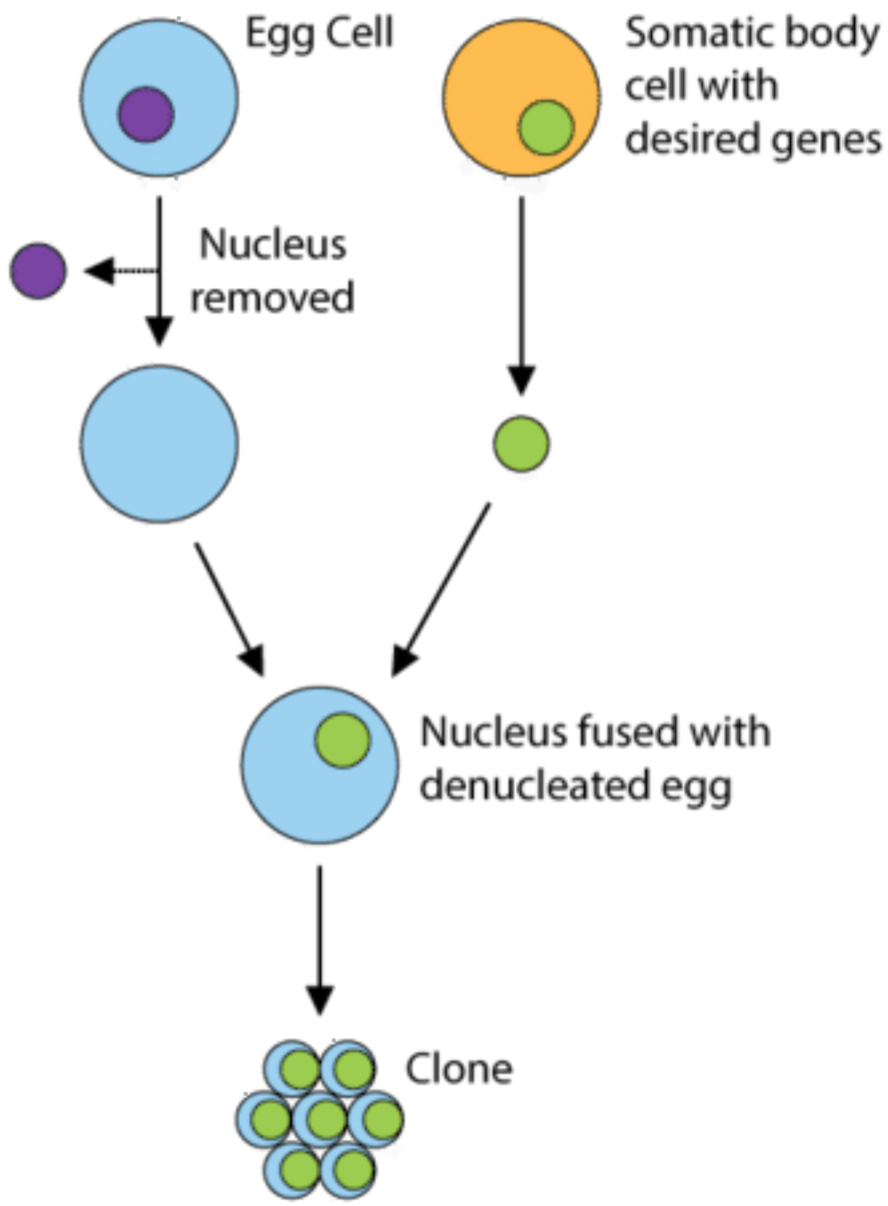


Figure 3.27

To clone an animal, a nucleus from the animal's cells are fused with an egg cell (from which the nucleus has been removed) from a donor.

Is Cloning Easy?

Cloning is not always successful. Most of the time, this cloning process does not result in a healthy adult animal. The process has to be repeated many times until it works. In fact, 277 tries were needed to produce Dolly. This high failure rate is one reason that human cloning is banned in the United States. In order to produce a cloned human, many attempts would result in the surrogate mothers experiencing miscarriages, stillbirths, or deformities in the infant. There are also many additional ethical considerations related to human cloning. Can you think of reasons why people are for or against cloning?

Summary

•Cloning, or creating an exact replica of an organism, is now possible for many animals.
•There are many ethical considerations related to human cloning, and it is now illegal to clone humans in the United States.

Explore More

Use the resource below to answer the questions that follow.

•**Click and Clone** at http://learn.genetics.utah.edu/content/cloning/clickandclone/ .
1.What is the first step in cloning?
2.How are the blunt and sharp pipettes used in the cloning process?

3. How many cell divisions does the modified embryo go through before it is implanted in the surrogate mother?
4. What step did scientists determine was crucial to the success of this process?

Review

1. Describe the process of creating an animal clone.
2. What are some reasons why human cloning is banned?

Section 20

Human Genome Project

Human Genome Project

•Explain the significance of the Human Genome Project.

What is your genetic code?

The sequence of letters above represents bases in someone's DNA. It is now possible to find out a person's entire genetic code by determining all the bases in his or her DNA. What might be the benefits?

Human Genome Project

A person’s **genome** is all of his or her genetic information. In other words, the human genome is all the information that makes us human.

The **Human Genome Project** (**Figure** below) was an international effort to sequence all 3 billion bases that make up our DNA and to identify within this code more than 20,000 human genes. Scientists also completed a chromosome map, identifying where the genes are located on each of the chromosomes. The Human Genome Project was completed in 2003. Though the Human Genome Project is finished, analysis of the data will continue for many years.

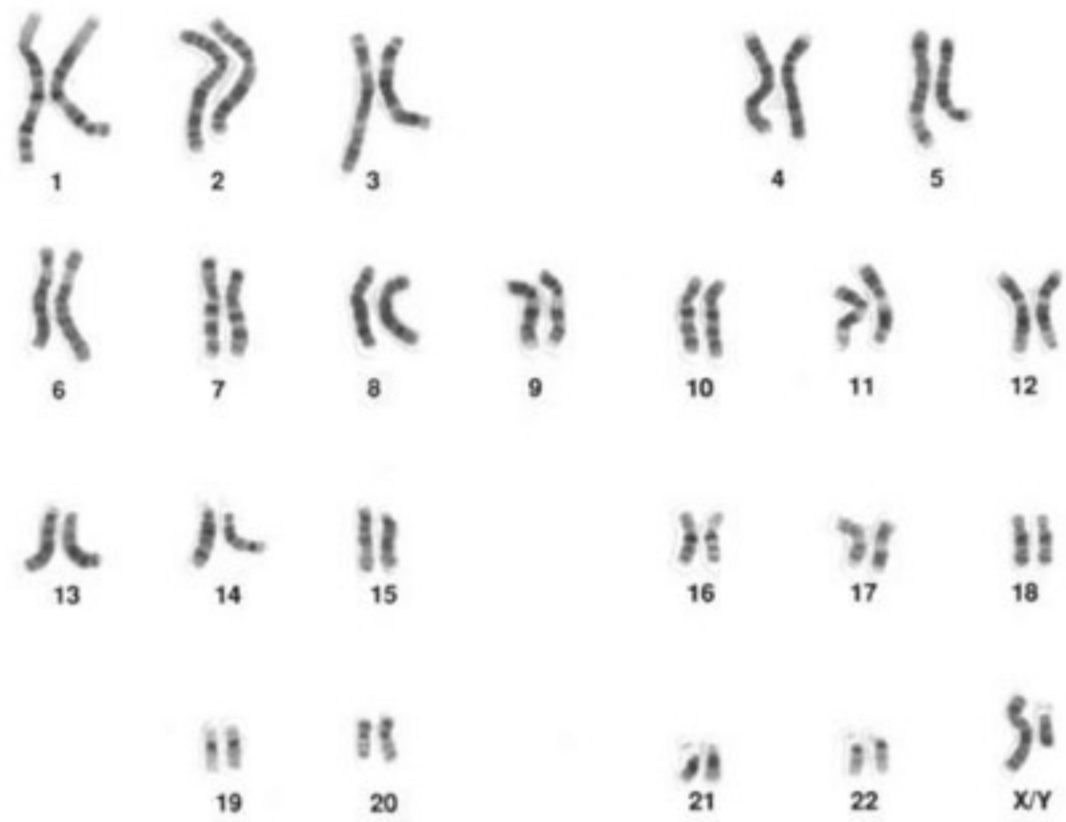


Figure 3.28

To complete the Human Genome Project, all 23 pairs of chromosomes in the human body were sequenced. Each chromosome contains thousands of genes. This is a karyotype, a visual representation of an individual's chromosomes lined up by size.

Exciting applications of the Human Genome Project include the following:

- The genetic basis for many diseases can be more easily determined. Now there are tests for over 1,000 genetic disorders.
- The technologies developed during this effort, and since the completion of this project, will reduce the cost of sequencing a person's genome. This may eventually allow many people to sequence their individual genome.
- Analysis of your own genome could determine if you are at risk for specific diseases.
- Knowing you might be genetically prone to a certain disease would allow you to make preventive lifestyle changes or have medical screenings.

The video *Our Molecular Selves* discusses the human genome, and is available at http://www.genome.gov/25520211 or http://www.youtube.com/watch?v=_EK3g6px7Ik . *Genome, Unlocking Life's Code* is the Smithsonian National Museum of Natural History's exhibit on the human genome. See http://unlockinglifescode.org to visit the exhibit.

Click on the image above for more content

Summary

- The Human Genome Project involved an international effort to sequence all 3 billion bases that make up our DNA and to identify within this code more than 20,000 human genes.
- Analysis of your own genome could determine if you are at risk for specific diseases.

Explore More

Use the resources below to answer the questions that follow.

Explore More I

- **PCR Virtual Lab** at http://learn.genetics.utah.edu/content/labs/pcr/

1. How many copies of a DNA sequence can be made in a matter of hours using PCR?
2. About how much DNA do you need to start the PCR process?
3. Can you use the same primers for every DNA sequence you want to investigate? Why or why not?

4. How many "ingredients" go into your PCR tube? What are they?
5. What happens at 95°C during the PCR process?
6. What happens at 72°C during the PCR process?

Explore More II

•**Personal Genome Project** at http://www.personalgenomes.org

1. What is the goal of the personal genome project?
2. What information are they seeking besides a person's genome?
3. Why participate in the PGP?

Review

1. What is a person's genome?
2. Describe the Human Genome Project.
3. Would you want to know your own genome? Why or why not?

Section 21

Gene Therapy

Gene Therapy

•Define gene therapy.
•Describe gene therapy.
•Distinguish *in vivo* gene therapy from *ex vivo* gene therapy.

Can doctors fix your DNA?

There are many genetic disorders that are due to a single gene. What if we could fix this faulty gene? With the development of gene therapy, that may eventually be possible for many types of genetic disorders.

Gene Therapy

Gene therapy is the insertion of genes into a person's cells to cure a genetic disorder. Could gene therapy be the cure for AIDS? No, AIDS is caused by a virus. Gene therapy only works to fix disorders caused by a faulty gene. The patient would have had this disorder from birth. Though gene therapy is still in experimental stages, the common use of this therapy may occur during your lifetime.

There are two main types of gene therapy:

1. One done inside the body (***in vivo***).
2. One done outside the body (***ex vivo***).

Both types of gene therapy use a **vector** , or carrier molecule for the gene. The vector helps incorporate the desired gene into the patient's DNA. Usually this vector is modified viral DNA in which the viral genes have been removed.

In Vivo Gene Therapy

During *in vivo* gene therapy, done inside the body, the vector with the gene of interest is introduced directly into the patient and taken up by the patient's cells (**Figure** below). For example, cystic fibrosis gene therapy is targeted at the respiratory system, so a solution with the vector can be sprayed into the patient's nose. Recently, *in vivo* gene therapy was also used to partially restore the vision of three young adults with a rare type of eye disease.

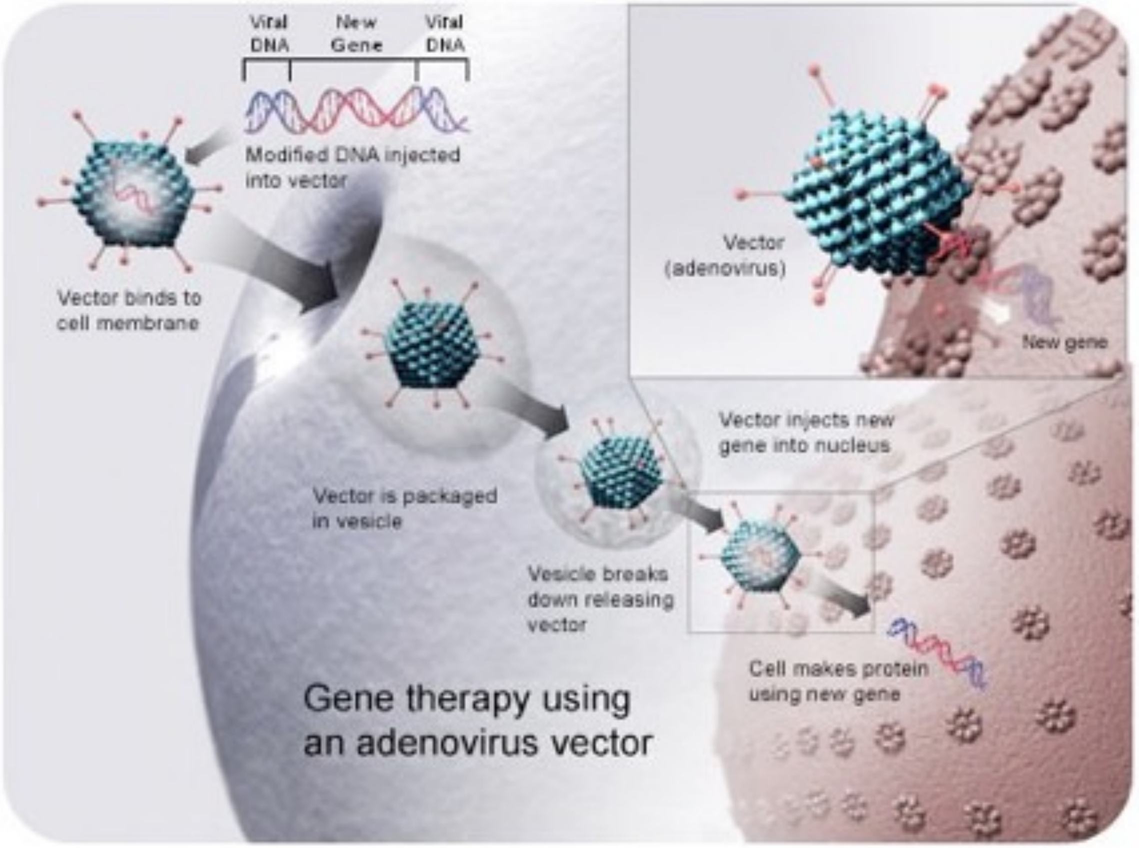


Figure 3.29

During gene therapy, adenovirus is a possible vector to carry the desired gene and insert it into the patient's DNA.

Ex Vivo Gene Therapy

In *ex vivo* gene therapy, done outside the body, cells are removed from the patient and the proper gene is inserted using a virus as a vector. The modified cells are placed back into the patient.

One of the first uses of this type of gene therapy was in the treatment of a young girl with a rare genetic disease, adenosine deaminase deficiency, or ADA deficiency. People with this disorder are missing the ADA enzyme, which breaks down a toxin called deoxyadenosine. If the toxin is not broken down, it accumulates and destroys immune cells. As a result, individuals with ADA deficiency do not have a healthy immune system to fight off infections. In the gene therapy treatment for this disorder, bone marrow stem cells were taken from the girl's body, and the missing gene was inserted into these cells outside the body. Then the modified cells were put back into her bloodstream. This treatment successfully restored the function of her immune system, but only with repeated treatments.

Summary

- Gene therapy, the insertion of genes into a person's cells to cure a genetic disorder, can be *ex vivo* (outside the body) or *in vivo* (inside the body).
- Gene therapy is still in the experimental stages, but some trials have been successful.

Explore More

Use the resources below to answer the questions that follow.

- **What is Gene Therapy?** at http://learn.genetics.utah.edu/content/genetherapy/gtintro/ .
- **Gene Delivery: Tools Of The Trade** at http://learn.genetics.utah.edu/content/genetherapy/gttools/ .

1. What is an "ionic gradient"? How does cystic fibrosis affect the ionic gradient in cells? What effect does this have?
2. What five questions need to be answered to determine if a disease is a good candidate for gene therapy?
3. Why would an adenovirus vector be a bad choice for treating cystic fibrosis?
4. What is a good choice for a viral vector?

Review

1. What is gene therapy?
2. Could gene therapy someday cure the common cold? Why or why not?
3. What's the difference between *ex vivo* and *in vivo* gene therapy?

Section 22

Biotechnology in Agriculture

Biotechnology in Agriculture

- •Define transgenic crop.
- •Explain how biotechnology can be used in agriculture.

Have you ever eaten genetically engineered foods?

Most likely, yes. The majority of the corn in the United States is genetically engineered. Corn syrup is used to sweeten many things, like this soft drink. Corn is also fed to the cows that provided this hamburger.

Biotechnology in Agriculture

Biotechnology is changing the genetic makeup of living things to make a useful product. Biotechnology has led scientists to develop useful applications in agriculture and food science. These include the development of **transgenic** crops. In transgenic crops, genes are placed into plants to give the crop a beneficial trait. Benefits include:

- Improved yield from crops.
- Increased resistance of crops to environmental stresses.
- Increased nutritional qualities of food crops.
- Improved taste, texture or appearance of food.
- Reduced dependence on fertilizers, insecticides, and other chemicals.

Crops are obviously dependent on environmental conditions. Drought can destroy crop yields, as can too much rain and floods. But what if crops could be developed to withstand these harsh conditions?

Biotechnology will allow the development of crops containing genes that will help them to withstand harsh conditions. For example, drought and salty soil are two significant factors affecting how well crops grow. But there are crops that can withstand these harsh conditions. Why? Probably because of that plant's genetics. So scientists are studying plants that can cope with these extreme conditions. They hope to identify and isolate the genes that control these beneficial traits. The genes could then be transferred into more desirable crops, with the hope of producing the same traits in those crops.

Thale cress (**Figure** below), a species of ***Arabidopsis*** (*Arabidopsis thaliana*), is a tiny weed that is often used for plant research, because it is very easy to grow, and its DNA has been mapped. Scientists have identified a gene from this plant, At-DBF2, that gives the plant resistance to some environmental stresses. When this gene is inserted into tomato and tobacco cells, the cells were able to withstand environmental stresses like salt, drought, cold, and heat far better than ordinary cells. If these results prove successful in larger trials, then At-DBF2 genes could help in engineering crops that can better withstand harsh environments.

Figure 3.30

Thale cress (*Arabidopsis thaliana*).

Summary

- Transgenic crops have extra genes that were placed into them to give the crop a beneficial trait.
- In the future, crops may be genetically altered to withstand harsh conditions.

Explore More

Use the resource below to answer the questions that follow.

- **How Do You Disable A Gene** at http://www.youtube.com/watch?v=QEbVpj7EbwU (6:19)

Click on the image above for more content

1. What approach do scientists use to disable genes in *Arabidopsis* ? How does this work?
2. What do scientists use to insert DNA into *Arabidopsis* ?
3. Can scientists insert whole genes into a plant's genome?
4. How are the *Araidopsis* mutants valuable to botanists in general?

Review

1. What is a transgenic plant?
2. What are three examples of how biotechnology might be used in agriculture?

Summary

Molecular Biology and Genetics focuses on DNA and how proteins are made, and how genetic information is passed from one generation to the next. DNA is the genetic material, which is the material passed from parents to offspring. It also contains the information used to make RNA. RNA leaves the nucleus and, together with a ribosome, makes proteins. Beginning with Mendel's pea plants, genetics has become one of the most important fields of biology. Human genetics affects many, if not every, field of medicine. Technologies associated with genetics are involved in developing products to make our lives better but have raised a number of ethical, legal, and social issues.

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Evolution

Evolution

Introduction

Do dinosaurs prove evolution?

For millions of years dinosaurs roamed and dominated the planet. Then 65 million years ago, they went extinct. It's hard to argue that dinosaurs did not exist. Where did they come from? Where are they now? Evolution is the "change in species over time."

Section 1

Theory of Evolution by Natu-

Theory of Evolution by Natural Selection

- Define evolution.
- Describe the significance of the voyage of the *HMS Beagle.*
- Summarize Darwin's finding on the Galápagos Islands.

Where in the world is this?

This picture was taken in the Galápagos Islands, which is off the west coast of South America. The Galápagos Islands are home to many unique organisms, such as these tree-like cacti. Darwin's observations on these islands led to his development of the theory of evolution.

Darwin's Theory of Evolution

Do you ever wonder why some birds are big like ostriches and some birds are small like robins? Or why a lion has a mane while a leopard has spots? In the 19th century, an English natural scientist named **Charles Darwin** (**Figure** below) was also fascinated by the diversity of life on Earth.

He set out to answer the following questions:

- Why are organisms different?
- Why are organisms similar?
- Why are there so many different types of organisms?

To answer his questions, he developed what we now call "the theory of evolution by natural selection." This theory is one of the most important theories in the field of life science. In everyday English, "evolution" simply means "change." In biology, **evolution** states that all living organisms came from earlier forms of life. The theory of evolution by natural selection explains why evolution occurs. Darwin spent over 20 years traveling around the world and making observations before he fully developed his theory.

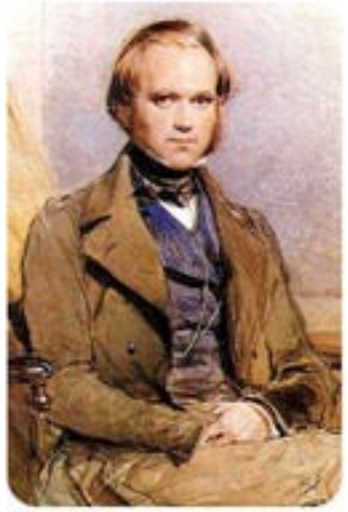


Figure 4.1

Charles Darwin was one of the most influential scientists who has ever lived. Darwin introduced the world to the theory of evolution by natural selection, which laid the foundation for how we understand the living world today.

Voyage of the *HMS Beagle*

In 1859, Charles Darwin published his book, *On the Origin of Species by Means of Natural Selection* . His book describes the observations and evidence that he collected more than 20 years of research, beginning with a five-year voyage around the world on a British research ship, the ***HMS Beagle*** . During the voyage (**Figure** below), Darwin made observations about plants and animals around the world. He also collected specimens to study for when he returned to England.

Each time the *HMS Beagle* stopped at a port, Darwin went on land to explore and look at the local plants, animals, and fossils. One of the most important things Darwin did was keep a diary. He took detailed notes and made drawings of his observations.

Figure 4.2

Charles Darwin's famous five year voyage was aboard the *HMS Beagle* from 1831-1836.

The Galápagos Islands

While the crew of the *HMS Beagle* mapped the coastline of South America, they traveled to a group of islands called the Galápagos. The Galápagos are a group of 16 volcanic islands near the equator, about 600 miles from the west coast of South America. Darwin spent months on foot exploring the islands. The specimens he collected from the Galápagos and sent back to England greatly influenced his ideas of evolution (**Figure** below).

Figure 4.3

The Galápagos Islands are a group of 16 volcanic islands 600 miles off the west coast of South America. The islands are famous for their many species found nowhere else.

On the Galápagos, Darwin observed that the same kind of animal differed from one island to another. For example, the iguanas (large lizards) differed between islands (**Figure** below). The members of one iguana species spent most of their time in the ocean, swimming and diving underwater for seaweed, while those of another iguana species lived on land and ate cactus. Darwin wondered why there were two species of iguanas on the same set of islands that were so different from one another. What do you think?

Figure 4.4

The Galápagos iguanas are among the signature animals of the Galápagos Islands. Here both a land iguana and a marine iguana are shown.

Giant Tortoises

Darwin also observed giant tortoises on the Galápagos (**Figure** below). These tortoises were so large that two people could ride on them. Darwin noticed that different tortoise species lived on islands with different environments. He realized that the tortoises had traits that allowed them to live in their particular environments. For example, tortoises that ate plants near the ground had rounded shells and shorter necks. Tortoises on islands with tall shrubs had longer necks and shells that bent upward, allowing them to stretch their necks (**Figure** below). Darwin began to hypothesize that organisms developed traits over time because of differences in their environments.

Figure 4.5

The name “Galápagos” means “giant tortoise.” When Darwin arrived on the Galápagos Islands, he was amazed by the size and variety of shapes of these animals. The giant tortoise (left) is a unique animal found only in the Galápagos Islands. There are only about 200 tortoises remaining on these islands. This Pinta Island tortoise (right) is able to reach leaves high in shrubs with its long neck and curved shell.

Darwin's Finches

The most studied animals on the Galápagos are finches, a type of bird (**Figure** below). When Darwin first observed finches on the islands, he did not even realize they were all finches. But when he studied them further, he realized they were related to each other. Each island had its own distinct species of finch. The birds on different islands had many similarities, but their beaks differed in size and shape.

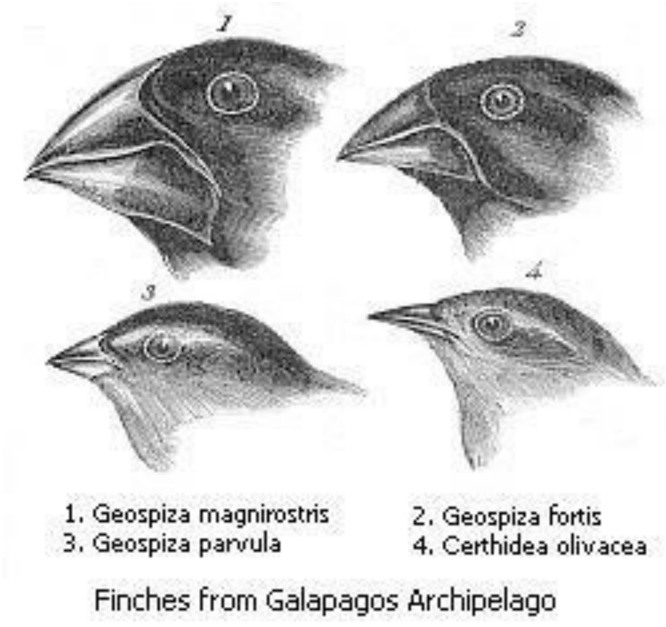


Figure 4.6

Four of Darwin’s finch species from the Galápagos Islands. The birds came from the same finch ancestor. They evolved as they adapted to different food resources on different islands. The first bird uses its large beak to crack open and eat large seeds. Bird #3 is able to pull small seeds out of small spaces.

In his diary, Darwin pointed out how each animal is well-suited for its particular environment. The shapes of the finch beaks on each island were well-matched with the seeds available on that island, but not the seeds on other islands. For example, a larger and stronger beak was needed to break open large seeds on one island, and a small beak was needed to eat the small seeds on a different island.

Summary

- Charles Darwin developed what we now call "the theory of evolution by natural selection."
- Darwin's observations on the Galápagos Islands suggested that animals are well-suited for their specific environments.

Explore More

Use the resource below to answer the questions that follow.

- **Richard Dawkins Talks About Darwin - Richard Dawkins Foundation** at http://cdn.cloudfiles.mosso.com/c148271/RDonDarwinGalapagosweb.mov (5:18)

1. How long was the voyage of the *HMS Beagle* ?
2. Did Charles Darwin conceive of natural selection on this voyage? Explain your answer.
3. What was wrong with Darwin's collection of finches from the Galápagos Islands? How was this mistake in collection corrected?
4. What did Darwin notice about the flora (plants) and fauna (animals) of Ecuador compared to the flora and fauna of the Galápagos Islands?
5. How does the distance of an island group from the mainland affect gene flow between that island group and the mainland?

Review

1. Define biological evolution.
2. Who was Charles Darwin?
3. What is special about the Galápagos islands?
4. Name an example of how animals were adapted for their specific environments on the Galápagos Islands.

Section 2

Influences on Darwin

Influences on Darwin

•Explain how Lamarck, Lyell, and Wallace influenced Darwin's work.

How old is Earth?

Earth is now believed to be over 4.5 billion years old. But during Darwin's time, most people believed that the Earth was only about 6,000 years old. If Darwin hadn't learned about the work of geologists that suggested that the Earth was much older, he might have never have developed his theory of evolution.

Darwin's Influences

When Darwin returned to England five years later, in 1836, at the end of his voyage, he did not rush to announce his discoveries. Unlike other naturalists before him, Darwin did not want to present any ideas unless he had strong evidence supporting them. Instead, once Darwin returned to England, he spent over twenty years examining specimens, talking with other scientists and collecting more information before he presented his theories.

Some of Darwin's ideas conflicted with widely held beliefs, including those from religious leaders. At that time, many people believed that organisms never change and never go extinct, and that the world was only about 6,000 years old. These beliefs delayed Darwin in presenting his findings.

How did Darwin come up with his theories? Charles Darwin was influenced by the ideas of several people.

1.Before the voyage of the *Beagle* , **Jean-Baptiste Lamarck** proposed the idea that species change over time. However, Darwin differed with Lamarck on several key points. Lamarck proposed that traits acquired during one's lifetime could be passed to the next generation. Darwin did not agree with this.
2.The findings of **Charles Lyell** , a well-known geologist, also influenced Darwin. Lyell's writings taught Darwin about geology, paleontology, and the changing Earth. Lyell's findings suggested the Earth must be much older than 6,000 years.

3.After the Voyage of the *Beagle* , another naturalist, **Alfred Russel Wallace** (**Figure** below), developed a similar theory of evolution by natural selection. Wallace toured South America and made similar observations to Darwin's. Darwin and Wallace presented their theories and evidence in public together. Due to the large number of observations and conclusions he made, Darwin is mostly credited and associated with this theory.

Figure 4.7

Alfred Wallace developed a similar theory of evolution by natural selection.

Summary

- Darwin's ideas conflicted with widely held beliefs, such as the idea that organisms never change and that the world was only about 6,000 years old.
- Darwin was influenced by other scientists, including Lamarck, Lyell, and Wallace.

Explore More

Use the resources below to answer the questions that follow.

Explore More I

- **An Introduction to Uniformitarianism** at http://www.youtube.com/watch?v=H9iuiBPc0tE (3:04)

Click on the image above for more content

1. Who first proposed that the Earth was far older than people thought?
2. What book by Charles Lyell did Darwin bring on his voyage?
3. What does "the present is the key to the past" mean in regard to geology? Do you think this phrase could apply to biology as well?
4. What is the "Principle of Geological Actualism"?

Explore More II

- **Nova: Great Minds Think Alike** at http://www.pbs.org/wgbh/nova/evolution/great-minds-think-alike.html .

1. Where did Wallace travel? How did he pay for his trip?
2. What happened to the collections Wallace collected in South America?
3. How does the Malay Archipelago compare to the Galapagos Islands?
4. What is the Wallace Line?

Review

1. Compare and contrast Darwin's and Lamarck's views of evolution.
2. Why did Darwin hesitate to publish his theory?
3. Who was Charles Lyell? What significant aspect of Lyell's influenced Darwin?
4. Who was Alfred Wallace?

Section 3

Natural Selection

Natural Selection

- •Define natural selection.
- •Explain the relationship between adaptations and natural selection.
- •Describe when natural selection occurs.
- •Explain the relationship between evolution and natural selection.

How is this deer mouse well adapted for life in the forest?

Notice how its dark coloring would allow the deer mouse to easily hide from predators on the darkened forest floor. On the other hand, deer mice that live in the nearby Sand Hills are a lighter, sand-like color. What caused the deer mice to be so well adapted to their unique environments? Natural selection.

Natural Selection

The theory of evolution by natural selection means that the inherited traits of a population change over time. **Inherited traits** are features that are passed from one generation to the next. For example, your eye color is an inherited trait. You inherited your eye color from your parents. Inherited traits are different from **acquired traits** , or traits that organisms develop over a lifetime, such as strong muscles from working out (**Figure** below).

Figure 4.8

Human earlobes may be attached or free. You inherited the particular shape of your earlobes from your parents. Inherited traits are influenced by genes, which are passed on to offspring and future generations. Things not influenced by genes are not passed on to your offspring. Natural selection only operates on traits like earlobe shape that have a genetic basis, not on traits that are acquired, like a summer tan.

Natural selection explains how organisms in a population develop traits that allow them to survive and reproduce. Natural selection means that traits that offer an advantage will most likely be passed on to offspring. Evolution occurs by natural selection. Take the giant tortoises on the Galápagos Islands as an example. If a short-necked tortoise lives on an island with fruit located at a high level, will the short-necked tortoise survive? No, it will not, because it will not be able to reach the food it needs to survive. If all of the short necked tortoises die, and the long-necked tortoises survive, then, over time, only the long-necked trait will be passed down to offspring. All of the tortoises with long-necks will be "naturally selected" to survive.

Every plant and animal depends on its traits to survive. Survival may include getting food, building homes, and attracting mates. Traits that allow a plant, animal, or other organism to survive and reproduce in its environment are called **adaptations** .

Natural selection occurs when:

1. There is some variation in the inherited traits of organisms within a species. Without this variation, natural selection would not be possible.
2. Some of these traits will give individuals an advantage over others in surviving and reproducing.
3. These individuals will be likely to have more offspring.

Imagine how in the Arctic, dark fur makes a rabbit easy for foxes to spot and catch in the snow. Therefore, white fur is a beneficial trait that improves the chance that a rabbit will survive, reproduce, and pass the trait of white fur on to its offspring (**Figure** below). Through this process of natural selection, dark fur rabbits will become uncommon over time. Rabbits will adapt to have white fur.

Figure 4.9

The white fur of the Arctic hares may make it more difficult for fox and other predators to locate hares against the white snow.

Why So Many Species?

Scientists estimate that there are between 5 million and 30 million species on the planet. But why are there so many? As environments change over time, organisms must constantly adapt to those environments. Diversity of species increases the chance that at least some organisms adapt and survive any major changes in the environment. For example, if a natural disaster kills all of the large organisms on the planet, then the small organisms will continue to survive.

Summary

- Evolution occurs by natural selection, the process by which organisms with traits that better enable them to adapt to their environment will tend to survive and reproduce in greater numbers.
- Natural selection occurs when there is some variation in the inherited traits, some of these traits will give individuals an advantage over others, and the individuals with certain traits will be more likely to have more offspring.

Explore More

Use the resource below to answer the questions that follow.

•**Sources of Variation** at http://learn.genetics.utah.edu/content/variation/sources/

1.Are all members of your family exactly alike? Are all members of a species exactly alike?
2.What is an important base of variation in species? Are all forms of a gene the same?
3.Give three examples of common mutations in DNA?
4.Do most mutations that are passed on to future generations come from the environment? What is the relationship between mutations and the environment?
5.How does recombination in sexually reproducing organisms ensure that every generation will have changes in the inherited DNA?
6.Describe the relationship between variation and natural selection.

Review

1.What's the difference between an acquired and inherited trait?
2.Define natural selection.
3.What is an adaptation?
4.What is required for natural selection to take place?
5.How many species are there on the planet?

Section 4

Fossils

Fossils

•Define fossil.
•Explain radiometric dating.
•Discuss the significance of the fossil record as evidence for evolution.

What's on this rock?

This rock contains a portion of a fossilized tree fern. Scientists study fossils of plants, animals, and other organisms in order to better understand what life was like on Earth many years ago and how it has changed over time. Fossils are important evidence for the theory of evolution.

The Fossil Record

Fossils are the preserved remains of animals, plants, and other organisms from the distant past. Examples of fossils include bones, teeth, and impressions. By studying fossils, evidence for evolution is revealed. **Paleontologists** are scientists who study fossils to learn about life in the past. Paleontologists compare the features of species from different periods in history. With this information, they try to understand how species have evolved over millions of years (**Figure** below).

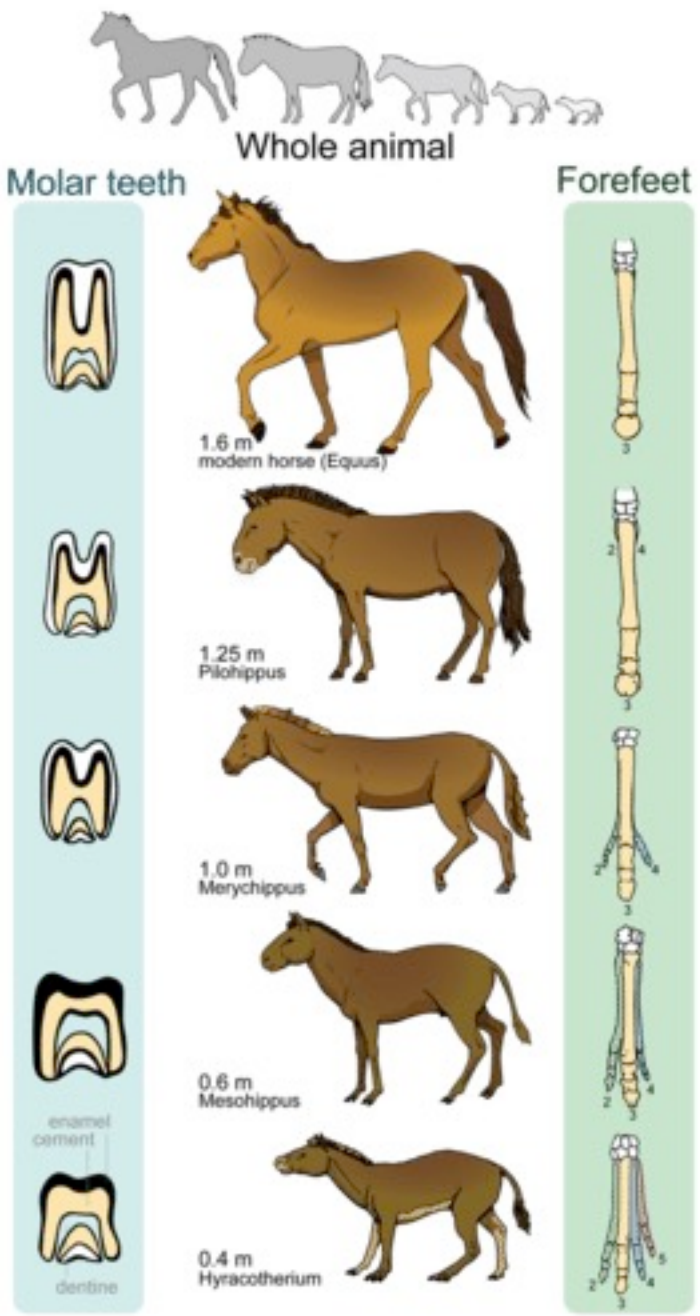


Figure 4.10

Evolution of the horse. Fossil evidence, depicted by the skeletal fragments, demonstrates evolutionary milestones in this process. Notice the 57 million year evolution of the horse leg bones and teeth. Especially obvious is the transformation of the leg bones from having four distinct digits to that of today's horse.

Until recently, fossils were the main source of evidence for evolution (**Figure** below). Through studying fossils, we now know that today's organisms look much different in many cases than those that were alive in the past. Scientists have also shown that organisms were spread out differently across the planet. Earthquakes, volcanoes, shifting seas, and other movements of the continents have all affected where organisms live and how they adapted to their changing environments.

Figure 4.11

About 25 to 40 million years ago these insects were trapped in a gooey substance, called resin, that comes from trees. The fossils in the movie *Jurassic Park* were trapped in resin.

Rock Layers and the Age of Fossils

There are many layers of rock in the Earth's surface. Newer layers form on top of the older layers. Therefore, you can tell how old a fossil is by observing in which layer of rock it was found. The fossils and the order in which fossils appear is called the **fossil record** . The fossil record provides evidence for when organisms lived on Earth, how species evolved, and how some species have gone extinct. Geologists use a method called **radiometric dating** to determine the exact age of rocks and fossils in each layer of rock. This technique measures how much of the radioactive materials in each rock layer have broken down (**Figure** below).

Figure 4.12

This device, called a spectrophotometer, can be used to measure the level of radioactive decay of certain elements in rocks and fossils to determine their age.

Radiometric dating has been used to determine that the oldest known rocks on Earth are between 4 and 5 billion years old. The oldest fossils are between 3 and 4 billion years old. Remember that during Darwin's time, people believed the Earth was just about 6,000 years old. The fossil record proves that Earth is much older than people once thought.

Summary

- Fossils, or preserved parts of organisms from the distant past, have shown that species change over time.
- Radiometric dating can be used to determine the age of fossils by measuring the how much of the radioactive materials in each rock layer have broken down.

Explore More

Use the resources below to answer the questions that follow.

Explore More I

- **James Hagadorn, Paleontologist: Traces of Early Animal Life** at http://shapeoflife.org/video/scientist/james-hagadorn-paleontologist-traces-early-animal-life (6:11)

Click on the image above for more content

1.Why is it believed the first animals left no fossilized bones?
2.What do paleontologists look for when they search for evidence of early organisms?
3.How old are the geologic deposits Dr. Hagadorn is searching? How old is the evidence he has found for the first mobile organisms?
4.What does the ability to hunt others do to the fossil record? Why?

Explore More II

•Jenny Clack, Paleontologist: The First Vertebrate Walks on Land at http://shapeoflife.org/video/scientist/jenny-clack-paleontologist-first-vertebrate-walks-land (7:04)

Click on the image above for more content

1.What is a "tetrapod"? What question do paleontologists hope they can answer by studying them?
2.What is special about "Boris"?

Explore More III

•Richard Dawkins: Show me the intermediate fossils! at http://www.youtube.com/watch?v=o92x6AvxCFg (2:34)

1.What evidence is there that modern whales once had hindlimbs?
2.*Pakicetus* and *Rodhocetus* are considered to be ancestors of modern whales. Scientists still argue about how aquatic *Pakicetus* was, but *Rodhocetus* is considered to be a largely aquatic animal.
   a.Where is the nostril located on *Pakicetus* ?
   b.Where is the nostril located on *Rodhocetus* ?
   c.What is the relationship in time between these two species?
3.What modern animal is most closely related to modern whales? What is the evidence? In what kind of environment does this modern relation live?

Review

1.What is a fossil? Give three examples.
2.What has the fossil record revealed about life on Earth?
3.How does radioactive dating work?
4.What is radioactive dating used for?

Structural Evidence for Evo-

Structural Evidence for Evolution

- Explain the evolutionary meaning of having a common ancestor.
- Discuss how vestigial structures and embryology support evolution theory.

Why do you have a tail bone?

If you look closely at a skeleton, you might notice a triangular bone at the end of the spinal column. This is your tailbone. Why would you have a tailbone when you don't have a tail? You have a tailbone because your ancient ancestors *did* have a tail. These sorts of "left-over" structures support the theory of evolution.

Structural Evidence

Even though two different species may not look similar, they may have similar internal structures that suggest they have a **common ancestor** . That means both evolved from the same ancestor organism a long time ago. Common ancestry can also be determined by looking at the structure of the organism as it first develops.

Vestigial Structures

Some of the most interesting kinds of evidence for evolution are body parts that have lost their use through evolution (**Figure** below). For example, most birds need their wings to fly. But the wings of an ostrich have lost their original use. Structures that have lost their use through evolution are called **vestigial structures** . They provide evidence for evolution because they suggest that an organism changed from using the structure to not using the structure, or using it for a different purpose. Penguins also do not use their wings, known as flippers, to fly in the air. However, they do use them to move in the water. The theory of evolution suggests that penguins evolved to use their wings for a different purpose. A whale's pelvic bones, which were once attached to legs, are also vestigial structures. Whales are descended from land-dwelling ancestors that had legs.

Figure 4.13

Moles live underground where they do not need eyes to find their way around. This mole's eyes are covered by skin. Body parts that do not serve their original function are vestigial structures.

Similar Embryos

Some of the oldest evidence of evolution comes from **embryology** , the study of how organisms develop. An embryo is an animal or plant in its earliest stages of development. This means looking at a plant or animal before it is born or hatched. Centuries ago, people recognized that the embryos of many different species have similar appearances. The embryos of some species are even difficult to tell apart. Many of these animals do not differ much in appearance until they develop further.

Some unexpected traits can appear in animal embryos. For example, human embryos have gill slits just like fish! In fish they develop into gills, but in humans they disappear before birth. The presence of the gill slits suggests that a long time ago humans and fish shared a common ancestor.

The similarities between embryos suggests that these animals are related and have common ancestors. For example, humans did not evolve from chimpanzees. But the similarities between the embryos of both species suggest that we have an ancestor in common with chimpanzees. As our common ancestor evolved, humans and chimpanzees went down different evolutionary paths and developed different traits.

Summary

- Vestigial structures, or structures that have lost their use through evolution, are important evidence of evolution.
- Studying the embryos of organisms also provides evidence that two very different animals could have descended from a common ancestor.

Explore More

Use the resource below to answer the questions that follow.

- **Richard Dawkins Vestigial Organs The Wings of the Flightless Cormorant** at http://www.youtube.com/watch?v=jhtOdv6ogyQ (2:19)

1. Are all cormorants flightless?
2. What is the vestigial trait most obvious in the flightless cormorant?
3. How have these birds compensated for their inability to fly?

Review

1. What is a vestigial structure? Give an example.
2. How does embryology provide evidence for evolution?
3. Given an example of a structure that is present in human embryos, but has disappeared by birth.

Section 6

Molecular Evidence for Evo-

Molecular Evidence for Evolution

- •Describe molecular clocks.
- •Explain the molecular evidence for evolution.

How similar are you to a chimpanzee?

Chimpanzees and humans turn out to be very similar—if you look at their DNA. When scientists determined the entire genetic code of both humans and chimpanzees, they found that we have over 98% identical DNA.

Molecular Evidence

Arguably, some of the best evidence of evolution comes from examining the molecules and DNA found in all living things.

Beginning in the 1940s, scientists studying molecules and DNA have confirmed conclusions about evolution drawn from other forms of evidence. **Molecular clocks** are used to determine how closely two species are related by calculating the number of differences between the species' DNA sequences or amino acid sequences. These clocks are sometimes called gene clocks or evolutionary clocks. The fewer the differences, the less time since the species split from each other and began to evolve into different species (**Figure** below). For example, a chicken and a gorilla will have more differences between their DNA and amino acid sequences than a gorilla and an orangutan. That means the chicken and gorilla had a common ancestor a very long time ago, while the gorilla and orangutan shared a more recent common ancestor. This provides additional evidence that the gorilla and orangutan are more closely related than the gorilla and the chicken.

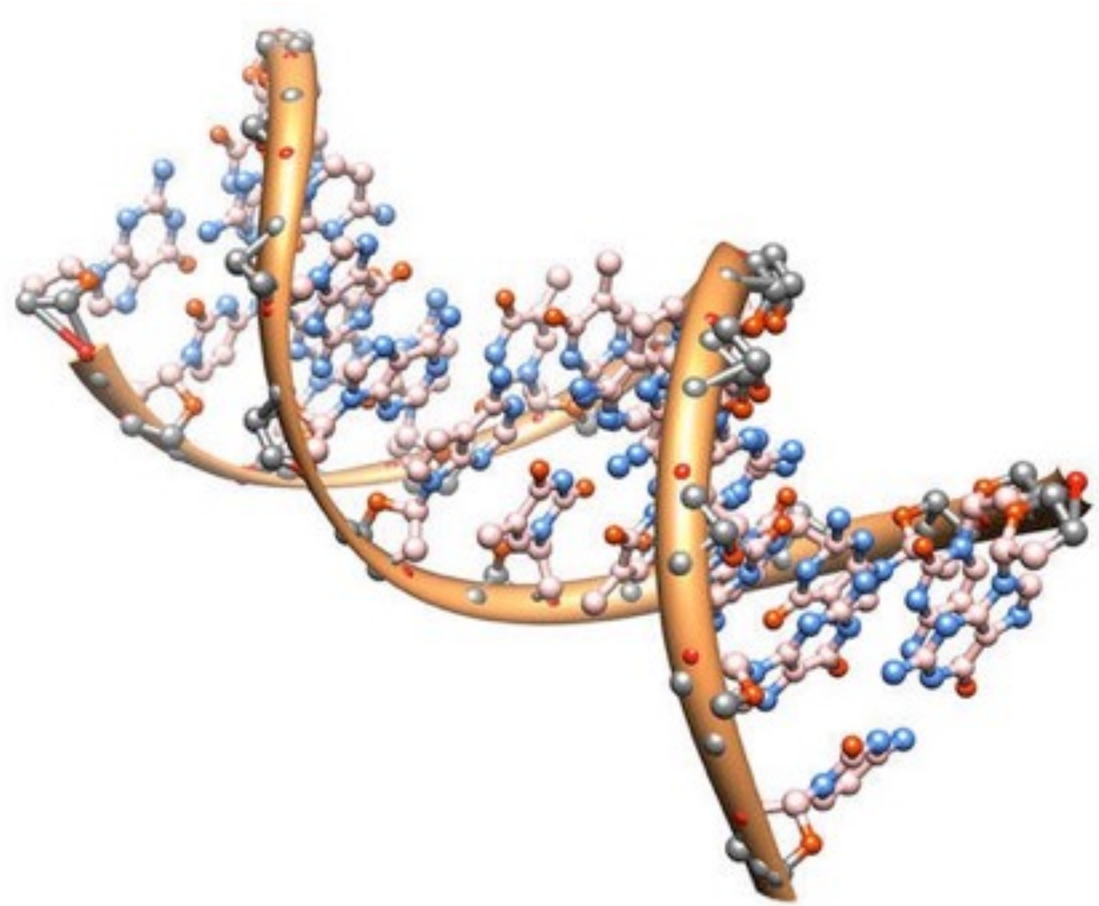


Figure 4.14

Almost all organisms are made from DNA with the same building blocks. The genomes (all of the genes in an organism) of all mammals are almost identical.

The **genomes** , or all the genes of an organism, have been determined for many different organisms. The comparison of genomes provides new information about the relationships among species and how evolution occurs (**Figure** below).

Molecular evidence for evolution also includes:

1. The same biochemical building blocks, such as amino acids and nucleotides, are found in all organisms, from bacteria to plants and animals.
2. DNA and RNA determine the development of all organisms.
3. The similarities and differences between the genomes confirm patterns of evolution.

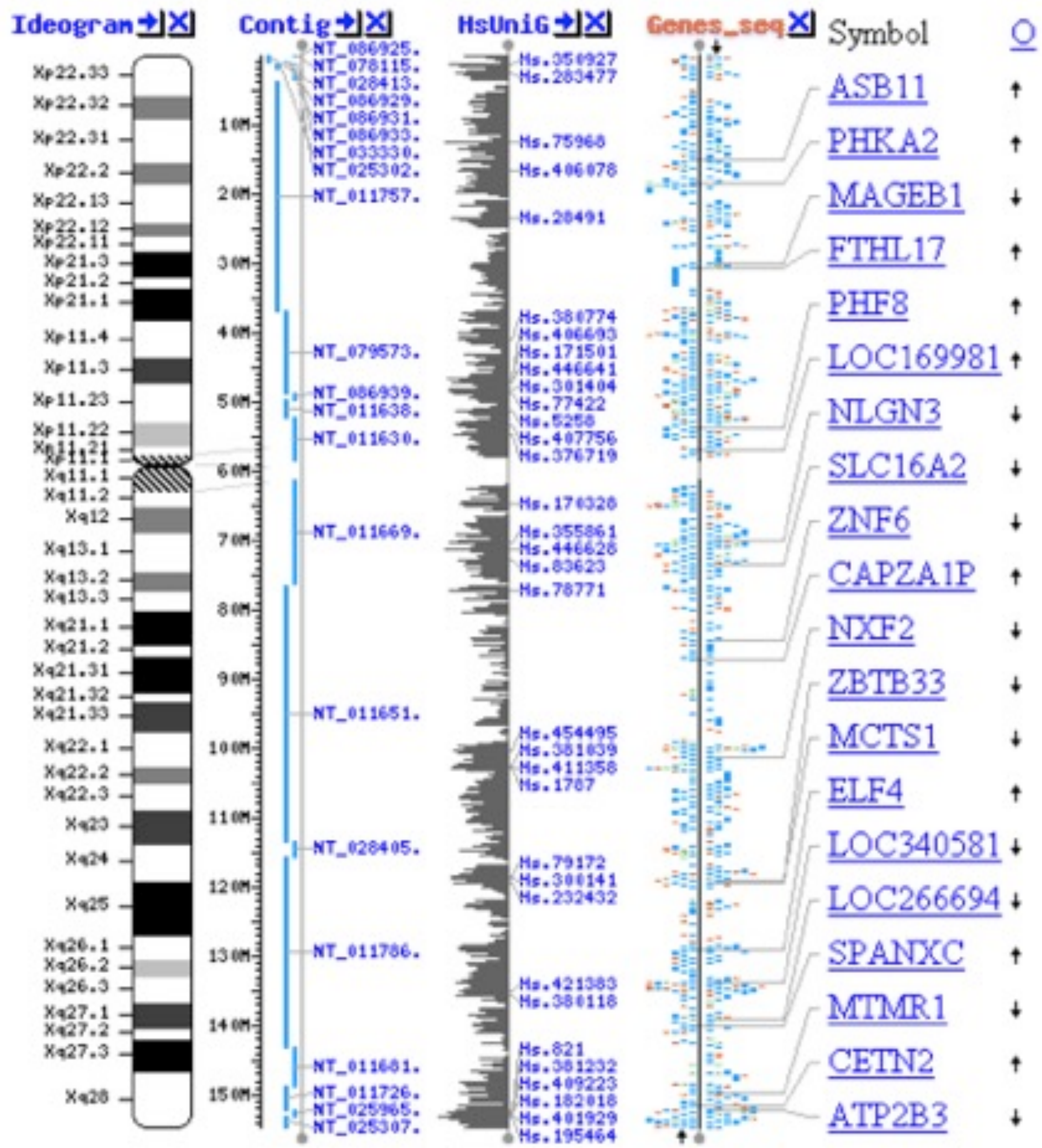


Figure 4.15

This is a map of the genes on just one of the 46 human chromosomes. How does this region of a chromosome compare to similar regions in other species? Similarities and differences between the genomes (the genetic makeup) of different organisms reveal the relationships between the species.

Summary

- Molecular clocks are used to determine how closely two species are related by calculating the number of differences between the species' DNA sequences or amino acid sequences.
- Molecular evidence for evolution includes that all living things share the same biochemical building blocks.

Explore More

Use the resources below to answer the questions that follow.

Explore More I

- **Genes Tell Us About Evolution - Shape of Life** at http://shapeoflife.org/video/other-topics/genetics-genes-tell-us-about-evolution (8:09)

Click on the image above for more content

1. How is the genetic sequence of an organism like a blueprint of that organism?
2. If two organisms have almost identical sequences for the same gene, are they considered closely related?
3. What type of animal have scientists long thought was basal to all other animals? How has genetic analysis affected this view?
4. How has genetic analysis become quicker than it once was? How has that greatly helped with the search for a basal organism?

Explore More II

- **How Genes Direct Development - Shape of Life** at http://shapeoflife.org/video/other-topics/genetics-how-genes-direct-development (6:04)

Click on the image above for more content

1. What is a regulatory gene? How might they explain differences between organisms?
2. What are "hox genes"? What phase of development are they a part of? What organisms have hox genes?
3. If you find a fly with a leg coming out of its head and can identify what happened genetically to cause this, what have you discovered?

Review

1. Explain how scientists use a molecular clock to determine relationships between species.
2. What is a genome?
3. What two species from the following should have the fewest differences in their genomes: chicken, mouse, duck, gorilla?
4. What two species from the following should have the most differences in their genomes: frog, mouse, cow, human?

Section 7

Microevolution and Macro-

Microevolution and Macroevolution

•Define microevolution and macroevolution.
•Distinguish between microevolution and macroevolution.

Why do pesticides sometimes stop working?

Pesticides were designed to kill bothersome insects. However, sometimes these pesticides will stop working. A pesticide that has worked in the past may no longer kill a particular type of insect. This is due to the development of resistance in the population of insects. The development of resistance to pesticides is one example of microevolution, a small change in a population.

Microevolution and Macroevolution

Does evolution only happen gradually through small changes? Or is it possible that drastic environmental changes can cause new species to evolve? Or can both small and large changes occur?

Evolutionary changes can be both big and small. Some evolutionary changes do not create new species, but result in changes at the population level. A **population** is a group of organisms of the same species that live in the same area (**Figure** below). But what exactly is the definition of a species? A **species** is a group of organisms that have similar characteristics (they are genetically similar) and can mate with one another to produce fertile offspring.

Figure 4.16

This school of fish are considered members of the same species because they are able to mate with one another. They are also considered a population because they live in the same part of the ocean.

Microevolution

You already know that evolution is the change in species over time. Most evolutionary changes are small and do not lead to the creation of a new species. When populations change in small ways over time, the process is called **microevolution** .

An example of microevolution is the evolution of mosquitoes that cannot be killed by pesticides, called pesticide-resistant mosquitoes. Imagine that you have a pesticide that kills most of the mosquitoes in your state. Through a random mutation, some of the mosquitoes have resistance to the pesticide. As a result of the widespread use of this pesticide, most of the remaining mosquitoes are the pesticide-resistant mosquitoes. When these mosquitoes reproduce the next year, they produce more mosquitoes with the pesticide-resistant trait. Soon, most of the mosquitoes in your state are resistant to the pesticide.

This is an example of microevolution because the number of mosquitoes with this trait changed. However, this evolutionary change did not create a new species of mosquito because the pesticide-resistant mosquitoes can still reproduce with other non-pesticide-resistant mosquitoes.

Macroevolution

Macroevolution refers to much bigger evolutionary changes that result in new species. Macroevolution may happen:

1. When microevolution occurs repeatedly over a long period of time and leads to the creation of a new species.
2. As a result of a major environmental change, such as a volcanic eruption, earthquake, or an asteroid hitting Earth, which changes the environment so much that natural selection leads to large changes in the traits of a species.

After thousands of years of isolation from each other, Darwin's finch populations have experienced both microevolution and macroevolution. These finch populations cannot breed with other finch populations when they are brought together. Since they do not breed together, they are classified as separate species.

Summary

- •Microevolution is the process by which organisms change in small ways over time.
- •Macroevolution refers to larger evolutionary changes that result in new species.

Explore More

Use the resources below to answer the questions that follow.

Explore More I

•**Microevolution vs. Macroevolution** at http://www.youtube.com/watch?v=jeza0g3E8wE (5:21)

1. How does microevolution differ from macroevolution with regard to species?
2. What are four factors believed to cause microevolution? How do these four factors relate to macroevolution?
3. What happens to the allele frequency of genes in a population that has undergone microevolution?
4. What is phyletic gradualism? How does this differ from "punctuated equilibrium"?

Explore More II

•**Cambrian Explosion - Shape of Life** at http://shapeoflife.org/video/other-topics/cambrian-explosion (13:07)

Click on the image above for more content

1. What was the Cambrian Explosion? When did it occur?
2. Do you think the Cambrian Explosion represents microevolution or macroevolution? Explain your reasoning.
3. What are some of the ideas about the cause of the Cambrian Explosion?
4. How much similarity can be seen between the current body plans of organisms and the body plans seen in fossils from the Cambrian Period?

Review

1. How do you know if two related organisms are members of the same species?
2. Compare and contrast microevolution and macroevolution.
3. Does microevolution lead to a new species? Why or why not?
4. What is the outcome of many microevolution events?

Section 8

Evolution Acts on the Pheno-

Evolution Acts on the Phenotype

•Define carrier.
•Explain how an unfavorable allele is kept in the gene pool.

Would albinism be an advantage?

This rabbit is albino, meaning it lacks pigment in its skin, fur, and eyes. The same thing happens in other species, including humans. To most animals albinism would be a disadvantage since they need to blend into their environment to avoid predators or catch prey. How, then, does the gene that causes albinism stay in the gene pool?

Evolution Acts on the Phenotype

Natural selection acts on the **phenotype** (the traits or characteristics) of an individual. On the other hand, natural selection does not act on the underlying **genotype** (the genetic makeup) of an individual. For many traits, the homozygous genotype, *AA* , for example, has the same phenotype as the heterozygous *Aa* genotype. If both an *AA* and *Aa* individual have the same phenotype, the environment cannot distinguish between them. So natural selection cannot select for a homozygous individual over a heterozygous individual. Even if the "aa" phenotype is lethal, the recessive *a* allele, will be maintained in the population through heterozygous *Aa* individuals. Furthermore, the mating of two heterozygous individuals can produce homozygous recessive (*aa*) individuals.

Carriers

Since natural selection acts on the phenotype, if an allele causes death in a homozygous individual, *aa* , for example, it will not cause death in a heterozygous *Aa* individual. These heterozygous *Aa* individuals will then act as **carriers** of the *a* allele, meaning that the *a* allele could be passed down to offspring. This allele is said to be kept in the population's gene pool. The **gene pool** is the complete set of alleles within a population.

For example, Tay-Sachs disease is a recessive human genetic disorder. That means only individuals with the homozygous recessive genotype, *rr* will be affected. Affected individuals usually die from complications of the disease in early childhood. The two parents are each heterozygous (*Rr*) for the Tay-Sachs gene; they will not die in childhood and will be carriers of the disease gene. This deadly allele is kept in the gene pool even though it does not help humans adapt to their environment. This happens because evolution acts on the phenotype, not the genotype (**Figure** below).

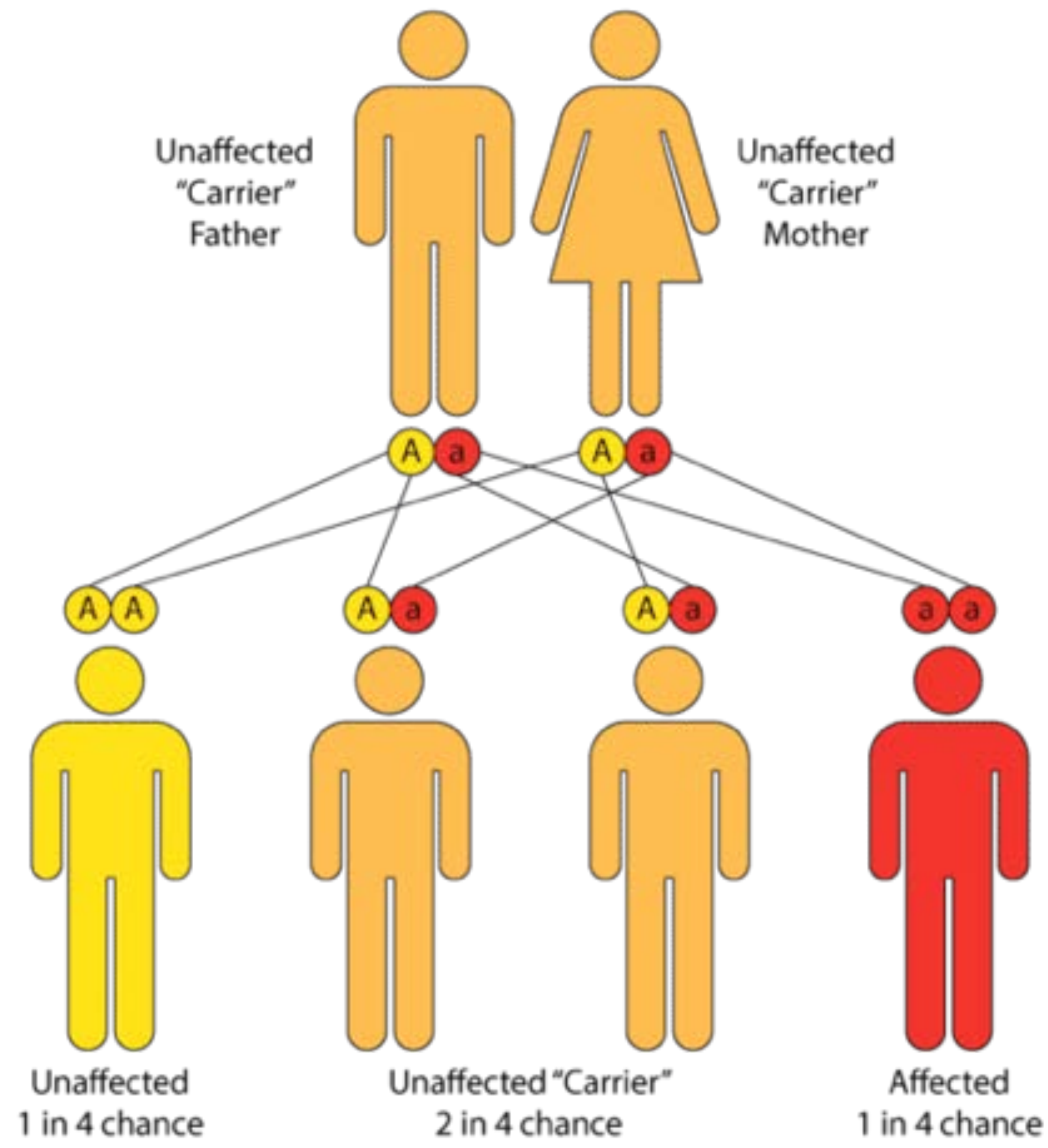


Figure 4.17

Tay-Sachs disease is inherited in the autosomal recessive pattern. Each parent is an unaffected carrier of the lethal allele.

Summary

- Natural selection acts on the phenotype (the traits or characteristics) of an individual, not on the underlying genotype.
- Carriers of a trait can show no symptoms of a recessive disease and, yet, still pass it on to their offspring.

Explore More

Use the resource below to answer the questions that follow.

- **Harmful Genes** at http://www.newton.dep.anl.gov/askasci/mole00/mole00460.htm .

1. What would happen if a harmful gene were dominant?
2. Give an example of a harmful recessive gene that provides carriers with an advantage.
3. How can a harmful gene "hide"?

Review

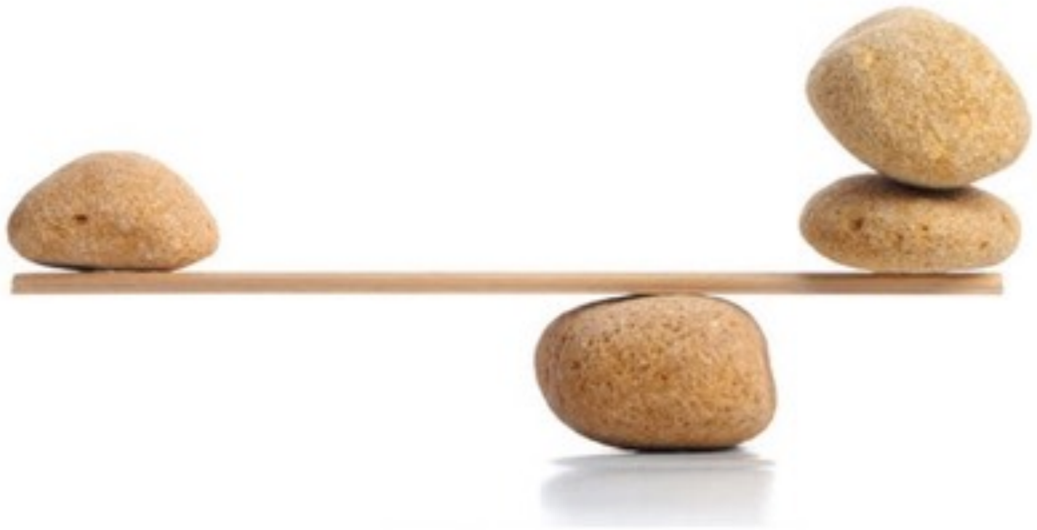
1. What's the difference between phenotype and genotype?
2. Does natural selection act on the genotype or phenotype?
3. Explain how a lethal recessive gene can stay in the gene pool.

Section 9

Hardy-Weinberg Theorem

Hardy-Weinberg Theorem

•Define genetic equilibrium.
•List the five conditions necessary for genetic equilibrium.
•Explain the Hardy-Weinberg model.



Can these stones keep balance indefinitely?

If balance, or equilibrium, is to be maintained, there must be no outside influences on the stones. Equilibrium can also be maintained within a population's genes; that means, no evolution can occur. But outside influences usually prevent equilibrium from staying established.

Hardy-Weinberg Equilibrium

Sometimes understanding how common a gene is within a population is necessary. Or, more specifically, you may want to know how common a certain form of that gene is within the population, such as a recessive form. This can be done using the Hardy-Weinberg model, but it can only be done if the frequencies of the genes are not changing.

The **Hardy-Weinberg model** describes how a population can remain at **genetic equilibrium** , referred to as the Hardy-Weinberg equilibrium. Genetic equilibrium occurs when there is no evolution within the population. In other words, the frequency of **alleles** (variants of a gene) will be the same from one generation to another. For example, let's assume that red hair is determined by the inheritance of a gene with two alleles— *R* and *r* . The dominant allele, *R* , encodes for non-red hair, while the recessive allele, *r* , encodes for red hair. If a population's **gene pool** contains 90% *R* and 10% *r* alleles, then the next generation would also have 90% *R* and 10% *r* alleles. However, this only works under a strict set of conditions.

The five conditions that must be met for genetic equilibrium to occur include:

1. No change in the DNA sequence.
2. No **migration** (moving into or out of a population).

3. A very large population size.
4. Random mating.
5. No natural selection.

These five conditions rarely occur in nature. When one or more of the conditions does not exist, then evolution can occur. As a result, allele frequencies are constantly changing, and populations are constantly evolving.

The Hardy-Weinberg model also serves a mathematical formula used to predict allele frequencies in a population at genetic equilibrium. If you know the allele frequencies of one generation, you can use this formula to predict the next generation. Again, this only works if all five conditions are being met in a population.

Summary

- If a population stays at genetic equilibrium, then no evolution takes place.
- The Hardy-Weinberg model states that a population will remain at genetic equilibrium as long as five conditions are met: (1) No change in the DNA sequence, (2) No migration, (3) A very large population size, (4) Random mating, and (5) No natural selection.

Explore More

Use the resource below to answer the questions that follow.

- **Hardy-Weinberg Equilibrium Model** at http://anthro.palomar.edu/synthetic/synth_2.htm .

1. What is happening when there is a change in the frequencies of alleles in the gene pool of a population?
2. Is it likely for gene pool frequencies to remain unchanged?
3. List four conditions that must be met for evolution not to occur.
4. In the Hardy-Weinberg equation, what does p represent?

Review

1. What is an allele?
2. What is meant by genetic equilibrium?
3. What conditions are required for the Hardy-Weinberg model to apply?
4. Why is Hardy-Weinberg equlilibrium unlikely?

Section 10

Origin of Species

Origin of Species

- Define speciation.
- Describe artificial selection.
- Summarize outcomes of reproductive isolation.
- Distinguish allopatric speciation from sympatric speciation.

Where did this diversity of life come from?

If you have ever been to the beach, then you realize there is not just one species of marine life. The wide variety of shells that wash up on the beach indicate that there are many forms of life in the ocean. This wide diversity of life requires that many new species have appeared over time. But how does a new species come into being?

The Origin of Species

The creation of a new species is called **speciation** . Most new species develop naturally. But humans have also artificially created new breeds and species for thousands of years.

New species develop naturally through the process of **natural selection** . Due to natural selection, organisms with traits that better enable them to adapt to their environment will tend to survive and reproduce in greater numbers. Natural selection causes beneficial heritable traits to become more common in a population and unfavorable heritable traits to become less common. For example, a giraffe's neck is beneficial because it allows the giraffe to reach leaves high in trees. Natural selection caused this beneficial trait to become more common than short necks.

As new changes in the DNA sequence are constantly being generated in a population's gene pool, some of these changes will be beneficial and result in traits that allow adaptation and survival. Natural selection causes evolution of a species as these beneficial traits become more common within a population.

Artificial Selection

Artificial selection occurs when humans select which plants or animals to breed in order to pass on specific traits to the next generation. For example, a farmer may choose to breed only cows that produce the best milk. Farmers would also avoid breeding cows that produce less milk. In this way, selective breeding of the cows would increase milk quality and quantity.

Humans have also artificially bred dogs to create new breeds (**Figure** below).

Figure 4.18

Artificial Selection: Humans used artificial selection to create these different breeds. Both dog breeds are descended from the same wolves, and their genes are almost identical.

Reproductive Isolation

There are two main ways that speciation happens naturally. Both processes create new species by reproductively isolating populations of the same species from each other. Organisms can be geographically isolated or isolated by a behavior. Either way, they will no longer be able to mate. Over a long period of time, usually thousands of years, each of the isolated populations evolves in a different direction, forming distinct species.

How do you think scientists test whether two populations are separate species? They bring species from two populations back together again. If the two populations do not mate and produce fertile offspring, they are separate species.

Geographic Isolation

Allopatric speciation occurs when groups from the same species are geographically isolated for long periods. Imagine all the ways that plants or animals could be isolated from each other:

- Emergence of a mountain range.
- Formation of a canyon.
- New rivers or streams.

Here are two examples of allopatric speciation:

- Darwin observed thirteen distinct finch species on the Galápagos Islands that had evolved from the same ancestor. Different finch populations lived on separate islands with different environments. They evolved to best adapt to those particular environments. Later, scientists were able to determine which finches had evolved into distinct species by bringing members of each population together. The birds that could not mate were a separate species.

•When the Grand Canyon in Arizona formed, two populations of one squirrel species were separated by the giant canyon. After thousands of years of isolation from each other, the squirrel populations on the northern wall of the canyon looked and behaved differently from those on the southern wall (**Figure** below). North rim squirrels have white tails and black bellies. Squirrels on the south rim have white bellies and dark tails. They cannot mate with each other, so they are different species.

Figure 4.19

Abert squirrel (*left*) on the southern rim of the Grand Canyon. Kaibab squirrel (*right*) found on northern rim of the Grand Canyon.

Isolation without Physical Separation

Sympatric speciation occurs when groups from the same species stop mating because of something other than physical or geographic separation. The behavior of two groups that live in the same region is an example of such separation. The separation may be caused by different mating seasons, for example. Sympatric speciation is more difficult to identify.

Here are two examples of sympatric speciation:

•Some scientists suspect that two groups of orcas (killer whales) live in the same part of the Pacific Ocean part of the year but do not mate. The two groups hunt different prey species, eat different foods, sing different songs, and have different social interactions (**Figure** below).

•Two groups of Galápagos Island finch species lived in the same space, but each had his or her own distinct mating signals. Members of each group selected mates according to different beak structures and bird calls. The behavioral differences kept the groups separated until they formed different species.

Figure 4.20

Scientists suspect that two types of orca whales live in the same part of the Pacific Ocean for part of the year, but they do not mate.

Summary

- Speciation, the creation of a new species, can happen through natural selection or artificial selection.
- Reproductive isolation is necessary for speciation to occur, and this can happen through a geographic barrier (allopatric speciation) or without a geographic barrier (sympatric speciation).
- Different behaviors can result in sympatric speciation.

Explore More

Use the resources below to answer the questions that follow.

Explore More I

- **Allopatric Speciation** at http://www.pbs.org/wgbh/evolution/library/05/2/l_052_03.html .

1. What is allopatric speciation?
2. Give two examples of events that can cause physical separation of members of a population?
3. How did scientists determine if the shrimp were two different species?

Explore More II

- **Richard Dawkins: Diatoms: The Evolution of a New Species** at http://www.youtube.com/watch?v=EUozZo8nOpY (2:10)

1. What is a diatom?
2. Where is *Stephanodiscus yellowstonensis* found?
3. What technique did scientists use to determine what diatoms occurred historically in the lake where *Stephanodiscus yellowstonensis* now occurs?
4. What were the environmental conditions when *Stephanodiscus niagarae* lived in the lake?
5. What has happened to the diatoms in the lake as the climate has changed over the last 14,000 years?

Review

1. Compare and contrast natural selection and artificial selection.
2. What is meant by reproductive isolation?

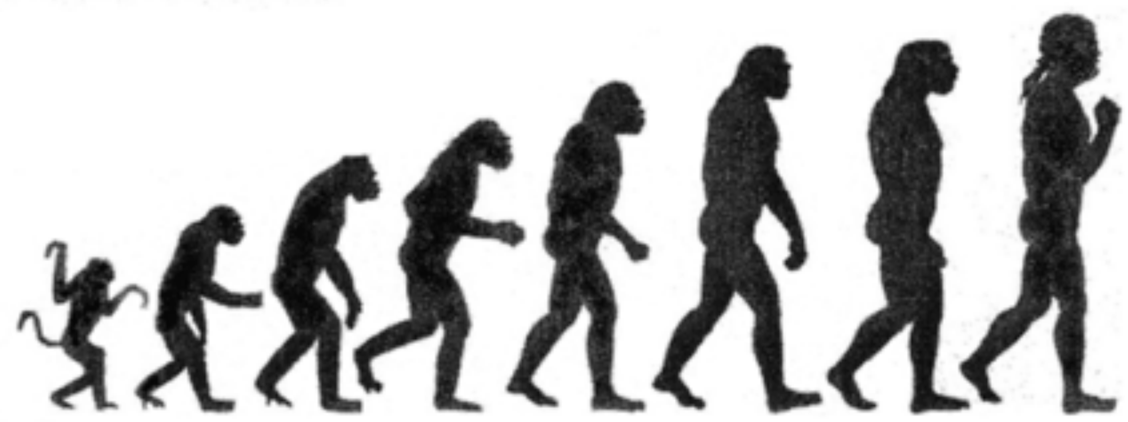
3.Compare and contrast allopatric speciation and sympatric speciation.

Section 11

Tracing Evolution

Tracing Evolution

- •Explain the rate of evolution.
- •Describe an evolutionary tree.



Can you watch evolution happening?

Usually evolutionary changes occur at a very slow pace. Human evolution took millions of years. However, sometimes evolution can also happen quite quickly.

Tracing Evolution

How fast is evolution? Can you actually see evolution happening within your lifetime? Usually evolution takes a long time. So how can we visualize how it has happened?

Rates of Evolution

How long did it take for the giraffe to develop a long neck? How long did it take for the Galápagos finches to evolve? How long did it take for whales to evolve from land mammals? These, and other questions about the rate of evolution, are difficult to answer.

The **rate of evolution** depends on how many of an organism's genes have changed over a period of time. Evolution is usually so gradual that we do not see the change for many, many generations.

Not all organisms evolve at the same rate. Humans took millions of years to evolve from a mammal that is now extinct. It is very difficult to observe evolution in humans. However, there are organisms that are evolving so fast that you can observe evolution! A human takes about 22 years to go through one generation. But some bacteria go through over a thousand generations in less than two months. Some bacteria go through many generations in a few days. And sometimes a bacterial generation is as fast as 20 minutes! We can actually trace their evolution as it is happening.

Evolutionary Trees

If evolution can take a very long time, how can we visualize how it happens? Charles Darwin came up with the idea of an **evolutionary tree** to represent the relationships between different species and their common ancestors (**Figure** below). The base of the tree represents the ancient ancestors of all life. The separation into large branches shows where these original species evolved into new species.

The branches keep splitting into smaller and smaller branches as species continue to evolve into more and more species. Some species are represented by short twigs spurting out of the tree, then stopping. These are species that went extinct before evolving into new species. Other "Trees of Life" have been created by other scientists (**Figure** below).

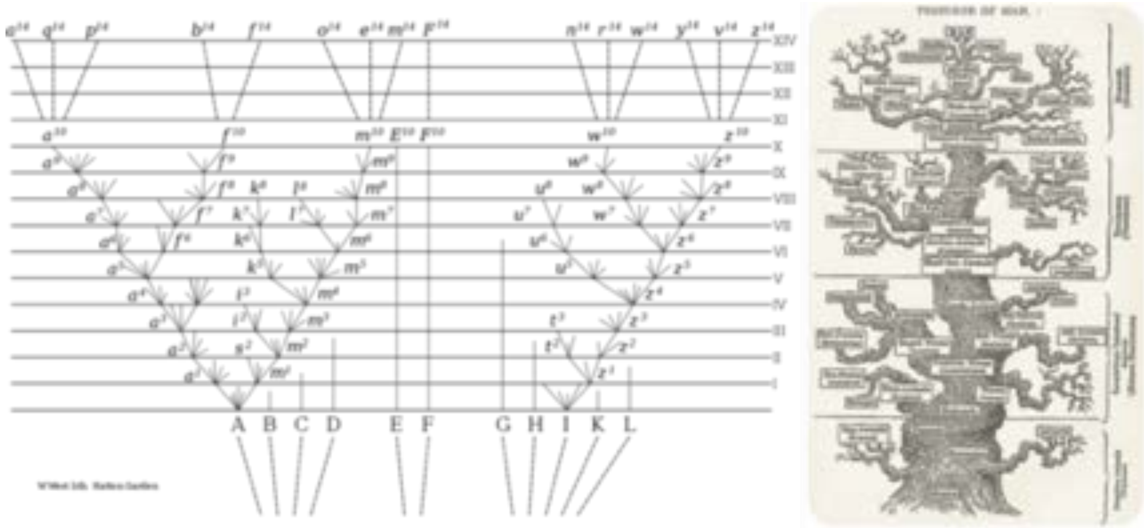


Figure 4.21

Darwin drew this version of the "Tree of Life" on the left to represent how species evolve and diverge into separate directions. Each point on the tree where one branch splits off from another represents the common ancestor of the species on the separate branches. Scientists have drawn many different versions of the "Tree of Life" to show different features of evolution. The Tree of Life on the right was made by Ernst Haeckel in 1879.

Summary

- Evolution is usually so gradual that we do not see the change for many, many generations.
- An evolutionary tree can be drawn to visualize the relationships between different species and their common ancestors.

Explore More

Use the resource below to answer the following questions.

- **Richard Dawkins: Why are there still Chimpanzees?** at http://www.youtube.com/watch?v=wh0F4FBLJRE (1:47)

1. Are we descended from chimpanzees? Explain your answer.
2. When reading an evolutionary tree, what does it mean if two species are very close on the tree?
3. What does it mean if two species are very far apart on a tree?
4. What five species comprise the Great Apes?

Review

1. How fast is evolution?
2. What is the purpose of an evolutionary tree?
3. Who came up with the idea for the evolutionary tree?

Section 12

Origins of Life

Origins of Life

•Describe the conditions of the early atmosphere.
•Explain how the first organic molecules and cells arose.

What did the first life forms look like?

The first forms of life on Earth were probably smaller and simpler than even these bacteria. The first forms of life had to be simple single-celled organisms.

Origin of Life

Fossils of blue-green algae found in Australia are the oldest fossils of life forms on Earth. They are at least 3.5 billion years old (**Figure** below).

How did life begin? In order to answer this question, scientists need to know what kinds of materials were available at that time. We know that the ingredients for life were present at the beginning of Earth's history. Scientists believe early Earth did not contain oxygen gas, but did contain other gases, including:

•nitrogen,
•carbon dioxide,
•carbon monoxide,
•water vapor,
•hydrogen sulfide.

Where did these ingredients come from? Some chemicals were in water and volcanic gases (**Figure** below). Other chemicals would have come from meteorites in space. Energy to drive chemical reactions was provided by volcanic eruptions and lightning. Today, we have evidence that life on Earth came from reactions between chemical compounds, which formed **molecules** , or groups of atoms bonded together. Small molecules, such as those present in the early atmosphere, can provide the components (including the elements C, H, N, O and S) to make larger molecules. These early molecules further reacted and eventually formed even larger molecules and **organic compounds** , such as amino acids (and then proteins), and nucleotides (which form nucleic acids - RNA or DNA). These molecules eventually came together in the right combinations to form basic cells. The components that were necessary for the formation of the first cells are still being studied.

How long did it take to develop the first life forms? As much as 1 billion years. Many scientists still study the origin of the first life forms because there are many questions left unanswered, such as, "Did proteins or nucleic acids develop first?" or "What exactly were early Earth's atmospheric conditions like?" There is a lot of work still left to answer these and similar questions.

Figure 4.22

Some clues to the origins of life on Earth come from studying the early life forms that developed in hot springs, such as the Grand Prismatic Spring at Yellowstone National Park. This spring is approximately 250 feet deep and 300 feet wide.

Summary

- Life has probably existed on Earth for most of Earth's history.
- Life on Earth came from reactions between chemical compounds, which formed molecules.

Explore More

Use the resource below to answer the questions that follow.

- **Thrombolites Differ From Stromatolites** at http://www.youtube.com/watch?v=liKu6rC80gU (6:24)

Click on the image above for more content

1. What are the environmental conditions like in Shark Bay? How does this differ from other oceanic conditions?
2. What type of organism do scientists believe was responsible for the increase in oxygen (O_2) in the Earth's atmosphere?
3. What types of structures did these organisms build that scientists are studying today? How old are the oldest of these structures?
4. When did the abundance of stromatolites go into decline? What else happened at this time?
5. What are thrombolites? How do they differ from stromatolites?

Review

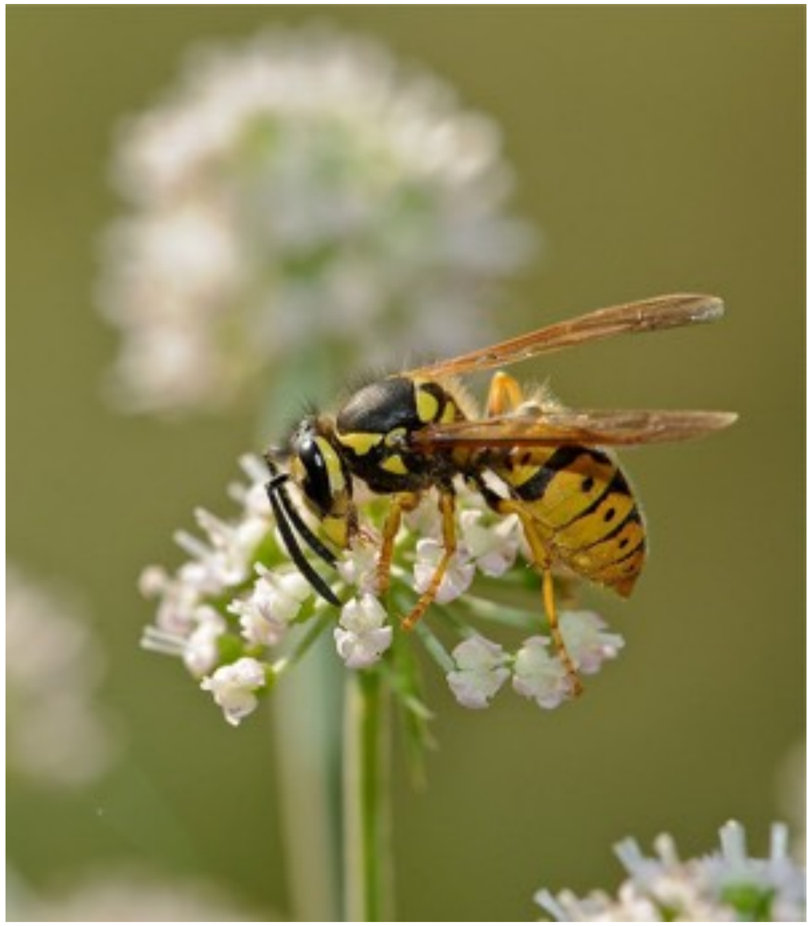
1. How did life on Earth begin?
2. Describe how the early atmosphere of Earth was different than it is today.
3. List three gases present in the early atmosphere.
4. How long did it take to develop the first life forms?

Section 13

Timeline of Evolution

Timeline of Evolution

•Define geologic time scale.
•Outline the age of the Earth and the basic timeline of the development life on Earth.



Which was first, the insect or the flower?

Although the land plants were here before insects, the first flowers evolved long after the first insects. The first land plants did not have flowers. Today insects and flowers are so interconnected, it's hard to imagine one without the other.

Timeline of Evolution

For life to evolve from simple single-celled organisms to many millions of species of prokaryotic species to simple eukaryotic species to all the protists, fungi, plants, and animals, took some time. Well over 3 billion years.

The Age of Earth

How old is Earth? How was it formed? How did life begin on Earth? These questions have fascinated scientists for centuries. During the 1800s, geologists, paleontologists, and naturalists found several forms of physical evidence that confirmed that Earth is very old.

The evidence includes:

•Fossils of ancient sea life on dry land far from oceans. This supported the idea that the Earth changed over time and that some dry land today was once covered by oceans.
•The many layers of rock. When people realized that rock layers represent the order in which rocks and fossils appeared, they were able to trace the history of Earth and life on Earth.
•Indications that volcanic eruptions, earthquakes, and erosion that happened long ago shaped much of the

Earth's surface. This supported the idea of an older Earth.

The Earth is at least as old as its oldest rocks. The oldest rock minerals found on Earth so far are crystals that are at least 4.404 billion years old. These tiny crystals were found in Australia. Likewise, Earth cannot be older than the solar system. The oldest possible age of Earth is 4.57 billion years old, the age of the solar system. Therefore, the age of Earth is between 4.4 and 4.57 billion years.

Geologic Time Scale

Geologists and other Earth scientists use **geologic time scales** to describe when events happened in the history of Earth. The time scales can be used to show when both geologic events and events affecting plant and animal life occurred. The geologic time scale pictured below (**Figure** below) illustrates the timing of events like:

- Earthquakes.
- Volcanic eruptions.
- Major erosion.
- Meteorites hitting Earth.
- The first signs of life forms.
- Mass extinctions.

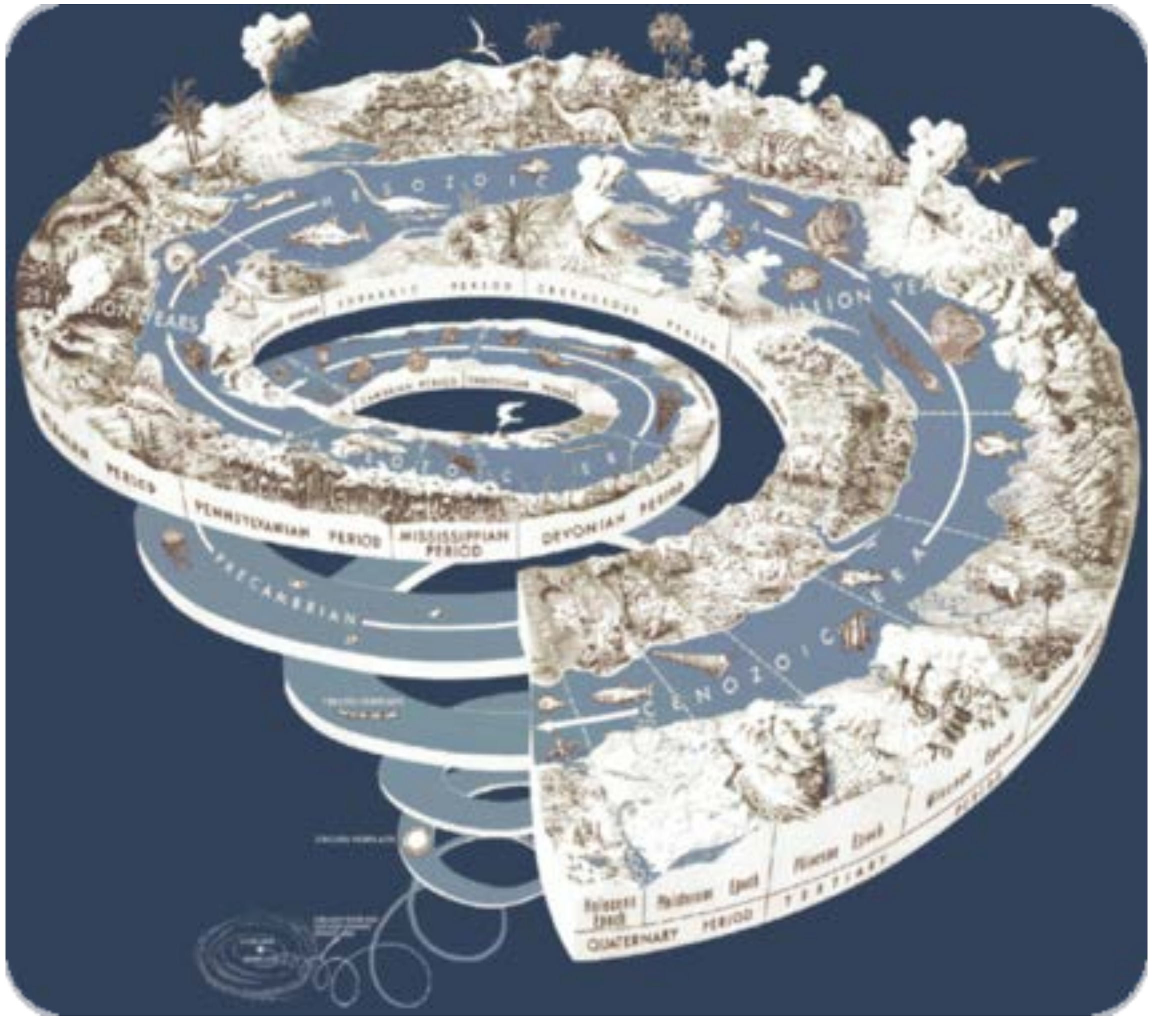


Figure 4.23

The geologic time scale of Earth's past is organized according to events that took place during different periods on the time scale. Geologic time is the same as the age of the Earth: between 4.404 and 4.57 billion years. Look closely for such events as the extinction of dinosaurs and many marine animals.

Evolution of Major Life Forms

Life on Earth began about 3.5 to 4 billion years ago. The first life forms were single-celled organisms similar to bacteria. The first multicellular organisms did not appear until about 610 million years ago. Many different types of organisms evolved during the next ten million years, in an event called the **Cambrian Explosion** . This sudden burst of evolution may have been caused by some environmental changes that made the Earth's environment more suitable for a wider variety of life forms.

Plants and fungi did not appear until roughly 500 million years ago. They were soon followed by arthropods (insects and spiders). Next came the amphibians about 300 million years ago, followed by mammals around 200 million years ago and birds around 100 million years ago.

Even though large life forms have been very successful on Earth, most of the life forms on Earth today are still prokaryotes—small, relatively simple single-celled organisms. Fossils indicate that many organisms that lived long ago are extinct. Extinction of species is common; in fact, it is estimated that 99% of the species that have ever lived on Earth no longer exist.

The basic timeline of a 4.6 billion-year-old Earth includes the following:

•About 3.5 - 3.8 billion years of simple cells (prokaryotes).
•3 billion years of photosynthesis.
•2 billion years of complex cells (eukaryotes).
•1 billion years of multicellular life.
•600 million years of simple animals.
•570 million years of arthropods (ancestors of insects, arachnids and crustaceans).
•550 million years of complex animals.
•500 million years of fish and proto-amphibians.
•475 million years of land plants.
•400 million years of insects and seeds.
•360 million years of amphibians.
•300 million years of reptiles.
•200 million years of mammals.
•150 million years of birds.
•130 million years of flowers.
•65 million years since the non-avian dinosaurs died out.
•2.5 million years since the appearance of *Homo* .
•200,000 years since the appearance of modern humans.
•25,000 years since *Neanderthals* died out.

Summary

•The age of Earth is between 4.4 and 4.57 billion years.
•Life on Earth began about 3.5 to 4 billion years ago, and the first life forms were single-celled organisms similar to bacteria.

Explore More

Use the resource below to answer the questions that follow.

•***Anomalocaris* - Shape of Life** at http://shapeoflife.org/video/other-topics/paleontology-new-evidence-revises-thinking-anomalocaris (4:09)

Click on the image above for more content

1. Most fossils found are not of complete organisms. How have scientists responded to this situation? What challenges has this presented?
2. What were some of the theories as to what type of animal *Anamolcaris* was? What happened to cause these theories to be abandoned?
3. How is *Anamalocaris* an example of the scientific process?

Review

1. What is a significant piece of evidence that was used in the 1800s to suggest Earth is very old?
2. Relative to the length of time life has been on Earth, have modern humans appeared recently or in the distant past?
3. What types of geological events help define geological time scales?
4. When did life on Earth begin? What was the first form of life?
5. What was the Cambrian Explosion?

Section 14

Mass Extinctions

Mass Extinctions

•Define mass extinction.
•Give examples of mass extinctions.
•Describe the importance of the mass extinction dated at 65.5 million years ago.

What happened to the dinosaurs?

Most of the dinosaurs disappeared from Earth about 65 million years ago. This is probably the most famous example of a mass extinction. So how do you define a mass extinction?

Mass Extinctions

An organism goes extinct when all of the members of a species die out and no more members remain. **Extinctions** are part of natural selection. Species often go extinct when their environment changes, and they do not have the traits they need to survive. Only those individuals with the traits needed to live in a changed environment survive (**Figure** below).

Figure 4.24

Humans have caused many extinctions by introducing species to new places. For example, many of New Zealand's birds have adapted to nesting on the ground. This was possible because there were no land mammals in New Zealand. Then Europeans arrived and brought cats, foxes, and other predators with them. Several of New Zealand's ground nesting birds, such as this flightless kiwi, are now extinct or threatened because of these predators.

Mass extinctions , such as the extinction of dinosaurs and many marine mammals, happened after major catastrophes such as volcanic eruptions and earthquakes (**Figure** below).

Figure 4.25

The fossil of Tarbosaurus, one of the land dinosaurs that went extinct during one of the mass extinctions.

Since life began on Earth, there have been several major mass extinctions. If you look closely at the geological time scale, you will find that at least five major mass extinctions have occurred in the past 540 million years. In each mass extinction, over 50% of animal species died. The total number of mass extinctions could be as high as 20.

Two of the largest extinctions are described below:

•At the end of the Permian Period, about 99.5% of individual organisms went extinct! Up to 95% of marine species perished, compared to “only” 70% of land species. Some scientists theorize that the extinction was caused by the formation of **Pangaea,** or one large continent made out of many smaller ones. One large continent has a smaller shoreline than many small ones, so reducing the shoreline space may have caused much of the marine life to go extinct (**Figure** below).

Figure 4.26

The supercontinent Pangaea encompassed all of today’s continents in a single land mass. This configuration limited shallow coastal areas which harbor marine species. This may have contributed to the dramatic event which ended the Permian—the most massive extinction ever recorded.

•At the end of the Cretaceous Period, or 65 million years ago, all dinosaurs (except those which led to birds) went extinct. Some scientists believe a possible cause is a collision between the Earth and a comet or asteroid. The collision could have caused tidal waves, changed the climate, and reduced sunlight by 10-20%. A decrease in photosynthesis would have resulted in less plant food, leading to the extinction of the dinosaurs.

Evidence for the extinction of dinosaurs by asteroid includes an iridium-rich layer in the Earth, dated at 65.5 million years ago. Iridium is rare in the Earth’s crust but common in comets and asteroids. Maybe the asteroid that hit the Earth left the iridium behind.

After each mass extinction, new species develop to fill the habitats where old species lived. This is well documented in the fossil record.

Summary

•Extinctions, when a species entirely dies out, can happen when the environment changes, and the organisms do not have the traits they need to survive.
•Since life began on Earth, there have been at least five major massive extinctions.

Explore More

Use the resource below to answer the questions that follow.

•**Mass Extinctions - PBS** at http://www.pbs.org/wgbh/nova/earth/mass-extinction.html (13:14)

Click on the image above for more content

1. What is a mass extinction? How many have occurred in the last 600 million years?
2. What are some of the reasons proposed for mass extinctions?
3. Which event wiped out 95% of animal species in the oceans? When did this occur?
4. How do scientists think the activity of the "Siberian Traps" changed the chemistry of the oceans?
5. How does the temperature of water affect how much gas can be dissolved in it?
6. How did the changing ocean environment lead to a mass extinction?

Review:

1. Why do species sometimes go extinct?
2. What is a mass extinction?
3. What may have caused the mass extinction that killed the dinosaurs, and what is the evidence?

Summary

Evolution focuses on past life forms and how they turned into present life forms. The history of life on Earth demonstrates how the first cells formed, turned into simple life forms, and then became more complex plants and animals. The studies of Charles Darwin have reshaped and influenced all aspects of biology. The vast amounts of evidence of evolution demonstrates the importance of the theory of evolution by natural selection. But has this process stopped? Of course not. Evolution does continue today.

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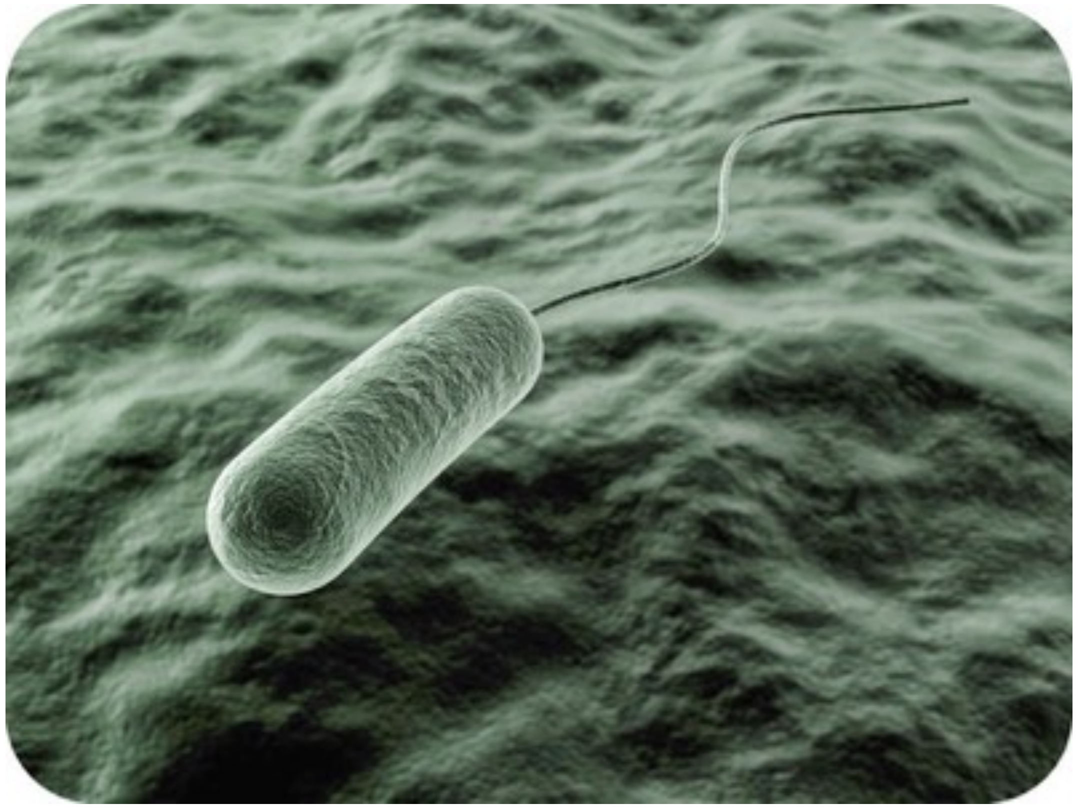
Prokaryotes

Introduction



What are the most numerous organisms on the planet?

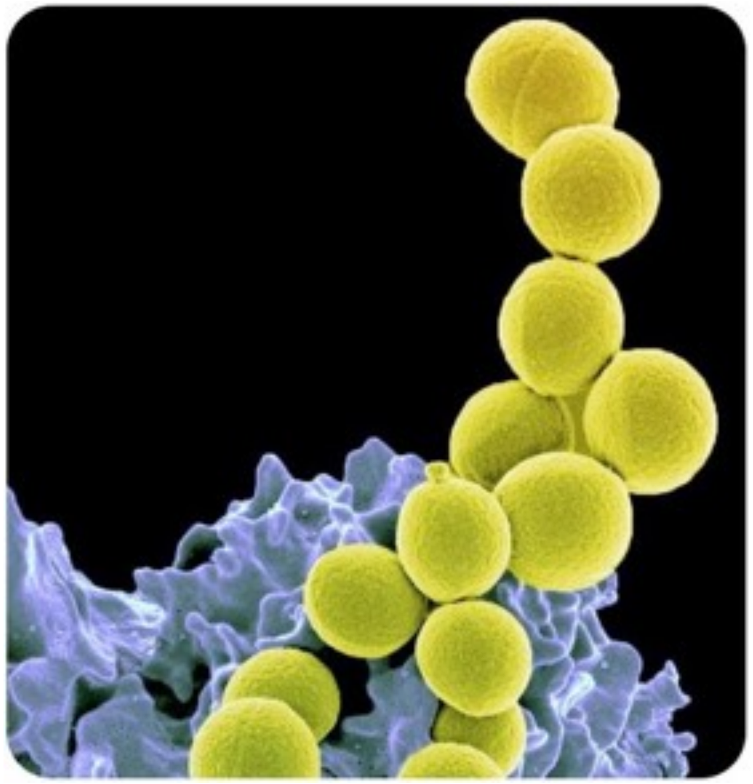
The single-celled prokaryotic organism otherwise known as bacteria. And all it takes is one to quickly grow, under just the right conditions, into millions and billions. Luckily, we know how to control bacteria when necessary. But bacteria do serve many important purposes. In fact, we could not survive without them.

Section 1

Bacteria Characteristics

Bacteria Characteristics

- •Describe common bacterial shapes.
- •Summarize the similarities between bacterial cells and eukaryotic cells.
- •Summarize the differences between bacterial cells and eukaryotic cells.
- •Explain the roles of the cell wall and the flagella in bacteria.



Are bacteria living things?

Bacteria are individual living cells. Bacteria cells are similar to your cells in many ways; yet, they also have distinct differences. Bacteria have many unique adaptations allowing them to live in many different environments.

Characteristics of Bacteria

Bacteria are the most successful organisms on the planet. They lived on this planet for two billion years before the first eukaryotes and, during that time, evolved into millions of different species.

Size and Shape

Bacteria are so small that they can only be seen with a microscope. When viewed under the microscope, they have three distinct shapes (**Figure** below). Bacteria can be identified and classified by their shape:

1. **Bacilli** are rod-shaped.
2. **Cocci** are sphere-shaped.
3. **Spirilli** are spiral-shaped.

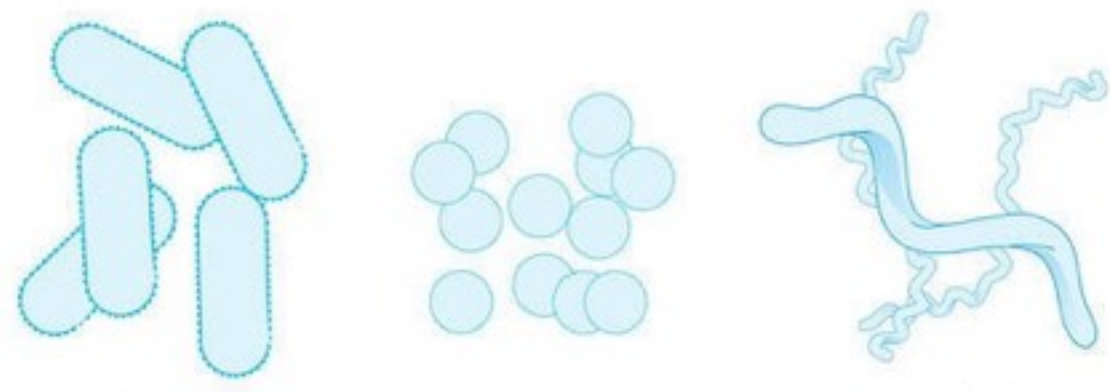


Figure 5.1

Bacteria come in many different shapes. Some of the most common shapes are bacilli (rods), cocci (spheres), and spirilli (spirals). Bacteria can be identified and classified by their shape.

Similarities to Eukaryotes

Like eukaryotic cells, bacterial cells have:

1. Cytoplasm, the fluid inside the cell.
2. A plasma or cell membrane, which acts as a barrier around the cell.
3. Ribosomes, in which proteins are put together.
4. DNA. By contrast though, bacterial DNA is contained in a large, circular strand. This single chromosome is located in a region of the cell called the **nucleoid** . Many bacteria also have additional small rings of DNA known as **plasmids** .

See bacterial cell pictured below (**Figure** below).

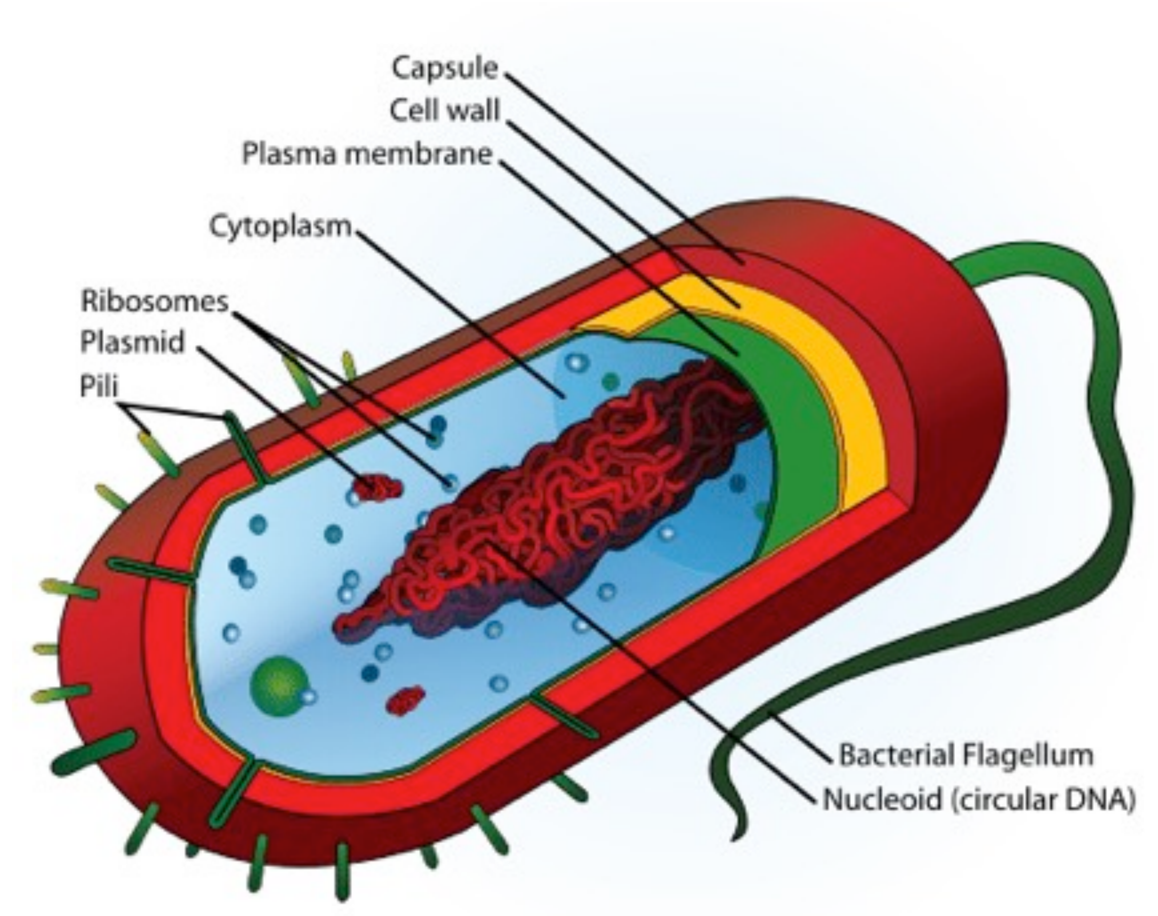


Figure 5.2

The structure of a bacterial cell is distinctive from a eukaryotic cell because of features such as an outer cell wall, the circular DNA of the nucleoid, and the lack of membrane-bound organelles.

Unique Features

Bacteria lack many of the structures that eukaryotic cells contain. For example, they don't have a nucleus. They also lack membrane-bound organelles, such as mitochondria or chloroplasts. The DNA of a bacterial cell is also different from a eukaryotic cell. Bacterial DNA is contained in one circular chromosome, located in the cytoplasm. Eukaryotes have several linear chromosomes. Bacteria also have two additional unique features: a cell wall and flagella.

The Cell Wall

Bacteria are surrounded by a **cell wall** consisting of **peptidoglycan** . This complex molecule consists of sugars and amino acids. The cell wall is important for protecting bacteria. The cell wall is so important that some antibiotics, such as penicillin, kill bacteria by preventing the cell wall from forming.

Some bacteria depend on a host organism for energy and nutrients. These bacteria are known as **parasites** . If the host starts attacking the parasitic bacteria, the bacteria release a layer of slime that surrounds the cell wall. This slime offers an extra layer of protection.

Flagella

Some bacteria also have tail-like structures called flagella (**Figure** below). **Flagella** help bacteria move. As the flagella rotate, they spin the bacteria and propel them forward. Though some eukaryotic cells do have a flagella, a flagella in eukaryotes is rare.

Figure 5.3

The flagella facilitate movement in bacteria. Bacteria may have one, two, or many flagella—or none at all.

Summary

- Bacteria can be classified by their shape, including bacilli (rods), cocci (spheres), and spirilli (spirals)

•Bacteria are like eukaryotic cells in that they have cytoplasm, ribosomes, and a plasma membrane.
•Features that distinguish a bacterial cell from a eukaryotic cell include the circular DNA of the nucleoid, the lack of membrane-bound organelles, the cell wall of peptidoglycan, and flagella.

Explore More

Use the resources below to answer the following questions.

Explore More I

•**Prokaryotic Cells** at http://www.youtube.com/watch?v=gGlhCWg5iOM (2:23)
1.What does the word prokaryote mean?
2.How does bacterial DNA differ from the DNA in eukaryotic cells? What is one explanation for this difference?
3.What is the bacterial capsule? Are all bacterial capsules made of the same material?
4.How does the movement of bacterial flagella differ from the movement of eukaryotic flagella?

Explore More II

•**Cells Alive** at http://www.cellsalive.com/cells/bactcell.htm
1.Describe three features of a bacterial cell?
2.What is the nucleoid?
3.What is a plasmid?

Review

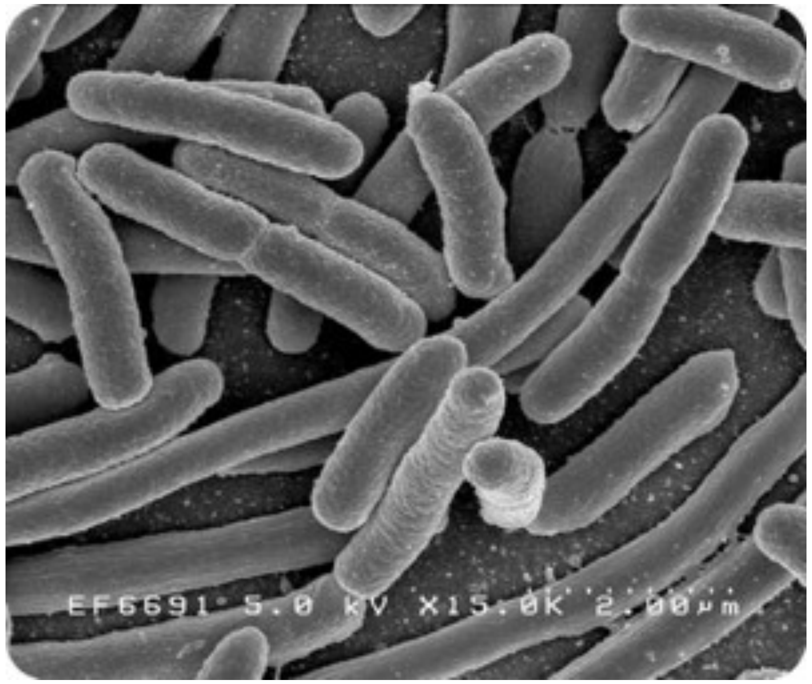
1.How are bacteria classified?
2.How are bacterial cells like your cells?
3.How are bacterial cells different from your cells?
4.Describe the bacterial flagella.

Section 2

Bacteria Nutrition

Bacteria Nutrition

•Identify how bacteria aquire energy.
•Explain the importance of chemosynthetic bacteria.



Can bacteria make their own food from sunlight?

Plants aren't the only organisms that use the energy of the sun to make food. Some bacteria can also perform photosynthesis. In fact, the first photosynthetic organisms on Earth were bacteria. Photosynthesis is just one of many ways that bacteria can obtain energy.

Bacteria Nutrition

Like all organisms, bacteria need energy, and they can acquire this energy through a number of different ways.

Photosynthesis

Photosynthetic bacteria use the energy of the sun to make their own food. In the presence of sunlight, carbon dioxide and water are turned into glucose and oxygen. The glucose is then turned into usable energy. Glucose is like the "food" for the bacteria. An example of photosynthetic bacteria is cyanobacteria, as seen in the opening image.

Decomposers

Bacteria known as decomposers break down wastes and dead organisms into smaller molecules. These bacteria use the organic substrates they break down to get their energy, carbon, and nutrients they need for survival.

Chemotrophs

Bacteria can also be chemotrophs. Chemosynthetic bacteria, or **chemotrophs** , obtain energy by breaking down chemical compounds in their environment. An example of one of these chemicals broken down by bacteria is nitrogen-containing ammonia. These bacteria are important because they help cycle nitrogen through the environment for other living things to use. Nitrogen cannot be made by living organisms, so it must be continually recycled. Organisms need nitrogen to make organic compounds, such as DNA.

Mutualism

Some bacteria depend on other organisms for survival. For example, some bacteria live in the roots of legumes, such as pea plants (**Figure** below). The bacteria turn nitrogen-containing molecules into nitrogen that the plant can use. Meanwhile, the root provides nutrients to the bacteria. In this relationship, both the bacteria and the plant benefit, so it is known as a **mutualism** .

Figure 5.4

These bacteria-containing nodules on a soybean root help provide the plant with nitrogen.

Parasitism

Other bacteria are parasitic and can cause illness. In **parasitism** , the bacteria benefit, and the other organism is harmed. Harmful bacteria will be discussed in another concept.

Summary

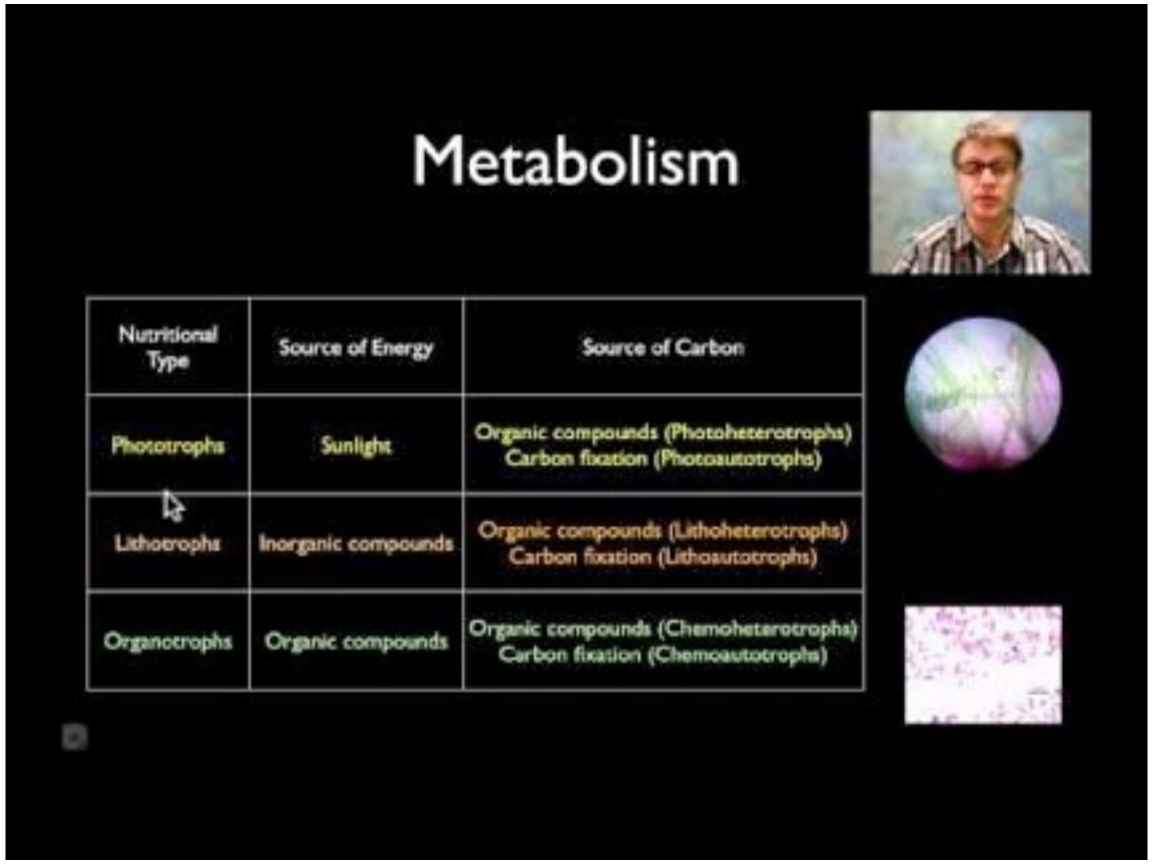
- Bacteria can obtain energy and nutrients by performing photosynthesis, decomposing dead organisms and wastes, or breaking down chemical compounds.
- Bacteria can obtain energy and nutrients by establishing close relationships with other organisms, including mutualistic and parasitic relationships.

Explore More

Use the resources below to answer the questions that follow.

Explore More I

- **Bacteria** http://www.youtube.com/watch?v=h-z9-9OOWC4 (11:04)



Click on the image above for more content

1. What are the three nutritional types of bacteria?
2. What is the base energy source for these three types?
3. Give an example of a photoautotroph.

Explore More II

- **Bacteria: Life History and Ecology** http://www.ucmp.berkeley.edu/bacteria/bacterialh.html

1. What is the difference between a heterotroph and an autotroph?
2. What is the difference between aerobic, anaerobic, and facultative anaerobic bacteria?
3. What are two ways bacteria play important roles in the ecosystem?

Review

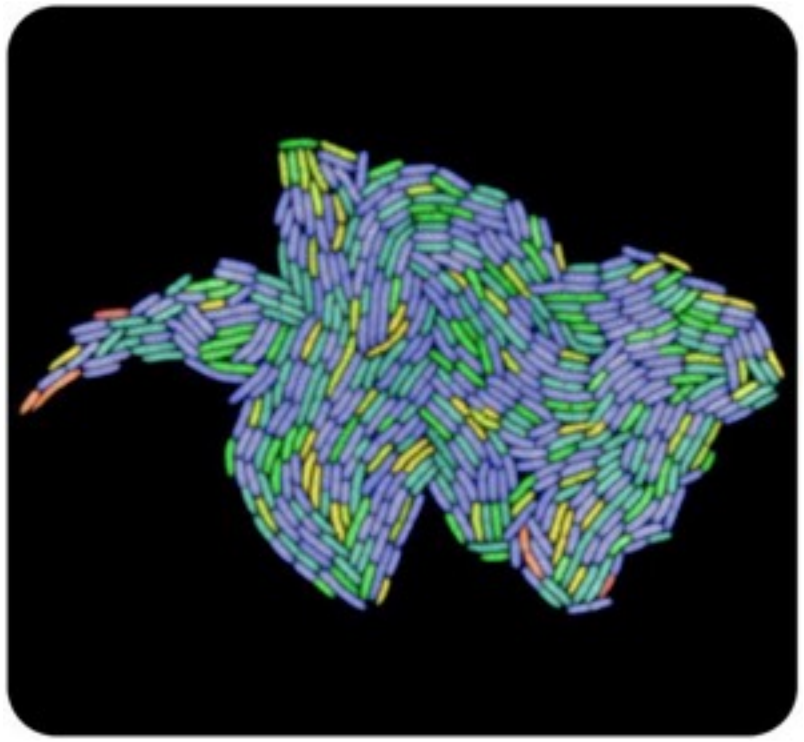
1. Describe two ways that bacteria obtain nutrients and energy?
2. What is an example of a mutualism with a bacteria?
3. What is an example of a photosynthetic bacteria.
4. Describe the importance of chemosynthetic bacteria.

Section 3

Bacteria Reproduction

Bacteria Reproduction

•Define asexual reproduction.
•Describe the process of binary fission.
•Compare conjugation, transformation, and transduction.



How can bacteria reproduce so rapidly?

Bacteria can divide very rapidly. This image is of a growing colony of *E. coli* bacteria. In the right environment, a single *E. coli* can divide to form a colony of hundreds of bacteria in just a few hours.

Bacteria Reproduction

Bacteria, being single-celled prokaryotic organisms, do not have a male or female version. Bacteria reproduce asexually. In **asexual reproduction** , the "parent" produces a genetically identical copy of itself.

Binary Fission

Bacteria reproduce through a process called **binary fission** . During binary fission, the chromosome copies itself, forming two genetically identical copies. Then, the cell enlarges and divides into two new daughter cells. The two daughter cells are identical to the parent cell. Binary fission can happen very rapidly. Some species of bacteria can double their population in less than ten minutes!

Exchanging DNA

Sexual reproduction does not occur in bacteria. But not all new bacteria are clones. This is because bacteria can acquire new DNA. This process occurs in three different ways:

1. **Conjugation** : In conjugation, DNA passes through an extension on the surface of one bacterium and travels to another bacterium (**Figure** below). Bacteria essential exchange DNA via conjugation.
2. **Transformation** : In transformation, bacteria pick up pieces of DNA from their environment.

3.**Transduction** : In transduction, viruses that infect bacteria carry DNA from one bacterium to another.

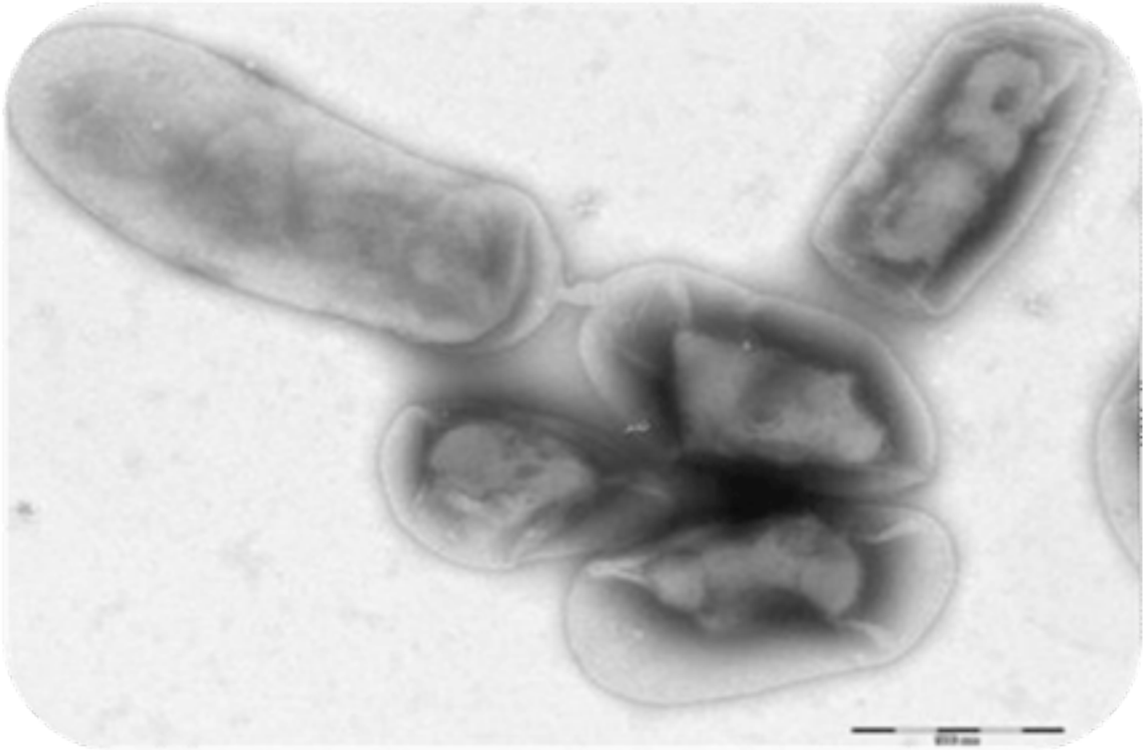


Figure 5.5

Bacteria can exchange small segments of DNA through conjugation. Notice two bacterial cells are attached by a short extension. DNA can be exchanged through this extension.

Summary

•Bacteria reproduce by binary fission, resulting in two daughter cells identical to the parent cell.
•Bacteria can exchange DNA through the processes of conjugation, transformation, or transduction.

Explore More

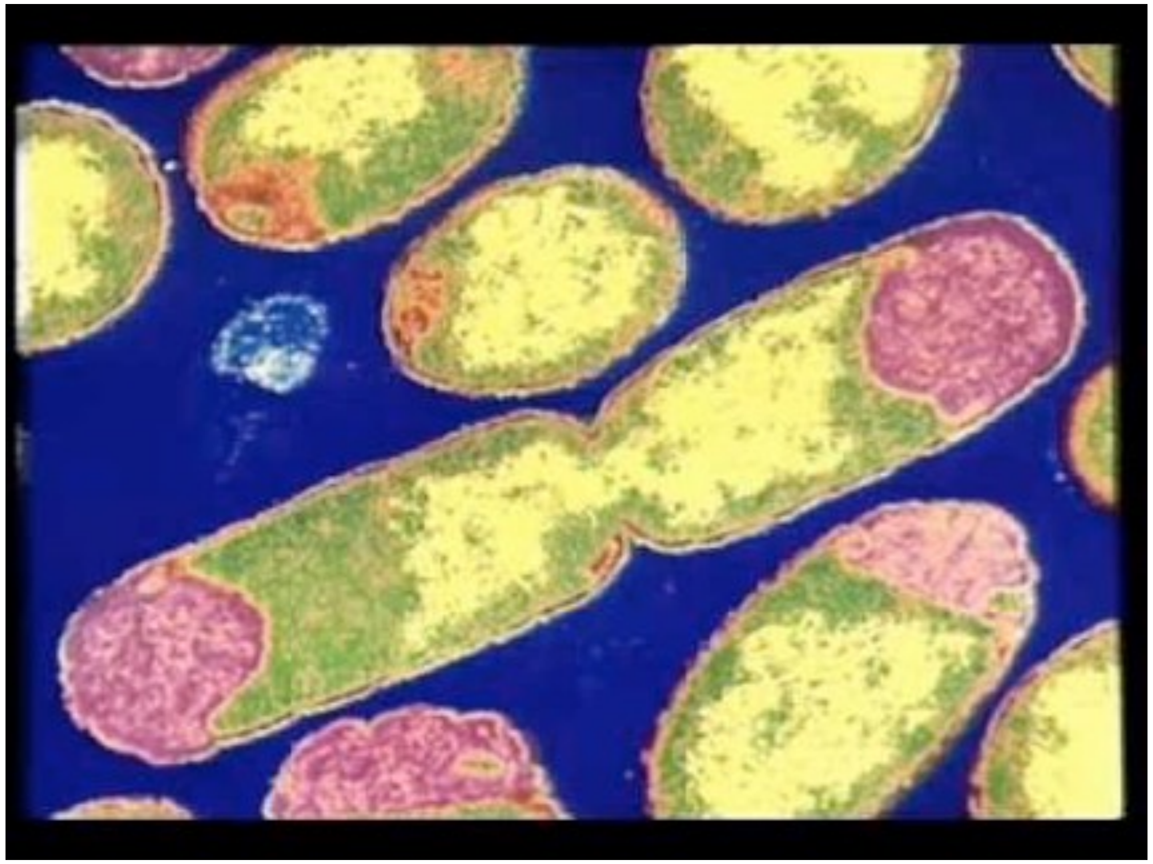
Use the resources below to answer the questions that follow.

Explore More I

•**Binary Fission** at http://www.boundless.com/biology/cell-reproduction/prokaryotic-cell-division/binary-fission/
1.Define binary fission.
2.During replication, what is the relationship between the bacterial chromosome and the plasma membrane?
3.When do the daughter cells separate?

Explore More II

•**Asexual Reproduction** at http://www.youtube.com/watch?v=DY9DNWcqxI4 (1:03)



Click on the image above for more content

1. There are approximately 7 billion humans on the planet. How long would it take some bacteria to make 7 billion copies of themselves?

Review

1. Describe how bacteria reproduce?
2. How do bacteria exchange DNA?
3. What is binary fission?
4. What is transformation involving bacteria?

Section 4

Helpful Bacteria

Helpful Bacteria

- •Identify how bacteria are beneficial to humans.
- •Explain how bacteria are used in food production and medicine.
- •Summarize the role of bacteria in digestion and as decomposers.

Where does cheese come from?

Bacteria are often used to make cheese from milk. But making foods is not the only beneficial role of bacteria. For example, they also play an essential role in your gut!

Helpful Bacteria

Can we survive without bacteria? Could bacteria survive without us? No and yes. No, we could not survive without bacteria. And yes, bacteria could survive without us.

Foods

Bacteria can be used to make cheese from milk. The bacteria turn the milk sugars into lactic acid. The acid is what causes the milk to curdle to form cheese. Bacteria are also involved in producing other foods. Yogurt is made by using bacteria to **ferment** milk (**Figure** below). Fermenting cabbage with bacteria produces sauerkraut.

Figure 5.6

Yogurt is made from milk fermented with bacteria. The bacteria ingest natural milk sugars and release lactic acid as a waste product, which causes proteins in the milk to form into a solid mass, which becomes the yogurt.

Medicines

In the laboratory, bacteria can be changed to provide us with a variety of useful materials. Bacteria can be used as tiny factories to produce desired chemicals and medicines. For example, insulin, which is necessary to treat people with diabetes, can be produced using bacteria.

Through the process of transformation, the human gene for insulin is placed into bacteria. The bacteria then use that gene to make a protein. The protein can be separated from the bacteria and then used to treat patients. The mass production of insulin by bacteria made this medicine much more affordable.

Digestion

Bacteria also help you digest your food. Several species of bacteria, such as *E. coli* , are found in your digestive tract. In fact, in your gut, bacteria cells outnumber your own cells!

Decomposers

Bacteria are important in practically all ecosystems because many bacteria are **decomposers** . They break down dead materials and waste products and recycle nutrients back into the environment. This recycling of nutrients, such as nitrogen, is essential for living organisms. Organisms cannot produce nutrients, so they must come from other sources.

We get nutrients from the food we eat; plants get them from the soil. How do these nutrients get into the soil? One way is from the actions of decomposers. Without decomposers, we would eventually run out of the materials we need to survive. We also depend on bacteria to decompose our wastes in sewage treatment plants.

Summary

- Bacteria can be used to make foods and medicines.
- Bacteria play an important role in animal digestion.

•Bacteria recycle nutrients in the environment.

Explore More

Use the resources below to answer the questions that follow.

Explore More I

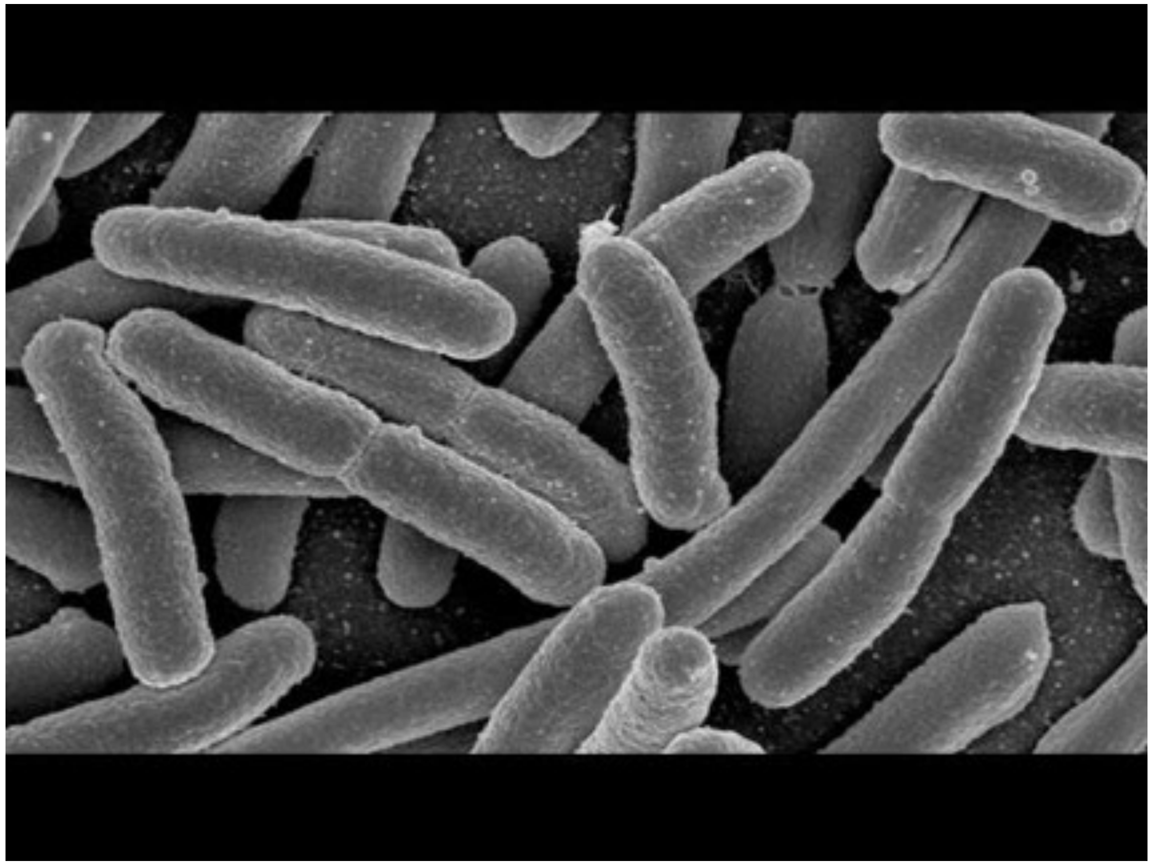
- **Intestinal Flora: A Virtual Organ** at http://www.youtube.com/watch?v=yFwrHoKkZBc (2:15)

Click on the image above for more content

1. How does the gut bacteria differ between the small intestine and the large intestine?
2. What can happen if something causes a reduction of "good" bacteria in your gut?
3. How do the number of bacterial cells in your intestines compare to the total number of cells in your body?

Explore More II

- **Gut Microbes in Early Life Have Effect on Adult Emotions** at http://www.youtube.com/watch?v=ADhDCMBwMFs (1:15)



Click on the image above for more content

1. What is one of the uses of serotonin in the body?
2. What have scientists discovered about the relationship between gut bacteria and serotonin?
3. What do scientists hope to do with this information?

Explore More III

- **Putting Bacteria to Work** at http://www.pbs.org/wgbh/nova/tech/putting-bacteria-to-work.html

1. How are bacteria used in making foods? What food are made with bacteria?
2. How are bacteria used in oil spills?
3. How are bacteria being used in nanotechnology?
4. How are bacteria used to combat insect pests?
5. How have bacteria been used in medicine?

Review

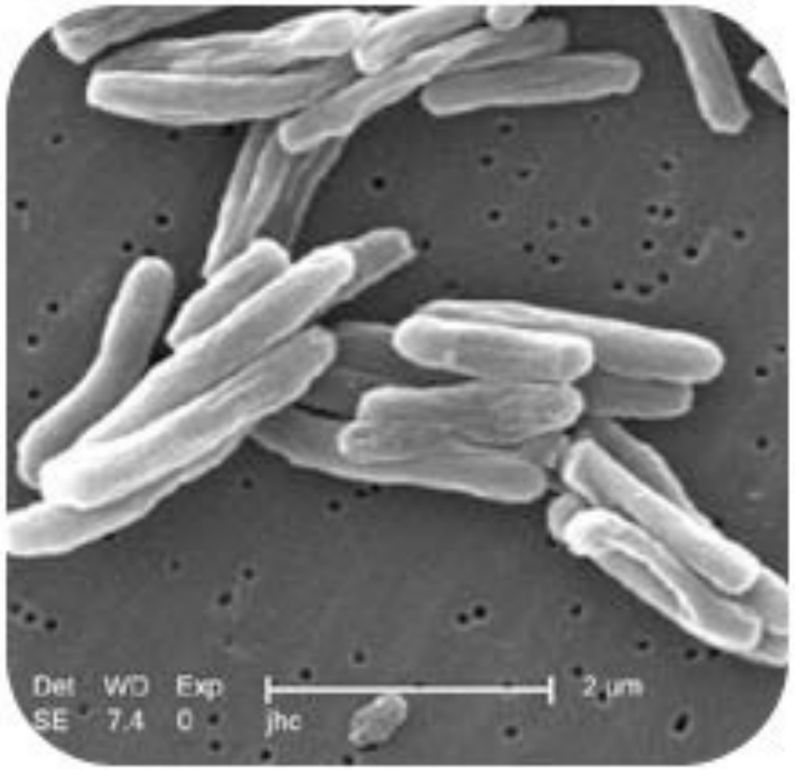
1. How are bacteria helpful in ecosystems?
2. How are bacteria beneficial to your health?
3. List two foods produced with the help of bacteria.

Section 5

Harmful Bacteria

Harmful Bacteria

- •Describe how some bacteria are harmful.
- •Name human diseases caused by bacteria.
- •Describe bacterial contamination of foods.
- •Explain the use of bacteria as a weapon.



Could this organism make you sick?

This bacterium, called *Mycobacterium tuberculosis* , causes the disease Tuberculosis (TB). These bacteria usually attack the lungs. If left untreated, the infection can be fatal. Many other illnesses, mild and severe, are also caused by certain types of bacteria.

Harmful Bacteria

With so many species of bacteria, some are bound to be harmful. Harmful bacteria can make you sick. They can also ruin food and be used to hurt people.

Diseases

There are also ways that bacteria can be harmful to humans and other animals. Bacteria are responsible for many types of human illness (**Figure** below), including:

- •Strep throat
- •Tuberculosis
- •Pneumonia
- •Leprosy
- •Lyme disease

Luckily most of these can be treated with **antibiotics.**

Figure 5.7

The Black Death, which killed at least one third of Europe's population in the 1300s, is believed to have been caused by the bacterium *Yersinia pestis* .

Food Contamination

Bacterial contamination of foods can lead to digestive problems, an illness known as **food poisoning** . Raw eggs and undercooked meats commonly carry the bacteria that can cause food poisoning. Food poisoning can be prevented by cooking meat thoroughly and washing surfaces that have been in contact with raw meat. Washing your hands before and after handling food also helps prevent contamination.

Weapons

Some bacteria also have the potential to be used as biological weapons by terrorists. An example is anthrax, a disease caused by the bacterium *Bacillus anthracis* . Inhaling the **spores** of this bacterium can lead to a deadly infection, and, therefore, it is a dangerous weapon. In 2001, an act of terrorism in the United States involved *B. anthracis* spores sent in letters through the mail.

Summary

- Bacteria are responsible for many types of diseases in humans.
- Some bacteria can contaminate food and cause food poisoning.
- Some bacteria have been used as biological weapons by terrorists.

Explore More

Use these resources to answer the questions that follow.

Explore More I

- http://www.youtube.com/watch?v=j5GvvQJVD_Y (5:06)

Click on the image above for more content

1. How does infection by the bacteria *Salmonella typhimurium* begin? Do all bacterial infections start this way?
2. Do all bacteria ingested make it to the intestines? Why or why not?
3. What does *Salmonella typhimurium* compete with in the intestines?
4. What are some possible effects of infection by *Salmonella typhimurium* ?

Explore More II

- **KidsHealth Food Poisoning** at http://kidshealth.org/kid/ill_injure/sick/food_poisoning.html .

1. What are the common bacteria that cause food poisoning?
2. What steps can you take to keep your food safe?

Review

1. What are three examples of diseases caused by bacteria?
2. How can you prevent food poisoning?
3. How are bacterial diseases treated?

Section 6

Archaea

Archaea

- •Distinguish between bacteria and archaea.
- •Describe how archaea obtain energy.

What organisms can grow in the hot springs of Yellowstone National Park?

In the 1970s, a new group of organisms was identified. Unlike other organisms, these organisms could thrive in temperatures near 100ºC, the boiling point of water! This new group of organisms was named archaea.

What are Archaea?

For many years, archaea were classified as bacteria. Like the bacteria, **archaea** lacked a nucleus and membrane-bound organelles and, therefore, were prokaryotic cells. However, when scientists compared the DNA of the two prokaryotes, they found that there were distinct differences. They concluded that there must be two distinct types of prokaryotes, which they named archaea and bacteria.

Even though the two groups might seem similar, archaea have many features that distinguish them from bacteria:

1. The cell walls of archaea are distinct from those of bacteria. While bacteria have cell walls made up of the polymer peptidoglycan, most archaea do not have peptidoglycan in their cell walls.
2. The plasma membranes of the archaea are also made up of lipids that are distinct from those in bacteria.
3. The ribosomal proteins of the archaea are similar to those in eukaryotic cells, not those in bacteria.

Although archaea and bacteria share some fundamental differences, they are still similar in many ways:

1. They both are single-celled, microscopic organisms that can come in a variety of shapes (**Figure** below).
2. Both archaea and bacteria have a single circular chromosome of DNA and lack membrane-bound organelles.
3. Like bacteria, archaea can have flagella to assist with movement.

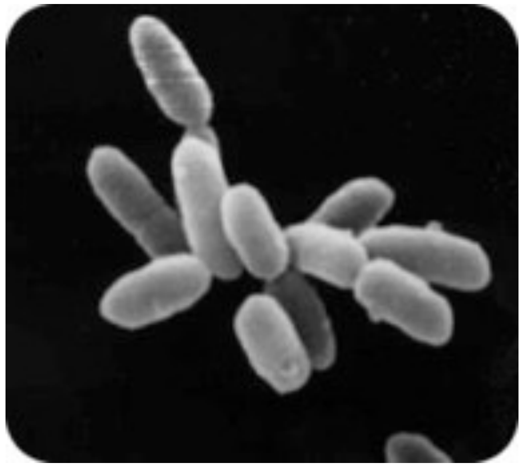


Figure 5.8

Archaea shapes can vary widely, but some are bacilli (rod-shaped).

Obtaining Food and Energy

Most archaea are **chemotrophs** and derive their energy and nutrients from breaking down molecules in their environment. A few species of archaea are photosynthetic and capture the energy of sunlight. Unlike bacteria, which can be parasites and are known to cause a variety of diseases, there are no known archaea that act as parasites. Some archaea do live within other organisms. But these archea form **mutualistic relationships** with their host, where both the archaea and the host benefit. In other words, they assist the host in some way, for example by helping to digest food.

Reproduction

Like bacteria, reproduction in archaea is asexual. Archaea can reproduce through **binary fission** , where a parent cell divides into two genetically identical daughter cells. Archaea can also reproduce asexually through budding and fragmentation, where pieces of the cell break off and form a new cell, also producing genetically identical organisms.

Summary

•Archaea are prokaryotes, but they differ from bacteria in their DNA and biochemistry.
•Most archaea are chemotrophs, but some are photosynthetic or form mutualistic relationships.
•Archaea reproduce asexually through binary fission, fragmentation, or budding.

Explore More

Use the resource below to answer the questions that follow.

•**Introduction to the Archaea** at http://www.ucmp.berkeley.edu/archaea/archaea.html .
1.What are the three domains of life?
2.Why was the name Archaeabacteria misleading?
3.What is bacteriorhodopsin? What is the role of bacteriorhodopsin in ATP production?

Review

1.Describe two ways archaea are different from bacteria?
2.How can archaea reproduction be distinct from bacterial reproduction?
3.How do most archaea obtain energy?

Section 7

Types of Archaea

Types of Archaea

- Distinguish between halophiles, thermophiles, and methanogens.

How can termites digest wood?

Unlike us, termites can get nutrition from wood. Mutualistic archaea found in the gut of termites help them digest the wood. This is just one example of the many extreme environments in which archaea can thrive.

Types of Archaea

The first archaea described could survive in extremely harsh environments in which no other organisms could survive. As a result, archaea are often distinguished by the environment in which they live.

Halophiles

The **halophiles** , which means "salt-loving," live in environments with high levels of salt (**Figure** below). They have been identified in the Great Salt Lake in Utah and in the Dead Sea between Israel and Jordan, which have salt concentrations several times that of the oceans.

Figure 5.9

Halophiles, like the Halobacterium shown here, require high salt concentrations.

Thermophiles

The **thermophiles** live in extremely hot environments. For example, they can grow in hot springs, geysers, and near volcanoes. Unlike other organisms, they can thrive in temperatures near 100°C, the boiling point of water!

Methanogens

Methanogens can also live in some strange places, such as swamps and inside the guts of cows and termites. They help these animals break down cellulose, a tough carbohydrate made by plants (**Figure** below). This is an example of a mutualistic relationship. Methanogens are named for their waste product, a gas called methane.

Figure 5.10

Cows are able to digest grass with the help of the methanogens in their gut.

Common Environments

Although archaea are known for living in unusual environments, such as the Dead Sea, inside hot springs, and in the guts of cows, they also live in more common environments. For example, new research shows that archaea are abundant in the soil. They also live among the plankton in the ocean (**Figure** below). Therefore, scientists are just beginning to discover some of the important roles that archaea have in the environment.

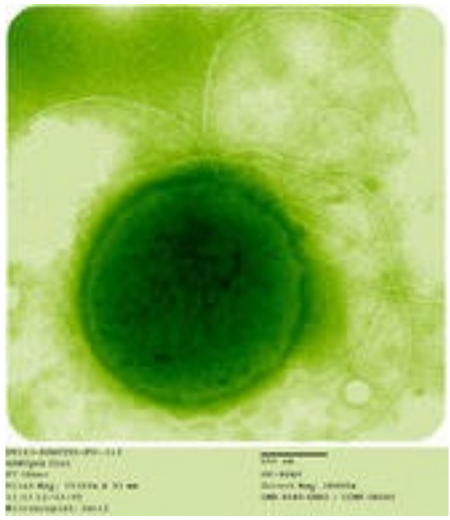


Figure 5.11

Thermococcus gammatolerans are another type of archaea.

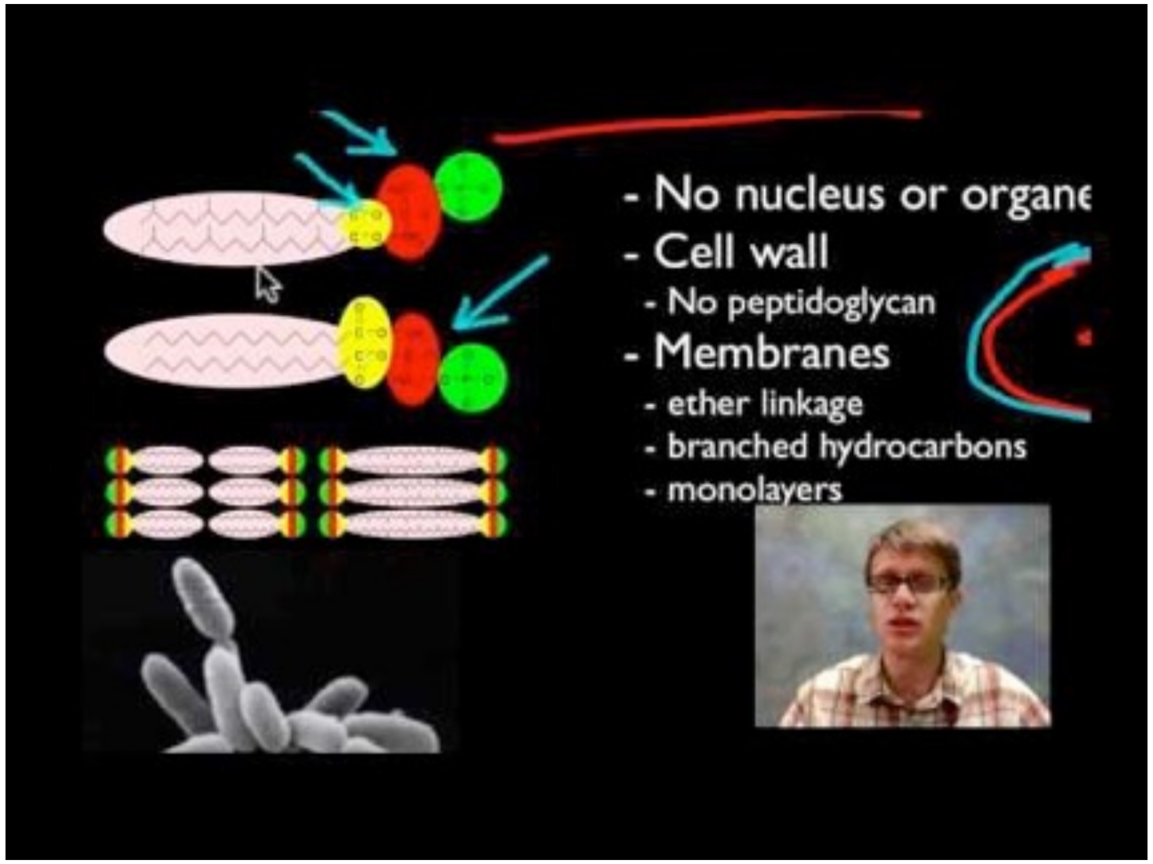
Summary

•Archaea that live in salty environments are known as halophiles.
•Archaea that live in extremely hot environments are called thermophiles.
•Archaea that produce methane are called methanogens.
•Archaea are known for living in extreme environments, but they also can be found in common environments, like soil.

Explore More

Use the resource below to answer the questions below.

•**Archaea** at http://www.youtube.com/watch?v=W25nI9kpxtU (7:16)



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1. Where can archaea be found? Where were they first found?
2. How does the cell wall of archaea differ from the common cell wall of bacteria?
3. How do the different phospholipids used by archaea allow them to withstand harsh environments?
4. If you wanted to find a photosynthetic archaea where would be a good place to look? Why?

Review

1. Where do halophiles live?
2. Why are some archaea classified as thermophiles?

3.What is an example of a mutualistic relationship between archaea and another organism?

Summary

Prokaryotes are the smallest living organisms. They were the first organisms to evolve, and lived on this planet all by themselves for two billion years. What did they do during that time? They evolved. These prokaryotic organisms are the most abundant and successful organisms around today, able to live in any and all environments.

References

1.Mariana Ruiz Villarreal (LadyofHats). Drawing of rod, sphere, and spiral shaped bacteria . Public Domain
2.Mariana Ruiz Villarreal (LadyofHats). Structure of a bacterial cell . Public Domain
3.Zappy's. Flagella help bacteria move . CC BY-NC 3.0
4.U.S. Department of Agriculture. Bacteria growing on a soybean root help provide the plant with nitrogen . Public Domain
5.Watcharee Saisongkorh, Catherine Robert, Bernard La Scola, Didier Raoult, Jean-Marc Rolain/Public Library of Science. Conjugation in bacteria . CC BY 2.5
6.Mom the Barbarian. Yogurt is made from milk fermented with bacteria . CC BY 2.0
7.Unknown. Drawing of the Black Death, caused by the bacteria Yersinia pestis . Public Domain
8.NASA. Some archaea are rod-shaped . Public Domain
9.NASA. Halophiles, like the Halobacterium shown here, require high salt concentrations . Public Domain
10.Kevin Walsh. Cows are able to digest grass with the help of the bacteria methanogens in their gut . CC BY 2.0
11.Angels Tapias. Thermococcus gammatolerans are another type of archaea . CC BY 3.0

Protists and Fungi

Introduction

Would you eat this mushroom?

Now that's an interesting mushroom! In fact, fungi can be some of the most colorful species. And protists can be some of the most interesting. These two kingdoms are the first two eukaryotic kingdoms we discuss, and they have some of the most diverse members.

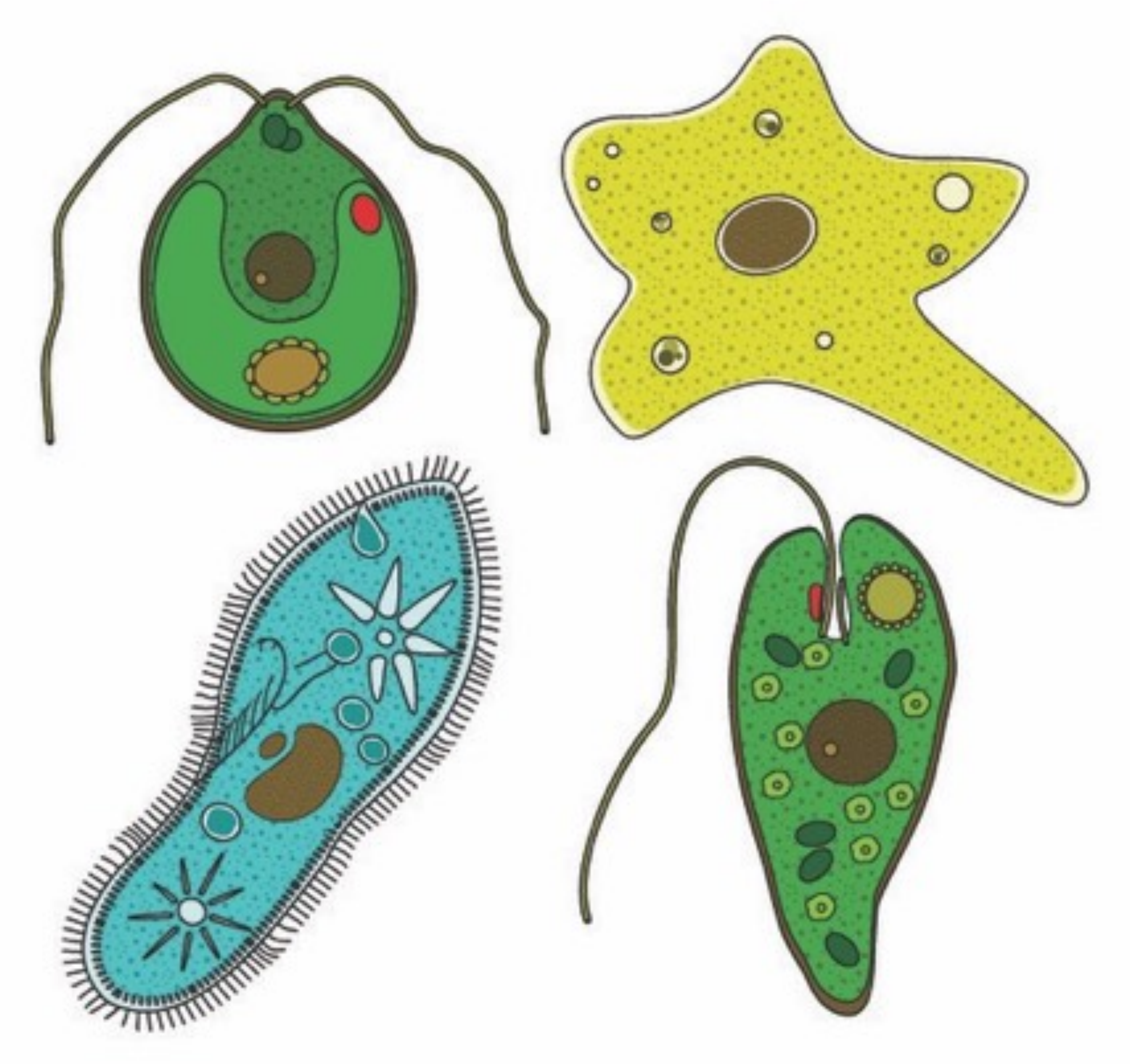
But this mushroom? Probably not a good idea to eat. This is a poisonous and psychoactive fungus. With its large, white-gilled, white-spotted, usually deep red appearance, it is one of the most recognizable and widely encountered mushrooms in popular culture. However, you shouldn't eat it!

Section 1

Protist Characteristics

Protist Characteristics

•Describe the main features of the protists.
•Explain protist classification.



Animal? Bacteria? Plant? Fungi? What do these figures represent?

None of the above! These organisms may be single-celled like bacteria, and they may look like a fungus. They also may hunt for food like an animal or photosynthesize like a plant. And, yet, they do not fit into any of these groups. These organisms are protists!

What are Protists?

Protists are **eukaryotes** , which means their cells have a nucleus and other membrane-bound organelles. Most protists are single-celled. Other than these features, they have very little in common. You can think about protists as all eukaryotic organisms that are neither animals, nor plants, nor fungi.

Although Ernst Haeckel set up the Kingdom *Protista* in 1866, this kingdom was not accepted by the scientific world until the 1960s. These unique organisms can be so different from each other that sometimes Protista is called the “junk drawer" kingdom. Just like a junk drawer, which contains items that don't fit into any other category, this kingdom contains the eukaryotes that cannot be put into any other kingdom. Therefore, protists can seem very different from one another.

Unicellular or Multicellular?

Most protists are so small that they can be seen only with a microscope. Protists are mostly unicellular (one-celled) eukaryotes. A few protists are multicellular (many-celled) and surprisingly large. For example, kelp is a multicellular protist that can grow to be over 100-meters long (**Figure** below). Multicellular protists, however, do not show cellular specialization or differentiation into tissues. That means their cells all look the same and, for the most part, function the same. On the other hand, your cells often are much different from each other and have special jobs.

Figure 6.1

Kelp is an example of a muticellular protist.

Characteristics of Protists

A few characteristics are common between protists.

1. They are eukaryotic, which means they have a nucleus.
2. Most have mitochondria.
3. They can be parasites.
4. They all prefer aquatic or moist environments.

Classification of Protists

For classification, the protists are divided into three groups:

1. Animal-like protists, which are heterotrophs and have the ability to move.
2. Plant-like protists, which are autotrophs that photosynthesize.
3. Fungi-like protists, which are heterotrophs, and they have cells with cell walls and reproduce by forming spores.

But remember, protists are not animals, nor plants, nor fungi (**Figure** below).

Figure 6.2

Protists come in many different shapes.

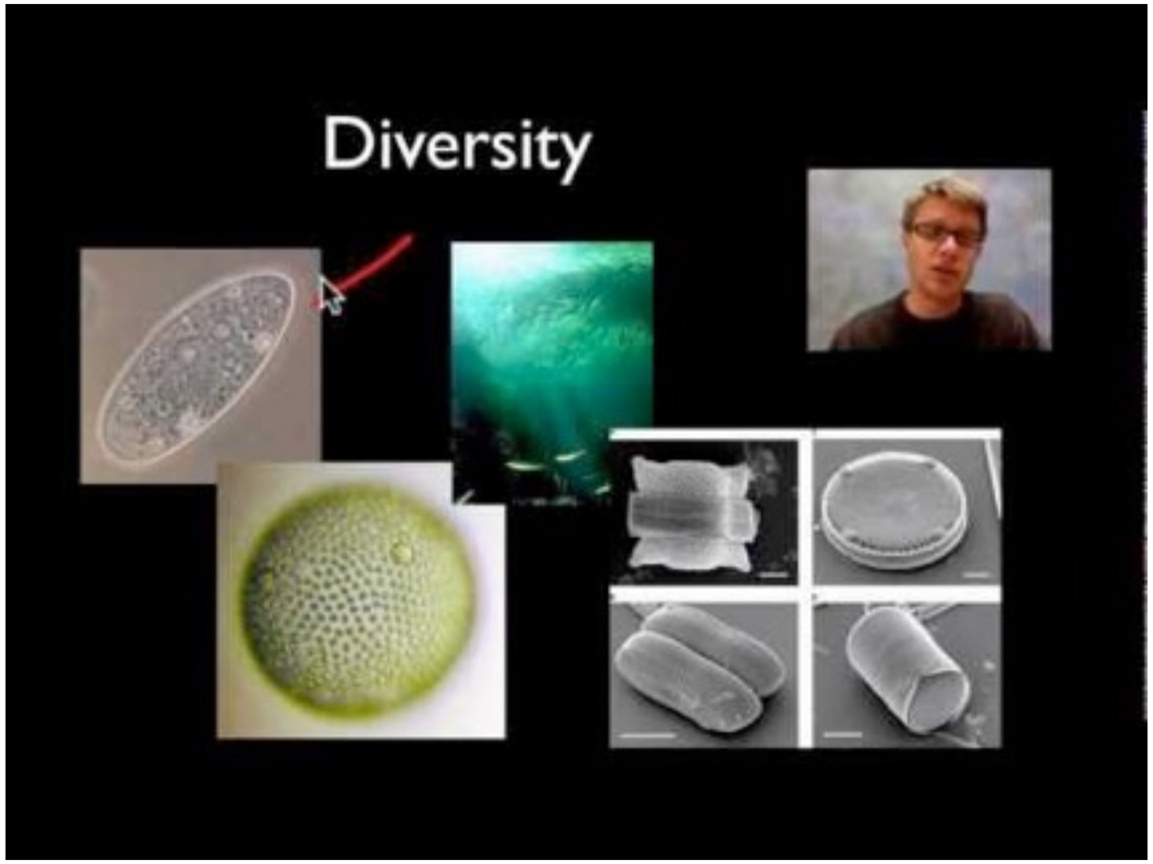
Summary

- Protists are a diverse kingdom, including all eukaryotic organisms that are neither animals, nor plants, nor fungi.
- For classification, the protists are divided into three groups: animal-like protists, plant-like protists, and fungi-like protists.

Explore More

Use the resource below to answer the questions that follow.

- **Protists** at http://www.youtube.com/watch?v=8deF3Rw4ti4 (5:07)



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1. What defines the Kingdom Protista?
2. Are relationships between protists clearly defined? Why or why not?
3. What are phototrophs? How do they obtain their food? Give an example.
4. What are organotrophs?

5.Do all protists reproduce in the same manner? Explain.

Review

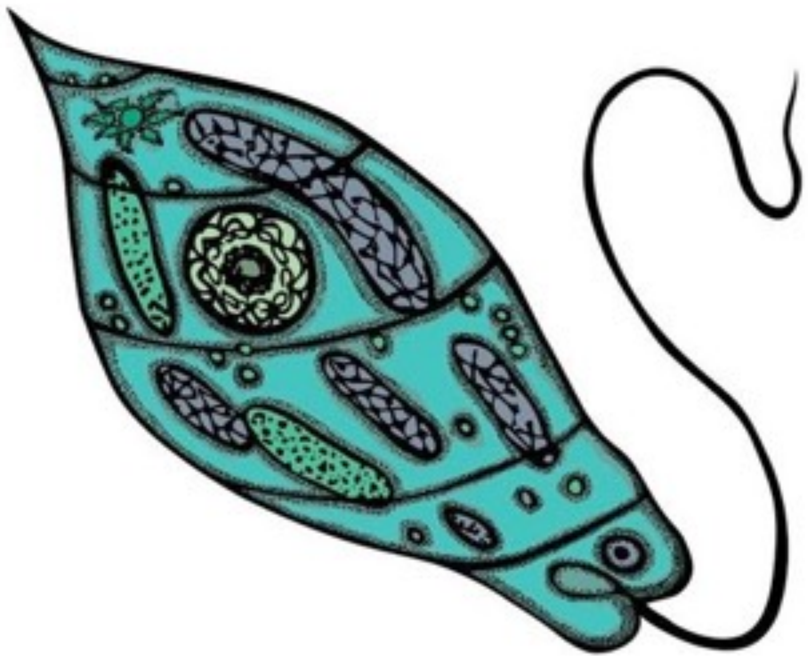
1.What do all protists tend to have in common?
2.How are protists generally classified?
3.What can generally be said about the environments of protists?
4.Why is the Kingdom Protista referred to as the "junk drawer" kingdom?

Section 2

Protists Nutrition

Protists Nutrition

•Describe how protists obtain food.
•Explain endocytosis in protists.



What can photosynthesize AND hunt for food?

No, there are no man-eating plants or leaf-growing animals. The idea of an organism both photosynthesizing and hunting for food might seem strange, but this isn't science fiction. These organisms, examples of *Euglena* , are protists that can feed like an animal or use the energy of the sun to make food like a plant.

Protists Nutrition

The cells of **protists** need to perform all of the functions that other cells do, such as grow and reproduce, maintain homeostasis, and obtain energy. They also need to obtain "food" to provide the energy to perform these functions.

Recall that protists can be plant-like, fungi-like, or animal-like. That means that protists can obtain food like plants, fungi, or animals do. There are many plant-like protists, such as algae, that get their energy from sunlight through photosynthesis. Some of the fungus-like protists, such as the slime molds (**Figure** below), decompose decaying matter. The animal-like protists must "eat" or ingest food.

Some animal-like protists use their "tails" to eat. These protists are called **filter-feeders** . They acquire nutrients by constantly whipping their tails, called **flagellum** , back and forth. The whipping of the flagellum creates a current that brings food into the protist.

Other animal-like protists must "swallow" their food through a process called **endocytosis** . Endocytosis happens when a cell takes in substances through its membrane. The process is described below:

1.The protist wraps around its prey, which is usually bacteria.
2.It creates a **food vacuole** , a sort of "food storage compartment," around the bacteria.
3.The protist produces toxins which paralyze its prey.
4.Once digested, the food material moves through the vacuole and into the cytoplasm of the protist.

Also, some of the animal-like and fungi-like protists are parasitic and absorb nutrients meant for their host, harming the host in the process.

Figure 6.3

Slime molds live on decaying plant life and in the soil.

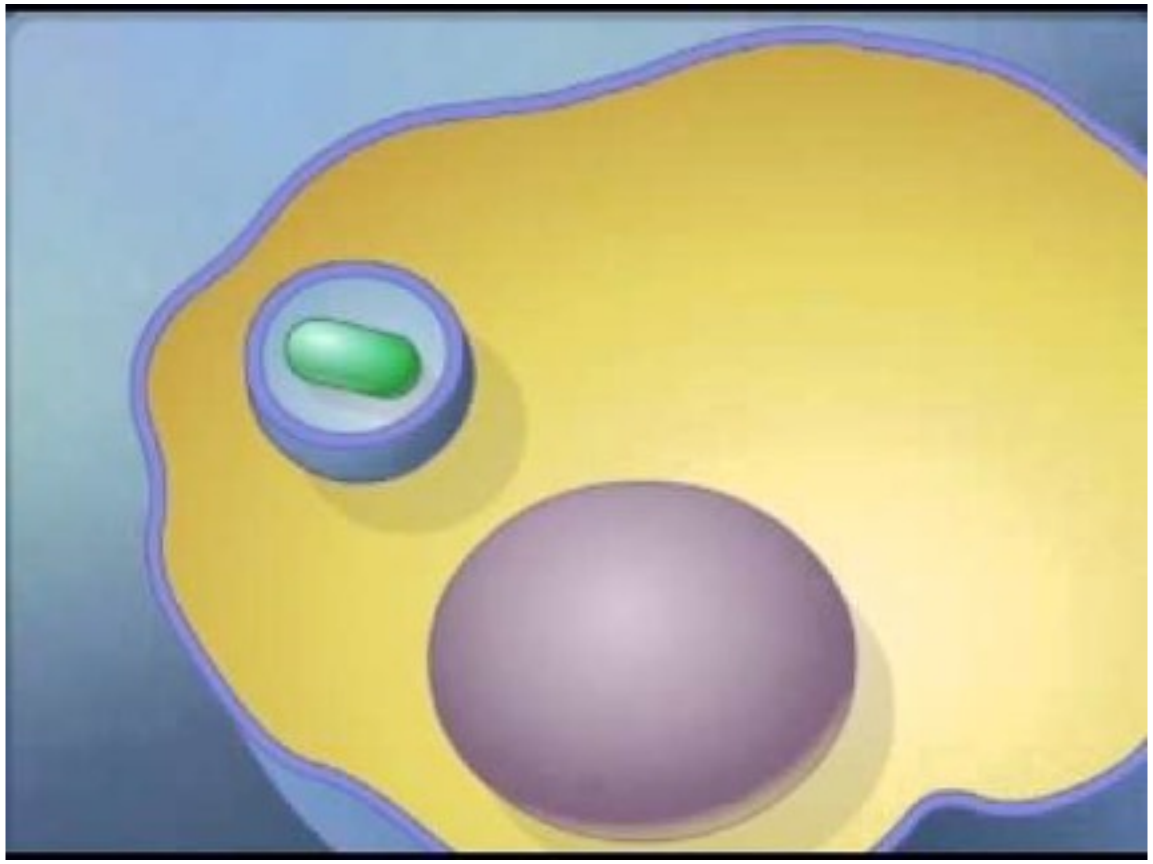
Summary

- Some protists are plant-like and photosynthesize.
- Some protists absorb nutrients from decaying matter like a fungus.
- Some protists hunt their food or act as parasites.

Explore More

Use the resource below to answer the following questions.

- **Endocytosis and Exocytosis** at http://www.youtube.com/watch?v=qpw2p1x9Cic (1:54)



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1. Why do some protista need endocytosis to take in nutrition?
2. What are the three types of endocytosis?
3. What differentiates the three types of endocytosis?
4. What process is used by a protist to ingest a bacterial cell. Be specific in your response.

Review

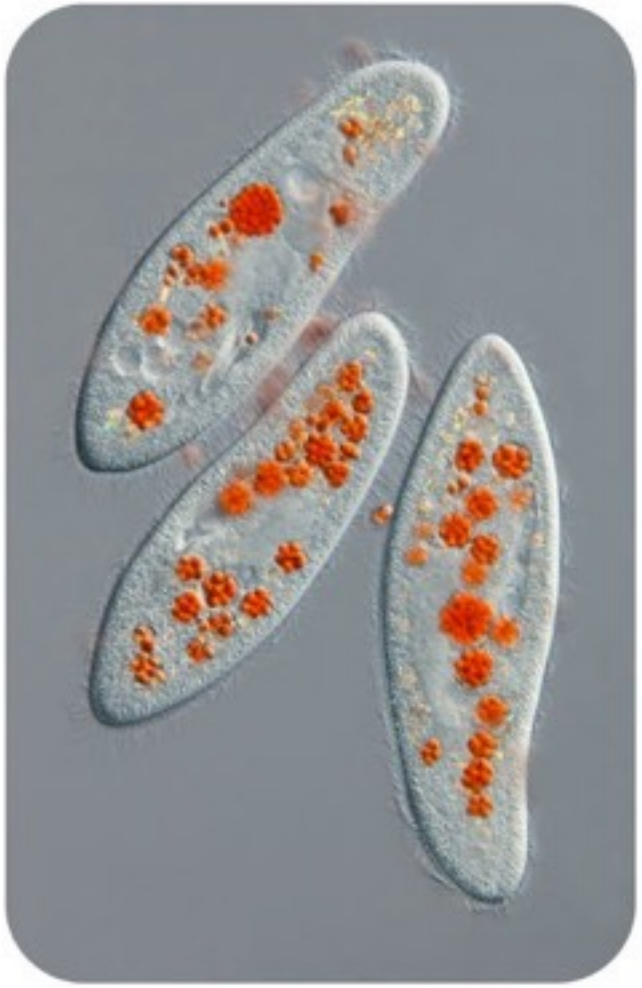
1.How do algae obtain food?
2.How do animal-like protists "swallow" their prey?
3.What is a filter-feeder?
4.How do slime molds get their energy?

Section 3

Animal-like Protists

Animal-like Protists

•Define protozoa.
•Describe the types of animal-like protists.
•Distinguish flagellates from ciliates.



What can hunt prey and move, but is not an animal?

Some protists, like these *Paramecium* , act much like animals. Notice the tiny hair-like cilia that help them move. The food vacuoles, where they digest their prey, are colored in orange.

Animal-like Protists

Animal-like protists are called protozoa. **Protozoa** are single-celled eukaryotes that share some traits with animals. Like animals, they can move, and they are **heterotrophs** . That means they eat things outside of themselves instead of producing their own food. Animal-like protists are very small, measuring only about 0.01–0.5mm. Animal-like protists include the flagellates, ciliates, and the sporozoans.

Different Kinds of Animal-like Protists

There are many different types of animal-like protists. They are different because they move in different ways.

•**Flagellates** have long flagella, or tails. Flagella rotate in a propeller-like fashion, pushing the protist through its environment (**Figure** below). An example of a flagellate is *Trypanosoma* , which causes African sleeping sickness.
•Other protists have what are called transient **pseudopodia** , which are like temporary feet. The cell surface extends out to form feet-like structures that propel the cell forward. An example of a protist with pseudopodia is the amoeba.
•The **ciliates** are protists that move by using cilia. **Cilia** are thin, very small tail-like projections that extend outward from the cell body. Cilia beat back and

forth, moving the protist along. *Paramecium* has cilia that propel it.
•The **sporozoans** are protists that produce spores, such as the *toxoplasma* . These protists do not move at all. The spores develop into new protists.

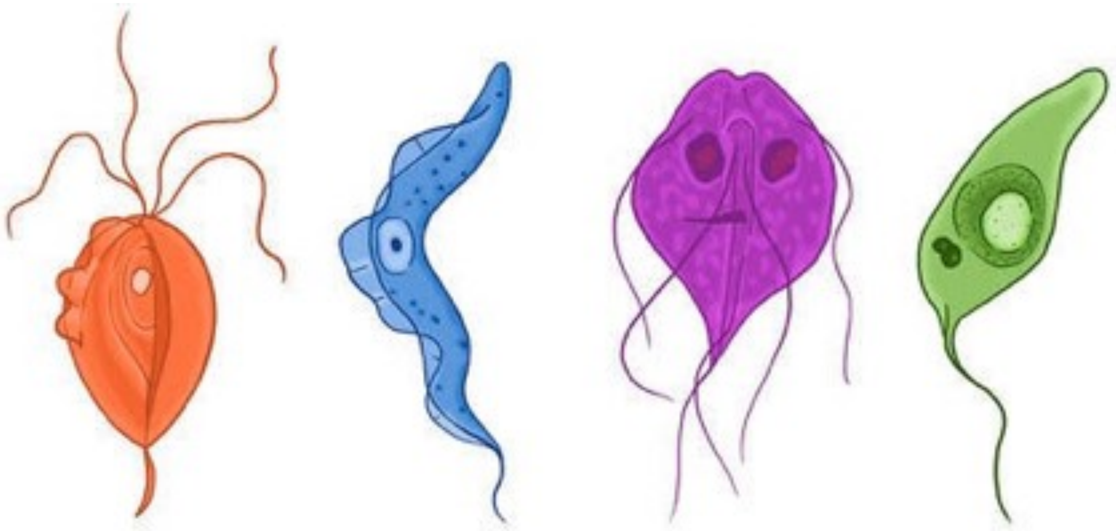


Figure 6.4

These flagellates all cause diseases in humans.

A video of the animal-like amoeba can be viewed at: http://commons.wikimedia.org/wiki/File:Amoeba_engulfing_diatom.ogg .

Summary

- •Protozoa are single-celled eukaryotes that share some traits with animals.
- •Protozoa can move by flagella, cilia, or pseudopodia, or they may not move at all.

Explore More

Use the resource below to answer the questions that follow.

- •**What are Protozoa? - Definition, Characteristics & Examples** at http://education-portal.com/academy/lesson/what-are-protozoa-definition-characteristics-examples.html#lesson

1. Who proposed the five kingdom taxonomic system?
2. How did the Kingdom Protista come about?
3. Define protozoa.
4. There are four groups of protozoa. What are the four groups and how are these groups distinguished?
5. What is a flagellate?
6. What distinguishes the sporozoans?

Review

1. What features describe the protozoa?
2. What are three main types of protozoa?
3. Distinguish flagellates from ciliates.

Section 4

Plant-like Protists

Plant-like Protists

- •Define algae.
- •Distinguish algae from plants.
- •Give examples of multicellular plant-like protists.

What is pond scum?

Polluted water can form a frothy green scum on the surface. This "pond scum" is actually a living organism, algae. The algae are plant-like protists. Usually the algae are too small to notice, but sometimes algae grow in excess because of the excess nutrients in polluted water.

Plant-like Protists

Plant-like protists are known as **algae** (**Figure** below). They are a large and diverse group. Plant-like protists are **autotrophs.** This means that they produce their own food. They perform photosynthesis to produce sugar by using carbon dioxide and water, and the energy from sunlight, just like plants. Unlike plants, however, plant-like protists do not have true stems, roots, or leaves.

Figure 6.5

Red algae are a very large group of protists making up about 5,000–6,000 species. They are mostly multicellular and live in the ocean. Many red algae are seaweeds and help create coral reefs.

Most plant-like protists live in oceans, ponds, or lakes. Protists can be unicellular (single-celled) or multicellular (many-celled). Seaweed and **kelp** are examples of multicellular, plant-like protists. Kelp can be as large as trees and form a "forest" in the ocean (**Figure** below).

Figure 6.6

Macrocystis pyrifera (giant kelp) is a type of multicellular, plant-like protist.

Plant-like protists are essential to the ecosystem. They are the base of the marine food chain, and they produce oxygen through photosynthesis for animals to breathe. They are classified into a number of basic groups (**Table** below).

Phylum	**Description**	**Approximate Number of Species**	**Examples**
Chlorophyta	Green algae (related to higher plants)	7,500	*Chlamydomnas, Ulva, Volvox*
Rhodophyta	Red algae	5,000	*Porphyra*
Phaeophyta	Brown algae	1,500	*Macrocystis*
Chrysophyta	Diatoms, golden-brown algae, yellow-green algae	12,000	*Cyclotella*
Pyrrophyta	Dinoflagellates	4,000	*Gonyaulax*
Euglenophyta	Euglenoids	1,000	*Euglena*

Summary

- Plant-like protists are autotrophs, meaning they make their own food.
- Plant-like protists include algae, kelp, and seaweed.

Explore More

Use the resources below to answer the questions that follow.

Explore More I

- **Plant Protists** at http://www.youtube.com/watch?v=o5ESHXKGBvA (4:03)

Click on the image above for more content

1. How much of the total photosynthesis on the globe is carried out by phytoplankton? What does this mean for aquatic ecosystems?
2. How are the flagella of dinoflagellates arranged?
3. What organisms have dinoflagellates as symbiotes? Why are dinoflagellates important to these organisms?
4. How do bivalves respond to red tides? What does this mean for humans?

Explore More II

- **Red Tides** at NOAA: http://oceanservice.noaa.gov/facts/redtide.html .

1. What is a red tide?
2. Are all algal blooms harmful? Explain your answer.
3. How can some algae be harmful?

Review

1. How are some protists similar to plants?
2. How are plant-like protists different from plants?
3. What are some examples of multicellular plant-like protists?
4. How are plant-like protists essential to their ecosystem?

Section 5

Fungus-like Protists

Fungus-like Protists

- •Describe features of the fungus-like protists.
- •Distinguish slime molds from water molds.

What's shrouding this dead insect?

The thin filaments growing out of this dead insect look a little like a fungus. Also this mystery organism, like a fungus, is feeding on decaying matter. However, this is not a fungus. This organism is a type of fungus-like protist, known as water mold.

Fungus-like Protists

Fungus-like protists share many features with fungi. Like fungi, they are heterotrophs, meaning they must obtain food outside themselves. They also have cell walls and reproduce by forming spores, just like fungi. Fungus-like protists usually do not move, but a few develop movement at some point in their lives. Two major types of fungus-like protists are **slime molds** and **water molds** .

Slime Molds

Slime molds usually measure about one or two centimeters, but a few slime molds are as big as several meters. They often have bright colors, such as a vibrant yellow (**Figure** below). Others are brown or white.

Stemonitis is a kind of slime mold which forms small brown bunches on the outside of rotting logs. *Physarum polycephalum* lives inside rotting logs and is a gooey mesh of yellow "threads" that are several centimeters long. *Fuligo* , sometimes called “vomit mold,” is a yellow slime mold found in decaying wood.

Figure 6.7

An example of a slime mold.

Water Molds

Water molds mostly live in water or moist soil. They can be parasites of plants and animals, getting their nutrients from these organisms and also from decaying organisms. They are a common problem for farmers since they cause a variety of plant diseases. One of the most famous of these diseases was the fungus that caused the Irish potato famine in the 1800s. At this time, potatoes were the main source of food for many of the Irish people. The failure of the potato crop meant that many people in Ireland died of starvation or migrated to other countries.

Summary

- Slime molds are fungus-like protists that grow as slimy masses on decaying matter. They are commonly found on items such as rotting logs.
- Water molds are fungus-like protists present in moist soil and surface water; they live as parasites or on decaying organisms.

Explore More

Use the resources below to answer the questions that follow.

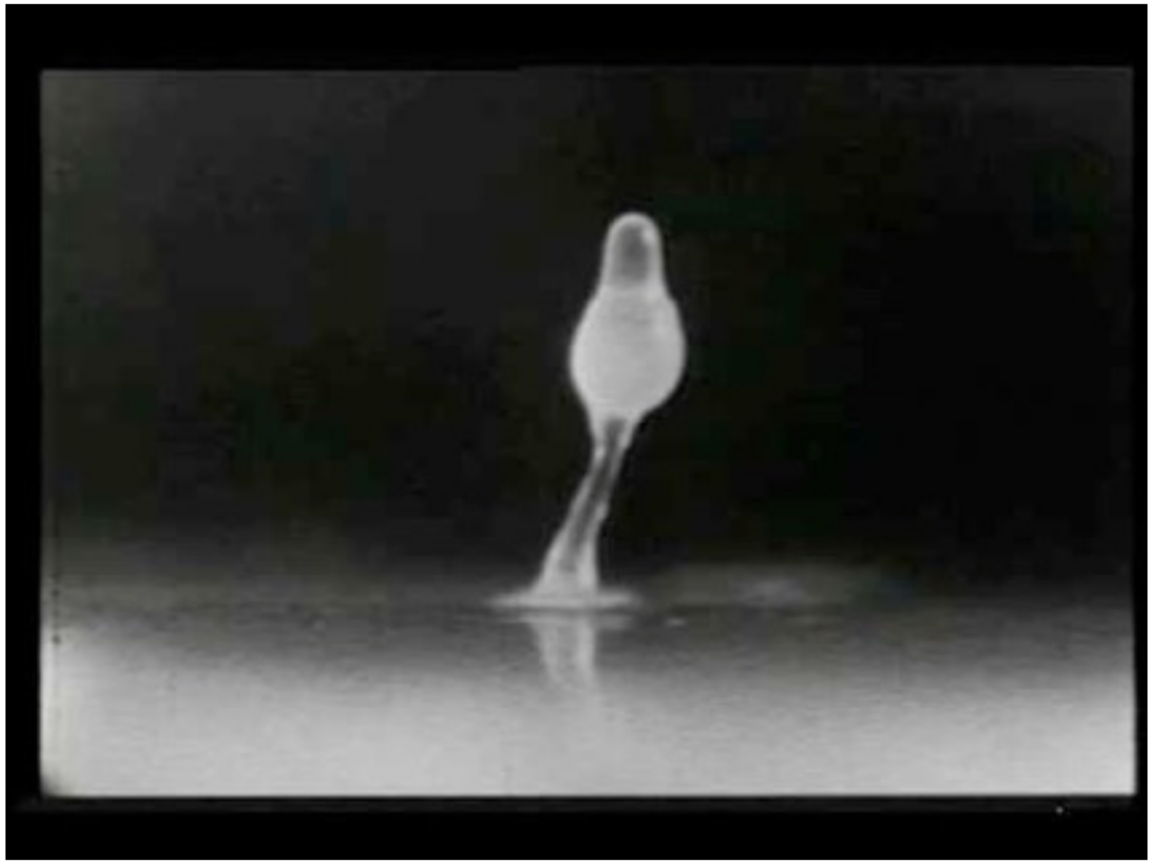
Explore More I

- **The Blob: Slime Mold** at http://herbarium.usu.edu/fungi/FunFacts/slimemold.htm .

1. Why are slime molds not classified as fungi?
2. What does a plasmodial slime mold eat?
3. What is different about the nucleus of the single cell of the plasmodial slime mold?

Explore More II

- **John Bonner's Slime Mold Movie** at http://www.youtube.com/watch?v=bkVhLJLG7ug (1:42)



Click on the image above for more content

1. What happens when you separate the cells of a slime mold?
2. Do you think this behavior represents intelligence? Why or why not?
3. Slime molds will form stalks with fruiting bodies.
    a. What happens to the cells of the stalk?
    b. What happens to the cells of the fruiting body?

Review

1. What are examples of fungus-like protists?
2. How do water molds get their nutrients?

Section 6

Importance of Protists

Importance of Protists

•Describe ways protists are important to humans.

Would you eat seaweed?

Seaweed is commonly eaten in many parts of the world. It's good for you, too; it's high in nutrients and low in calories. You have probably eaten processed seaweed and not even known it, since it's used as a thickener in foods like ice cream. Seaweed and other protists are also food for many, many animals in the ecosystem.

Importance of Protists

Humans could not live on Earth if it were not for protists. Why? Protists produce almost one-half of the oxygen on the planet through photosynthesis, decompose and recycle nutrients that humans need to live, and make up a huge part of the food chain.

Humans use protists for many other reasons:

- •Many protists are also commonly used in medical research. For example, medicines made from protists are used in treatment of high blood pressure, digestion problems, ulcers, and arthritis.
- •Other protists are used in scientific studies. For example, slime molds (including *D. discoideum* , a soil-living protist) are used to analyze the chemical signals in cells.
- •Protists are also valuable in industry. Look on the back of a milk carton. You will most likely see **carrageenan** , which is extracted from red algae. This is used to make puddings and ice cream solid (**Figure** below). Chemicals from other kinds of algae are used to produce many kinds of plastics.

Figure 6.8

Ice cream is an example of a food made with ingredients derived from algae.

Summary

- Protists make up a huge part of the food chain and supply much of the oxygen we breathe.
- Protists are used in medicine and as food additives.

Explore More

Use the resource below to answer the following questions.

- **Algae to Fuels** at http://www.youtube.com/watch?v=IxyvVkeW7Nk (2:34)

Click on the image above for more content

1. What would the potential benefit be to having algae ponds next to power plants?
2. Where in the algae cell is oil stored?
3. How is oil extracted from algae?
4. What does "carbon neutral power source" mean?

Review

1. What are two ways protists are important to people?
2. How are protists important to the ecosystem?
3. What is carrageenan?

Section 7

Fungi

Fungi

- Give examples of fungi.
- Describe the characteristics of fungi.
- Explain why fungi can grow quickly.

What does this fungus have in common with mold?

This colorful bracket fungus doesn't look much like mold. But they have a lot in common. They both break down organic matter to obtain nutrients. They both reproduce by spores. They are both eukaryotic, but they are not plants, and they are definitely not animals. They are both fungi.

What are Fungi?

Ever notice blue-green mold growing on a loaf of bread? Do you like your pizza with mushrooms? Has a physician ever prescribed an antibiotic for you?

If so, then you have encountered **fungi** . Fungi are organisms that belong to the Kingdom Fungi (**Figure** below). Our environment needs fungi. Fungi help decompose matter to release nutrients and make nutritious food for other organisms. Fungi are all around us and are useful in many ways.

Figure 6.9

These many different kinds of organisms demonstrate the huge diversity within the Kingdom Fungi.

Classification of the Fungi

If you had to guess, would you say a fungus is a plant or an animal? Scientists used to debate about which kingdom to place fungi in. Finally they decided that fungi were plants. But they were wrong. Now, scientists know that fungi are not plants at all. Fungi are very different from plants.

The main difference between plants and fungi is how they obtain energy. Plants are **autotrophs** , meaning that they make their own "food" using the energy from sunlight. Fungi are **heterotrophs** , which means that they obtain their "food" from outside of themselves. In other words, they must "eat" their food like animals do. But they don't really eat. Instead, they absorb their nutrients.

Yeasts, molds, and mushrooms are all different kinds of fungi. There may be as many as 1.5 million species of fungi (**Figure** below). You can easily see bread mold and mushrooms without a microscope, but most fungi you cannot see. Fungi are either too small to be seen without a microscope, or they live where you cannot see them easily —deep in the soil, under decaying logs, or inside plants or animals. Some fungi even live in, or on top of, other fungi.

Figure 6.10

The blue in this blue cheese is actually mold, which is a fungus.

Fungi are Good Eaters

Fungi can grow fast because they are such good eaters. Fungi have lots of surface area, and this large surface area “eats” or absorbs. Surface area is how much exposed area an organism has, compared to their overall volume. Most of a mushroom's surface area is actually underground. If you see a mushroom in your yard, that is just a small part of a larger fungus growing underground.

These are the steps involved in fungi "eating":

1. Fungi squirt special enzymes into their environment.
2. The enzymes help digest large organic molecules, similar to cutting up your food before you eat.
3. Cells of the fungi then absorb the broken-down nutrients.

Summary

- Fungi are heterotrophs, meaning they obtain food from outside themselves.
- Common fungi include yeasts, molds, and mushrooms.

Explore More

Use the resources below to answer the questions that follow.

Explore More I

- **Planet World - Fungi** at http://www.youtube.com/watch?v=5_rprVa-RY4 (3:03)

Click on the image above for more content

1. What are two ways fungi differ from plants?
2. How many spores can a fungi disperse per day? What methods of dispersal do they use?
3. How do fungi benefit trees?

Explore More II

- **Fungi: What They Eat** at http://archives.microbeworld.org/microbes/fungi/eat.aspx

1. Some fungi "hunt" for prey.
    a. What structure do they use to form "nooses"?
    b. How do they close these nooses?
    c. How do they "consume" their prey?
    d. What hunting technique do some fungi use other than nooses or loops?
2. What is a lichen? What does a lichen do to increase the types of habitats in which it can live?

Review

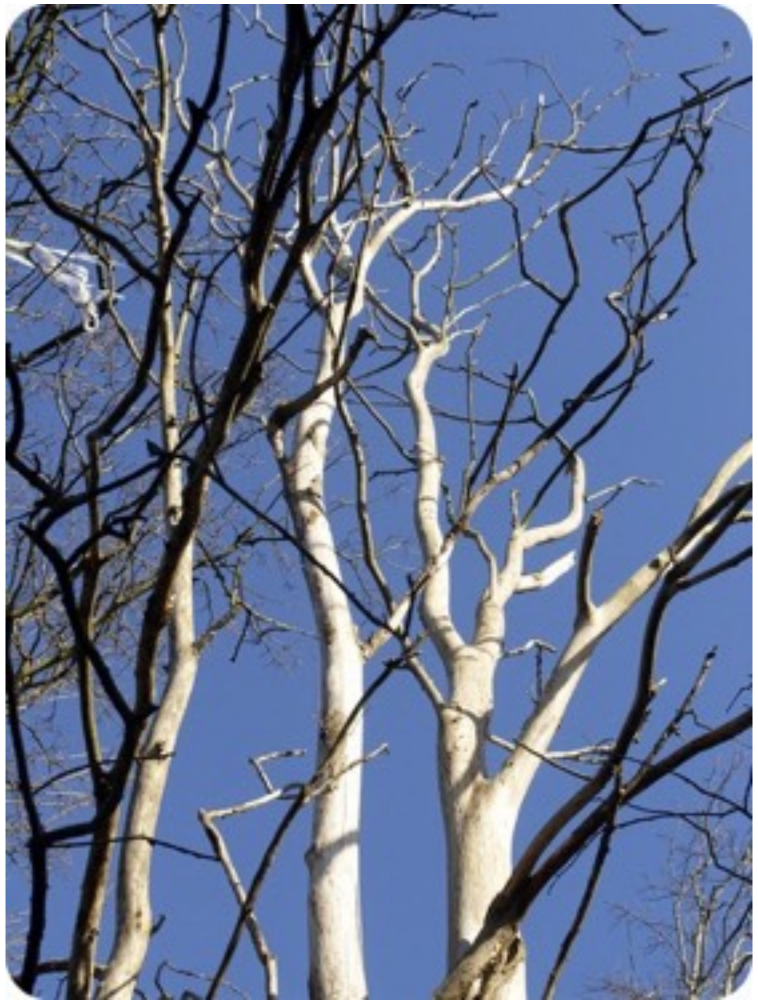
1. How are fungi different from plants.
2. What are three common types of fungi?
3. Where might fungi live? Give two habitats.
4. Describe how fungi absorb nutrients.

Section 8

Symbiotic Relationships of

Symbiotic Relationships of Fungi

•Define mycorrhizae and lichen.
•Describe symbiotic relationships that fungi have with other organisms.



What killed this tree?

Dutch elm trees used to be common, beautiful trees in the United States. Now most of them, like this tree, have been killed by Dutch elm disease. Dutch elm disease is caused by a fungus. This is just one example of how fungi can interact with other species.

Symbiotic Relationships with Fungi

Fungi don't live in isolation. They often interact with other species. In fact, fungi can be dependent on another organism for survival. When two species live close together and form a relationship, it is called **symbiosis** . Symbiosis can be beneficial to one or both organisms, or sometimes one organism hurts the other. Some of the partners in these relationships include plants, algae, insects, and even humans.

Fungi and Plants

If it were not for fungi, many plants would go hungry. In the soil, fungi grow closely around the roots of plants, and they begin to help each other. The plant roots together with the special root-dwelling fungi are called **mycorrhizae** (**Figure** below).

As plants and fungi form a close relationship, the plant and the fungus “feed” one another. The plant provides sugars to the fungus that the plant makes through photosynthesis, which the fungus cannot do. The fungus then provides minerals and water to the roots of the plant. Since the plant and the fungus are helping each other out, this is a

mutualistic relationship , a type of symbiosis known as mutualism. In a mutualistic relationship, both organisms benefit.

Figure 6.11

These roots (brown) and the mycorrhizae (white) help to feed one another.

Lichens

Have you ever seen an organism called a lichen? Lichens are crusty, hard growths that you might find on trees, logs, walls, and rocks (**Figure** below). Although lichens may not be the prettiest organisms in nature, they are unique. A **lichen** is really two organisms, sometimes referred to as a composite organism, that live very closely together: a fungus and a bacterium or an alga. The cells from the alga or bacterium live inside the fungus. Besides providing a home, the fungus also provides nutrients. In turn, the bacterium or the alga provides food to the fungus by performing photosynthesis. A lichen is also an example of a mutualistic relationship. Because lichens can grow on rocks, these organisms are some of the earliest life forms in new ecosystems.

Figure 6.12

This tree is covered in lichen, a symbiotic relationship between a fungus and a bacterium or an alga.

Fungi and Insects

Many insects have a symbiotic relationship with certain types of fungi:

- Ants and termites grow fungi in underground “fungus gardens” that they create. When the ants or termites have eaten a big meal of wood or leaves, they also eat some fungi from their gardens. The fungi help them digest the wood or leaves.
- Ambrosia beetles live in the bark of trees. Like ants and termites, they grow fungi inside the bark of trees and use it to help digest their food.

Fungi as Parasites

Although lots of symbiotic relationships help both organisms, sometimes one of the organisms is harmed. When that happens, the organism that benefits, and is not harmed, is called a **parasite** . This type of relationship is known as parasitism.

Examples of parasitic fungi include the following:

- Beginning in 1950, Dutch Elm trees in the United States began to die. Since then, most of these trees have been eliminated. The disease was caused by a fungus that acted as a parasite. The fungus that killed the trees was carried by beetles to the trees.
- Some parasitic fungi cause human diseases such as athlete’s foot and ringworm. These fungi feed on the outer layer of warm, moist skin.

Summary

- Fungi can form a mutualistic relationship with photosynthetic organisms, including plants, bacteria, and algae.
- Fungi can also be parasites of trees and people.

Explore More

Use the resources below to answer the questions that follow.

Explore More I

- **Arbuscular Mycorrhizae** at http://www.youtube.com/watch?v=PiZHFaQdcX8 (1:06)

Click on the image above for more content

1. What controls hyphae growth?
2. What is an arbuscule? What is its function?

Explore More II

- **An Ancient Hidden Partnership** at http://www.youtube.com/watch?v=JF-i6cJecm0 (3:25)

Click on the image above for more content

1. Why was it harder for plants to obtain phosphorus when they moved from an aquatic to a terrestrial environment? How did fungi help this situation?
2. How old is the fossil evidence for this association between plant and fungi?
3. What other types of nutrients do fungi help plants obtain?
4. What other beneficial effects of this symbiosis have been shown?

Review

1. What is a lichen?
2. Describe the mutualistic relationship within a lichen.
3. Describe a symbiotic relationship between fungi and insects.
4. Give an example of a fungal parasite in humans.

Section 9

Fungi Structure

Fungi Structure

•List the most important body parts of fungi.
•Distinguish a hyphae from a mycelium and from a fruiting body.

What, exactly, is a mushroom?

Mushrooms aren't around just so you can put them on your pizza. The mushroom is part of a large fungus that lives underground. The mushroom develops above the ground when the fungus is ready to reproduce.

Body Parts of Fungi

The most important body parts of fungi include:

1. Cell wall: A layer around the cell membrane of fungi cells made largely of chitin and other polysaccharides. It is similar to that found in plant cells, though the plant cell wall contains the polysaccharide cellulose.
2. **Hyphae** : These are thread-like strands which interconnect and bunch up into a **mycelium** (**Figure** below). Ever see mold on a damp wall or on old bread? The things that you are seeing are really mycelia. The hyphae and mycelia help the fungi absorb nutrients from other organisms. Most of the mycelium is hidden from view deep within the fungal food source, such as rotting matter in the soil, leaf litter, rotting wood, or dead animals.
3. Specialized structures for reproduction: One example is a fruiting body. A mushroom is a **fruiting body** , which is the part of the fungus that produces spores (**Figure** below). The spores are the basic reproductive units of fungi. The mycelium remains hidden until it develops one or more fruiting bodies.

The fruiting bodies are usually produced at the surface of the food source, rather than hidden within it. This allows the reproductive spores to be easily shed and carried away by the wind, water, or animals. The fruiting bodies are usually the only indication that a fungus is present. Like icebergs, the fruiting bodies represent only a tiny fraction of the whole fungus, with most of the fungus hidden from view.

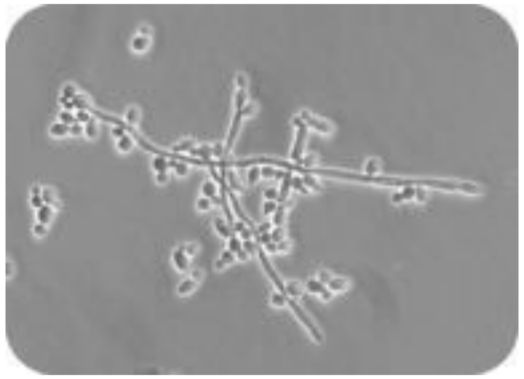


Figure 6.13

Hyphae of a *Penicillium* mold. The little “trees” are specialized hyphae on which spores are produced.

Figure 6.14

A mushroom is a fruiting body.

Summary

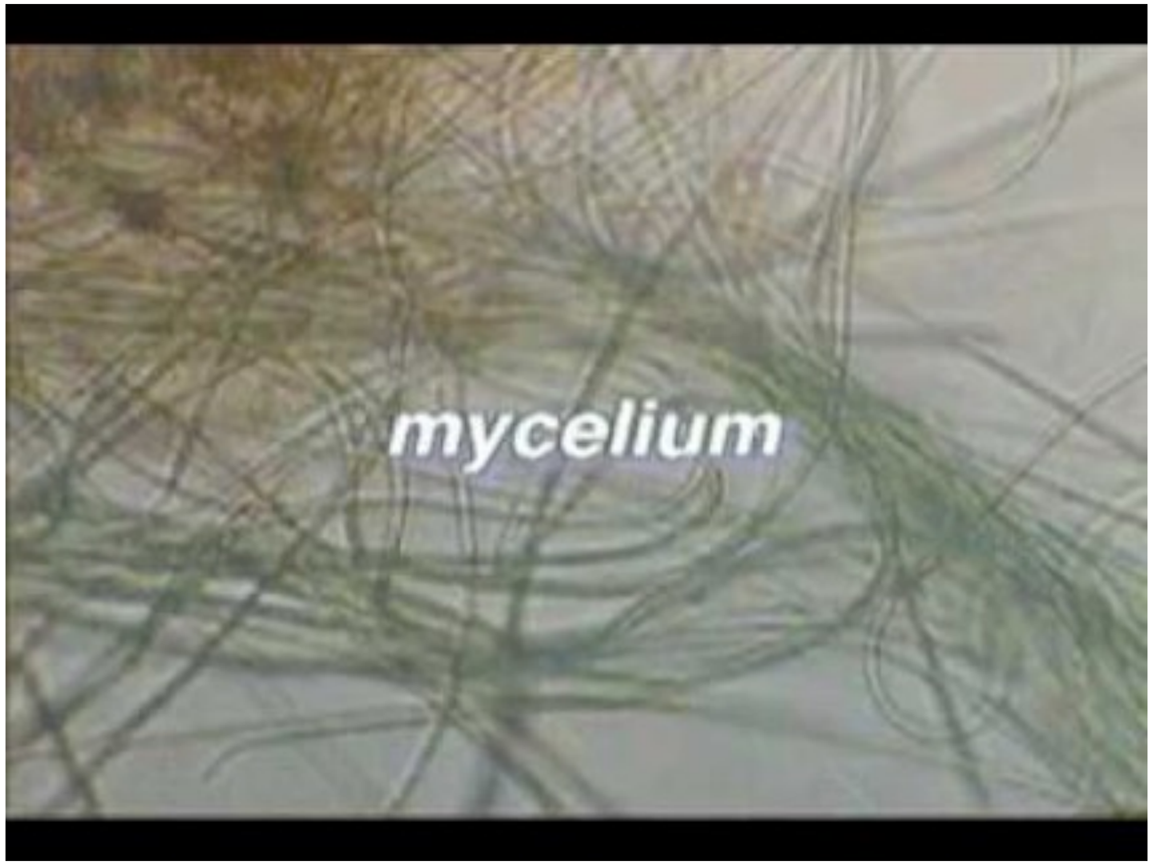
- Fungi have a cell wall.
- The fungal body consists of thread-like structures called hyphae, which can bunch up into a mycelium.
- Fungi often make specialized reproductive structures, such as a mushroom.

Explore More

Use the resources below to answer the questions that follow.

Explore More I

- **Structure of Fungi** at http://www.youtube.com/watch?v=dM_g_p4h6CM (1:33)



Click on the image above for more content

1. What are fruiting bodes?
2. How fast can a mycelium grow?

3.What is the function of mushrooms from the fungi point of view?

Explore More II

•**Structure of Fungi** at http://www.countrysideinfo.co.uk/fungi/struct.htm

1.What is the fungal body made up of?
2.Why is the fungal mycelium usually hidden from view?
3.What part of a fungus is usually most visible?

Review

1.What makes up the main "body" of the fungus?
2.What is the purpose of a mushroom?
3.What are hyphae? How do they relate to the mycelium?

Section 10

Fungi Reproduction

Fungi Reproduction

•Describe asexual reproduction in fungi.
•Summarize sexual reproduction in fungi.

What's this brown powder coming out of the fungus?

This is a "puffball" fungus. At maturity, clouds of a brown dust-like power escape when they are touched. This powdery substance is made up of spores, the reproductive structure of the fungus.

Reproduction in Fungi

Different fungi reproduce in different ways. Many fungi reproduce both sexually and asexually. However, some reproduce only sexually and some only asexually. Asexual reproduction involves just one parent and sexual reproduction involves two parents.

Asexual Reproduction

Through **asexual reproduction** , new organisms are produced that are genetically identical to the parent. That is, they have exactly the same DNA. Fungi reproduce asexually through three methods:

1.**Spores** : Spores are formed by the fungi and released to create new fungi. This is the powdery substance released by puffballs.
2.Budding: The fungus grows a new part of its body, which eventually breaks off. The broken-off piece becomes a “new” organism (**Figure** below).
3.Fragmentation: In this method, a piece of the mycelium, the body of the fungus, splits off. The resulting fragment can eventually produce a new colony of fungi.

Figure 6.15

Yeast reproduce asexually by budding.

Asexual reproduction is faster and produces more fungi than sexual reproduction. This form of reproduction is controlled by many different factors. Outside conditions, such as the availability of food, determine when a fungus undergoes asexual reproduction.

Sexual Reproduction

Almost all fungi can reproduce sexually. But why reproduce sexually when asexual reproduction is much quicker? **Sexual reproduction** brings together traits from the two parents. This increases the genetic diversity of the species. In plants and animals, sexual reproduction occurs when sperm and egg from two parents join to make a new individual. In fungi, however, two haploid hyphae meet together and their nuclei fuse. Instead of calling a hyphae male or female, they have different mating types, such as (+) and (-) (**Figure** below).

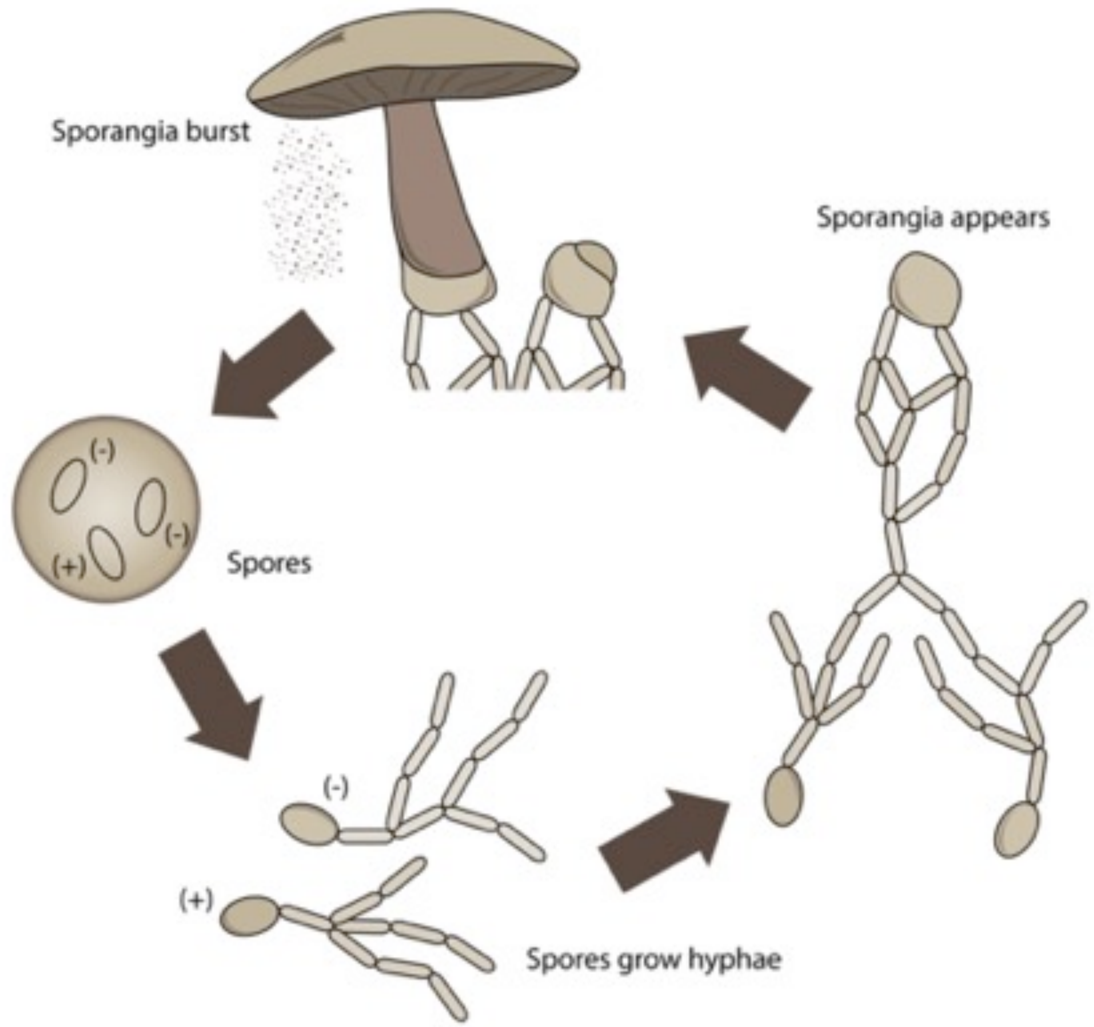


Figure 6.16

The common mushroom, a fruiting body, results after sexual reproduction when two hyphae, one (+) and one (-), mate.

Summary

- Fungi can reproduce asexually by spores, budding, or fragmentation.
- Fungi can reproduce sexually to create a zygospore.

Explore More

Use the resources below to answer the questions that follow.

Explore More I

- **Reproduction in Fungi** at http://www.youtube.com/watch?v=qDwgSWDqKoQ (2:06)

Click on the image above for more content

1. Where are spores made in a fungi?
2. When does fertilization occur in fungi?
3. When does meiosis occur during the reproduction cycle of a fungus?
4. What disperses the fungal spores?
5. What happens to the spores in favorable conditions?

Explore More II

- **Sexual and Asexual Reproduction in Fungi** at http://www.youtube.com/watch?v=A1uQ5rXmbO8 (2:33)

Click on the image above for more content

1. When is asexual reproduction advantageous to fungi?
2. When is sexual reproduction advantageous to fungi?

3. How does the ability to reproduce sexually or asexually make fungi adaptive to a wider range of environments?

Review

1. How do fungi reproduce asexually?
2. What is the advantage of sexual reproduction?
3. What is a spore?
4. What are the two "sexes" of fungi?

Section 11

Fungi Classification

Fungi Classification

•Summarize characteristics that distinguish fungi from plants.
•List the three common types of fungi.

What's growing on these oranges?

Mold, of course! Did you know that mold is a type of fungus? There are many different types of fungi besides molds, however, including mushrooms. Mold and mushrooms are obviously different. So how are these fungi classified?

Fungi Classification

Scientists used to think that fungi were members of the plant kingdom. They thought this because fungi had several similarities to plants. For example:

•Fungi and plants have similar structures.
•Plants and fungi live in the same kinds of habitats, such as growing in soil.
•Plants and fungi cells both have a cell wall, which animals do not have.

How Fungi and Plants Differ

However, there are a number of characteristics that make fungi different from plants:

1.Fungi cannot make their own food like plants can, since they do not have chloroplasts and cannot carry out photosynthesis. Fungi are more like animals because they are **heterotrophs** . They have to obtain their food, nutrients and glucose, from outside sources.
2.The cell walls in many species of fungi contain chitin. **Chitin** is tough carbohydrate found in the shells of animals such as beetles and lobsters. The cell wall of a plant is made of cellulose, not chitin.
3.Unlike many plants, most fungi do not have structures, such as xylem and phloem, that transfer water and nutrients.

The Types of Fungi

The Kingdom Fungi can be broken down into several phyla. Each phyla has some unique traits. And even within the same phyla there are many differences among the fungi. Various types of fungi are pictured below (**Table** below). Notice how different each of these organisms are from one another.

Click on the image above to view the table

Summary

- Fungi are no longer classified as plants.
- Although fungi have cell walls like plants, the cell walls are made of chitin instead of cellulose.
- Types of fungi include molds, yeasts, and mushrooms.

Explore More

Use the resources below to answer the questions that follow.

Explore More I

- **The Fungi Kingdom** at http://www.wisc-online.com/Objects/ViewObject.aspx?ID=bio304

1. How many of the existing fungi do scientist feel they have identified?
2. What are three general characteristics of Chrytid fungi?
3. Give three examples of Basidiomycetes.
4. What is the defining characteristic of Ascomycetes?
5. How are all fungi the same? How do they differ?

Explore More II

- **Asomycete Fungi** at http://www.youtube.com/watch?v=ioBGnZwRjsQ (5:52)

Click on the image above for more content

1. In what kind of habitats do you find Ascomycete fungi?
2. How large is their fruiting body?
3. Do you think you can find Ascomycerte in marine environments? Why or why not?
4. What characteristics do scientists use to distinguish between different species of fungi?

Review

1. What do plants and fungi have in common?
2. What are the significant differences between plants and fungi?
3. How are fungi more like animals than plants?

Section 12

Human Uses of Fungi

Human Uses of Fungi

•Describe how fungi are important to humans.

What would happen if there were no fungi?

We'd be living in a huge trash pile! All the fallen leaves, grass clippings, dead trees, and other organic waste would just build up. Fungi are important decomposers in the environment. Not only do they get rid of wastes, they make the nutrients in the wastes available to other organisms. This is just one way that fungi are important to us.

Fungi Roles

Fungi are extremely important to the ecosystem because they are one of the major decomposers of organic material. But they have other roles in addition to being decomposers. How do fungi help people? They are used to help prepare food and beverages, and they have many other uses.

Importance of Fungi for Human Use

•Yeasts are crucial for the **fermentation** process that makes beer, wine, and bread. Fermentation occurs in the absence of oxygen and allows the first step of cellular respiration, glycolysis, to continue.
•Some fungi are used in the production of soy sauce and tempeh, a source of protein used in Southeast Asia.
•Fungi can produce **antibiotics** , such as penicillin. Antibiotics are important medicines that kill bacteria.
•Mushrooms are fungi that are eaten by people all over the globe.

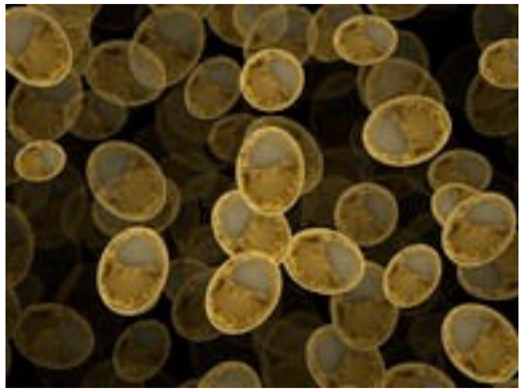


Figure 6.17

Saccharomyces cerevisiae , a single-celled fungus called brewer's or baker's yeast, is used in the baking of bread and in making wine and beer through fermentation.

The video *Bread Mold Kills Bacteria* at https://www.youtube.com/watch?v=pvEfyJc4QPA explains Alexander Fleming's famous discovery that lead to the discovery of the antibiotic penicillin. See *Alexander Fleming 1881 - 1955* at http://www.pbs.org/wgbh/aso/databank/entries/bmflem.html for more information about Dr. Fleming.

Click on the image above for more content

Edible and Poisonous Fungi

Some of the best known types of fungi are mushrooms, which can be edible or poisonous (**Figure** below). Many species are grown commercially, but others are harvested from the wild. When you order a pizza with mushrooms or add them to your salad, you are most likely eating *Agaricus bisporus* , known as white or button mushrooms, the most commonly eaten species. Other mushroom species are gathered from the wild for people to eat or for commercial sale. Many mushroom species are poisonous to humans. Some mushrooms will simply give you a stomachache, while others may kill you. Some mushrooms you can eat when they are cooked but are poisonous when raw. So if you find mushrooms in the wild, don't eat them until you are certain they are safe!

Have you ever eaten blue cheese? Do you know what makes it blue? You guessed it. A fungus. For certain types of cheeses, producers add fungus spores to milk curds to promote the growth of mold, which makes the cheese blue. Molds used in cheese production are safe for humans to eat.

Figure 6.18

Some fungi are poisonous and must be avoided.

Summary

- Yeast are used for the fermentation process that makes beer, wine, and bread.
- Some mushrooms are edible, but others can make you sick or even kill you.

Explore More

Use the resources below to answer the questions that follow.

Explore More I

- **Penicillin** at http://herbarium.usu.edu/fungi/FunFacts/penicillin.htm

1. What did Alexander Fleming observe that led to the discovery of penicillin?
2. What does penicillin do?
3. Where was penicillin isolated from?
4. What did scientists need to do to grow *Penicillium notatum* in deep fermentation vats?

Explore More II

- **Decomposition** at http://www.youtube.com/watch?v=h6gZY4OJCuA (1:57)

Click on the image above for more content

1. Do the same species of fungi take care of the entire decomposition process? Explain your answer.
2. Do all species of fungi seek the same resources from decaying matter? Explain your answer.
3. Why is biodiversity among fungi important?

Review

1. What are two human uses of fungi?
2. Do you think it is safe to eat a mushroom you find in your yard? Why or why not?

Summary

Protists and Fungi are two types of eukaryotic organisms. What do they have in common? Protists are the earliest eukaryotes, and this kingdom contains some of the simplest eukaryotes. Many are single-celled organisms. Protists consist of animal-like, plant-like, and fungus-like species. Protists evolved into the other three types of eukaryotes, including fungi. Other than that, these two types of eukaryotes are very different. Fungi are eukaryotic organisms that cannot make their own food and do not "eat." They must absorb their nutrients, usually from decaying organisms.

References

1. Amit Patel. Kelp is an example of a muticellular protist . CC BY 2.0
2. (Clockwise from top left) Giuseppe Vago; Ute Frevert, colored by Margaret Shear; Yuiuji Tsukii; Ernst Haeckel; Dr. Myron G. Schultz/CDC. Protists come in many different shapes . (Clockwise from top left) CC BY 2.0; CC BY 2.5; Public Domain; Public Domain; Public Domain
3. Doug Bowman. Slime molds live on decaying plant life and in the soil . CC BY 2.0
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9. (Clockwise from top left) Tim Bekaert; Velela; Nick Saltmarsh; Jason Hollinger; Dominic Alves. Picture showing the diversity in fungi . (Clockwise from top left) Public Domain; Public Domain; CC BY 2.0; CC BY 2.0; CC BY 2.0
10. Jon Sullivan. The blue in this blue cheese is actually mold, which is a fungus . Public Domain
11. R Henrik Nilsson, Erik Kristiansson, Martin Ryberg, Karl-Henrik Larsson/BioMed Central. Plant roots and fungi, mycorrhizae, help feed each other . CC BY 2.0
12. Axel Kuhlmann. This tree is covered in lichen, a symbiotic relationship between a fungus and a bacterium or an alga . Public Domain
13. Image copyright Andre Nantel, 2014. Hyphae of a penicillium mold . Used under license from Shutterstock.com
14. Janet Ramsden. A mushroom is a fruiting body . CC BY 2.0
15. National Institute of Allergy and Infectious Diseases/NIH. Yeast reproduce asexually by budding . Public Domain
16. Zachary Wilson. The common mushroom, a fruiting body, results after sexual reproduction when two hyphae mate . CC BY-NC 3.0
17. Zappy's. Microscope image of baker's yeast . CC BY-NC 3.0
18. Maja Dumat. Picture of poisonous fungi . CC BY 2.0

Plants

Plants

Introduction

What exactly is a plant?

Does a plant have to be green? Do they all photosynthesize? They are eukaryotic organisms that are not animals, fungi, or protists. And yes, they have to photosynthesize.

Section 1

Plant Characteristics

Plant Characteristics

- •Describe the three major characteristics of all plants.
- •Explain the primary role of plants in ecosystems.

What is this?

You may be surprised that this is a picture of plants. They look a little like stones. In fact, these plants are often called "living stones." Organisms don't need to have big green leaves to be considered plants. What do you think distinguishes plants from other organisms?

What are Plants?

Plants have adapted to a variety of environments, from the desert to the tropical rain forest to lakes and oceans. In each environment, plants have become crucial to supporting animal life. Plants are the food that animals eat. Plants also provide places for animals, such as insects and birds, to live. From tiny mosses to gorgeous rose bushes to extremely large redwood trees (**Figure** below), the organisms in this kingdom, Kingdom Plantae, have three main features. They are all:

1. Eukaryotic.
2. Photosynthetic.
3. Multicellular.

Recall that **eukaryotic** organisms also include animals, protists, and fungi. Eukaryotes have cells with nuclei that contain DNA and membrane-bound organelles, such as mitochondria. **Photosynthesis** is the process by which plants capture the energy of sunlight and use carbon dioxide from the air (and water) to make their own food, the carbohydrate glucose. Plants have chloroplasts, the organelle of photosynthesis, and are known as **producers** and **autotrophs** . Other organisms are heterotrophic consumers, meaning they must obtain their nutrients from another organism. Lastly, plants must be multicellular, composed of more than one cell. There are no single-celled plants. Recall that some protists are eukaryotic and photosynthetic but are not considered plants because they are mostly unicellular.

Figure 7.1

There is great diversity in the plant kingdom, from tiny mosses to huge trees.

Summary

- Plants are multicellular and eukaryotic, meaning their cells have a nucleus and membrane-bound organelles.
- Plants perform photosynthesis, the process by which plants capture the energy of sunlight and use carbon dioxide from the air to make their own food.

Explore More

Use the resource below to answer the questions that follow.

- **Kingdom Plantae** at http://www.youtube.com/watch?v=gJrOATCtV-k (7:59)

Click on the image above for more content

1. What three characteristics do all plants share?
2. What is the role of they plant cell wall?
3. What allows for photosynthesis in the plant cell?
4. What is the main difference between a sporophyte and a gametophyte?

Review

1. If a fern is a plant, then what are three characteristics you know to be true about ferns?

2.Mushrooms gain their energy from decomposing dead organisms. Explain why a mushroom is not a plant.

3.What is the organelle of photosynthesis?

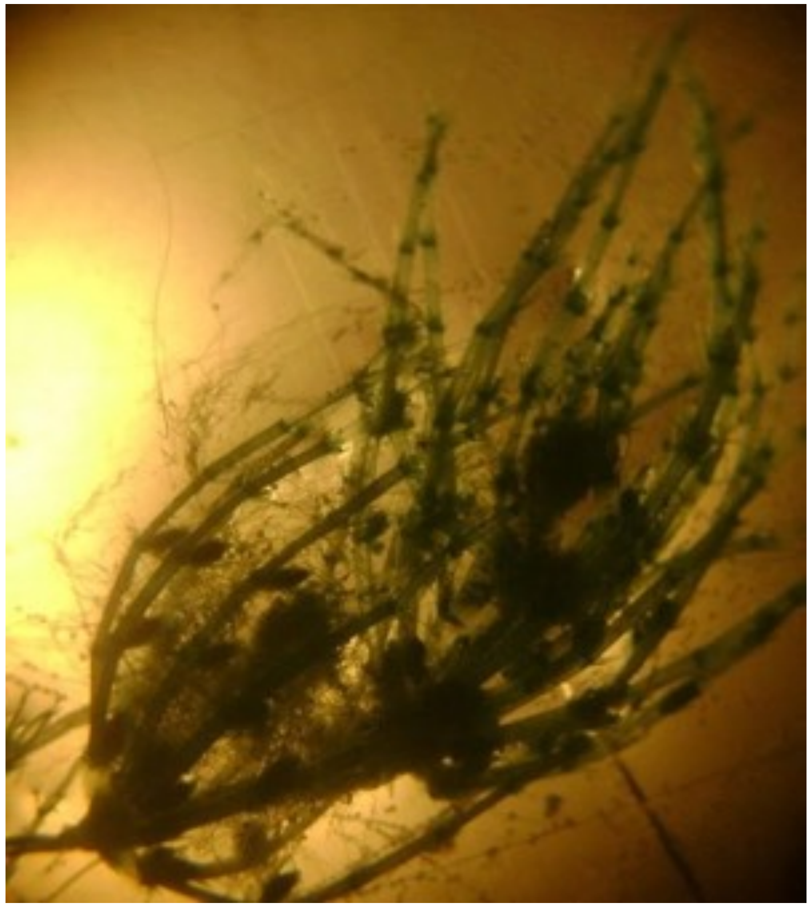
4.Describe the relationship between producers and autotrophs.

Section 2

Plants' Adaptations for Life

Plants' Adaptations for Life on Land

- •Define cuticle, stomata, and vascular tissue as related to plants.
- •Distinguish xylem from phloem.
- •Describe plants' major adaptations for life on land.



Where did plants come from?

Plants have not always been around on land. For a long time, life was confined to water. The first plants evolved from green algae that looked somewhat like the *Chara* pictured above.

Plants' Adaptations for Life on Land

The first photosynthetic organisms were bacteria that lived in the water. So, where did plants come from? Evidence shows that plants evolved from freshwater green algae, a protist (**Figure** below). The similarities between green algae and plants is one piece of evidence. They both have cellulose in their cell walls, and they share many of the same chemicals that give them color. So what separates green algae from green plants?

Figure 7.2

The ancestor of plants is green algae. This picture shows a close up of algae on the beach.

There are four main ways that plants adapted to life on land and, as a result, became different from algae:

1. In plants, the embryo develops inside of the female plant after fertilization. Algae do not keep the embryo inside of themselves but release it into water. This was the first feature to evolve that separated plants from green algae. This is also the only adaptation shared by all plants.
2. Over time, plants had to evolve from living in water to living on land. In early plants, a waxy layer called a **cuticle** evolved to help seal water in the plant and prevent water loss. However, the cuticle also prevents gases from entering and leaving the plant easily. Recall that the exchange of gasses—taking in carbon dioxide and releasing oxygen—occurs during photosynthesis.
3. To allow the plant to retain water and exchange gases, small pores (holes) in the leaves called **stomata** also evolved (**Figure** below). The stomata can open and close depending on weather conditions. When it's hot and dry, the stomata close to keep water inside of the plant. When the weather cools down, the stomata can open again to let carbon dioxide in and oxygen out.
4. A later adaption for life on land was the evolution of vascular tissue. **Vascular tissue** is specialized tissue that transports water, nutrients, and food in plants. In algae, vascular tissue is not necessary since the entire body is in contact with the water, and the water simply enters the algae. But on land, water may only be found deep in the ground. Vascular tissues take water and nutrients from the ground up into the plant, while also taking food down from the leaves into the rest of the plant. The two vascular tissues are xylem and phloem. **Xylem** is responsible for the transport of water and nutrients from the roots to the rest of the plant. **Phloem** carries the sugars made in the leaves to the parts of the plant where they are needed.

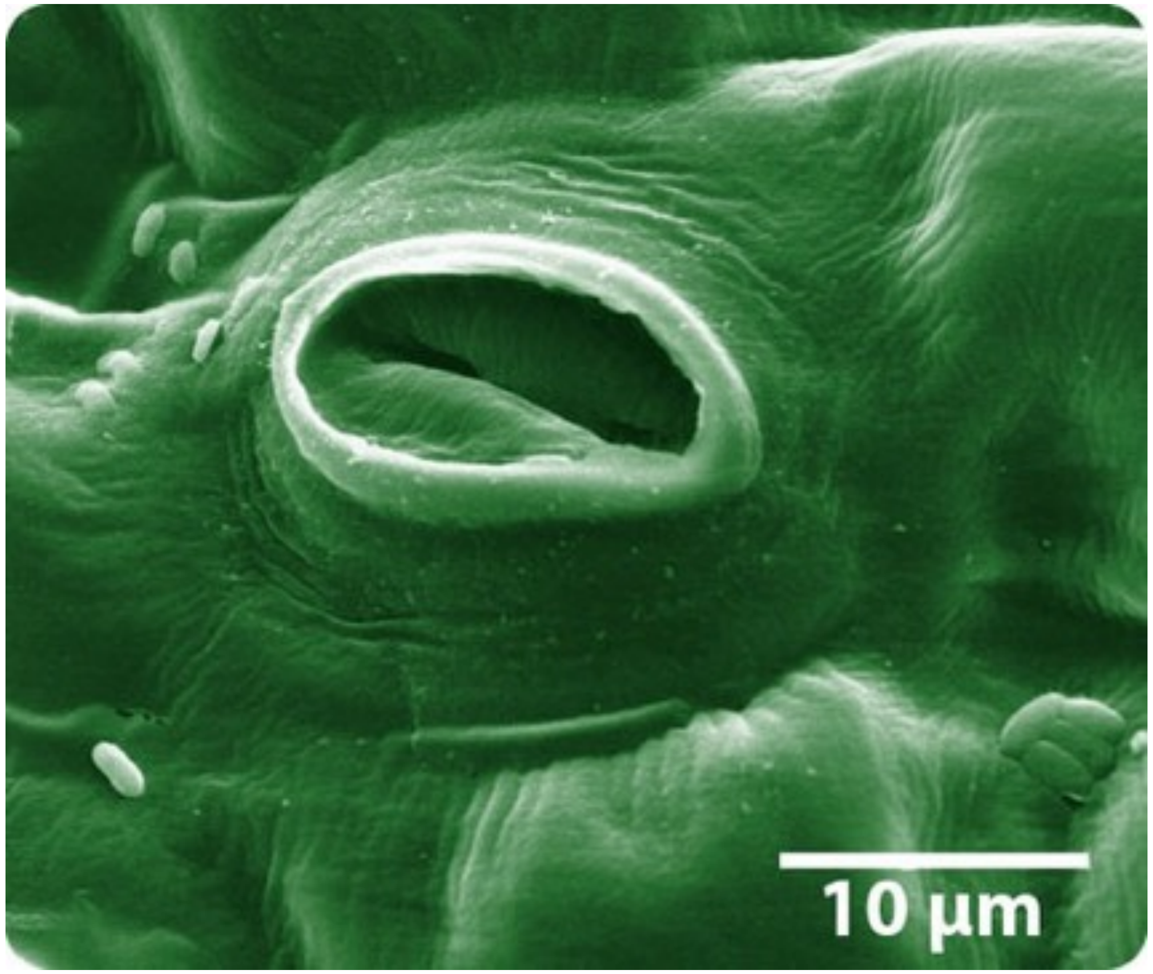


Figure 7.3

Stomata are pores in leaves that allow gasses to pass through, but they can be closed to conserve water.

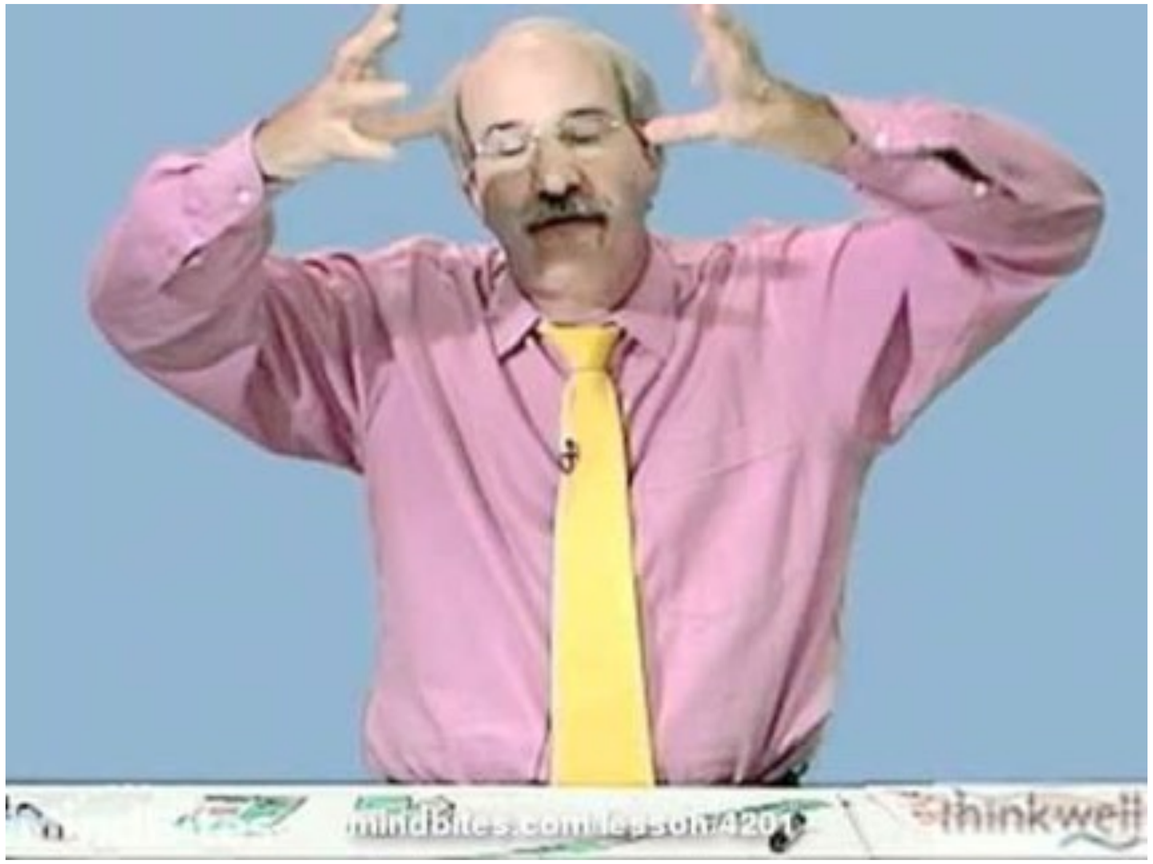
Summary

- Plants evolved from freshwater green algae.
- Plants have evolved several adaptations to life on land, including embryo retention, a cuticle, stomata, and vascular tissue.

Explore More

Use the resources below to answer the questions that follow.

- **The Role of Xylem Tissue and Stomata** at http://www.youtube.com/watch?v=QBMkiLIyETc (3:34)



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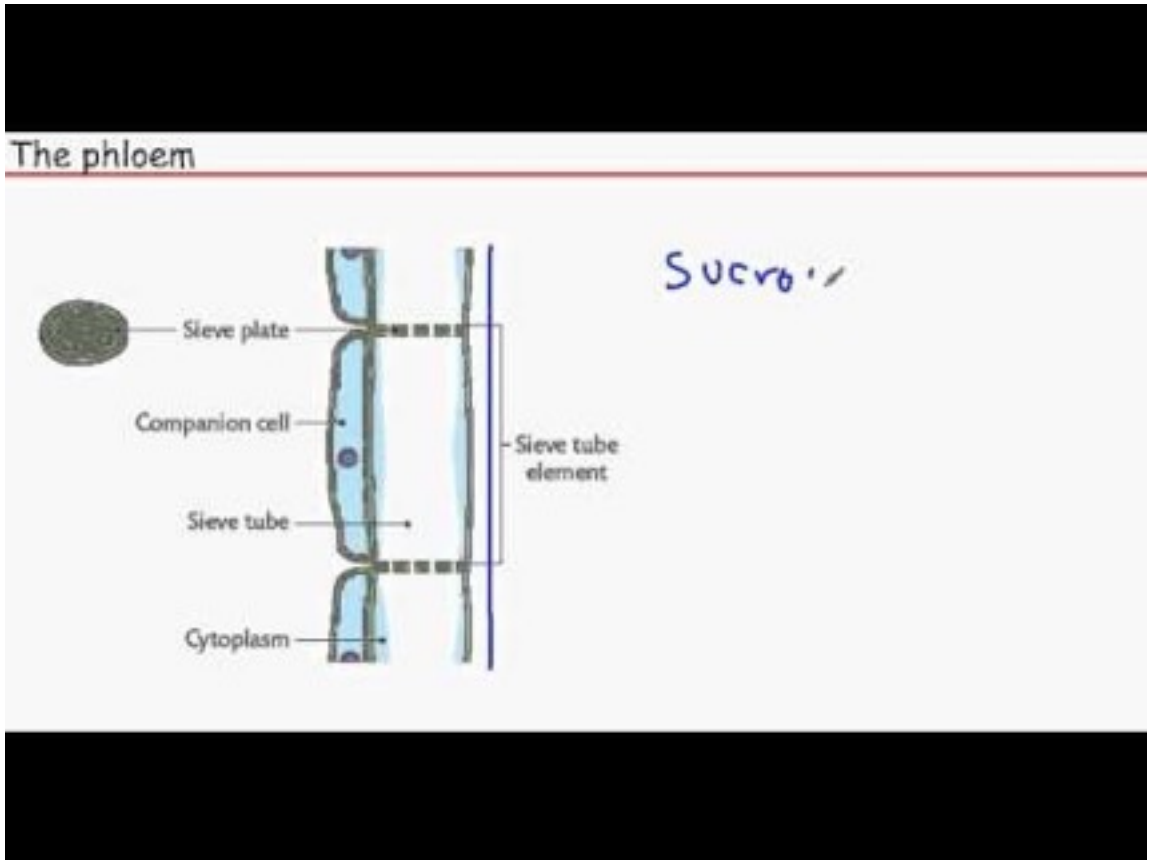
- **The Phloem** at http://www.youtube.com/watch?v=M4onP3_4ERU (3:03)



Click on the image above for more content

1. In what groups of plants do you find xylem and phloem? Hint: refer to previous lesson if necessary.
2. What are the main components of sap?
3. Compare and contrast xylem and phloem.
    a. What does each transport?
    b. How are their structures similar?
4. What is "transpirational pull"? How is it key to the functioning of xylem?

Review

1. How are plants different from green algae? How are they the same?
2. What is the purpose of vascular tissue?
3. How do plants prevent excess water loss?
4. Compare xylem to phloem.
5. What is the role of stomata?

Section 3

Plant Reproduction and Life

Plant Reproduction and Life Cycle

•Define alternation of generations.
•Outline plants' reproductive cycle.
•Distinguish a sporophyte from a gametophyte.

Do all plants have flowers?

No, plants do not all have flowers. For example, the mosses and ferns pictured here are both types of plants. However, they never produce flowers. They don't produce seeds, either. They do, however, make tiny spores to reproduce.

Plant Reproduction and Life Cycle

The life cycle of a plant is very different from the life cycle of an animal. Humans are made entirely of **diploid cells** (cells with two sets of chromosomes). Our only cells that are **haploid cells** (cells with one set of chromosomes) are sperm and egg cells. Plants, however, can live when they are are at the stage of having haploid cells or diploid cells.

Plants alternate between diploid-cell plants and haploid-cell plants. This is called **alternation of generations** , because the plant type alternates from generation to generation. In alternation of generations, the plant alternates between a **sporophyte** that has diploid cells and a **gametophyte** that has haploid cells.

Alternation of generations can be summarized in the following four steps: follow along in the **Figure** below as you read through the steps.

1. The gametophyte produces the gametes, or sperm and egg, by mitosis. Remember, gametes are haploid, having one set of chromosomes.
2. Then, the sperm fertilizes the egg, producing a diploid zygote that develops into the sporophyte.
3. The diploid sporophyte produces haploid **spores** by meiosis.

4.The haploid spores go through mitosis, developing into the haploid gametophyte.

As we will see in additional *Plants* concepts, the generation in which the plant spends most of its life cycle is different between various plants. In the plants that first evolved, the gametophyte takes up the majority of the life cycle of the plant. During the course of evolution, the sporophyte became the major stage of the life cycle of the plant.

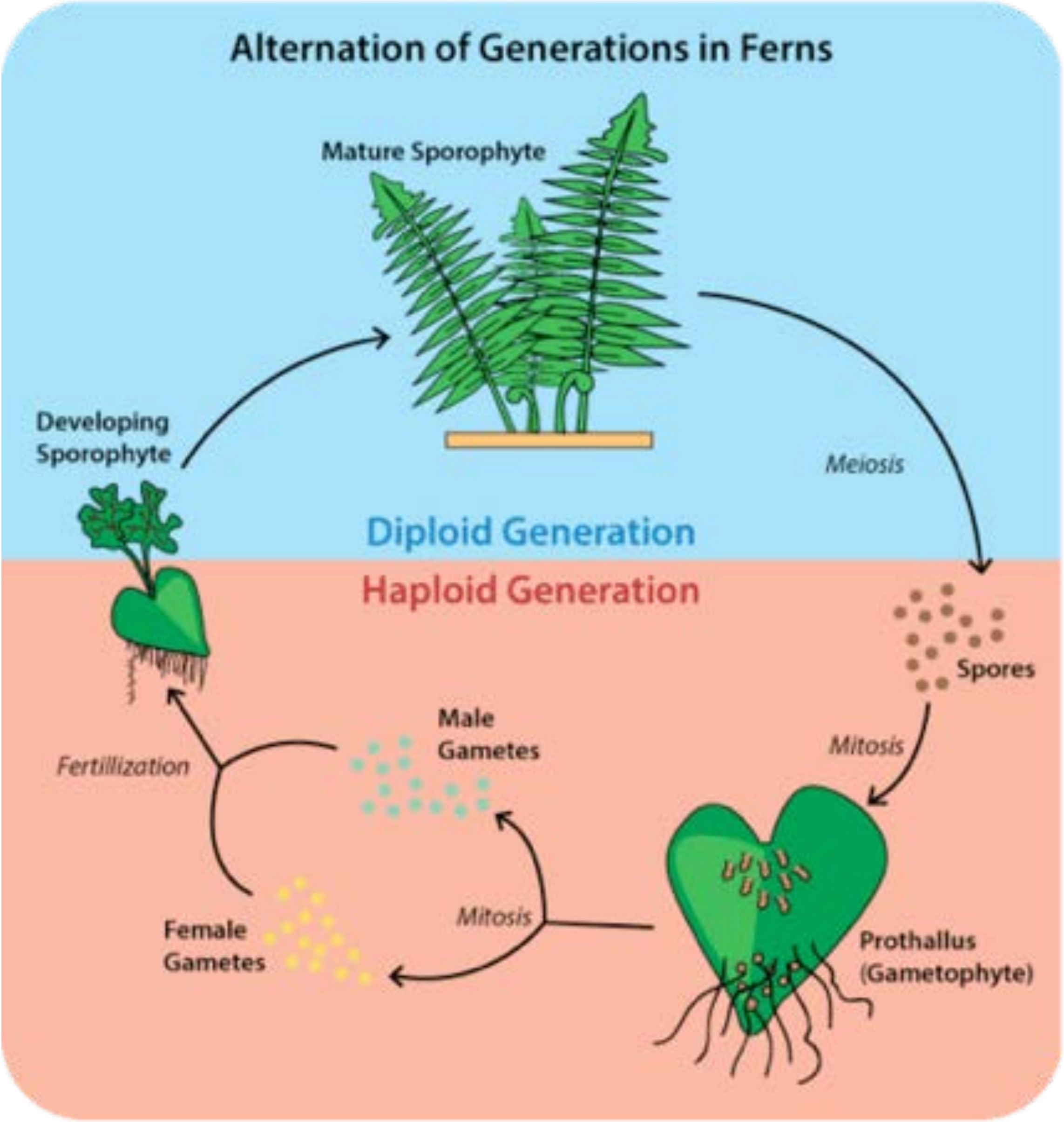


Figure 7.4

In ferns, the sporophyte is dominant and produces spores that germinate into a heart-shaped gametophyte.

Summary

- •Plants undergo alternation of generations, meaning they alternate between diploid-cell plants and haploid-cell plants.
- •During the course of evolution, the sporophyte (diploid) became the major stage of the life cycle of the plant.

Explore More

Use the resource below to answer the questions that follow.

- •**Plant Reproduction** at http://www.youtube.com/watch?v=ZvBMQIrlhYw (2:23)

Click on the image above for more content

1. When does meiosis occur during a plant's life cycle?
2. When does mitosis occur during a plant's life cycle?
3. How do gametophytes with both male and female parts avoid self-fertilization?
4. Describe the fertilization process for an Angiosperm.

Review

1. What is the difference between a haploid and diploid cell?
2. What does "alternation of generations" mean?
3. What part of the plant life cycle is made of haploid cells, the sporophyte or the gametophyte?
4. What process is used by the sporophyte to produce spores?

Section 4

Plant Classification

Plant Classification

- Explain how plants are classified.
- Distinguish vascular plants from nonvascular plants.
- Distinguish gymnosperms from angiosperms.

Do all plants grow from seeds?

No, there are actually a few plants that do not make seeds. Whether or not a plant makes seeds is one criteria used to classify plants. How else could you distinguish between plants?

Plant Classification

Plants are formally divided into 12 phyla (plural for phylum), and these phyla are gathered into four groups (**Figure** below). These four groups are based on the evolutionary history of significant features in plants:

1. **Nonvascular plants** evolved first. They are distinct from the algae because they keep the embryo inside of the reproductive structure after fertilization. These plants do not have vascular tissue, xylem or phloem, to transport nutrients, water, and food. Examples include mosses, liverworts, and hornworts.
2. **Seedless vascular plants** evolved to have vascular tissue after the nonvascular plants but do not have seeds. Examples include the ferns, whisk ferns, club mosses, and horsetails.
3. **Gymnosperms** evolved to have seeds but do not have flowers. Examples of gymnosperms include the Redwood, Fir, and Cypress trees.
4. Flowering plants, or **angiosperms** , evolved to have vascular tissue, seeds, and flowers. Examples of angiosperms include magnolia trees, roses, tulips, and tomatoes.

Figure 7.5

The plant kingdom contains a diversity of organisms.

Summary

- •Nonvascular plants were the first plants to evolve and do not have vascular tissue.
- •Seedless vascular plants have vascular tissue but do not have seeds.
- •Gymnosperms have seeds but do not have flowers.
- •Angiosperms have vascular tissue, seeds, and flowers.

Explore More

Use the resource below to answer the questions that follow.

- •**Plant Body Systems and Classification Part 1** at http://www.youtube.com/watch?v=6FnPVFPSt3A (7:21)

Click on the image above for more content

1. What plant groups are included in non-vascular plants

2.Give an example of a seedless vascular plant.
3.What groups of plants have seeds?
4.What groups of plants have fruit?
5.Where do you usually find non-vascular plants? Why?

Review

1.What distinguishes the gymnosperms from other plants?
2.What were the first types of plants to evolve?
3.List the following major features of plants in the order they evolved: seeds, vascular tissue, flowers.
4.Give two examples of seedless vascular plants.
5.Give two examples of angiosperms.

Section 5

Nonvascular Plants

Nonvascular Plants

- •Define bryophyte.
- •Describe examples of nonvascular seedless plants.

What did forests look like millions of years ago?

The trees you see today did not exist. Nonvascular plants and vascular seedless plants first dominated the forest. The remains of these forests formed the coal that we depend on today.

Nonvascular Seedless Plants

Nonvascular seedless plants , as their name implies, lack vascular tissue. **Vascular tissue** is specialized tissue that transports water, nutrients, and food in plants. As they lack vascular tissue, they also do not have true roots, stems, or leaves. Nonvascular plants do often have a “leafy” appearance, though, and they can have stem-like and root-like structures. These plants are very short because they cannot move nutrients and water up a stem.

Nonvascular seedless plants, also known as **bryophytes** , are classified into three phyla:

1. Mosses
2. Hornworts
3. Liverworts

Mosses

Mosses are most often recognized as the green “fuzz” on damp rocks and trees in a forest. If you look closely, you will see that most mosses have tiny stem-like and leaf-like structures. This is the gametophyte stage. Remember that a **gametophyte** is haploid, having only one set of chromosomes. The gametophyte produces the gametes that, after fertilization, develop into the diploid **sporophyte** with two sets of chromosomes. The sporophyte forms a capsule, called the **sporangium** , which releases spores (**Figure** below).

Figure 7.6

Sporophytes sprout up on stalks from this bed of moss gametophytes. Notice that both the sporophytes and gametophytes exist at the same time.

Hornworts

Hornworts are named for their appearance. The "horn" part of the name comes from their hornlike sporophytes, and “wort” comes from the Anglo-Saxon word for herb. The hornlike sporophytes grow from a base of flattened lobes, which are the gametophytes (**Figure** below). They usually grow in moist and humid areas.

Figure 7.7

In hornworts, the “horns” are the sporophytes that rise up from the leaflike gametophyte.

Liverworts

Liverworts have two distinct appearances: they can either be leafy like mosses or flattened and ribbon-like. Liverworts get their name from the type with the flattened bodies, which can resemble a liver (**Figure** below). Liverworts can often be found along stream beds.

Figure 7.8

Liverworts with a flattened, ribbon-like body are called thallose liverworts.

Summary

- Nonvascular plants lack seeds and vascular tissue.
- Nonvascular plants include the mosses, the hornworts, and the liverworts.

Explore More

Use the resource below to answer the questions that follow.

- **Nonvascular Plants** at http://www.youtube.com/watch?v=kBPLKUTtXBM (3:22)

Click on the image above for more content

1. How do bryophytes keep their eggs from drying out?
2. How does bryophyte sperm locate the bryophyte egg?
3. What happens in the archegonia?
4. What happens in the antheridium?
5. Where does fertilization of the bryophyte egg occur?

Review

1. What is a bryophyte?
2. What are examples of nonvascular plants?
3. Why do nonvascular plants tend to be very short?

Section 6

Vascular Seedless Plants

Vascular Seedless Plants

•Give properties of vascular seedless plants.
•Describe examples of vascular seedless plants.

How do these trees and mosses differ?

The trees tower in the sky, while the mosses carpet the forest floor. Mosses, like the first plants, are restricted to life near the ground because they lack vascular system. Only with a vascular system can these trees transport sugars, nutrients, and water up and down their tall trunks. The evolution of the vascular system was a big step in the evolutionary history of plants.

Vascular Seedless Plants

For these plants, the name says it all. **Vascular seedless plants** have vascular tissue but do not have seeds. Remember that vascular tissue is specialized tissue that transports water and nutrients throughout the plant. The development of vascular tissue allowed these plants to grow much taller than nonvascular plants, forming ancient swamp forests. Most of these large vascular seedless plants are now extinct, but their smaller relatives still remain. Vascular tissue includes xylem, which transports water from the roots to the rest of the plant; and phloem, which transports sugars and nutrients from the leaves throughout the plant.

Seedless vascular plants include:

1. Clubmosses.
2. Ferns.
3. Horsetails.
4. Whisk ferns.

Clubmosses

Clubmosses are so named because they can look similar to mosses (**Figure** below). Clubmosses are not true mosses, though, because they have vascular tissue. The “club” part of the name comes from club-like clusters of sporangia found on the plants. One type of clubmoss is called the "resurrection plant" because it shrivels and turns brown when it dries out but then quickly turns green when watered again.

Figure 7.9

Clubmosses can resemble mosses; however, clubmosses have vascular tissue, while mosses do not.

Ferns

Ferns are the most common seedless vascular plants (**Figure** below). They usually have large divided leaves called fronds. In most ferns, fronds develop from a curled-up formation called a fiddlehead (**Figure** below). The fiddlehead looks like the curled decoration on the end of a stringed instrument, such as a fiddle. Leaves unroll as the fiddleheads grow and expand. Ferns grow in a variety of habitats, ranging in size from tiny aquatic species to giant tropical plants.

Figure 7.10

Ferns are common in the understory of the tropical rainforest.

Figure 7.11

The first leaves of most ferns appear curled up into fiddleheads.

Horsetails

Horsetails have hollow, ribbed stems and are often found in marshes (**Figure** below). Whorls of tiny leaves around the stem make the plant look like a horse's tail, but these soon fall off and leave a hollow stem that can perform photosynthesis. This is unusual since photosynthesis most often occurs in leaves. The stems are rigid and rough to the touch because they are coated with a scratchy mineral. Because of their scratchy texture, these plants were once used as scouring pads for cleaning dishes.

Figure 7.12

Horsetails are common in marshes.

Whisk Ferns

Whisk ferns have green branching stems with no leaves, so they resemble a whisk broom (**Figure** below). Another striking feature of the whisk ferns is its spherical yellow sporangia.

Figure 7.13

Whisk ferns have yellow sporangia and no leaves.

Summary

- Vascular seedless plants have vascular tissue, a specialized tissue that transports water and nutrients throughout the plant.
- Vascular seedless plants include the club mosses, ferns, whisk ferns, and horsetails.

Explore More

Use the resource below to answer the questions that follow.

- **Seedless Vascular Plants** at http://www.youtube.com/watch?v=VKS-smv1g7A (1:32)

Click on the image above for more content

1. How many species of ferns and horsetails have scientists identified today?
2. How do scientists feel the present day diversity of ferns and horsetails compares to the diversity of these plants before the appearance of plants with seeds?
3. What sex are the spores of a fern?
4. What happens to the fertilized embryo of a fern?

Review

1. Why are the vascular seedless plants different from the nonvascular plants?
2. What are two examples of vascular seedless plants?
3. What is the role of vascular tissue in plants?
4. What was the primary result of the evolution of vascular tissue in plants?
5. What is the most common seedless vascular plant?

Section 7

Reproduction in Seedless

Reproduction in Seedless Plants

•Describe reproductive benefits of spores.
•Distinguish between a sporophyte and gametophyte.
•Outline the alternation of generations life cycle.

Have you ever noticed these little capsules on moss?

These tiny capsules produce spores. This is one stage in the process of reproduction in the mosses. Remember mosses and other seedless plants do not have flowers, so their life cycle is quite different from other plants.

Reproduction in Seedless Plants

Seedless plants can reproduce asexually or sexually. Some seedless plants, like hornworts and liverworts, can reproduce asexually through fragmentation. When a small fragment of the plant is broken off, it can form a new plant.

Reproduction in Nonvascular Seedless Plants

Like all plants, nonvascular plants have an **alternation of generations** life cycle. That means they alternate between **diploid cell** stages (having two sets of chromosomes) and **haploid cell** stages (having one set of chromosomes) during their life cycle. Recall the haploid stage is called the **gametophyte** , and the diploid stage is called the **sporophyte** .

In the life cycle of the nonvascular seedless plants, the gametophyte stage is the longest part of the cycle. The gametophyte is the green photosynthetic carpet that you would recognize as a moss.

The life cycle of nonvascular seedless plants can be described as follows:

1. The male gametophyte produces flagellated sperm that must swim to the egg formed by the female gametophyte. For this reason, sexual reproduction

must happen in the presence of water. Therefore, nonvascular plants tend to live in moist environments.
2.Following fertilization, the sporophyte forms. The sporophyte is connected to, and dependent on, the gametophyte.
3.The sporophyte produces **spores** that will develop into gametophytes and start the cycle over again.

Reproduction in Seedless Vascular Plants

For the seedless vascular plants, the sporophyte stage is the longest part of the cycle, but the cycle is similar to nonvascular plants. For example, in ferns, the gametophyte is a tiny heart-shaped structure, while the leafy plant we recognize as a fern is the sporophyte.

The fern's **sporangia** , where spores are produced, are often on the underside of the fronds (**Figure** below). Like nonvascular plants, ferns also have flagellated sperm that must swim to the egg. Unlike nonvascular plants, once fertilization takes place, the gametophyte will die, and the sporophyte will live independently.

Figure 7.14

This fern is producing spores underneath its fronds.

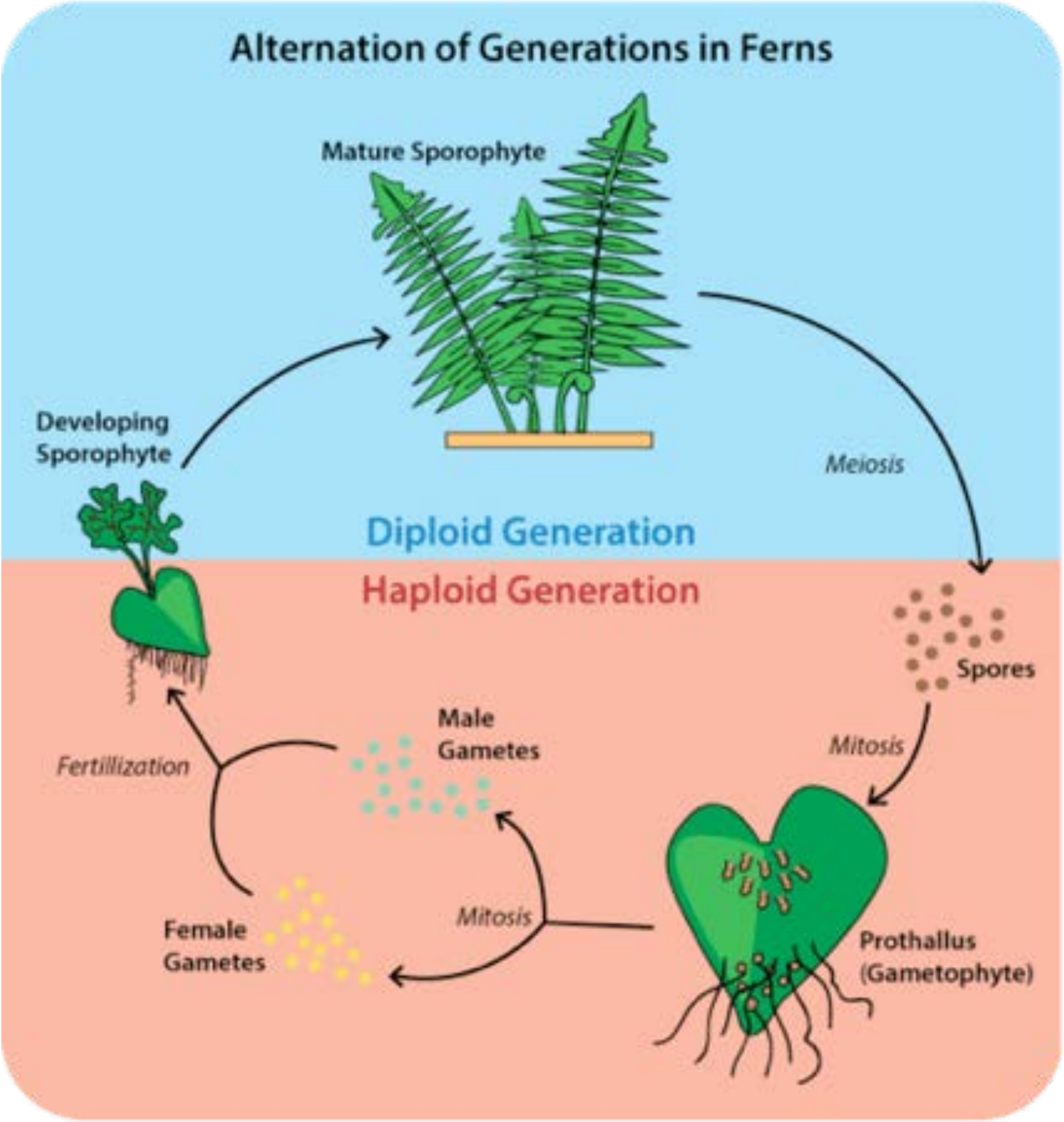


Figure 7.15

In ferns, the sporophyte is dominant and produces spores that germinate into a heart-shaped gametophyte.

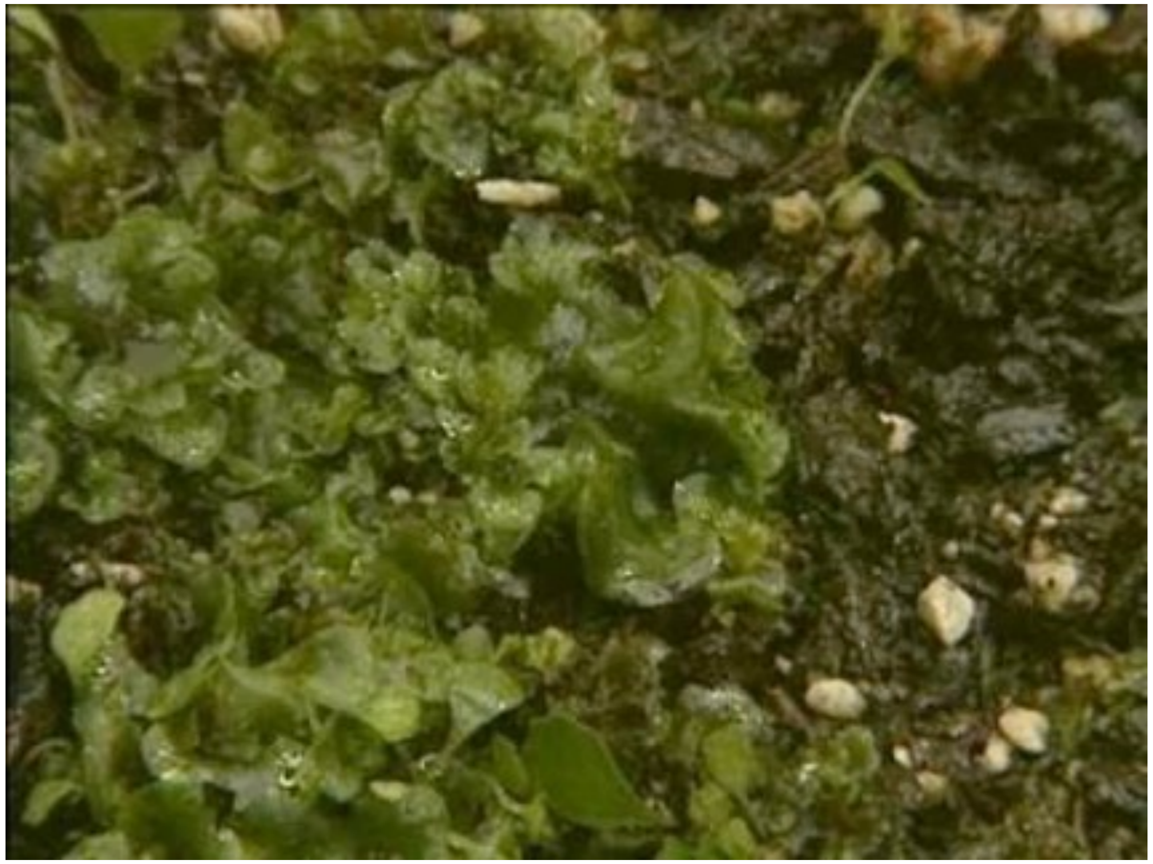
Summary

- In nonvascular seedless plants, the gametophyte (haploid) stage is the longest part of the cycle.
- In seedless vascular plants, the sporophyte (diploid) stage is the longest part of the cycle.

Explore More

Use the resource below to answer the questions that follow.

- **Ferns-Pteridophyte Life Cycle** at http://www.youtube.com/watch?v=c4YtOT0Z6Ek (12:30)



Click on the image above for more content

1. Where can the sorus on ferns be found?
2. What is found in the sorus?

3.How is the mechanism that causes spores to be released similar to the mechanism that causes water to move up xylem? Explain your answer.
4.What is meant by a bisexual gametophyte?
5.What is the affect of the plant hormone antheridiogen? Why is this hormone crucial to ferns?

Review

1.How do some seedless plants reproduce asexually?
2.What is alternation of generations?
3.Why must nonvascular plants live in moist environments?
4.Compare and contrast the fern gametophyte and sporophyte.

Section 8

Importance of Seedless

Importance of Seedless Plants

•Describe ways seedless plants impact humankind.

Where does electricity come from?

You probably have noticed these huge power lines delivering electricity across the country. But how is this electricity generated? Although there are some alternate sources like wind power and nuclear power, the majority of electricity in the United States is generated by burning coal. Seedless plants were central in forming the coal deposits that we depend on.

Importance of Seedless Plants

Seedless plants have been tremendously useful to humans. Without these plants evolving millions of years ago, life as we know it would be very different.

Seedless Plants Became Coal

The greatest influence seedless plants have had on human society is in the formation of coal millions of years ago. When the seedless plants died, became buried deep in the Earth, and were exposed to heat and pressure, coal formed. **Coal** is essentially made of the fossilized carbon from these plants. Now coal is burned to provide energy, such as electricity.

Current Uses

But some seedless plants still have uses in society today. **Peat moss** is commonly used by gardeners to improve soils, since it is really good at absorbing and holding water (**Figure** below).

Depending on the location, ferns have several different uses worldwide. Ferns are found in many gardens as ornaments, and are used as indoor plants. In tropical regions, the fern is used as a food source by many locals. The fronds can also be used to weave hats and baskets. The fiddleheads of certain species of ferns are used in gourmet food. Some species of ferns, such as the maidenhair fern, are used as medicines. In Southeast Asia, the fern is used in rice fields as a biological fertilizer. Much of the world's fossil fuels consist of remains of ferns and their relatives.

The horsetail's reedy exterior and silica content made it popular as a metal polisher and abrasive cleanser. Herbalists still use horsetail to treat a variety of kidney/bladder problems, including inflammation, infection, and kidney stones, and it is used as a remedy for brittle nails. Club moss is also used to treat kidney ailments and digestive problems. Club moss spores can be dusted onto the skin and provide relief from itching and irritation, and provide the skin with protection. Extinct forests of club moss have fossilized and developed into huge beds of coral.

Figure 7.16

Sphagnum, or peat moss, is commonly added to soil to help absorb water, and keep it in the soil.

Summary

- Seedless plants were responsible for the formation of coal millions of years ago.
- Two ways that gardeners utilize seedless plants are peat moss as a soil amendment and ferns as ornamental plants.

Explore More

Use the resource below to answer the questions that follow.

- **Coal Thickness Mystery** at http://www.youtube.com/watch?v=hdRlwKM4eIc (1:57)

Click on the image above for more content

1. How does coal form?
2. Low sulfur coal produces less pollution when burned than high sulfur coal. Name one factor that affects the sulfur content in coal.
3. How do scientists feel the Powder River Basin coal was formed?

Review

1. How was coal formed?
2. What is one use of ferns?

Section 9

Seeds and Seed Dispersal

Seeds and Seed Dispersal

- •Describe the importance of the seed.
- •Explain how seeds are dispersed.

Why are seeds important?

Many important crops, such as corn, are planted and harvested as seeds. These seeds are important sources of food. For example, corn is ground into feed for chickens and cows. And corn syrup is used to sweeten beverages and candy. But most importantly, seeds are the starting point for a new plant.

Seeds and Seed Dispersal

Plants seem to grow wherever they can. How? Plants can't move on their own. So how does a plant start growing in a new area?

What is a Seed?

If you've ever seen a plant grow from a tiny seed, then you might realize that seeds are amazing structures. A **seed** is a plant ovule containing an embryo. The seed allows a plant embryo to survive droughts, harsh winters, and other conditions that would kill an adult plant. The tiny plant embryo can simply stay **dormant** , in a resting state, and wait for the perfect environment to begin to grow. In fact, some seeds can stay dormant for hundreds of years!

Another impressive feature of the seed is that it stores food for the young plant after it sprouts. This greatly increases the chances that the tiny plant will survive. So being able to produce a seed is a beneficial adaptation, and, as a result, seed plants have been very successful. Although the seedless plants were here on Earth first, today there are many more seed plants than seedless plants.

How are Seed Plants Successful?

For a seed plant species to be successful, the seeds must be **dispersed** , or scattered around in various directions. If the seeds are spread out in many different areas, there is a better chance that some of the seeds will find the right conditions to grow. But how do seeds travel to places they have never been before? To aid with seed dispersal, some plants have evolved special features that help their seeds travel over long distances.

One such strategy is to allow the wind to carry the seeds. With special adaptations in the seeds, the seeds can be carried long distances by the wind. For example, you might have noticed how the "fluff" of a dandelion moves in the wind. Each piece of fluff carries a seed to a new location. If you look under the scales of pine cone, you will see tiny seeds with "wings" that allow these seeds to be carried away by the wind. Maple trees also have specialized fruits with wing-like parts that help seed dispersal (**Figure** below).

Figure 7.17

Maple trees have fruits with “wings” that help the wind disperse the seeds.

Some flowering plants grow fleshy fruit that helps disperse their seeds. When animals eat the fruit, the seeds pass through an animal’s digestive tract unharmed. The seeds germinate after they are passed out with the animal's feces. Berries, citrus fruits, cherries, apples, and a variety of other types of fruits are all adapted to be attractive to animals, so the animals will eat them and disperse the seed (**Figure** below). Some non-fleshy fruits are specially adapted for animals to carry them on their fur. You might have returned from a walk in the woods to find burrs stuck to your socks. These burrs are actually specialized fruits designed to carry seeds to a new location.

Figure 7.18

Fleshy fruits aid in seed dispersal, since animals eat the fruits and carry the seeds to a new location.

Summary

•The seed contains a dormant embryo and stored food.
•Fruits are adapted to disperse seeds with the help of animals or the wind.

Explore More

Use the resource below to answer the questions that follow.

•**Fruit and Seed Dispersal** at http://www.youtube.com/watch?v=mGAeS8JuyBM (6:08)

Click on the image above for more content

1. What are four mechanisms of seed and fruit dispersal?
2. What is the difference between a true fruit and a false fruit? Give an example of each.
3. List three ways that animals disperse fruit and seeds?
4. What causes the "explosion" for the explosive dispersal of seeds?

Review

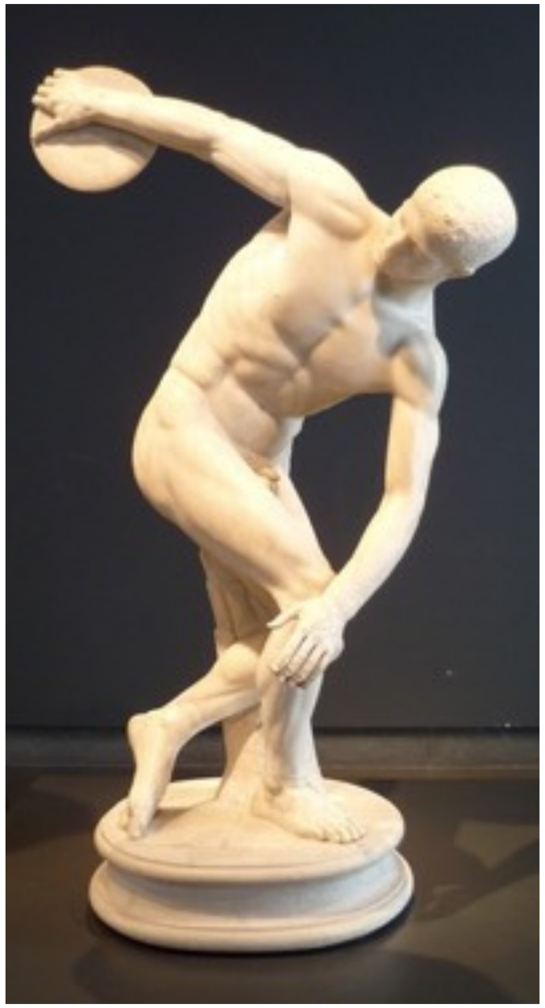
1. What is a seed?
2. Why was the evolution of the seed so beneficial to plants?
3. Why is the vast dispersal of seeds beneficial to plants?
4. What are two ways that fruits are adapted to disperse seeds?

Section 10

Gymnosperms

Gymnosperms

- •Define gymnosperm.
- •List the four phyla of gymnosperms.
- •Give examples of gymnosperms.



What does "gymnasium" mean?

Today a gymnasium means a place for playing indoor sports. In ancient Greece, sports were done in the nude, so the word "gymnasium" is based on the Greek word for naked (gymnos). The root word is the same for "gymnosperm," which means "naked seed." Gymnosperms are those plants that do not have a fruit encasing the seed.

Gymnosperms

Gymnosperms have seeds, but they do not produce fruit. Instead, the seeds of gymnosperms are usually found in cones.

There are four phyla of gymnosperms:

1. Conifers
2. Cycads
3. Ginkgoes
4. Gnetophytes

Conifers

Conifers , members of the phylum *Coniferophyta* , are probably the gymnosperms that are most familiar to you. Conifers include trees such as pines, firs, spruces, cedars, and the coastal redwood trees in California, which are the tallest living vascular plants.

Conifers have their reproductive structures in cones, but they are not the only plants to have that trait (**Figure** below). Conifer pollen cones are usually very small, while the seed cones are larger. **Pollen** contains gametophytes that produce the male gamete of seed plants. The pollen, which is a powder-like substance, is carried by the wind to fertilize the seed cones that contain the female gamete (**Figure** below).

Figure 7.19

A red pine, which bears seeds in cones, is an example of a conifer.

Figure 7.20

The end of a pine tree branch bears the male cones that produce the pollen.

Conifers have many uses. They are important sources of lumber and are also used to make paper. Resins, the sticky substance you might see oozing out of a wound on a pine tree, are collected from conifers to make a variety of products, such as the solvent turpentine and the rosin used by musicians and baseball players. The sticky rosin improves the pitcher’s hold on the ball or increases the friction between the bow and the strings to help create music from a violin or other stringed instrument.

Cycads

Cycads , in the phylum *Cycadophyta* , are also gymnosperms. They have large, finely-divided leaves and grow as short shrubs and trees in tropical regions. Like conifers, they produce cones, but the seed cones and pollen cones are always on separate plants (**Figure** below). One type of cycad, the Sago Palm, is a popular landscape plant. During the Age of the Dinosaurs (about 65 to 200 million years ago), cycads were the dominant plants. So you can imagine dinosaurs grazing on cycad seeds and roaming through cycad forests.

Figure 7.21

Cycads bear their pollen and seeds in cones on separate plants.

Ginkgoes

Ginkgoes , in the phylum *Ginkgophyta* , are unique because they are the only species left in the phylum. Many other species in the fossil record have gone extinct (**Figure** below). The ginkgo tree is sometimes called a "living fossil" because it is the last species from its phylum.

One reason the ginkgo tree may have survived is because it was often grown around Buddhist temples, especially in China. The ginkgo tree is also a popular landscape tree today in American cities because it can live in polluted areas better than most plants.

Ginkgoes, like cycads, has separate female and male plants. The male trees are usually preferred for landscaping because the seeds produced by the female plants smell terrible when they ripen.

Figure 7.22

Ginkgo trees are gymnosperms with broad leaves.

Gnetophytes

Gnetophytes , in the phylum *Gnetophyta* , are a very small and unusual group of plants. *Ephedra* is an important member of this group, since this desert shrub produces the ephedrine used to treat asthma and other conditions. *Welwitschia* produces extremely long leaves and is found in the deserts of southwestern Africa (**Figure** below). Overall, there are about 70 different species in this diverse phylum.

Figure 7.23

One type of gnetophyte is *Welwitschia* .

Summary

- Gymnosperms have seeds, but they do not produce fruit; the seeds of gymnosperms are usually found in cones.
- There are four phyla of gymnosperms: conifers, cycads, ginkgoes, and gnetophytes.

Explore More

Use the resource below to answer the questions that follow.

- **Gymnosperms** at http://www.youtube.com/watch?v=zKnrlUI85ys (4:31)

Click on the image above for more content

1. Which division of gymnosperm has the most living species? How many species are in this division?
2. Where are cycads most abundant?
3. Where are conifers most abundant?
4. What are the characteristics of conifers?
5. What climate change led to conifers becoming more abundant than ferns? When did this occur?

Review

1. What features define the gymnosperms?
2. What are two examples of conifers?
3. Where are the reproductive structures of conifers located?
4. What was the dominant plant during the Age of Dinosaurs?
5. What gymnosperm is known as a living fossil? Explain your answer.

Section 11

Angiosperms

Angiosperms

•Define angiosperm.
•List and define the major parts of the flower.
•Distinguish self-pollination from cross-fertilization.

Why do plants make fruit?

When this bird eats a berry, it also consumes the seeds contained inside. The bird may fly for many miles before digestion is complete and the seeds are excreted. This allows the plant to spread its seeds to a new location. For this reason, plants that make fruits have been very successful.

Angiosperms

Angiosperms , in the phylum *Anthophyta* , are the most successful phylum of plants. This category also contains the largest number of individual plants (**Figure** below). Angiosperms evolved the structure of the flower, so they are also called the flowering plants. Angiosperms live in a variety of different environments. A water lily, an oak tree, and a barrel cactus, although different, are all angiosperms.

Figure 7.24

Angiosperms are the flowering plants.

The Parts of a Flower

Even though flowers may look very different from each other, they do have some structures in common. The structures are explained in the picture below (**Figure** below).

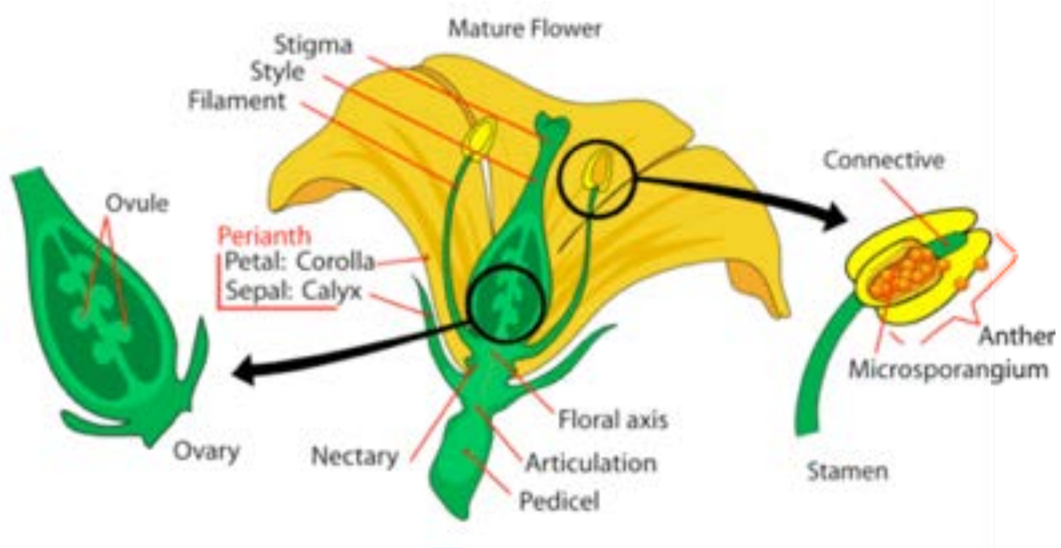


Figure 7.25

A complete flower has sepals, petals, stamens, and one or more carpels.

- •The green outside of a flower that often looks like a leaf is called the **sepal** (**Figure** below). All of the sepals together are called the **calyx** , which is usually green and protects the flower before it opens.
- •All of the petals (**Figure** below) together are called the **corolla** . They are bright and colorful to attract a particular **pollinator** , an animal that carries pollen from one flower to another. Examples of pollinators include birds and insects.
- •The next structure is the **stamen** , consisting of the stalk-like **filament** that holds up the **anther** , or pollen sac. The **pollen** is the male gametophyte.
- •At the very center is the **carpel,** which is divided into three different parts: (1) the sticky **stigma** , where the pollen lands, (2) the tube of the **style** , and (3) the large, bottom part, known as the **ovary** .

The ovary holds the **ovules** , the female gametophytes. When the ovules are fertilized, the ovule becomes the seed and the ovary becomes the fruit.

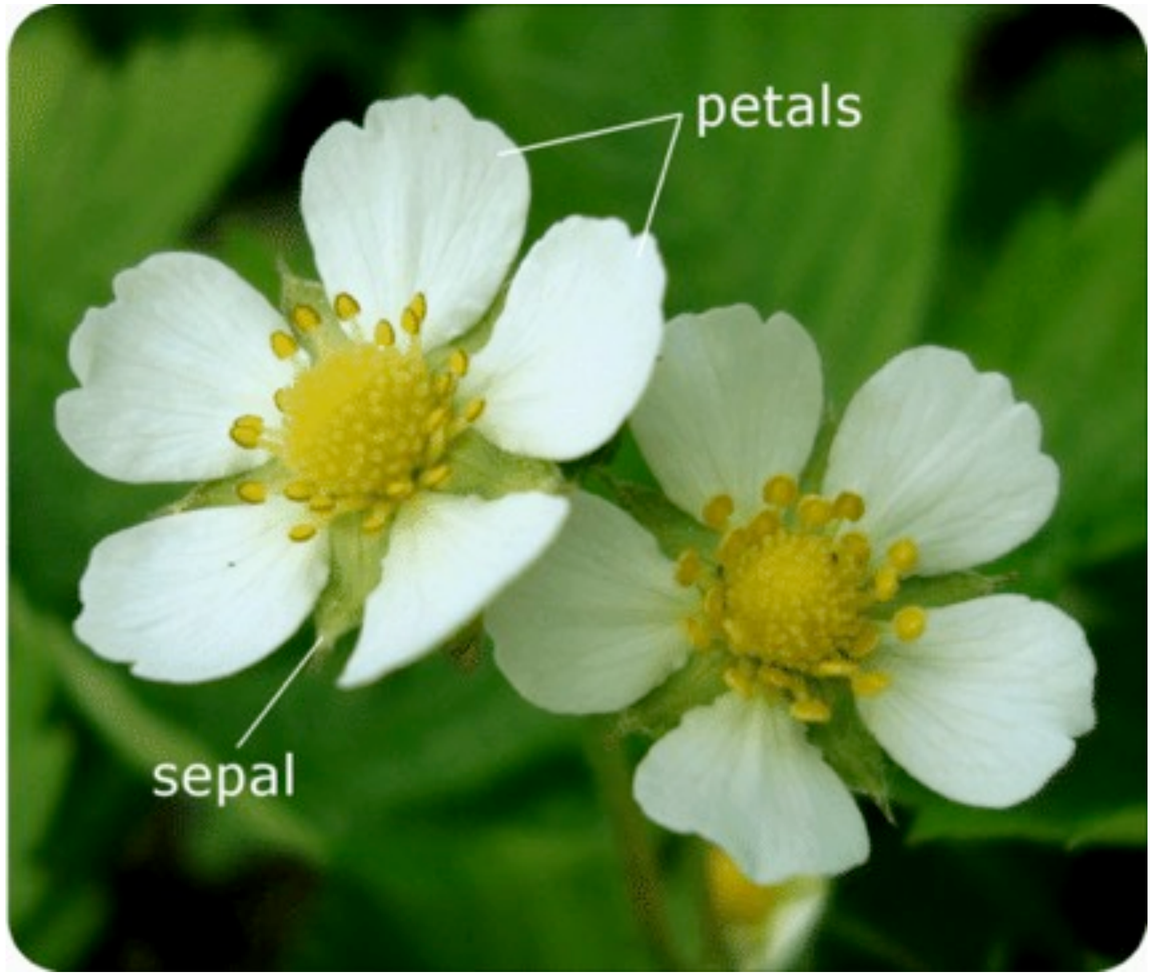


Figure 7.26

This image shows the difference between a petal and a sepal.

The following table summarizes the parts of the flower (**Table** below).

Part	Definition
sepals	The green outside of the flower.
calyx	All of the sepals together, or the outside of the flower.
corolla	The petals of a flower collectively.
stamens	The part of the flower that produces pollen.
filament	Stalk that holds up the anther.
anther	The structure that contains pollen in a flower.
carpel	“Female” part of the flower; includes the stigma, style, and ovary.
stigma	The part of the carpel where the pollen must land for fertilization to occur.
style	Tube that makes up part of the carpel.
ovary	Large bottom part of the carpel where the ovules are contained.
ovules	Part of the ovary that is the female gametophyte and that after fertilization becomes the seed.

How Do Angiosperms Reproduce?

Flowering plants can reproduce two different ways:

1. Self-pollination: Pollen falls on the stigma of the same flower. This way, a seed will be produced that can turn into a genetically identical plant.
2. Cross-fertilization: Pollen from one flower travels to a stigma of a flower on another plant. Pollen travels from flower to flower by wind or by animals. Flowers that are pollinated by animals such as birds, butterflies, or bees are often colorful and provide nectar, a sugary reward, for their animal pollinators.

Why Are Angiosperms Important to Humans?

Angiosperms are important to humans in many ways, but the most significant role of angiosperms is as food. Wheat, rye, corn, and other grains are all harvested from flowering plants. Starchy foods, such as potatoes, and legumes, such as beans, are also angiosperms. And, as mentioned previously, fruits are a product of angiosperms that increase seed dispersal and are nutritious.

There are also many non-food uses of angiosperms that are important to society. For example, cotton and other plants are used to make cloth, and hardwood trees are used for lumber.

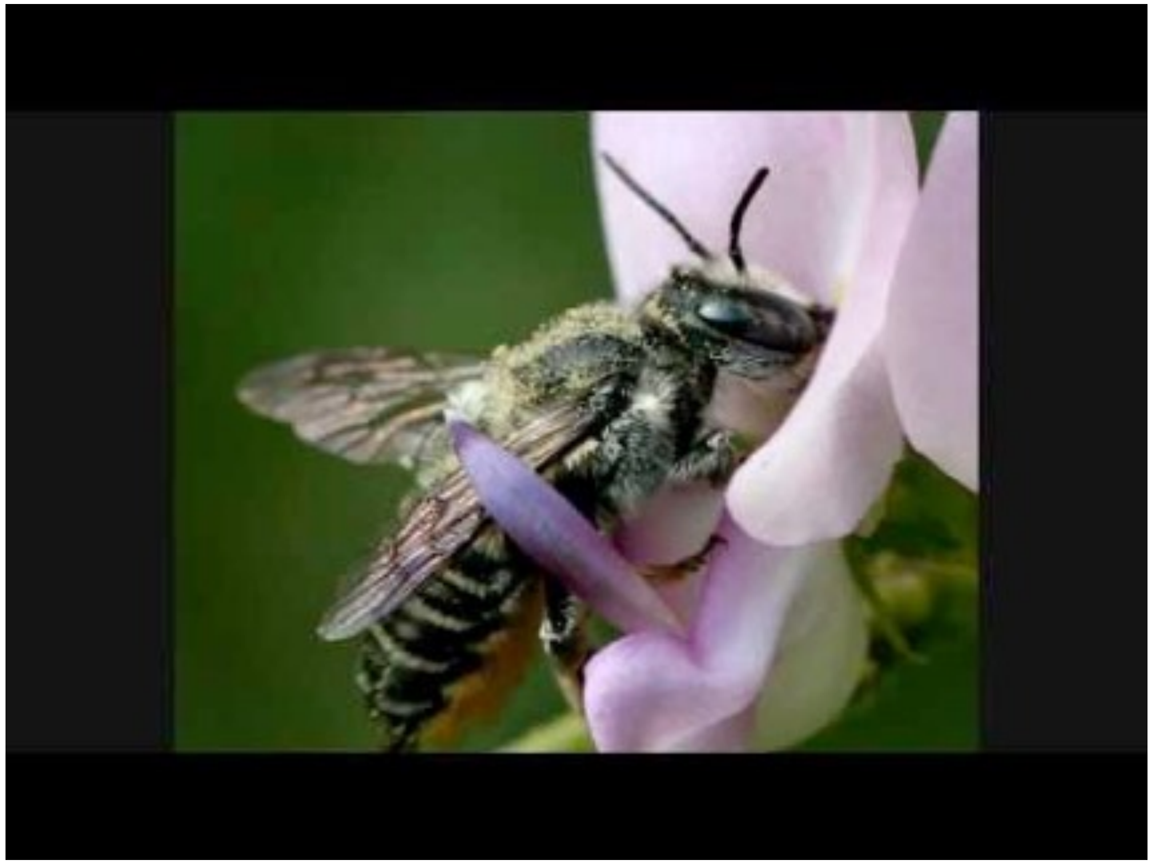
Summary

- Angiosperms are plants that produce flowers and fruit.
- Angiosperms can be self-pollinated, meaning pollen falls on the stigma of the same flower, or cross-fertilized, during which pollen from one flower travels to a stigma of a flower on another plant.

Explore More

Use the resource below to answer the questions that follow.

- **Angiosperms: The Secrets of Flowers** at http://www.youtube.com/watch?v=sr4Khc7BUzA (5:46)



Click on the image above for more content

1. How many species of angiosperms exist today?
2. How many species of gymnosperm exist today?
3. When did angiosperms become the most abundant type of plant on the planet?
4. When do angiosperms grow fruit?
5. Where are the sex organs of angiosperms located?
6. What part of the plant becomes the fruit?
7. What is the difference between a superior and inferior ovary?

Review

1. How are angiosperms like gymnosperms? How are they different?
2. What makes up the female part of the flower?
3. What part of the flower is the male gametophyte?
4. What is self-pollination?
5. How does pollen travel to another plant?

Section 12

Plant Hormones

Plant Hormones

•Define hormone.
•Define abscission and apical dominance.
•List the major types of plant hormones.
•Describe the main functions of plant hormones.

How do fruits know when to fall?

Fruits, such as these peaches, do not leave their trees until it's the right time. The seeds are mature, and the fruit is ripe. But what tells the fruits it's time to drop? The signal that is sent through the tree is a type of hormone. Hormones also send signals through your body.

Plant Hormones

Plants may not move, but that does not mean they don't respond to their environment. Plants can sense gravity, light, touch, and seasonal changes. For example, you might have noticed how a house plant bends toward a bright window. Plants can sense and then grow toward the source of light. Scientists say that plants are able to respond to "stimuli," or something—usually in the environment—that results in a response. For instance, light is the stimulus, and the plant moving toward the light is the "response."

Hormones are special chemical messengers that help organisms, including plants, respond to stimuli in their environment. In order for plants to respond to the environment, their cells must be able to communicate with other cells. Hormones send messages between the cells. Animals, like humans, also have hormones, such as testosterone or estrogen, to carry messages from cell to cell. In both plants and animals, hormones travel from cell to cell in response to a stimulus; they also activate a specific response.

Types of Plant Hormones

Five different types of plant hormones are involved in the main responses of plants, and they each have different functions (**Table** below).

Hormone	Function
Ethylene	Fruit ripening and abscission
Gibberellins	Break the dormancy of seeds and buds; promote growth

Ethylene

The hormone **ethylene** has two functions. It (1) helps ripen fruit and (2) is involved in the process of **abscission** , the dropping of leaves, fruits, and flowers. When a flower is done blooming or a fruit is ripe and ready to be eaten, ethylene causes the petals or fruit to fall from a plant (**Figure** below and **Figure** below).

Ethylene is an unusual plant hormone because it is a gas. That means it can move through the air, and a ripening apple can cause another apple to ripen, or even over-ripen. That's why one rotten apple spoils the whole barrel! Some farmers spray their green peppers with ethylene gas to cause them to ripen faster and become red peppers.

You can try to see how ethylene works by putting a ripe apple or banana with another unripe fruit in a closed container or paper bag. What do you think will happen to the unripe fruit?

Figure 7.27

The hormone ethylene is signaling these tomatoes to ripen.

Figure 7.28

The hormone ethylene causes flower petals to fall from a plant, a process known as abscission.

Gibberellins

Gibberellins are hormones that cause the plant to grow. When gibberellins are applied to plants by scientists, the stems grow longer. Some gardeners or horticulture scientists add gibberellins to increase the growth of plants. Dwarf plants (small plants), on the other hand, have low levels of gibberellins (**Figure** below). Another function of gibberellins is to stop **dormancy** (resting time) of seeds and buds. Gibberellins signal that it's time for a seed to **germinate** (sprout) or for a bud to open.

Figure 7.29

Dwarf plants like this bonsai tree often have unusually low concentrations of gibberellins.

Cytokinins

Cytokinins are hormones that cause plant cells to divide. Cytokinins were discovered from attempts to grow plant tissue in artificial environments (**Figure** below). Cytokinins prevent the process of aging. So florists sometimes apply cytokinins to cut flowers, so they do not get old and die.

Figure 7.30

Cytokinins promote cell division and are necessary for growing plants in tissue culture. A small piece of a plant is placed in sterile conditions to regenerate a new plant.

Abscisic Acid

Abscisic acid is misnamed because it was once believed to play a role in abscission (the dropping of leaves, fruits, and flowers), but we now know abscission is caused by ethylene. The actual role of abscisic acid is to close the stomata, the tiny openings in leaves that allow substances to enter and leave, and to maintain dormancy. When a plant is stressed due to lack of water, abscisic acid tells the stomata to close. This prevents water loss through the stomata.

When the environment is not good for a seed to germinate, abscisic acid signals for the dormancy period of the seed to continue. Abscisic acid also tells the buds of plants to stay in the dormancy stage. When conditions improve, the levels of abscisic acid drop and the levels of gibberellins increase, signaling that is time to break dormancy (**Figure** below).

Figure 7.31

A decrease in levels of abscisic acid allows these buds to break dormancy and put out leaves.

Auxins

Auxins are hormones that play a role in plant growth. Auxins produced at the tip of the plant are involved in **apical dominance** , when the main central stem grows more strongly than other stems and branches. When the tip of the plant is removed, the auxins are no longer present, and the side branches begin to grow. This is why pruning a plant by cutting off the main branches helps produce a fuller plant with more branches. You actually need to cut branches off of a plant for it to grow more branches! Auxins are also involved in tropisms, responses to stimuli in the environment

Summary

- Plant hormones are chemical signals that control different processes in plants.
- Plant hormones include ethylene, gibberellins, cytokinins, abscisic acid, and auxins.

Explore More

Use the resource below to answer the questions that follow.

- **Plant Hormones** at http://www.youtube.com/watch?v=ZbRiKlIYa-k (5:39)

1. What hormones stimulate plant growth?
2. What hormones inhibit plant growth?
3. Why is it important for a plant to be able to both stimulate and inhibit growth? Explain your answer.
4. Do you think hormones are more important to plants or mammals? Explain your thinking.

Review

1. What are three stimuli that plants respond to?
2. List the roles of gibberellins.
3. What hormone is involved in fruit ripening?
4. What happens to an unripe fruit when placed in a paper bag with a ripe fruit?
5. What is apical dominance?

Section 13

Tropisms

Tropisms

- Define tropism.
- Distinguish phototropism from gravitropism and from thigmotropism.

Why are these plants turning sideways?

Plants respond to their environment in how they grow. In this picture, the light source is probably off to the left side. As a result, the plants grow in this direction to get more light.

Tropisms

Plants may not be able to move, but they are able to change how they grow in response to their environment. Growth toward or away from a stimulus is known as a **tropism** (**Table** below). Auxins, a class of plant hormones, allow plants to curve in specific directions as they grow. The auxin moves to one side of the stem, where it starts a chain of events that cause rapid cell growth on just that one side of the stem. With one side of the stem growing faster than the other, the plant begins to bend.

Name	Stimulus
Phototropism	Light
Gravitropism	Gravity
Thigmotropism	Touch

Phototropism

You might have noticed that plants bend toward the light. This is an example of a tropism where light is the stimulus, known as **phototropism** (**Figure** below). To obtain more light for photosynthesis, leaves and stems grow toward the light. On the other hand, roots grow away from light. This is beneficial for the roots, because they need to obtain water and nutrients from deep within the ground.

Figure 7.32

These seedlings bending toward the sun are displaying phototropism.

Gravitropism

So, how do the roots of seeds underground know to grow downward? How do the roots deep in the soil know which way is up? **Gravitropism** is a growth toward or away from the pull of gravity (**Figure** below). **Shoots** , the new growth of a plant, also show a gravitropism, but in the opposite direction. If you place a plant on its side, the stem and new leaves will curve upward.

Figure 7.33

This shoot is exhibiting gravitropism: it is growing against the pull of gravity.

Thigmotropism

Plants also have a touch response called **thigmotropism** . If you have ever seen a morning glory or the tendrils of a pea plant twist around a pole, then you know that plants must be able to sense the pole. Thigmotropism works much like the other tropisms. The plant grows straight until it comes in contact with the pole. Then, the side of the stem that is in contact with the pole grows slower than the opposite side of the stem. This causes the stem to bend around the pole.

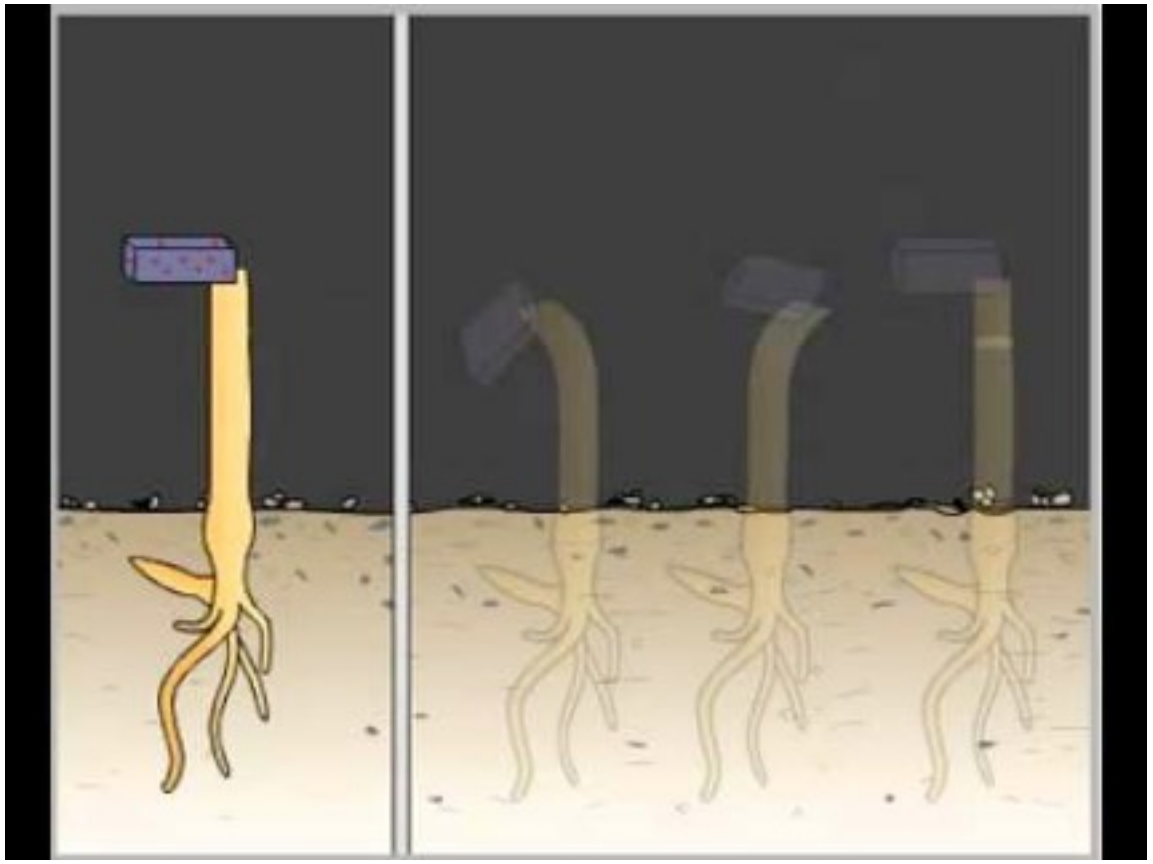
Summary

- Tropisms are growth toward or away from a stimulus.
- Types of tropisms include gravitropism (gravity), phototropism (light), and thigmotropism (touch).

Explore More

Use the resource below to answer the questions that follow.

- **Phototropism and Auxin** at http://www.youtube.com/watch?v=4-2DZo2ppAY (2:13)



Click on the image above for more content

1. Explain how scientists determined that the signal for phototropism was occurring in the growing tip of a plant?
2. Explain how scientists determined the signal for phototropism migrated up and down a plant shoot but did not move across the plant shoot?
3. How did an agar block help scientists determine that some substance moving through the plant was responsible for the phototropic response?
4. What hormone causes the phototropic response to light?

Review

1. What is a tropism?
2. If you tip a plant on its side, what will happen? Why?
3. The tendril of a bean meets a metal pole. What will happen to the tendril? Why?
4. Why do leaves and stems grow towards light?

Section 14

Seasonal Changes in Plants

Seasonal Changes in Plants

- •Describe how plants sense changes of season.
- •Explain photoperiodism.

How does this plant know it's Christmas?

This plant is known as a Christmas cactus because it only blooms once a year, during the Christmas season. But plants can't read a calendar. How can a houseplant know the time of the year?

Seasonal Changes

Have you seen the leaves of plants change colors? During what time of year does this happen? What causes it to happen? Plants can sense changes in the **seasons** . Leaves change color and drop each autumn in some climates (**Figure** below).

Figure 7.34

Leaves changing color is a response to the shortened length of the day in autumn.

Certain flowers, like poinsettias, only bloom during the winter. And, in the spring, the winter buds on the trees break open, and the leaves start to grow. How do plants detect time of year?

Although you might detect seasonal changes by the change in temperature, this is not the way in which plants know the seasons are changing. Plants determine the time of year by the length of daylight, known as the photoperiod. Because of the tilt of the Earth, during winter days, there are less hours of light than during summer days. That's why, in the winter, it starts getting dark very early in the evening, and then stays dark while you're getting ready for school the next morning. But in the summer it will be bright early in the morning, and the sun will not set until late that night. With a light-sensitive chemical, plants can sense the differences in day length.

For example, in the fall, when the days start to get shorter, the trees sense that there is less sunlight. The plant is stimulated, and it sends messages telling the leaves to change colors and fall. This is an example of **photoperiodism** , the reaction of organisms, such as plants, to the length of day or night. Photoperiodism is also the reaction of plants to the length of light and dark periods. Many flowering plants sense the length of night, a dark period, as a signal to flower. Each plant has a different photoperiod, or night length. When the plant senses the appropriate length of darkness, resulting in an appropriate length of daylight, it flowers. Flowering plants are classified as long-day plants or short-day plants. Long-day plants flower when the length of daylight exceeds the necessary photoperiod, and short-day plants flower when the day length is shorter than the necessary photoperiod. Long-day plants include carnations, clover, lettuce, wheat, and turnips. Short-day plants include cotton, rice, and sugar cane.

Summary

- Plants can respond to the change of season by losing their leaves, flowering, or breaking dormancy.
- Plants go through seasonal changes after detecting differences in day length.

Explore More

Use the resource below to answer the questions that follow.

- **Why Do Leaves Change Color?** at http://www.youtube.com/watch?v=CI3maQMpj-4 (3:43)

1. What happens to the chlorophyll in the leaves that causes them to change color?
2. Why do the leaves of trees in the tropics not change color in the fall?
3. Why do some trees drop their leaves in the winter?
4. How does temperature affect the color of the leaves? Explain your answer fully.

Review

1. How do plants detect the change in seasons?
2. What signals a tree to drop its leaves?
3. Distinguish between long-day plants and short-day plants.
4. Give two examples of long-day plants.

Summary

The Kingdom Plantae ranges from small nonvascular plants to towering redwood trees. It is probable that without plants, most life, including us, would not exist. Why? Photosynthesis. This process brings energy into our ecosystems and produces the oxygen that all of our cells need. This concept discusses the types of plants, the structures of plants, reproduction of plants, and the adaptations and responses of plants.

References

1. Mateusz Kulawik. Mosses and trees are all part of the plant kingdom . CC BY 2.0
2. Flickr: solarshakti. Close up of algae on a beach . CC-BY 2.0
3. Dartmouth Electron Microscope Facility, colorized by Photohound (Wikimedia). Stomata are pores in leaves that allow gasses to pass through . Public Domain
4. Zachary Wilson. Alternation of generations on ferns . CC BY-NC 3.0
5. Left to right, by row: Flickr:AvidlyAbide; S. Rae; Ray Bouknight; Flickr:Reza; Lori Branham; Mary T. Moore; Flickr:kanegen; Flickr:GaggieITMI; Flickr:kkmarais. Diversity of plants in the plant kingdom . CC BY 2.0
6. takomabibelot. Sporophytes sprout up on stalks from this bed of moss gametophytes . CC BY 2.0
7. Jason Hollinger. In hornworts, the horns are the sporophytes that rise up from the leaflike gametophyte . CC BY 2.0
8. Jason Hollinger. Liverworts with a flattened, ribbon-like body are called thallose liverworts . CC BY 2.0
9. Benny Mazur. Clubmosses can resemble mosses; however, clubmosses have vascular tissue, while mosses do not . CC BY 2.0
10. Photography by Kat. Ferns are common in the understory of the tropical rainforest . CC BY 2.0
11. David Sim. The first leaves of most ferns appear curled up into fiddleheads . CC BY 2.0
12. Bradley Davis/BackpackPhotography. Horsetails are common in marshes. . CC BY 2.0
13. Forest and Kim Starr/Starr Environmental. Whisk ferns have yellow sporangia and no leaves . CC BY 3.0
14. Paige Filler. This fern is producing spores underneath its fronds . CC BY 2.0
15. Zachary Wilson. In ferns, the sporophyte is dominant and produces spores that germinate into a heart-shaped gametophyte . CC BY-NC 3.0
16. Nat Tarbox. Sphagnum, or peat moss, is commonly added to soil to help absorb water, and keep it in the soil . CC BY 2.0
17. Laura Harris. Maple seeds have wings that help the wind disperse them . CC BY 2.0
18. heydrienne. Fleshy fruits aid in seed dispersal, since animals eat the fruits and carry the seeds to a new location . CC BY 2.0
19. Keith Kanoti/Maine Forest Service. A red pine, which bears seeds in cones, is an example of a conifer . CC BY 3.0
20. John Haslam. The end of a pine tree branch bears the male cones that produce the pollen . CC BY 2.0
21. Glenn Fleishman. Cycads bear their pollen and seeds in cones on separate plants . CC BY 2.0

22.Roberto Verzo. Ginkgo trees are gymnosperms with broad leaves . CC BY 2.0
23.Derek Keats. One type of gnetophyte is "Welwitschia" . CC BY 2.0
24.Navdeep Raj. Angiosperms are the flowering plants. . CC BY 2.0
25.Mariana Ruiz Villarreal (LadyofHats). A complete flower has sepals, petals, stamens, and one or more carpels . Public Domain
26.David J. The difference between a petal and a sepal . CC BY 2.0
27.Todd Petit. The hormone ethylene is signaling these tomatoes to ripen . CC BY 2.0
28.Lynn Wohlers. The hormone ethylene causes flower petals to fall from a plant, a process known as abscission . CC BY 2.0
29.Sheila Thomson. Dwarf plants like this bonsai tree often have unusually low concentrations of gibberellins . CC BY 2.0
30.Image copyright Zenphotography, 2014. Cytokinins promote cell division and are necessary for growing plants in tissue culture . Used under license from Shutterstock.com
31.nvainio. =A decrease in levels of abscisic acid allows these buds to break dormancy and put out leaves . CC BY 2.0
32.Russell Neches. These seedlings bending toward the sun are displaying phototropism . CC BY 2.0
33.Mark Tighe. This shoot is exhibiting gravitropism: it is growing against the pull of gravity . CC BY 2.0
34.Flickr:Leesa0502. Leaves change color in a response to the shortened length of the day in autumn . CC BY 2.0

Animals

Introduction

Fighting or playing?

You might think that these young tigers are fighting, but they're really just playing. Like most other young mammals, tigers like to play. Why do mammals play? Is playing just for fun, or does it serve some other purpose as well? Playing is actually an important way of learning. By playing, these tigers are learning moves that will help them become successful predators as adults. Playing is just one of many ways that mammals and other animals learn how to behave.

Section 1

Animal Behaviors

Animal Behaviors

- Explain the meaning of animal behavior.
- Give examples of animal behaviors.
- Discuss the importance of animal behavior.
- Explain how animal behaviors can increase fitness.

Why do spiders spin webs?

You have probably seen a spider web before. You may even know that spiders create webs to catch their prey. This is an example of animal behavior. Animals have many different behaviors.

Introduction to Animal Behavior

Barking, purring, and playing are just some of the ways in which dogs and cats behave. These are examples of animal behaviors. **Animal behavior** is any way that animals act, either alone or with other animals.

Examples of Animal Behavior

Can you think of examples of animal behaviors? What about insects and birds? How do they behave? Pictured below are just some of the ways in which these, and other animals act (**Figure** below). Look at the pictures and read about the behaviors. Think about why the animal is behaving that way.

Figure 8.1

These pictures show examples of animal behaviors. Why do the animals behave these ways?

Importance of Animal Behavior

Why do animals behave the way they do? The answer to this question depends on what the behavior is. A cat chases a mouse to catch it. A mother dog nurses her puppies to feed them. All of these behaviors have the same purpose: getting or providing food. All animals need food for energy. They need energy to move around. In fact, they need energy just to stay alive. Energy allows all the processes inside cells to occur. Baby animals also need energy to grow and develop.

Birds and wasps build nests to have a safe place to store their eggs and raise their young. Many other animals build nests for the same reason. Animals protect their young in other ways, as well. For example, a mother dog not only nurses her puppies. She also washes them with her tongue and protects them from strange people or other animals. All of these behaviors help the young survive and grow up to be adults.

Rabbits run away from foxes and other predators to stay alive. Their speed is their best defense. Lizards sun themselves on rocks to get warm because they cannot produce their own body heat. When they are warmer, they can move faster and be more alert. This helps them escape from predators and also find food.

All of these animal behaviors are important. They help the animals get food for energy, make sure their young survive, or ensure that they, themselves, survive. Behaviors that help animals or their young survive, increase the animals' **fitness.** Animals with higher fitness have a better chance of passing their **genes** on to the next generation. If genes control behaviors that increase fitness, the behaviors become more common in the species. This occurs through the process of evolution by natural selection.

Summary

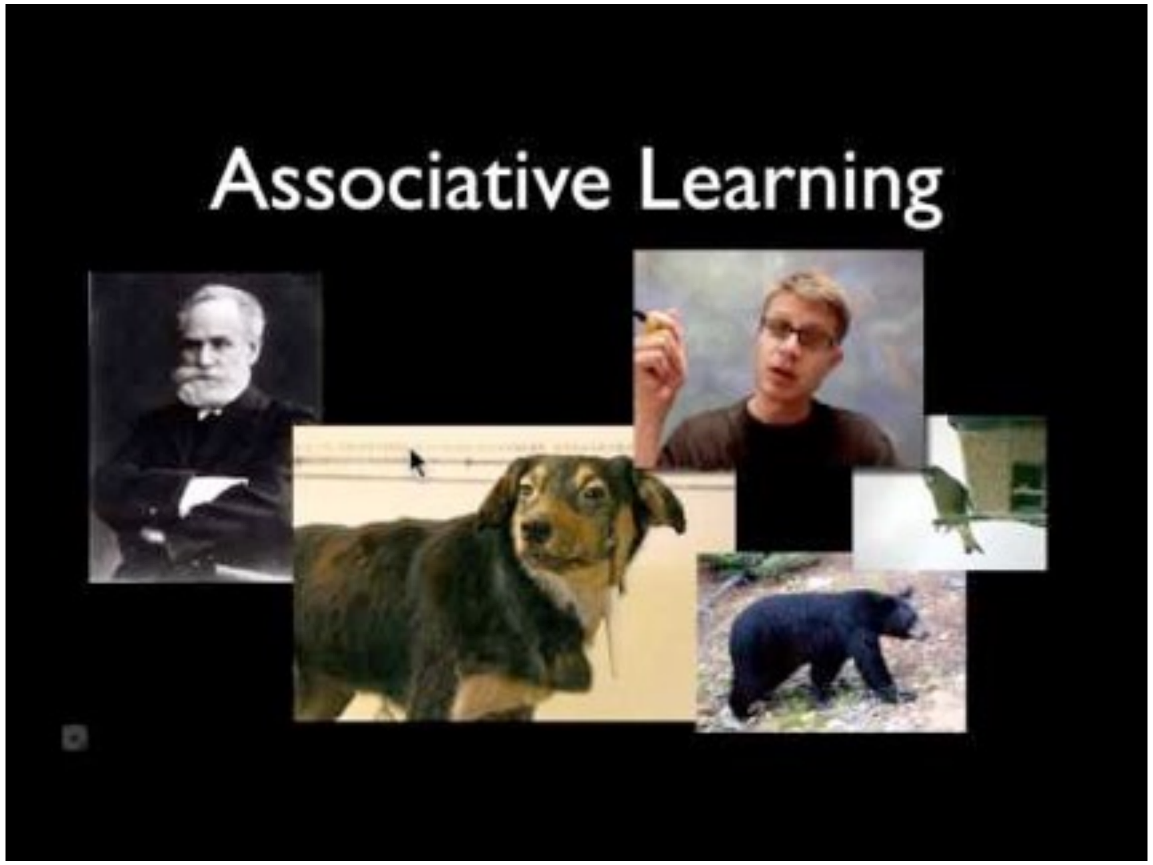
- Animal behavior is any way that animals act, either alone or with other animals.
- Animal behavior may be aimed at getting food for energy, making sure their young survive, or ensuring that they, themselves, survive.

Explore More

Use the resources below to answer the questions that follow.

Explore More I

- **Animal Behavior** at http://www.youtube.com/watch?v=6hREwakXmAo (9:52)



Click on the image above for more content

1. When do animals learn innate behavior?
2. Can you think of why "grasping" behavior would help human babies survival?
3. A crow vending machine is associated with what type of learning?
4. Compare and contrast "trial and error" learning and "observational" learning.
5. How do "mirror neurons" work?

Explore More II

- **Cnidarians: Anemone Swims Away From Sea Star** at http://vimeo.com/37443347 (2:01)

Click on the image above for more content

1. What type of behavior do you think the sea anemone (*Stomphia coccinea*) is exhibiting? Explain your thinking fully and be specific.

Review

1. What are two examples of animal behaviors that are aimed at getting food?
2. What are two examples of animal behaviors that are aimed at protecting the young?
3. What is meant by fitness? What is the relationship between animal behaviors and fitness?
4. Is there a relationship between genes and fitness? Explain your answer.

Section 2

Learned Behavior of Ani-

Learned Behavior of Animals

•Distinguish between learned behavior and innate behavior.
•Describe habituation.
•Explain observational learning
•Give examples of conditioning.
•Summarize learning by playing.
•Define insight learning.

Do you play a sport?

If you play a sport like soccer, then you realize it takes a lot of work. Remember how you didn't know at all what you were doing when you first started? You had rules to figure out and skills to practice. Playing a sport is an example of a learned behavior.

Learned Behavior

Just about all human behaviors are learned. **Learned behavior** is behavior that occurs only after experience or practice. Learned behavior has an advantage over **innate behavior** : it is more flexible. Learned behavior can be changed if conditions change. For example, you probably know the route from your house to your school. Assume that you moved to a new house in a different place, so you had to take a different route to school. What if following the old route was an innate behavior? You would not be able to adapt. Fortunately, it is a learned behavior. You can learn the new route just as you learned the old one.

Although most animals can learn, animals with greater intelligence are better at learning and have more learned behaviors. Humans are the most intelligent animals. They depend on learned behaviors more than any other species. Other highly intelligent species include apes, our closest relatives in the animal kingdom. They include chimpanzees and gorillas. Both are also very good at learning behaviors.

You may have heard of a gorilla named Koko. The psychologist, Dr. Francine Patterson, raised Koko. Dr. Patterson wanted to find out if gorillas could learn human language. Starting when Koko was just one year old, Dr. Patterson taught her to use sign language. Koko learned to use and understand more than 1,000 signs. Koko showed how much gorillas can learn. See *A Conversation with Koko* at http://www.pbs.org/wnet/nature/koko .

Think about some of the behaviors you have learned. They might include riding a bicycle, using a computer, and playing a musical instrument or sport. You probably did not learn all of these behaviors in the same way. Perhaps you learned some behaviors on your own, just by practicing. Other behaviors you may have learned from other people. Humans and other animals can learn behaviors in several different ways.

The following methods of learning will be explored below:

1. Habituation (forming a habit)
2. Observational learning
3. Conditioning
4. Play
5. Insight learning

Habituation

Habituation is learning to get used to something after being exposed to it for a while. Habituation usually involves getting used to something that is annoying or frightening, but not dangerous. Habituation is one of the simplest ways of learning. It occurs in just about every species of animal.

You have probably learned through habituation many times. For example, maybe you were reading a book when someone turned on a television in the same room. At first, the sound of the television may have been annoying. After a while, you may no longer have noticed it. If so, you had become habituated to the sound.

Another example of habituation is shown below (**Figure** below). Crows and most other birds are usually afraid of people. They avoid coming close to people, or they fly away when people come near them. The crows landing on this scarecrow have become used to a "human" in this place. They have learned that the scarecrow poses no danger.

They are no longer afraid to come close. They have become habituated to the scarecrow.

Figure 8.2

This scarecrow is no longer scary to this crow. The crow has become used to its being in this spot and learned that it is not dangerous. This is an example of habituation.

Can you see why habituation is useful? It lets animals ignore things that will not harm them. Without habituation, animals might waste time and energy trying to escape from things that are not really dangerous.

Observational Learning

Observational learning is learning by watching and copying the behavior of someone else. Human children learn many behaviors this way. When you were a young child, you may have learned how to tie your shoes by watching your dad tie his shoes. More recently, you may have learned how to dance by watching a pop star dancing on TV. Most likely, you have learned how to do math problems by watching your teachers do problems on the board at school. Can you think of other behaviors you have learned by watching and copying other people?

Other animals also learn through observational learning. For example, young wolves learn to be better hunters by watching and copying the skills of older wolves in their pack. Another example of observational learning is how some monkeys have learned to wash their food. They learned by watching and copying the behavior of other monkeys.

Conditioning

Conditioning is a way of learning that involves a reward or punishment. Did you ever train a dog to fetch a ball or stick by rewarding it with treats? If you did, you were using conditioning. Another example of conditioning is shown in the video below; the rats have been taught to “play basketball” by being rewarded with food pellets. What do you think would happen if the rats were no longer rewarded for this behavior?

Click on the image above for more content

Conditioning also occurs in wild animals. For example, bees learn to find nectar in certain types of flowers because they have found nectar in those flowers before.

Humans learn behaviors through conditioning, as well. A young child might learn to put away his toys by being rewarded with a bedtime story. An older child might learn to study for tests in school by being rewarded with better grades. Can you think of behaviors you have learned by being rewarded for them?

Conditioning does not always involve a reward. It can involve a punishment, instead. A toddler might be punished with a time-out each time he grabs a toy from his baby brother. After several time-outs, he may learn to stop taking his brother's toys.

A dog might be scolded each time she jumps up on the sofa. After repeated scolding, she may learn to stay off the sofa. A bird might become ill after eating a poisonous insect. The bird may learn from this "punishment" to avoid eating the same kind of insect in the future.

Learning by Playing

Most young mammals, including humans, like to play. Play is one ways they learn the skills that they will need as adults. Think about how kittens play. They pounce on toys and chase each other. This helps them learn how to be better predators when they are older. Big cats also play. The lion cubs pictured below are playing and practicing their hunting skills at the same time (**Figure** below). The dogs are playing tug-of-war with a toy (**Figure** below). What do you think they are learning by playing together this way?

Other young animals play in different ways. For example, young deer play by running and kicking up their hooves. This helps them learn how to escape from predators.

Figure 8.3

Left: These two lion cubs are playing. They are not only having fun, but they are also learning how to be better hunters. Right: These dogs are really playing. This play fighting can help them learn how to be better predators.

Human children learn by playing as well. For example, playing games and sports can help them learn to follow rules and work with others. The toddlers pictured below are playing in the sand (**Figure** below). They are learning about the world through play. What do you think they might be learning?

Figure 8.4

Playing in a sandbox is fun for young children. It can also help them learn about the world.

Insight Learning

Insight learning is learning from past experiences and reasoning. It usually involves coming up with new ways to solve problems. Insight learning generally happens quickly. An animal has a sudden flash of insight. Insight learning requires relatively great intelligence. Human beings use insight learning more than any other species. They have used their intelligence to solve problems ranging from inventing the wheel to flying rockets into space.

Think about problems you have solved. Maybe you figured out how to solve a new type of math problem or how to get to the next level of a video game. If you relied on your past experiences and reasoning to do it, then you were using insight learning.

One type of insight learning is making tools to solve problems. Scientists used to think that humans were the only animals intelligent enough to make tools. In fact, tool-making was believed to set humans apart from all other animals.

In 1960, primate expert Jane Goodall discovered that chimpanzees also make tools. She saw a chimpanzee strip leaves from a twig. Then he poked the twig into a hole in a termite mound. After termites climbed onto the twig, he pulled the twig out of the hole and ate the insects clinging to it. The chimpanzee had made a tool to “fish” for termites. He had used insight to solve a problem. Since then, chimpanzees have been seen making several different types of tools. For example, they sharpen sticks and use them as spears for hunting. They use stones as hammers to crack open nuts.

Scientists have also observed other species of animals making tools to solve problems. A crow was seen bending a piece of wire into a hook. Then the crow used the hook to pull food out of a tube.

An example of a gorilla using a walking stick is shown below (**Figure** below). Behaviors such as these show that other species of animals can use their experience and reasoning to solve problems. They can learn through insight.

Figure 8.5

This gorilla is using a branch as a tool. She is leaning on it to keep her balance while she reaches down into swampy water to catch a fish.

Summary

- Learned behavior is behavior that occurs only after experience or practice.
- Methods of learning include habituation, observational learning, conditioning, play, and insight learning.

Explore More

Use the resources below to answer the questions that follow.

Explore More I

- **Octopus Tool Use: The World's Smartest Invertebrate** at http://www.youtube.com/watch?v=AP_dpbTbess (1:21)

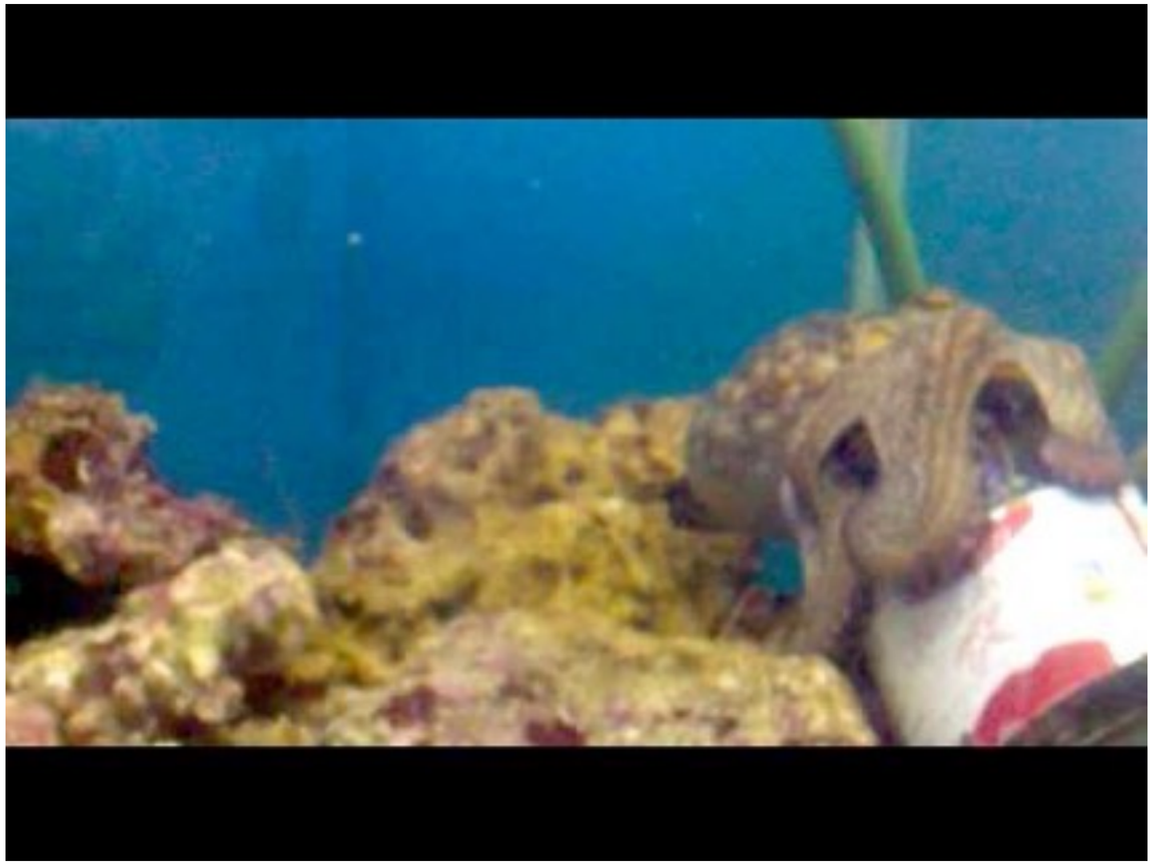
Click on the image above for more content

1. What sort of behavior do you feel this octopus is exhibiting? Explain your reasoning fully.

2.Do you think this behavior counts as "tool use"? Explain your thinking fully.

Explore More II

•**Octopus Open a Jar** at http://www.youtube.com/watch?v=5LYxJHi-RO0 (2:59)



Click on the image above for more content

•**Octopus Opening Jar** at http://www.youtube.com/watch?v=bU_J8TuBkwE (1:05)

Click on the image above for more content

1.The octopi in the above two videos are both opening jars. Observe their behavior closely.
   a.Do you think they are both displaying the same type of learning? Explain your reasoning fully, and be as specific as you can be.
   b.Do you think the amount of time it takes an octopus to open the jar is reflective of intelligence? Explain your thinking fully.

Review

1.What is observational learning? Give an example.
2.What is conditioning?

3.Why are some crows not afraid of scarecrows?
4.Describe insight learning. Give an example.

Section 3

Innate Behavior of Animals

Innate Behavior of Animals

- •Explain and give examples of innate behavior.
- •Describe reflex behaviors in humans.

How do kittens know how to "hunt"?

This kitten was probably adopted and separated from its mother at a young age. It never got a lesson in how to stalk and pounce on prey. So how does this kitten know how to attack the ball of yarn? Some behaviors do not need to be learned.

Innate Behavior

Many animal behaviors are ways that animals act, naturally. They don't have to learn how to behave in these ways. Cats are natural-born hunters. They don't need to learn how to hunt. Spiders spin their complex webs without learning how to do it from other spiders. Birds and wasps know how to build nests without being taught. These behaviors are called innate.

An **innate behavior** is any behavior that occurs naturally in all animals of a given species. An innate behavior is also called an **instinct** . The first time an animal performs an innate behavior, the animal does it well. The animal does not have to practice the behavior in order to get it right or become better at it. Innate behaviors are also predictable. All members of a species perform an innate behavior in the same way. From the examples described above, you can probably tell that innate behaviors usually involve important actions, like eating and caring for the young.

There are many other examples of innate behaviors. For example, did you know that honeybees dance? The honeybee pictured below has found a source of food (**Figure** below). When the bee returns to its hive, it will do a dance. This dance is called the **waggle dance** . The way the bee moves during its dance tells other bees in the hive where to find the food. Honeybees can do the waggle dance without learning it from other bees, so it is an innate behavior.

Figure 8.6

When this honeybee goes back to its hive, it will do a dance to tell the other bees in the hive where it found food.

Besides building nests, birds have other innate behaviors. One example occurs in gulls, which are pictured below (**Figure** below); one of the chicks is pecking at a red spot on the mother's beak. This innate behavior causes the mother to feed the chick. In many other species of birds, the chicks open their mouths wide whenever the mother returns to the nest (**Figure** below). This innate behavior, called **gaping** , causes the mother to feed them.

Figure 8.7

Left: This mother gull will feed her chick after it pecks at a red spot on her beak. Both pecking and feeding behaviors are innate. Right: When these baby birds open their mouths wide, their mother instinctively feeds them. This innate behavior is called gaping.

Another example of innate behavior in birds is egg rolling. It happens in some species of water birds, like the graylag goose (**Figure** below). Graylag geese make nests on the ground. If an egg rolls out of the nest, a mother goose uses her bill to push it back into the nest. Returning the egg to the nest helps ensure that the egg will hatch.

Figure 8.8

This female graylag goose is a ground-nesting water bird. Before her chicks hatch, the mother protects the eggs. She will use her bill to push eggs back into the nest if they roll out. This is an example of an innate behavior. How could this behavior increase the goose's fitness?

Innate Behavior in Human Beings

All animals have innate behaviors, even human beings. Can you think of human behaviors that do not have to be learned? Chances are, you will have a hard time thinking of any. The only truly innate behaviors in humans are called **reflex behaviors** . They occur mainly in babies. Like innate behaviors in other animals, reflex behaviors in human babies may help them survive.

An example of a reflex behavior in babies is the sucking reflex. Newborns instinctively suck on a nipple that is placed in their mouth. It is easy to see how this behavior evolved. It increases the chances of a baby feeding and surviving. Another example of a reflex behavior in babies is the grasp reflex (**Figure** below). Babies instinctively grasp an object placed in the palm of their hand. Their grip may be surprisingly strong. How do you think this behavior might increase a baby's chances of surviving?

Figure 8.9

One of the few innate behaviors in human beings is the grasp reflex. It occurs only in babies.

Summary

- Innate behavior, or instinct, is any behavior that occurs naturally in all animals of a given species.
- Examples of innate behavior include honeybees doing the waggle dance or spiders spinning a web.

Explore More

Use the resources below to answer the questions that follow.

Explore More I

- **Molluscs: Moon Snail Preys On Cockles** at http://vimeo.com/37449634 (2:05)

Click on the image above for more content

1. What sort of behavior is the moon snail exhibiting? Do you think the moon snail this is learned or innate behavior? Explain and defend your answer.
2. What sort of behavior is the cockle exhibiting? Do you think this is learned or innate behavior? Explain and defend your answer.

Explore More II

- **Spider Crabs vs. Stingray** at http://www.youtube.com/watch?v=fjwWLOIk1oA (2:37)

Click on the image above for more content

1. How many different types of behavior can you see in the crabs in this video? Which behaviors of the crabs do you think are innate and which are learned?
2. How many different types of behavior can you see in the stingray? Which behaviors of the stingray do you feel are innate and which are learned?

Review

1. What is an innate behavior?
2. What are two examples of reflex behaviors in humans?

3.What are two examples of innate behavior in animals?
4.Is an instinct an innate behavior? Explain your answer.

Section 4

Animal Communication

Animal Communication

•Define communication.
•List and describe methods of animal communication.
•Explain human communication.

How do monkeys communicate?

You won't find a monkey texting a friend. They make noises. They make faces. They even use scents to pass along a message. Just because monkeys don't talk like you and me doesn't mean that they don't communicate!

Communication

What does the word "communication" make you think of? Talking on a cell phone? Texting? Writing? Those are just a few of the ways in which human beings communicate. Most other animals also communicate. **Communication** is any way in which animals share information, and they do this in many different ways.

Do all animals talk to each other? Probably not, but many do communicate. Like human beings, many other animals live together in groups. Some insects, including ants and bees, are well known for living in groups. In order for animals to live together in groups, they must be able to communicate with each other.

Animal communication, like most other animal behaviors, increases the ability to survive and have offspring. This is known as fitness. Communication increases fitness by helping animals find food, defend themselves from predators, mate, and care for offspring.

Communication with Sound

Some animals communicate with sound. Most birds communicate this way. Birds use different calls to warn other birds of danger, or to tell them to flock together. Many other animals also use sound to communicate. For example, monkeys use warning cries to tell other monkeys in their troop that a predator is near. Frogs croak to attract female frogs as mates. Gibbons use calls to tell other gibbons to stay away from their area.

Communication with Sight

Another way some animals communicate is with sight. By moving in certain ways or by "making faces," they show other animals what they mean. Most primates communicate in this way. For example, a male chimpanzee may raise his arms and stare at another male chimpanzee. This warns the other chimpanzee to keep his distance. The chimpanzee pictured below may look like he is smiling, but he is really showing fear (**Figure** below). He is communicating to other chimpanzees that he will not challenge them.

Figure 8.10

This chimpanzee is communicating with his face. His expression is called a "fear grin." It tells other chimpanzees that he is not a threat.

Look at the peacock pictured below (**Figure** below). Why is he raising his beautiful tail feathers? He is also communicating. He is showing females of his species that he would be a good mate.

Figure 8.11

This peacock is using his tail feathers to communicate. What is he "saying"?

Communication with Scent

Some animals communicate with scent. They release chemicals that other animals of their species can smell or detect in some other way. Ants release many different chemicals. Other ants detect the chemicals with their antennae. This explains how ants are able to work together. The different chemicals that ants produce have different meanings. Some of the chemicals signal to all of the ants in a group to come together. Other chemicals warn of danger. Still other chemicals mark trails to food sources. When an ant finds food, it marks the trail back to the nest by leaving behind a chemical on the ground. Other ants follow the chemical trail to the food.

Many other animals also use chemicals to communicate. You have probably seen male dogs raise their leg to urinate on a fire hydrant or other object. Did you know that the dogs were communicating? They mark their area with a chemical in their urine. Other dogs can smell the chemical. The scent of the chemical tells other dogs to stay away.

Human Communication

Like other animals, humans communicate with one another. They mainly use sound and sight to share information. The most important way in which humans communicate is with language. **Language** is the use of symbols to communicate. In human languages, the symbols are words. They stand for many different things. Words stand for things, people, actions, feelings, or ideas. Think of several common words. What does each word stand for? Another important way in which humans communicate is with facial expressions. Look at the face of the young child pictured below (**Figure** below). Can you tell from her face how she is feeling?

Humans also use gestures to communicate. What are people communicating when they shrug their shoulders? When they shake their head? These are just a few examples of the ways in which humans share information without using words.

Figure 8.12

What does this girl’s face say about how she is feeling?

Summary

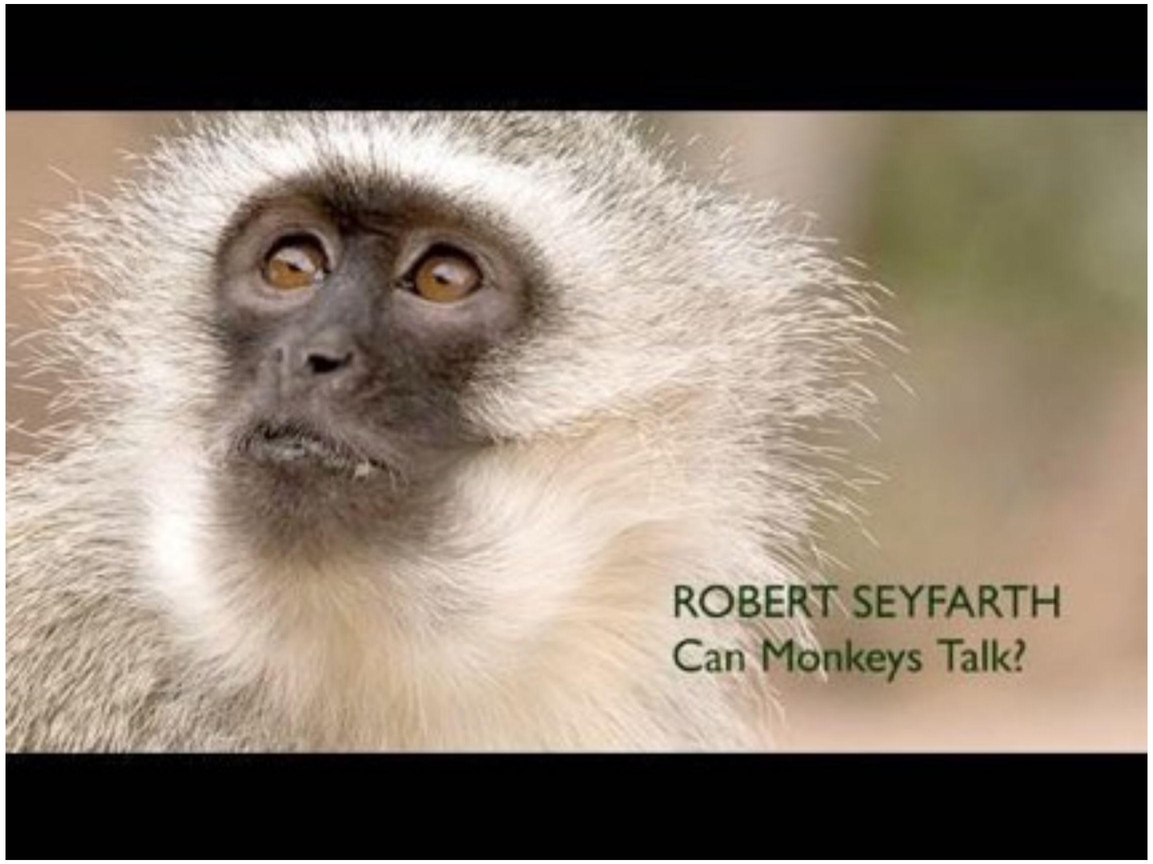
- Animals communicate, or share information, through sound, sight, and scent.
- Humans primarily communicate through use of language, facial expressions, and gestures.

Explore More

Use the resources below to answer the questions that follow.

Explore More I

•Can Monkeys Talk? at http://www.youtube.com/watch?v=3lsF83rHKFc (3:36)



Click on the image above for more content

1. How do the vervet monkeys (*Chlorocebus pygerythrus*) respond when they hear a "leopard" call?
2. How do the vervet monkeys respond when they hear an "eagle" call?
3. How do the vervet monkeys respond when the hear a "snake" call?
4. Given the vervet monkeys responses to specific calls, do you think they are using language? Explain your reasoning fully.

Explore More II

•How Do Tigers Communicate? at http://www.youtube.com/watch?v=LL99pufzHjo (1:33)

Click on the image above for more content

1. What are some of the different ways tigers (*Panthera tigris*) communicate?
2. In what sort of ways do tigers communicate through smell?

3. Do you think using different smells to communicate is analogous to using different words? Explain your reasoning.

Review

1. What is communication?
2. Why is communication important?
3. Give two examples of how animals communicate with scent.
4. Give two examples of how animals communicate through sight.
5. Define language.

Section 5

Social Behavior of Animals

Social Behavior of Animals

- •Define social animals.
- •Describe social behavior in animals.
- •Explain and give examples of cooperation.

How are you social?

When you think about being social, do you think about hanging out and chatting with friends? Sending a text or posting to Facebook? Humans socialize in many ways. Social behavior is not limited to humans, however. Many animals are social.

Social Behavior

Why is animal communication important? Without it, animals would not be able to live together in groups. Animals that live in groups with other members of their species are called **social animals** . Social animals include many species of insects, birds, and mammals. Specific examples of social animals are ants, bees, crows, wolves, and humans. To live together with one another, these animals must be able to share information.

Highly Social Animals

Some species of animals are very social. In these species, members of the group depend completely on one another. Different animals within the group have different jobs. Therefore, group members must work together for the good of all. Most species of ants and bees are highly social animals.

Ants live together in large groups called colonies (**Figure** below). A colony may have millions of ants. All of the ants in the colony work together as a single unit. Each ant has a specific job. Most of the ants are workers. Their job is to build and repair the colony's nest. Worker ants also leave the nest to find food for themselves and other colony members. The workers care for the young as well. Other ants in the colony are soldiers. They defend the colony against predators. Each colony also has a queen. Her only job is to lay eggs. She may lay millions of eggs each month.

A few ants in the colony are called drones. They are the only male ants in the colony. Their job is to mate with the queen.

Figure 8.13

The ants in this picture belong to the same colony. They have left the colony's nest to search for food.

Honeybees and bumblebees also live in colonies (**Figure** below). Each bee in the colony has a particular job. Most of the bees are workers. Young worker bees clean the colony's hive and feed the young. Older worker bees build the waxy honeycomb or guard the hive. The oldest workers leave the hive to find food. Each colony usually has one queen that lays eggs. The colony also has a small number of male drones. They mate with the queen.

Figure 8.14

All the honeybees in this colony work together. Each bee has a certain job to perform. Notice the queen to the left. She is the largest bee in the colony.

Cooperation

Ants, bees, and other social animals must cooperate. **Cooperation** means working together with others. Members of the group may cooperate by sharing food. They may also cooperate by defending each other. Look at the ants pictured below (**Figure** below). They show very clearly why cooperation is important. A single ant would not be able to carry this large bee back to the nest to feed the other ants. With cooperation, the job is easy.

Figure 8.15

These ants are cooperating. By working together, they are able to move this much larger insect prey back to their nest. At the nest, they will share the bee with other ants that do not leave the nest.

Animals in many other species cooperate. For example, lions live in groups called prides (**Figure** below). All the lions in the pride cooperate. Male lions work together to defend the other lions in the pride. Female lions work together to hunt. Then, they share the meat with other pride members. Another example is meerkats. Meerkats are small mammals that live in Africa. They also live in groups and cooperate with one another. For example, young female meerkats act as babysitters. They take care of the baby meerkats while their parents are away looking for food.

Figure 8.16

Members of this lion pride work together. Males cooperate by defending the pride. Females cooperate by hunting and sharing the food.

Summary

- Social animals, or animals that live in groups with other members of their species, include ants, bees, crows, wolves, and humans.
- Social animals must cooperate (work together) with others.

Explore More

Use the resource below to answer the questions that follow.

•**Wolf Hunting Tactics** at http://www.youtube.com/watch?v=2jXxtQRy47A (2:54)

Click on the image above for more content

1. Observe the wolves (*Canis lupus*) in this video:
   a. Do you think they are displaying learned behavior, innate behavior, or both? Explain your reasoning fully.
   b. As social animals, which behavior do you think is most important to them? Explain your reasoning.
   c. Does your answer apply to all situations?

Review

1. What makes social animals unique?
2. Give three examples of social animals.
3. What is one example of how social animals cooperate?

Section 6

Reproductive Behavior of

Reproductive Behavior of Animals

- •Define courtship behavior.
- •Explain the purpose of mating behavior.
- •Describe how animals care for their young and defend their territory.

Why do these birds pair up?

These birds are pairing up so that they can produce offspring. Many birds keep the same mate for an entire season. In some species, they even stay paired for their entire life.

Mating Behavior and Defending Territory

Some of the most important animal behaviors involve mating. **Mating** is the pairing of an adult male and female to produce young. Adults that are most successful at attracting a mate are most likely to have offspring. Traits that help animals attract a mate and have offspring increase their fitness. As the genes that encode these traits are passed to the next generation, the traits will become more common in the population.

Courtship Behaviors

In many species, females choose the male they will mate with. For their part, males try to be chosen as mates. They show females that they would be a better mate than the other males. To be chosen as a mate, males may perform **courtship behaviors** . These are special behaviors that help attract a mate. Male courtship behaviors get the attention of females and show off a male’s traits.

Different species have different courtship behaviors. One example is a peacock raising his tail feathers. The colorful peacock is trying to impress females of his species with his beautiful feathers. Another example of courtship behavior in birds is the blue-footed booby. He is doing a dance to attract a female for mating. During the dance, he spreads out his wings and stamps his feet on the ground. You can watch the following video of a blue-footed booby doing his courtship dance at: http://www.youtube.com/watch?v=oYmzdvMoUUA .

Click on the image above for more content

Courtship behaviors occur in many other species. For example, males in some species of whales have special mating songs to attract females as mates. Frogs croak for the same reason. Male deer clash antlers to court females. Male jumping spiders jump from side to side to attract mates.

Courtship behaviors are one type of display behavior. A **display behavior** is a fixed set of actions that carries a specific message. Although many display behaviors are used to attract mates, some display behaviors have other purposes. For example, display behaviors may be used to warn other animals to stay away, as you will read below.

Caring for the Young

In most species of birds and mammals, one or both parents care for their offspring. Caring for the young may include making a nest or other shelter. It may also include feeding the young and protecting them from predators. Caring for offspring increases their chances of surviving. Birds called killdeers have an interesting way of protecting their chicks. When a predator gets too close to her nest, a mother killdeer pretends to have a broken wing. The mother walks away from the nest holding her wing as though it were injured (**Figure** below). The predator thinks she is injured and will be easy prey. The mother leads the predator away from the nest and then flies away.

Figure 8.17

This mother killdeer is pretending she has a broken wing. She is trying to attract a predator's attention in order to protect her chicks. This behavior puts her at risk of harm. How can it increase her fitness?

In most species of mammals, parents also teach their offspring important skills. For example, meerkat parents teach their pups how to eat scorpions without being stung. A scorpion sting can be deadly, so this is a very important skill. Teaching the young important skills makes it more likely that they will survive.

Defending Territory

Some species of animals are **territorial** . This means that they defend their area. The area they defend usually contains their nest and enough food for themselves and their offspring. A species is more likely to be territorial if there is not very much food in their area. Animals generally do not defend their territory by fighting. Instead, they are more likely to use display behavior. The behavior tells other animals to stay away. It gets the message across without the need for fighting. Display behavior is generally safer and uses less energy than fighting. Male gorillas use display behavior to defend their territory. They pound on their chests and thump the ground with their hands to warn other male gorillas to keep away from their area. The robin displays his red breast to warn other robins to stay away (**Figure** below).

Figure 8.18

The red breast of this male robin is easy to see. The robin displays his bright red chest to defend his territory. It warns other robins to keep out of his area.

Some animals deposit chemicals to mark the boundary of their territory. This is why dogs urinate on fire hydrants and other objects. Cats may also mark their territory by depositing chemicals. They have scent glands in their face. They deposit chemicals by rubbing their face against objects.

Summary

- Males of some species may perform courtship behaviors, special behaviors that help attract a mate.
- Some species of animals are territorial and defend their area.

Explore More

Use the resources below to answer the questions that follow.

Explore More I

- **Dominant Male Elephant Seal** at http://www.youtube.com/watch?v=9UYFGSyUxRc (2:26)

Click on the image above for more content

The Northern elephant seal (*Mirounga angustirostris*) has a harem based mating system, where a dominant male defends the females in his harem from other males attempting to mate with them.

1. Does the dominant male father all the pups from his harem?

2.How do you think the size of a harem affects a male's ability to defend his harem? Explain your reasoning.

Explore More II

•**Behavior on a Sage Grouse Lek** at http://www.youtube.com/watch?v=QYMHbFUTgAY (1:15)

Click on the image above for more content

1.What is a lek? What sort of behavior is seen in a lek?
2.When do sage grouse (*Centrocercus urophasianus*) put on the most weight? How does this affect their reproductive success?

Explore More III

•**Elk Fighting in River** at http://www.youtube.com/watch?v=GUQcMZLZpx8 (2:45)

Click on the image above for more content

1.Notice the male elk (*Cervus canadensis*) which enters the video at the 2:05 mark. What do you think it is trying to do? Do you think its behavior helps or hurts the survival of elk in Yellowstone National Park?
2.What sort of behavior are the male elk displaying?

Review

1.What is a courtship behavior. Give an example.

2.Give an example of display behavior exhibited by a territorial animal.

Section 7

Cyclic Behavior of Animals

Cyclic Behavior of Animals

•Identify animal behaviors that occur in cycles.
•Explain hibernation and migration.
•Define circadian rhythms and biological clock.

What are these butterflies doing?

Monarch butterflies gather in large groups as they migrate 2,500 miles south each fall. They return to the north in the spring. This migration is a cycle that repeats every year.

Cycles of Behavior

Many animal behaviors change in a regular way. They go through cycles. Some cycles of behavior repeat each year. Other cycles of behavior repeat every day.

Yearly Cycles

An example of a behavior with a yearly cycle is **hibernation** . Hibernation is a state in which an animal's body processes are slower than usual, and its body temperature falls. An animal uses less energy than usual during hibernation. This helps the animal survive during a time of year when food is scarce. Hibernation may last for weeks or months. Animals that hibernate include species of bats, squirrels, and snakes.

Most people think that bears hibernate. In fact, bears do not go into true hibernation. In the winter, they go into a deep sleep. However, their body processes do not slow down very much. Their body temperature also remains about the same as usual. Bears can be awakened easily from their winter sleep.

Another example of a behavior with a yearly cycle is **migration** . Migration is the movement of animals from one place to another. Migration is an innate behavior that is triggered by changes in the environment. For example, animals may migrate when the days get shorter in the fall. Migration is most common in birds, fish, and insects. In the Northern Hemisphere, many species of birds, including robins and geese, travel south for the winter. They migrate to areas where it is warmer and where there is more food.

They return north in the spring. A flock of migrating geese is pictured below (**Figure** below).

Figure 8.19

These geese are flying south for the winter. Flocks of geese migrate in V-shaped formations.

Some animals migrate very long distances. The map shown below shows the migration route of a species of hawk called Swainson's hawk (**Figure** below). About how many miles do the hawks travel from start to finish? Are you surprised that birds migrate that far? Some species of birds migrate even farther. Whales also are known to migrate thousands of miles each year to take advantage of warmer waters in the winter months. The great migration of millions of zebra, wildebeest and other antelope in East Africa also occurs yearly. Each year around 1.5 million wildebeest and 300,000 zebra (along with other antelope) go in search of food and water, traveling a distance of around 1800 miles.

Figure 8.20

The migration route of Swainson's hawk starts in North America and ends in South America. Scientists learned their migration route by attaching tiny tracking devices to the birds. The birds were then tracked by satellite. On the migration south, the hawks travel almost 5,000 miles from start to finish.

Birds and other migrating animals follow the same routes each year. How do they know where to go? It depends on the species. Some animals follow landmarks, such as rivers or coastlines. Other animals are guided by the position of the sun, the usual direction of the wind, or other clues in the environment.

Daily Cycles

Many animal behaviors change at certain times of day, day after day. For example, most animals go to sleep when the sun sets and wake up when the sun rises. Animals that are active during the daytime are called **diurnal** . Some animals do the opposite. They sleep all day and are active during the night. These animals are called **nocturnal** . Examples of nocturnal animals include bats, foxes, possums, skunks and coyotes. Many mammals (including humans), insects, reptiles and birds are diurnal.

Animals may eat and drink at certain times of day as well. Humans have daily cycles of behavior, too. Most people start to get sleepy after dark and have a hard time sleeping when it is light outside. Daily cycles of behavior are called **circadian rhythms** .

In many species, including humans, circadian rhythms are controlled by a tiny structure called the **biological clock** . This structure is located in a gland at the base of the brain. The biological clock sends signals to the body. The signals cause regular changes in behavior and body processes. The amount of light entering the eyes helps control the biological clock. The clock causes changes that repeat every 24 hours.

Summary

- Yearly cycles of behavior include hibernation and migration.
- Daily cycles of behavior, including sleeping a waking, are called circadian rhythms.

Explore More

Use the resources below to answer the questions that follow.

Explore More I

- **Red Knot Migration - Port Royal Sound** at http://www.youtube.com/watch?v=P21xTCFrJbU (2:07)

Click on the image above for more content

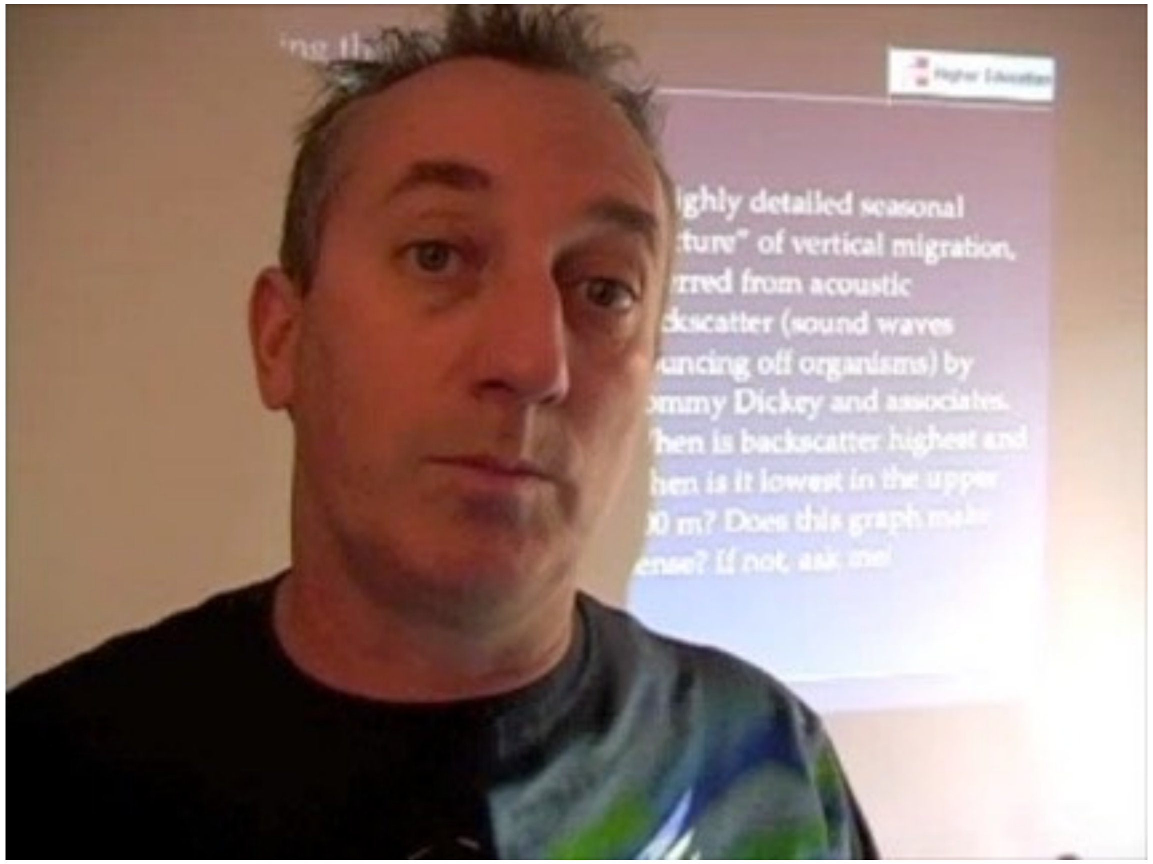
- **Thousands of Red Knots migrate through New Jersey** at http://www.youtube.com/watch?v=TE5EHoBWdAA (2:55)

Click on the image above for more content

1. How far do Red Knots (*Calidris canutus*) migrate each year?
2. Are Red Knots the only species of bird to use horseshoe crab (*Limulus polyphemus*) eggs as a resource?
3. What information do scientists collect from the red Knots? How do they use this information?
4. Why do scientists think Red Knot populations are declining? How is this connected to their extremely long migration?

Explore More II

•**Ocean Life - Vertical Migration & Aggregation** at http://www.youtube.com/watch?v=zVQd9pn8j6E (7:16)



Click on the image above for more content

1. What is the largest migration of animals on the planet? When does this occur?
2. Why do animals undergo this migration? What types of organisms undergo this migration?
3. How does the timing of this migration vary throughout the year?

Review

1. What are two examples of yearly cycles of behavior?
2. What is the difference between a nocturnal and a diurnal animal?
3. What is a circadian rhythm?
4. What controls circadian rhythms in humans? Explain how this process works.

Summary

Animals. Currently the end of the line for evolution. But there are all sorts of animals, from the extremely simple to the extremely complex. Along with this range of animals comes a range of behaviors. These behaviors are discussed in this concept.

References

1. Cat and mouse: Vorstius; Dog: Robin Taylor; Bird: Lilla Frerichs; Wasps: GanMed64; Lizard: Jimmy Harris; Rabbit: Lauris Rubenis. Examples of animal behaviors include hunting, nursing, building a nest, sunning, and running away from predators . Bird: Public Domain; Remaining images: CC BY 2.0
2. Image copyright Svetolk, 2013. A crow that has habituated to a scarecrow . Used under license from Shutterstock.com
3. Katie Hunt; Bill Mulder. Lion cubs and dogs playing . CC BY 2.0
4. Image copyright Danila, 2014. Child playing in a sandbox . Used under license from Shutterstock.com
5. Thomas Breuer, Mireille Ndoundou-Hockemba, Vicki Fishlock/PLOS Biology. Gorilla using a branch as a tool . CC BY 2.5

6. Thangaraj Kumaravel. When this honeybee goes back to its hive, it will do a dance to tell the other bees in the hive where it found food . CC BY 2.0
7. Brian Gratwicke; Bill and Vicki T.. A bird's feeding behavior are innate . CC BY 2.5; CC BY 2.0
8. Steve Webster. A goose returning an egg to the nest is an innate behavior . CC BY 2.0
9. Vera Kratochvil. A human baby's grasp reflex . Public Domain
10. Frans de Waal/Emory University. Chimpanzee showing a fear grin . CC BY 2.5
11. Madison Berndt. A peacock using his tail feathers to communicate . CC BY 2.0
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14. Lance Cheung/USDA. Honeybees in a colony . CC BY 2.0
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16. Rick Marin. Members of this lion pride work together . Public Domain
17. audreyjm529. This mother killdeer is pretending she has a broken wing in order to protect her chicks . CC BY 2.0
18. Dwight Sipler. The robin displays his bright red chest to defend his territory . CC BY 2.0
19. Chris Burke. These geese fly in a V-shaped formation while migrating south for the winter . CC BY 2.0
20. U.S. Geological Survey. The route of migration for Swainson's hawk . Public Domain

Invertebrates

Introduction

Why does not having a backbone make things so complex?

Invertebrates could be described as simple animals. And though some are very simple, the vastness of the invertebrate species makes this group of animals anything but simple.

Section 1

Invertebrates

Invertebrates

•Distinguish between invertebrates and vertebrates.
•List invertebrate phyla, and give examples of each.

How are these jellyfish like an insect?

Jellyfish and insects don't seem to have much in common. They look much different. They live in very different environments. But both of these animals are classified as invertebrates.

What Are Invertebrates?

Animals are often identified as being either invertebrates or vertebrates. These are terms based on the skeletons of the animals. **Vertebrates** have a backbone made of bone or cartilage (**cartilage** is a flexible supportive tissue. You have cartilage in your ear lobes.). **Invertebrates** , on the other hand, have no backbone (**Figure** below). Invertebrates live just about anywhere. There are so many invertebrates on this planet that it is impossible to count them all. There are probably billions of billions of invertebrates. They come in many shapes and sizes, live practically anywhere and provide many services that are vital for the survival of other organisms, including us. They have been observed in the upper reaches of the atmosphere, in the driest of the deserts and in the canopies of the wettest rainforests. They can even be found in the frozen Antarctic or on the deepest parts of the ocean floor.

Figure 9.1

Snails are an example of invertebrates, animals without a backbone.

All vertebrate organisms are in the phylum Chordata. Invertebrates, which make up about 95% (or more) of the animal kingdom, are divided into over 30 different phyla, some of which are listed below (**Table** below). Numerous invertebrate phyla have just a few species; some have only one described species, yet these are classified into separate phyla because of their unique characteristics.

Phylum	Meaning	Examples
Porifera	Pore bearer	Sponges

Summary

- Invertebrates are animals without a backbone.
- Invertebrates include insects, earthworms, jellyfish, and many other animals.

Explore More

Use the resource below to answer the questions that follow.

- **Invertebrates** at http://www.youtube.com/watch?v=5E4TsarJk7Y (4:58)

1. Where do invertebrates live?
2. What do invertebrates eat?
3. Why are invertebrates important to the environment?
4. What are the main invertebrate groups?

Review

1. What are three examples of invertebrates?
2. How do you determine if an animal is an invertebrate?
3. About what percent of the animal kingdom is composed of invertebrates?

Section 2
Sponges

Sponges

- •Describe the key features of sponges.
- •Summarize feeding in sponges.

Do animals wash your dishes?

Natural sponges, like the one in the picture above, are actually animals taken from the sea! The sponges in your home, however, were most likely never living things. Most sponges used in kitchens today are made from unnatural materials.

Sponges

Sponges (**Figure** below) are classified in the phylum Porifera, from the Latin words meaning "having pores." These pores allow the movement of water into the sponges' sac-like bodies. Sponges must pump water through their bodies in order to eat. Because sponges are **sessile** , meaning they cannot move, they filter water to obtain their food. They are, therefore, known as **filter feeders.** Filter feeders must filter the water to separate out the organisms and nutrients they want to eat from those they do not.

Figure 9.2

The sponges often have tube-like bodies with many tiny pores. There are roughly 5,000 sponge species.

You might think that sponges don't look like animals at all. They don't have a head or legs. Internally, they do not have brains, stomachs, or other organs. This is because sponges evolved much earlier than other animals. In fact, sponges do not even have true tissues. Instead, their bodies are made up of specialized cells (cell-level organization) that do specific jobs. Sponge cells perform a variety of bodily functions and appear to be more independent of each other than are the cells of other animals. For example, some cells control the flow of water, in and out of the sponge, by increasing or decreasing the size of the pores.

Sponges are characterized by a feeding system unique among animals. As sponges don't have mouths, they must feed by some other method. Sponges have tiny pores in their outer walls through which water is drawn. Cells in the sponge walls filter food from the water as the water is pumped through the body and out other larger openings. The flow of water through the sponge is unidirectional, driven by the beating of flagella, which line the surface of chambers connected by a series of canals.

Sponges reproduce by both asexual and sexual means. Sponges that reproduce asexually produce buds or, more often, structures called **gemmules** , which are packets of several cells of various types inside a protective covering. Freshwater sponges often produce gemmules prior to winter, which then develop into adult sponges beginning the following spring. Most sponges that reproduce sexually are hermaphroditic and produce eggs and sperm at different times. Sperm are frequently released into the water, where they are captured by sponges of the same species. The sperm are then transported to eggs, fertilization occurs and the zygotes develop into larvae. Some sponges release their larvae, where others retain them for some time. Once the larvae are in the water, they settle and develop into juvenile sponges.

Summary

- •Sponges are sessile filter feeders.
- •Sponges lack true tissues.

Explore More

Use the resource below to answer the questions that follow.

- •**Sponges: Origins** at http://vimeo.com/37032195 (14:02)

Click on the image above for more content

1. How do sponge cells work together?
2. How do most sponges feed? Explain your answer as fully as possible.
3. Where do sponges take in water? Where do they expel water?

4. What evidence do scientists point to when they say sponges may be the oldest type of animal on the planet?
5. What is the "heart" of sponges that controls circulation?

Review

1. What is a sea sponge?
2. How do sponges gain nutrition?
3. What is meant by cell-level organization?
4. Define sessile.

Section 3

Cnidarians

Cnidarians

- Describe the key features of the cnidarians.
- Define nematocyst.
- Distinguish between a polyp and a medusa body plan.
- Describe cnidarian colonies.

Are corals animal, plant, or mineral?

Some corals may look like rocks. But they are alive! And some corals may look like plants, but they are actually animals. Just like all other animals, they eat food to get energy.

Cnidarians

Cnidarians , in the phylum *Cnidaria* , include organisms such as the jellyfish, corals, and sea anemones. These animals are found in shallow ocean water. You might know that these animals can give you a painful sting if you step on them. That's because cnidarians have stinging cells known as **nematocysts** . Cnidarians use nematocysts to catch their food. When touched, the nematocysts release a thread of poison that can be used to paralyze prey. Cnidarians are among the simplest of the so-called "higher" organisms, but are also among the most beautiful.

Body plan

The body plan of cnidarians is unique because these organisms show radial symmetry. This means that they have a circular body plan, and any cut through the center of the animal leaves two equal halves.

The cnidarians have two basic body forms:

1. **Polyp** : The polyp is a cup-shaped body with the mouth facing upward, such as a sea anemone and coral.
2. **Medusa** : The medusa is a bell-shaped body with the mouth and tentacles facing downward, such as a jellyfish.

Unlike the sponges, the cnidarians are made up of true tissues. The inside of a cnidarian is called the **gastrovascular cavity** , a large space that helps the organism digest and move nutrients around the body. The cnidarians also have nerve tissue organized into a net-like structure, known as a nerve-net. Cnidarians do not have true organs, however.

Reproduction is by asexual budding (polyps) or sexual formation of gametes (medusae, some polyps). The result of sexual reproduction is a larva, which can swim on its own.

Cnidarian Colonies

Some types of cnidarians are also known to form colonies. Two examples are described below.

1.The Portuguese Man o' War (**Figure** below) looks like a single organism but is actually a colony of polyps. One polyp is filled with air to help the colony float, while several feeding polyps hang below with tentacles. The tentacles are full of nematocysts. The Portuguese Man o' War is known to cause extremely painful stings to swimmers and surfers who accidentally brush up against it in the water.

Figure 9.3

The Portuguese Man o' War can deliver nasty stings with its tentacles.

2.Coral reefs (**Figure** below) look like big rocks, but they are actually alive. They are built from cnidarians called corals. The corals are sessile polyps that can use their tentacles to feed on ocean creatures that pass by. Their skeletons are made up of calcium carbonate, which is also known as limestone. Over long periods of time, their skeletons build on each other to produce large structures known as coral reefs. Coral reefs are important habitats for many different types of ocean life.

Corals are colonial cnidarians.

Summary

- Cnidarians have radial symmetry and true tissues.
- Some cnidarians form colonies, such as corals.

Explore More

Use the resource below to answer the questions that follow.

Explore More I

- **Cnidarians: Life on the Move** at http://vimeo.com/37267733 (14:44)

Click on the image above for more content

1. How do cnidarians move?
2. Why was movement a useful innovation for cnidarians?
3. What is a nematocyst? For what purpose(s) are they used?
4. What allowed cnidarians to swim the world's oceans?

Explore More II

- **Cnidarians: Moon Jelly Life Cycle** at http://vimeo.com/40232821 (3:15)

Click on the image above for more content

1. How do polyps differ from medusas?
2. Describe the mating of moon jellies.

Review

1. What are three examples of cnidarians?
2. What is an nematocyst? What does it do?
3. Distinguish between the two body plans of a cnidarian.
4. How is a jellyfish different from a Portuguese Man o' War?

Section 4

Flatworms

Flatworms

•Describe the major features of flatworms.
•Describe parasitic flatworms.

Do worms have eyes?

You might think that worms can't see. But some worms, such as the above *Dugesia* flatworm, do have eyespots. These are not exactly like your eyes, however. Eyespots can only detect light in their environment.

Flatworms

The word "worm" is not very scientific. But it is a word that informally describes animals (usually invertebrates) that have long bodies with no arms or legs. (Snakes are vertebrates, so they are not usually described as worms.) Worms show bilateral symmetry, meaning that the right side of their bodies is a mirror of the left.

One type of worm is the **flatworm** . Worms in the phylum *Platyhelminthes* are called flatworms because they have flattened bodies. There are more than 18,500 known species of flatworms.

Features of Flatworms

The main characteristics of flatworms (**Figure** below) include:

1. Flatworms have no true body cavity, but they do have bilateral symmetry.
2. Flatworms have an incomplete digestive system. This means that the digestive tract has only one opening. Digestion takes place in the gastrovascular cavity.
3. Flatworms do not have a respiratory system. Instead, they have pores that allow oxygen to enter through their body. Oxygen enters the pores by diffusion.

4.There are no blood vessels in the flatworms. Their **gastrovascular cavity** helps distribute nutrients throughout the body.
5.Flatworms have a ladder-like nervous system; two interconnected parallel nerve cords run the length of the body.
6.Most flatworms have a distinct head region that includes nerve cells and sensory organs, such as eyespots. The development of a head region, called **cephalization** , evolved at the same time as bilateral symmetry in animals.

Figure 9.5

Marine flatworms can be brightly colored, such as this one from the class Turbellaria. These worms are mostly carnivores or scavengers.

Flatworms in the Environment

Flatworms live in a variety of environments. Some species of flatworms are free-living organisms that feed on small organisms and rotting matter. These types of flatworms include marine flatworms and freshwater flatworms, such as *Dugesia* .

Other types of flatworms are parasitic. That means they live inside another organism, called a host, in order to get the food and energy they need. For example, **tapeworms** have a head-like area with tiny hooks and suckers (known as the **scolex**) that help the worm attach to the intestines of an animal host (**Figure** below). There are over 11,000 species of parasitic flatworms.

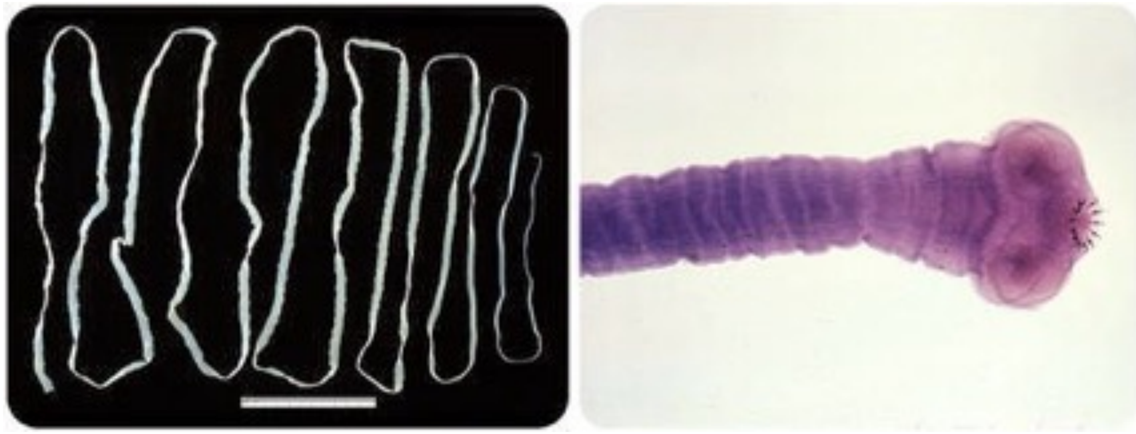


Figure 9.6

Tapeworms are parasitic flatworms that live in the intestines of their hosts. They can be very long (*left*). Tapeworms attach to the intestinal wall with a head region that has hooks and suckers (*right*).

Summary

- Flatworms have no true body cavity and no blood vessels.
- Flatworms can be free-living or parasitic. Tapeworms are parasitic flatworms.

Explore More

Use the resources below to answer the questions that follow.

- **Flatworms: The First Hunter** at http://vimeo.com/37282961 (9:54)

Click on the image above for more content

1. Why was cephalization important for flatworms? What did this allow them to do effectively?
2. How is the nervous system of flatworms different from those of most cnidarians? What does this make them better at than cnidarians?
3. What do flatworm eyes sense?
4. How do stereo senses help animals survive?
5. What is internal fertilization as opposed to external fertilization? Considering that there is an energetic cost to making gametes, what advantage can internal fertilization have over external fertilization?

Review

1. What is a flatworm?
2. What is cephalization?
3. How do flatworms transport oxygen and nutrients?
4. Describe the flatworm nervous system.
5. What is one example of a flatworm?

Section 5

Roundworms

Roundworms

- •Describe the major features of the roundworms.
- •Describe parasitic roundworms.

What is heartworm?

You may have heard that you need to protect your pets from heartworm. Heartworms are a type of roundworm. They can be parasites in cats and dogs. That means, once they infect your pet, they can cause harm. However, there are preventative treatments available.

Roundworms

The word "worm" is not very scientific. This informal term describes animals (usually invertebrates) that have long bodies with no arms or legs. Worms with round, non-segmented bodies are known as nematodes or **roundworms** (**Figure** below). They are classified in the phylum *Nematoda* , which has over 28,000 known species. Some scientists believe there could be over a million species of Nematodes.

Nematodes are slender bilaterally symmetrical worms, typically less than 2.5 mm long. The smallest nematodes are microscopic, while free-living species can reach as much as 5 cm, and some parasitic species are larger still, reaching over a meter in length. The worm body is often covered with ridges, rings, bristles, or other distinctive structures. The radially symmetrical head of a nematode also has distinct features. The head is covered with sensory bristles and, in many cases, solid "head-shields" around the mouth region. The mouth has either three or six lips, which often have a series of teeth on their inner edges.

Figure 9.7

Nematodes can be parasites of plants and animals.

Features of Roundworms

1. Unlike the flatworms, the roundworms have a body cavity with internal organs.
2. A roundworm has a complete digestive system, which includes both a mouth and an anus. This is a significant difference from the incomplete digestive system of flatworms. The roundworm digestive system also include a large digestive organ known as the gut. Digestive enzymes that start to break down food are produced here. There is no stomach, but there is an intestine which produces enzymes that help absorb nutrients. The last portion of the intestine forms a rectum, which expels waste through the anus.
3. Roundworms also have a simple nervous system with a primitive brain. There are four nerves that run the length of the body and are connected from the top to the bottom of the body. At the anterior end of the animal (the head region), the nerves branch from a circular ring which serves as the brain. The head of a nematode has a few tiny sense organs, including chemoreceptors, which sense chemicals.

Roundworms in the Environment

Roundworms can be free-living organisms, but they are probably best known for their role as significant plant and animal parasites. Most Nematodes are parasitic, with over 16,000 parasitic species described. Heartworms, which cause serious disease in dogs while living in the heart and blood vessels, are a type of roundworm. Roundworms can also cause disease in humans. Elephantiasis, a disease characterized by the extreme swelling of the limbs (**Figure** below), is caused by infection with a type of roundworm.

Figure 9.8

One roundworm parasite causes elephantiasis, a disease characterized by swelling of the limbs.

Most parasitic roundworm eggs or larvae are found in the soil and enter the human body when a person picks them up on the hands and then transfers them to the mouth. The eggs or larvae also can enter the human body directly through the skin. The best solution to these diseases is to try to prevent these diseases rather than treat or cure them. Many parasitic diseases caused by roundworms result from poor personal hygiene. Contributing factors may include

- •lack of a clean water supply,
- •inadequate sanitation measures,
- •crowded living conditions, combined with a lack of access to health care and low levels of education.

Summary

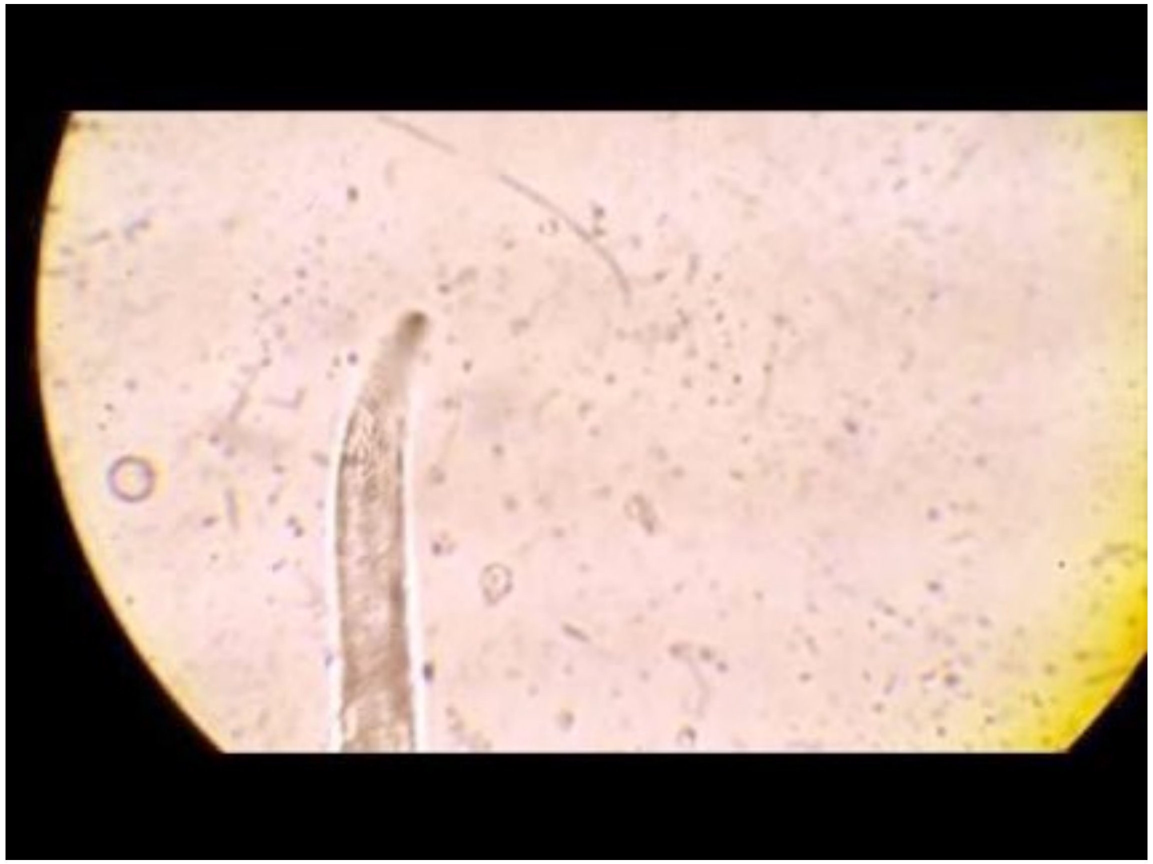
- •Roundworms have a body cavity with internal organs and a simple nervous system.
- •Roundworms can be free-living or parasitic.

Explore More

Use the resources below to answer the questions that follow.

Explore More I

- •**Nematode Movement** at http://www.youtube.com/watch?v=SpgjnXEFadg (1:52)



Click on the image above for more content

1. How does the movement of a nematode differ from the movement of an earthworm?
2. Why can't a nematode move like an earthworm?
3. What is the purpose of the nematode's cuticle?

Explore More II

- •**Mushroom Mycelium Feeding on Nematodes** at http://www.youtube.com/watch?v=0n04wCkIpuQ (1:41)

Click on the image above for more content

1. Why do some fungi trap nematodes?

Explore More III

- **Heartworm Quiz** at http://www.heartwormsociety.org/pet-owner-resources/quiz.html

Review

1. What is a roundworm?
2. How are the internal structures of the roundworms different from flatworms?
3. What is the main cause of many parasitic diseases caused by roundworms?

Section 6

Segmented Worms

Segmented Worms

- Describe the major features of the segmented worms.
- Compare flatworms, roundworms, and segmented worms.

Does an earthworm have a brain?

Just like you, earthworms do have a brain. Their brains are much simpler than yours, however. Earthworms' brains allow them to sense and respond to light and touch.

Segmented Worms

When you think of worms, you probably picture earthworms. There are actually many types of worms, including flatworms, roundworms, and segmented worms. Earthworms are segmented worms.

Segmented worms are in the phylum *Annelida* , which has over 22,000 known species. These worms are known as the **segmented worms** because their bodies are segmented, or separated into repeating units. Besides the earthworm, the segmented worms also include leeches and some marine worms. Most segmented worms like the earthworm, feed on dead organic matter. **Leeches** (**Figure** below), however, can live in fresh water and suck blood from their animal host. You may have noticed many earthworms in soil. Earthworms support terrestrial ecosystems both as prey and by aerating and enriching soil.

Figure 9.9

Leeches are parasitic worms. Notice the presence of segments.

Features of Segmented Worms

Segmented worms have a number of characteristic features.

1. The basic form consists of multiple segments, each of which has the same sets of organs and, in most a pair of **parapodia** that many species use for locomotion.
2. Segmented worms have a well-developed body cavity filled with fluid. This fluid-filled cavity serves as a **hydroskeleton** , a supportive structure that helps move the worm's muscles.
3. Segmented worms also tend to have organ systems that are more developed than the roundworms' or flatworms'. Earthworms, for example, have a complete digestive tract with two openings, as well as an esophagus and intestines. The circulatory system consists of paired hearts and blood vessels. Actually there are five pairs of hearts that pump blood along the two main vessels. And the nervous system consists of the brain and a ventral nerve cord.

Comparison of Worms

The following table compares the three worm phyla (**Table** below).

Phylum	Common Name	Body Cavity	Segmented	Digestive System	Example
Platyhelminthes	Flatworm	No	No	Incomplete	Tapeworm
Nematoda	Roundworm	Yes	No	Complete	Heartworm
Annelida	Segmented worm	Yes	Yes	Complete	Earthworm

Summary

- Segmented worms include the common earthworm and leeches.
- Segmented worms have a digestive system, nervous system, and circulatory system.

Explore More

Use the resources below to answer the questions that follow.

Explore More I

- **Annelids: Powerful and Capable Worms** at http://vimeo.com/37255842 (13:38)

Click on the image above for more content

1. What new realms did animals like *Abarenicola* open up for other animals?
2. Where are the eyes of feather duster worms (*Sabellidae*) located?
3. What effect do tube dwelling worms have on mudflat ecosystems?
4. How much can a giant tube dwelling worm from a hydrothermal vent grow in a year?
5. How do earthworms help breakdown leaf litter?

Review

1. What features distinguish Phylum Annelida from the other worms?
2. Describe the skeletal system of the segmented worms.
3. Describe the circulatory system and nervous system of the earthworm.

Section 7

Mollusks

Mollusks

- •Define mollusk.
- •Discuss characteristics of mollusks.
- •Describe the mantle and radula.

What does this snail have in common with a clam?

You might notice that both have a shell. That is one feature of the group they both belong to, the mollusks. Mollusks are a very diverse group. They include animals that live on land and in the ocean. With well over 100,000 species, there can be a lot of shells.

What are Mollusks?

When you take a walk along a beach, what do you find there? Sand, the ocean, lots of sunlight. You may also find shells. The shells you find are most likely left by organisms in the phylum *Mollusca* . On the beach, you can find the shells of many different mollusks (**Figure** below), including clams, mussels, scallops, oysters, and snails. **Mollusks** are invertebrates that usually have a hard shell, a mantle, and a radula. Their glossy pearls, mother of pearl, and abalone shells are like pieces of jewelry. Some mollusks, such as squid and octopus, do not have shells.

Figure 9.10

On the beach, you can find a wide variety of mollusk shells.

Features of the Mollusk

The Mollusk's body is often divided into different parts (**Figure** below):

1.A head with eyes or tentacles.
2.In most species, a muscular foot, which helps the mollusk move. Some mollusks use the foot for burrowing into the sand, and others use it for jet-propulsion.
3.A **mantle** , or fold of the outer skin lining the shell. The mantle often releases calcium carbonate, which creates an external shell, just like the ones you find on the beach. The shell is also made of **chitin** , a tough, semitransparent substance.
4.A mass housing the organs.
5.A complete digestive tract that begins at the mouth and runs to the anus.
6.Most ocean mollusks have a gill or gills to absorb oxygen from the water.
7.Many species have a feeding structure, the **radula** , found only in mollusks. The radula can be thought of as a "tongue-like" structure. The radula is made mostly of chitin. Types of radulae range from structures used to scrape algae off of rocks to the beaks of squid and octopuses.

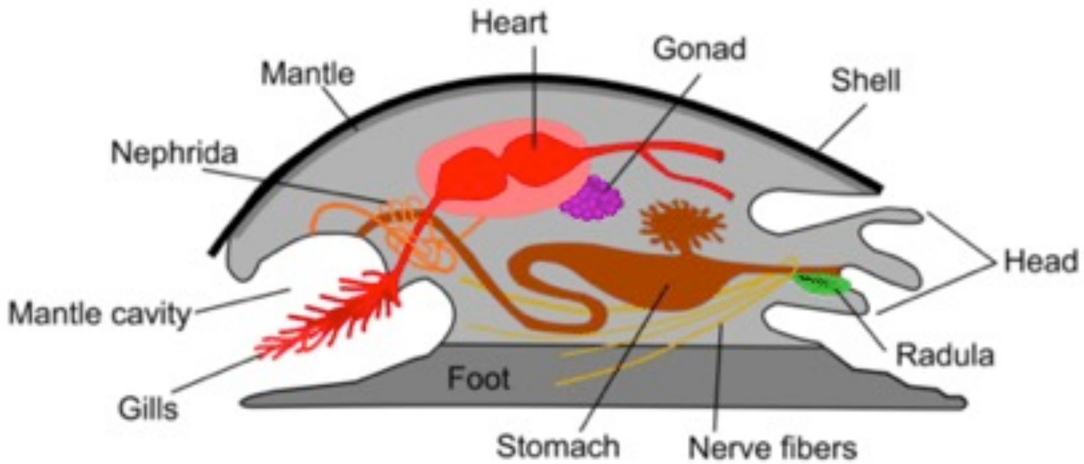


Figure 9.11

This is the basic body plan of a mollusk. Note the mantle, gills, and radula. Keep in mind the basic body plan can differ slightly among the mollusks.

Evolution of Mollusks

Mollusks are probably most closely related to organisms in the phylum *Annelida* , also known as segmented worms. This phylum includes the earthworm and leech. Scientists believe these two groups are related because, when they are in the early stage of development, they look very similar. Unlike segmented worms, however, mollusks do not have body segmentation. The basic mollusk body shape is usually quite different as well.

Summary

- The mollusk body often has a head with tentacles, a muscular foot, a feeding organ called the radula, and a complete digestive tract.
- Mollusks have a mantle, which often secretes an external shell.
- Mollusks are most closely related to segmented worms.

Explore More

Use the resource below to answer the questions that follow.

- **Molluscs: The Survival Game** at http://vimeo.com/37325960 (15:08)

Click on the image above for more content

1. How does the shell of the leafy hornmouth (*Ceratostoma foliatum*) help it against crushing predators?
2. For what purpose do cockles use their foot?
3. How and why do the radula of different mollusks vary?
4. For what purpose has the nautilus adapted its foot?
5. What change in predatory fish behavior seems to have led to a squid body plan being advantageous over a nautiliod body plan?

Review

1. What is a mollusk?
2. Give three examples of mollusks.
3. Describe three main characteristics of mollusks?
4. What evidence shows that mollusks and segmented worms are related? How are they different?

Section 8

Types of Mollusks

Types of Mollusks

- •Describe the different types of mollusks.
- •Distinguish gastropods from bivalves and from cephalopods.

What's the world's largest mollusk?

The colossal squid, one of the largest invertebrates, measures 14 feet in length here. Some of these squids are even larger and can grow up to almost 50 feet long! The smallest mollusks are snails that are microscopic in size.

Types of Mollusks

There are approximately 160,000 living species and probably 70,000 extinct species of mollusks. They are typically divided into ten classes, of which two are extinct. The major classes of living mollusks include gastropods, bivalves, and cephalopods (**Figure** below).

Gastropods

Gastropods include snails and slugs. They use their foot to crawl. They have a well-developed head. There are many thousands of species of sea snails and sea slugs, as well as freshwater snails, freshwater limpets, land snails and land slugs. Gastropods live in many diverse habitats, from gardens to deserts and mountains. They also live in rivers, lakes and the ocean. Most shelled gastropods have a one-piece shell that is typically coiled or spiraled. Gastropods have no sense of hearing, but they can see and have a keen sense of smell. In land-based gastropods, the olfactory organs (for smell) are the most important. These are located on the tentacles.

Bivalves

Bivalves include clams, scallops, oysters, and mussels. As their name implies, they have two parts of their shell, which can open and close. Bivalves live in both marine and freshwater habitats. Most bivalves have a pair of large gills that enable them to extract oxygen from the water (to breathe) and to capture food. Water is drawn into the bivalve and washes over the gills. Mucus on the gills helps capture food and cilia transfer the food particles to the mouth. Once in the mouth, food passes into the stomach to be digested. Bivalves have a mouth, heart, intestine, gills, and stomach, but no head. Bivalves have a muscular foot, which in many species such as clams, is used to anchor their body to a surface or dig down into the sand.

Cephalopods

Cephalopods include the octopus and squid. They have a prominent head and a well-developed brain. Typically the foot has been modified into a set of arms or tentacles. Members of this class can change color. They can also change texture and body shape, and, and if those camouflage techniques don't work, they can still "disappear" in a cloud of ink. Cephalopods have three hearts that pump blue blood, they're jet powered, and they're found in all oceans of the world. Cephalopods are thought to be the most intelligent of invertebrates. They have eyes and other senses that rival those of humans.

Figure 9.12

(left) An example of a gastropod species, the ostrich foot. (right) A Caribbean reef squid, an example of a cephalopod.

Summary

- •Mollusks are divided into ten living classes, including the familiar gastropods, cephalopods, and bivalves.
- •Mollusks live in marine and freshwater habitats, as well as on land.

Explore More

Use the resources below to answer the questions that follow.

- •**Mollusk Animation: Abalone Body Plan** at http://vimeo.com/42588195 (1:22)

Click on the image above for more content

- •**Mollusk Animation: Nautilus Body Plan** at http://vimeo.com/42588196 (2:35)

Click on the image above for more content

•**Mollusk Animation: Squid Body Plan** at http://vimeo.com/37431310 (1:34)

Click on the image above for more content

1. How does the foot compare between abalone, nautilus, and a squid?
2. How does the shell of an abalone differ from the shell of a nautilus?
3. How many hearts does a squid have? How do these hearts help the squid?
4. Describe the mantle of a squid.

Review

1. Name five examples of mollusks.
2. What habitats do gastropods live in?
3. What is the defining feature of a bivalve?
4. What mollusk is through to be very intelligent?
5. Describe the foot of a gastropod, bivalve, and cephalopod.

Section 9

Importance of Mollusks

Importance of Mollusks

- •Explain why mollusks are important to humans.
- •Describe the use of mollusks as food.
- •Define pearl.
- •Discuss the use of mollusks for scientific studies.

Where do pearls come from?

Pearls are highly valued as gemstones. Most gemstones come from the Earth, but pearls come from living things. They are created by mollusks, such as oysters.

Importance of Mollusks

Mollusks are important in a variety of ways; they are used as food, for decoration, in jewelry, and in scientific studies. They are even used as roadbed material and in vitamin supplements.

Mollusks as Food

Edible species of mollusks include numerous species of clams, mussels, oysters, scallops, marine and land snails, squid, and octopuses. Many species of mollusks, such as **oysters** , are farmed in order to produce more than could be found in the wild (**Figure** below).

Figure 9.13

An oyster harvest in France.

Today, fisheries in Europe, Japan, and the US alone produce over 1 billion pounds of oyster meat each year. Abalone (a marine gastropod mollusk), a great delicacy, can fetch up to three hundred dollars per pound. Eating mollusks is associated with a risk of food poisoning from toxins that accumulate in molluscs under certain conditions, and many countries have regulations to reduce this risk. At certain times of the year, (usually the warmer months) many species of saltwater mollusks become very poisonous due to an algal bloom known as "red tide." The mollusks filter feed on the tiny creatures (called "dinoflagellates" in the bloom) that produce the toxins. Eating shellfish during a red tide can cause serious illness and even death to humans.

Tastes in molluscan food vary tremendously from one person to the next and from culture to culture; however, when it comes to a question of survival, most mollusks are edible. Some are considered delicacies such as oysters and escargot while others such as the clams and mussels of freshwater ponds and streams are less likely to be consumed due to taste, but none-the-less are very edible. Land-based mollusks are also eaten. France alone consumes 5 million pounds of escargot (a snail that lives in trees) every year. Of course, some people are allergic to mollusks and need to be careful about consuming any kind of shelled animals.

Mollusks in Decoration and Jewelry

Two natural products of mollusks used for decorations and jewelry are pearls and nacre. A **pearl** is the hard, round object produced within the mantle of a living shelled mollusk. Pearls are produced by many bivalves when a tiny particle of sand or grit is trapped between the mantle and the shell. It's as if the mollusk has a splinter. The mollusk forms a protective covering around the irritant. Most pearls used as jewelry are made by pearl oysters and freshwater mussels; most of the ones sold are cultured and not wild. Natural pearls have been highly valued as gemstones and objects of beauty for many centuries. The most desirable pearls are produced by oysters and river mussels. The substance used to form the pearl covering, is made from the mother of pearl material that lines the interior of the shell.

Mother of pearl is also known as nacre. **Nacre** is the iridescent inner shell layer. It can be found in buttons, watch faces, knives, guns, and jewelry. It is also used to decorate various musical instruments.

Mollusks in Scientific Studies

Several mollusks are ideal subjects for scientific investigation of the nervous system. The giant squid has a sophisticated nervous system and a complex brain for study. The California sea slug, also called the California sea hare, is used in studies of learning and memory because it has a simple nervous system, consisting of just a few thousand large, easily identified neurons. These **neurons** are responsible for a variety of learning tasks. Some slug brain studies have even allowed scientists to better understand human brains. Some octopuses and squid are incredibly smart. They are capable of learning to solve problems and do mazes.

Summary

- Some mollusks, such as oysters and scallops, are important food sources.

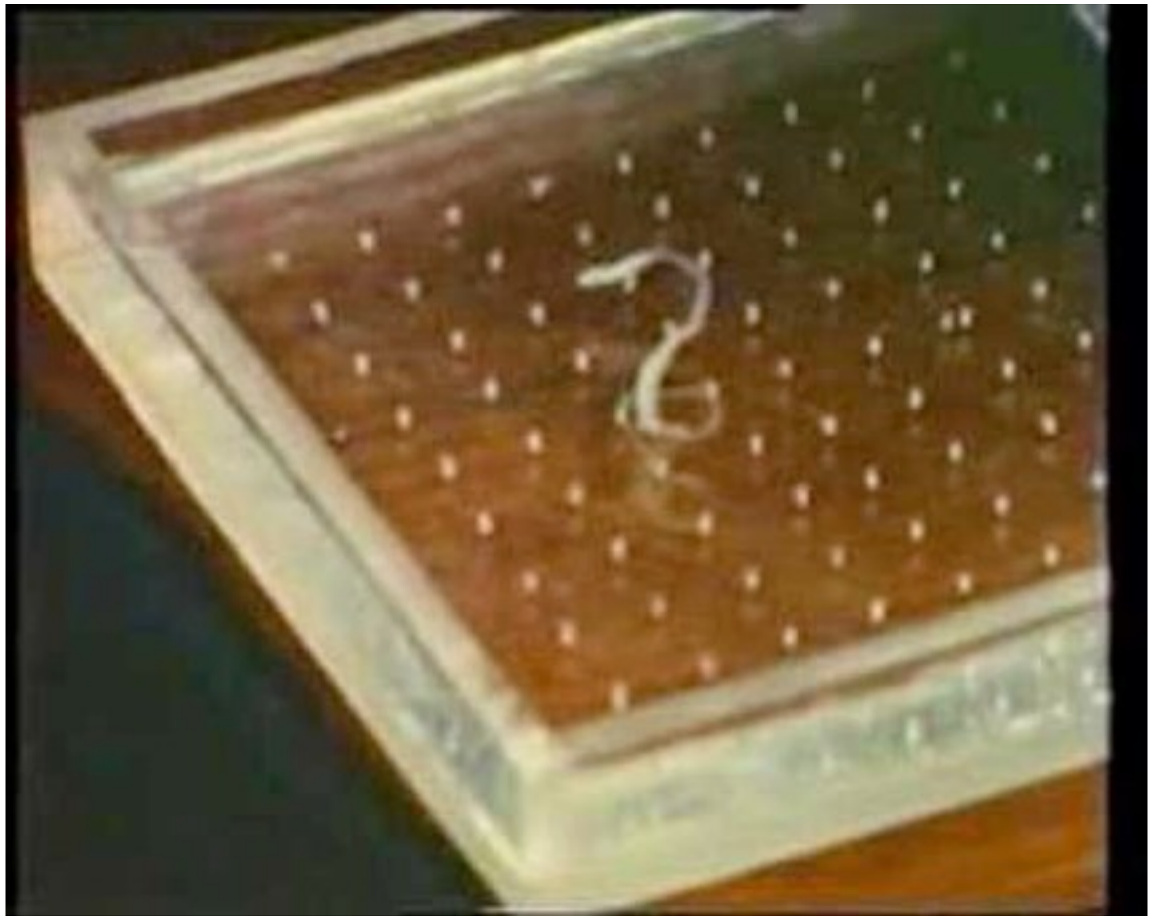
- Mollusks are used for decoration and are important in scientific studies.

Explore More

Use the resources below to answer the questions that follow.

Explore More I

- **The Squids Giant Axons** at http://www.youtube.com/watch?v=omXS1bjYLMI (4:49)



Click on the image above for more content

1. What large tubular structures did Professor Young find in squids?
2. Why were the size of these structures important to Professor Young's work?
3. What did scientists discover when they were able to empty the contents of a squid axon?
4. How did World War II help the study of neuron functioning?

Explore More II

- **How are pearls made?** at http://www.whyzz.com/how-are-pearls-made

1. How are natural pearls made?
2. How are cultured pearls made?

Review

1. Name three mollusks that are used for food.
2. What is a pearl?
3. What mollusks produce pearls? How are they made?
4. What makes the California sea slug ideal for studies of learning and memory?

Section 10

Echinoderms

Echinoderms

- •Give examples of echinoderms.
- •Discuss the major features of echinoderms.
- •Define radial symmetry.
- •Describe the water vascular system.
- •Summarize eating in echinoderms.

What is a sea cucumber?

A sea cucumber is not a vegetable! It is an invertebrate animal found in the ocean. Note the spines on this sea cucumber. The spines are a key feature of echinoderms.

What are Echinoderms?

You're probably familiar with starfish and sand dollars (**Figure** below). They are both **echinoderms** . **Sea urchins** and sea cucumbers are also echinoderms. What's similar between these three organisms? They all have **radial symmetry** . This means that the body is arranged around a central point.

Echinoderms belong to the phylum *Echinodermata* . This phylum includes 7,000 living species. It is the largest animal phylum without freshwater or land-living members.

Figure 9.14

A starfish (*left*) and a keyhole sand dollar (*right*), showing the radial symmetry characteristic of the echinoderms. Starfish are also known as sea stars.

Characteristics of Echinoderms

As mentioned earlier, echinoderms show radial symmetry. Other key echinoderm features include an internal skeleton and spines, as well as a few organs and organ systems. Although echinoderms look like they have a hard exterior, they do not have an external skeleton. Instead, a thin outer skin covers an internal skeleton made of tiny plates and spines. This provides rigid support. Some groups of echinoderms, such as sea urchins (**Figure** below), have spines that protect the organism. Sea cucumbers use these spines to help them move.

Figure 9.15

Another echinoderm, a sea urchin (*Echinus esculentus*), showing its spines.

Echinoderms have a unique **water vascular system** . This network of fluid-filled tubes helps them to breathe, eat, and move. Therefore, they can function without gill slits. Echinoderms also have a very simple digestive system, circulatory system, and nervous system. The digestive system often leads directly from the mouth to the anus. The echinoderms have an open circulatory system, meaning that fluid moves freely in the body cavity. But echinoderms have no heart. The echinoderm nervous system is a **nerve net** , or interconnected neurons with no central brain.

Many echinoderms have amazing powers of regeneration. For example, some sea stars are capable of regenerating lost arms. In some cases, lost arms have been observed to regenerate a second complete sea star! Sea cucumbers often release parts of their internal organs if they perceive danger. The released organs and tissues are then quickly regenerated.

How do Echinoderms Eat?

Feeding strategies vary greatly among the different groups of echinoderms. There's no one food or technique that's shared by all echinoderms. Different eating-methods include:

1. Passive filter-feeders, which are organisms that absorb suspended nutrients from passing water. Some echinoderms use their long arms to capture food particles floating past in the currents.
2. Grazers, such as sea urchins, are organisms that feed on available plants. Sea urchins are omnivorous, eating both plant and animals. The sea urchin mainly feeds on algae on the coral and rocks, along with

decomposing matter such as dead fish, mussels, sponges, and barnacles.

3. Deposit feeders, which are organisms that feed on small pieces of organic matter, usually in the top layer of soil. Sea cucumbers are deposit feeders, living on the ocean floor. They eat the tiny scrap particles that are usually abundant in the environments that they inhabit.
4. Active hunters, which are organisms that actively hunt their prey. Many sea stars are predators, feeding on mollusks like clams by prying apart their shells and actually placing their stomach inside the mollusk shell to digest the meat.

How do Echinoderms Reproduce?

Echinoderms reproduce sexually. In most echinoderms, eggs and sperm cells are released into open water, and fertilization takes place when the eggs and sperm meet. This is called external fertilization. The release of sperm and eggs often occurs when organisms are in the same place at the same time. Internal fertilization takes place in only a few species. Some species even take care of their offspring, like parents!

Summary

- Echinoderms show radial symmetry and have an endoskeleton and a unique water vascular system. Some have spines.
- Echinoderms generally reproduce by external fertilization; regeneration is fairly common among echinoderms.

Explore More

Use the resource below to answer the questions that follow.

- **Echinoderms: The Ultimate Animal** at http://vimeo.com/37295088 (13:54)

Click on the image above for more content

1. What can sea star muscles do that our muscles cannot? How would this trait help sea stars living in the intertidal zone?
2. How are deep-sea sea cucumbers like earthworms?
3. Why are brittle stars often found with their arms raised in the water current?
4. What organ system do echinoderms possess that is not seen in any other animal group?
5. Where do sea stars have their "eyes"? How does this arrangement help them coordinate movement?
6. Some sea stars evert their stomachs to digest their prey, but *Pycnopodia* can do something else as well. What does *Pycnopodia* do to some of its prey?

Review

1. List three examples of echinoderms.
2. What is radial symmetry?

3. What are two important characteristics of echinoderms (other than radial symmetry)?
4. How do sea urchins eat?
5. Give an example of an echinoderm that is an active hunter.

Section 11

Types of Echinoderms

Types of Echinoderms

- List several types of echinoderms.
- Describe echinoderm movement.

How can you find feathers in the ocean?

Birds aren't the only creatures that have feathers. One type of echinoderm, the feather star, has feathery arms. These animals don't fly or even move much at all. They usually cling to rocks, using a root-like structure.

Types of Echinoderms

The echinoderms can be divided into two major groups:

1. Eleutherozoa are the echinoderms that can move. This group includes the starfish and most other echinoderms.
2. Pelmatozoa are the immobile echinoderms. This group includes **crinoids** , such as the **feather stars** .

Listed below are the four main classes of echinoderms present in the Eleutherozoa Group (**Table** below).

Class	Representative Organisms	Characteristics
Asteroidea	Starfish and asteroids	Capture prey for their own food
Ophiuroidea	Brittle stars (**Figure** below)	Bottom feeders with long, narrow arms that allow relatively fast movement
Echinoidea	Sea urchins and sand dollars	Have movable spines
Holothuroidea	Sea cucumbers	Armless, elongated, generally soft-bodied animals

Figure 9.16

The giant red brittle star, an ophiuroid echinoderm.

Habitat

Echinoderms are spread all over the world at almost all depths, latitudes, and environments in the ocean. Most feather stars (crinoids) live in shallow water. In the deep ocean, sea cucumbers are common, sometimes making up 90% of the organisms. Most echinoderms, however, are found in reefs just lying beneath the surface of the water. No echinoderms are found in freshwater habitats or on land. This makes *Echinodermata* the largest animal phylum to only have ocean-based species.

Do Echinoderms Move?

While almost all echinoderms live on the sea floor, some sea-lilies can swim at great speeds for brief periods of time, and a few sea cucumbers are fully floating. Some echinoderms find other ways of moving. For example, crinoids attach themselves to floating logs, and some sea cucumbers move by attaching to the sides of fish.

On the underside side of a sea star, there are hundreds of tiny feet usually arranged into several rows on each ray of the star. These are called tube feet, or podia, and are filled with seawater in most echinoderms. The water vascular system within the body of the animal is also filled with seawater. By expanding and contracting chambers within the water vascular system, the echinoderm can force water into certain tube feet to extend them. The animal has muscles in the tube feet, which are used to retract them. By expanding and retracting the right tube feet in the proper order, the animal can walk.

Summary

- Echinoderms include the star fish, sea urchins, sand dollars, and feather stars.
- Echinoderms are found in many different ocean environments, but most are found in reefs.

Explore More

Use the resources below to answer the questions that follow.

Explore More I

•**Feather Stars and Sea Lilies** at http://www.youtube.com/watch?v=IFWeqDcAYGk (1:49)

Click on the image above for more content

1.What is the difference between sea lilies and feather stars?
2.Some crinoids can be seen at night in shallow tropical waters, but where have they been found to be most abundant?

Explore More II

•**Brittle Star Food Fight** at http://www.youtube.com/watch?v=Myhp8ifW6ig (1:59)

Click on the image above for more content

1.What kind of feeding behavior are these brittle stars displaying?
2.How is this feeding behavior related to the ecosystem in which they live?

Explore More III

•**The Sand Dollar** at http://www.youtube.com/watch?v=O3uKWy5VIjs (4:16)

Click on the image above for more content

1. Where is a sand dollar's mouth located?
2. How do the sand dollars in this video feed? What are they eating?

Practice IV

- **Sea cucumbers** at National Geographic http://animals.nationalgeographic.com/animals/invertebrates/sea-cucumber/

1. Where do sea cucumbers live?
2. How do sea cucumbers eat?

Review

1. Name four examples of echinoderms.
2. Where are most echinoderms found?
3. Describe the land-based echinoderms.
4. How do sea stars move?

Section 12

Importance of Echinoderms

Importance of Echinoderms

- •Describe the role of echinoderms in their ecosystems.
- •Explain how echinoderms are important to humans.

What do sea otters eat?

Sea otters are known for being playful and frisky. They are serious eaters, however! A major part of a sea otter's diet are echinoderms, such as sea urchins. They manage to eat the soft part of the sea urchins while avoiding the huge sea urchin spines.

Importance of Echinoderms

Echinoderms are important for the ecosystem. They are also a source of food and medicine for humans.

Ecological Role

Echinoderms play numerous ecological roles. Sand dollars and sea cucumbers burrow into the sand, providing more oxygen at greater depths of the sea floor. This allows more organisms to live there. In addition, starfish prevent the growth of algae on coral reefs. This allows the coral to filter-feed more easily. And many sea cucumbers provide a habitat for parasites such as crabs, worms, and snails.

Echinoderms are also an important step in the ocean food chain. Echinoderms are the staple diet of many animals, including the sea otter. On the other hand, echinoderms eat seaweed and keep its growth in check. Recall that the sea urchin is a grazer, mainly feeding on algae on the coral and rocks. Recently, some marine ecosystems have been overrun by seaweed. Excess seaweed can destroy entire reefs. Scientists believe that the extinction of large quantities of echinoderms has caused this destruction (**Figure** below).

Figure 9.17

A large die-off of the sea urchin, *Diadema antillarum* , in the Caribbean Sea coincided with increases in algal growth in some areas but not others.

Echinoderms as Food

In some countries, echinoderms are considered delicacies. Around 50,000 tons of sea urchins are captured each year for food. They are consumed mostly in Japan, Peru, Spain and France. Both male and female gonads of sea urchins are also consumed. The taste is described as soft and melting, like a mixture of seafood and fruit. Sea cucumbers are considered a delicacy in some southeastern Asian countries. In China they are used as a basis for gelatinous soups and stews.

Echinoderms as Medicine

Echinoderms are also used as medicine and in scientific research. For example, some sea cucumber toxins slow down the growth rate of tumor cells, so there is an interest in using these in cancer research.

Sea urchins are also model organisms used in developmental biology research. Sea urchins have been used to study the mechanisms of fertilization and egg activation, physiological processes that occur during early development, and the regulation of differentiation in the early embryo. In addition, the molecular basis of early development was studied in sea urchins. Gametes can be obtained easily, sterility is not required, and the eggs and early embryos of many commonly used species are beautifully transparent. In addition, the early development of sea urchin embryos is a highly conserved process. When a batch of eggs is fertilized, all of the resulting embryos typically develop at the same time. This makes biochemical and molecular studies of early embryos possible in the sea urchin, and has led to a number of major discoveries.

Echinoderms in Farming

The hard skeleton of echinoderms is used as a source of lime by farmers in some areas where limestone is unavailable. **Lime** is added to the soil to allow plants to take up more nutrients. About 4,000 tons of the animals are used each year for this purpose.

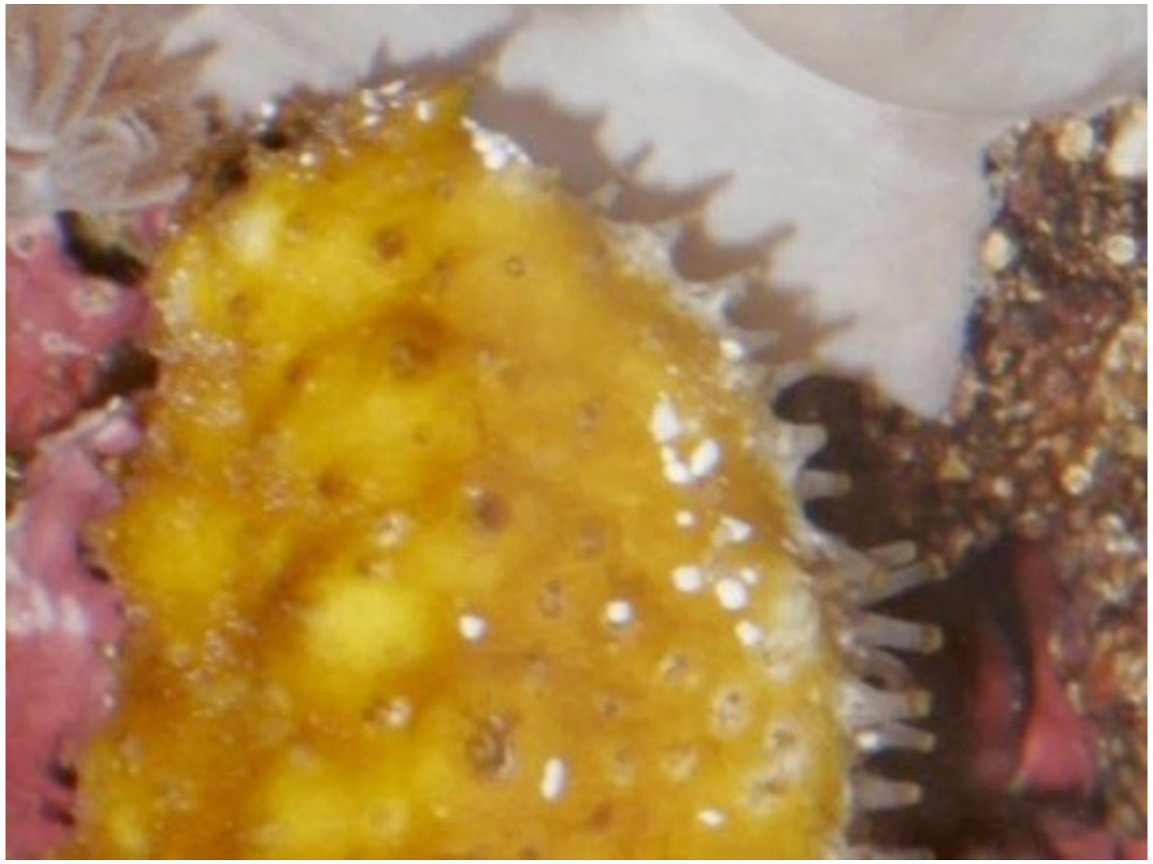
Summary

- Echinoderms are an important part of the ocean food chain, keeping seaweed in check as grazers and serving as food sources for animals like otters.
- Echinoderms are used as food, medicine, and a source of lime for farmers.

Explore More

Use the resource below to answer the questions that follow.

- **Smart Polymer Inspired by Sea Cucumbers** at http://www.youtube.com/watch?v=tZ2HZVxsZ5U (0:59)



Click on the image above for more content

1. What characteristics of the sea cucumbers inspired scientists to use them to develop new polymers?
2. Why do scientists feel these new polymers may be useful for medical implants?

Review

1. How are sand dollars important to the ecosystem?
2. What role do echinoderms play in the food chain?
3. How has the sea urchin been used in research?

Section 13

Arthropods

Arthropods

- •Give examples of arthropods.
- •Describe the characteristics of the arthropods.
- •Describe adaptations of land-living arthropods.

What does this lobster have in common with a wasp?

You might notice that their bodies have segments. And they both have a hard outer layer. Because they share these and other features, they are both classified as arthropods.

What are Arthropods?

How often do you think you see an arthropod? Well, have you ever looked up close at an ant? A spider? A fly? A moth? With over a million described species (and many more yet to be described) in the phylum containing arthropods, chances are, you encounter one of these organisms every day, without even leaving your house. Arthropods are a very diverse group of animals. In fact, they are the biggest group of animals on the planet, with upwards of 5 million distinct species.

Types of Arthropods

Arthropods belong to the phylum Arthropoda, which means "jointed feet," and includes four living subphyla.

- •Chelicerata, which includes spiders (**Figure** below), mites, and scorpions. In these animals, the first pair of appendages are often modified as fangs or pincers, and are used to manipulate food.
- •Myriapoda, which includes centipedes and millipedes. All of these animals live on land, and can have anywhere from ten to nearly 200 pairs of appendages.
- •Hexapoda, which includes the insects. These animals dominate the land. All hexapods have three pairs of walking appendages.
- •Crustacea, which includes lobsters, crabs, barnacles, crayfish, and shrimp. These animals dominate the ocean, and usually have a set of anterior appendages that are modified as mandibles, which function in grasping, biting, and chewing food.

Figure 9.18

Spiders are one type of arthropod.

Characteristics of Arthropods

Characteristics of arthropods include:

1. A segmented body (**Figure** below) with a head, a thorax, and abdomen segments.
2. Appendages on at least one segment. They can be used for feeding, sensory reception, defense, and locomotion.
3. A nervous system.
4. A hard exoskeleton made of chitin, which gives them physical protection and resistance to drying out. In order to grow, arthropods shed this covering in a process called **molting** .
5. An open circulatory system with **hemolymph** , a blood-like fluid. A series of hearts move the hemolymph into the body cavity where it comes in direct contact with the tissues.
6. A complete digestive system with a mouth and an anus.
7. Aquatic arthropods use gills to exchange gases. These gills have a large surface area in contact with the water, so they can absorb more oxygen.
8. Land-living arthropods have internal surfaces that help exchange gasses. Insects and most other terrestrial species have a tracheal system, where air sacs lead into the body from pores in the exoskeleton. Others use book lungs, gills modified for breathing air, as seen in species like the coconut crab. Some areas of the legs of soldier crabs are covered with an oxygen absorbing skin. Land crabs sometimes have two different structures: one used for breathing underwater, and another used to absorb oxygen from the air.

Figure 9.19

The blue American lobster illustrates the segmented body plan of the arthropods.

Summary

- The arthropods include four living subphyla: chelicerates, including spiders, mites, and scorpions; myriapods, including centipedes and millipedes; hexapods, including insects; and crustaceans.
- Arthropods are characterized by a segmented body, a hard exoskeleton, and appendages used for feeding, sensory structures, defense, and locomotion.

Explore More

Use the resources below to answer the questions that follow.

Explore More I

- **Marine Arthropods: A Successful Design** at http://vimeo.com/37289745 (9:28)

Click on the image above for more content

1. Why are jointed limbs significant for Arthropods?
2. How are appendage adaptations and segmentations key to the success of Arthropods as a group?
3. Soft shell crabs are delicacies in some restaurants. Where do soft shell crabs come from?
4. What aspect of horseshoe crabs' behavior do scientists feel gives clues to why Arthropods first left the ocean?

Explore More II

- **Arthropod** at http://animal.discovery.com/animal-facts/arthropod-info.htm

1. What are five examples of arthropods?
2. How do arthropods affect people? Give three examples.

Review

1. What are three examples of arthropods?
2. What are three distinguishing features of the arthropods?
3. Describe the arthropod circulatory system.
4. Describe how insects obtain oxygen.

Section 14

Crustaceans

Crustaceans

- •Define crustacean.
- •Give examples of crustaceans.
- •Describe the features of crustaceans.

What are shrimp?

Shrimp are an example of crustaceans, one group within the arthropods. Shrimp live on the ocean floor in many parts of the world. Shrimp are not only food for humans; they are also an important food source for larger marine animals.

Crustaceans

Crustaceans are a large group of arthropods, consisting of almost 52,000 species. The majority of crustaceans are aquatic. Some live in the ocean, while others live in fresh water. A few groups have adapted to living on land, such as land crabs, hermit crabs, and woodlice (**Figure** below). Crustaceans are among the most successful animals and are found as much in the oceans as insects are on land.

Figure 9.20

A terrestrial arthropod, a species of woodlice.

Classes of Crustaceans

Six classes of crustaceans are generally recognized (**Table** below).

Class	Characteristics	Examples
Branchiopoda	Mostly small, freshwater animals that feed on plankton and detritus	Brine shrimp
Remipedia	A small class of blind organisms found in deep caves connected to salt water	Nectiopoda
Cephalocarida	Small crustaceans, with an eyeless head covered by a horseshoe-shaped shield; has two pairs of antennae and two pairs of jaws	Horseshoe shrimp
Maxillopoda	Mostly small, with a small abdomen, and generally no appendages	Barnacles, copepods
Ostracoda	Small animals with bivalve shells	Seed shrimp
Malacostraca	The largest class, with the largest and most familiar animals	Crabs, lobsters, shrimp, krill, woodlice

Can Crustaceans Move?

Remember that crustaceans are an arthropod subphylum, and that arthropod means "jointed feet." As expected, the majority of crustaceans can move. A few groups are parasitic and live attached to their hosts. Adult barnacles (**Figure** below) cannot move, so they attach themselves headfirst to a rock or log.

Figure 9.21

Barnacles are non-moving crustaceans.

Characteristics of Crustaceans

Characteristics of crustaceans include:

1. An exoskeleton that may be bound together, such as in the **carapace** , the thick back shield seen in many crustaceans that often forms a protective space for the gills.
2. A main body cavity with an expanded circulatory system. Blood is pumped by a heart located near the back.

3. A digestive system consisting of a straight tube that has a **gastric mill** for grinding food and a pair of digestive glands that absorb food.
4. Structures that function like kidneys to remove wastes. These are located near the antennae.
5. A brain that exists in the form of **ganglia** , or connections between nerve cells.
6. Crustaceans periodically shed the outer skeleton, grow rapidly for a short time, and then form another hard skeleton. They cannot grow underneath their outer exoskeleton.

Crustaceans Reproduction

Most crustaceans have separate sexes, so they reproduce sexually using eggs and sperm. Many land crustaceans, such as the Christmas Island red crab, mate every season and return to the sea to release the eggs. Others, such as woodlice, lay their eggs on land when the environment is damp. In some crustaceans, the females keep the eggs until they hatch into free-swimming larvae.

Summary

- Crustaceans include crabs, lobsters, shrimp, krill, and woodlice.
- Features of crustaceans include an exoskeleton that may be bound together.

Explore More

Use the resource below to answer the questions that follow.

- http://www.darwinsgalapagos.com/animals/custacea_crustaceans.htm

1. How do some crustaceans strengthen their exoskeleton?
2. How many antennae do crustaceans have? How does this differ from a butterfly?
3. How does filter feeding among crustaceans differ from filter feeding among mollusks?
4. Why do scientists feel filter feeding evolved multiple times among crustaceans?
5. What are three functions of appendages in the crustacean?

Review

1. What are three examples of crustaceans?
2. What are two characteristics of crustaceans?
3. Why do crustaceans shed their outer skeleton.
4. What is the carapace?

Section 15

Centipedes and Millipedes

Centipedes and Millipedes

- •Distinguish centipedes from millipedes.
- •Describe the habitat of Myriapoda.

How many legs does a centipede have?

You might think that centipedes have a hundred legs. But many species of centipedes don't have quite that many legs! The common house centipide has only 15 pairs of legs.

Centipededs and Millipedes

Centipedes and **millipedes** belong to the subphylum Myriapoda, which contains 13,000 species. They all live on land. The Myriapoda are divided among four classes: (1) Chilopoda (centipedes), (2) Diplopoda (millipedes), (3) Symphyla (symphylans), and (4) Pauropoda (pauropods). They range from having over 750 legs to having fewer than ten legs. They have a single pair of antennae and simple eyes.

Habitat

Myriapoda are mostly found in moist forests, where they help to break down decaying plant material. A few live in grasslands, semi-arid habitats, or even deserts. The majority are herbivores, but centipedes are nighttime predators. They roam around looking for small animals to bite and eat; their prey includes insects, spiders, and other small invertebrates. If the centipede is large enough, it will even attack small vertebrates, like lizards. Although not generally considered dangerous to humans, many from this group can cause temporary blistering and discoloration of the skin.

Centipedes

Centipedes (**Figure** below) are fast, predatory carnivores, and venomous. There are around 3,300 described species, ranging from one tiny species (less than half an inch in length) to one giant species (the Peruvian giant yellow-leg centipede or Amazonian giant centipede), which may grow larger than 12 inches. This giant centipede has been known to attack, kill and eat much larger animals, including tarantulas. Centipedes have one pair of legs per body segment, with the first pair of legs behind the head modified into a pair of fangs containing a poison gland. Many centipedes also guard their eggs and young by curling around them.

Figure 9.22

Centipede.

Millipedes

Most millipedes are slower than centipedes and feed on leaf litter and loose organic material. They can be distinguished from centipedes by looking at the number of legs per body segment. Millipedes have two pairs of legs per body segment, while centipedes have a single pair of legs per body segment. Millipedes protect their eggs from predators in a nest of hard soil. Millipedes are not poisonous. They lack the pair of fangs containing a poison gland that centipedes have.

Symphyla

The third class, Symphyla, contains 200 species. **Symphylans** resemble centipedes but are smaller and translucent. These arthropods have an elongated body, with three pairs of thoracic and about nine pairs of abdominal legs. Many spend their lives in the soil, but some live in trees.

Pauropods

The **pauropods** are typically 0.5-2.0 mm long and live on all continents except Antarctica. They are usually found in soil, leaf litter, or other moist places. They feed on fungi and decaying organic matter. Adult pauropods have 11 or 12 body segments and 9-11 pairs of legs. They also possess unique forked antennae and a distinctive pattern of movement characterized by rapid burst of movement and frequent abrupt changes in direction. Over 700 species have been described, and they are believed to be closely related to millipedes.

Summary

•Myriapoda are usually found in moist forests, where they break down decaying plant material.
•Millipedes have two pairs of legs per body segment, while centipedes have a single pair of legs per body segment.

Explore More

Use the resources below to answer the questions that follow.

Explore More I

•Centipede at http://www.enchantedlearning.com/subjects/invertebrates/arthropod/Centipede.shtml
1. Where do centipedes live?
2. What and how do centipedes eat?
3. Do centipedes have 100 legs?

Explore More II

•Millipede at http://www.enchantedlearning.com/subjects/invertebrates/arthropod/Millipede.shtml
1. What is the diet of most millipedes?
2. In what kind of habitats are millipedes found?
3. What is interesting about the legs of a newly hatched millipede?

Explore More III

•Arthropod Animation: Millipede Breathing Tubes at http://vimeo.com/37410640

Click on the image above for more content

1. How do millipedes draw air into their body?

Review

1. Where do centipedes and millipedes generally live?
2. List two ways centipedes are different from millipedes.
3. What are the differences between the legs of a centipede and millipede.
4. What are the main food sources of centipedes?

Section 16

Arachnids

Arachnids

•Describe the characteristics of the arachnids.
•Describe the chelicerae and the pedipalps.
•Give examples from the arachnid subgroups.

Is a spider a type of insect?

Although spiders and insects are both arthropods, a spider is not an insect. One key difference is that insects have six legs, while spiders have eight legs.

Arachnids

Arachnids are a class of joint-legged invertebrates in the subphylum Chelicerata. They live mainly on land but are also found in fresh water and in all marine environments, except for the open ocean. There are over 100,000 named species, including many species of spiders, scorpions, daddy-long-legs, ticks, and mites (**Figure** below). There may be up to 600,000 species in total, including unknown ones.

Figure 9.23

(*left*) A daddy-long-legs spider. (*right*) Various diseases are caused by bacteria that are spread to humans by arachnids, like the tick shown here.

Characteristics of Arachnids

Arachnids have the following characteristics:

1.Four pairs of legs (eight total). You can tell the difference between an arachnid and an insect because insects have three pairs of legs (six total).
2.Arachnids also have two additional pairs of appendages. The first pair, the **chelicerae** , serve in feeding and defense. The next pair, the **pedipalps** , help the organisms feed, move, and reproduce.
3.Arachnids do not have antennae or wings.
4.The arachnid body is organized into the **cephalothorax** , a fusion of the head and thorax, and the abdomen.
5.To adapt to living on land, arachnids have internal breathing systems, like a trachea or a book lung.
6.Arachnids are mostly carnivorous, feeding on the pre-digested bodies of insects and other small animals.
7.Several groups are venomous. They release the venom from specialized glands to kill prey or enemies.
8.Several mites are parasitic, and some of those are carriers of disease.
9.Arachnids usually lay eggs, which hatch into immature arachnids that are similar to adults. Scorpions, however, give birth to live young.

Arachnid Subgroups

The arachnids are divided into eleven subgroups. Below are the four most familiar subgroups, with a description of each (**Table** below).

Subgroup	Representative Organisms	Approximate Number of Species	Characteristics
Araneae	Spiders	40,000	•Found all over the world, ranging from tropics to the Arctic, some in extreme environments. •All produce **silk** , which is used for trapping insects in webs, aiding in climbing, producing egg sacs, and wrapping prey. •Nearly all spiders inject venom to protect themselves or to kill prey. Only about 200 species

Summary

- Arachnids have four pairs of legs, specialized appendages, and a fused head and thorax.
- Arachnids include spiders, daddy-long-legs, scorpions, and ticks.

Explore More

Use the resource below to answer the questions that follow.

- **Spiders** at http://www.youtube.com/watch?v=ALsnmm-ghIA (4:03)

Click on the image above for more content

1. How do spiders differ from insects?
2. What are some of the uses of their silk?
3. How do spiders keep from becoming stuck in their own webs?
4. What role do spiders play in their ecosystem?

Review

1. List three types of arachnids.
2. What are two key features of arachnids?
3. Arachnids also have two additional pairs of appendages. Describe these two pairs.
4. List two specific features of spiders.
5. List two specific features of scorpions.

Section 17

Importance of Arthropods

Importance of Arthropods

- •Give examples of arthropods as food.
- •Discuss the roles of arthropods in their ecosystem.
- •Describe the importance of arthropods to humans.

Are arthropods just creepy and scary?

Many arthropods, such as scorpions, insects, and spiders, have a reputation of being a nuisance or even harmful. But even if they are a little scary to you, that doesn't mean that the world would be fine without them.

Importance of Arthropods

Have you ever been startled by a bee landing on a flower? Or surprised by a swarm of pill bugs when you overturned a rock? These arthropods might seem a little scary to you, but they are actually performing important roles in the environment. Arthropods are important to the ecosystem and to humans in many ways.

Arthropods as Food

Many species of crustaceans, especially crabs, lobsters (**Figure** below), shrimp, prawns, and crayfish, are consumed by humans, and are now farmed on a large commercial scale. Nearly 10,000,000 tons of arthropods as food were produced in 2005. Over 70% by weight of all crustaceans caught for consumption are shrimp and prawns. Over 80% is produced in Asia, with China producing nearly half the world's total.

Insects and their grubs are at least as nutritious as meat, and are eaten both raw and cooked in many cultures. Beetles, locusts, butterflies, ants, and stinkbugs (which have an apple flavor) are insects that are regularly eaten by people in dozens of countries. In fact, there are more than 1,900 edible insect species on Earth, hundreds of which are already part of the diet of about two billion people worldwide. This is just under one of every three people worldwide, and this number should continue to grow in the future.

The intentional cultivation of arthropods and other small animals for human food, referred to as minilivestock, is now emerging in animal husbandry as an ecologically sound concept. However, the greatest contribution of arthropods to human food supply is by pollination. Three-fourths of the world's flowering plants and about 35% of the world's food crops depend on animal pollinators to reproduce and increase crop yields. More than 3,500 species of native bees pollinate crops. Some scientists estimate that one out of every three bites of food we eat exists because of animal pollinators, including birds and bats and arthropods like bees, butterflies and moths, and beetles and other insects.

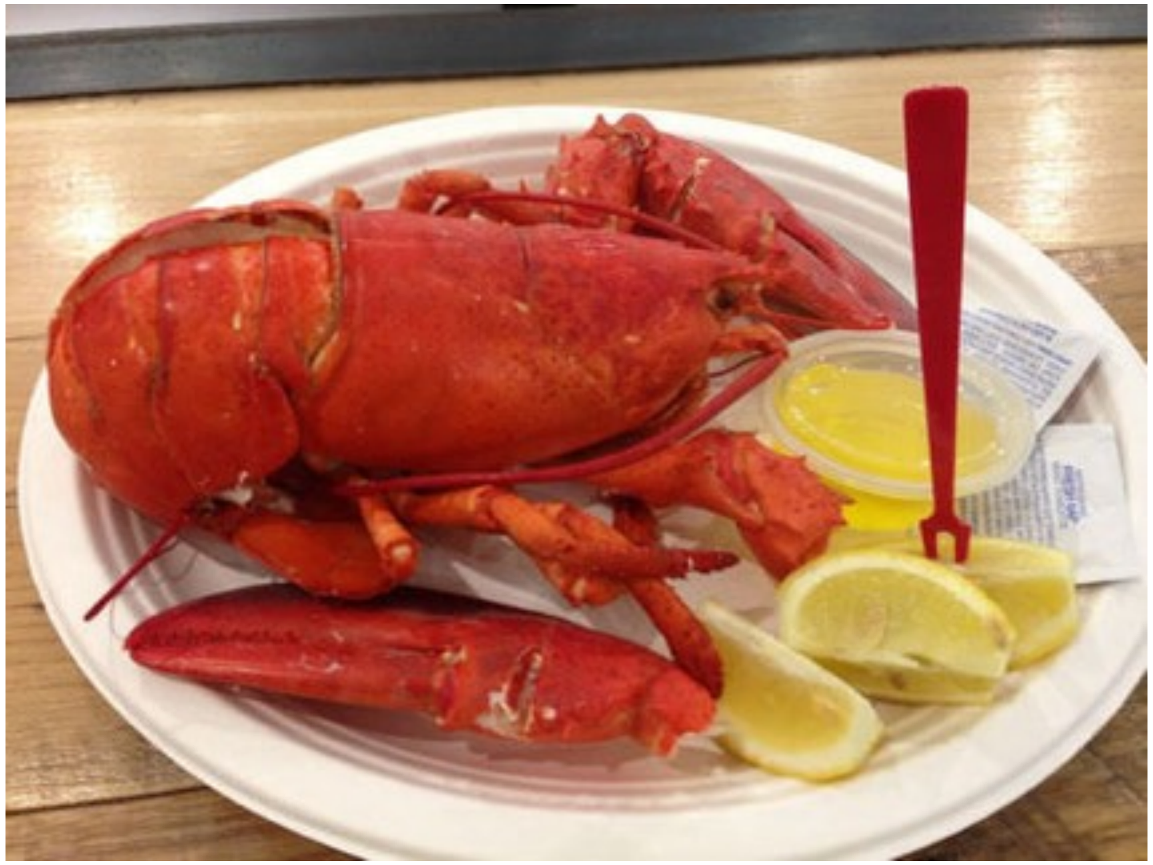


Figure 9.24

Lobsters are one kind of arthropod food source.

Arthropods in Pest Control

Humans use mites to prey on unwanted arthropods on farms or in homes. Other arthropods are used to control weed growth. Populations of whip scorpions added to an environment can limit the populations of cockroaches and crickets. Millipedes also control the harmful growth of destructive fungi and bacteria. When the numbers of millipedes is low, the imbalance between predator and prey can cause harmful microorganisms to flourish, and it can became difficult to manage plagues and diseases through natural processes.

Cockroaches, spiders, mites, ticks and all other insects considered as carnivorous, prey on smaller species to maintain ecological balance. Thus, communities that have a good balance of these arthropods tend to have better pest control.

Ecological Roles

Many arthropods have extremely important roles in ecosystems. Arthropods are of ecological importance because of their sheer numbers and extreme diversity. As mentioned above, bees, wasps, ants, butterflies, moths, flies and beetles are invaluable agents of pollination. Pollens and grains became accidentally attached to their chests and legs and are transferred to other agricultural crops as these animals move about, either by walking or flying. Most plants actually produce scents to send signals to insects that food (in the form of nectar) is available.

Mites, ticks, centipedes, and millipedes are **decomposers** , meaning they break down dead plants and animals and turn them into soil nutrients. This is an important role because it supplies the plants with the minerals and nutrients necessary for life. It also keeps dead material from accumulating in the environment. Plants then pass along those minerals and nutrients to the animals that eat the plants.

Human Uses

Arthropods are also invaluable to humans, as they are used in many different human-made products. Examples are:

- Bees produce honey and their honeycombs contain beeswax, widely used for making candles, furniture wax and polishes, waxed papers, antiseptics, and fillings for surgical uses.
- The pollens stored in honeycombs were discovered to have a rich mixture of vitamins, enzymes, and amino acids that could provide medical benefits. They were used as ingredients for supplements and medications that could provide relief for colds, asthma, and hay fever.
- Silk produced by arthropods, like those produced by caterpillars to protect their cocoons, is strong enough to use and be woven into fabrics, a discovery first used in ancient China's silk industry.
- The spiders' web was discovered as an additional material that could provide strength, and has became essential raw materials for Kevlar vests, fishing nets, surgical sutures, and adhesives, as they contained natural antiseptics.

Summary

- Many crustaceans, especially crabs, lobsters, shrimp, prawns, and crayfish, are food sources for humans.
- Mites, ticks, centipedes, and millipedes are decomposers, meaning they break down dead plants and animals and turn them into soil nutrients.

Explore More

Use the resources below to answer the questions that follow.

Explore More I

- **Arthropod Locomotion: Engineering** at http://vimeo.com/37341942 (7:15)

Click on the image above for more content

1. Why do scientists study the movement of arthropods?
2. What arthropod characteristic(s) have been integrated into the robot, Ariel?
3. What benefits may we see from robots like Ariel?

Explore More II

•**Lobster Mariculture** at http://www.marinebio.net/marinescience/06future/lobsterfarm.htm

1. What is one of the biggest obstacles to raising lobsters?
2. How many eggs will a female lobster produce at one time?
3. What is done with the fourth stage juvenile lobsters? Why?

Review

1. Name three examples of an arthropod used as a food source for humans.
2. Describe one important role that arthropods play in the ecosystem.
3. What is one human use of material produced by an arthropod.

Section 18

Insects

Insects

- •Describe the characteristics of the insects.
- •Summarize the insect head, thorax, and abdomen.
- •Describe insect movement and communication.
- •Explain the meaning of insects as a social animal.
- •Give examples of winged insects.

What animals were the first to evolve wings?

When someone says the word "wing," you probably think of soaring birds. Or maybe chicken wings smothered in hot sauce. But insects were actually the first animals to evolve wings.

What are Insects

Insects, with over a million described species, are the most diverse group of animals on Earth. They may be found in nearly all environments on the planet. No matter where you travel, you will see organisms from this group. Adult insects range in size from a minuscule fairy fly to a 21.9-inch-long stick insect (**Figure** below).

Figure 9.25

A stick insect, showing how well it blends into its environment.

Characteristics of Insects

Characteristics of Insects include:

•Segmented bodies with an **exoskeleton** . The outer layer of the exoskeleton is called the **cuticle** . It is made up of two layers. The outer layer, or **exocuticle** , is thin, waxy, and water-resistant. The inner layer is much thicker. The exocuticle is extremely thin in many soft-bodied insects, such as caterpillars.
•The segments of the body are organized into three distinct but joined units: a head, a thorax, and an abdomen (**Figure** below and **Table** below).

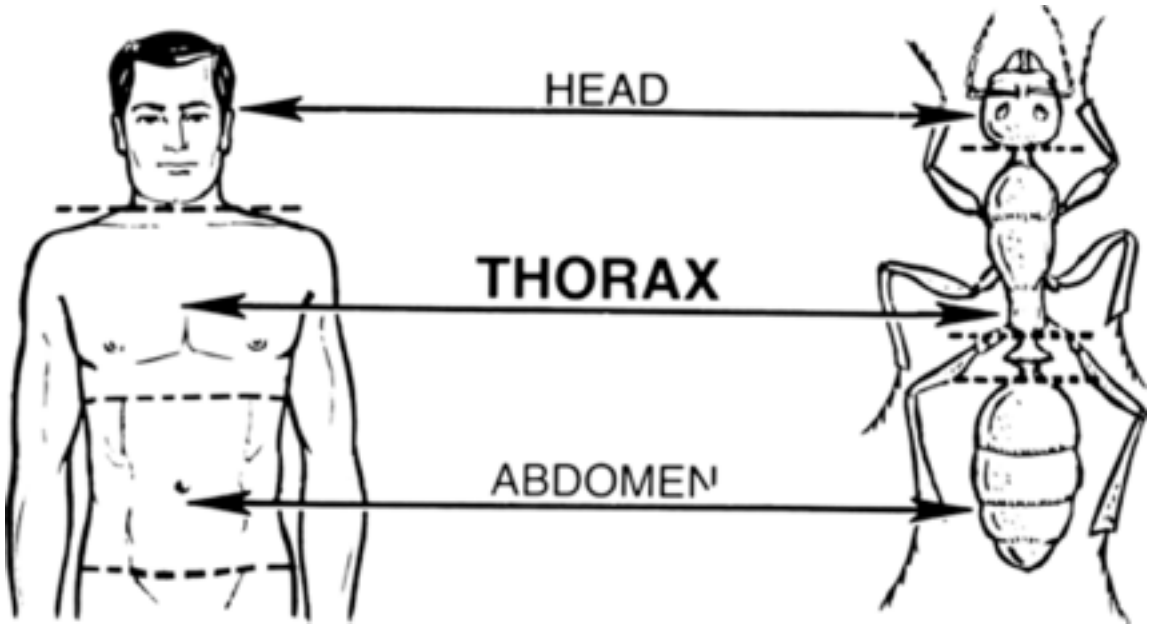


Figure 9.26

A diagram of a human and an insect, comparing the three main body parts: head, thorax, and abdomen.

Structure	Description
Head	A pair of antennae, a pair of compound eyes, and three sets of appendages that form the mouthparts.
Thorax	Six segmented legs and two or four wings.
Abdomen	Contains most of the digestive, respiratory, excretory, and reproductive structures.

•A nervous system that is divided into a brain and a ventral nerve cord.
•Respiration that occurs without lungs. Insects have a system of internal tubes and sacs that oxygen travels through to reach body tissues. Air is taken in through the **spiracles** , openings on the sides of the abdomen.
•A closed digestive system, with one long enclosed coiled tube which runs lengthwise through the body, from the mouth tho the anus.
•A circulatory system that is simple and consists of only a single tube with openings. The tube pulses and circulates blood-like fluids inside the body cavity.
•Various types of movement. Insect movement can include flight, walking, and swimming. Insects were the only invertebrates to develop the ability to fly, and this has played an important role in their success. Many adult insects use six legs for walking, and they walk in alternate triangles touching the ground. This allows the insect to walk quickly while staying stable. A few insects have evolved to walk on the surface of the water, like water striders (**Figure** below). A large number of other insects also live parts of their lives underwater. Water beetles and water bugs have legs adapted to paddle in the water. Young dragonflies use

jet propulsion, sending water out of their back end to move.

Figure 9.27

A water strider utilizing water surface tension to stand on the water.

Communication in Insects

Insects use many different senses for both communicating and receiving information. The types of communication that are used by various insects are summarized below (**Table** below).

Types of Communication	Representative Organisms	Description
Visual		
Bioluminescence	Fireflies	Reproduction and predation: Some species produce flashes to attract mates; other species to attract prey.
Sound Production		
By moving appendages	Cicadas	Loudest sounds among insects; have special muscles to produce sounds.
Ultrasound clicks	Moths	Predation: Produced mostly by moths to warn bats.
Chemical		

Figure 9.28

A yellow-collared scape moth, showing its feathery antennae.

Insects are Social

Social insects, such as termites, ants, and many bees and wasps (**Figure** below), are the most familiar social species. They live together in large, well-organized colonies. Only those insects which live in nests or colonies can home. **Homing** means that an insect can return to a single hole among many other apparently identical holes, even after a long trip or after a long time.

A few insects migrate in groups. For example, the monarch butterfly flies between Mexico and North America each spring and fall (**Figure** below).

Figure 9.29

(*left*) Damage to this nest brings the workers and soldiers of this social insect, the termite, to repair it. (*center*) A wasp building its nest. (*right*) Monarch butterflies in an overwintering cluster.

Two Major Groups of Insects

Insects are divided into two major groups:

1. Wingless: Consists of two orders, the bristle tails and the silverfish.
2. Winged insects: All other orders of insects. They are named below.

Mayflies; dragonflies and damselflies; stoneflies; webspinners; angel insects; earwigs; grasshoppers, crickets, and katydids; stick insects; ice-crawlers and gladiators; cockroaches and termites; mantids; lice; thrips; true bugs, aphids, and cicadas; wasps, bees, and ants;

beetles; twisted-winged parasites; snakeflies; alderflies and dobsonflies; lacewings and antlions; hangingflies (including fleas); true flies; caddisflies; and butterflies, moths, and skippers.

Summary

- Characteristics of insects include segmented bodies, a system of internal tubes and sacs through which oxygen travels, and a simple circulatory system.
- Insects use many types of communication, including bioluminescence, sounds, and phermones.
- Some insects are social and live in groups.

Explore More

Use the resource below to answer the questions that follow.

- **Terrestrial Arthropods: The Conquerors** at http://vimeo.com/37321126 (13:41)

Click on the image above for more content

1. How many times did arthropods invade the land?
2. Describe the rapid underwater movement of the dragonfly larva.
3. What arthropod adaptations led to the class Insecta? Which adaptation do you think was key?
4. Where are insect wings the thickest?
5. How have flowers taken advantage of the complex eyes of insects?
6. How may the type of food available to arthropods when they first left the sea be connected to present day insects' role as decomposers?

Review

1. What are three key characteristics of insects?
2. What are two ways in which insects communicate?
3. What are the five components of the insect head?
4. What are the features of the insect thorax?
5. Name five types of winged insects.

Section 19

Insect Food

Insect Food

- •Distinguish methods of insect eating.
- •Define proboscis.
- •Explain sponging.

How do butterflies eat?

You might have seen butterflies searching for food on a flower before. They have long, tube-like mouthparts that can reach deep within a flower. The butterfly uses this mouth-tube to siphon nectar from the flower, as if sucking through a straw.

Insect Food

What do insets eat? Practically anything they want. There are so many different insects, that among all of them, no potential food is safe. Lots of insects eat plants, some insects eat other insects, and some even drink blood. Many insects eat nectar from plants. And some insects will eat whatever scraps of food you leave lying around.

A few insects, such as mayflies and some moths, never eat. That's because their lives are over in just a few hours or days. Once these insects become adults, they lay eggs, and then die. On the other hand, some insects are very healthy eaters. A silkworm eats enough leaves to increase its weight more than 4,000 times in just 56 days, as the silkworm increases in size about 10,000 times since birth. A locust eats its own weight in plants every day. Just imagine eating your own weight in food every day. You probably couldn't. You would most likely get very sick even if you tried.

How do Insects Eat?

Insects eat in many different ways and they eat a huge range of foods. Around half are plant-eaters, feeding on leaves, roots, seeds, nectar, or wood. Aphids and leafhoppers suck up the sap from plants. Praying mantises are predators, hunting other small creatures. Insects like mosquitoes and aphids have special mouthparts that help them pierce and suck. Others, like assassin bugs (**Figure** below) and certain species of female mosquitoes, eat other insects. Fleas and lice are parasites, eating the flesh or blood of larger animals without killing them.

Insects have different types of appendages (arms and legs) adapted for capturing and feeding on prey. They also have special senses that help them detect prey. Furthermore, insects have a wide range of mouthparts used for feeding.

Figure 9.30

An assassin bug feasts on a beetle.

Examples of chewing insects include dragonflies, grasshoppers, and beetles. These insects use one pair of jaws to bite off bits of food and grind them down. Another pair of jaws helps to push the food down the throat. Some larvae also have chewing mouthparts, as in the caterpillar stages of moths and butterflies (**Figure** below).

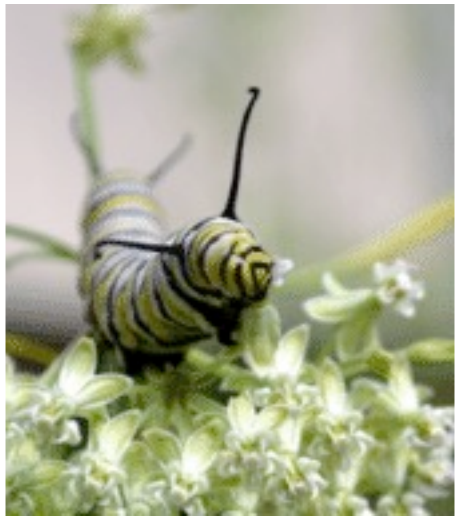


Figure 9.31

Caterpillar feeding on a host plant.

Some insects use siphoning, as if sucking through a straw, like moths and butterflies. This long mouth-tube that they use to suck up the nectar of the flower is called a **proboscis** . Some moths, however, have no mouthparts at all. Some insects obtain food by **sponging** , like the housefly. Sponging means that the mouthpart can absorb liquid food and send it to the esophagus. The housefly is able to eat solid food by releasing saliva and dabbing it over the food. As the saliva dissolves the food, the sponging mouthpart absorbs the liquid food.

Method	Description	Examples
Piercing-sucking	Used to penetrate solid tissue and then suck up liquid food	Cicadas, aphids, sucking lice, stable flies, mosquitoes

Summary

- Some insects, such as aphids, have piercing-sucking mouthparts. Other insects, like grasshoppers, have chewing mouthparts.
- Insects can have specialized mouthparts, such as a proboscis, to siphon the nectar from a flower.

Explore More

Use the resources below to answer the questions that follow.

Explore More I

- **Bug Mouthparts** at Museum Victoria: http://museumvictoria.com.au/bugs/foodchains/mouthparts.aspx .

1. Describe a honeybee's mouthparts.
2. Describe the process of sponging.
3. How do the mouthparts of cockroaches differ from the mouthparts of butterflies?
4. What do the design of insect mouthparts tell us about their lifestyles?

Explore More II

- **Ants that Farm, Compost, and Weed** at http://www.youtube.com/watch?v=DNN2E2bWU3A (2:23)

1. What do these ants do with the plants they gather?
2. What would happen to the ants' "crop" if the ants in a colony were to all die?
3. What tool do the ants have to try to control "pest" fungi?

Review

1. How do butterflies obtain their food?
2. What do fleas and lice eat?
3. What is sponging? Explain how insects use sponging to obtain their food.
4. What is meant by the piercing-sucking method of eating?

Section 20

Insect Reproduction and

Insect Reproduction and Life Cycle

•Describe reproduction in insects.
•Distinguish complete from incomplete metamorphosis.
•Define nymph and pupa.

What is this?

These butterfly eggs look like tiny pearls on a leaf. The adult butterfly often lays her eggs on a specific type of plant. This ensures that the future caterpillars will have plenty of food to eat.

Insect Reproduction and Life Cycle

Most insects can reproduce very quickly within a short period of time. With a short generation time, they evolve faster and can quickly adjust to environmental changes. Most insects reproduce by **sexual reproduction** . The female produces eggs, which are fertilized by the male, and then the eggs are usually placed near the required food. In some insects, there is **asexual reproduction** during which the offspring come from a single parent. In this type of reproduction, the offspring are almost identical to the mother. This is most often seen in aphids and scale insects.

With a few exceptions, all insect life begins as an egg. After leaving the egg, insects must grow and transform until reaching adulthood. Only the adult insect can mate and reproduce. The physical transformation of an insect from one stage of its life cycle to another is known as **metamorphosis** .

Three Types of Metamorphosis

An insect can have one of three types of metamorphosis and life cycles (**Table** below). Metamorphosis describes how insects transform from an immature or young insect into an adult insect in at least two stages. Insects may undergo gradual metamorphosis (incomplete), where transformation is subtle, or complete metamorphosis, where each stage of the life cycle appears quite different from the others. In some insects, there may be no true metamorphosis at all.

Type of Metamorphosis	Characteristics	Examples
None	•Only difference between adult and **larvae** (young or non-adult insects) is size. •Occurs in the most primitive insects. •Newborn insect looks like a tiny version of the adult.	Silverfish, firebrats, springtails
Incomplete	•Three stages: egg, nymph, and adult. •Young, called **nymphs** , usually similar to adult. •Growth occurs during the nymph stage. •Wings then appear as buds on nymphs or early forms. •When last molt is completed, wings expand to full adult size.	Dragonflies, grasshoppers, mantids, cockroaches, termites

Figure 9.32

The chrysalis (pupal stage) of a monarch butterfly.

Summary

- Insects reproduce rapidly, usually by sexual reproduction.
- Metamorphosis, or how insects transform from an immature form into an adult, can be part of the insect life cycle.

Explore More

Use the resources below to answer the questions that follow.

Explore More I

- **Growing Up Butterfly** at http://www.natgeotv.com/ca/great-migrations/videos/growing-up-butterfly

1. How many eggs will a female monarch butterfly lay?

2.How much heavier is the caterpillar two weeks after birth?
3.Describe the changes that turn the caterpillar into a butterfly.

Explore More II

•**Insect Reproductive Systems** at http://www.youtube.com/watch?v=lopc1CrGCX4 (2:18)

Click on the image above for more content

1.How do male insects try to keep other males from impregnating a female with which they have mated?
2.Do most insects use internal or external fertilization?
3.What do male insects make with the accessory glands of their reproductive system?

Review

1.Describe how most insects reproduce.
2.Define metamorphosis.
3.What is the difference between complete and incomplete metamorphosis.
4.What are the four stages of complete metamorphosis?
5.Describe the differences between the immature and adult forms of most insects.
6.Give three examples of insects that go through complete metamorphosis.

Section 21

Importance of Insects

Importance of Insects

- •Explain the role of insects in their ecosystems.
- •Discuss the importance of insects to people.
- •Describe the use of insects as food.

Would you like to try a grasshopper taco?

It might seem disgusting to you, but insects are an important food source in many places across the globe. Crickets, ants, grasshoppers, and other insects are traditional foods in parts of Latin America, Africa, and Asia.

Importance of Insects

Many insects are considered to be pests by humans. However, insects are also very important for numerous reasons.

Ecological Importance

Insects can be found in every environment on Earth. While a select few insects, such as the Arctic Wooly Bear Moth, live in the harsh Arctic climate, the majority of insects are found in the warm and moist tropics. Insects have adapted to a broad range of habitats, successfully finding their own niche, because they will eat almost any substance that has nutritional value.

Insects are crucial components of many ecosystems, where they perform many important functions. They aerate the soil, pollinate blossoms, and control insect and plant pests. Many insects, especially beetles, are scavengers, feeding on dead animals and fallen trees, thereby recycling nutrients back into the soil. As **decomposers** , insects help create top soil, the nutrient-rich layer of soil that helps plants grow. Burrowing bugs such as ants and beetles dig tunnels that provide channels for water, benefiting plants. Bees, wasps, butterflies and ants **pollinate** flowering plants (**Figure** below). Gardeners love the big-eyed bug and praying mantis because they control the size of certain insect populations, such as aphids and caterpillars, which feed on new plant growth. Finally, all insects fertilize the soil with the nutrients from their droppings.

Figure 9.33

Bees are important pollinators of flowering plants.

Economic Importance

Insects have tremendous economic importance. Some insects produce useful substances, such as honey, wax, lacquer, and silk. Honeybees have been raised by humans for thousands of years for honey. The silkworm greatly affected human history. When the Chinese used worms to develop silk, the silk trade connected China to the rest of the world. Adult insects, such as crickets, as well as insect larvae, are also commonly used as fishing bait.

Insects as Food

Insects, of course, are not just eaten by people. Insects are the sole food source for many amphibians, reptiles, birds, and mammals, making their roles in food chains and food webs extremely important. It is possible that food webs could collapse if insect populations decline.

In some parts of the world, insects are used for food by humans. Insects are a rich source of protein, vitamins, and minerals, and are prized as delicacies in many third-world countries. In fact, it is difficult to find an insect that is not eaten in one form or another by people. Among the most popular are cicadas, locusts, mantises, grubs, caterpillars, crickets, ants, and wasps. Many people support this idea to provide a source of protein in human nutrition. From South America to Japan, people eat roasted insects, like grasshoppers or beetles.

Insects in Medicine

Insects have also been used in medicine. In the past, fly larvae (**maggots**) were used to treat wounds to prevent or stop gangrene. Gangrene is caused by infection of dead flesh. Maggots only eat dead flesh, so when they are placed on the dead flesh of humans, they actually clean the wound and can prevent infection. Some hospitals still use this type of treatment.

Summary

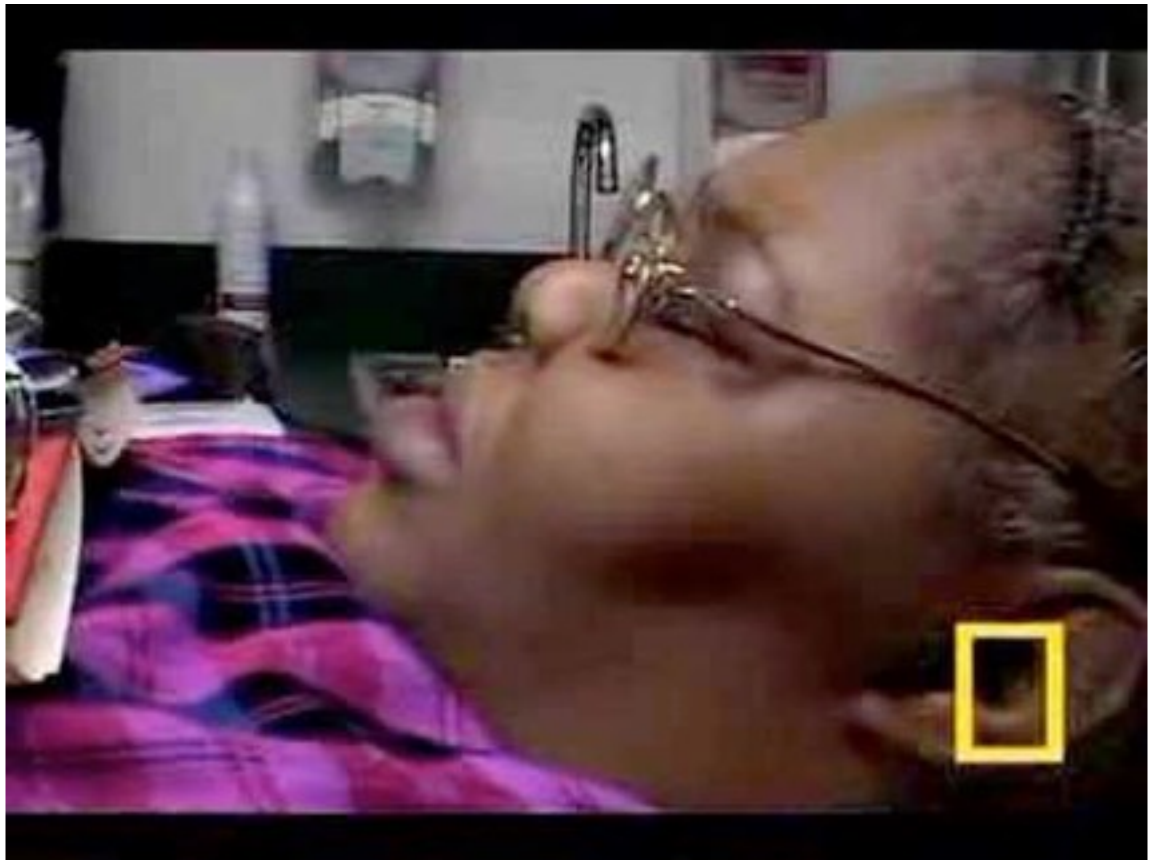
•In the environment, some insects pollinate flowering plants.
•Insects produce useful substances, such as honey, wax, lacquer, and silk.
•Insects are food sources in some parts of the world.

Explore More

Use the resources below to answer the questions that follow.

Explore More I

•**Maggot Medicine** at http://www.youtube.com/watch?v=6Xt6NWkgydM (3:33)



Click on the image above for more content

1. What characteristic of maggots make them useful in medicine?
2. How do maggots help wounds heal?

Explore More II

•**Creature Feature: Silkworms** at http://www.abc.net.au/creaturefeatures/facts/silkworms.htm

1. What is the best food for silkworms?
2. Why does the silkworm make silk?

Review

1. Where are the majority of insects found?
2. Name two ways in which insects are important to the ecosystem.
3. Give three examples of insects that act as pollinators.
4. List three products produced by insects.
5. Give an example of how insects are used in medicine?

Section 22

Control of Insects

Control of Insects

- •Summarize common insect pests.
- •Explain methods to control insects.
- •Distinguish biological control from chemical control of insects.

Are ladybugs dangerous?

Ladybugs won't hurt you. But they are dangerous to some other insects! This ladybug is eating plant-harming bugs known as aphids. Since they have an appetite for aphids, ladybugs are a farmer's friend.

Control of Insects

Though insects can be very important, some are also considered pests. Common insect pests include:

1. Parasitic insects, such as mosquitoes, lice, and bed bugs.
2. Insects that transmit diseases, including mosquitoes and flies.
3. Insects that damage structures, such as termites (**Figure** below).
4. Insects that destroy crops, including locusts and weevils.

Figure 9.34

Termites can destroy wooden structures.

Many scientists who study insects are involved in various forms of pest control. Most utilize insect-killing chemicals, but more and more rely on other methods. Ways to control insect pests are described below.

Biological Control

Biological control of pests in farming is a method of controlling pests by using other insects (or other natural predators of the pests). Biological control of insects relies on predation and parasitism. Insect predators, such as ladybugs and lacewings, consume a large number of other insects during their lifetime. If you add ladybugs to your farm or garden, they will help keep insect pests, such as aphids, under control. Aphids are among the most destructive insect pests on cultivated plants in temperate regions, so any control of these pests is beneficial.

Ladybugs also consume mites, scale insects and small caterpillars. The larvae of many hoverfly species also feed upon aphids, with one larva consuming up to fifty aphids a day, which is about 1,000 in its lifetime. They also eat fruit tree spider mites and small caterpillars. Dragonflies are important predators of mosquitoes, and can be used to control this pest. Parasitic insects include insects such as wasps and flies that lay their eggs on or in the body of an insect host, which is then used as a food for developing larvae. The host is ultimately killed. Caterpillars also tend to be one likely target of parasitic wasps.

Chemical Control

Chemical control of pests involves the use of insecticides. **Insecticides** , which are also known as pesticides, are most often used to kill insects. Insecticides are chemicals that kill insects. The U.S. spends $9 billion each year on pesticides. Disadvantages to using pesticides include human, fish, and honeybee poisonings, and the contamination of meat and dairy products.

When choosing to use an insecticide, there are numerous points to consider. Negative effects of the pesticide should try to be minimized. Important questions to consider include the following.

- What is the chemical's success against the target pest? Will the insecticide provide the desired level of control of the pest? If the answer is no, other methods of control should be considered.
- Does the chemical have an impact on natural enemies of the pest? In large scale efforts to rid areas of mosquitoes, the insecticide used also killed the dragonfly. This effort removed a natural predator of the mosquito. This may be an unacceptable negative effect of using the insecticide.
- How susceptible is the crop to insect damage? If the crop is not heavily damaged, only minor pest control may be needed. This may affect the amount or type of insecticide used.
- How toxic is the chemical to the environment and humans? Some older insecticides are extremely poisonous. Keep in mind that users of these poisons have a community responsibility to minimize the contamination of the surrounding environment, as well as keeping animals, surrounding crops and humans safe.
- Does using the pesticide result in the development of resistance? If so, this can make additional use of the pesticide less effective. As the resistance will be

passed to future generations of the insect (which is natural selection in action), this could be considered a negative side-effect of pesticide use.

Summary

- Harmful insects include those that can destroy buildings and crops or transmit disease.
- Insecticides are commonly used to control insect pests, but they can have harmful effects on the environment.

Explore More

Use the resources below to answer the questions that follow.

Explore More I

- **Deadly Mating** at http://www.youtube.com/watch?v=m2H-uTg51_c (3:05)

Click on the image above for more content

1. How are farmers seeking to control diamondback moths (*Plutella xylostella*)?

Explore More II

- **Biological Control** at Cornell University's Department of Entomology: http://www.biocontrol.entomology.cornell.edu/kids.php

1. What is an entomologist?
2. What is a danger of introducing a new insect as a biological control mechanism?
3. Why do people like biological control for food crops?

Review

1. What are three examples of insects that are pests?
2. Name two ways that insects can be pests.
3. What is meant by biological control of insects?
4. What are two disadvantages to pesticides?

Summary

Invertebrates describes eight invertebrate phyla with the greatest number of species. From the simple sponge to the echinodermata, this diverse group of organisms is anything but simple. Essentially, the only common characteristic among all the groups is the lack of a backbone. Many people may not even recognize the sponge as an animal. But it is. And how many people think a worm is an insect? But it is not. Add to this group all the different species of insects, and the diverseness of this group is easily apparent.

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Vertebrates

Vertebrates

Introduction

What do all animals—from fish to mammals—have in common?

Vertebrates. From the smallest of fish to us. One of the main features we all have in common is our backbone. *Vertebrates* describes main biological features of fish, amphibians, reptiles, birds, and mammals.

Section 1

Chordates

Chordates

•Define chordate.
•Explain the importance of the notochord.
•Describe the features of the chordates.
•Outline the classification of chordates.

What do these two animals have in common with you?

Notice the orange fish. Around him is another type of animal, a tunicate, in blue. Tunicates, fish, and humans seem very different from one another, but they do have some things in common. They are all chordates.

Chordates

Did you know that fish, amphibians, reptiles, birds, and mammals are all related? They are all chordates. **Chordates** are a group of animals that includes vertebrates, as well as several closely related invertebrates. Chordates (phylum *Chordata*) are named after a feature they all share, a notochord. A **notochord** is a hollow nerve cord along the back.

Characteristics of the Chordates

Chordates are defined by a set of four characteristics that are shared by these animals at some point during their development. In some chordates, all four traits are present in the adult animal and serve important functions. However, in many chordates, including humans, some traits are present only during the embryonic stage. After that, these traits may disappear.

All chordates have four main traits (**Figure** below):

1. **Post-anal tail** : The tail is opposite the head and extends past the anus.
2. **Dorsal hollow nerve cord** : "Dorsal" means that the nerve cord runs along the top of the animal. In some animals, the nerve cord develops into the brain and spinal cord.

3.Notochord: The notochord lies below the nerve cord. It is a rigid structure where muscles attach.
4.**Pharyngeal slits** : Pharyngeal slits are used to filter out food from water by some simple chordates. In most chordates, however, they are only present during the embryonic stages and serve no apparent purpose.

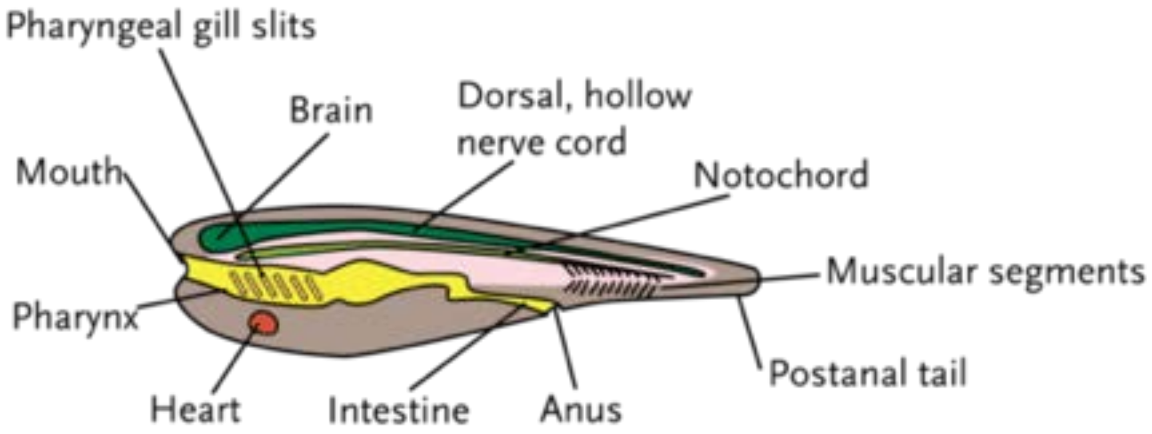


Figure 10.1

Body Plan of a Typical Chordate. The body plan of a chordate includes a post-anal tail, notochord, dorsal hollow nerve cord, and pharyngeal slits.

Classification of the Chordates

The chordates are divided into nine classes. Five of the classes are the fish, amphibians, reptiles, birds, and mammals. There are actually five classes of marine chordates (for example, sharks are cartilaginous fish which are distinct from bony fish), and these will be discussed in additional concepts.

The chordate phylum is broken down into three subphyla:

1.Urochordata: The tunicates, pictured in the introduction, make up this group. The urochordates are sessile (non-moving) marine animals with sack-like bodies and tubes for water movement. Urochordates have a notochord and nerve cord only during the larval stage.
2.Cephalochordata: Cephalochordates include the lancelets (**Figure** below), fish-like marine animals often found half-buried in the sand. Cephalochordates have a notochord and nerve cord but no backbone.
3.Vertebrata: Humans and other mammals, along with fish, amphibians, reptiles, and birds, fall in this category. The notochord is typically smaller and surrounded by a backbone.

Figure 10.2

The lancelet, an example of a chordate, is found in shallow ocean waters.

Summary

•Chordates are animals that have a notochord, post-anal tail, dorsal hollow nerve cord, and pharyngeal slits.
•Chordates include all vertebrates and some invertebrates.

Explore More

Use the resource below to answer the questions that follow.

(*Note* : this resource refers to human embryos as having gill slits. This is a commonly held misconception which seems to have originated in a now defunct theory by Ernst Haeckel. In the embryonic development of chordates, there is a stage where an invagination, called "gill pouches" or "pharyngeal pouches," appear in vertebrate embryos. This invagination does develop into gills in some species, but in other species the invagination develops into other structures. So, while parallels in the development of chordates are accurate, it is misleading to say human embryos have gill slits. You can find out more here http://www.angelfire.com/journal/Philsviews/Science/embryo.html .)

- **Chordate Animation: Amphioxus to Vertebrate Body Plan** at http://vimeo.com/37411858 (1:31)

Click on the image above for more content

1. What does the nerve cord in *Amphioxus* do?
2. What is a notochord, and what characteristics does it give *Amphioxus* ?
3. What signs of a notochord do we see in human beings (*Homo sapiens*)?
4. What is the relationship of the vertebrate backbone to the vertebrate skeleton?

Review

1. What is the main common feature of all chordates?
2. Name three examples of chordates.
3. List three characteristics of chordates.
4. What is the dorsal hollow nerve cord?

Section 2

Vertebrate Characteristics

Vertebrate Characteristics

- •Define vertebrate.
- •List the general features of vertebrates.
- •List and describe the seven vertebrate classes.

What animals have a backbone?

You have a backbone. A backbone can also be called a spine, spinal column or vertebral column. Most backbones are composed of a series of vertebrae and cartilage disks. Typically, each vertebra is separated from the next vertebra by one disk of cartilage. Some backbones of some types of fish are composed solely of cartilage. Can you guess what other animals also have a backbone? Frogs, snakes, birds, and many other animals all have backbones. Animals that have backbones are known as vertebrates.

Introduction to Vertebrates

Vertebrates are animals with backbones. These include fish, amphibians, reptiles, birds, and mammals.

Characteristics of Vertebrates

The primary feature shared by all vertebrates is the **vertebral column** , or backbone. The vertebral column protects the spinal cord.

Other typical vertebrate traits include:

- •The **cranium** (skull) to protect the brain. The brain is attached to the spinal cord.
- •An internal skeleton. The internal skeleton supports the animal, protects internal organs, and allows for movement.
- •A defined head region with a brain. The head region has an accumulation of sense organs.

Living vertebrates range in size from a carp species, as little as 0.3 inches, to the blue whale, which can be as large as 110 feet (**Figure** below).

Figure 10.3

A species of carp and an image of the blue whale (a mammal), the largest living vertebrate, reaching up to 110 feet long. Shown below it is the smallest whale species, Hector's dolphin (about 5 feet in length), and beside it is a human. These images are not to scale. The carp is greatly exaggerated in size and is even smaller than depicted when compared to the blue whale.

Classification of Vertebrates

Vertebrates, or subphylum Vertebrata, are all members of the phylum Chordata. Although there is some disagreement on how to classify animals, the traditional system divides the vertebrates into seven classes (**Table** below).

Class	Common Name	Characteristics	Examples
Agnatha	Jawless fishes	No jaws or scales	Lampreys, hagfish

Summary

- Vertebrates are animals with a backbone.
- Vertebrates include the mammals, birds, reptiles, amphibians, and fish.

Explore More

Use the resources below to answer the questions that follow.

Explore More I

- **Chordates: We're All Family** at http://vimeo.com/42588192 (15:43)

Click on the image above for more content

1. What do scientists feel was a key factor in vertebrates getting "big"?
2. What advantages do big animals have over small animals?
3. What advantages do small animals have over big animals?
4. What did jaws allow vertebrates to do?
5. What is a "larvacean"? How does it feed?

Review

1. What are five examples of vertebrates?
2. What are the primary feature shared by vertebrates? What is the role of this feature?
3. What is the defining characteristic of the cartilaginous fish?
4. What are the defining characteristics of reptiles?
5. What is the defining characteristic of mammals?

Section 3

Fish

Fish

•List the general traits of fish.
•Define ectothermic.
•Describe how fish breathe and reproduce.
•Explain how fish are important to people.

Is this animal a fish?

This mudskipper might not seem like a fish. It's not swimming in a lake or an ocean, and it appears to be using its fins like legs. Mudskippers can breathe through their skin and burrow in the mud, essentially living on land for a brief amount of time. These features are not typical of fish, and, yet, mudskippers are still classified as fish. So what features define a fish?

Characteristics of Fish

What exactly is a fish? You probably think the answer is obvious. You may say that a fish is an animal that swims in the ocean or a lake, using fins. But as we saw with the mudskipper, not all fish spend all their time in water. So how do scientists define fish?

Some characteristics of fish include:

1. They are **ectothermic** , meaning their temperature depends on the temperature of their environment. Ectothermic animals are cold-blooded in that they cannot raise their body temperature on their own. This is unlike humans, whose temperature is controlled from inside the body.
2. They are covered with scales.
3. They have two sets of paired fins and several unpaired fins.
4. They also have a streamlined body that allows them to swim rapidly.

Fish are aquatic vertebrates, meaning they have backbones. They became a dominant form of sea life and eventually evolved into land vertebrates. There are three classes of fish: Class Agnatha (the jawless fish), Class Chondrichthyes (the cartilaginous fish), and Class Osteichthyes (the bony fish). All have the characteristics of fish in common, though there are differences unique to each class.

Figure 10.4

The humphead or Napoleon wrasse shows some of the general traits of fish, including scales, fins, and a streamlined body.

How do Fish Breathe?

In order to absorb oxygen from the water, fish use gills (**Figure** below). **Gills** take dissolved oxygen from water as the water flows over the surface of the gill.

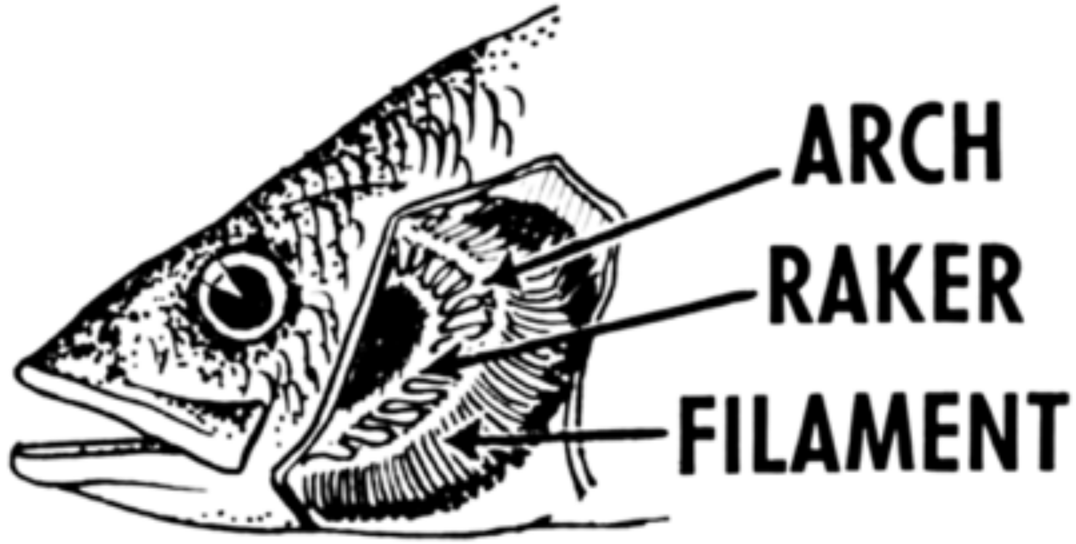


Figure 10.5

Gills help a fish breathe.

How Do Fish Reproduce?

Fish reproduce sexually. They lay eggs that can be fertilized either inside or outside of the body. In most fish, the eggs develop outside of the mother's body. In the majority of these species, fertilization also takes place outside the mother's body. The male and female fish release their gametes into the surrounding water, where fertilization occurs. Female fish release very high numbers of eggs to increase the chances of fertilization.

How Big Are Fish?

Fish range in size from the 65-foot, 75,000 pound whale shark (**Figure** below) to the stout infantfish, which is about 0.33 inches (8.4 mm), and the *Paedocypris progenetica* carp species of the Indonesian island of Sumatra, which is about 0.31 inches (7.9 mm) long, making it also the smallest known vertebrate animal. The second-largest fish is the basking shark, which grows to about 40 feet and 8,000 pounds. Both of the large sharks may look ferocious, and would probably scare anyone who comes across one in the water, but both species are filter-feeders, and feed on tiny fish and plankton. The tiny carp species is unique in that it has the appearance of larvae, with a reduced skeleton which leaves the brain unprotected by bone. The fish lives in dark acidic waters, having a pH of 3.

Figure 10.6

Whale sharks are the largest cartilaginous fish.

Exceptions to Common Fish Traits

There are exceptions to many of these fish traits. For example, tuna, swordfish, and some species of shark show some warm-blooded adaptations and are able to raise their body temperature significantly above that of the water around them.

Some species of fish have a slower, more maneuverable swimming style, like eels and rays (**Figure** below). Body shape and the arrangement of fins are highly variable, and the surface of the skin may be naked, as in moray eels, or covered with scales. Scales can be of a variety of different types.

Figure 10.7

One of the cartilaginous fish, a stingray, shows very flexible pectoral fins connected to the head.

Why Fish are Important

How are fish important? Of course, they are used as food (**Figure** below). In fact, people all over the world either catch fish in the wild or farm them in much the same way as cattle or chickens. Farming fish is known as **aquaculture** . Fish are also caught for recreation to display in the home or in a public aquarium.

Figure 10.8

Workers harvest catfish from the Delta Pride Catfish farms in Mississippi.

Summary

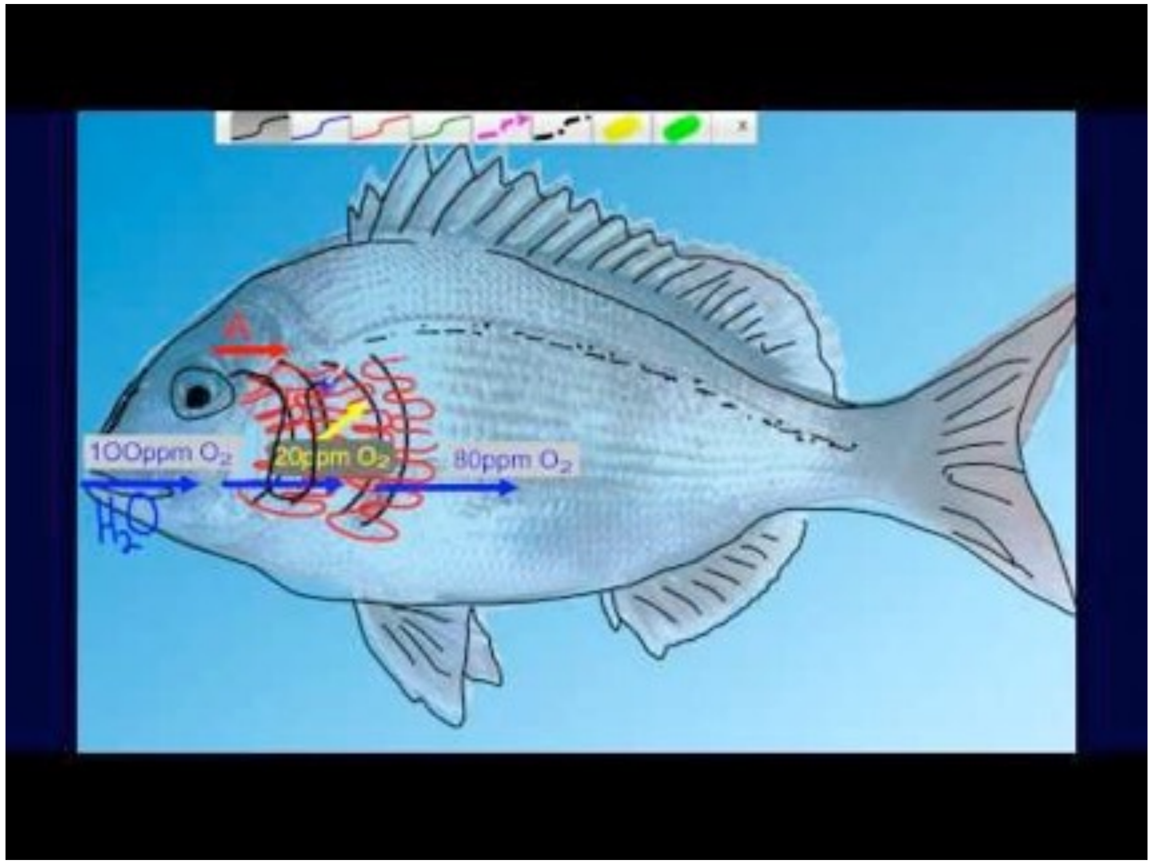
- Fish are ectothermic, have a streamlined body covered with scales, and have two sets of paired fins and several unpaired fins.
- To obtain fish for food, people catch fish in the wild or farm them.

Explore More

Use the resources below to answer the questions that follow.

Explore More I

- **Countercurrent Gas Exchange in Fish Gills** at http://www.youtube.com/watch?v=cVFqME-NW9s (4:50)



Click on the image above for more content

1. Why do gills appear bright red?

2.When a fish breathes, where does it take in water and where does it expel water?
3.What direction does a fish's blood flow through its gills?
4.Why does this system in fishes' gills allow for more energetic fish?

Review

1.What are three main features that define fish?
2.How do fish breath?
3.Explain how most fish reproduce?
4.How are fish important to humans?

Section 4

Jawless Fish

Jawless Fish

- •Describe the characteristics of jawless fish.
- •Name the two living groups of jawless fish.

What is this organism?

With this huge sucker lined with teeth, this organism might look like something out of science fiction. But this is a real fish found in the ocean, known as a lamprey. They use their teeth and sucker to bore into other fish and suck their blood. The lamprey is an example of a jawless fish.

Jawless Fish

What defines a jawless fish? You can probably guess. A jawless fish is a fish without a jaw. But there are other features that are shared by this class of organisms. Why would such an organism evolve? These fish were the first vertebrates to evolve. Logically, this makes sense, in that the vertebral column would evolve first, with the more complex jaw bones evolving later. The early jawless fish are thought to have relied on filter feeding to capture their food, and most likely would have sucked water and debris from the seafloor into their mouth, releasing water and waste out of their gills. As other sea life evolved, these jawless fish began to feed on other fish species, and are now considered a pest in their habitat. Lampreys have no natural predators.

Features of Jawless Fish

Jawless fish are missing the following parts:

1. Jaws.
2. Paired fins.
3. A stomach.

Characteristics they do have include:

1. A notochord, both in larvae and adults. Recall a **notochord** is a support rod that runs along the back of the fish.
2. Seven or more paired **gill pouches** . These organs take dissolved oxygen from water.

3.The **branchial arches** , a series of arches that support the gills of aquatic amphibians and fishes. They lie close to the body's surface.
4.A light sensitive **pineal eye** , an eye-like structure that can detect light.
5.A **cartilaginous skeleton** , a skeleton made of a flexible rubber-like supportive material called cartilage. This is similar to the skeleton of cartilaginous fish, which includes sharks and rays.
6.A heart with two chambers.
7.Reproduction using external fertilization.
8.They are **ectothermic** . This means that their internal temperature depends on the temperature of their environment.

Classification of Jawless Fish

Most scientists agree that the jawless fish are part of the the superclass Agnatha. They belong to the phylum Chordata, subphylum Vertebrata. There are two living groups of jawless fish, with about 100 species in total: lampreys and hagfish (**Figure** below). Although hagfish belong to the subphylum Vertebrata, they do not technically have vertebrae (though they do have a skull), whereas lampreys do have vertebrae. For this reason, scientists still disagree on the classification of jawless fish.

Figure 10.9

A hagfish.

Summary

•The jawless fish include the lampreys and the hagfish.
•Jaws, fins, and stomachs are absent in the jawless fish.
•Features of the jawless fish include a notochord, paired gill pouches, a pineal eye, and a two-chambered heart.

Explore More

Use the resources below to answer the questions that follow.

•**Invading Species Awareness PSA - Sea Lamprey** at http://www.youtube.com/watch?v=x-KJZ22-wTQ (2:06)

Click on the image above for more content

1. How do lamprey eat?
2. How did lampreys reach the Great Lakes?
3. What techniques are people using to try to control lampreys in the Great Lakes?

Review

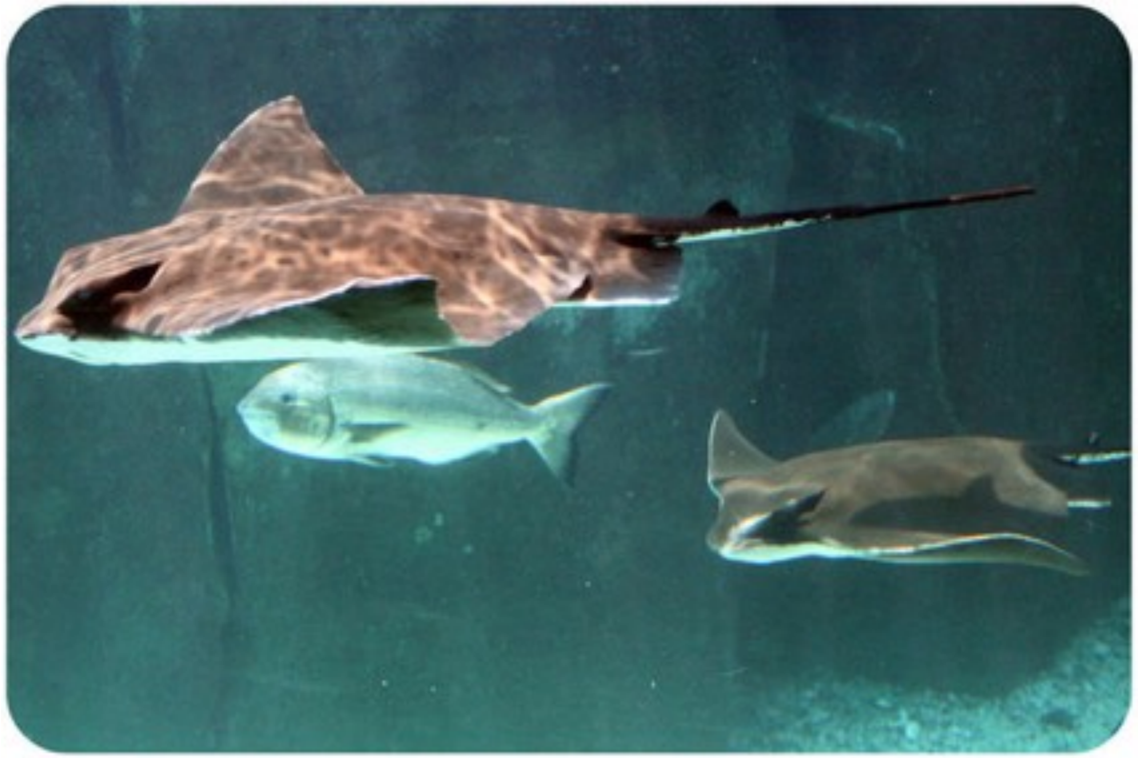
1. What are two examples of jawless fish?
2. What are three characteristics of jawless fish?
3. What is the pineal eye?

Section 5

Cartilaginous Fish

Cartilaginous Fish

•Give examples of cartilaginous fish.
•Describe the features of the cartilaginous fish.
•Explain the importance of Leydig's organ and placoid scales.
•Discuss how sharks are distinguished.



How are these organisms different?

The two rays and the other fish pictured here do have a lot in common. They have streamlined bodies well suited for movement in the ocean. One difference, however, is their skeletons. The lone fish has a skeleton of bone. The rays have a skeleton of cartilage, and so they are known as cartilaginous fish.

Cartilaginous Fish

The 1,000 or so species of **cartilaginous fish** are subdivided into two subclasses: the first includes sharks, rays, and skates; the second includes chimaera, sometimes called ghost sharks. Fish from this group range in size from the dwarf lanternshark, at 6.3 inches, to the over 50-foot whale shark. Sharks obviously have jaws, as do the other cartilaginous fish. These fish evolved from the jawless fish. So why did fish eventually evolve to have jaws? Such an adaptation would allow fish to eat a much wider variety of food, including plants and other organisms.

Other characteristics of cartilaginous fish include:

•Paired fins.
•Paired nostrils.
•Scales.
•Two-chambered hearts.
•Skeletons made of **cartilage** rather than bone. Cartilage is supportive tissue that does not have as much calcium as bones, which makes bones rigid. Cartilage is softer and more flexible than bone.

Blood, Skin, and Teeth

Since they do not have bone marrow (as they have no bones), red blood cells are produced in the spleen, in special tissue around the reproductive organs, and in an organ called **Leydig's organ** , only found in cartilaginous fishes. The tough skin of this group of fish is covered with **placoid scales** , which are hard scales formed from modified teeth. The scales are covered with a hard enamel. The hard covering and the way the scales are arranged, gives the fish skin rough, sandpaper-like feel. The function of these scales is for protection against predators.

The shape of sharks' teeth differ according to their diet. Species that feed on mollusks and crustaceans have dense flattened teeth for crushing, those that feed on fish have needle-like teeth for gripping, and those that feed on larger prey, such as mammals, have pointed lower teeth for gripping and triangular upper teeth with serrated edges for cutting. Sharks continually shed and replace their teeth, with some shedding as much as 35,000 teeth in a lifetime.

Superorders

The sharks, rays, and skates (which are similar to stingrays) are further broken into two superorders:

1. Rays and skates.
2. Sharks.

Sharks are some of the most frequently studied cartilaginous fish. Sharks are distinguished by such features as:

- The number of gill slits.
- The number and type of fins.
- The type of teeth.
- The size of their jaws.
- Body shape.
- Their activity at night.
- An elongated, toothed snout used for slashing the fish that they eat, as seen in sawsharks.
- Teeth used for grasping and crushing shellfish, a characteristic of bullhead sharks.
- A whisker-like organ named **barbels** that help sharks find food, a characteristic of carpet sharks.
- A long snout (or nose-like area), characteristic of groundsharks.
- **Ovoviviparous** reproduction, where the eggs develop inside the mother's body after internal fertilization, and the young are born alive. This trait is characteristic of mackerel sharks. All sharks mate by internal fertilization. Some sharks then lay their eggs, others allow internal development.

Figure 10.10

A spotted Wobbegong shark showing skin flaps around the mouth and camouflage coloration.

Summary

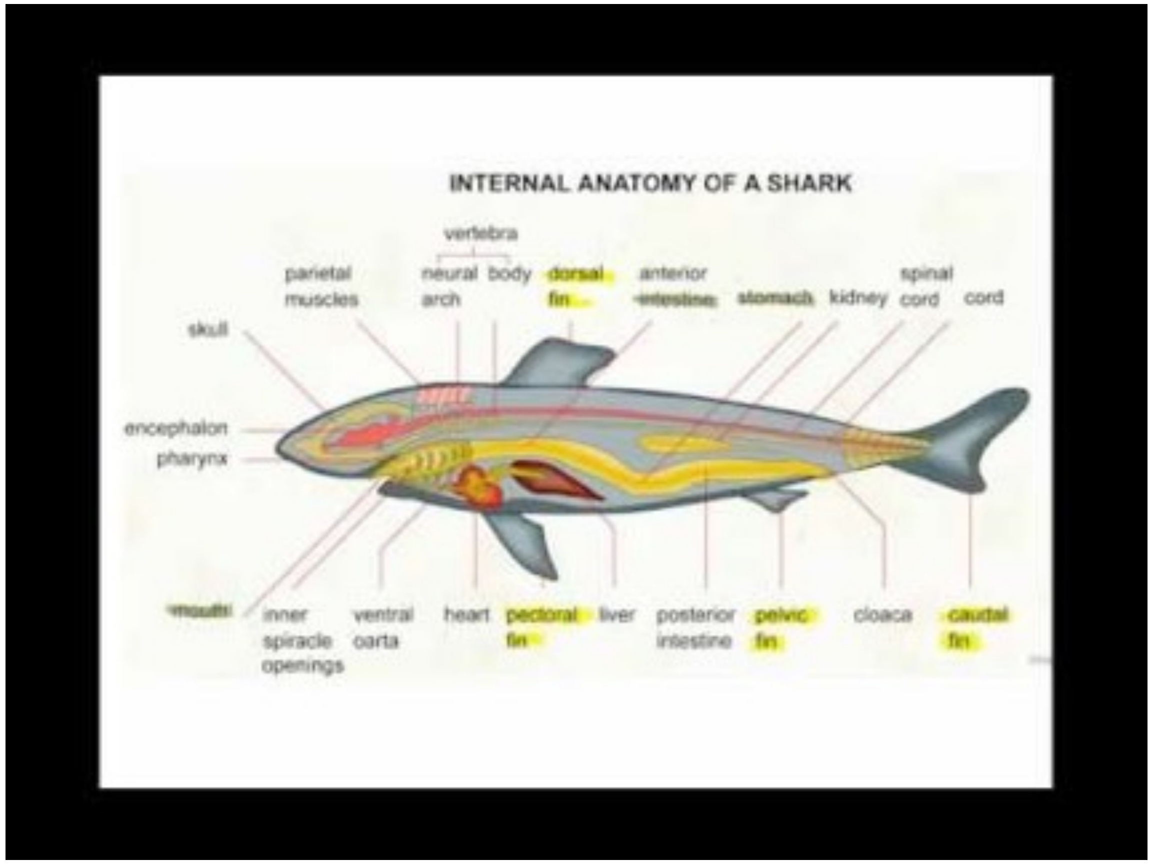
- •The cartilaginous fish are jawed fish with paired fins, paired nostrils, scales, two-chambered hearts, and skeletons made of cartilage rather than bone.
- •Examples of the cartilaginous fish include sharks, rays, and skates.

Explore More

Use the resources below to answer the questions that follow.

Explore More I

- •**Chondrichthyes** at http://www.youtube.com/watch?v=6i6wlz8V5x0 (13:15)



Click on the image above for more content

1. How do Chondrichthyes differ from jawless fish (Agnatha)?
2. How is the keel shape of their scales beneficial?
3. What is the function of the cloaca in sharks?
4. What is a nodochord made of in sharks?
5. How do sharks sense prey? Explain.

Explore More II

- •**Skates and Rays** at http://animals.howstuffworks.com/fish/skate-and-ray-info.htm

1. What do skates and rays have in common with sharks?
2. What part of the ocean do skates and rays inhabit?

Explore More III

- http://www.pbs.org/wnet/nature/episodes/sharkland/interactive-anatomy-the-great-whites-weapons/4093/

1. What are the ampullae of Lorenzini used for?
2. What is the relationship between the surface area of gill filaments and the amount of gas they can exchange? Why is this important to the shark?
3. Why do great white sharks have to roll their eyes back to protect them when they attack?
4. What do sharks use to strengthen their cartilaginous skeleton?

Review

1. What are three features of cartilaginous fish?
2. What are three examples of cartilaginous fish?
3. What is Leydig's organ?
4. List three features that distinguish sharks.

Section 6

Bony Fish

Bony Fish

- •Describe the characteristics of the bony fish.
- •Discuss the importance of the swim bladder and operculum.
- •Distinguish ray-finned fish from lobe-finned fish.

Can fish have bones?

Of course. Many fish have bones. They serve the same function as our bones: protection and support. Notice how the skeleton protects the fish's brain. Also, notice the bones along the body of the fish would allow muscles to attach to aid in movement.

Bony Fish

There are about 27,000 species of bony fish (**Figure** below), which are divided into two classes: ray-finned fish and lobe-finned fish. Most bony fish are ray-finned. These thin fins consist of webs of skin over flexible spines. Lobe-finned fish, on the other hand, have fins that resemble stump-like appendages.

Figure 10.11

Fins of bony fish: ray fin (left) and lobe fin (right).

Characteristics of Bony Fish

Most fish are bony fish, making them the largest group of vertebrates in existence today. They are characterized by:

1.A head and **pectoral girdles** (arches supporting the forelimbs) that are covered with bones derived from the skin.
2.A lung or **swim bladder** , which helps the body create a balance between sinking and floating by either filling up with or emitting gases such as oxygen.
3.Jointed, segmented rods supporting the fins.
4.A cover over the gill called the **operculum** , which helps them breathe without having to swim.

5.The ability to see in color, unlike most other fish.

Ray-finned Fish

The ray-finned fish have fin rays, with fins supported by bony spines known as rays. The ray-finned fish are the dominant class of vertebrates, with nearly 99% of fish falling into this category. They live in all aquatic environments, from freshwater and marine environments from the deep sea to the highest mountain streams.

Lobe-finned fish

The lobe-finned fish are characterized by fleshy lobed fins, as opposed to the bony fins of the ray-finned fish. There are two types of living lobe-finned fish: the coelacanths and the lungfish. The pectoral and pelvic fins have joints resembling those of tetrapod (four-limbed land vertebrates) limbs. These fins evolved into legs of amphibians, the first tetrapod land vertebrates. They also possess two dorsal fins with separate bases, as opposed to the single dorsal fin of ray-finned fish. All lobe-finned fishes possess teeth covered with true enamel.

How Big Are Bony Fish?

The ocean sunfish is the most massive bony fish in the world, up to 11 feet long and weighing up to 5,070 pounds (**Figure** below). Other very large bony fish include the Atlantic blue marlin, the black marlin, some sturgeon species, the giant grouper, and the goliath grouper. The long-bodied oarfish can easily be over 30 feet long, but is not nearly as massive as the ocean sunfish. In contrast, the dwarf pygmy goby measures only 0.6 inches. Fish can also be quite valuable. In January 2013, at an auction in Tokyo's Tsukiji fish market, a 222-kilogram (489-pound) tuna caught off northeastern Japan sold for 155.4 million yen, which is $1,760,000.

Figure 10.12

An ocean sunfish, the most massive bony fish in the world, can reach up to 11 feet long and weigh up to 5,070 pounds!

Summary

- •The bony fish are divided into two classes: ray-finned fish and lobe-finned fish.
- •The bony fish are characterized by a lung or swim bladder, a cover over the gills, and bones covering the head and pectoral girdles.

Explore More

Use the resources below to answer the questions that follow.

Explore More I

- **Bony Fish (Perch) Anatomy** at http://www.youtube.com/watch?v=pNZQEmGp11k (5:55)

Click on the image above for more content

1. What is one of the purposes of the operculum?
2. What is the lateral line used for? Where is it located?
3. Not all fish have swim bladders, but, for those who do, what are they used for? Why do you think some fish don't have swim bladders?

Explore More II

- **Pregnant Males** at http://www.youtube.com/watch?v=EaOHLQy_bjU (2:25)

Click on the image above for more content

1. What type of fish is a seahorse?
2. What is unusual about seahorse reproduction?
3. How wide is a seahorse's field of vision? How is it so wide?
4. What do seahorses feed on?

Review

1.What is the largest group of vertebrates in existence today?
2.Name three characteristics of the bony fish?
3.What are the two classes of the bony fish?
4.What is the swim bladder?
5.What is the operculum?

Section 7

Amphibians

Amphibians

- •Give examples of amphibians.
- •Describe the characteristics of the amphibians.
- •Describe amphibian adaptations for life on land.
- •Summarize amphibian habitats.

What were the first land vertebrates?

Amphibians! In order for water-dwelling animals to adapt to life on land, many new adaptations had to take place. First, they needed to be able to breathe air instead of obtaining oxygen from water. And fins don't work well as legs! They needed to be able to move around well on land.

Characteristics of Amphibians

What group of animals begins its life in the water, but then spends most of its life on land? Amphibians! Amphibians are a group of vertebrates that has adapted to live in both water and on land. Amphibian larvae are born and live in water, and they breathe using gills. The adults live on land for part of the time and breathe both through their skin and with their lungs.

There are approximately 6,000 species of amphibians. They have many different body types, physiologies, and habitats, ranging from tropical to subarctic regions. Frogs, toads, salamanders (**Figure** below), newts, and caecilians are all types of amphibians.

Figure 10.13

One of the many species of amphibian is this dusky salamander.

How did Amphibians Adapt to Living on Land?

In order to live on land, amphibians replaced gills with another respiratory organ, the lungs. Other adaptations include:

- •Skin that prevents loss of water.
- •Eyelids that allow them to adapt to vision outside of the water.
- •An eardrum developed to separate the external ear from the middle ear.
- •A tail that disappears in adulthood (in frogs and toads).

Classification of the Amphibians

Like fish, amphibians are ectothermic vertebrates. They belong to the class Amphibia. There are three orders:

1. Urodela, containing salamanders and newts.
2. Anura, containing frogs and toads.
3. Apoda, containing caecilians.

Where do Amphibians Live?

Most amphibians live in fresh water, not salt water. Their habitats can include areas close to springs, streams, rivers, lakes, swamps and ponds. They can be found in moist areas in forests, meadows and marshes. Amphibians can be found almost anywhere there is a source of fresh water. Although there are no true saltwater amphibians, a few can live in brackish (slightly salty) water. Some species do not need any water at all, and several species have also adapted to live in drier environments. Most amphibians still need water to lay their eggs.

How do Amphibians Reproduce?

Amphibians reproduce sexually. The life cycle of amphibians happens in the following stages:

1. Egg Stage: Amphibian eggs are fertilized in a number of ways. **External fertilization** , employed by most frogs and toads, involves a male gripping a

female across her back, almost as if he is squeezing the eggs out of her. The male releases sperm over the female's eggs as they are laid. Another method is used by salamanders, whereby the male deposits a packet of sperm onto the ground. The female then pulls it into her **cloaca** , a single opening for her internal organ systems. Therefore, fertilization occurs internally. By contrast, caecilians and tailed frogs use **internal fertilization** , just like reptiles, birds, and mammals. The male deposits sperm directly into the female's cloaca.
2.Larval stage: When the egg hatches, the organism is legless, lives in water, and breathes with gills.
3.During the larval stage, the amphibian slowly transforms into an adult by losing its gills and growing four legs. Once development is complete, it can live on land.

Summary

•Amphibians live in both water and on land; amphibian larvae are born and live in water, and they breathe using gills. The adults live on land for part of the time and breathe both through their skin and with their lungs.
•Adaptations for land in amphibians include protective skin and eyelids that allow them to adapt to vision outside of the water.

Explore More

Use the resources below to answer the questions that follow.

Explore More I

•**San Diego Zoo Amphibians** at http://kids.sandiegozoo.org/animals/amphibians
1.Describe the skin of an amphibian.
2.What is metamorphosis?
3.What is meant by "ectothermic"? How does this affect an animals behavior?

Explore More II

•**Respiratory Organs In Amphibians** at http://www.youtube.com/watch?v=Nfojq4ikHH0 (3:29)

Click on the image above for more content

1. How do frogs fill their lungs?
2. Why do amphibians need less oxygen than birds or mammals?
3. How do frogs breathe when they are underwater?

Review

1. List three adaptions amphibians have for life on land?
2. List four examples of amphibians.
3. How do amphibians reproduce?
4. Describe the amphibian larval stage. What changes occur during this stage?

Section 8

Salamanders

Salamanders

•Describe the features of salamanders.
•Explain the classification of salamanders.

What type of animal is this?

A salamander! You might have mistaken it for a lizard, but lizards are very different from salamanders. Salamanders have moist skin, while lizards have dry scales on their skin. Furthermore, lizards live their entire lives on land. Salamanders must reproduce in water.

Salamanders

Salamanders are characterized by slender bodies, short legs, and long tails. They are most closely related to the caecilians, little-known legless amphibians (**Figure** below). Most of the animals in the salamander order look like a cross between a lizard and a frog. They have moist, smooth skin like frogs and long tails like lizards.

Salamanders are found in most moist or arid habitats in the Northern Hemisphere, but can also be found south of the equator. They live on all continents except Antarctica and Australia. Salamanders live in or near water or on moist ground, often in a swamp. Some species live in water most of their life, some live their entire adult life on land, and some live in both habitats. Some salamanders live in caves. These salamanders have pale skin and reduced eyes as they have adapted to living in complete darkness in underground pools of water.

Salamanders are **carnivorous** , eating only other animals, not plants. They will eat almost any smaller animal, such as worms, centipedes, crickets, spiders, and slugs. Some will even eat small invertebrates. Finally, salamanders have the ability to grow back lost limbs, as well as other body parts. This process is known as **regeneration** .

Salamanders have developed ways not to be eaten. Most salamanders have brightly colored, poisonous skin. The bold color tells predators not to eat the salamander. Many salamanders have glands on the back of the neck or on the tail that give off a poisonous or bad-tasting liquid. Some species can even shed their tail during an attack and grow a new one later. Some salamanders stand high on its legs and waves its tail to scare away danger. One particular salamander, the ribbed newt, has needle-like rib tips. It can squeeze its muscles to make the rib tips pierce through its skin and into its enemy, telling the predator to stay away.

Figure 10.14

The marbled salamander (*left*) shows the typical salamander body plan: slender body, short legs, long tail, and moist skin. Caecilian (*right*) are a type of legless amphibian most closely related to salamanders.

How Do Salamanders Breathe?

Different salamanders breathe in different ways. In those that have gills, breathing occurs through the gills as water passes over the gill slits. Sirens keep their gills all their lives, which allows them to breathe underwater.

Species that live on land lose their gills as they grow older. These salamanders develop lungs that are used in breathing, much like breathing in mammals. Other land-living salamanders do not have lungs or gills. These are called lungless salamanders. Instead, they "breathe," or exchange gases, through their skin. This requires blood vessels that exchange gases to be spread throughout the skin.

How Big Are Salamanders?

Salamanders are generally small. However, some can reach a foot or more, as in the mudpuppy of North America. In Japan and China, the giant salamander reaches 6 feet and weighs up to 66 pounds (**Figure** below).

Figure 10.15

The Pacific giant salamander can reach up to 6 feet in length and weigh up to 66 pounds.

Classification of Salamanders

Salamanders belong to a group of approximately 500 species of amphibians. The order Urodela, containing salamanders and newts, is divided into three suborders:

1. Giant salamanders, including the hellbender and Asiatic salamanders.
2. Advanced salamanders, including lungless salamanders, mudpuppies, and newts. Newts are salamanders that spend most of each year living on land.
3. Sirens. Sirens are salamanders that have lungs as well as gills and never develop beyond the larval stage.

Sirens have only two legs, but the other salamander species develop four legs as adults, with fleshy toes at the end of each foot. The legs on four-legged salamanders are so short that the salamander belly drags on the ground as the animal walks. Sirens have long, strong tails that are flat to help sirens swim like a fish, with the tail swinging from side to side.

Summary

- Salamanders live in or near water or on moist ground, often in a swamp.
- Salamanders can breathe with the help of gills, lungs, or their skin surface.

Explore More

Use the resources below to answer the questions that follow.

Explore More I

- **Spotted Salamander** at http://animals.nationalgeographic.com/animals/amphibians/spotted-salamander/

1. Where does the spotted salamander live?
2. How does the spotted salamander discourage predators?
3. Describe the diet of the spotted salamander.

Explore More II

- **Giant Salamander as Big as a Dog** at http://www.youtube.com/watch?v=buzqM1kHS5M (3:40)

Click on the image above for more content

1. What led to the giant salamanders (*Andrias japonicus*) being threatened with extinction?
2. What effect have dams had on giant salamanders?
3. How does the habitat of the giant salamander differ from the habitat of the spotted salamander?

Review

1. What are the main characteristics of salamanders?
2. Where do salamanders live?
3. How do salamanders breathe?
4. Describe the salamander known as the siren.

Section 9

Frogs and Toads

Frogs and Toads

•Distinguish frogs from toads.
•Describe the characteristics of frogs and toads.
•Explain frog reproduction and development.
•Describe the diet of frogs.

Frog or toad?

Although there is actually little difference between toads and frogs, this animal would most often be called a toad. Frogs have moist skin, while toads have dry, bumpy skin.

Frogs and Toads

Frogs and toads are amphibians in the order Anura. In terms of classification, there is actually not a big difference between frogs and toads. Frogs often have long legs that are good for hopping, skin that is smooth and moist, and special pads on their toes that help them climb. Toads are more heavyset with shorter legs, and usually have drier skin, often with warty-looking bumps. Frogs are more likely to live in or near water than toads.

Frogs are found in many areas of the world, from the tropics to subarctic regions, but most species are found in tropical rainforests. Consisting of more than 5,000 species (about 88% of amphibian species are frogs), they are among the most diverse groups of vertebrates. Frogs range in size from less than 0.5 inches in species in Brazil and Cuba to the over 1-foot (33 cm) long goliath frog of Cameroon, which can weigh up to 7 pounds. That is 1-foot from the nose to the back of the body, not including the length of the legs.

Characteristics of Frogs

Adult frogs are characterized by long hind legs, a short body, webbed finger-like parts, and the lack of a tail. They also have a three-chambered heart, as do all tetrapods except birds and mammals. Most frogs live part of the time in water and part of the time on land. They move easily on land by jumping or climbing. To become great jumpers, frogs evolved long hind legs and long ankle bones. They also have a short backbone with only ten vertebrae. Frog and toad skin hangs loosely on the body, and skin texture can be smooth, warty, or folded.

Frogs and toads don't have fur, feathers, or scales on their skin. Instead, they have a moist and permeable skin layer covered with mucous glands. Their special skin allows them to breathe through their skin in addition to using their lungs. They are vulnerable to water loss through the skin in dry conditions, which is why they need to live near water or in moist environments. The thin layer of mucous keeps the skin moist.

In order to live on land and in water, frogs have three eyelid membranes: one is see-through to protect the eyes underwater, and the two other ones let them see on land. Frogs also have a **tympanum** , which acts like a simple ear. They are found on each side of the head. In some species, the tympanum is covered by skin.

Figure 10.16

A tree frog. Notice the powerful muscles in the limbs and the coverings around the eyes.

How do Frogs Reproduce?

Frogs typically lay their eggs in puddles, ponds, or lakes. Their larvae, or **tadpoles** , have gills, a tail, but no legs. Tadpoles develop into adult frogs in water (**Figure** below). During this transformation, they develop lungs, lose their tails and form their four legs.

You may hear males "ribbiting," producing a mating call used to attract females to the bodies of water best for mating and breeding. Frog calls can occur during the day or night. Each frog species has a different call that is used to attract mates and warn off rivals. When a female picks a male whose call she likes, the male grabs her and squeezes across her back and around her abdomen. This causes the female to release her eggs. The male then fertilizes the eggs and, in some species, also guards them.

Figure 10.17

Frogs develop from tadpoles, which develop from eggs. Notice the formation of the two powerful back legs used for jumping.

How Do Frogs Eat?

Adult frogs are meat-eaters and eat mostly insects, spiders, slugs and worms. Larger species will eat mice, birds, and even other small reptiles and amphibians. Frogs do not have teeth on their lower jaw, so they usually swallow their food whole. Some frogs have teeth on the upper jaw that are used to hold the prey in place.

Frogs and toads are responsible for keeping a large part of the world's insect population under control. They catch these insects using their long tongue. The frog tongue is about a third the length of the frog's body, though they can grow even longer. They can easily reach 12 inches long in an adult frog. Frog’s tongues are attached to the front of their mouths rather than at the back like humans. They release a sticky substance at the precise moment of impact with their food. When a frog catches an insect it throws its sticky tongue out of it’s mouth and wraps it around its prey. The frog’s tongue then snaps back and throws the food down its throat. This happens about as fast as a blink of your eyes.

Summary

- Frogs are characterized by long hind legs, webbed finger-like parts, a tympanum, and the lack of a tail.
- A frog's "ribbit" is a mating call used to attract females.

Explore More

Use the resources below to answer the questions that follow.

Explore More I

- **Amazing Rain Frogs - Life in Cold Blood** at http://www.youtube.com/watch?v=mISMwN-0ggE (3:30)

Click on the image above for more content

1. Where do Rain Frogs spend most of their time?
2. How does the Rain Frog mate?
3. Why is "glue" used in Rain Frog mating? What problems can this cause?
4. Why do Rain Frogs make their nurseries?
5. How is the Rain Frog's behavior adaptive to its environment.

Explore More II

- **Frogs and Toads: Red-Eyed Tree Frog's Life Cycle** at http://video.nationalgeographic.com/video/animals/amphibians-animals/frogs-and-toads/frog_greentree_lifecycle/ (2:50)

Click on the image above for more content

1. What characteristics are important to where the red-eyed tree frog lays its eggs?

Review

1. Distinguish between frogs and toads.
2. What are three characteristics of frogs?
3. What allowed frogs to become effective jumpers?
4. Why do frogs "ribbit"?
5. Describe the frog tadpole and the changes it undergoes.

Section 10

Role of Amphibians

Role of Amphibians

- •Describe the importance of amphibians to humans.
- •Discuss the use of amphibians as food.
- •Explain the role of amphibians in research.

Would you eat this?

This is a plate of frog legs! Many people would view this dish as a tasty treat. As you can see, one way amphibians are important to people is that they can be used as a food source.

Role of Amphibians

Humans have used amphibians for a number of purposes for thousands of years, if not longer. Amphibians play significant roles in many food webs and are thus an important part of many ecosystems. Humans have also consumed amphibians, especially frogs, probably since they first ate meat. More recently, amphibians have been tremendously useful in research.

Amphibians as Foods

Amphibians play important roles in many ecosystems, especially as middle players in many food chains and food webs. In addition to consuming many worms and insects and other arthropods, and even some small reptiles and mammals and fish, they are prey for turtles and snakes, as well as some fish and birds. Tadpoles keep waterways clean by feeding on algae.

Frogs are raised as a food source for humans. Frog legs are a delicacy in China, France, the Philippines, northern Greece, and the American south, especially the Frensh-speaking parts of Louisiana. Only the upper joint of the hind leg is served, which has a single bone similar to the upper joint of a chicken or turkey wing. They are commonly prepared by grilling or deep frying, sometimes breaded, though they can also be served with garlic, or turned into a soup or stew. Some estimates have well over a billion frogs harvested a year as food.

Amphibians in Research

Amphibians have long been used in scientific research, especially developmental and physiological processes, largely due to their unique ability to undergo metamorphosis, and in some species, to regenerate limbs. They are also used to study embryos because their eggs lack shells, so it is easy to watch their development.

The African clawed frog, *Xenopus laevis* , is a species that is studied to understand aspects of developmental biology. It is a good model organisms because it is easy to raise in a lab and has a large embryo, which is easy to study (**Figure** below). Many *Xenopus* genes have been identified and cloned, especially those involved in development. Developing *Xenopus* embryos can be easily observed and studied with a basic microscope, though the eggs are large enough to see without a microscope. Because of their size, the exact developmental stage after fertilization can be easily determined. This allows proteins that are used at a specific developmental time to be collected and analyzed.

Many environmental scientists believe that amphibians, including frogs, indicate when an environment is damaged. When species of frogs begin to decline, it often indicates that there is a bigger problem within the ecosystem. This could have dramatic effects on food webs and ecosystems.

- Frogs are raised as a food source in many parts of the world.
- Amphibian embryos are ideal to study development since they lack a shell.

Explore More

Use the resource below to answer the questions that follow.

- **Global Warming: Rocky Mountain Bio Lab: Amphibians** at http://video.nationalgeographic.com/video/environment/global-warming-environment/rm-amphibians/ (3:14)

Click on the image above for more content

1. What is an "indicator" species? Why are amphibians considered to be good indicator species?
2. What yearly fluctuations are seen in these alpine salamander populations?

Review

1. Describe the role of amphibians in the food chain.
2. How are amphibians important in environmental science?
3. Describe one way amphibians are used in research?

Section 11

Reptiles

Reptiles

- •Describe the main features of reptiles.
- •Define ectothermic.
- •Identify reptilian traits for life on land.
- •Describe reptile reproduction.

What does this chameleon have in common with a snake?

Though they are both reptiles and seem very different, chameleons and snakes actually share several traits. For example, they both have skin covered in scales and are cold-blooded animals. But notice the distinct eyes and "horns" on the chameleon. Snakes don't have these. And some chameleons have the ability to change color.

Characteristics of Reptiles

What reptiles can you name? Snakes, alligators, and crocodiles are all reptiles. Modern reptiles live on every continent except Antarctica. They range in size from the newly-discovered Jaragua Sphaero (a dwarf gecko), at 0.6 inches, to the saltwater crocodile, at up to 23 feet.

There are four living orders of reptiles:

1. Squamata, which includes lizards, snakes, and amphisbaenids (or “worm-lizards”).
2. Crocodilia, which includes crocodiles, gharials (**Figure** below), caimans, and alligators.
3. Testudines, which includes turtles and tortoises.
4. Sphenodontia, which includes tuatara (**Figure** below).

Figure 10.18

A gharial crocodile (*left*). A tuatara (*right*).

Traits of Reptiles

Reptiles are tetrapods (four-legged) and **ectothermic** , meaning their internal temperature depends on the temperature of their environment. This is why you may see reptiles sunbathing as they use the energy from the sun to warm their bodies. Usually the sense organs of reptiles, like ears, are well developed, though snakes do not have external ears. All reptiles have advanced eyesight. Reptiles also have a sense of smell. Crocodilians, turtles, and tortoises smell like most other land vertebrates. But, some lizards, and all snakes, smell with their tongues, which is flicked out of the mouth to pick up scent molecules from the air.

Reptiles also have several adaptations for living on land. They have a skin covered in scales to protect them from drying out. All reptiles have lungs to breathe air. Reptiles are also **amniotes** , which means their embryos are surrounded by a thin membrane. This membrane protects the embryo from the harsh conditions of living on land. Reptile eggs are also surrounded by a protective shell, which may be either flexible or inflexible.

How Do Reptiles Reproduce?

Most reptiles reproduce sexually, meaning there are two parents involved. In some families of lizards and one snake family, however, **asexual reproduction** is possible. This is when only one parent is involved in creating new life. For example, the gecko females can make tiny clones of themselves without the aid of a male.

All reptiles have a **cloaca** , a single exit and entrance for sperm, eggs, and waste, located at the base of the tail. Most reptiles lay amniotic eggs covered with leathery or hard shell. These eggs can be placed anywhere as they don't have to be in a moist environment, like the eggs of amphibians. However, not all species lay eggs, as certain species of squamates can give birth to live young.

Unlike the amphibians, there are no larval stages of development. The young reptiles look like miniature versions of the adult. The young reptiles are generally left to fend for themselves. However, some reptiles provide care for their young. For example, crocodiles and alligators may defend their young from predators.

Summary

- Reptiles are also amniotes, which means their embryos are surrounded by a thin membrane.
- Reptiles typically reproduce sexually and lay eggs.

Explore More

Use the resources below to answer the questions that follow.

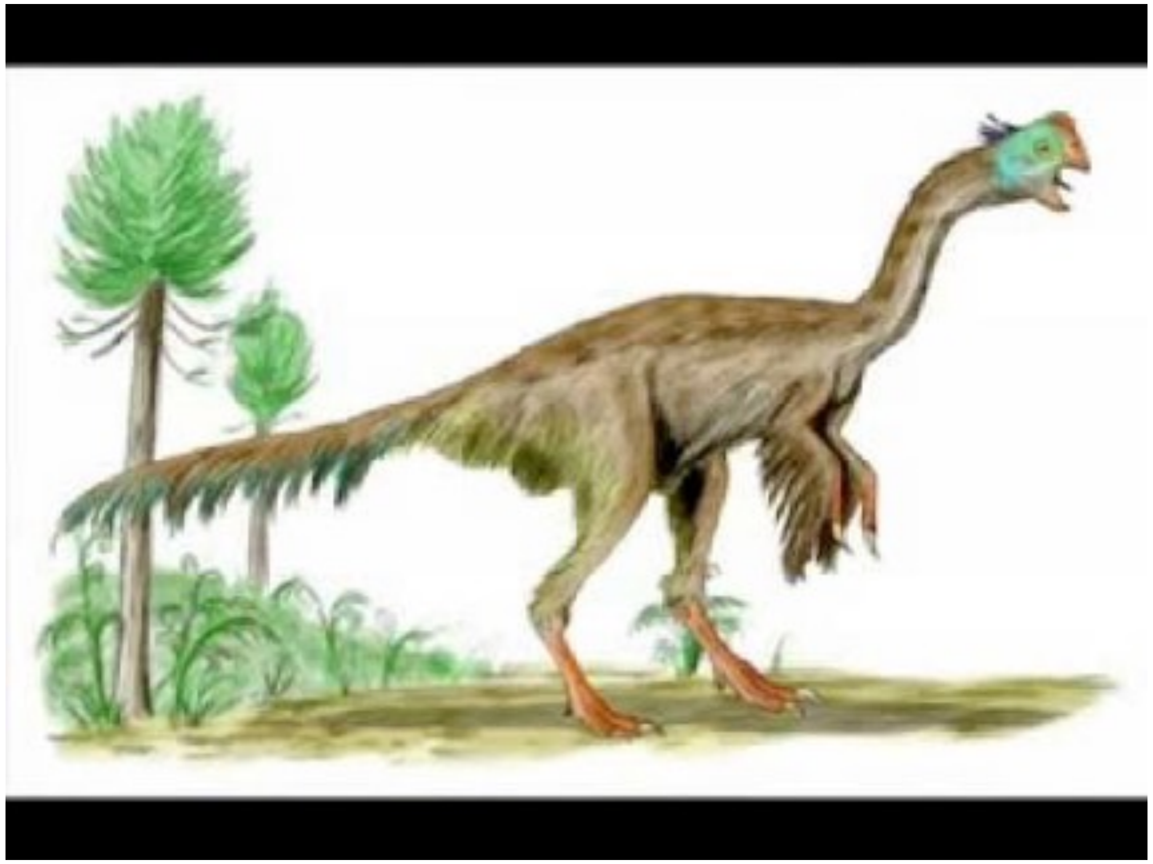
Explore More I

•**Fun Facts About reptiles and Amphibians** at http://nationalzoo.si.edu/animals/reptilesamphibians/facts/

1.Which continent does not have any reptiles?
2.Compare the amount of food eaten by reptiles and birds and mammals.
3.Name three poisonous snakes found in the United States.
4.What is the largest venomous snake anywhere?

Explore More II

•**Greatest Misconception 1: Birds Evolved from Dinosaurs** at http://www.youtube.com/watch?v=EUBcHOYls20 (2:06)



Click on the image above for more content

1.How does the stance of reptiles compare to the stance of birds?
2.Compare and contrast modern reptiles to modern birds. Include as many characteristics for both groups as you can.
3.Do ancient "reptiles" have all the same characteristics as present day reptiles? Explain your answer fully.

Review

1.Name four examples of reptiles.
2.What is ectothermic?
3.What are the reptilian adaptations for life on land?
4.Compared to the amphibian egg, what is special about the reptile egg?

Section 12

Lizards and Snakes

Lizards and Snakes

- •Describe the major traits of lizards and snakes.
- •Explain the significance of quadrate bones.

Are snakes deadly?

Some snakes are poisonous, but the majority of snakes are fairly harmless if they are left alone. This rat snake is actually beneficial to humans because it eats mice and rats, keeping those populations in balance. Some related species are so tame that they are often kept as pets.

Lizards and Snakes

Lizards and snakes belong to the largest order of reptiles, Squamata. Lizards are a large group of reptiles, with nearly 5,000 species, living on every continent except Antarctica.

Characteristics of Lizards and Snakes

Lizards and snakes are distinguished by scales or shields and movable **quadrate bones** , which make it possible to open the upper jaw very wide. Quadrate bones are especially visible in snakes, because they are able to open their mouths very wide to eat large prey (**Figure** below).

Figure 10.19

A corn snake swallowing a mouse.

Characteristics of Lizards

Key features of lizards include:

- Four limbs.
- External ears.
- Movable eyelids.
- A short neck.
- A long tail, which they can shed in order to escape from predators.
- They eat insects.

Vision, including color vision, is well-developed in lizards. You may have seen a lizard camouflaged to blend in with its surroundings. Since they have great vision, lizards communicate by changing the color of their bodies. They also communicate with chemical signals called **pheromones** .

Adult lizards range from one inch in length, like some Caribbean geckos, to the nearly 10-foot-long Komodo dragon (**Figure** below).

Figure 10.20

A Komodo dragon, the largest of the lizards, attaining a length of ten feet. Komodo dragons will eat just about anything and they often attack deer, goats, pigs, dogs and, occasionally, humans.

With 40 lizard families, there is an extremely wide range of color, appearance, and size of lizards. Many lizards are capable of regenerating lost limbs or tails. Almost all lizards are **carnivorous** , meaning they eat animals, although most are so small that insects are their primary prey. However, some have reached sizes where they can prey on birds and mammals. On the other hand, a few species of lizards exclusively eat plants.

Lizard Behavior

Many lizards are good climbers or fast sprinters. Some can run on two feet, such as the collared lizard. Some, like the basilisk, can even run across the surface of water to escape danger. Many lizards can change color in response to their environments or in times of stress (**Figure** below). The most familiar example is the chameleon, but more subtle color changes can occur in other lizard species.

Figure 10.21

A species of lizard, showing general body form and camouflage against background.

Legless Lizards

Some lizard species, including the glass lizard and flap-footed lizards, have evolved to lose their legs, or their legs are so small that they no longer work. This provides these species an evolutionary advantage in their way of life. Legless lizards almost look like snakes, though structures leftover from earlier stages of evolution remain. For example, flap-footed lizards can be distinguished from snakes by their external ears.

Characteristics of Snakes

Snakes are different from legless lizards because they do not have eyelids, limbs, external ears, or forelimbs. The more than 2,700 species of snake can be found on every continent except Antarctica and range in size from the tiny, 4-inch-long thread snake to pythons, to the over 17-foot-long anaconda (**Figure** below).

In order to fit inside of snakes' narrow bodies, paired organs, such as kidneys, appear one in front of the other instead of side by side. Snakes' eyelids are transparent "spectacle" scales which remain permanently closed. Most snakes are not venomous, but some have venom capable of causing painful injury or death to humans. However, snake venom is primarily used for killing prey rather than for self-defense.

Figure 10.22

A species of anaconda, one of the largest snakes, which can be as long as 17 feet.

Most snakes use specialized belly scales, which grip surfaces to move (**Figure** below). In the shedding of scales, known as **molting** , the complete outer layer of skin is shed in one layer (**Figure** below). Molting replaces old and worn skin, allows the snake to grow, and helps it get rid of parasites such as mites and ticks.

Figure 10.23

A close-up of scales on a scarlet kingsnake, showing a tricolored pattern of red, black, and white bands. Notice the distinction between the belly scales and the rest of the snake's scales.

Figure 10.24

A Centralian carpet python shedding its skin.

Although different snake species reproduce in different ways, all snakes use **internal fertilization,** where fertilization of the egg takes place inside the female. The male uses sex organs stored in its tail to transfer sperm to the female. Most species of snakes lay eggs, and most species abandon these eggs shortly after laying them.

How do Snakes Eat?

All snakes are strictly carnivorous, eating small animals including lizards, other snakes, small mammals, birds, eggs, fish, snails, or insects. Because snakes cannot bite or tear their food to pieces, prey must be swallowed whole. Therefore, the body size of a snake has a major influence on its eating habits.

The snake's jaw is unique in the animal kingdom. Snakes have a very flexible lower jaw, the two halves of which are not rigidly attached. They also have many other joints in their skull, allowing them to open their mouths wide enough to swallow their prey whole.

Some snakes have a venomous bite, which they use to kill their prey before eating it. Other snakes kill their prey by strangling them, and still others swallow their prey whole and alive. After eating, snakes enter a resting stage, while the process of digestion takes place. The process is highly efficient, with the snake's digestive enzymes dissolving and absorbing everything but the prey's hair and claws!

Summary

- Snakes and lizards are both in the order Squamata, distinguished by horny scales or shields and movable quadrate bones, which make it possible to open the upper jaw very wide.
- Snakes are different from legless lizards because they do NOT have eyelids, limbs, external ears, or forelimbs.

Explore More

Use the resources below to answer the questions that follow.

Explore More I

•**Lizards, Snakes, and Poisonous Animals Roaming the Deserts of Australia** at http://www.youtube.com/watch?v=bWfslaxznGw (3:01)

Click on the image above for more content

1. How many species of reptiles can be supported by a single sand dune in the Australian desert?
2. Are there more mammals or reptiles in the Australian desert?
3. How does the physiology of reptiles and mammals explain their observed abundances in the Australian desert?
4. Where do goanna lizards (*Varanus spp.*) lay their eggs? What about the environment they live in leads them to choose this location?

Explore More II

•Go to this link to see how a Komodo dragon (*Varanus komodoensis*) hunts: http://dsc.discovery.com/tv-shows/life/videos/komodo-dragons-hunt-buffalo.htm

1. Would the hunting strategy of a Komodo dragon be effective for mammals? Explain and defend your answer

Explore More III

•**Amazing Arctic Snakes Mating and Fighting - Deadly Vipers** at http://www.youtube.com/watch?v=7TF7d4jvays (3:50)

Click on the image above for more content

1. How many months a year are snakes active above the Arctic Circle?
2. Why is black a good color for snakes above the Arctic Circle? How does this explain why the black snakes tend to be bigger than the zigzag patterned snakes?
3. Why is it advantageous for females above the Arctic Circle to be black? Consider how this impacts their reproductive success.

Review

1. List three characteristics of lizards.
2. How are snakes different from legless lizards?
3. How do snakes eat? Describe the snake jaw.

Section 13

Alligators and Crocodiles

Alligators and Crocodiles

- •Describe the features of alligators and crocodiles.
- •Describe crocodilian senses.
- •Explain sex determination in crocodilians.

Crocodile or Alligator?

This picture is a crocodile, identified by it's V-shaped snout. Alligators have more of a U-shaped snout. Although crocodiles and alligators have a few differences, they are very much alike and belong to the same order, Crocodilia.

Alligators and Crocodiles

Crocodilia, containing both alligators and crocodiles, is an order of large reptiles. Reptiles belonging to Crocodilia are the closest living relatives of birds. Reptiles and birds are the only known living descendants of the dinosaurs.

The basic crocodilian body plan (**Figure** below) is a very successful one and has changed little over time. Modern species actually look very similar to their Cretaceous ancestors of 84 million years ago. All species of crocodilians have similar body structures, including an elongated snout, powerful jaws, muscular tail, large protective scales, streamlined body, and eyes and nostrils that are positioned on top of the head.

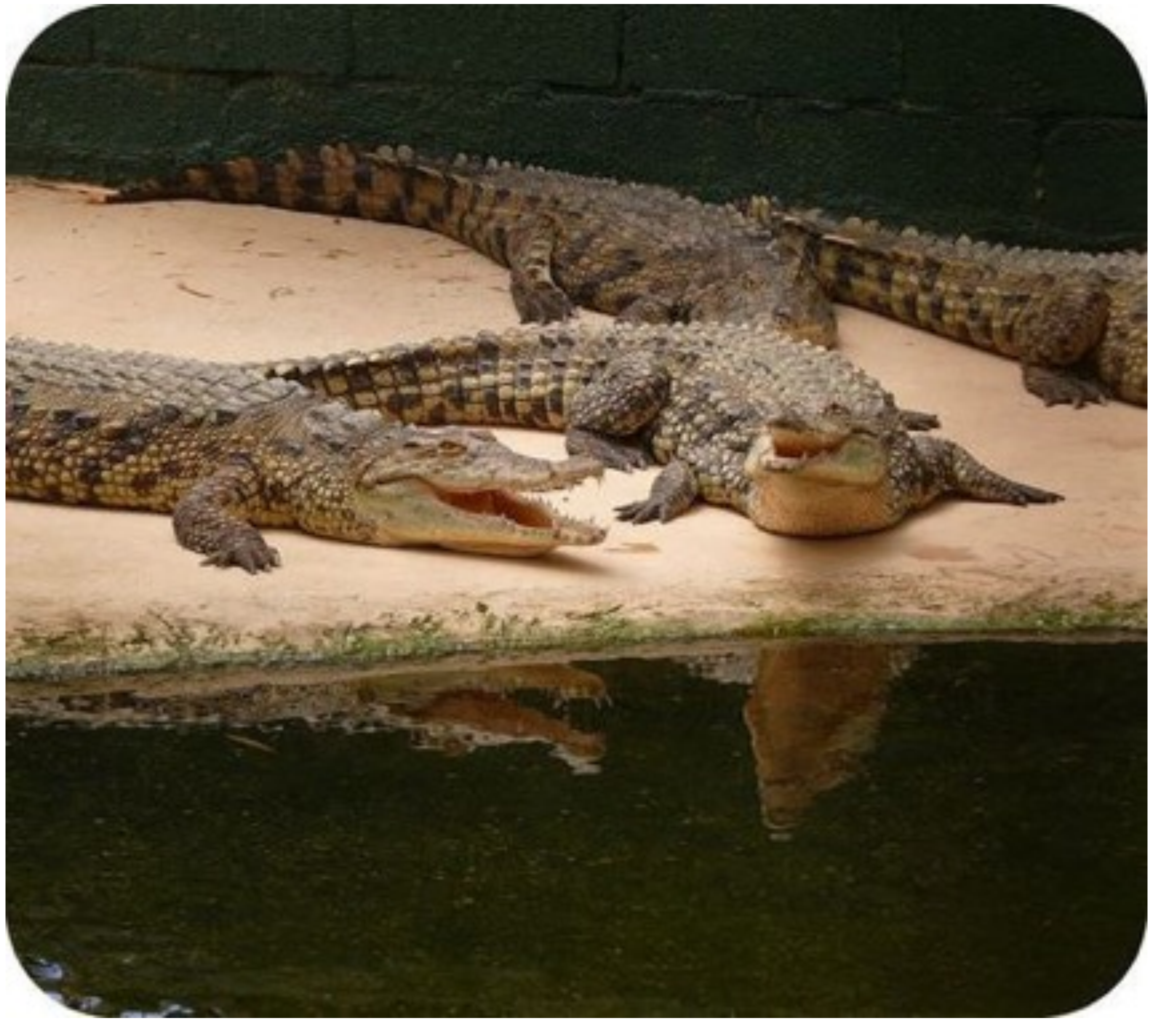


Figure 10.25

Nile crocodiles display the basic crocodilian body plan.

Characteristics of Crocodiles

Crocodilians have a flexible, semi-erect posture. They can walk either in a low, sprawled “belly walk,” or hold their legs more directly underneath them to perform the “high walk.” Most other reptiles can only walk in a sprawled position.

All crocodilians have, like humans, teeth set in bony sockets. But unlike mammals, they replace their teeth throughout life. Crocodiles and gharials (large crocodilians with longer jaws) have salivary glands on their tongue, which are used to remove salt from their bodies. Crocodilians are often seen lying with their mouths open, a behavior called **gaping** . One of its functions is probably to cool them down.

Crocodilians are known to swallow stones, known as **gastroliths** , which help digest their prey. The crocodilian stomach is divided into two chambers. The first is powerful and muscular. The other stomach is the most acidic digestive system of any animal. It can digest mostly everything from their prey, including bones, feathers, and horns!

All crocodilians are carnivores. They feed on live animals such as birds, small mammals and fish. Crocodilians use several methods of attack when pursuing live prey. One approach is that of the ambush. The crocodilian lies motionless beneath the water's surface with only their nostrils above the water line. This keeps them concealed while they watch for prey that approaches the water's edge. The crocodilian then lunges out of the water, taking their prey by surprise and dragging it from the shoreline into deep water where the prey is killed.

The sex of developing crocodilians is determined by the temperature of the eggs during **incubation** , when eggs are kept warm before they hatch. This means that the sex of crocodilians is not determined genetically. If the eggs are kept at a cold or a hot temperature, then their offspring may be all male or all female. To get both male and female offspring, the temperature must be kept within a narrow range.

Female crocodilians care for the young after they hatch, providing them with protection until they grow large enough to defend themselves. In many species of crocodilians, the female carries her tiny offspring in her mouth.

Evolving More Complex Structures

Like all reptiles, crocodilians have a relatively small brain, but the crocodilian brain is more advanced than those of other reptiles. Because of their aquatic habitat, the eyes, ears, and nostrils are all located on the same "face" in a line one after the other.

The crocodiles have advanced sensory organs. They see well during the day and may even have color vision, and they also have excellent night vision. A third transparent eyelid, the **nictitating membrane** , protects their eyes underwater. The eardrums are located behind the eyes and are covered by a movable flap of skin. This flap closes, along with the nostrils and eyes, when they dive. This prevents water from entering their external head openings. Their jaws are covered with **sensory pits** , which hold bundles of nerve fibers that respond to the slightest disturbance in surface water. Crocodiles can detect vibrations and small pressure changes in water. This makes it possible for them to sense prey and danger even in total darkness.

Like mammals and birds, and unlike other reptiles, crocodiles have a four-chambered heart. But, unlike mammals, blood with and without oxygen can be mixed.

See *Supersize Crocs* at http://www.pbs.org/wnet/nature/episodes/supersize-crocs/interactive-crocodile-anatomy/1747/ for additional material on the anatomy of a crocodile.

Summary

- Crocodilians swallow stones, known as gastroliths, which help digest their prey.
- The sex of developing crocodilians is determined by the temperature of the eggs during incubation.
- The crocodiles have advanced sensory organs, including keen eyesight, eardrums, and sensory pits that detect disturbances in the water.

Explore More

Use the resources below to answer the questions that follow.

Explore More I

- **American Alligator** at http://animals.nationalgeographic.com/animals/reptiles/american-alligator/

1. Where do American alligators live?
2. What do alligators eat?
3. What conditions have led to the recovery of the American alligator?

Explore More II

- **Bubble-Blowing Saltwater Crocodiles** at http://www.youtube.com/watch?v=5OntFsIwGEw (1:53)

Click on the image above for more content

1. In what kind of courting displays do saltwater crocodiles (*Crocodylus porosus*) engage?
2. Do saltwater crocodiles have internal or external fertilization?

Explore More III

- **Baby Siamese Crocodiles** at http://www.youtube.com/watch?v=CUQMkS8Et2s (4:05)

Click on the image above for more content

1. What kind of maternal care do crocodile mothers show their young? When does this care begin?
2. What do baby crocodiles do as soon as they hatch?
3. Why is it important for mother crocodiles to guard their nests?

Review

1. Name four features that all crocodilians share.
2. How is the sex of alligators and crocodiles determined?
3. Describe digestion in the crocodilians.
4. Describe the special sensory organs of crocodiles.

Section 14

Turtles

Turtles

•Describe the features of the turtles.
•Explain how turtles obtain nutrition.

What are these?

This picture might look like a bunch of ping-pong balls, but actually it's a picture of turtle eggs. Notice the soft, leathery shell that is typical of reptile eggs.

Turtles

Turtles are reptiles in the order Testudines. If you have seen turtles before, what is the most noticeable thing about them? Their shells. Most turtle bodies are covered by a special shell developed from their ribs. Their shells can be bony or **cartilaginous** , made from a more flexible supportive tissue. About 300 species are alive today, and some are highly endangered. Like other reptiles, turtles cannot regulate their body temperature, except with behavioral means, such as burrowing underground. The major difference between turtles and tortoises is that the land dwelling ones are called tortoises and water dwelling are called turtles.

Turtles are broken down into two groups, based on how they bring their neck back into their shell:

1. Cryptodira, which can draw their neck inside and under their spine.
2. Pleurodira, which fold their necks to one side.

Characteristics of Turtles

Although many turtles spend large amounts of their lives underwater, they can also spend much of their lives on dry land and breathe air. Turtles cannot breathe in water, but can hold their breath for long periods of time. Turtles must surface at regular intervals to refill their lungs.

The position of a turtle's eyes can give a clue to their natural habitat. Most turtles that spend most of their lives on land have their eyes looking down at objects in front of them.

Some aquatic turtles, such as snapping turtles and soft-shelled turtles, have eyes closer to the top of the head. These species of turtles can hide from predators in shallow water, where they lie entirely submerged in water except for their eyes and nostrils.

Sea turtles (**Figure** below) have glands near their eyes that produce salty tears, which remove excess salt taken in from the water they drink.

Figure 10.26

A species of sea turtle, showing placement of eyes, shell shape, and flippers.

Turtles have exceptional night vision due to the unusually large number of cells that sense light in their eyes. Turtles also have color vision.

Turtles don't lay eggs underwater. Turtles lay slightly soft and leathery eggs, like other reptiles. The eggs of the largest species are spherical, while the eggs of the rest are longer in shape. After internal fertilization, a female is ready to lay her eggs, she places a large numbers of eggs in holes dug into mud or sand. They are then covered and left to grow and develop by themselves. When the turtles hatch, they squirm their way to the surface and head toward the water. They need to get to the water as fast as possible before they are fed upon by animals such as seabirds, crabs, and raccoons.

How do Turtles Eat?

Turtles can be either herbivores or carnivores, with most sea turtles **carnivorous** . Turtles have a rigid beak and use their jaws to cut and chew food. Instead of teeth, the upper and lower jaws of the turtle are covered by horny ridges. Carnivorous, or animal-eating turtles usually have knife-sharp ridges for slicing through their prey. But as the turtle is not a very fast animal, and it cannot quickly turn its head to snap at prey, it does have some limitations. Sea turtles typically feed on jellyfish, sponges and other soft-bodied organisms. Some species of sea turtle with stronger jaws, eat shellfish while some species, such as the green sea turtle do not eat any meat at all. Herbivorous turtles have serrated ridges that help them cut through tough plants.

How Big Are Turtles?

The largest turtle is the great leatherback sea turtle (**Figure** below), which can have a shell length of seven feet and can weigh more than 2,000 pounds. The only surviving giant tortoises are on the Seychelles and Galápagos Islands and can grow to over four feet in length and weigh about 670 pounds (**Figure** below). The smallest turtle is the speckled padloper tortoise of South Africa, measuring no more than three inches in length, and weighing about five ounces. The largest ever turtle was the know extinct *Archelon* genus, a Late Cretaceous sea turtle known to have been up to 15 ft long, and 16 ft wide from flipper to flipper. The closest living relative of this genus is the leatherback sea turtle.

Figure 10.27

The leatherback turtle can reach up to seven feet in length and weigh over 2,000 pounds.

Figure 10.28

A giant tortoise can grow to over feet ft in length and weigh about 670 lb. These animals can easily live over 100 years, spending their days grazing on grass, leaves, and cactus, basking in the sun, and napping nearly 16 hours each day.

Summary

- •Most turtle bodies are covered by a special bony or cartilaginous shell developed from their ribs.
- •Turtles cannot breathe in water, although many turtles spend large amounts of their lives underwater.

Explore More

Use the resources below to answer the questions that follow.

Explore More I

•**A Moment of Science** at http://www.youtube.com/watch?v=963t4MN80eM (1:25)

Click on the image above for more content

1.How does cloacal respiration work?
2.Why is this sort of respiration vital for the turtles?

Explore More II

•**The Leatherback Turtles and Ocean Currents** at http://www.youtube.com/watch?v=mPH8LI_EgPk (4:06)

Click on the image above for more content

1.How many populations of leatherback turtles (*Dermochelys coriacea*) are there in the Pacific Ocean?
2.Why do scientists feel that beaches like Playa Grande are important to the survival of this species?
3.How could natural selection explain why leatherback turtles favor beaches like Playa Grande?

Review

1.How are turtles divided into two groups?
2.How and what do turtles eat?
3.Do turtles breath underwater? Explain.

Section 15

Importance of Reptiles

Importance of Reptiles

•Describe how reptiles are important to humans.
•Describe the use of reptiles as food.
•Summarize the use of reptiles as pets.
•Explain the place of reptiles in the arts and in culture.

What good are reptiles?

There is a lot of fear surrounding snakes and other reptiles. What you might not realize is that reptiles do a lot of good. For example, snakes eat rats and other small animals. Rats can carry diseases to people, so keeping their population under control is very important.

Importance of Reptiles

Reptiles play an important role in the life of humans. In addition to playing an important role in many food chains, which keep the populations of small animals under control, reptiles serve as food, pets, and have played roles in art and culture for thousands of years.

Reptiles as Food

Reptiles are important as food sources for people:

•Green **iguanas** , a type of large lizard, are eaten in Central America.
•The tribals of Irulas from Andhra Pradesh and Tamil Nadu in India are known to eat some of the snakes they catch.
•Cantonese snake soup is consumed by local people in the fall to prevent colds. The soup is believed to warm up their body of those who eat it.
•Cooked rattlesnake meat is commonly consumed in parts of the Midwestern United States.
•Turtle soup is consumed throughout the world.

Reptiles as Pets

Reptiles also make good pets. In the Western world, some snakes, especially less aggressive species, like the ball python or corn snake, are kept as pets. Turtles, particularly small land-dwelling and freshwater turtles, are also common pets. Among the most popular are Russian tortoises, Greek spur-thighed tortoises, and terrapins. Large constrictor snakes like pythons, boa constrictors, and anacondas are powerful wild animals capable of killing an adult human, and they are commonly kept as pets. Many people don't think this is a wise idea, as these reptiles pose dangerous threats to people, especially children.

Reptiles are capable of recognizing people by voice, sight and smell; many are capable of learning. Some species actually benefit from interaction with humans. When cared for properly, all live as long or longer than mammalian pets of similar size. Having a reptile as a pet, you get to learn about everything from adaptation, behavior and the environment, to nutrition, camouflage and reproductive strategies. Learning about the natural history and proper captive care of these animals just might change your world outlook and get you thinking more about the environment as a whole.

Keep in mind that if you want to have a snake as a pet, that there are no herbivorous snakes, and you must be willing to feed it a proper diet. Be prepared to feed your snake or other reptile mice, rats, birds' eggs, insects, or fish. And these need to be served raw. Of course, the herbivorous reptiles, such as the green iguanas and some tortoises, are much easier to feed. They eat foods such as chopped collard greens, romaine lettuce, chopped squash and bananas.

Reptiles in Art and Culture

Finally, reptiles play a significant role in folklore, religion, and popular culture. The Moche people of ancient Peru worshipped reptiles and often put lizards in their art. Snakes or serpents are connected to healing and to the Devil. Since snakes shed and then heal again, they are a symbol of healing and medicine, as shown in the **Rod of Asclepius** (**Figure** below). In Egyptian history, the Nile cobra is found on the crown of the pharaoh. This snake was worshiped as one of the gods.

Figure 10.29

The Rod of Asclepius, where the snake is a symbol of healing and medicine.

Reptiles have also played roles in more recent popular culture. Unforgettable reptiles include Leonardo, Donatello, Michaelangelo, and Raphael, otherwise known as the Teenage Mutant Ninja Turtles, and Godzilla, one of the most famous movie reptiles who has been terrorizing Japanese cities for years. Dino, from *The Flintstones* is one of the more lovable television reptiles. On the other hand is Nagini from the *Harry Potter* series. This tremendously long snake (roughly 12 feet) is difficult to forget as she was very important to Lord Voldemort. Though her appearances are far and few between, her unwavering loyalty to the Dark Lord makes her one of the more infamous reptiles.

Summary

- Reptiles are eaten as food and kept as pets.
- Reptiles have served as symbols in folklore, religion, and popular culture.

Explore More

Use the resource below to answer the questions that follow.

- **From Hairy Feet to High Tech** at http://www.youtube.com/watch?v=uEYcY7WfDTY (5:46)

Click on the image above for more content

1. Explain how gecko lizards can climb walls and walk across ceiling?
2. What do you find on the tips of the hairs on geckos' feet? Why are these important to their climbing ability?
3. What is gecko tape?
4. What uses can you imagine for gecko tape? List two uses.

Review

1. What would be the downside if you exterminated all snakes?

2.What dangerous snakes are kept as pets? Why is this not a good idea?
3.What reptile is your favorite? Why?

Section 16

Birds

Birds

•Define endothermic.
•Describe the characteristics of birds.
•Summarize the adaptations in birds for flight.
•Explain the role of the aerofoil.

Can all birds fly?

No, not all birds can fly. And not all birds have wings. This penguin is a good example. Their wings have evolved into flippers, adapted for swimming instead of flying. The kiwi of New Zealand is another bird without wings.

Characteristics of Birds

How many different types of birds can you think of? Robins, ostriches, hummingbirds, chickens, and eagles. All of these are birds, but they are very different from one another. There is an amazingly wide variety of birds. Like amphibians, reptiles, mammals, and fish, birds are **vertebrates** . What does that mean? It means they have a backbone. Almost all birds have forelimbs modified as wings, but not all birds can fly. In some birds, the wings have evolved into other structures.

Birds are in the class Aves. All birds have the following key features: they are **endothermic** (warm-blooded), have two legs, and lay eggs.

Birds range in size from the tiny two-inch bee hummingbird to the nine-foot ostrich (**Figure** below). With approximately 10,000 living species, birds are the most numerous vertebrates with four limbs. They live in diverse habitats around the globe, from the Arctic to the Antarctic.

Figure 10.30

The ostrich can reach a height of nine feet! Pictured here is an ostrich with her young in the Negev Desert, southern Israel.

Features of Birds

The digestive system of birds is unique, with a **gizzard** that contains swallowed stones for grinding food. Birds do not have teeth. What do you think the stones do? They help them digest their food. Defining characteristics of modern birds also include:

- Feathers.
- High metabolism.
- A four-chambered heart.
- A beak with no teeth.
- A lightweight but strong skeleton.
- Production of hard-shelled eggs.

Which of the above traits do you think might be of importance to flight?

Adaptations for Flight

In comparing birds with other vertebrates, what do you think distinguishes them the most? In most birds, flight is the obvious difference. Birds have adapted their body plan for flight:

- Their skeleton is especially lightweight, with large, air-filled spaces connecting to their respiratory system.
- Their neck bones are flexible. Birds that fly have a bony ridge along the breastbone that the flight muscles attach to (**Figure** below). This allows them to remain stable in the air as they fly.
- Birds also have wings that function as an **aerofoil** . The surface of the aerofoil is curved to help the bird control and use the air currents to fly. Aerofoils are also found on planes.

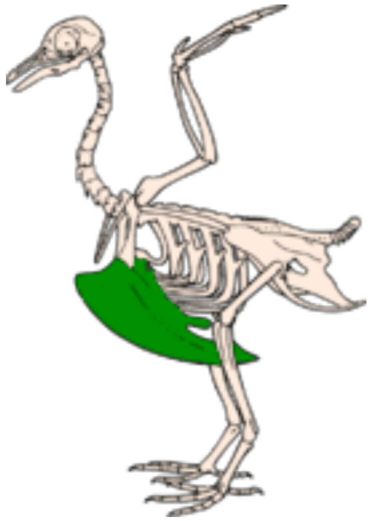


Figure 10.31

A bony ridge along the breastbone (green) allows birds to remain stable as they fly.

What other traits do you think might be important for flight? Feathers help because they're more lightweight than scales or fur. A bird’s wing shape and size will determine how a species flies. For example, many birds have powered flight at certain times, requiring the flapping of their wings, while at other times they soar, using up less energy (**Figure** below).

Figure 10.32

One bird's flight.

About 60 living bird species are flightless, such as penguins, as were many extinct birds. Flightlessness often evolves when birds live on isolated islands. The absence of land predators might make flying no longer necessary. Other birds evolved into new niches where flying was no longer necessary. This may have been in response to limited resources. For example, the flightless cormorant can no longer fly, but its wings are now adapted to swim in the sea (**Figure** below).

Figure 10.33

A flightless cormorant can no longer fly, but it uses its wings for swimming.

Summary

- Birds are endothermic (warm-blooded), have beaks, and lay eggs.
- Adaptations for flight include a lightweight skeleton and flexible neck bones.

Explore More

Use the resources below to answer the questions that follow.

Explore More I

- **Birds Vertebrates** at http://www.youtube.com/watch?v=jGkP7IrDp_4 (5:19)

Click on the image above for more content

1. What benefits do birds gain from being able to fly?
2. Where do you see scales on birds?
3. What do scientists think was the first use of feathers?
4. How are the feathers of birds similar to the fur of mammals? Consider this question in terms of form and function.
5. How do the oxygen requirements of birds differ from the oxygen requirements of reptiles? Why does this difference exist?

Explore More II

- **Emperor Penguin** at http://animals.nationalgeographic.com/animals/birds/emperor-penguin/

1. Where do Emperor penguins live?
2. How do they conserve warmth?
3. What do they eat?

Review

1. Can all birds fly?
2. What are three key features of birds?
3. What is unique about a bird's digestive system?
4. How are birds adapted for flight?

Section 17

Bird Reproduction

Bird Reproduction

- •Describe how birds reproduce,
- •Summarize how bird parents care for their offspring.
- •Compare altricial to precocial.
- •Define brood parasitism.

Why do peacocks have huge, bright feathers?

Male peacocks use their colorful feathers to attract females. Females tend to mate with the males with the largest, brightest feathers. A large, bright tail indicates the male is healthy and likely to produce healthy offspring. You've probably also heard birds "sing." Eagles do aerial acrobatics and tumbling. These are other ways to attract mates.

Reproduction in Birds

How do birds reproduce? We know that chickens lay eggs. But how do they do that?

It all starts with behavior aimed at attracting a mate. In birds, this will involve a type of display, usually performed by the male. Some displays are very elaborate and may include dancing, aerial flights, or wing or tail drumming. Most male birds also sing a type of song to attract females. If they are successful at attracting a female, it will lead to breeding.

Birds reproduce by **internal fertilization** , during which the egg is fertilized inside the female. Like reptiles, birds have **cloaca** , or a single exit and entrance for sperm, eggs, and waste. The male brings his sperm to the female cloaca. The sperm fertilizes the egg. Then the hard-shelled egg develops within the female. The hard-shelled eggs have a fluid-filled **amnion** , a thin membrane forming a closed sac around the embryo. Eggs are usually laid in a nest.

Protecting Offspring

Why do you think eggs come in so many different colors? Birds that make nests in the open have camouflaged eggs (**Figure** below). This gives the eggs protection against predation. Some species, like ground-nesting nightjars, have pale eggs, but the birds camouflage the eggs with their feathers.

To protect their young, different species of birds make different nests. Birds of all types, from hummingbirds to ostriches, make nests. Many can be elaborate, shaped like cups, domes, plates, mounds, or burrows. However, some birds, like the common guillemot, do not use nests. Instead, they lay their eggs on bare cliffs. Emperor penguins do not have a nest at all; they sit on eggs to keep them warm before they hatch, a process called **incubation** .

How else might a bird help protect its young from predators? Most species locate their nests in areas that are hidden, in order to avoid predators. Large birds, or those that nest in groups, may build nests in the open, since they are more capable of defending their young.

Figure 10.34

Nest and eggs of the common moorhen, showing camouflaged eggs.

Parental Care

In birds, 90% to 95% of species are **monogamous** , meaning the male and female remain together for breeding for a few years or until one mate dies. Birds of all types, from parrots to eagles and falcons, are monogamous. Usually, the parents take turns incubating the eggs. Birds usually incubate their eggs after the last one has been laid. In **polygamous** species, where there is more than one mate, one parent does all of the incubating. The wild turkey is an example of a polygamous bird.

The length and type of parental care varies widely amongst different species of birds. At one extreme, in a group of birds called the magapodes (which are chicken-like birds), parental care ends at hatching. In this case, the newly-hatched chick digs itself out of the nest mound without parental help and can take care of itself right away. These birds are called **precocial** . Other precocial birds include the domestic chicken and many species of ducks and geese. At the other extreme, many seabirds care for their young for extended periods of time. For example, the chicks of the Great Frigatebird receive intensive parental care for six months, or until they are ready to fly, and then take an additional 14 months of being fed by the parents (**Figure** below). These birds are the opposite of precocial birds and are called **altricial** .

In most animals, male parental care is rare. But it is very common in birds. Often both parents share tasks such as defense of territory and nest site, incubation, and the feeding of chicks. Since birds often take great care of their young, some birds have evolved a behavior called **brood parasitism.** This happens when a bird leaves her eggs in another bird's nest. The host bird often accepts and raises the parasite bird's eggs.

Figure 10.35

Great Frigatebird adults are known to care for their young for up to 20 months after hatching, the longest in a bird species. Here, a young bird is begging for food.

Summary

- •Birds often use flashy displays to attract mates.
- •Breeding in birds is through internal fertilization, where the egg is fertilized inside the female.
- •Birds generally are monogamous, and both parents help to care for the young.

Explore More

Use the resources below to answer the questions that follow.

Explore More I

- **Male Birds Show Off** at http://www.youtube.com/watch?v=gqsMTZQ-pmE (3:24)

Click on the image above for more content

1. Describe two of the displays used by male pheasants to attract females.
2. Why might a display be dangerous for the African widow bird?
3. Why do you think birds maintain mating displays which are dangerous to them? What benefit do they seem to gain?

Explore More II

- **Reproduction in Fish and Birds** at http://www.youtube.com/watch?v=jGnTTcVA5xk (5:07)

Click on the image above for more content

1. Do you think that the complexity of birds' mating behavior is reflective of their intelligence? Explain your response.
2. How long do mated bird pairs stay together?

3. Why is parental care by both parents important for some birds?

Review

1. What are examples of displays used by birds to attract mates?
2. Describe parental care of offspring in birds.
3. Distinguish between altricial and precocial birds.
4. Give three examples of precocial birds.
5. What is brood parasitism?

Section 18

Diversity of Birds

Diversity of Birds

- •Describe how birds can vary.
- •Define generalist.
- •Describe differences in bird beaks and feet.

How are birds different?

Not all birds look the same. They are obviously different in many ways. They come in all colors and sizes. They live in a variety of habitats. They eat a variety of foods.

Diversity of Birds

Turkey, hummingbird, penguin, parrot, owl and eagle. These are just some of the many different types of birds. If you just think about the birds in this list, the differences are striking. About 10,000 bird species belong to 29 different orders within the class Aves. They live and breed on all seven continents. The tropics are home to the greatest biodiversity of birds. The diversity among birds is striking. Birds can vary greatly in size and color. Some fly, some swim, some just walk or run. Some are savage carnivores, others are gentle herbivores. Some are low on the food chain, others are at the top.

Birds live in a variety of different habitats. Birds that live in different habitats will encounter different foods and different predators. Birds can be **carnivores** (feeding on other animals), **herbivores** (feeding on plants), or **generalists** (feeding on a variety of foods). The lifestyle of the bird can affect what it looks like. For example, can you think of some examples of beaks that are adapted to the type of food a bird eats? Carnivorous birds include hawks, falcons, eagles, osprey, vultures and owls. Herbivorous birds include the goose, cockatoo and parrot. The American Crow is an example of a generalist. In addition, a specialist is a bird (or other animal) that is specially adapted to eat a certain food. An example of a specialist is a hummingbird, whose long, thin beak is excellent for reaching into flowers for nectar, but not very good for eating other foods.

Waterfowl are birds that live on the water. These include ducks, geese, swans, and pelicans, to name a few. Landfowl are ground-feeding birds such as chickens and turkeys. Penguins are a group of flightless birds adapted for life in the water with flippers. Diurnal raptors are birds of prey that hunt during the day. These include falcons, eagles and hawks. Nocturnal raptors hunt during the night. These include various types of owls. Parrots are brightly colored and very intelligent. They are found in the tropics and include cockatoos, parrots, and parakeets.

Beaks

The size and shape of the beak is related to the food the bird eats and can vary greatly among different birds. Parrots have down-curved, hooked bills, which are well-adapted for cracking seeds and nuts (**Figure** below). Hummingbirds, on the other hand, have long, thin, pointed bills, which are adapted for getting the nectar out of flowers (**Figure** below). Hawks, eagles, falcons and owls have a sharp, hooked beak.

Figure 10.36

(*left*) The down-curved, hooked bill of a scarlet macaw, a large colorful parrot. (*right*) A long, thin and pointed bill of the hummingbird.

Feet

Bird feet can also vary greatly among different birds. Some birds, such as gulls and terns and other waterfowl, have webbed feet used for swimming or floating (**Figure** below). Other birds, such as herons, gallinules, and rails, have four long spreading toes, which are adapted for walking delicately in the wetlands (**Figure** below). You can predict how the beaks and feet of birds will look depending on where they live and what type of food they eat. Flightless birds also have long legs that are adapted for running. Flightless birds include the ostrich and kiwi.

Raptors have clawed feet. They also have strong legs. Hawks, eagles and falcons also have excellent vision and they hunt by sight. Owls, with excellent hearing, can hunt by that sense alone.

Figure 10.37

(*left*) The webbed feet of a great black-backed gull. (*right*) The long spreading toes of an American purple gallinule.

See **Wild African Vulture Birds Scavage Bones of Dead Animals** at http://www.youtube.com/watch?v=zxj9YO4Qtx0 and **Ruby-Throated Hummingbird** at http://animals.nationalgeographic.com/animals/birds/ruby-throat-hummingbird/ for additional information.

Click on the image above for more content

Summary

- Birds have beaks adapted for what foods they eat.
- The feet of birds can be adapted for their specific habitat.

Explore More

Use the resources below to answer the questions that follow.

Explore More I

- **Evolution Birds Dinosaurs** at http://www.youtube.com/watch?v=ah_9qmAj5k8 (6:58)

Click on the image above for more content

1. How big were velociraptors?
2. How does the skeleton of a bird compare to the skeleton of a velociraptor? Cite as many examples as you can.
3. Were birds descended from herbivorous dinosaurs or carnivorous dinosaurs? What evidence leads scientists to this conclusion?
4. What is the significance of the fossil, "Dave" from China?
5. Why do the teeth of velociraptors suggest they preyed on animals larger than themselves?

Explore More II

- **Diving with Penguins** at http://www.youtube.com/watch?v=OyNuupV-09U (3:58)

Click on the image above for more content

1. What are the penguins in the video feeding on?

2.How do penguins store oxygen differently than other birds? How is this related to their lifestyle?
3.Why do penguins control how much oxygen they carry in their lungs when they dive?

Explore More III

•Flying with the Fastest Birds on the Planet: Peregrine Falcon & Gos Hawk http://www.youtube.com/watch?v=p-_RHRAzUHM (3:02)

Click on the image above for more content

1.What is the fastest animal on the planet? How fast is this animal?
2.How much g-force can a diving raptor experience? How would humans respond to these forces?

Review

1.What is a generalist? Name one bird that is a generalist.
2.List three carnivorous birds.
3.Give two examples of flightless birds.
4.Give two examples of how a bird's beak is adapted to a specific food source.
5.Give two examples of how a bird's feet are adapted to a specific environment.

Section 19

Importance of Birds

Importance of Birds

- •Describe how birds are important to people.
- •Summarize the roles of birds within an ecosystem.
- •Explain the role of birds as pollinators.

Do you eat birds?

If you've eaten a turkey or a chicken nugget, then you've eaten a bird! Providing a food source is just one way that birds are important to humans. In the United States, more than 230 million turkeys are consumed each year, with almost 50 million of those turkeys being eaten at Thanksgiving.

Importance of Birds

You are probably familiar with birds as food. People have always hunted birds for food. People eventually discovered that certain wild fowl (ducks, chickens, turkeys) could be tamed. This discovery led to the development of poultry, which is domesticated fowl that farmers raise for meat and eggs. Chickens are probably the oldest kinds of poultry. Chickens were domesticated in Asia at least 3,000 years ago. Since then, farmers have developed other poultry, including ducks, geese, guineafowl, pheasants, and turkeys. Around the world, people consume all these birds, and even more exotic birds, like ostriches. Today, chickens rank as the most widely raised poultry by far. Farmers throughout the world produce hundreds of millions of chickens annually for meat and eggs. Ducks and turkeys rank second and third in production worldwide. Ducks are raised for both meat and eggs. Turkeys are raised mainly for meat.

Can you think of other ways that birds are important?

Birds and Humans

1.In agriculture, humans harvest bird droppings for use as fertilizer. These droppings have a high content of nitrogen, phosphate, and potassium, three nutrients essential for plant growth.
2.Chickens are also used as an early warning system of human diseases, such as West Nile virus. Mosquitoes carry the West Nile virus, bite young

chickens and other birds, and infect them with the virus. When chickens or other birds become infected, humans may also become infected in the near future.
3.Birds have important cultural relationships with humans. Birds are common pets in the Western world. Common bird pets include canaries, parrots, finches, and parakeets. Sometimes, people act cooperatively with birds. For example, the Borana people in Africa use birds to guide them to honey that they use in food.
4.Birds also play prominent and diverse roles in folklore, religion, and popular culture. They have been featured in art since prehistoric times, when they appeared in early cave paintings. Many young child know of Big Bird, a very large canary of *Sesame Street* fame.
5.Feathers are also used all over the world to stuff pillows, mattresses, sleeping bags, coats, and quilting. Goose feathers are preferred because they are soft. Manufacturers often mix goose feathers with down feathers to provide extra softness.

Birds and the Ecosystem

Birds are obviously important members of many ecosystems. They are integral parts of food chains and food webs. In a woodland ecosystem for example, some birds get their food mainly from plants. Others chiefly eat small animals, such as insects or earthworms. Birds and bird eggs, in turn, serve as food for such animals as foxes, raccoons, and snakes. The feeding relationships among all the animals in an ecosystem help prevent any one species from becoming too numerous. Birds play a vital role in keeping this balance of nature. In addition to being important parts of food webs, birds play other roles within ecosystems.

1.Birds eat insects. They are a natural way to control pests in gardens, on farms, and other places. A group of birds gliding through the air can easily eat hundreds of insects each day. Insect eating birds include warblers, bluebirds and woodpeckers.
2.Nectar-feeding birds are important **pollinators** , meaning they move the pollen from flower to flower to help fertilize the sex cells and create new plants. Hummingbirds, sunbirds, and the honey-eaters are common pollinators.
3.Many fruit-eating birds help disperse seeds. After eating fruit, they carry the seeds in their intestines and deposit them in new places. Fruit-eating birds include mockingbirds, orioles, finches and robins.
4.Birds are often important to island ecology. In New Zealand, the kereru and kokako are important browsers, or animals that eat or nibble on leaves, tender young shoots, or other vegetation (**Figure** below). Seabirds add nutrients to soil and to water with their production of **guano** , their dung.

Figure 10.38

The kereru (*left*) and the kokako (*right*) are important browser species in New Zealand

Summary

- Birds are important to humans in many ways; they are a source of food and fertilizer.
- Birds are important to the ecosystem in many ways; they pollinate flowers and disperse seeds.

Explore More

Use the resources below to answer the questions that follow.

Explore More I

- **Dispersal of Seeds by Animals** at http://theseedsite.co.uk/sdanimal.html

1. Why are seeds enclosed in a tasty pulp?
2. Give two examples of how animals disperse seeds.

Explore More II

- **One Century On, the Guano Boom is Back** at http://www.youtube.com/watch?v=HOq8PKX18A4 (2:10)

1. How many seabirds were there at the 19th-century peak of guano collection? How many are there now? What direction is the population going?
2. How has the Peruvian government changed the way guano is collected?

Explore More III

- **Bird Poop and Its Surprising Uses** at http://www.youtube.com/watch?v=UKPn2lEUVYI (1:24)

Click on the image above for more content

1. For what purposes are people using guano?
2. How does climate affect the quality of bird guano? Why is this quality important to the use of guano as fertilizer?

Review

1. What is poultry?
2. What are two ways birds are important to humans?

3.What are two ways birds are important to the ecosystem?
4.How to birds disperse seeds? Give two examples of fruit-eating birds.

Section 20

Mammal Characteristics

Mammal Characteristics

•Describe the characteristics of mammals.
•List the three general categories of mammals.
•Define viviparous.

What do you have in common with a bat?

Both humans and bats have body hair, and both humans and bats can nurse their young. These are both characteristics of mammals, the class that both bats and humans belong to.

Characteristics of Mammals

What is a mammal? These animals range from bats, cats, and rats to dogs, monkeys, elephants, and whales. They walk, run, swim, and fly. They live in the ocean, fly in the sky, walk on the prairies, and run in the savanna. There is a tremendous amount of diversity within the group in terms of reproduction, habitat, and adaptation for living in those different habitats.

What allows them to live in such diverse environments? They have evolved specialized traits, unlike those of any other group of animal. Mammals (class Mammalia) are **endothermic** (warm-blooded) vertebrate animals with a number of unique characteristics. In most mammals, these include:

•The presence of hair or fur.
•Sweat glands.
•Glands specialized to produce milk, known as **mammary glands** .
•Three middle ear bones.
•A **neocortex** region in the brain, which specializes in seeing and hearing.
•Specialized teeth.
•A four-chambered heart.

There are approximately 5,400 mammalian species, ranging in size from the tiny 1-2 inch bumblebee bat to the 108-foot blue whale. These are distributed in 29 orders, 153 families, and about 1,200 genera.

There are three types of mammals, characterized by their method of reproduction. All mammals, except for a few, are **viviparous** , meaning they produce live young instead of laying eggs. The **monotremes** , however, have birdlike and reptilian characteristics, such as laying eggs and a cloaca. An example of a monotreme is the platypus with its birdlike beak and egg-laying characteristics. The echidnas are the only other monotreme mammals. A second type of mammal, the marsupial mammal, includes kangaroos, wallabies, koalas and possums. These mammals give birth to underdeveloped embryos, which then climb from the birth canal into a pouch on the front of the mother's body, where it feeds and continues to grow. The remainder of mammals, which is the majority of mammals, are placental mammals. These mammals develop in the mother's uterus, receiving nutrients across the placenta. Placental mammals include humans, rabbits, squirrels, whales, elephants, shrews, and armadillos. Dogs and cats, and sheep, cattle and horses are also placental mammals.

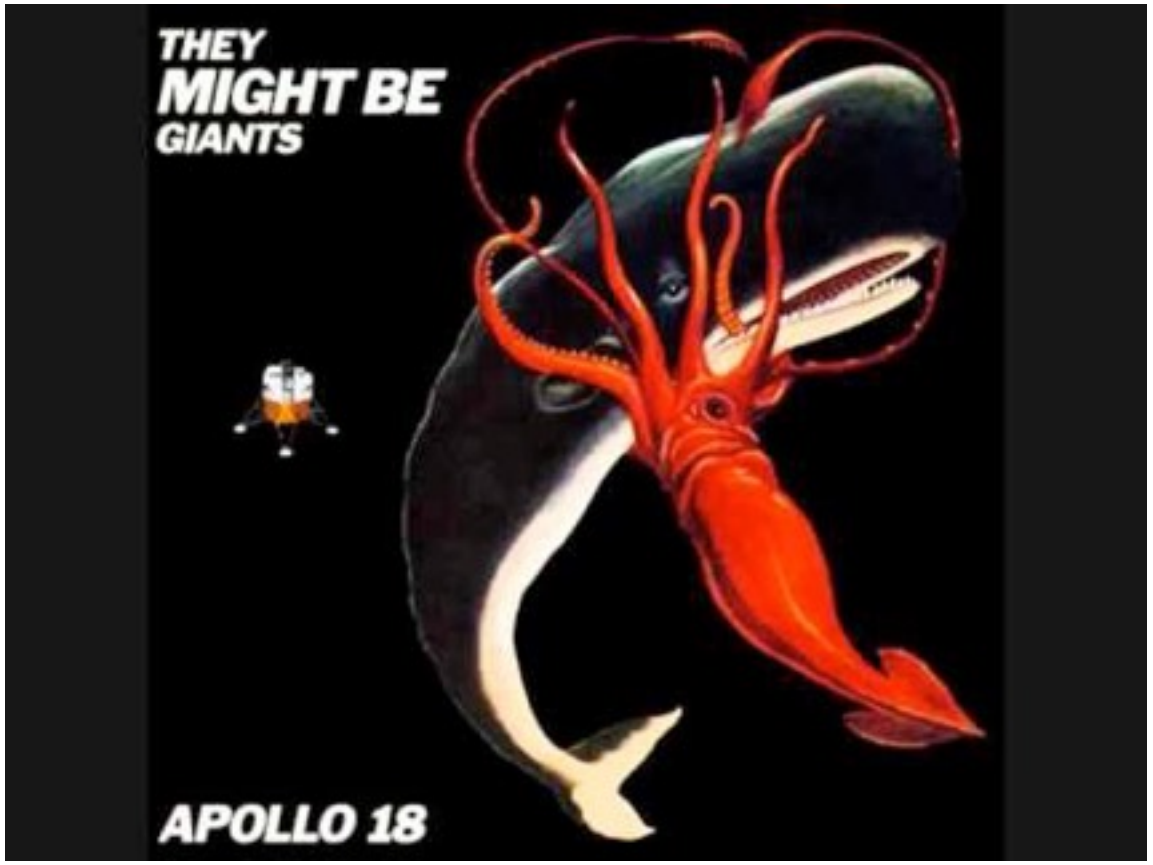
Mammals are also the only animal group that evolved to live on land and then back to live in the ocean. Whales, dolphins, and porpoises have all adapted from land-dwelling creatures to a life of swimming and reproducing in the water (**Figure** below). Whales have evolved into the largest mammals.

Figure 10.39

Dolphins have adapted to swimming and reproducing in water.

See *Mammals- San Diego Kids* at http://kids.sandiegozoo.org/animals/mammals and *The Cheetah Orphans* at http://www.pbs.org/wnet/nature/episodes/the-cheetah-orphans/interactive-anatomy-of-a-cheetah/662/ for additional material.

Listen to *They Might Be Giants - Mammal* at http://www.youtube.com/watch?v=mXD7YOoHpAs for a description of numerous mammal traits.



Click on the image above for more content

Summary

- Mammals have several traits in common, including the presence of hair or fur, sweat glands, and mammary glands.
- Some mammals, such as dolphins and whales, evolved to live back in the ocean by adapting from land-dwelling creatures.

Explore More

Use the resources below to answer the questions that follow.

Explore More I

- **What is a Mammal?** at http://www.youtube.com/watch?v=0jw74pfWfxA (1:36)

Click on the image above for more content

1. How do mammals differ from other vertebrates?
2. What characteristics are unique to mammals?

Explore More II

- **Famous Fossil "Ida" (Plate B): Analysis with Dr. Robert Bakker** at http://www.youtube.com/watch?v=vyx-ryWHB2s (3:17)

Click on the image above for more content

1. What characteristics does "Ida" display?
2. What did she probably eat based on her dentition?
3. What do her eyes tell us about her probable behavior?
4. What type of mammal was Ida? How is this known?

Review

1. What are three characteristics of mammals?
2. What is meant by viviparous?
3. What are monotremes? Give an example.
4. What is the largest land mammal?

Section 21

Mammal Reproduction

Mammal Reproduction

- •List and describe the three general ways mammals reproduce.
- •Summarize the unique characteristics of embryonic development in marsupials.
- •Describe the role of the placenta.

Do mammals lay eggs?

Could a rabbit really lay eggs? Rabbits are mammals, and most mammals do not lay eggs. Mammals usually give birth to live offspring. But there are some mammals that do lay eggs.

Mammal Reproduction

You probably realize that cats, dogs, people, and other mammals don't typically lay eggs. There are exceptions, however. Egg-laying is possible among the **monotremes** , mammals with birdlike and reptilian characteristics. Recall that mammals can be classified into three general groups, based on their reproductive strategy: the monotremes, the marsupials and the placental mammals.

The egg-laying monotremes, such as echidnas (**Figure** below) and platypuses (**Figure** below), use one opening, the **cloaca** , to urinate, release waste, and reproduce, just like birds. They lay leathery eggs, similar to those of lizards, turtles, and crocodilians. Monotremes feed their young by "sweating" milk from patches on their bellies, as they lack the nipples present on other mammals.

Figure 10.40

The echidna (*right*) is a member of the monotremes, the most primitive order of mammals. Another monotreme, the platypus (*left*), like other mammals in this order, lays eggs and has a single opening for the urinary, genital, and digestive organs.

All other mammals give birth to live young and belong to one of two different categories, the marsupials and the placental mammals. A **marsupial** is an animal in which the embryo, which is often called a joey, is born at an immature stage. Development must be completed outside the mother's body. Most female marsupials have an abdominal pouch or skin fold where there are mammary glands. The pouch is a place for completing the development of the baby. Although blind, without fur, and with only partially formed hind legs, the tiny newborns have well developed forelimbs with claws that enable them to climb their way into their mother's pouch where they drink their mother's milk and continue their development. Marsupials include kangaroos, koalas, and opossums. Other marsupials are the wallaby and the Tasmanian Devil. Most marsupials live in Australia and nearby areas. (**Figure** below).

The majority of mammals are **placental** mammals. These are mammals in which the developing baby is fed through the mother's placenta. Female placental mammals develop a **placenta** after fertilization. A placenta is a spongy structure that passes oxygen, nutrients, and other useful substances from the mother to the fetus. It also passes carbon dioxide and other wastes from the fetus to the mother. The placenta allows the fetus to grow for a long time within the mother.

Figure 10.41

A marsupial mammal, this eastern gray kangaroo has a joey (young kangaroo) in its abdominal pouch.

Some mammals are alone until a female can become pregnant. Others form social groups with big differences between sexes, such as size differences, a trait called **sexual dimorphism** . Dominant males are those that are the largest or best-armed. These males usually have an advantage in mating. They may also keep other males from mating with females within a group. This is seen in elephant seals (**Figure** below), and also with elk, lions and non-human primates, including the orangutans and gorillas. Male elk grow antlers, while female elk do not have antlers. Adult male lions are not only larger than females, they have a mane of long hair on the side of the face and top of the head.

Figure 10.42

A mating system with a group of many females and one male, as seen in the seal species. Male elephant seals can grow to 14 feet long, whereas females can grow to 11 feet long.

Summary

- Monotremes can lay eggs, but most mammals give birth to live young.
- Mammals can be marsupial, where the embryo is born at an immature stage and develops in the pouch.
- Mammals can be placental, where substances are passed from the mother to the fetus so that it can stay longer in the womb.

Explore More

Use the resources below to answer the questions that follow.

Explore More I

- **Marsupials** at http://www.biokids.umich.edu/critters/Didelphimorphia/

1. What are four examples of marsupials?
2. Where are most marsupials found?
3. What is the primary difference between marsupial and placental mammals? Explain your response.

Explore More II

- **Marsupial Reproduction Process** at http://www.youtube.com/watch?v=IloOJ3kc8us (4:06)

Click on the image above for more content

1.How does parental care in marsupial mammals differ from parental care in placental mammals?
2.Why do marsupials lick themselves during birth?
3.How do scientists think marsupial babies find the pouch?

Explore More III

•**Creation of Placenta** at http://www.youtube.com/watch?v=I8sqaJVZRmo (3:51)

Click on the image above for more content

1.What are two of the purposes of the placenta?
2.What does the placenta allow to pass to the embryo?
3.What does the placenta keep from the embryo?
4.What is the function of the umbilical cord?

Review

1.How are monotremes more like reptiles and birds than other mammals?
2.What's the difference between marsupial and placental animals?
3.What are three marsupials?

4.Define and describe the role of the placenta.
5.What is sexual dimorphism?

Section 22

Mammal Classification

Mammal Classification

•Describe the lagomorphs.
•List the unique traits of the rodents, bats, and ungulates.
•Give examples of the carnivores and insectivores.
•List the defining features of the primates.

To what group do rats belong?

Rats are mammals, but this class can be divided into more specific groups. Rats are in a group known as rodents. Rodents are gnawing animals that include beavers, mice, and squirrels.

Groups of Mammals

Traditionally, mammals were divided into groups based on their characteristics. Scientists took into consideration their **anatomy** (body structure), their habitats, and their feeding habits. Mammals are divided into three subclasses and about 26 orders. Some of the groups of mammals include:

1. **Lagomorphs** include hares and rabbits. Rabbits and hares characteristically have long ears, a short tail, and strong hind limbs that provide for a bouncing method of locomotion. They are all are small to medium-sized terrestrial herbivores.
2. **Rodents** include rats, mice, and other small gnawing mammals. They have a single pair of continuously growing incisors (teeth) in each of the upper and lower jaws that must be kept short by gnawing.
3. **Carnivores** include cats and lions and tigers, dogs and wolves, polar bears, and other meat eaters.
4. **Insectivores** include moles and shrews (**Figure** below). These mammals eat primarily insects, other arthropods, and earthworms.

Figure 10.43

One of the subgroups of mammals is the insectivores, including this shrew.

5.**Bats** include the vampire bat. These mammals have forelimbs that form webbed wings, making bats the only mammals naturally capable of true and sustained flight.

6.**Primates** include monkeys, apes and humans. These mammals are characterized by detailed development of the hands and feet, a shortened snout, and a large brain.

7.**Ungulates** include hoofed animals, such as deer, sheep, goats, pigs, buffalo, and giraffe (**Figure** below). These mammals use their hoofs to sustain their whole body weight while moving. Hoofs are formed by a thick nail rolled around the tip of the toe.

Figure 10.44

The ungulates (hoofed animals), like the giraffe here, is one of the subgroups of mammals.

Mammals can also be grouped according to the adaptations they form to live in a certain habitat. For example, terrestrial mammals with leaping kinds of movement, as in some marsupials and lagomorphs, typically live in open habitats. Other terrestrial mammals are adapted for running, such as dogs or horses. Still others, such as elephants, hippopotamuses, and rhinoceroses, move slowly. Other mammals are adapted for living in trees, such as many monkeys (**Figure** below). Others live in water, such as manatees, whales, dolphins, and seals. Still others are adapted for flight, like bats.

Figure 10.45

This howler monkey shows adaptations for life among the trees.

Summary

- Traditionally, mammals were divided into groups based on their anatomy (body structure), their habitats, and their feeding habits.
- Subgroups of the mammals include rodents, carnivores, insectivores, bats, and primates.

Explore More

Use the resources below to answer the questions that follow.

Explore More I

- **Mammal Conservation in Island Ecosystems** at http://www.youtube.com/watch?v=JlsbH-MGsMI (5:21)

Click on the image above for more content

1. What is the average size of a mammal?
2. What groups of mammals are most abundant?

3.How often does Dr. Healey find new species in his work?
4.How does the diversity of bats compare to the diversity of other mammals in the Philippines? What does this tell you about generalized statements about species diversity?

Explore More II

•**Platypus Parts** at http://www.youtube.com/watch?v=QNoQvjlmGdk (3:44)

Click on the image above for more content

1.Where does the platypus (*Ornithorhynchus anatinus*) live?
2.What do platypus eat?
3.How do platypus look for food?
4.What is the purpose of the "spur" on males?

Explore More III

•**Ungulates: Animal Planet** at http://animals.howstuffworks.com/animal-facts/ungulate-info.htm
1.What distinguishes the ungulates?
2.What are three examples of ungulates?

Review

1.What are rodents? Give two examples.
2.What are characteristics of primates. Give three examples of primates.
3.What are ungulates? Give four examples.
4.List five examples of carnivores.

Section 23

Importance of Mammals

Importance of Mammals

- •Describe how mammals are important to humans.
- •Summarize the roles of mammals in ecosystems.
- •Give examples of the roles of mammals in the arts and culture.

How are mammals helpful?

An example of a helpful mammal is a service dog. Like many dogs, service dogs can pick up or retrieve objects for their owners. They can also perform many other tasks for a disabled person, depending on the type of disability.

Importance of Mammals

Mammals play many important roles in ecosystems, and they also benefit people.

Importance to Ecosystems

Mammals have important roles in the food webs of practically every ecosystem. Mammals are important members of food chains and food webs, as grazers and predators. Mammals can feed at various levels of food chains, as herbivores, insectivores, carnivores and omnivores.

Mammals also interact with other species in many symbiotic relationships. For example, bats have established mutually beneficial relationships with plants. Nectar-feeding bats receive a tasty treat from each flower, and, in return, they **pollinate** the flowers. That means they transfer pollen from one flower to another, allowing the plant to reproduce. Non-flying mammalian pollinators include of marsupials, primates, and rodents. In most cases, these animals visit flowers to eat their nectar, and end up with pollen stuck to their bodies. When the animal visits another flower to eat the nectar, the pollen is transferred to that flower.

Fruit-eating bats (**Figure** below) also receive food from plants. In return, they help these plants spread their seeds. When bats consume fruit, they also consume the seeds within the fruit. Then they carry the seeds in their guts to far-away locations.

Zebras have been known to befriend ostriches. In this symbiotic relationship, both species benefit. The ostrich, with its terrible senses of smell and hearing and the zebra with its poor eyesight, are both able to warn the other when danger is near. The zebra can smell or hear certain dangers approaching, while the ostrich can see other dangers. Both are prepared to warn one another at a moment's notice so they can each flee when necessary.

Baboons and impala have a similar relationship. Impala are one of the most common prey species for all predators and need to be constantly alert. Impala have good hearing and eyesight, raising an alarm when danger is near. Baboons use trees to check for danger and bark an alarm when danger is sensed. What do the baboons receive? Male baboons sometimes prey on young antelope soon after birth. So, though both alert others to dangers, sometimes this is not the best of relationships for young antelope.

Zebra and wildebeest are found together on the African savanna grazing different parts of the same grass. The zebra grazes the tougher parts of the plant, saving the softer parts for the wildebeest. A zebra will move into an area of tall grass before other herbivores and graze the grass down to the area that the wildebeest prefers.

Figure 10.46

Bats, like this Egyptian fruit bat, play an important role in seed dispersal.

Importance to Humans

We see examples of mammals (other than people!) serving our needs everywhere. We have pets that are mammals, such as dogs and cats. Mammals are also used around the world for transport. For example, horses, donkeys, mules, or camels (**Figure** below) may be the primary means of transport in some parts of the world. Mammals also do work for us. **Service dogs** can be trained to help the disabled. These include guide dogs, which are assistance dogs trained to lead blind and visually impaired people around obstacles. Horses and elephants can carry heavy loads. Humans also use some mammals for food. For example, cows and goats are commonly raised for their milk and/or meat. Mammals' more highly developed brains have made them ideal for use by scientists in studying such things as learning, as seen in maze studies of mice and rats.

Figure 10.47

This camel provides transportation in Egypt.

Cultural Importance

Mammals have also played a significant role in different cultures' folklore and religion. For example, the grace and power of the cougar have been admired in the cultures of the native peoples of the Americas. The Inca city of Cuzco is designed in the shape of a cougar, and the thunder god of the Inca, Viracocha, has been associated with the animal. In North America, mythological descriptions of the cougar have appeared in the stories of several American Indian tribes.

Important mammals include Dolly the sheep, Lassie the dog, and flipper the dolphin. Dolly was the first mammal to be cloned from an adult somatic (body) cell, using the process of nuclear transfer. Lassie was a collie dog who appeared in seven full length feature films in the 1940s and 1950s, starting with *Lassie Come Home* in 1943. Additional Lassie movies were made as recently as 2005. Between 1954 and 1973, the *Lassie* television series aired, with plenty of additional productions as recently as 2007. Flipper was a bottle nose dolphin that starred in a television series between 1964 and 1967. The most famous mammal may be *King Kong,* the giant gorilla that terrorized New York City in 1933 in the movie of the same name.

Summary

- •Ecologically, nectar-feeding and fruit-eating bats play an important role in plant pollination and seed dispersal, respectively.
- •Mammals meet people's needs by serving as pets, transport, food, or research subjects.

Explore More

Use the resources below to answer the questions that follow.

Explore More I

•Sled Dogs: An Alaskan Epic at http://www.pbs.org/wnet/nature/episodes/sled-dogs-an-alaskan-epic/interactive-dogsledding-101/4355/

1. What breed of dogs were originally used for sled pulling?
2. What kind of weather is optimal for sled dogs?
3. Why do the dogs like these conditions?
4. What are the two most common types of sleds?

Explore More II

•Arctic: Greenland Sled Dogs at http://www.youtube.com/watch?v=QeDv3hVcc8A (3:02)

Click on the image above for more content

1. How many sled dogs are there living above the Arctic Circle in Greenland?
2. How far can a sled dog team travel in a day?
3. What advantages do sled dogs have over snowmobiles?
4. What are some ways in which the Inuit depend on sled dogs?

Review

1. How do mammals impact ecosystems? Describe two ways.
2. Describe one symbiotic relationship between mammals.
3. How do mammals help people? Describe two ways.
4. Which mammals is your favorite? Why?

Section 24

Primates

Primates

- •Give examples of primates.
- •Describe the key features of the primates.
- •Explain the importance of the opposable thumb.
- •Explain where non-human primates live.

How are the monkey and the girl alike?

Both are intelligent and can learn new things quickly. They both like to play. And they are both primates.

What Are Primates?

If primates are mammals, what makes them seem so different from most mammals? Primates, including humans, have several unique features. Some adaptations give primates advantages that allow them to live in certain habitats, such as in trees. Other features have allowed them to adapt to complex social and cultural situations.

Primates are mostly **omnivorous** , meaning many primate species eat both plant and animal material. The order contains all of the species commonly related to lemurs, monkeys, and apes. The order also includes humans (**Figure** below).

Figure 10.48

(*top left*) Ring-tailed lemurs. Lemurs belong to the prosimian group of primates. (*top right*) One of the New World monkeys, a squirrel monkey. (*bottom left*) Chimpanzees belong to the great apes, one of the groups of primates. (*bottom right*) Reconstruction of a Neanderthal man, belonging to an extinct subspecies of *Homo sapiens* .

This subspecies of humans lived in Europe and western and central Asia from about 100,000 – 40,000 BCE.

Key features of primates include:

•Five fingers, known as **pentadactyl** .
•Several types of teeth.
•Certain eye orbit characteristics, such as a **postorbital bar** , or a bone that runs around the eye socket.
•An **opposable thumb** , a finger that allows a grip that can hold objects.

What's the difference between monkeys and apes? The easiest way to distinguish monkeys from the other primates is to look for a tail. Most monkey species have tails, but no apes or humans do. Monkeys are much more like other mammals than apes and humans are.

Big Brains

In intelligent mammals, such as primates, the cerebrum is larger compared to the rest of the brain. A larger cerebrum allows primates to develop higher levels of intelligence. Primates have the ability to learn new behaviors. They also engage in complex social interactions, such as fighting and play.

Social Relationships

Old World species, such as apes and some monkeys (**Figure** above and **Figure** below), tend to have significant size differences between the sexes. This is known as

sexual dimorphism . Males tend to be slightly more than twice as heavy as females. This dimorphism may have evolved when one male had to defend many females. *Old World* generally refers to monkeys of Africa and Asia. *New World* refers to monkeys of the Americas.

New World species, including tamarins (squirrel-sized monkeys) and marmosets (very small primitive monkeys) (**Figure** below), form **pair bonds** , which is a partnership between a mating pair that lasts at least one season. The pair cooperatively raise the young and generally do not show a significant size difference between the sexes. Old World monkeys do not tend to form monogamous relationships.

Figure 10.49

(*left*) An Old World monkey, a species of macaque, in Japan. (*center*) A New World species of monkey, a tamarin. (*right*) Another New World species of monkey, the pygmy marmoset.

Where Do Non-human Primates Live?

Non-human primates live mostly in Central and South America, Africa, and South Asia. Since primates evolved from animals living in trees, many modern species still live mostly in trees. Other species live on land most of the time, such as baboons (**Figure** below) and the Patas monkey. Only a few species live on land all of the time, such as the gelada and humans.

Figure 10.50

Baboons are partially terrestrial. Pictured here is a mother baboon and her young.

Primates live in a diverse number of forested habitats, including rain forests, mangrove forests and mountain forests to altitudes of over 9,800 feet. The combination of opposable thumbs, short fingernails, and long, inward-closing fingers has allowed some species to develop the ability to move by swinging their arms from one branch to another (**Figure** below). Another feature for climbing are expanded finger-like parts, such as those in tarsiers, which improve grasping (**Figure** below).

A few species, such as the proboscis monkey, De Brazza's monkey, and Allen's swamp monkey, evolved webbed fingers so they can swim and live in swamps and aquatic habitats. Some species, such as the rhesus macaque and the Hanuman langur, can even live in cities by eating human garbage.

Figure 10.51

(*left*) A gibbon shows how its limbs are modified for hanging from trees. (*right*) A species of tarsier, with expanded digits used for grasping branches.

Summary

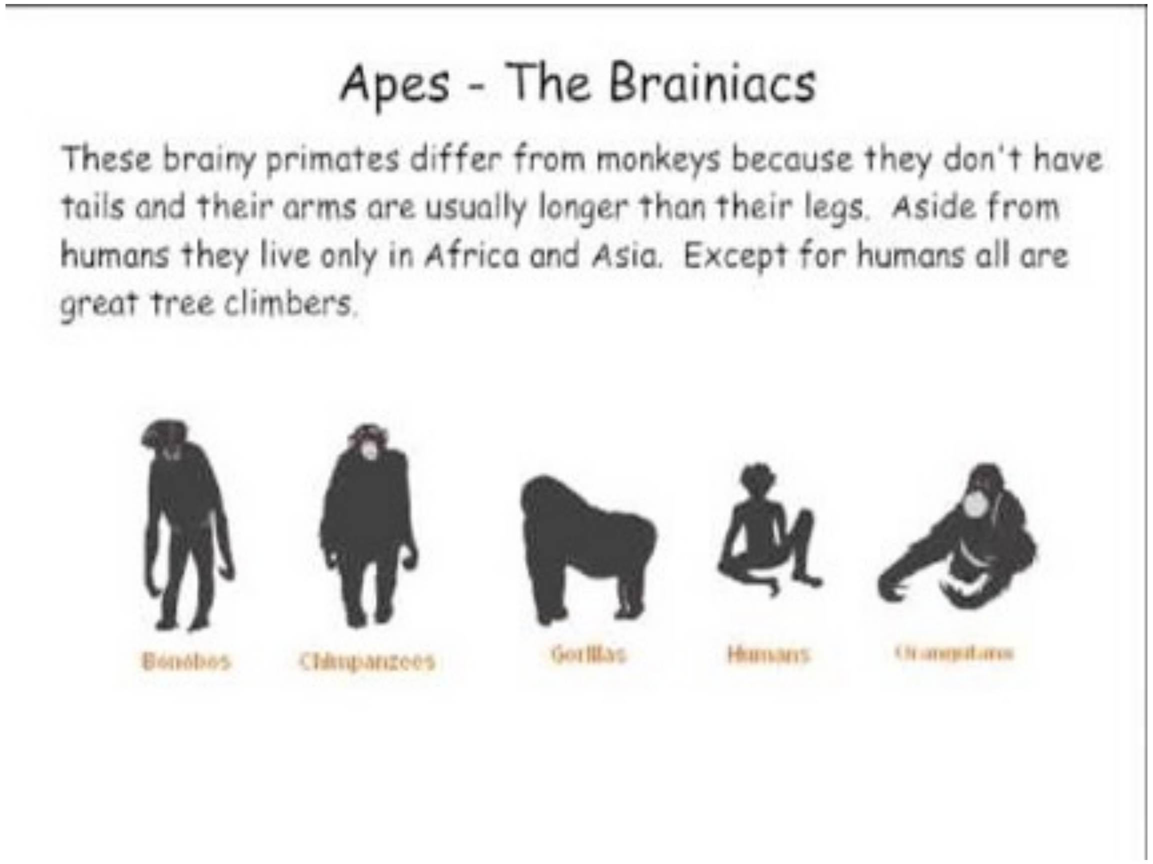
- Features of primates include five fingers, several types of teeth, an opposable thumb, and a large brain.
- Primates live in a variety of places, including trees, swamps, and on land.

Explore More

Use the resources below to answer the questions that follow.

Explore More I

- **Primate Classification** at http://www.youtube.com/watch?v=Zd7syFmutjU (2:15)



Click on the image above for more content

1. How do primates differ from other animals?
2. How do prosimians differ from monkeys?
3. How do Old World monkeys differ from New World monkeys?
4. How do apes differ from monkeys?

Explore More II

- **Ring-Tailed Lemurs** at http://kids.nationalgeographic.com/kids/animals/creaturefeature/ring-tailed-lemur/

1. Why are lemurs endangered?
2. Where do lemurs live?
3. How do lemurs mark their territory?

Review

1. What's the difference between monkeys and apes?
2. What is an opposable thumb?
3. What is the significance of a large cerebrum?
4. What is meant by pentadactyl?

Section 25

Humans and Primates

Humans and Primates

•Describe the characteristics of the great apes.
•Summarize the genetic and behavioral similarities among the great apes.
•List specialized human features.

What animals are humans' closest cousins?

Looking at our evolutionary tree, our closest relatives include the orangutans pictured here. Notice the way this mother cradles her child; they look very human-like. Orangutans are also highly intelligent. Notice the detail in the hand. In the wild, they can create and use tools.

Humans and Primates

The great apes are the members of the biological family Hominidae, which includes four living genera: chimpanzees, gorillas, orangutans and humans. Among these four genera are just seven species, two of each except humans, which has only one species, *Homo sapiens.*

Characteristics

The Great Apes are large, tailless primates, ranging in size from the pygmy chimpanzee, at 66-88 pounds in weight, to the gorilla, at 300-400 pounds (**Figure** below). In all species, the males are, on average, larger and stronger than the females.

Figure 10.52

A Western Lowland gorilla, member of the great apes. The gorilla is the largest of the hominids, weighing up to 309-397 lbs.

Most living primate species are four-footed, but all are able to use their hands for gathering food or nesting materials. In some cases, hands are used as tools, such as when gorillas use sticks to measure the depth of water (**Figure** below). Chimpanzees sharpen sticks to use as spears in hunting; they also use sticks to gather food and to “fish” for termites.

Figure 10.53

Tool using in a primate. A gorilla uses a stick to determine the water's depth.

Most primate species eat both plants and meat (**omnivorous**), but fruit is the preferred food among all but humans. In contrast, humans eat a large amount of highly processed, low fiber foods, and unusual proportions of grains and vertebrate meat. As a result of our diets, human teeth and jaws are markedly smaller for our size than those of other apes. Humans may have been eating cooked food for a million years or more, so perhaps our teeth adapted to eating cooked food.

Gestation (pregnancy) lasts 8-9 months and usually results in the birth of a single offspring. The young are born helpless, and thus, they need parental care for long periods of time. Compared with most other mammals, great apes have a long adolescence and are not fully mature until 8-13 years of age (longer in humans). Females usually give birth only once every few years.

Gorillas and chimpanzees live in family groups of approximately five to ten individuals, although larger groups are sometimes observed. The groups include at least one dominant male, and females leave the group when they can mate. Orangutans, however, generally live alone.

Genetic and Behavioral Similarities

Gorillas, chimpanzees, and humans have more than 97% of their DNA sequence in common. This means that a similar percent of the amino acid sequences of the proteins will be the same, resulting in many proteins with similar or identical functions.

All organisms in the Hominidae communicate with some kind of language. They can also create simple **cultures** beyond the family or group of animals. Having a culture means that knowledge and behaviors can be passed on from generation to generation.

Specialized Human Features

Specialized features of *Homo sapiens* include the following:

•small front teeth (canines and incisors) and very large molars relative to other primate species,
•a fully upright posture resulting in bipedalism (walking on two limbs instead of four),
•shortening of the arms relative to the legs,
•increased usefulness (dexterity) of the hands,
•increase in brain size, especially in the frontal lobes
•and a decrease in bone mass of the skull and face.

See *Communication - the Jane Goodall Institute* at http://www.janegoodall.org/chimpanzees/communication , *Comparing the Human and Chimpanzee Genomes* at http://wrl.it/show/197403/12898478 , and *Discovering Gibbons* at http://www.youtube.com/watch?v=C6HucIWKsVc for additional material.

Click on the image above for more content

Summary

- The biological family Hominidae includes four living genera: chimpanzees, gorillas, humans, and orangutans.
- Gorillas, chimpanzees, and humans have more than 97% of their DNA in common.
- All organisms in the family Hominidae can develop language and culture.

Explore More

Use the resources below to answer the questions that follow.

Explore More I

- **Human and Primate Relationship** ' at http://www.youtube.com/watch?v=i8PNWZDhGq4 (1:21)

Click on the image above for more content

1. Where do chimpanzees (*Pan troglodytes*) live geographically?
2. What tool are the chimpanzees in the video using?

Explore More II

• **Silverback Gorilla and Family** at http://www.youtube.com/watch?v=l1GZC3lQGbg (2:51)

Click on the image above for more content

1. What do gorillas do when they approach each other or feel other gorillas are around?
2. Who is the leader of a gorilla family?

Explore More III

• **Amazing DIY Orangutans** at http://www.youtube.com/watch?v=IFACrIx5SZ0 (2:41)

Click on the image above for more content

1. Are the orangutans in the video displaying learned or innate behavior? Explain your answer.

Review

1. What organisms share the same biological family as humans?
2. Why do chimpanzees and humans have many similar proteins?
3. What is important about a primate culture?
4. What are three specialized human features?

Summary

Vertebrates. From fish to mammals. Obviously, there is a tremendous amount of differences among these groups of species. But there also exist many similarities. Fish had to evolve first. Then they moved onto land as amphibians, but they still had to live close to the water. Then they moved farther away from the water as reptiles. Reptiles could live anywhere, and they did. Reptiles became very large and dominated life on the planet. Some reptiles evolved flight and turned into birds. Others stayed small and became mammals. When all the large reptiles were extinct, what remained? Smaller animals, including mammals, which then became the dominant form of life.

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3.Carp: Elisabeth Östman; Whale, dolphin, human: T. Bjornstad. Comparison of the size of a whale, carp, and human . Public Domain
4.Derek Keats. The humphead or Napoleon wrasse shows some of the general traits of fish, including scales, fins, and a streamlined body . CC BY 2.0
5.Pearson Scott Foresman. Gills help a fish breathe . Public Domain
6.Mike Johnston. Whale sharks are the largest cartilaginous fish . CC BY 2.0
7.Sam Pullara. One of the cartilaginous fish, a stingray, shows very flexible pectoral fins connected to the head . CC BY 2.0
8.Courtesy of Ken Hammond, U.S. Department of Agriculture. Workers harvest catfish from a fish farm in Mississippi . Public Domain
9.Charles Keith. Picture of a hagfish . Public Domain
10.Flickr:prilfish. A spotted Wobbegong shark showing skin flaps around the mouth and camouflage coloration . CC BY 2.0
11.(left) Brian Gratwicke; (right) Daniel Jolivet. The fins of a ray fin and a lobe fin fish . CC BY 2.0
12.Brian Snelson. Picture of an ocean sunfish . CC BY 2.0
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14.Marbled salamander: Courtesy of the U.S. Geological Survey; Caecilian: Cliff (Flickr:cliff1066™). Picture of a marbled salamander and a caecilian . Marbled salamander: Public Domain; Caecilian: CC BY 2.0
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19.User:Bachrach44/Wikimedia. A corn snake swallowing a mouse . Public Domain

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21.Brent Myers. A lizard camouflaged against the background . CC BY 2.0
22.© Patrick JEAN / Nantes Natural History Museum. A species of anaconda, one of the largest snakes, which can be as long as 17 feet . The photographer of this work allows anyone to use it for any purpose including unrestricted redistribution, commercial use, and modification
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37.Gull: Tony Hisgett (Flickr:ahisgett); Gallinule: Miguel Vieira. The webbed feet of a seagull and the long toes of a gallinule . CC BY 2.0
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44.Dimitry B.. A giraffe is an ungulate, hoofed animals . CC BY 2.0
45.Richie Diesterheft. This howler monkey shows adaptations for life among the trees . CC BY 2.0

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47.TownePost Network. This camel provides transportation in Egypt . CC BY 2.0
48.Lemur: Josef Vybiral; Squirrel monkey: Tony Hisgett; Chimps: Afrika Force; Neanderthal man: Stefan Scheer, Stefanie Krull, Neanderthal Museum. Lemurs, squirrel monkeys, chimpanzees, and Neanderthals are all primates . Lemur, squirrel monkey, and chimps: CC BY 2.0; Neanderthal man: CC BY 2.5
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51.Gibbon: Rene Mensen; Tarsier: Roberto Verzo. A gibbon and tarsier have evolved fingers for hanging on trees and branches . CC BY 2.0
52.User:Ltshears/Wikimedia Commons. Picture of a gorilla . Public Domain
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Human Biology

Introduction

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

Section 1

Organization of the Human

Organization of the Human Body

- List the levels of organization in the human body.
- Define cell, tissue, organ, and organ system.
- Identify the four types of tissues that make up the body.
- Give examples of organ systems and their functions.

Do cells work together?

Cells, like these nerve cells, do not work in isolation. To send orders from your brain to your legs, for example, signals pass through many nerve cells. These cells work together to perform a similar function. Just as muscle cells work together, bone cells and many other cells do as well. A group of similar cells that work together is known as a tissue.

Organization of Your Body: Cells, Tissues,

Organs

Cells are grouped together to carry out specific functions. A group of cells that work together form a **tissue** . Your body has four main types of tissues, as do the bodies of other animals. These tissues make up all structures and contents of your body. An example of each tissue type is pictured in the **Figure** below .

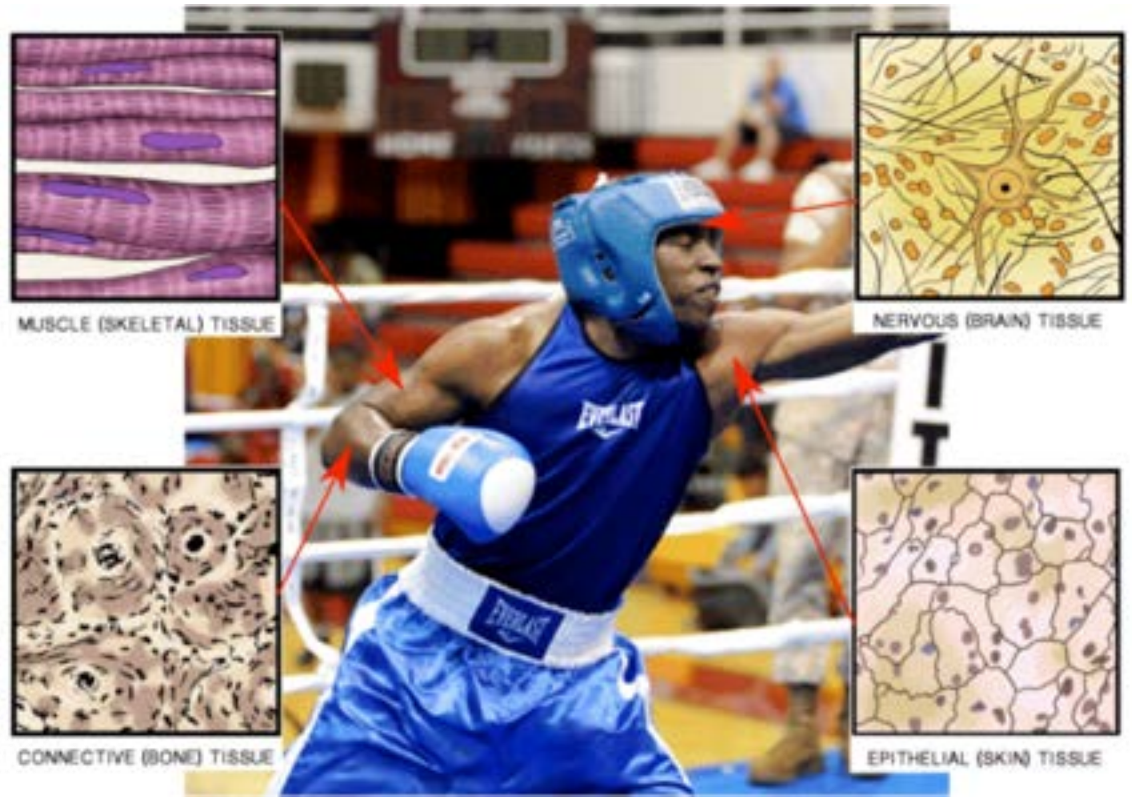


Figure 11.1

Your body has four main types of tissue: nervous tissue, epithelial tissue, connective tissue, and muscle tissue. They are found throughout your body.

1. **Epithelial tissue** is made up of layers of tightly packed cells that line the surfaces of the body. Examples of epithelial tissue include the skin, the lining of the mouth and nose, and the lining of the digestive system.
2. **Connective tissue** is made up of many different types of cells that are all involved in supporting and binding other tissues of the body. Examples include tendon, cartilage, and bone. Blood is also classified as a specialized connective tissue.
3. **Muscle tissue** is made up of bands of cells that contract and allow movement.
4. **Nervous tissue** is made up of nerve cells that sense stimuli and transmit signals. Nervous tissue is found in nerves, the spinal cord, and the brain.

Groups of Tissues Form Organs

A single tissue alone cannot do all the jobs that are needed to keep you alive and healthy. Two or more tissues working together can do a lot more. An **organ** is a structure made of two or more tissues that work together. The heart (**Figure** below) is made up of the four types of tissues.

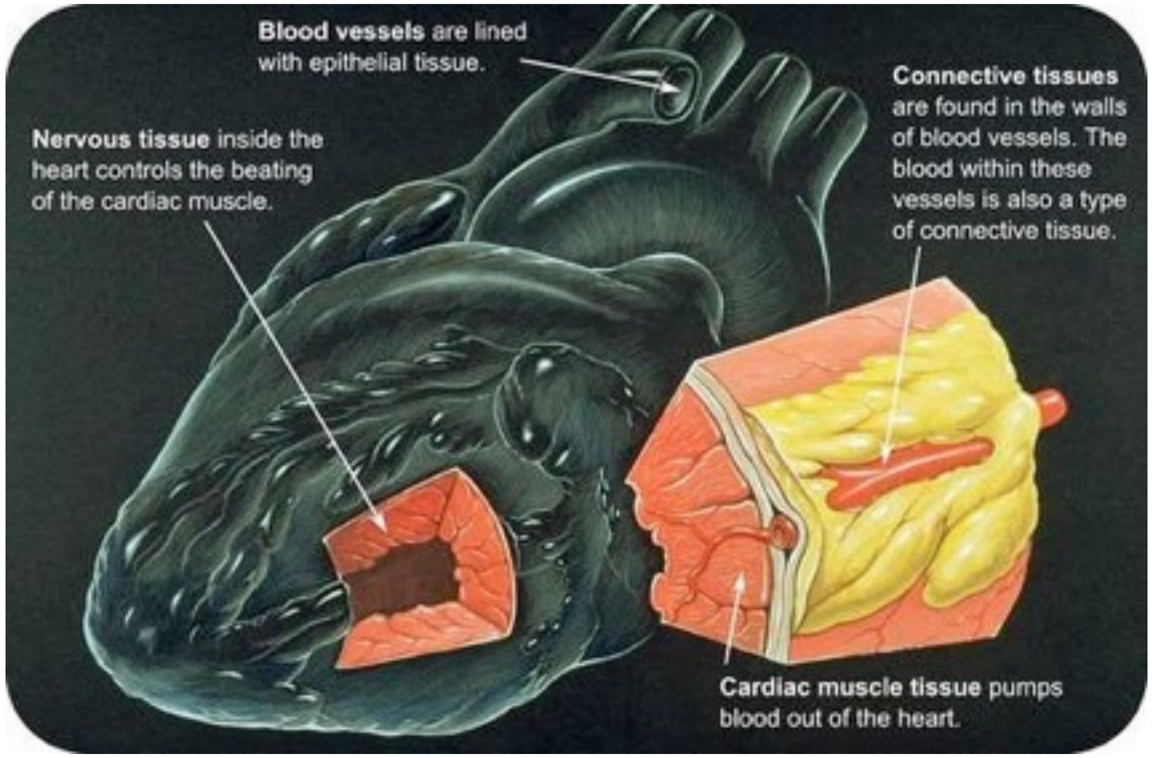


Figure 11.2

The four different tissue types work together in the heart as they do in the other organs.

Groups of Organs Form Organ Systems

Your heart pumps blood around your body. But how does your heart get blood to and from every cell in your body? Your heart is connected to blood vessels such as veins and arteries. Organs that work together form an **organ system** . Together, your heart, blood, and blood vessels form your **cardiovascular system** .

What other organ systems can you think of?

Organ Systems Work Together

Your body's 12 organ systems are shown below (**Table** below). Your organ systems do not work alone in your body. They must all be able to work together.

For example, one of the most important functions of organ systems is to provide cells with oxygen and nutrients and to remove toxic waste products such as carbon dioxide. A number of organ systems, including the cardiovascular and respiratory systems, all work together to do this.

Organ System	Major Tissues and Organs	Function
Cardiovascular	Heart; blood vessels; blood	Transports oxygen, hormones, and nutrients to the body cells. Moves wastes and carbon dioxide away from cells.
Lymphatic	Lymph nodes; lymph vessels	Defend against infection and disease, moves lymph between tissues and the blood stream.
Digestive	Esophagus; stomach; small intestine; large intestine	Digests foods and absorbs nutrients, minerals, vitamins, and water.

Summary

- The levels of organization in the human body include: cells, tissues, organs, and organ systems.
- There are four tissue types in the body: epithelial tissue, connective tissue, muscle tissue, and nervous tissue.

Explore More

Use the resources below to answer the following questions.

- **Human Body Plan** at http://vimeo.com/37349968 (2:28)

Click on the image above for more content

1. What kind of symmetry does the human body plan show? Explain what this means.
2. How does this symmetry extend to our senses?
3. How much of our body is made of muscle? What does this muscle do?
4. How are oxygen and nutrients delivered to the cells of the body?
5. What controls all the activity on the body? How much energy does this organ use?

Go here to see the placement of some organs and body parts. See how fast you can assemble the systems.

- **All Systems Go** at http://sciencenetlinks.com/interactives/systems.html

Review

1. What are the four levels of organization in an organism?
2. List the four types of tissues that make up the human body.
3. Describe epithelial tissue.
4. Give two examples of connective tissue.
5. What is the role of the nervous system?
6. What is the role of the cardiovascular system?

Section 2

Homeostasis

Homeostasis

•Define homeostasis.
•Describe homeostasis and how it is maintained.
•Distinguish negative feedback from positive feedback.

How does your body react to cold?

These people may be having fun in the icy water, but their bodies are struggling to react to the cold. For example, they may begin to shiver. Shivering helps the body return to a stable temperature. The body is always working to achieve stability, or homeostasis.

Homeostasis and Feedback Regulation

When you walk outside on a cool day, does your body temperature drop? No, your body temperature stays stable at around 98.6 degrees Fahrenheit. Even when the temperature around you changes, your internal temperature stays the same.

This ability of the body to maintain a stable internal environment despite a changing environment is called **homeostasis** . Homeostasis doesn't just protect against temperature changes. Other aspects of your internal environment also stay stable. For example, your body closely regulates your fluid balance. You may have noticed that if you are slightly dehydrated, your urine is darker. That's because the urine is more concentrated and less water is mixed in with it.

Maintaining Homeostasis

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

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

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

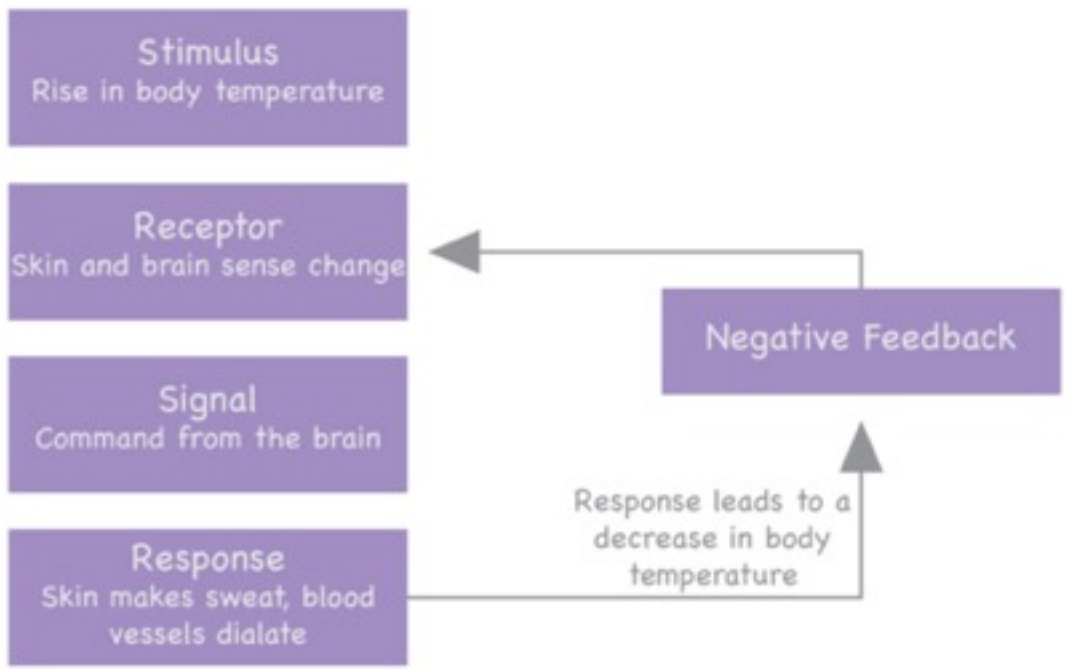


Figure 11.3

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

Positive Feedback

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

Summary

- Homeostasis is the ability of the body to maintain a stable internal environment despite a changing external environment.
- Homeostasis is maintained primarily through negative feedback, when a response to a stimulus keeps a variable close to a set value.

Explore More

Use the resources below to answer the questions that follow.

Explore More I

- **Homeostasis** at http://www.phys.unsw.edu.au/biosnippets/

1. What are three variables affected by homeostasis? What is the normal human range for these variables?
2. What is negative feedback? What is a sensor and an effector? How does this relate to homeostasis?
3. How does temperature affect enzymes? Why is this important to organisms?
4. How is the body temperature of ectotherms related to environmental temperatures? How does this differ from endotherms?
5. What happens if a fish is exposed to a rapid change in water temperature? What mechanism is involved in this response?

Explore More II

- **Homeostasis** at http://www.think-bank.com/iwb/flash/homeostasis.html

1. List four internal conditions that humans regulate?
2. What happens to blood flow in your body when your internal temperature increases?
3. What happens to blood flow in your body when your internal temperature decreases?
4. What is ADH? What is its function?
5. What are the roles of insulin and glucagon? What do they help the body regulate?

Review

1. What is homeostasis?
2. What is the difference between negative feedback and positive feedback?
3. What is a hormone?

Section 3

Skin

Skin

•Describe the functions of the skin.
•Summarize skin structure.
•Identify the roles of sebum and sweat glands.

Why is your skin important?

Some people put a lot of time and money into maintaining their skin. They may use special creams and lotions. While expensive creams may not be necessary, it is a good idea to take care of your skin. It does a lot of things for you, from protecting you from disease to sensing your environment.

Your Skin

Did you know that you see the largest organ in your body every day? You wash it, dry it, cover it up to stay warm, and uncover it to cool off. Yes, your skin is your body's largest organ. Your skin is part of your **integumentary system** (**Figure** below), which is the outer covering of your body. The integumentary system is made up of your skin, hair, and nails.

Functions of Skin

Figure 11.4

Skin acts as a barrier that stops water and other things, like soap and dirt, from getting into your body.

The skin has many important functions. The skin:

- Provides a barrier. It keeps organisms that could harm the body out. It stops water from entering or leaving the body.
- Controls body temperature. It does this by making sweat (or **perspiration**), a watery substance that cools the body when it evaporates.
- Gathers information about your environment. Special nerve endings in your skin sense heat, pressure, cold, and pain.
- Helps the body get rid of some types of waste, which are removed in sweat.
- Acts as a sun block. A pigment called **melanin** blocks sunlight from getting to deeper layers of skin cells, which are easily damaged by sunlight.

Structure of Skin

Your skin is always exposed to your external environment, so it gets cut, scratched, and worn down. You also naturally shed many skin cells every day. Your body replaces damaged or missing skin cells by growing more of them. Did you know that the layer of skin you can see is actually dead? As the dead cells are shed or removed from the upper layer, they are replaced by the skin cells below them.

Two different layers make up the skin: the epidermis and the dermis (**Figure** below). A fatty layer lies under the dermis, but it is not part of your skin.

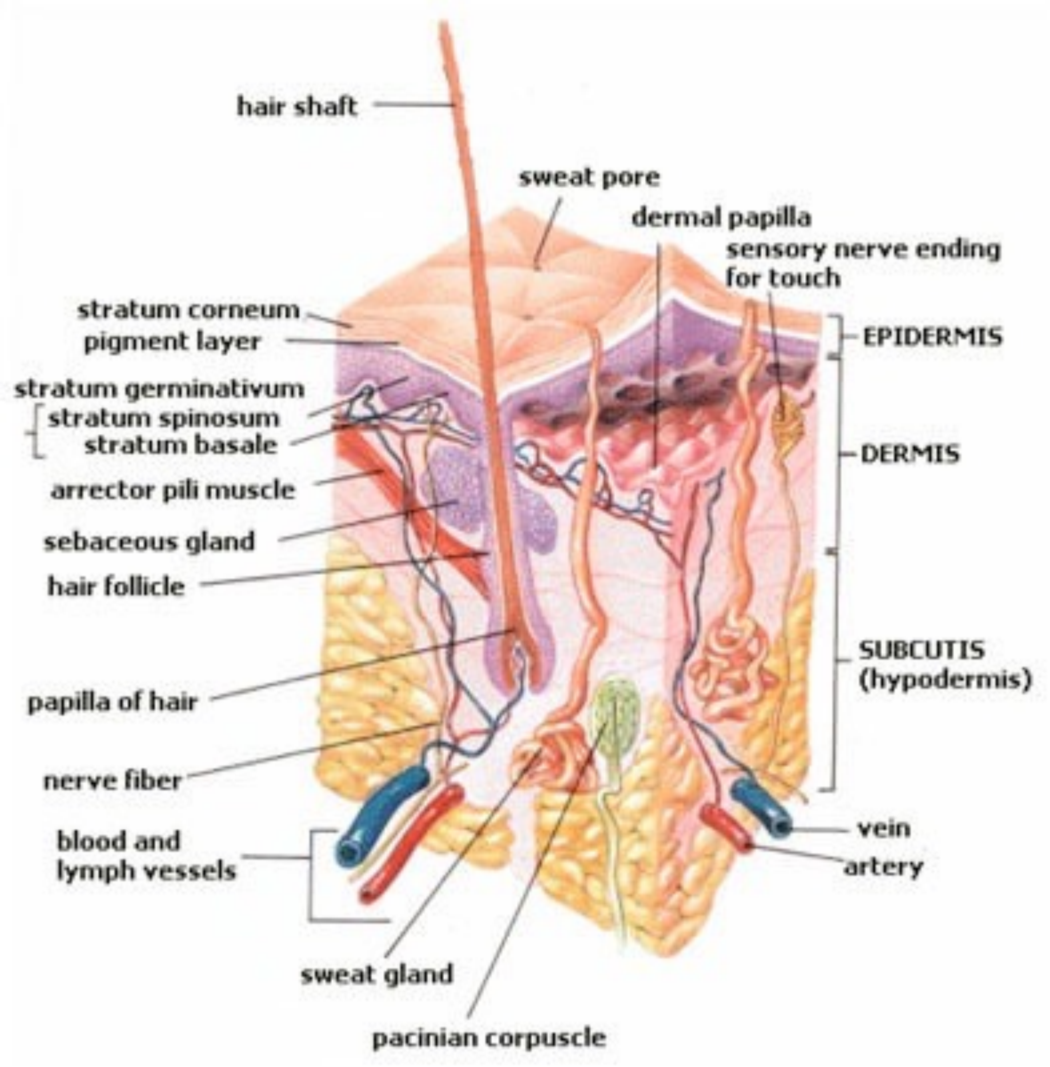


Figure 11.5

Skin is made up of two layers, the epidermis on top and the dermis below. The tissue below the dermis is called the hypodermis, but it is not part of the skin.

The Epidermis

The **epidermis** is the outermost layer of the skin. It forms the waterproof, protective wrap over the body's surface. Although the top layer of epidermis is only about as thick as a sheet of paper, it is made up of 25 to 30 layers of cells. The epidermis also contains cells that produce melanin. Melanin is the brownish pigment that gives skin and hair their color. Melanin-producing cells are found in the bottom layer of the epidermis. The epidermis does not have any blood vessels. The lower part of the epidermis receives blood by diffusion from blood vessels of the dermis.

The Dermis

The **dermis** is the layer of skin directly under the epidermis. It is made of a tough connective tissue. The dermis contains hair follicles, sweat glands, oil glands, and blood vessels (**Figure** above). It also holds many nerve endings that give you your sense of touch, pressure, heat, and pain.

Do you ever notice how your hair stands up when you are cold or afraid? Tiny muscles in the dermis pull on hair follicles which cause hair to stand up. The resulting little bumps in the skin are commonly called "goosebumps" (**Figure** below).

Figure 11.6

Goosebumps are caused by tiny muscles in the dermis that pull on hair follicles, which causes the hairs to stand up straight.

Oil Glands and Sweat Glands

Glands and hair follicles open out into the epidermis, but they start in the dermis. Oil glands (**Figure** above) release, or secrete an oily substance, called **sebum** , into the hair follicle. Sebum “waterproofs” hair and the skin surface to prevent them from drying out. It can also stop the growth of bacteria on the skin. It is odorless, but the breakdown of sebum by bacteria can cause odors. If an oil gland becomes plugged and infected, it develops into a pimple. Up to 85% of teenagers get pimples, which usually go away by adulthood. Frequent washing can help decrease the amount of sebum on the skin.

Sweat glands (**Figure** [above](#)) open to the skin surface through skin pores. They are found all over the body. Evaporation of sweat from the skin surface helps to lower skin temperature. The skin also releases excess water, salts, and other wastes in sweat.

The *Integumentary System Song* can be heard at https://www.youtube.com/watch?v=MeTaBniB0ok .

Summary

- Skin serves many functions, from acting as a barrier that keeps particles and water out of the body, to helping to cool the body.
- Skin is made up of two layers, the epidermis and the dermis.

Explore More

Use the resources below to answer the questions that follow.

Explore More I

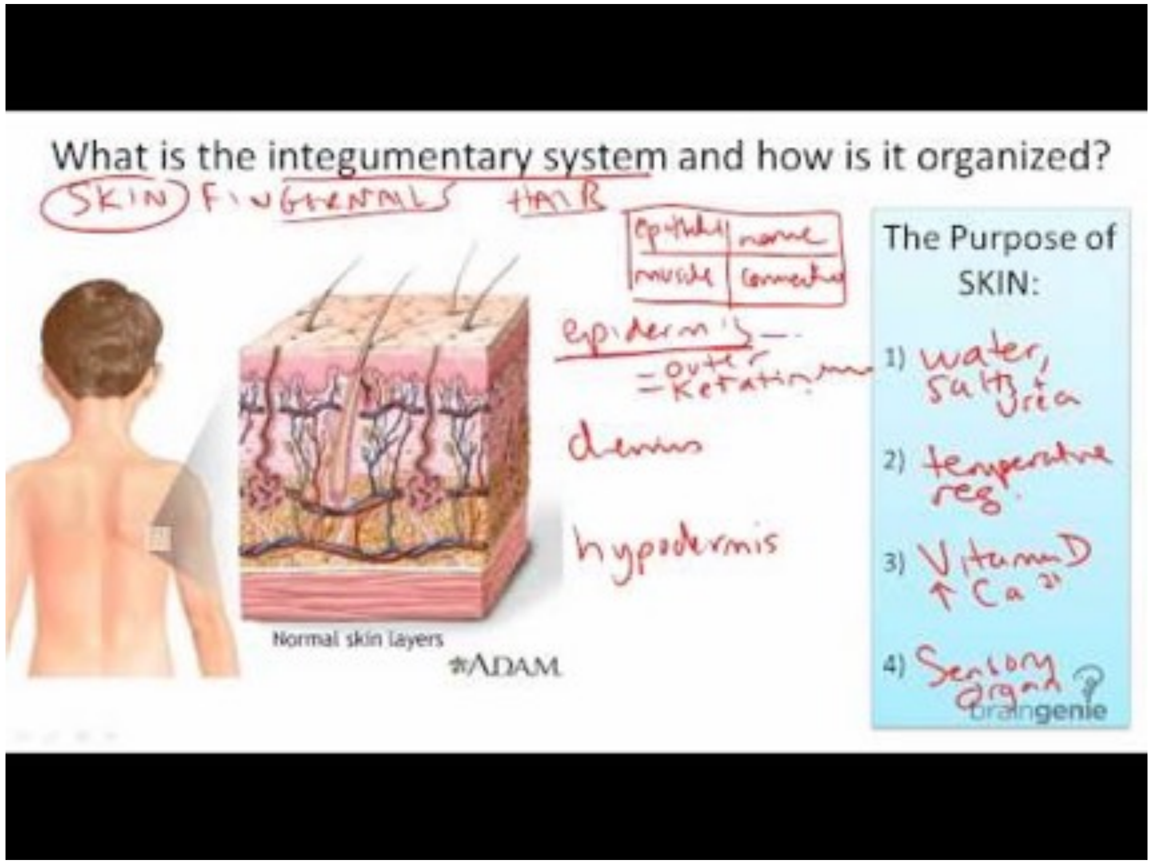
- **The Human Skin** at http://www.youtube.com/watch?v=d-IJhAWrsm0 (1:08)

Click on the image above for more content

1. What is the relationship of the epidermis to the dermis?
2. What is the importance of the basal layer? Is this part of the epidermis or the dermis?
3. What structures can you find in the dermis?

Explore More II

- **Integumentary System Structure and Function** at http://www.youtube.com/watch?v=PaHOd5fyKfE (2:59)



Click on the image above for more content

1. What are the four functions of skin?
2. What is the hypodermis? What kinds of tissue are found here? Why is it important to controlling homeostasis?
3. What is the function of keratin?

Review

1. Is the skin an organ?
2. What are two functions of the skin?
3. Your skin gathers information about your environment. What is meant by this statement?
4. Describe the structure of the skin.
5. List three components of the dermis.

Section 4

Nails and Hair

Nails and Hair

- •Describe the structure of hair and nails.
- •Explain the role of keratin.

Why do you have arm hair?

Hair covers much of our bodies. But why? Think of the way that you can sense something brush against your arm. Your arm hair is important in providing this type of sensation and making you aware of your environment. Also, hair can trap heat and keep your body warm.

Hair and Nails

Along with the skin, the integumentary system includes the nails and hair. Both the skin and hair contain the tough protein, **keratin** . The keratin forms fibers, which makes your nails and hair tough and strong. Keratin is similar in toughness to chitin, the carbohydrate found in the exoskeleton of arthropods.

Nails

Nails are similar to claws in other animals. They cover the tips of fingers and toes. Fingernails and toenails both grow from nail beds. As the nail grows, more cells are added at the nail bed. Older cells get pushed away from the nail bed and the nail grows longer. There are no nerve endings in the nail. Otherwise cutting your nails would hurt a lot!

Nails act as protective plates over the fingertips and toes. Fingernails also help in sensing the environment. The area under your nail has many nerve endings. These nerve endings allow you to receive more information about objects you touch.

The *Guinness Book of World Records* began tracking record fingernail lengths in 1955. At that time the record was 1 foot 10.75 inches long. The current record-holder for men is from India, with a record of 20 feet 2.25 inches for all nails on his left hand, the longest being his thumbnail at 4 feet 9.6 inches. The record for women is held by an American woman. The record is 28 feet (850 cm) for all nails of both hands, with the longest nail on her right thumb at 2 feet 11 inches. Since adult nails grow at about 3 mm a month (1/10 of an inch), how long would it take to grow such long nails?

Hair

Hair is one of the defining characteristics of mammals. In fact, mammals are the only animals to have hair. Hair sticks out from the epidermis, but it grows from the dermis (**Figure** below). Hair grows from inside the **hair follicle** . New cells grow in the bottom part of the hair, called the bulb. Older cells get pushed up, and the hair grows longer. The cells that make up the hair strand are dead and filled with the rope-like protein keratin.

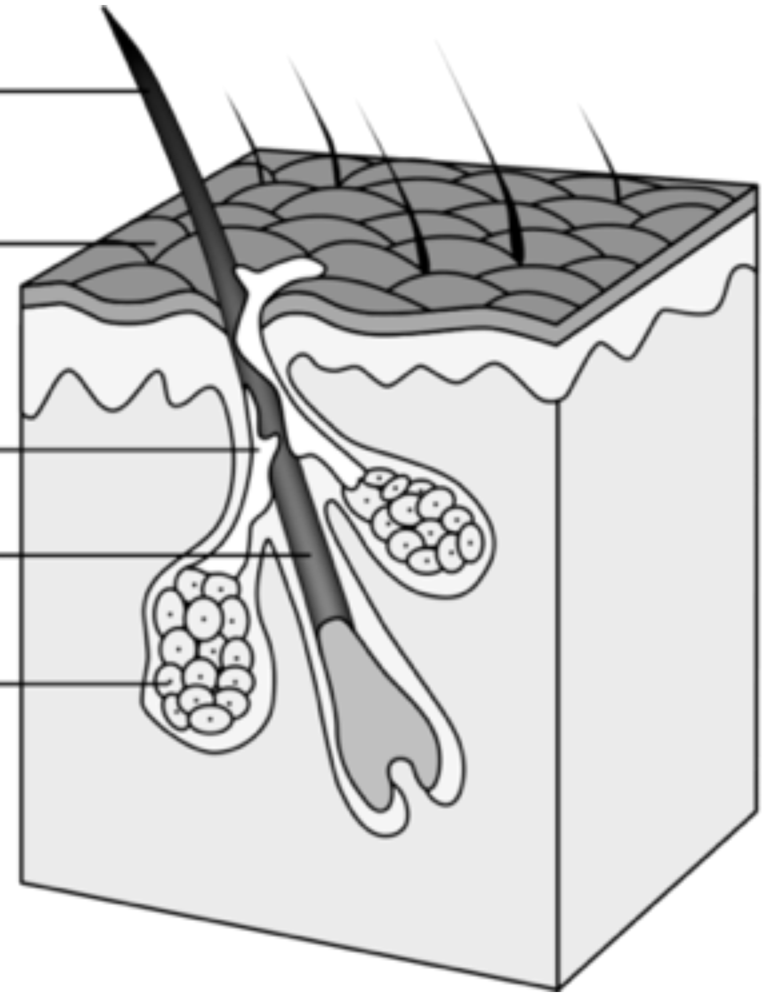


Figure 11.7

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

In humans, hair grows everywhere on the body except the soles of the feet and the palms of the hands, the lips, and the eyelids (except for eyelashes). Hair grows at a rate of about half an inch (1.25 cm) each month, or about 6 inches (15 cm) a year.

Hair, especially on the head, helps to keep the body warm. The air traps a layer of warm air near the skin and acts like a warm blanket. Hair can also act as a filter. Nose hair helps to trap particles in the air that may otherwise travel to the lungs. Eyelashes shield eyes from dust and sunlight. Eyebrows stop salty sweat and rain from flowing into the eye.

The world's longest documented hair, according to Guinness World Records, belongs to Xie Qiuping of China at just under 18 feet 6 inches (5.627 m) when measured on May 8, 2004. She had been growing her hair since 1973 when she was 13 years old.

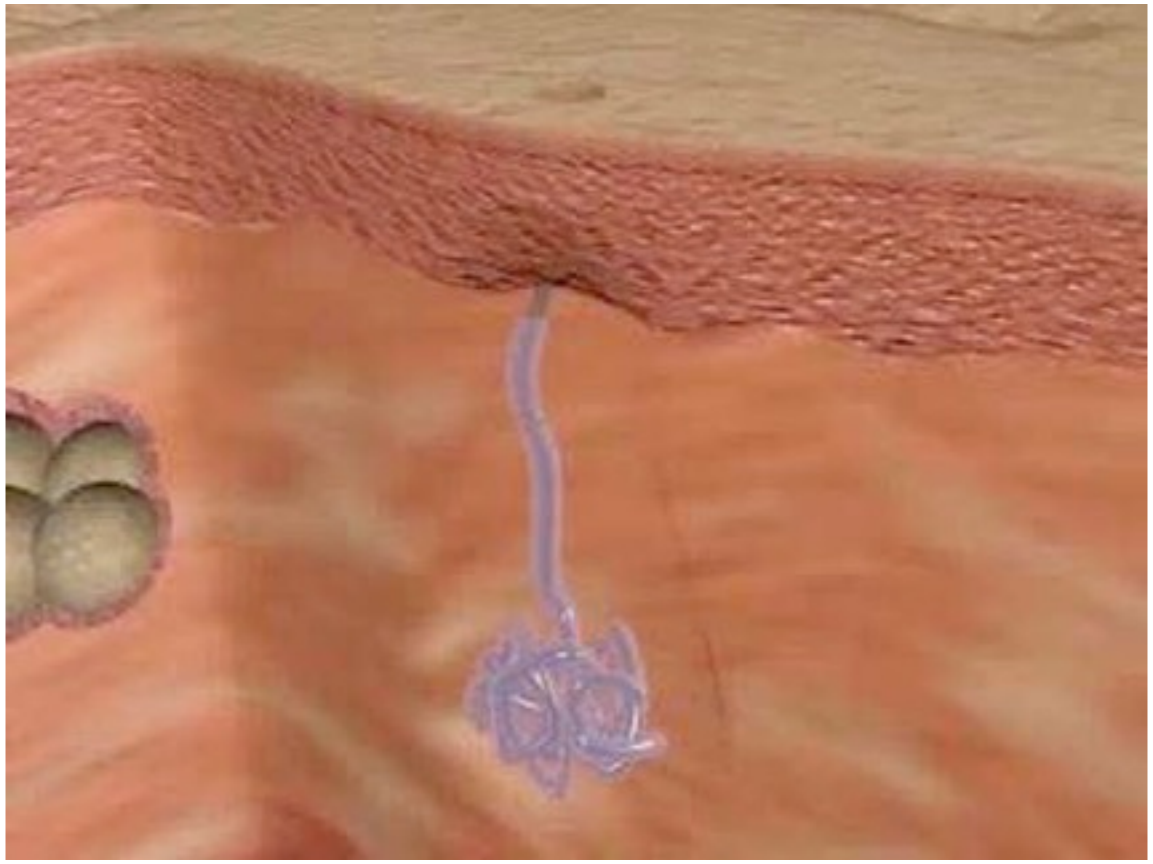
Summary

- Hair and nails are made of keratin, a tough protein.
- Nails act as protective plates over the fingertips and toes.
- Hair serves many functions such as acting as a filter and keeping the body warm.

Explore More

Use the resources below to answer the questions that follow.

- **Skin, Hair, Nails** at http://www.youtube.com/watch?v=IAAt_MfIJ-Y (1:12)



Click on the image above for more content

1. What is the function of your nails?
2. What is the function of the oil glands in your skin?
3. What are the functions of hair?

Review

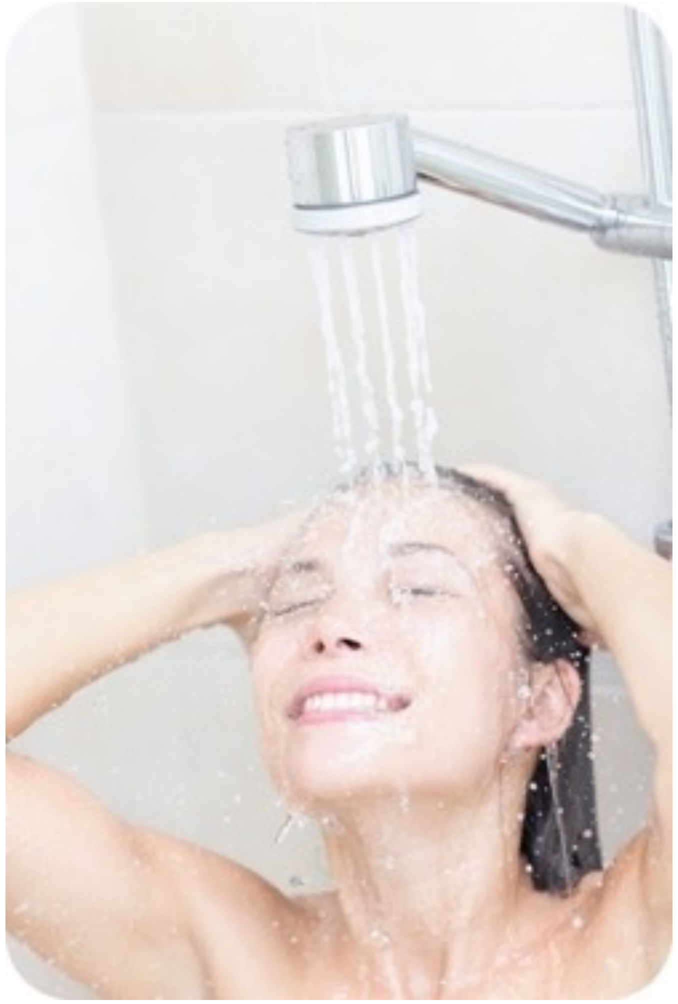
1. What is keratin?
2. What are two functions of your nails?
3. What are two functions of your hair?
4. What animals, other than mammals, have hair?

Section 5

Keeping Skin Healthy

Keeping Skin Healthy

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



Why shower every day?

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

Keeping Skin Healthy

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

Avoiding Sunburn

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

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

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

Figure 11.8

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

Keeping Clean

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

Skin Disorders

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

Acne

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

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

Cold Sores

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

Canker Sore

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

Summary

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

Explore More

Use the resource below to answer the questions that follow.

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

Click on the image above for more content

1. What nutrients are important for healthy skin?
2. What are good sources for these nutrients?

3. What is one of the roles that zinc plays in healthy skin?

Review

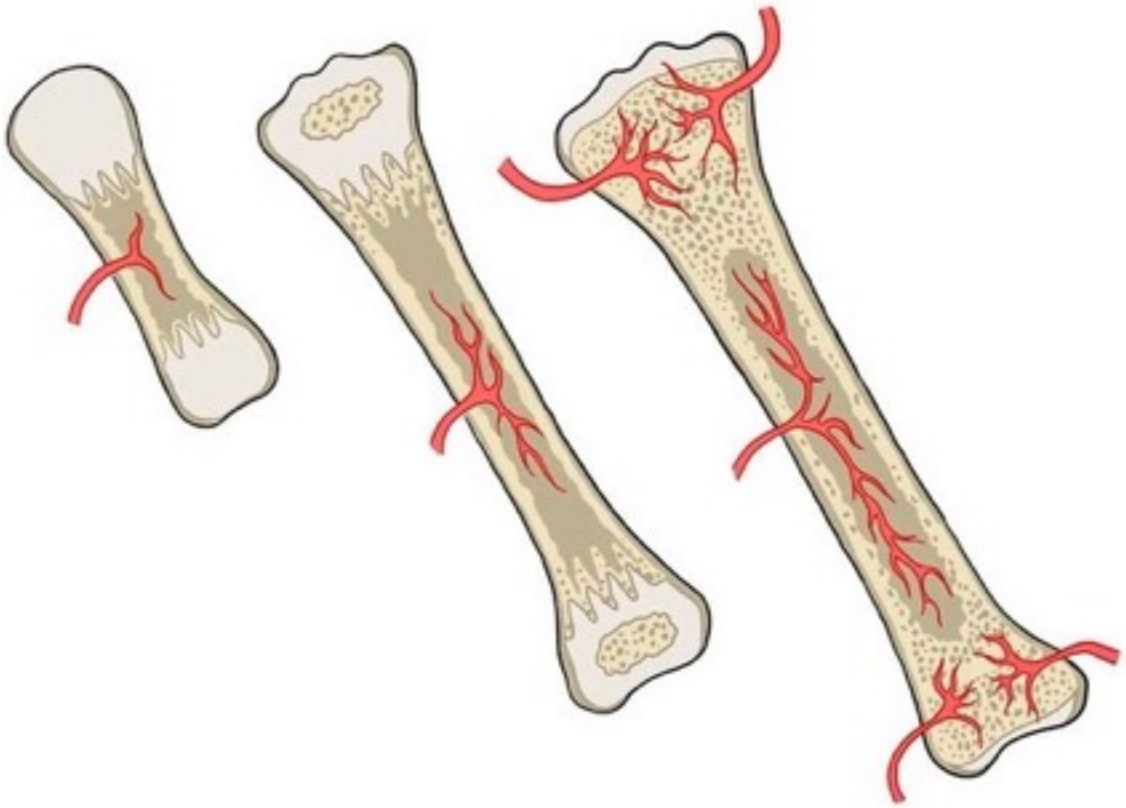
1. Why is keeping your skin clean important?
2. Why is it important to avoid too much sun exposure?
3. What pigment in the skin acts as a natural sunblock?
4. What is acne? How do pimples form?
5. What usually causes a cold sore?

Section 6

Human Skeletal System

Human Skeletal System

- •Identify the main structures and functions of the skeletal system.
- •Describe the structure of bones and how bones grow.
- •Define cartilage and ligament.
- •Explain bone growth.



Are bones alive?

From seeing a skeleton, you might think that bones are just dead, hollow structures. But in a living person, those hollow spaces are full of living cells. Bones have a blood supply and nerves. Bones are a living tissue.

Your Skeleton

How important is your skeleton? Can you imagine your body without it? You would be a wobbly pile of muscle and internal organs, and you would not be able to move.

The adult human skeleton has 206 bones, some of which are named below (**Figure** below). Bones are made up of living tissue. They contain many different types of tissues. **Cartilage** is found at the end of bones and is made of tough protein fibers. Cartilage creates smooth surfaces for the movement of bones that are next to each other, like the bones of the knee.

Ligaments are made of tough protein fibers and connect bones to each other. Your bones, cartilage, and ligaments make up your **skeletal system** .

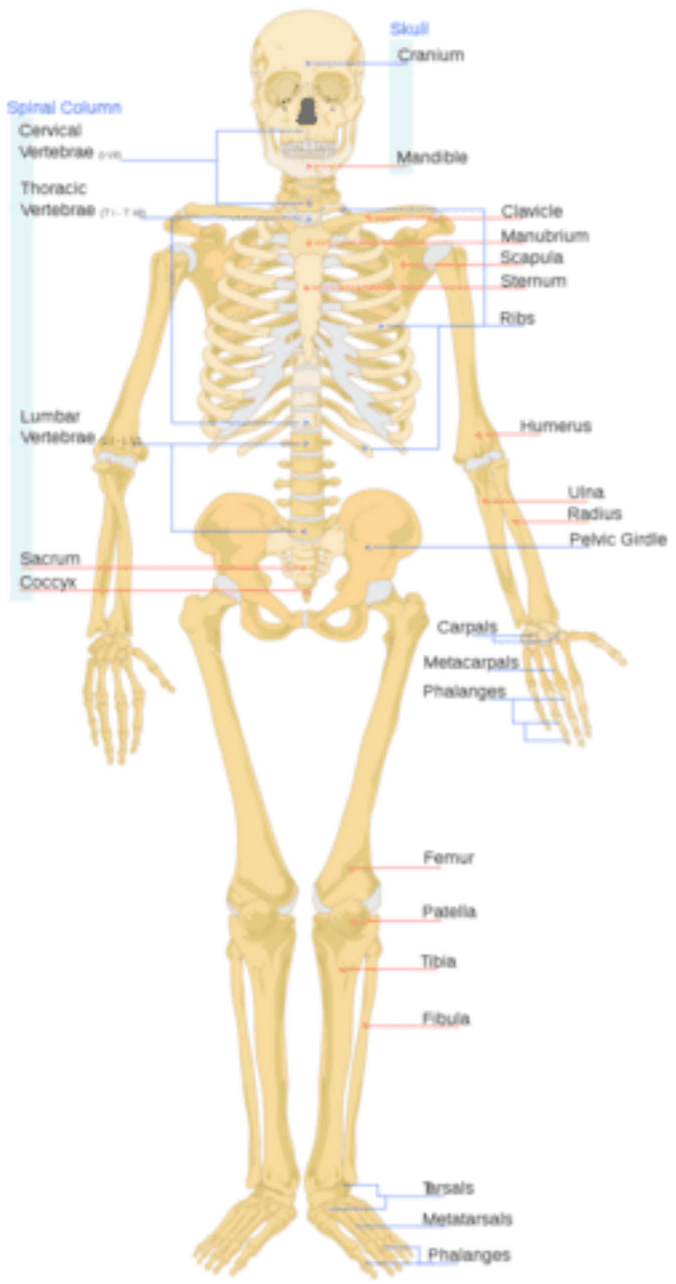


Figure 11.9

The skeletal system is made up of bones, cartilage, and ligaments. The skeletal system has many important functions in your body. What bones protect the heart and lungs? What protects the brain?

Functions of Bones

Your skeletal system gives shape and form to your body, but it also plays other important roles. The main functions of the skeletal system include:

- Support. The skeleton supports the body against the pull of gravity, meaning you don't fall over when you stand up. The large bones of the lower limbs support the rest of the body when standing.
- Protection. The skeleton supports and protects the soft organs of the body. For example, the skull surrounds the brain to protect it from injury. The bones of the rib cage help protect the heart and lungs.
- Movement. Bones work together with muscles to move the body.
- Making blood cells. Blood cells are mostly made inside certain types of bones.
- Storage. Bones store calcium. They contain more calcium than any other organ. Calcium is released by the bones when blood levels of calcium drop too low. The mineral, phosphorus is also stored in bones.

Structure of Bones

Bones come in many different shapes and sizes, but they are all made of the same materials. Bones are organs, and recall that organs are made up of two or more types of tissues.

The two main types of bone tissue are compact bone and spongy bone (**Figure** below).

•**Compact bone** makes up the dense outer layer of bones.
•**Spongy bone** is found at the center of the bone and is lighter and more porous than compact bone.

Bones look tough, shiny, and white because they are covered by a layer called the **periosteum** . Many bones also contain a soft connective tissue called **bone marrow** in the pores of the spongy bone. Bone marrow is where blood cells are made.

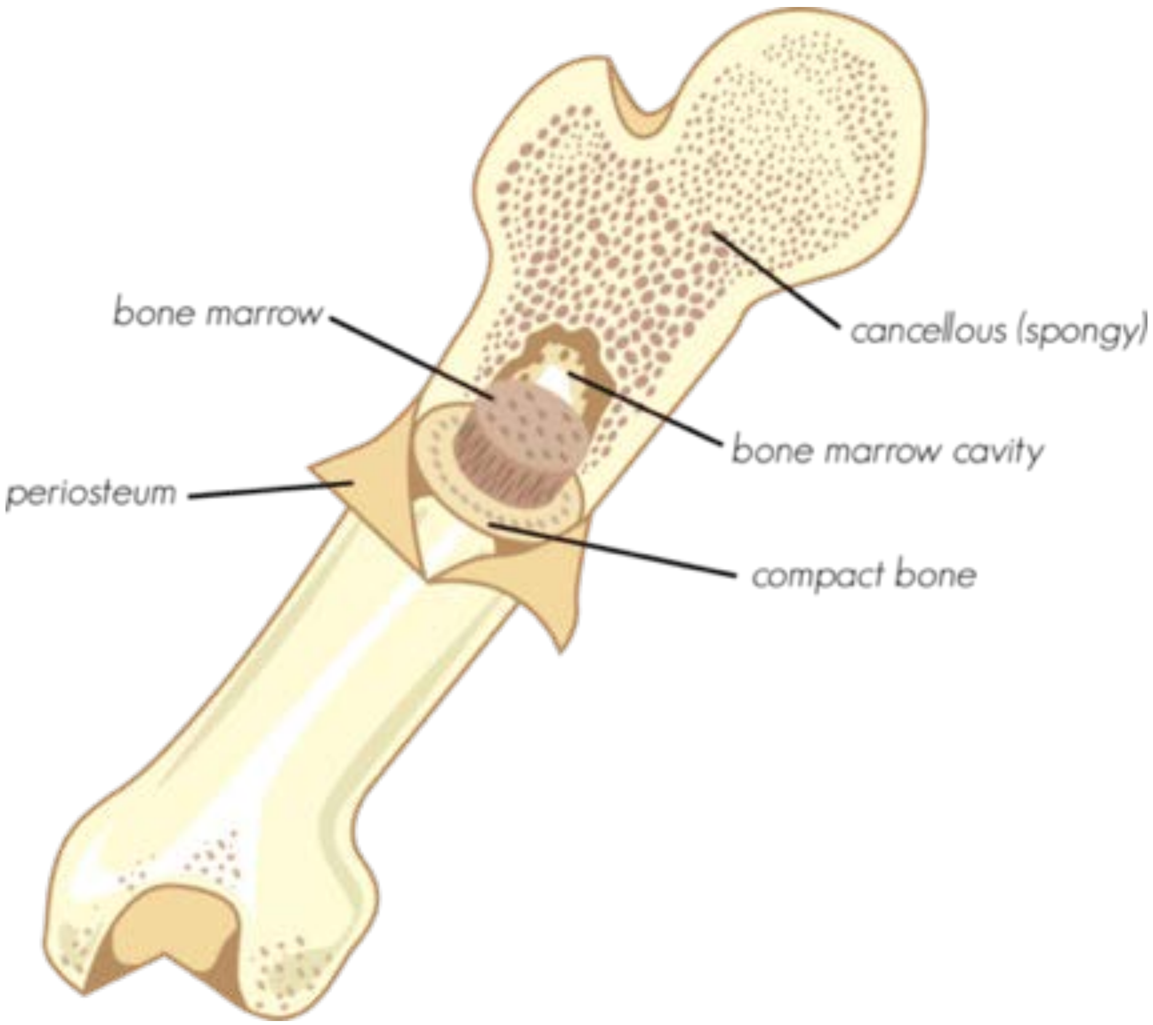


Figure 11.10

Bones are made up of different types of tissues.

Bone Growth

Early in human development, the skeleton consists of only cartilage and other connective tissues. At this point, the skeleton is very flexible. As the fetus develops, hard bone begins to replace the cartilage, and the skeleton begins to harden. Not all of the cartilage, however, is replaced by bone. Cartilage remains in many places in your body, including your joints, your rib cage, your ears, and the tip of your nose.

A baby is born with zones of cartilage in its bones that allow growth of the bones. These areas, called **growth plates** , allow the bones to grow longer as the child grows. By the time the child reaches an age of about 18 to 25 years, all of the cartilage in the growth plate has been replaced by bone. This stops the bone from growing any longer. Even though bones stop growing in length in early adulthood, they can continue to increase in thickness throughout life. This thickening occurs in response to strain from increased muscle activity and from weight-lifting exercises.

Summary

•Bones, cartilage, and ligaments make up the skeletal system.
•Functions of the skeletal system include providing support, protecting the soft organs of the body, aiding in movement, and making blood cells.

Explore More

Use the resource below to answer the questions that follow.

- **Human Skeleton** at http://www.getbodysmart.com/ap/skeletalsystem/skeleton/menu/menu.html

1. What makes up the axial skeleton? What makes up the appendicular skeleton?
2. What is the scapula commonly known as? What other bone helps the scapula function? What do these two bones do?
3. How many thoracic vertebrae do humans have? Where are they located in the spinal column?
4. To which type of vertebrae do ribs attach?
5. What is the atlas bone? What is the role of this bone?

Review

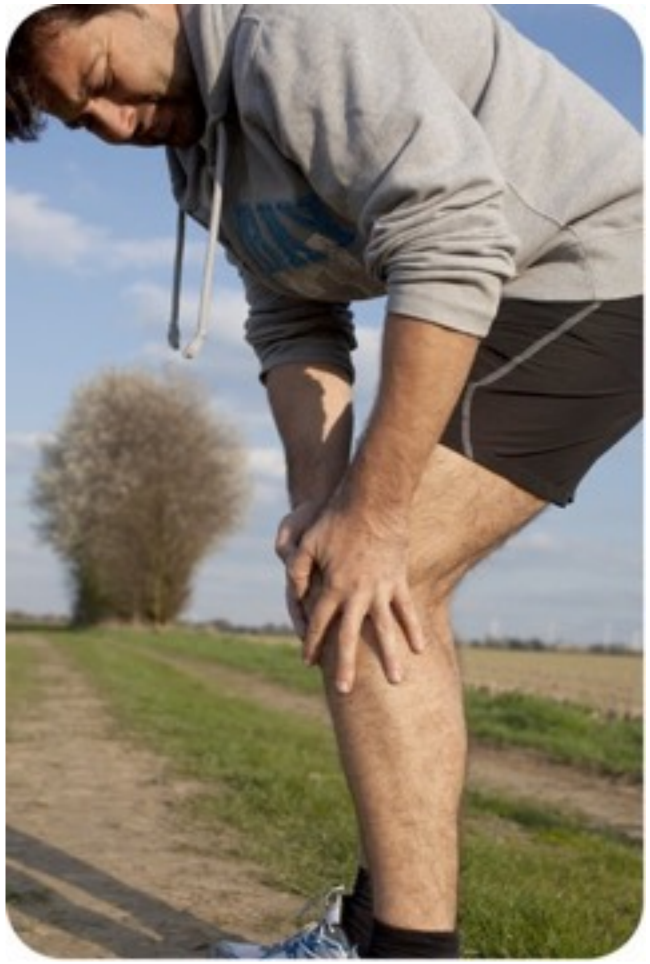
1. Are bones a living organ?
2. What are the three components of the skeletal system?
3. List four functions of the skeletal system.
4. Name and describe the two types of tissue that make up a bone.

Section 7

Skeletal System Joints

Skeletal System Joints

•Describe the different types of joints and how they work.
•Give examples of fixed joints, partly movable joints, and movable joints.
•Distinguish a ball-and-socket joint from a hinge joint and a pivot joint.



Why does his knee hurt?

As you age, you might start noticing pain in your knees or elbows. These are examples of joints. Joints are the part of the skeletal system that connect your bones. Joint pain is a common problem as people age.

Joints and How They Move

A **joint** is a point at which two or more bones meet. There are three main types of joints in the body:

1. **Fixed joints** do not allow any bone movement. Many of the joints in your skull are fixed (**Figure**

below). There are eight bones that fuse together to form the cranium. The joints between these bones do not allow movement, which helps protect the brain.

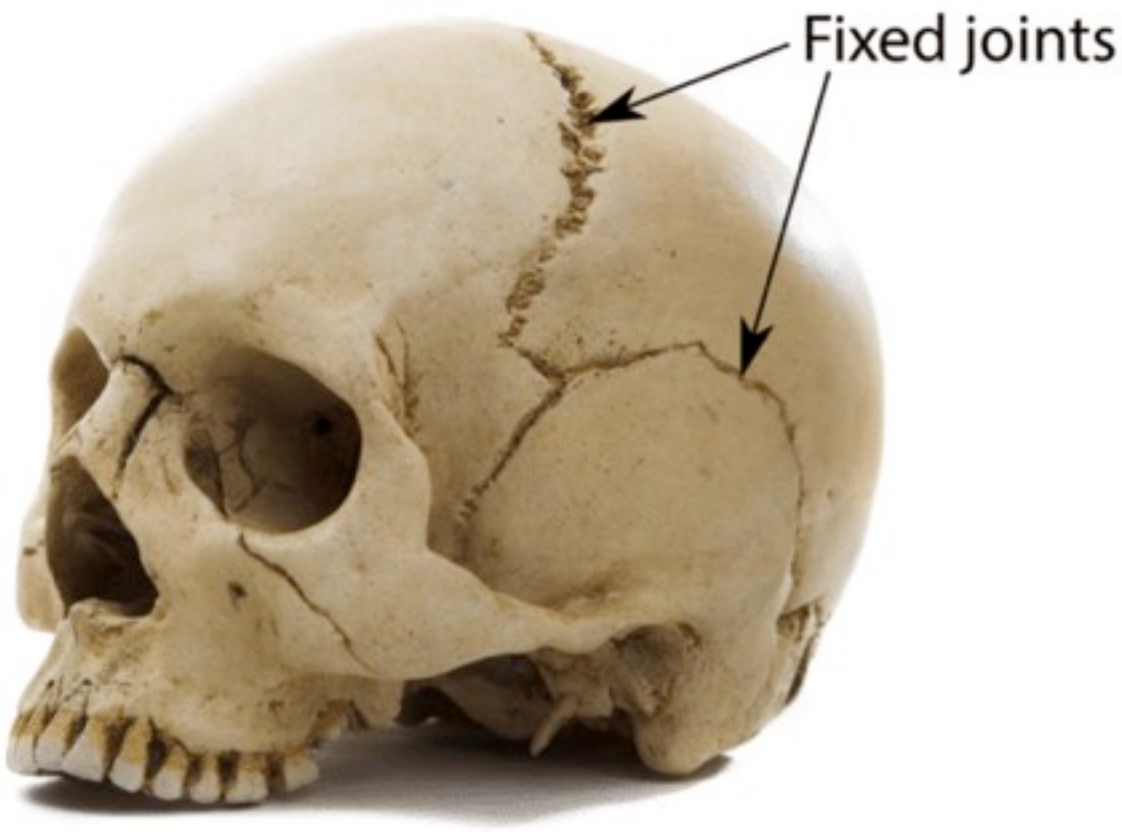


Figure 11.11

The skull has fixed joints. Fixed joints do not allow any movement of the bones, which protects the brain from injury.

2.**Partly movable joints** allow only a little movement. Your backbone has partly movable joints between the vertebrae (**Figure** below).

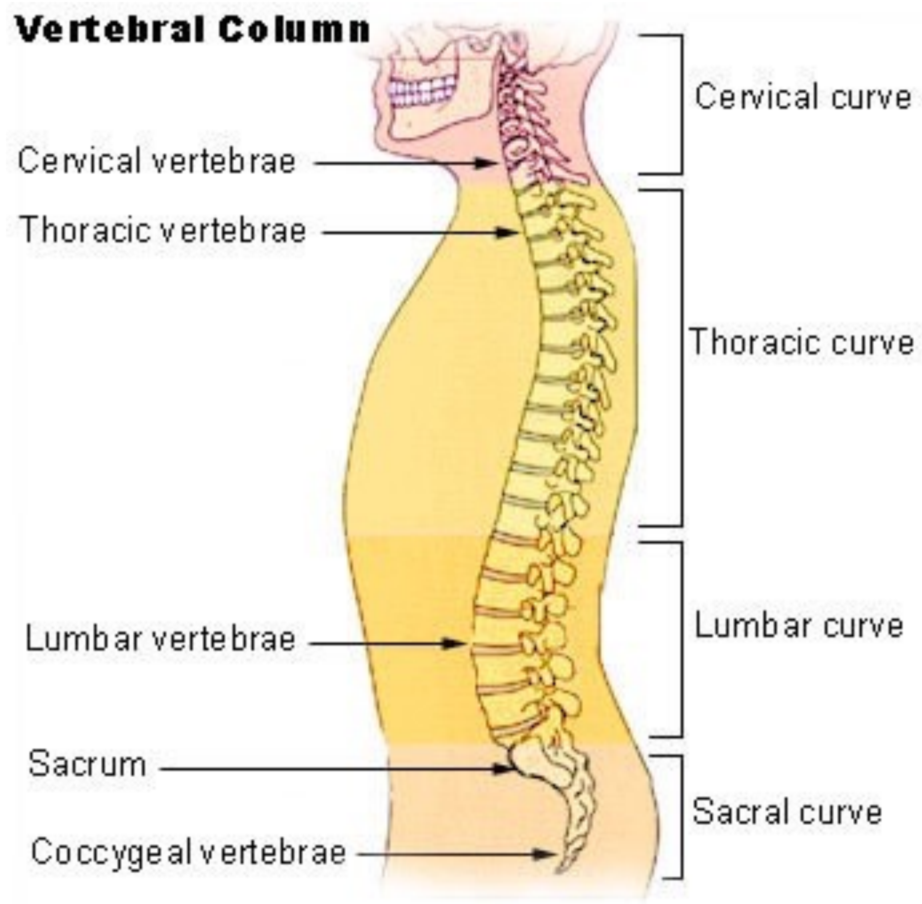


Figure 11.12

The joints between your vertebrae are partially movable.

3.**Movable joints** allow the most movement.

Movable joints are also the most common type of joint in your body. Your fingers, toes, hips, elbows, and knees all provide examples of movable joints. The surfaces of bones at movable joints are covered with a smooth layer of cartilage. The cartilage reduces friction between the bones. Ligaments often cross a joint, holding two nones together. For example, there are numerous ligaments connecting the leg bones across the knee joint.

Types of Movable Joints

Four types of movable joints are discussed here.

1.In a **ball-and-socket joint** , the ball-shaped surface of one bone fits into the cup-like shape of another. Examples of a ball-and-socket joint include the hip (**Figure** below) and the shoulder.

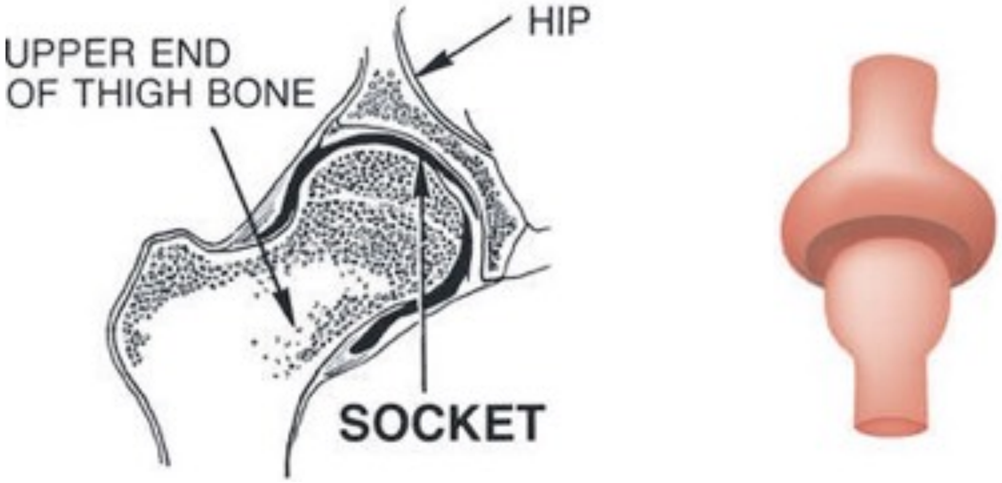


Figure 11.13

Your hip joint is a ball-and-socket joint. The “ball” end of one bone fits into the “socket” of another bone. These joints can move in many different directions.

2.In a **hinge joint** , the ends of the bones are shaped in a way that allows motion in two directions, forward and backward. Examples of hinge joints are the knees (**Figure** below) and elbows.

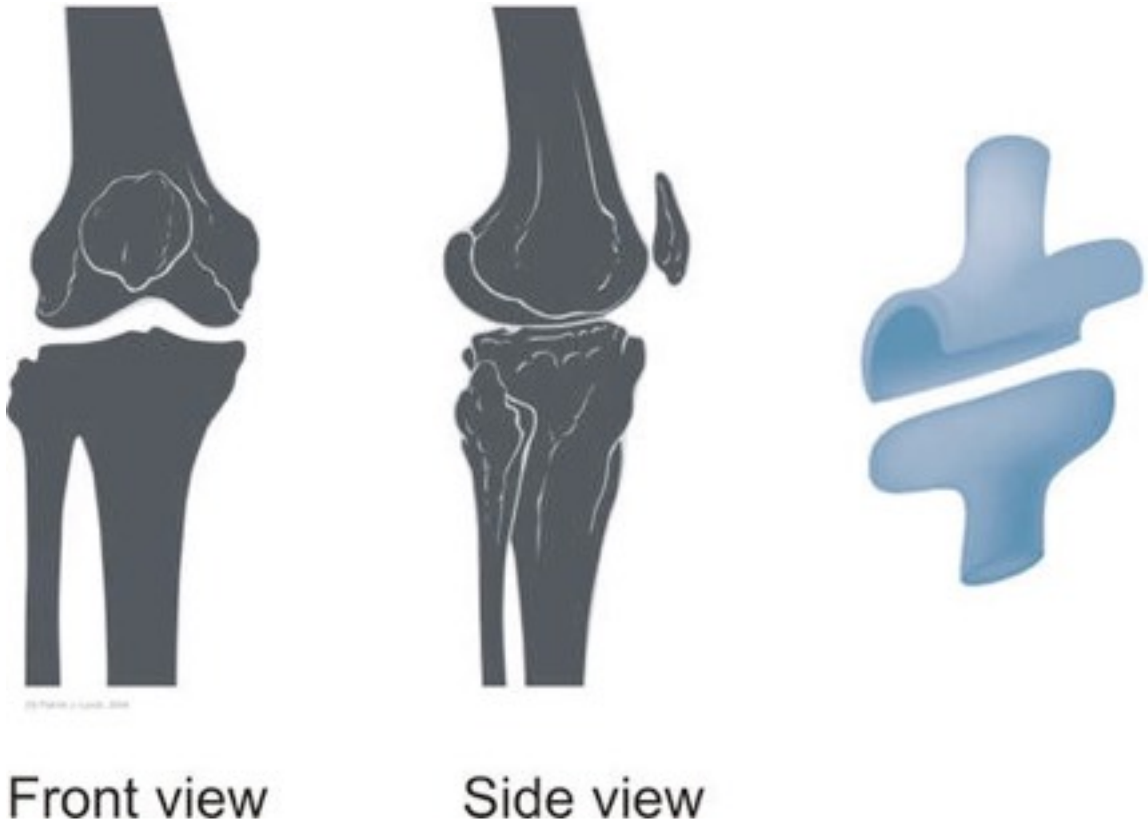


Figure 11.14

Hinge Joint. The knee joint is a hinge joint. Like a door hinge, a hinge joint allows backward and forward movement.

3.The **pivot joint** (**Figure** below) only allows rotating movement. An example of a pivot joint is the joint between the radius and ulna that allows you to turn the palm of your hand up and down.

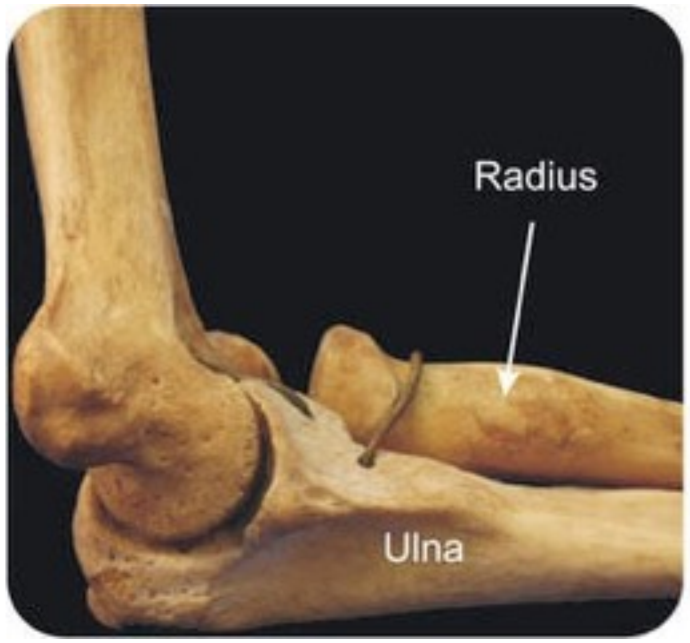


Figure 11.15

Pivot Joint. The joint at which the radius and ulna meet is a pivot joint. Movement at this joint allows you to flip your palm over without moving your elbow joint.

4.A **gliding joint** is a joint which allows only gliding movement. The gliding joint allows one bone to slide over the other. The gliding joint in your wrist allows you to flex your wrist. It also allows you to make very small side-to-side motions. There are also gliding joints in your ankles.

Summary

- Joints, a point at which two or more bones meet; they can be fixed, partly movable, or movable.
- Types of movable joints include the ball-and-socket joint, hinge joint, pivot joint, and gliding joint.

Explore More

Use the resource below to answer the questions that follow.

- **Joints of the Skeleton** at http://www.youtube.com/watch?v=VsBJ4oUff10 (0:45)

Click on the image above for more content

1.What is an example of a fixed joint? How would an organism be affected if this joint was moveable?
2.What are the best joints for movement?
3.What is the function of synovial fluid? Where is it located?
4.What is the function of the knee cap?

Review

1. What's the difference between a fixed joint and a movable joint? Give examples of each.
2. Describe the four types of movable joints.
3. What type of joint are each of the following?
    a. the shoulder
    b. the wrist
    c. the knee

Section 8

Keeping Bones and Joints

Keeping Bones and Joints Healthy

•Describe problems of the skeletal system and steps you can take to keep your bones and joints healthy.
•Explain the importance of calcium and vitamin D.
•Describe osteoporosis.
•Distinguish cartilage injuries from ligament injuries.

Why drink milk?

Milk is naturally a good source of calcium. Vitamin D is also often added to milk. Both these nutrients help build strong bones.

Keeping Bones and Joints Healthy

You can help keep your bones and skeletal system healthy by eating well and getting enough exercise. Weight-bearing exercises help keep bones strong. Weight-bearing exercises and activities work against gravity. Such activities include basketball, tennis, gymnastics, karate, running, and walking. When the body is exercised regularly by performing weight-bearing activity, bones respond by adding more bone cells to increase their bone density.

Eating Well

Did you know that what you eat as a teenager can affect how healthy your skeletal system will be in 30, 40, and even 50 years? **Calcium** and **vitamin D** are two of the most important nutrients for a healthy skeletal system. Your bones need calcium to grow properly. If you do not get enough calcium in your diet as a teenager, your bones may become weak and break easily later in life.

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

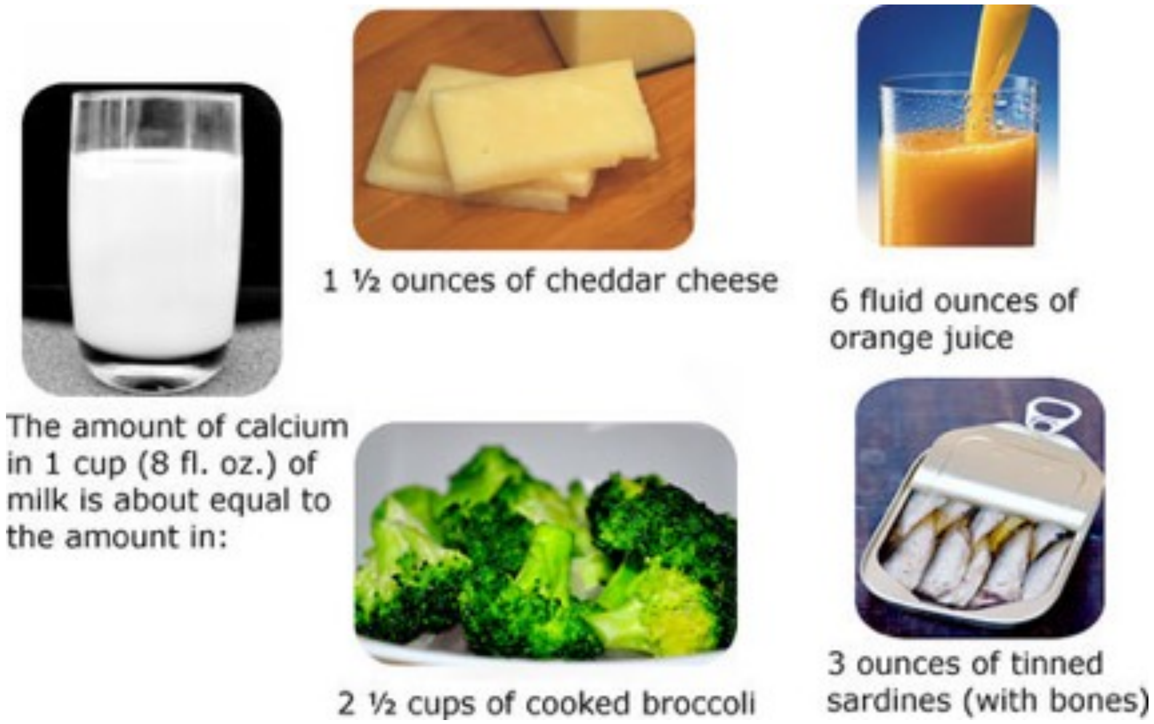


Figure 11.16

There are many different sources of calcium. Getting enough calcium in your daily diet is important for good bone health.

Vitamin D is unusual since you don't have to rely on your diet alone to get enough of this vitamin. Your skin makes vitamin D when exposed to sunlight. Pigments in the skin act like a filter that can prevent the skin from making vitamin D. As a result, people with darker skin need more time in the sun than people with lighter skin to make the same amount of vitamin D.

You can also get vitamin D from foods. Fish is naturally rich in vitamin D. In the United States, vitamin D is added to other foods, including milk, soy milk, and breakfast cereals. Teenagers are recommended to get 5 micrograms (200 IU) of vitamin D every day. A 3½-ounce portion of cooked salmon provides 360 IU of vitamin D. A 8-ounce glass of milk is fortified with about 100 IU of vitamin D.

Bone Fractures

Even though they are very strong, bones can **fracture** , or break. Fractures can happen at different places on a bone. They are usually caused by excess bending stress on the bone. Bending stress is what causes a pencil to break if you bend it too far.

Soon after a fracture, the body begins to repair the break. The area becomes swollen and sore. Within a few days, bone cells travel to the break site and begin to rebuild the bone. It takes about two to three months before compact and spongy bone form at the break site. Sometimes the body needs extra help in repairing a broken bone. In such a case, a surgeon will piece a broken bone together with metal pins. Moving the broken pieces together will help keep the bone from moving and give the body a chance to repair the break. Below, a broken ulna has been repaired with pins (**Figure** below).

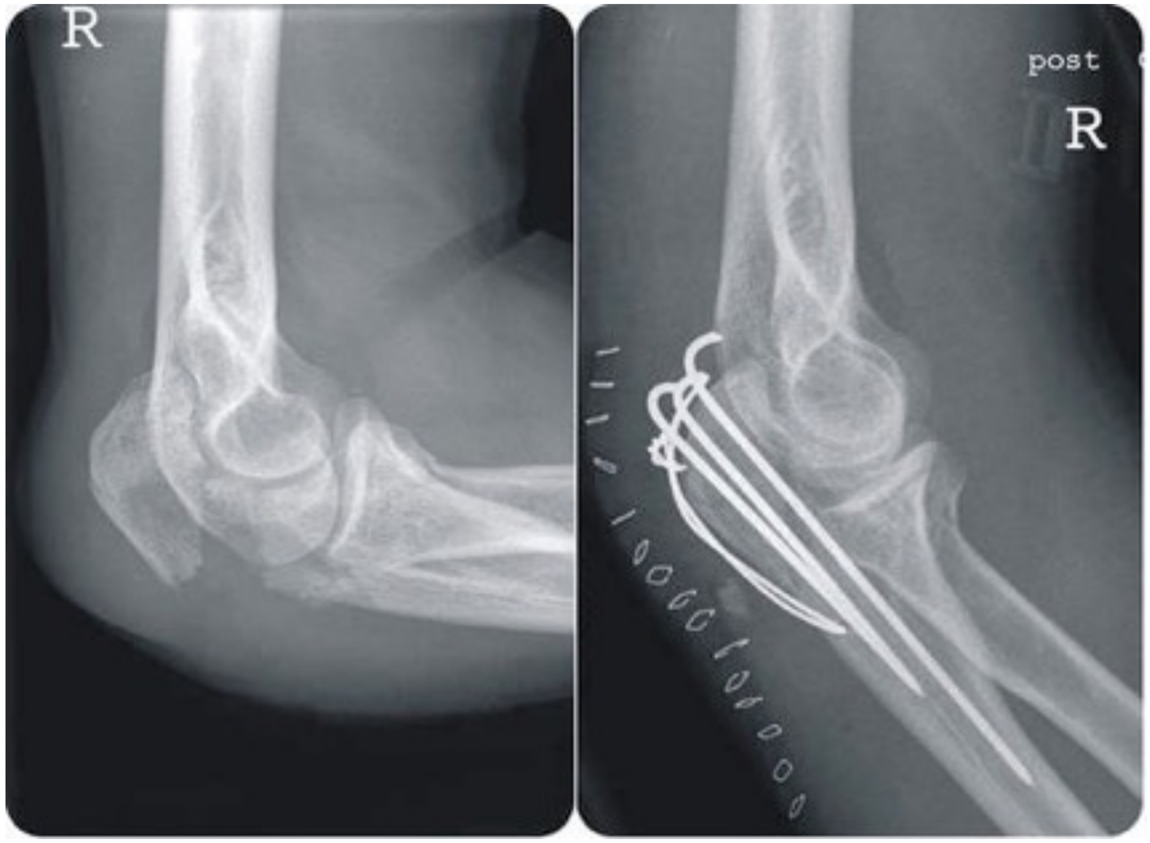


Figure 11.17

The upper part of the ulna, just above the elbow joint, is broken, as you can see in the X-ray to the left. The x-ray to the right was taken after a surgeon inserted a system of pins and wires across the fracture to bring the two pieces of the ulna into close proximity.

Cartilage Injuries

Osteoarthritis occurs when the cartilage at the ends of the bones breaks down. The break down of the cartilage leads to pain and stiffness in the joint. Decreased movement of the joint because of the pain may lead to weakening of the muscles that normally move the joint, and the ligaments surrounding the joint may become loose. Osteoarthritis is the most common form of **arthritis** . It has many contributing factors, including aging, sport injuries, fractures, and obesity.

Ligament Injuries

Recall that a **ligament** is a short band of tough connective tissue that connects bones together to form a joint. Ligaments can get injured when a joint gets twisted or bends too far. The protein fibers that make up a ligament can get strained or torn, causing swelling and pain. Injuries to ligaments are called **sprains** . Ankle sprains are a common type of sprain.

Preventing Injuries

Preventing injuries to your bones and ligaments is easier and much less painful than treating an injury. Wearing the correct safety equipment when performing activities that require such equipment can help prevent many common injuries. For example, wearing a bicycle helmet can help prevent a skull injury if you fall. Warming up and cooling down properly can help prevent ligament and muscle injuries. Stretching before and after activity also helps prevent injuries.

Summary

- You can keep your bones healthy through weight-bearing exercises and getting enough calcium and vitamin D in your diet.
- Possible problems of the skeletal system include osteoporosis, osteoarthritis, fractures, and sprains.

Explore More

Use the resource below to answer the questions that follow.

- **Healthy Bones and Joints** at http://www.youtube.com/watch?v=jHwJq1TJE18 (1:47)

Click on the image above for more content

1. How much calcium does the average person need per day? What are good sources of calcium? What vitamin helps you process calcium?
2. How do weight-bearing exercises help your bones?
3. How can table salt (NaCl) be bad for your bones?

Review

1.What are two good habits to keep your skeletal system healthy?
2.Give three examples of weight-bearing activities.
3.List three good sources of calcium.
4.What is osteoporosis?
5.What is osteoarthritis?

Section 9

Smooth, Skeletal, and Car-

Smooth, Skeletal, and Cardiac Muscles

•Explain the roles of the muscular system.
•Define muscle fiber.
•Identify and describe the three muscle types in the body.

Does the heart have muscles?

When you think of muscles, you might think of biceps and the external muscles you see in a bodybuilder. However, some muscles are found deep inside your body. The heart, for example, is a very muscular organ. It has to pump blood all around your body.

Types of Muscles

The **muscular system** consists of all the muscles in the body. This is the body system that allows us to move. You also depend on many muscles to keep you alive. Your heart, which is mostly muscle, pumps blood around your body.

Each muscle in the body is made up of cells called muscle fibers. **Muscle fibers** are long, thin cells that can do something that other cells cannot do—they are able to get shorter. Shortening of muscle fibers is called **contraction** . Muscle fibers can contract because they are made of proteins, called actin and myosin, that form long filaments (or fibers). When muscles contract, these protein filaments slide or glide past one another, shortening the length of the cell. When your muscles relax, the length extends back to the previous position. Nearly all movement in the body is the result of muscle contraction.

You can control some muscle movements. However, certain muscle movements happen without you thinking about them. Muscles that are under your conscious control are called **voluntary muscles** . Muscles that are not under your conscious control are called **involuntary muscles** .

Muscle tissue is one of the four types of tissue found in animals. There are three different types of muscle in the body (**Figure** below):

1. **Skeletal muscle** is made up of voluntary muscles, usually attached to the skeleton. Skeletal muscles move the body. They can also contract involuntarily by reflexes. For example, you can choose to move your arm, but your arm would move automatically if you were to burn your finger on a stove top. This voluntary contraction begins with a thought process. A signal from your brain tells your muscles to contract or relax. Quickly contract and relax the muscles in your fingers a few times. Think about how quickly these signals must travel throughout your body to make this happen.
2. **Smooth muscle** is composed of involuntary muscles found within the walls of organs and structures such as the esophagus, stomach, intestines, and blood vessels. These muscles push materials like food or blood through organs. Unlike skeletal muscle, smooth muscle can never be under your control.
3. **Cardiac muscle** is also an involuntary muscle, found only in the heart. The cardiac muscle fibers all contract together, generating enough force to push blood throughout the body. What would happen if this muscle was under conscious or voluntary control?

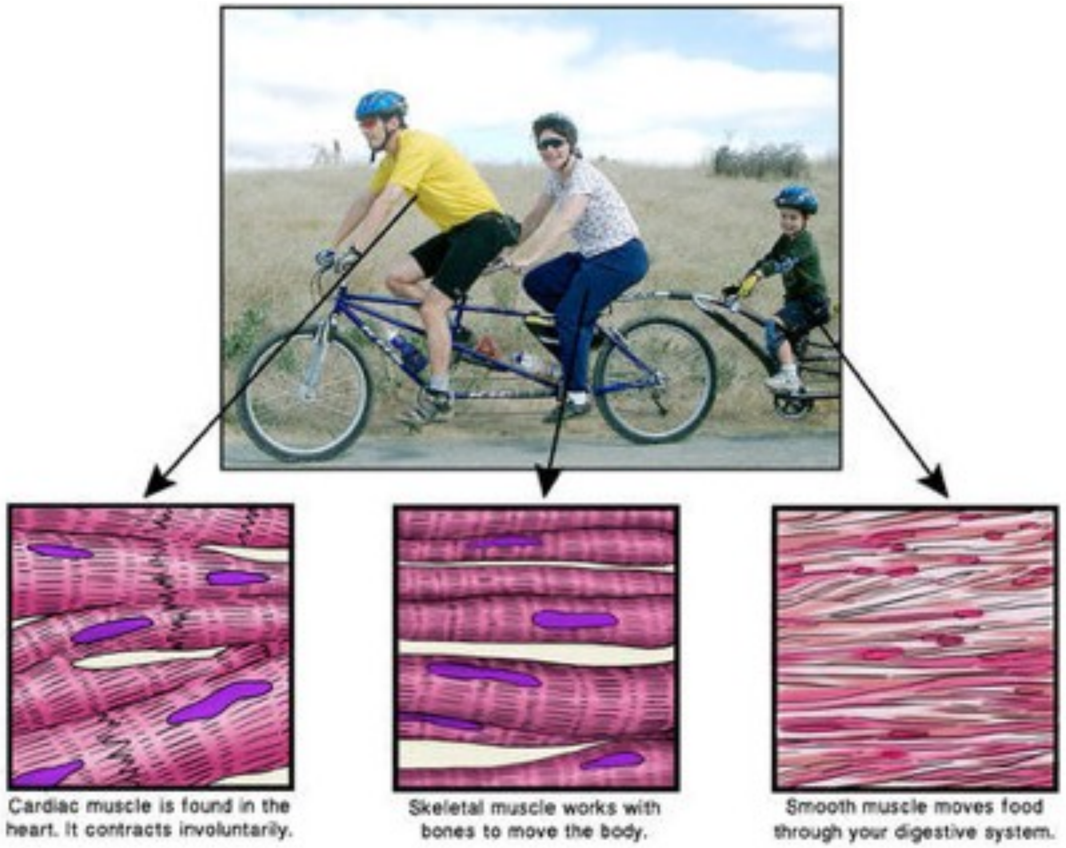


Figure 11.18

There are three types of muscles in the body: cardiac, skeletal, and smooth.

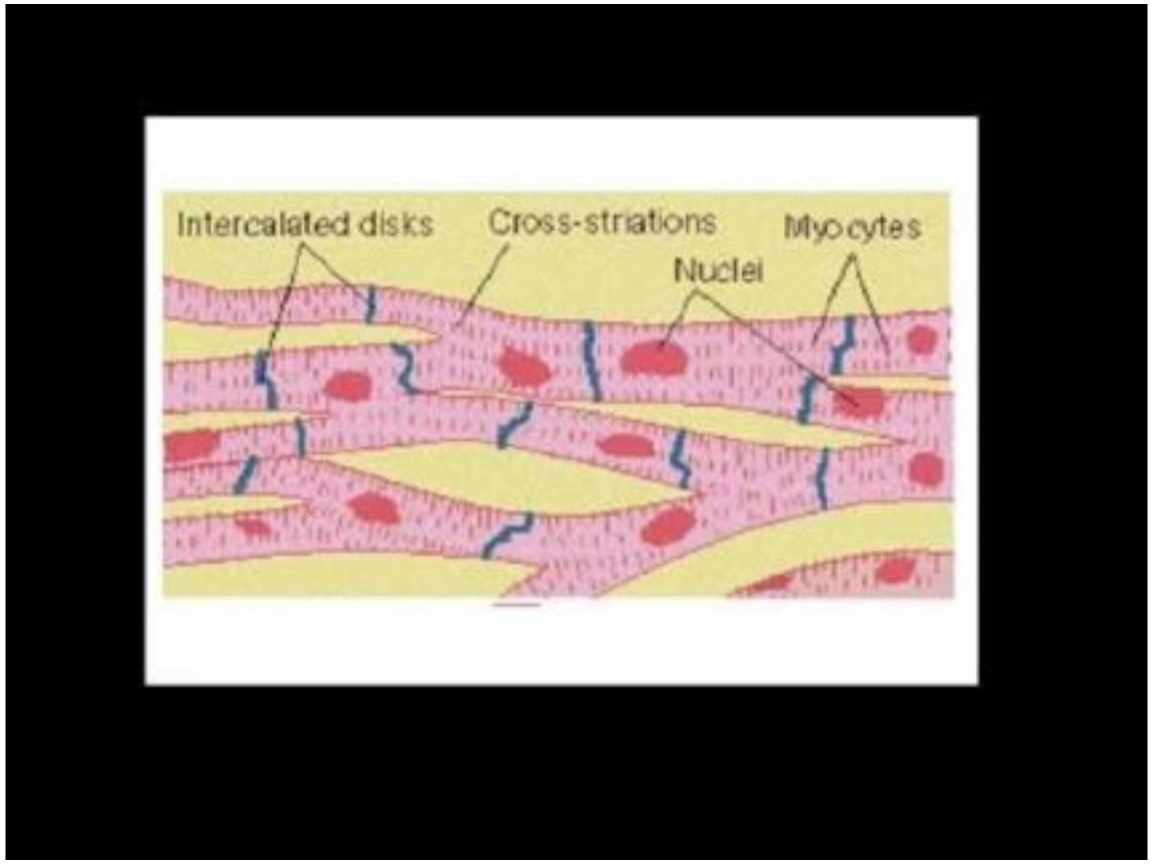
Summary

- Muscles that are under your conscious control are called voluntary muscles, while muscles that are not under your conscious control are called involuntary muscles.
- The three types of muscles in the body include skeletal muscle, smooth muscle, and cardiac muscle.

Explore More

Use the resource below to answer the questions that follow.

- **Three Types of Muscles** at http://www.youtube.com/watch?v=Y9yTwS4v0Gc (4:04)



Click on the image above for more content

1. Why are some muscles called "voluntary" and some called "involuntary"?
2. What is the function of skeletal muscles? What is the function of cardiac muscles?
3. Where are smooth muscles found?
4. What muscles are not under voluntary control?

Review

1. What are muscle fibers? What is unique about these fibers?
2. Describe voluntary muscle.
3. Which two of the three types of muscles in the body are involuntary?
4. Distinguish between skeletal muscle and smooth muscle.

Section 10

Muscles, Bones, and Move-

Muscles, Bones, and Movement

•Describe how skeletal muscles and bones work together to move the body.
•Compare the flexor to the extensor.
•Describe functions of smooth muscle.
•Explain the importance of cardiac muscle.

Do muscles come in pairs?

This woman is doing a stretch for the muscles on the back of her legs, the hamstrings. She also has a muscles on the front of her legs, directly opposite the hamstrings. These are the quadriceps. The hamstrings and quadriceps work together as a pair to move your legs back and forth while you run.

Muscles, Bones, and Movement

When skeletal muscles contract, bones move. But how do muscles make your bones move? A voluntary muscles usually works across a joint. It is attached to both the bones on either side of the joint by strong cords called tendons. A **tendon** is a tough band of connective tissue that connects a muscle to a bone. Tendons are similar to ligaments, except that ligaments join bones to each other. Muscles move the body by contracting against the skeleton. When muscles contract, they get shorter. By contracting, muscles pull on bones and allow the body to move.

Muscles can only contract. They cannot actively extend, though they can move or relax back into the non-contracted neutral position. Therefore, to move bones in opposite directions, pairs of muscles must work in opposition. Each muscle in the pair works against the other to move bones at the joints of the body. The muscle that contracts to cause a joint to bend is called the **flexor** . The muscle that contracts to cause the joint to straighten is called the **extensor** . When one muscle is contracted, the other muscle from the pair is always elongated.

For example, the biceps and triceps muscles work together to allow you to bend and straighten your elbow. When you want to bend your elbow, your biceps muscle contracts (**Figure** below), and, at the same time, the triceps muscle relaxes. The biceps is the flexor, and the triceps is the extensor of your elbow joint. Other muscles that work together are the quadriceps and hamstrings used to bend and straighten the knee, and the pectorals and trapezius used to move the arms and shoulders forward and backward. During daily routines we do not use muscles equally. For example, we use our biceps more than our triceps due to lifting against gravity.

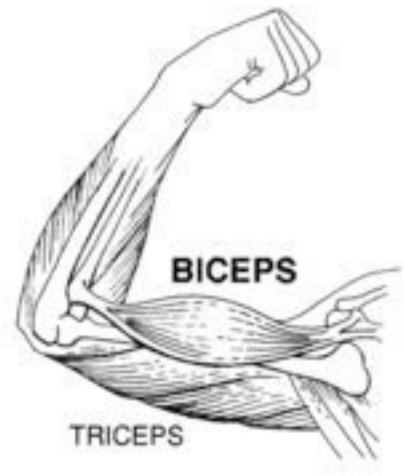


Figure 11.19

The biceps and triceps act against one another to bend and straighten the elbow joint. To bend the elbow, the biceps contracts and the triceps relaxes. To straighten the elbow, the triceps contract and the biceps relax.

Smooth Muscles and Cardiac Muscles

Smooth muscles and cardiac muscles are not attached to bone. Recall that these types of muscles are under involuntary control. Smooth muscle is responsible for the contractility of hollow organs, such as blood vessels, the gastrointestinal tract, the bladder, or the uterus. Like skeletal muscles, smooth muscle fibers do contract together, causing the muscle to shorten. Smooth muscles have numerous functions, including the following.

- The smooth muscle in the uterus helps a woman to push out her baby.
- In the bladder, smooth muscle helps to push out urine.
- Smooth muscles move food through the digestive tract.
- In arteries, smooth muscle movements maintain the arteries' diameter.
- Smooth muscle regulates air flow in lungs.
- Smooth muscle in the lungs helps the airways to expand and contract as necessary.
- Smooth muscles in arteries and veins are largely responsible for regulation of blood pressure.

Cardiac muscle also contracts and gets shorter. This muscle is found only in the heart. The sudden burst of contraction forces blood throughout your body. When the cardiac muscle relaxes, the heart fills with blood. This rhythmic contraction must continue for your whole life, luckily the heart muscle never gets tired. If your heart beats 75 times a minute, how many times does it beat in an hour? A day? A year? 85 years?

Summary

- Muscles move the body by contracting against the skeleton.
- Muscles work together in pairs to bend or straighten the joint.

Explore More

Use the resource below to answer the questions that follow.

- **Muscles and Movement** at http://www.youtube.com/watch?v=1SGM06DiXLc (1:38)

Click on the image above for more content

1. How does the biceps muscle move when you bend your arm? How does the triceps muscle move when you bend your arm?
2. How does the triceps muscle move when you straighten your arm? How does the biceps muscle move when you straighten your arm?
3. Why can muscles only pull and not push? How is this related to muscles working in pairs?

Review

1. How are skeletal muscles attached to the skeleton?
2. Explain why many skeletal muscles must work in opposing pairs.
3. List three functions of smooth muscles.
4. What happens when cardiac muscle contracts?

Section 11

Muscles and Exercise

Muscles and Exercise

•Define lifestyle disease.
•Describe how exercise affects the muscular system.
•Distinguish between aerobic exercises and anaerobic exercises.
•Describe common muscle injuries.

What is aerobic exercise?

When you hear the word "aerobic," an aerobics class may come to mind. But that's just one type of aerobic exercise. Aerobic exercise is any exercise that strengthens your cardiovascular system—playing basketball or swimming, for example.

Muscles and Exercise

Regular physical exercise is important in preventing **lifestyle diseases** such as cardiovascular disease, some types of cancer, type 2 diabetes, and obesity. Regular exercise also improves the health of the muscular system. Muscles that are exercised are bigger and stronger than muscles that are not exercised.

Exercise improves both muscular strength and muscular endurance. **Muscular strength** is the ability of a muscle to use force during a contraction. **Muscular endurance** is the ability of a muscle to continue to contract over a long time without getting tired.

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

•**Aerobic exercises** , such as cycling, walking, and running, increase muscular endurance and cardiovascular health.
•**Anaerobic exercises** , such as weight training or sprinting, increase muscle strength.
•Flexibility exercises, such as stretching, improve the range of motion of muscles and joints. Regular stretching helps people avoid activity-related injuries.

Anaerobic Exercise and Muscular Strength

Anaerobic exercises comprise brief periods of physical exertion and high-intensity, strength-training activities. Anaerobic exercises cause muscles to get bigger and stronger. Anaerobic exercises use a resistance against which the muscle has to work to lift or push away. The resistance can be a weight or a person's own body weight (**Figure** below). Sports such as basketball, tennis, football and even baseball can be anaerobic.

Figure 11.20

Anaerobic exercises involve the muscles working against resistance. In this case the resistance is the weight of a barbell.

Aerobic Exercise and Muscular Endurance

Aerobic exercises are exercises in which a low to moderate level of exertion can be sustained over long periods. These are exercises that cause your heart to beat faster and allow your muscles to use oxygen to contract. If you exercise aerobically, overtime, your muscles will not get easily tired, and you will use oxygen more efficiently. Aerobic exercise (**Figure** below) also helps improve cardiac muscle.

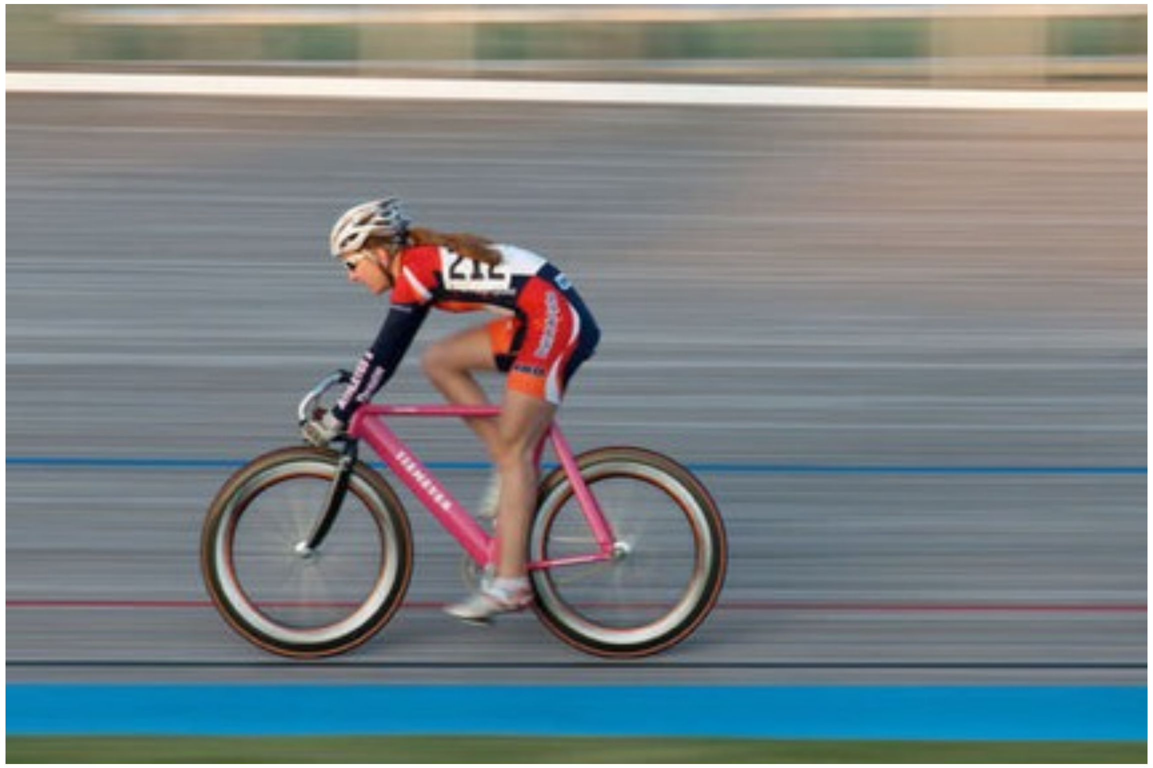


Figure 11.21

When done regularly, aerobic activities, such as cycling, make the heart stronger. Other aerobic activities include mowing lawn, shoveling snow and cross country skiing.

Muscle Injuries

Sometimes muscles and tendons get injured when a person starts doing an activity before they have warmed up properly. A warm up is a slow increase in the intensity of a physical activity that prepares muscles for an activity. Warming up increases the blood flow to the muscles and increases the heart rate. Warmed-up muscles and tendons are less likely to get injured. For example, before running or playing soccer, a person might jog slowly to warm muscles and increase their heart rate. Even elite athletes need to warm up (**Figure** below).

When you don't do a proper warm-up, several types of injuries can occur. A **strain** happens when muscle or tendons tear. Strains are also known as "pulled muscles." Another common injury is **tendinitis** , the irritation of the tendons. Strains and tendinitis are usually treated with rest, cold compresses, and stretching exercises that a physical therapist designs for each patient.

Injuries can also be prevented by proper rest and recovery. If you do not get enough rest, your body will become injured and will not react well to exercise, or improve. You can also rest by doing a different activity. For example, if you run, you can rest your running muscles and joints by swimming.

Figure 11.22

Warming up before the game helps the players avoid injuries. Some warm-ups may include stretching exercises.

Summary

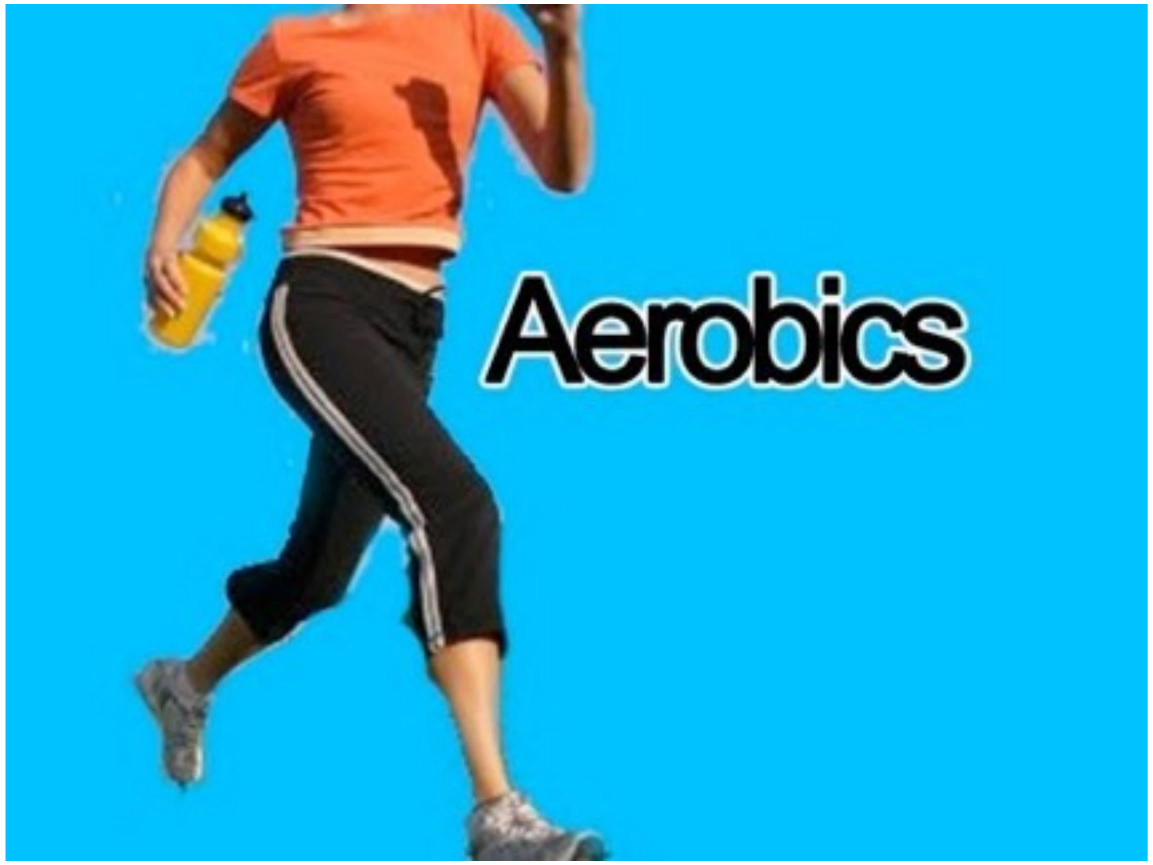
- Aerobic exercise helps improve the cardiovascular system, while anaerobic exercise causes muscles to get bigger and stronger.
- Muscle strain and tendinitis can be prevented by warming up before rigorous exercise and allowing your muscles to rest and recover.

Explore More

Use the resources below to answer the questions that follow.

Explore More I

•**What is Aerobic Exercise?** at http://www.youtube.com/watch?v=7g65AeKO6Dw (2:05)

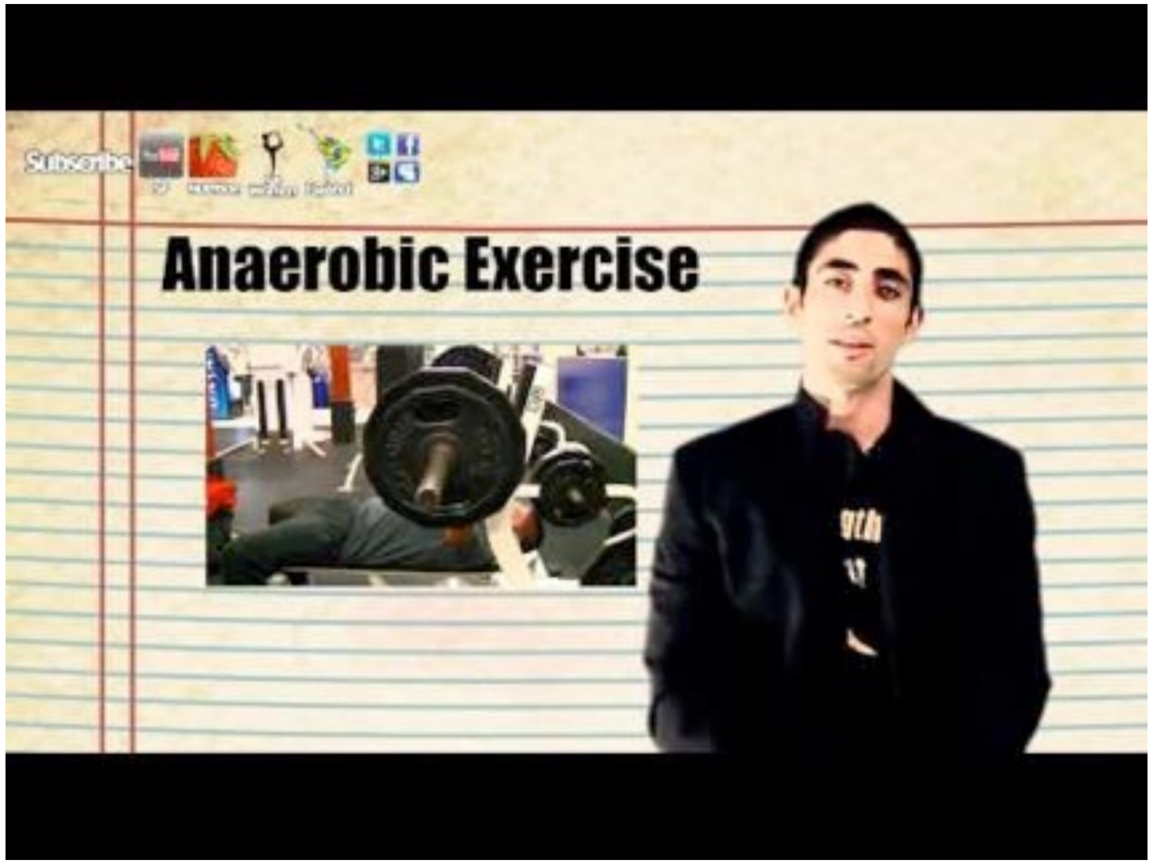


Click on the image above for more content

1. What makes an exercise aerobic?
2. What are some of the benefits of aerobic exercise?
3. How does aerobic exercise benefit your heart?

Explore More II

•**What is Anaerobic Exercise?** at http://www.youtube.com/watch?v=kqEX1MQXCt8 (2:42)



Click on the image above for more content

1. What makes an exercise anaerobic?
2. What are some of the benefits of anaerobic exercise?
3. How can anaerobic exercise affect your skeletal system?

Review

1. What are lifestyle diseases? Given an example.
2. Describe muscular strength and endurance.
3. What are the health benefits of aerobic exercise?

4.Describe two types of muscle injuries.

Section 12

Food and Nutrients

Food and Nutrients

•Explain why the body needs food.
•Define nutrient.
•List and describe the five types of nutrients.

What happens when you don't eat?

Refusing one meal won't stunt your growth. But lack of proper food over a period of time can lead to malnutrition. That means, the body is not getting enough nutrients to grow and stay healthy. Kids who are malnourished may not grow as tall as they would otherwise.

Why We Need Food

Did you ever hear the old saying, *An apple a day keeps the doctor away* ? Do apples really prevent you from getting sick? Probably not, but eating apples and other fresh fruits can help keep you healthy. Do you eat your vegetables? Maybe you do, but you may have friends who won't touch a piece of broccoli or asparagus. Should you eat these foods and food like them? The girls pictured in the **Figure** below are eating salads. Why do you need foods like these for good health? What role does food play in the body?

Figure 11.23

These girls are eating leafy green vegetables. Fresh vegetables such as these are excellent food choices for good health.

Your body needs food for three reasons:

1. Food gives your body energy. You need energy for everything you do. Remember that **cellular respiration** converts the glucose in the food you eat into **ATP** , or cellular energy. Which has more glucose, a salad or a piece of meat? Do you remember what types of foods produce glucose? Recall that glucose is the product of photosynthesis.
2. Food provides building materials for your body. Your body needs building materials so it can grow and repair itself. Specifically, it needs these materials to produce more cells and its components.
3. Food contains substances that help control body processes. Your body processes must be kept in balance for good health.

For all these reasons, you must have a regular supply of nutrients. **Nutrients** are chemicals in food that your body needs. There are five types of nutrients:

1. **Carbohydrates** .
2. **Proteins** .
3. **Lipids** .
4. **Vitamins** .
5. **Minerals** .

Carbohydrates, proteins, and lipids are categories of organic compounds. They give your body energy, though carbohydrates are the main source of energy. Proteins provide building materials, such as amino acids to build your own proteins. Proteins, vitamins, and minerals also help control body processes. Carbohydrates include sugars such as the glucose made by photosynthesis. Often glucose is stored in large molecules such as starch. Proteins are found in foods like meats and nuts. Lipids includes fats and oils. Though you should stay away from many types of fats, others are needed by your body. Important vitamins include vitamins A, B (multiple types) C, D, and E. Important minerals include calcium and potassium. What should you drink to get calcium? Milk is a good source.

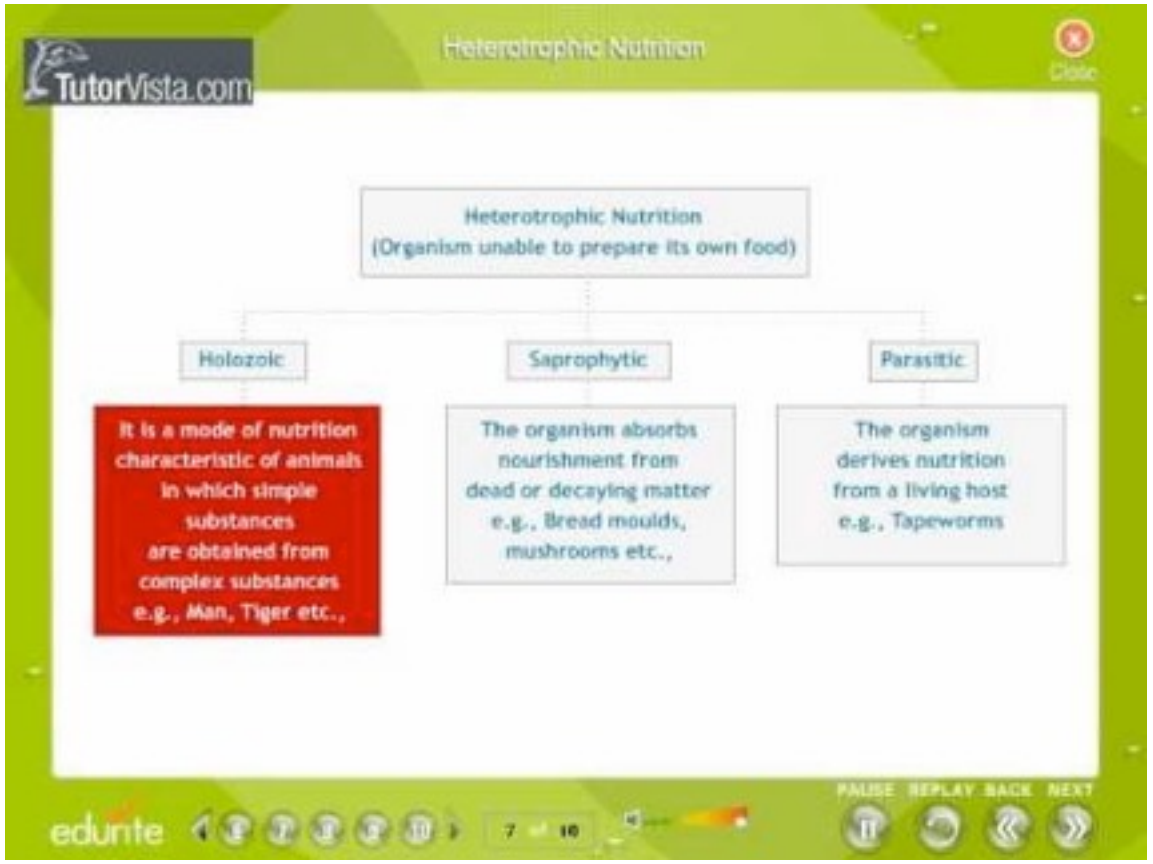
Summary

- Your body needs food to obtain energy, to get building blocks for your body, and to get substances that help control body processes.
- Nutrients, chemicals in food that your body needs, include carbohydrates, proteins, lipids, vitamins, and minerals.

Explore More

Use the resource below to answer the questions that follow.

- **Nutrition** at http://www.youtube.com/watch?v=2xbD6--X0IA (6:39)



Click on the image above for more content

1. What is nutrition?
2. What do organisms use "food" for?
3. What is a heterotroph? Are humans autotrophic or heterotrophic?
4. What are the three types of heterotrophic organisms?

Review

1. Why does your body need food? Give two reasons.
2. What are nutrients?
3. What are the five types of nutrients?
4. Why are carbohydrates a necessary part of your diet?
5. Why are proteins a necessary part of your diet?

Section 13

Types of Nutrients

Types of Nutrients

- •Identify sources of nutrients.
- •Identify the roles of carbohydrates, proteins, and lipids.
- •Distinguish simple carbohydrates from complex carbohydrates.
- •Distinguish saturated fats from unsaturated fats.

What nutrients are in this meal?

There are many different nutrients that are present in this meal. For example, the steak is a source of protein. The french fries are a source of carbohydrates. Both these nutrients help supply the body with energy.

Nutrients

Carbohydrates, proteins, and lipids contain energy. When your body digests food, it breaks down the molecules of these nutrients. This releases the energy so your body can use it.

Carbohydrates

Carbohydrates are nutrients that include sugars, starches, and fiber. There are two types of carbohydrates: simple and complex. Pictured below are some foods that are good sources of carbohydrates (**Figure** below).

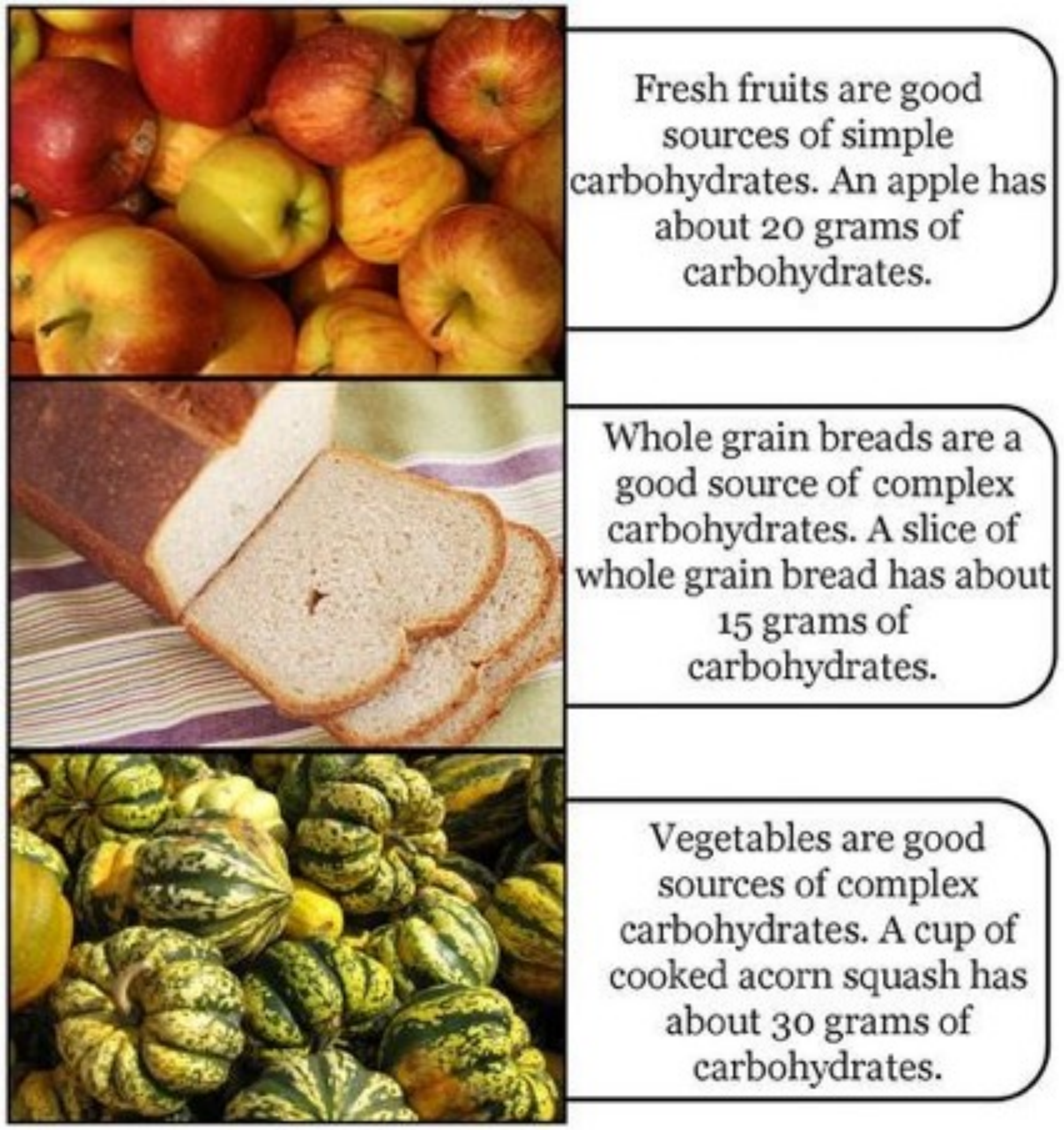


Figure 11.24

Up to the age of 13 years, you need about 130 grams of carbohydrates a day. Most of the carbohydrates should be complex. They are broken down by the body more slowly than simple carbohydrates. Therefore, they provide energy longer and more steadily.

Simple Carbohydrates

Sugars are small, simple carbohydrates that are found in foods such as fruits and milk. The sugar found in fruits is called fructose. The sugar found in milk is called lactose. These sugars are broken down by the body to form glucose ($C_6H_{12}O_6$), the simplest sugar of all.

Where does glucose come from? Recall that glucose is the product of photosynthesis, so some organisms such as plants are able to make their own glucose. As animals cannot photosynthesize, they must eat to obtain carbohydrates. Through the process of **cellular respiration** , glucose is converted by cells into energy that is usable by the cell (ATP).

Complex Carbohydrates

Starch is a large, complex carbohydrate made of thousands of glucose units (monomers) joined together. Starches are found in foods such as vegetables and grains. Starches are broken down by the body into sugars that provide energy.

Fiber is another type of large, complex carbohydrate that is partly indigestible. Unlike sugars and starches, fiber does not provide energy. However, it has other important roles in the body. For example, fiber is important for maintaining the health of your gastrointestinal tract. Eating foods high in fiber also helps fill you up without providing too many calories. Most fruits and vegetables are high in fiber. Some examples are pictured below (**Figure** below).

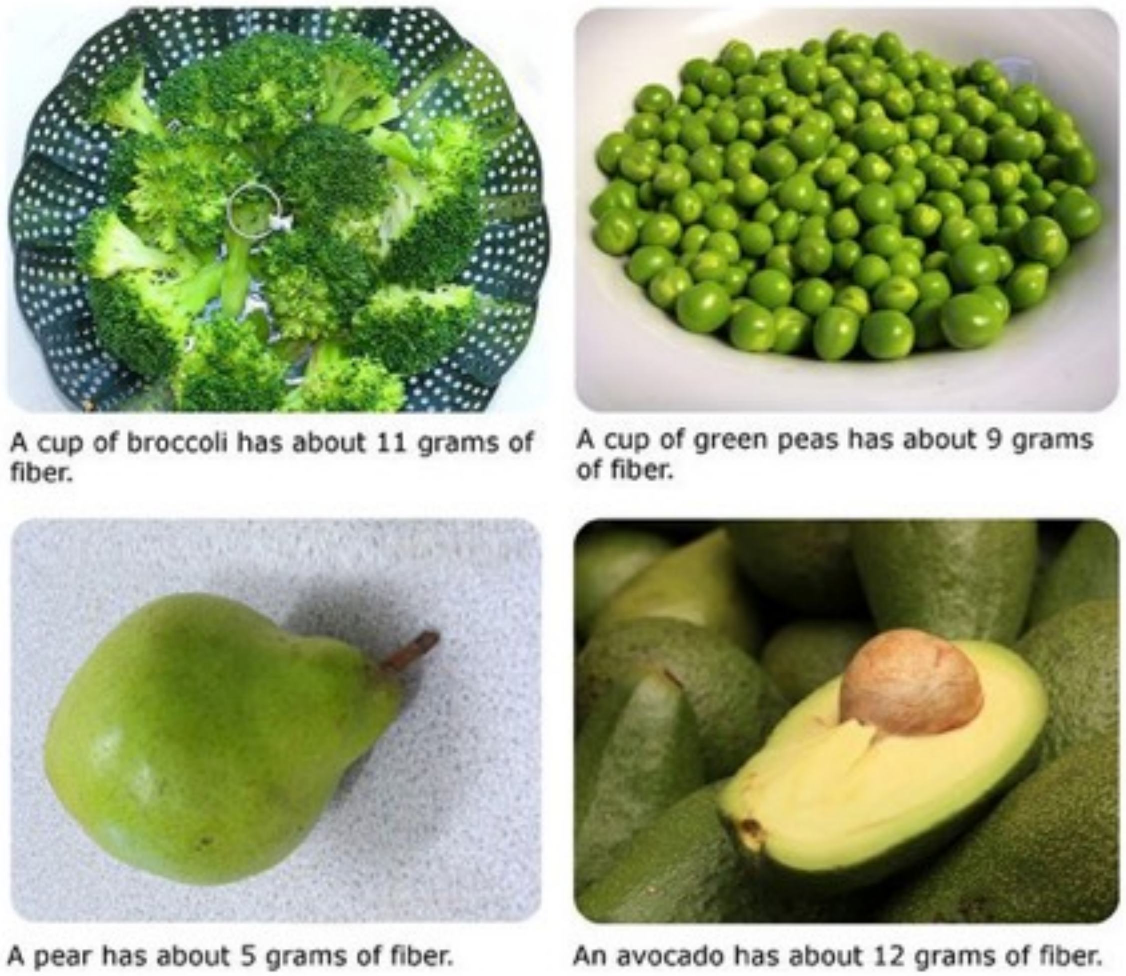


Figure 11.25

Between the ages of 9 and 13 years, girls need about 26 grams of fiber per day, and boys need about 31 grams of fiber per day.

Proteins

Proteins are nutrients made up of smaller molecules called **amino acids** . Recall that there are 20 different amino acids arranged like "beads on a string" to form proteins. These amino acid chains then fold up into a three-dimensional molecule, giving the protein a specific function. Proteins have several important roles in the body. For example, proteins make up antibodies, muscle fibers and enzymes that help control cell and body processes. You need to make sure you have enough protein in your diet to obtain the necessary amino acids to make your proteins.

If you eat more than you need for these purposes, the extra protein is used for energy. The image below shows how many grams of protein you need each day (**Figure** below). It also shows some foods that are good sources of protein.

Figure 11.26

Between the ages of 9 and 13 years, you need about 34 grams of proteins a day. Seafood and eggs are other good sources of protein.

Lipids

Lipids are nutrients, such as fats that store energy. Lipids also have several other roles in the body. For example, lipids protect nerves and make up the membranes that surround cells.

Fats are one type of lipid. Stored fat gives your body energy to use for later. It's like having money in a savings account: it's there in case you need it. Stored fat also cushions and protects internal organs. In addition, it insulates the body. It helps keep you warm in cold weather.

There are two main types of fats, saturated and unsaturated.

1. **Saturated fats** can be unhealthy, even in very small amounts. They are found mainly in animal foods, such as meats, whole milk, and eggs. So even though these foods are good sources of proteins, they should be eaten in limited amounts. Saturated lipids increase cholesterol levels in the blood. Too much cholesterol in the blood can lead to heart disease.
2. **Unsaturated fats** are found mainly in plant foods, such as vegetable oil, olive oil, and nuts. Unsaturated lipids are also found in fish, such as salmon. Unsaturated lipids are needed in small amounts for good health. Most lipids in your diet should be unsaturated.

Another type of lipid is called **trans fat** . Trans fats are manufactured and added to certain foods to keep them fresher for longer. Foods that contain trans fats include cakes, cookies, fried foods, and margarine. Eating foods that contain trans fats increases the risk of heart disease.

Beginning with Denmark in 2003, many nations now limit the amount of trans fat that can be in food products or ban these products all together. On January 1, 2008, Calgary became the first city in Canada to ban trans fats from restaurants and fast food chains. Beginning in 2010, California banned trans fats from restaurant products, and in 2011, from all retail baked goods.

Summary

- Carbohydrates, proteins, and lipids provide energy and have other important roles in the body.
- Unsaturated fats are better for your health than trans fats or saturated fats.

Explore More

Use the resource below to answer the questions that follow.

- **Nutrients Your Body Needs** at http://www.pbs.org/wgbh/nova/body/nutrients-body-needs.html

1. What does your body use iodine for? What are good sources of iodine? What are some of the problems of iodine deficiency?
2. What does your body use magnesium for? What are good sources of magnesium? What problems come from magnesium deficiency?
3. What does your body use riboflavin for? What are good sources of riboflavin? What can happen if your diet is deficient in riboflavin?

Review

1. Which nutrients can be used for energy?
2. What is starch?
3. Why is it important that you get enough proteins in foods?
4. What foods contain saturated fats? How much of these foods should you eat? Why?

Section 14

Vitamins and Minerals

Vitamins and Minerals

- •Define vitamin and mineral.
- •Give examples of vitamins and minerals, and state their functions.
- •Identify sources of vitamins and minerals.

How do you get your vitamins?

You may take a vitamin pill. That is a good way to make sure you are getting most of the vitamins your body needs to grow. But the best way to get your vitamins is through eating a healthy diet.

Vitamins and Minerals

Vitamins and minerals are also nutrients. They do not provide energy, but they are needed for good health.

Vitamins

Vitamins are organic compounds that the body needs in small amounts to function properly. Humans need 13 different vitamins. Some of them are listed below (**Table** below). The table also shows how much of each vitamin you need every day. Vitamins have many roles in the body. For example, Vitamin A helps maintain good vision. Vitamin B_9 helps form red blood cells. Vitamin K is needed for blood to clot when you have a cut or other wound.

Vitamin	Necessary for	Available from	Daily Amount Required (at ages 9–13 years)
A	Good vision	Carrots, spinach, milk, eggs	600 µg (1 µg = 1 × 10^{-6} g)
B_1	Healthy nerves	Whole wheat, peas, meat, beans, fish, peanuts	0.9 mg (1 mg = 1 × 10^{-3} g)

Some vitamins are produced in the body. For example, vitamin D is made in the skin when it is exposed to sunlight. Vitamins B_{12} and K are produced by bacteria that normally live inside the body. Most other vitamins must come from foods. Foods that are good sources of vitamins include whole grains, vegetables, fruits, and milk (**Table** above).

Not getting enough vitamins can cause health problems. For example, too little vitamin C causes a disease called scurvy. People with scurvy have bleeding gums, nosebleeds, and other symptoms.

Minerals

Minerals are chemical elements that are needed for body processes. Minerals that you need in relatively large amounts are listed below (**Table** below). Minerals that you need in smaller amounts include iodine, iron, and zinc.

Minerals have many important roles in the body. For example, calcium and phosphorus are needed for strong bones and teeth. Potassium and sodium are needed for muscles and nerves to work normally.

Mineral	Necessary for	Available from	Daily Amount Required (at ages 9–13 years)
Calcium	Strong bones and teeth	Milk, soy milk, leafy green vegetables	1,300 mg

Your body cannot produce any of the minerals that it needs. Instead, you must get minerals from the foods you eat. Good sources of minerals include milk, leafy green vegetables, and whole grains (**Table** above).

Not getting enough minerals can cause health problems. For example, too little calcium may cause osteoporosis. This is a disease in which bones become soft and break easily. Getting too much of some minerals can also cause health problems. Many people get too much sodium. Sodium is added to most packaged foods. People often add more sodium to their food by using table salt. Too much sodium causes high blood pressure in some people.

Summary

- Vitamins and minerals do not provide energy but are needed in small amounts for the body to function properly.
- Some vitamins are produced in your body, while others must come from the foods you eat.

Explore More

Use the resource below to answer the questions that follow.

- **Smart Nutrition** at http://www.youtube.com/watch?v=3wL0BghxeHc (3:42)

Click on the image above for more content

1. Why is calcium so important to teenagers? What are sources of calcium?
2. Why is it important to have enough iron in your diet? What vitamin helps you utilize iron?
3. Why is vitamin D so important to teenagers? What are good sources of vitamin D?

Review

1. What are vitamins?
2. List two vitamins and their roles in the body.
3. What are minerals?
4. List two minerals and their roles in the body.

Section 15

Choosing Healthy Foods

Choosing Healthy Foods

•Describe how to choose foods wisely for optimal health.
•Explain MyPyramid and MyPlate.
•List eating healthy guidelines.
•Read and understand a nutrition facts label.
•Define obesity.

Which foods would be the best choice?

Each day you make many food choices. You decide which lunch line to get into. Then you may choose an after-school snack. How can you make the most healthy decisions?

Choosing Healthy Foods

Foods such as whole grain breads, fresh fruits, and fish provide nutrients you need for good health. But different foods give you different types of nutrients. You also need different amounts of each nutrient. How can you choose the right mix of foods to get the proper balance of nutrients? Three tools can help you choose foods wisely: MyPyramid, MyPlate, and food labels.

MyPyramid

MyPyramid (**Figure** below) is a diagram that shows how much you should eat each day of foods from six different food groups. It recommends the amount of nutrients you need based on your age, your gender, and your level of activity. The six food groups in MyPyramid are:

- Grains, such as bread, rice, pasta, and cereal.
- Vegetables, such as spinach, broccoli, carrots, and sweet potatoes.
- Fruits, such as oranges, apples, bananas, and strawberries.
- Oils, such as vegetable oil, canola oil, olive oil, and peanut oil.
- Dairy, such as milk, yogurt, cottage cheese, and other cheeses.
- Meat and beans, such as chicken, fish, soybeans, and kidney beans.

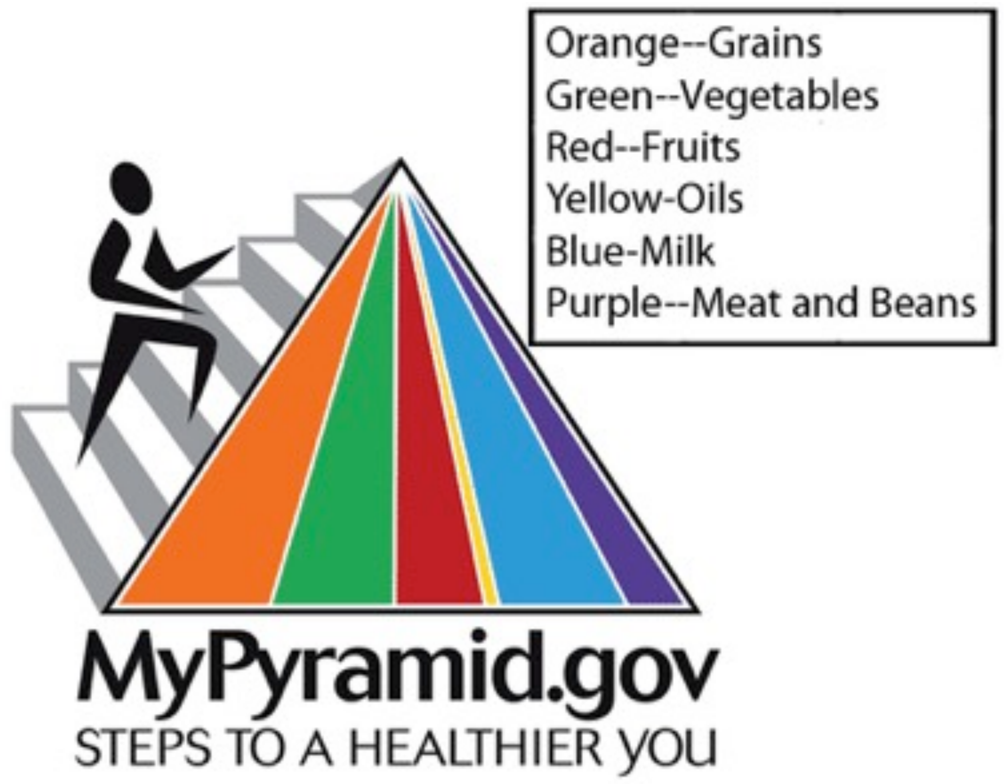


Figure 11.27

MyPyramid can help you choose foods wisely for good health. Each colored band represents a different food group. The key shows which food group each color represents. Which colored band of MyPyramid is widest? Which food group does it represent?

In MyPyramid, each food group is represented by a band of a different color. For example, grains are represented by an orange band, and vegetables are represented by a green band. The wider the band, the more foods you should choose from that food group each day.

The orange band in MyPyramid is the widest band. This means that you should choose more foods from the grain group than from any other single food group. The green, blue, and red bands are also relatively wide. Therefore, you should choose plenty of foods from the vegetable, dairy, and fruit groups as well. You should choose the fewest foods from the food group with the narrowest band. Which band is narrowest? Which food group does it represent?

Are you wondering where foods like ice cream, cookies, and potato chips fit into MyPyramid? The white tip of MyPyramid represents foods such as these. These are foods that should be eaten only in very small amounts and not very often. Such foods contain very few nutrients and are called nutrient-poor. Instead, they are high in fats, sugars, and sodium, which are nutrients that you should limit in a healthy eating plan. Ice cream, cookies, and potato chips are also high in calories. Eating too much of them may lead to unhealthy weight gain.

Healthy Eating Guidelines

- •Make at least half your daily grain choices whole grains. Examples of whole grains are whole wheat bread, whole wheat pasta, and brown rice.
- •Choose a variety of different vegetables each day. Be sure to include both dark green vegetables, such as spinach and broccoli, and orange vegetables, such as carrots and sweet potatoes.
- •Choose a variety of different fruits each day. Select mainly fresh fruits rather than canned fruits, and whole fruits instead of fruit juices.
- •When choosing oils, choose unsaturated oils, such as olive oil, canola oil, or vegetable oil.
- •Choose low-fat or fat-free milk and other dairy products. For example, select fat-free yogurt and low-fat cheese.
- •For meats, choose fish, chicken, and lean cuts of beef. Also, be sure to include beans, nuts, and seeds.

MyPlate

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

Figure 11.28

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

The following guidelines accompany MyPlate:

1. Balancing Calories

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

2. Foods to Increase

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

3. Foods to Reduce

•Compare sodium in foods like soup, bread, and frozen meals; choose the foods with lower levels.
•Drink water instead of drinks with high levels of sugar.

Using Nutrition Facts Labels

In the United States and other nations, packaged foods are required by law to have nutrition facts labels. A **nutrition facts label** (**Figure** below) shows the nutrients in a food. Packaged foods are also required to list their ingredients.

The information listed at the right of the label tells you what to look for. At the top of the label, look for the serving size. The serving size tells you how much of the food you should eat to get the nutrients listed on the label. A cup of food from the label pictured below is a serving. The calories in one serving are listed next. In this food, there are 250 calories per serving.

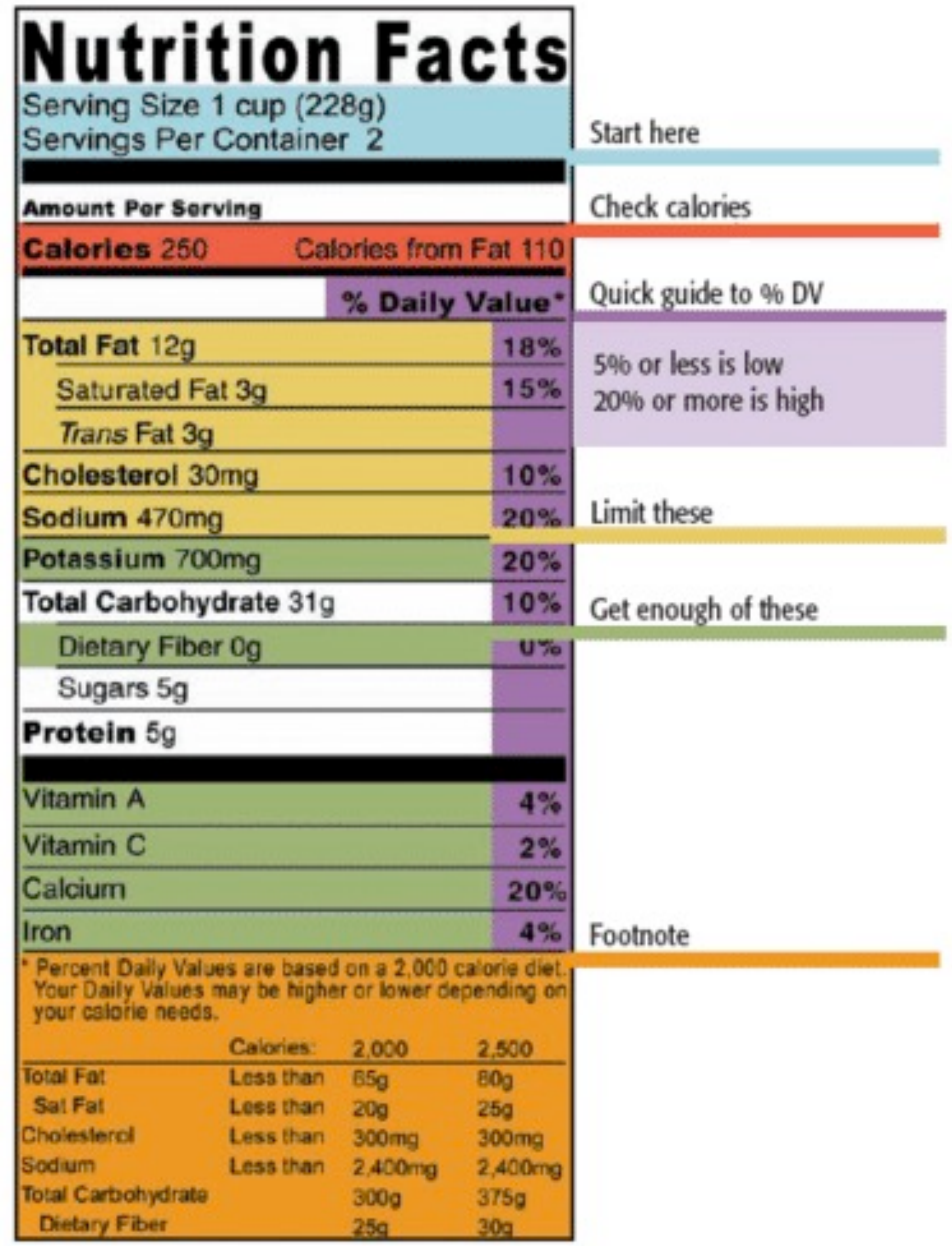


Figure 11.29

Reading nutrition facts labels can help you choose healthy foods. Look at the nutrition facts label shown here. Do you think this food is a good choice for a healthy eating plan? Why or why not?

Next on the nutrition facts label, look for the percent daily values (% DV) of nutrients. Remember the following tips when reading a food label:

- •A food is low in a nutrient if the percent daily value of the nutrient is 5% or less.
- •The healthiest foods are low in nutrients such as fats and sodium.
- •A food is high in a nutrient if the percent daily value of the nutrient is 20% or more.
- •The healthiest foods are high in nutrients such as fiber and proteins.

Look at the percent daily values on the food label (**Figure** above). Which nutrients have values of 5% or less? These are the nutrients that are low in this food. They include fiber, vitamin A, vitamin C, and iron. Which nutrients have values of 20% or more? These are the nutrients that are high in this food. They include sodium, potassium, and calcium.

Balancing Food with Exercise

Look at MyPyramid (**Figure** above). Note the person walking up the side of the pyramid. This shows that exercise is important for balanced eating. Exercise helps you use any extra energy in the foods you eat. The more active you are, the more energy you use. You should try to get at least an hour of physical activity just about every day. Pictured below are some activities that can help you use extra energy (**Figure** below).

Figure 11.30

All of these activities are good ways to exercise and use extra energy. The calories given for each activity are the number of calories used in an hour by a person that weighs 100 pounds. Which of these activities uses the most calories? Which of the activities do you enjoy?

Weight Gain and Obesity

Any unused energy in food is stored in the body as fat. This is true whether the extra energy comes from carbohydrates, proteins, or lipids. What happens if you take in more energy than you use, day after day? You will store more and more fat and become overweight.

Eventually, you may become obese. **Obesity** is having a very high percentage of body fat. Obese people are at least 20 percent heavier than their healthy weight range. The excess body fat of obesity is linked to many diseases. Obese people often have serious health problems, such as diabetes, high blood pressure, and high cholesterol. They are also more likely to develop arthritis and some types of cancer. People who remain obese during their entire adulthood usually do not live as long as people who stay within a healthy weight range.

The current generation of children and teens is the first generation in our history that may have a shorter life than their parents. The reason is their high rate of obesity and the health problems associated with obesity. You can avoid gaining weight and becoming obese. The choice is yours. Choose healthy foods by using MyPyramid and reading food labels. Then get plenty of exercise to balance the energy in the foods you eat.

Summary

- MyPlate, MyPyramid, and food labels are tools that can help you choose the best foods for healthy eating.
- Eating too much and exercising too little can lead to weight gain and obesity.

Explore More

Use the resource below to answer the questions that follow.

- **How To Create A Balanced Meal** at http://www.youtube.com/watch?v=KchFa8QCQSk (4:25)

Click on the image above for more content

1. What should the biggest section of your plate be filled with?
2. What does it mean when vegetables have bright colors?
3. Why are whole grains better for you than refined grains?
4. What are good five sources of whole grains?

Review

1. Which food group contains soybeans, kidney beans, and fish?
2. Complete this sentence: The healthiest foods are low in nutrients such as _______ and _______, and high in nutrients such as _______ and _______.
3. What happens if you take in more energy than you use, day after day?
4. According to MyPyramid, you should eat most from what group of foods each day?

Section 16

Human Digestive System

Human Digestive System

•List the functions of the digestive system.
•Define digestion and absorption.
•Distinguish chemical digestion from mechanical digestion.

Do you know when you're digesting food?

Unless you have an upset stomach, digestion usually happens without you even noticing. You consciously chew up your food, but most of the digestive process takes place without your conscious awareness. Long after you put down your fork, food is still passing through your stomach and small intestine. It may take over a day for a meal to pass all the way through your digestive system.

Function of the Digestive System

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

The **digestive system** is the body system that breaks down food and absorbs nutrients. It also gets rid of solid food waste. The digestive system is mainly one long tube from the mouth to the anus, known as the gastrointestinal tract (GI tract). The main organs of the digestive system include the esophagus, stomach and the intestine, and are pictured below (**Figure** below). The intestine is divided into the small and large intestine. The small intestine has three segments. The ileum is the longest segment of the small intestine, which is well over 10 feet long. The large intestine is about 5 feet long.

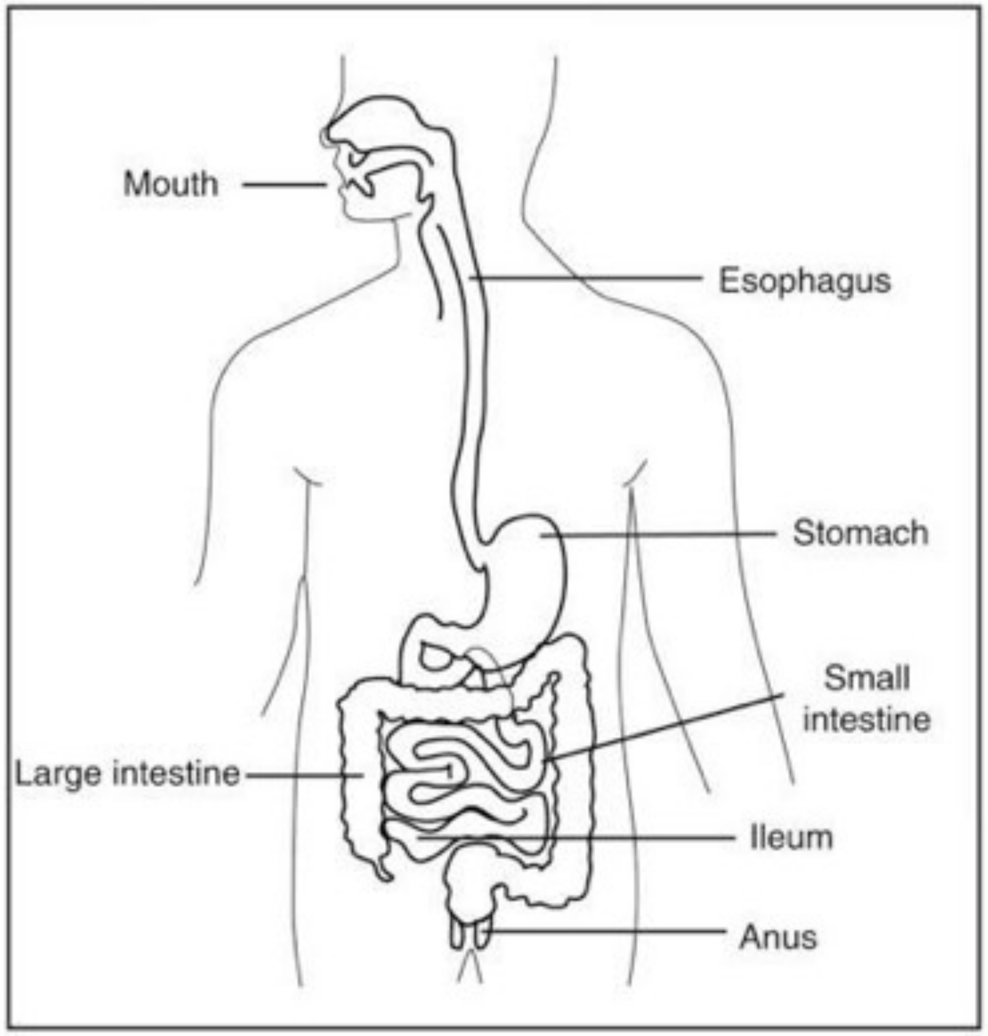


Figure 11.31

This drawing shows the major organs of the digestive system. The liver, pancreas and gallbladder are also organs of the digestive system.

Digestion is the process of breaking down food into nutrients. There are two types of digestion, mechanical and chemical. In **mechanical digestion** , large chunks of food are broken down into small pieces. Mechanical digestion begins in the mouth and involves physical processes, such as chewing. This process continues in the stomach as the food is mixed with digestive juices. In **chemical digestion** , large food molecules are broken down into small nutrient molecules. This is a chemical process which also begins in the mouth as **saliva** begins to break down food and continues in the stomach as stomach enzymes further digest the food.

Absorption is the process that allows substances you eat to be taken up by the blood. After food is broken down into small nutrient molecules, the molecules are absorbed by the blood. After absorption, the nutrient molecules travel in the bloodstream to cells throughout the body. This happens mostly in the small intestine.

Some substances in food cannot be broken down into nutrients. They remain behind in the digestive system after the nutrients are absorbed. Any substances in food that cannot be digested and absorbed pass out of the body as solid waste. The process of passing solid food waste out of the body is called **elimination.**

Summary

- The digestive system is the body system that breaks down food, absorbs nutrients, and gets rid of solid wastes.
- Digestion is the process of breaking down food into nutrients, while absorption is the process that allows nutrients to be taken up by the blood.

Explore More

Use the resources below to answer the questions that follow.

Explore More I

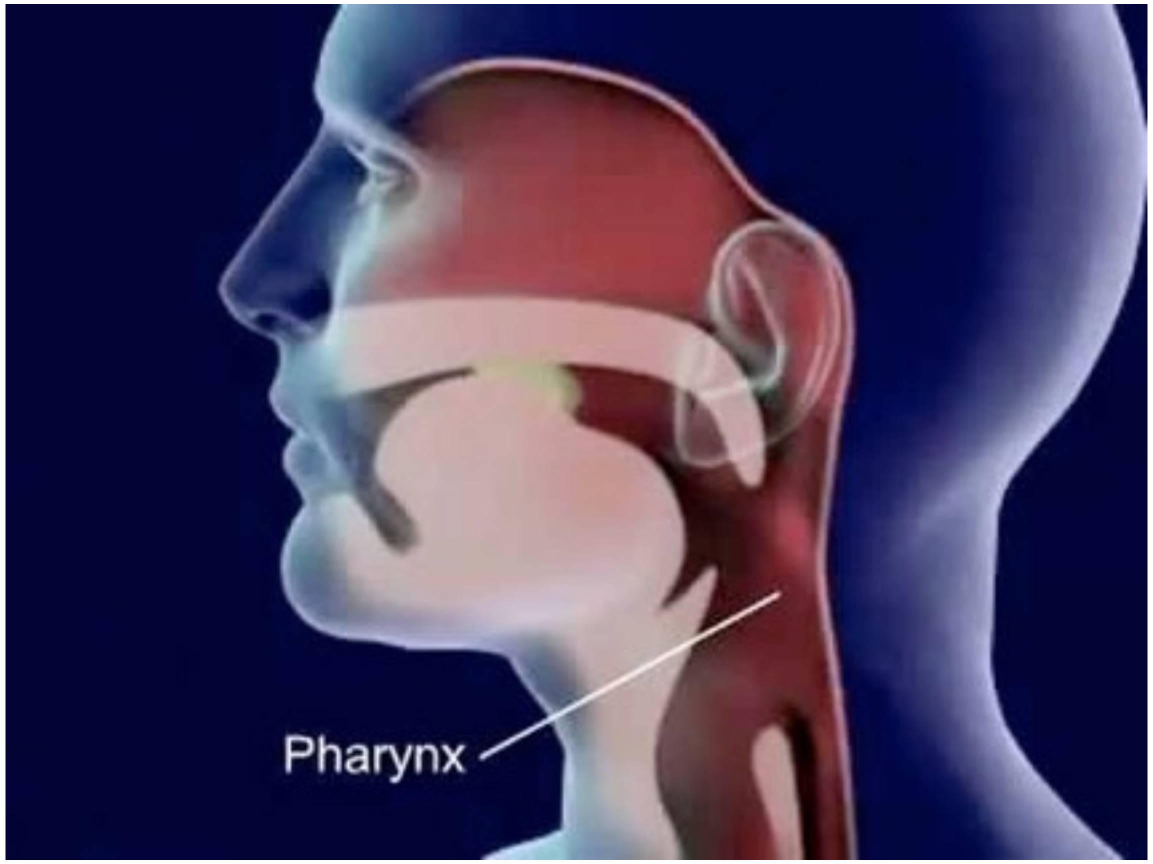
- **How Food is Digested** at http://www.youtube.com/watch?v=RsTwabX4ggI (1:44)

Click on the image above for more content

1. What type of muscles do you think you have in your esophagus?
2. How long does food stay in your stomach? Where does it go next?
3. What is the role of bile in the digestion process?

Explore More II

- **Human Digestive System** at http://www.youtube.com/watch?v=b20VRR9C37Q (1:49)



Click on the image above for more content

1. What does the digestive system do to food?
2. Where does digestion start? What happens during the start of digestion?
3. Where are most of the nutrients from food absorbed? What happens to the nutrients once they are absorbed?
4. What happens in the colon (large intestine)?

Review

1.Describe the primary structure of the digestive system.
2.What are three functions of the digestive system?
3.Define mechanical and chemical digestion.
4.Describe mechanical digestion.
5.Describe chemical digestion.
6.What is the difference between mechanical and chemical digestion?

Section 17

Enzymes in the Digestive

Enzymes in the Digestive System

- •Explain the role of enzymes in digestion.
- •List and describe digestive enzymes.
- •List and describe digestive hormones.

What happens if you suck on a piece of white bread?

If you kept a bite of white bread in your mouth for a long period of time, it would start to get really mushy. Then it would start tasting sweet. That's because you have enzymes in your saliva. The enzymes break down the complex carbohydrates in the bread into simple sugars.

The Role of Enzymes in the Digestive System

Chemical digestion could not take place without the help of digestive enzymes. An **enzyme** is a protein that speeds up chemical reactions in the body. Digestive enzymes speed up chemical reactions that break down large food molecules into small molecules.

Did you ever use a wrench to tighten a bolt? You could tighten a bolt with your fingers, but it would be difficult and slow. If you use a wrench, you can tighten a bolt much more easily and quickly. Enzymes are like wrenches. They make it much easier and quicker for chemical reactions to take place. Like a wrench, enzymes can also be used over and over again. But you need the appropriate size and shape of the wrench to efficiently tighten the bolt, just like each enzyme is specific for the reaction it helps.

Digestive enzymes are released, or secreted, by the organs of the digestive system. These enzymes include proteases that digest proteins, and nucleases that digest nucleic acids. Examples of digestive enzymes are:

- Amylase, produced in the mouth. It helps break down large starch molecules into smaller sugar molecules.
- Pepsin, produced in the stomach. Pepsin helps break down proteins into amino acids.
- Trypsin, produced in the pancreas. Trypsin also breaks down proteins.
- Pancreatic lipase, produced in the pancreas. It is used to break apart fats.
- Deoxyribonuclease and ribonuclease, produced in the pancreas. They are enzymes that break bonds in nucleic acids like DNA and RNA.

Bile salts are bile acids that help to break down fat. Bile acids are made in the liver. When you eat a meal, bile is secreted into the intestine, where it breaks down the fats (**Figure** below).

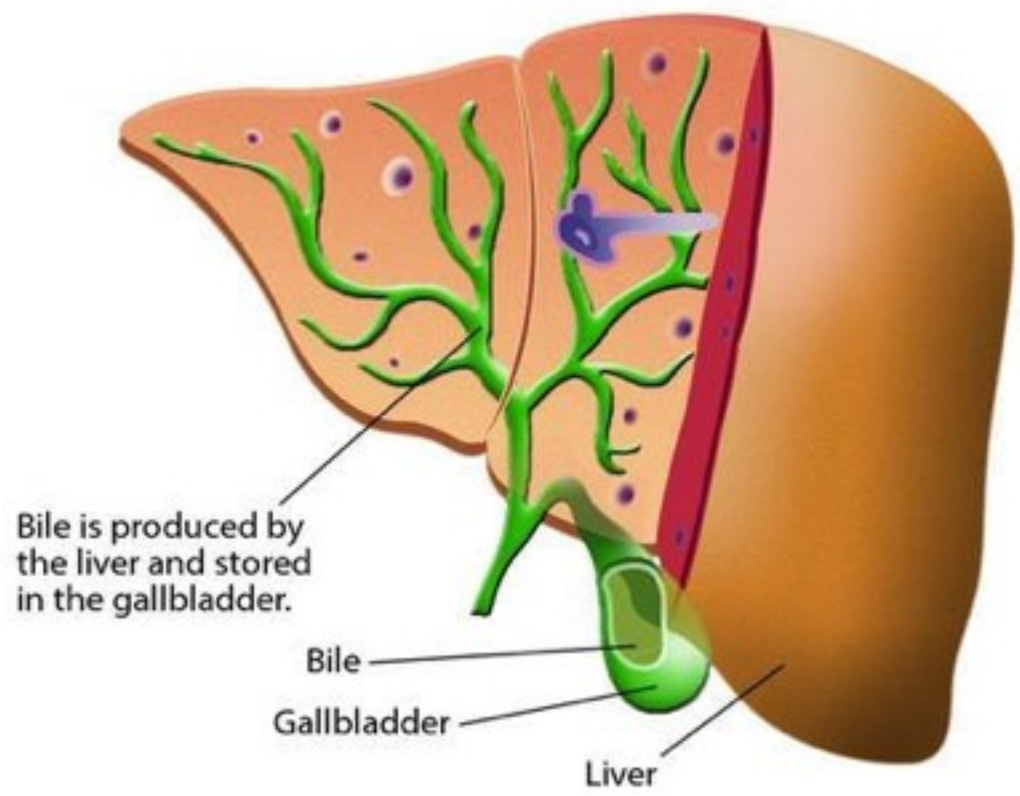


Figure 11.32

Bile is made in the liver, stored in the gallbladder, and then secreted into the intestine. It helps break down fats.

Hormones and Digestion

If you are a typical teenager, you like to eat. For your body to break down, absorb and spread the nutrients from your food throughout your body, your digestive system and **endocrine system** need to work together. The endocrine system sends **hormones** around your body to communicate between cells. Essentially, hormones are chemical messenger molecules.

Digestive hormones are made by cells lining the stomach and small intestine. These hormones cross into the blood where they can affect other parts of the digestive system. Some of these hormones are listed below.

- Gastrin, which signals the secretion of gastric acid.
- Cholecystokinin, which signals the secretion of pancreatic enzymes.
- Secretin, which signals secretion of water and bicarbonate from the pancreas.
- Ghrelin, which signals when you are hungry.
- Gastric inhibitory polypeptide, which stops or decreases gastric secretion. It also causes the release of insulin in response to high blood glucose levels.

Summary

- Digestive enzymes speed up the reactions of chemical digestion.
- Hormones, chemical messengers used to communicate between cells, are important in regulating digestion.

Explore More

Use the resource below to answer the questions that follow.

- **Digestive Enzymes** at http://faculty.stcc.edu/AandP/AP/AP2pages/Units24to26/digestion/whatsec.htm

1. What is amylase? Where is it secreted? What does it do?
2. What does pancreatic amylase do?
3. What does lactase do?
4. Why are there three disaccharide splitters released in the small intestine?
5. Why are there three enzymes to digest proteins?

Review

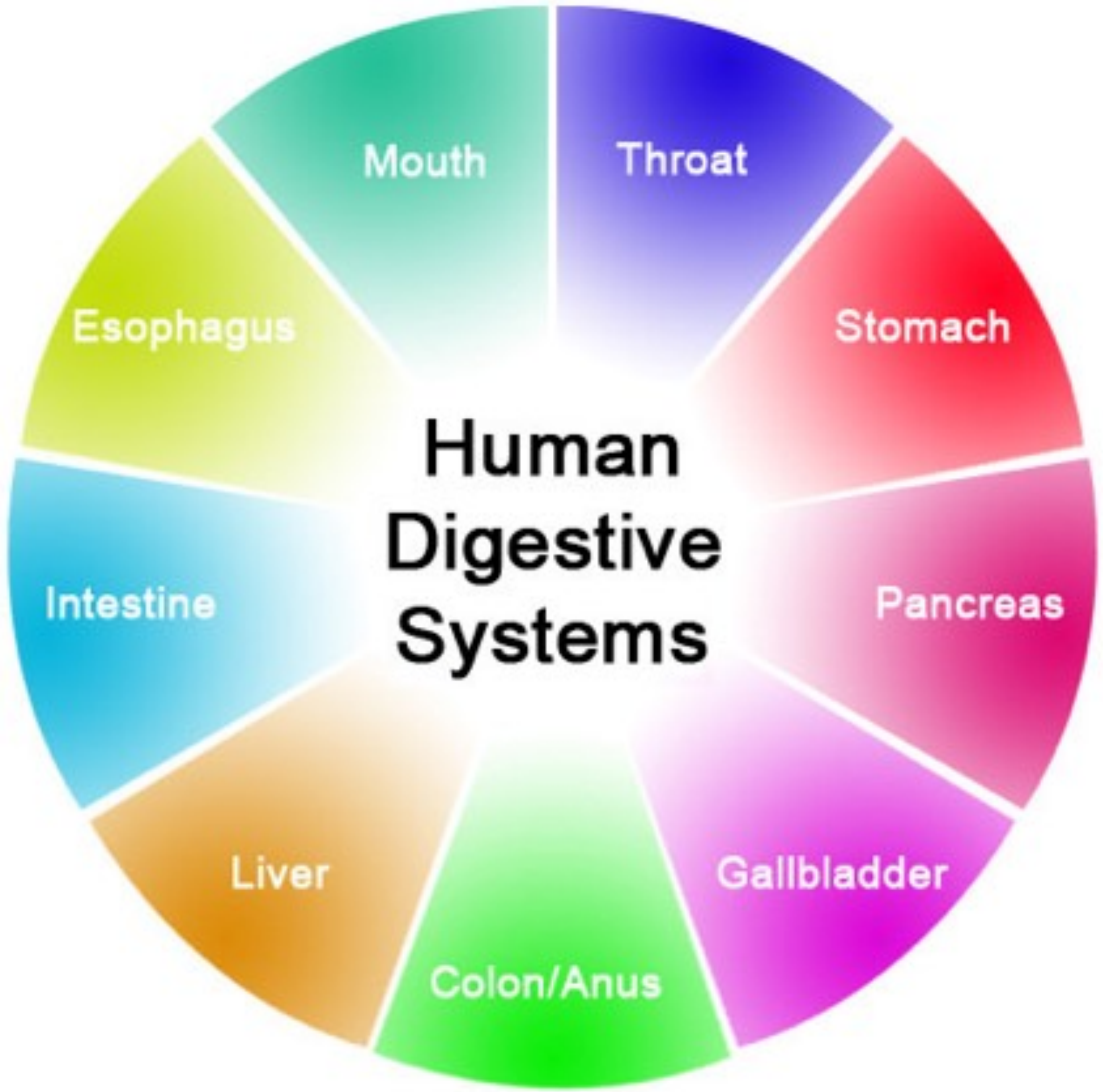
1. What is an enzyme?
2. Explain the role of enzymes in digestion. Give an example to illustrate your answer.
3. Give an example of how a hormone affects digestion.

Section 18

Digestive System Organs

Digestive System Organs

•List the organs of the digestive system.
•Describe the digestive organs and their functions.
•Define peristalsis.
•Explain the function of the villi of the small intestine.



How many organs of the digestive system can you name?

Stomach? Mouth? It takes many different organs working together in order to digest your food. Some are part of the pipeline that food passes through. Others make special chemicals that are needed for digestion.

Organs of the Digestive System

The mouth and stomach are just two of the organs of the digestive system. Other digestive system organs are the esophagus, small intestine, and large intestine. Below, you can see that the digestive organs form a long tube (**Figure** below). In adults, this tube is about 30 feet long! At one end of the tube is the mouth. At the other end is the anus. Food enters the mouth and then passes through the rest of the digestive system. Food waste leaves the body through the anus.

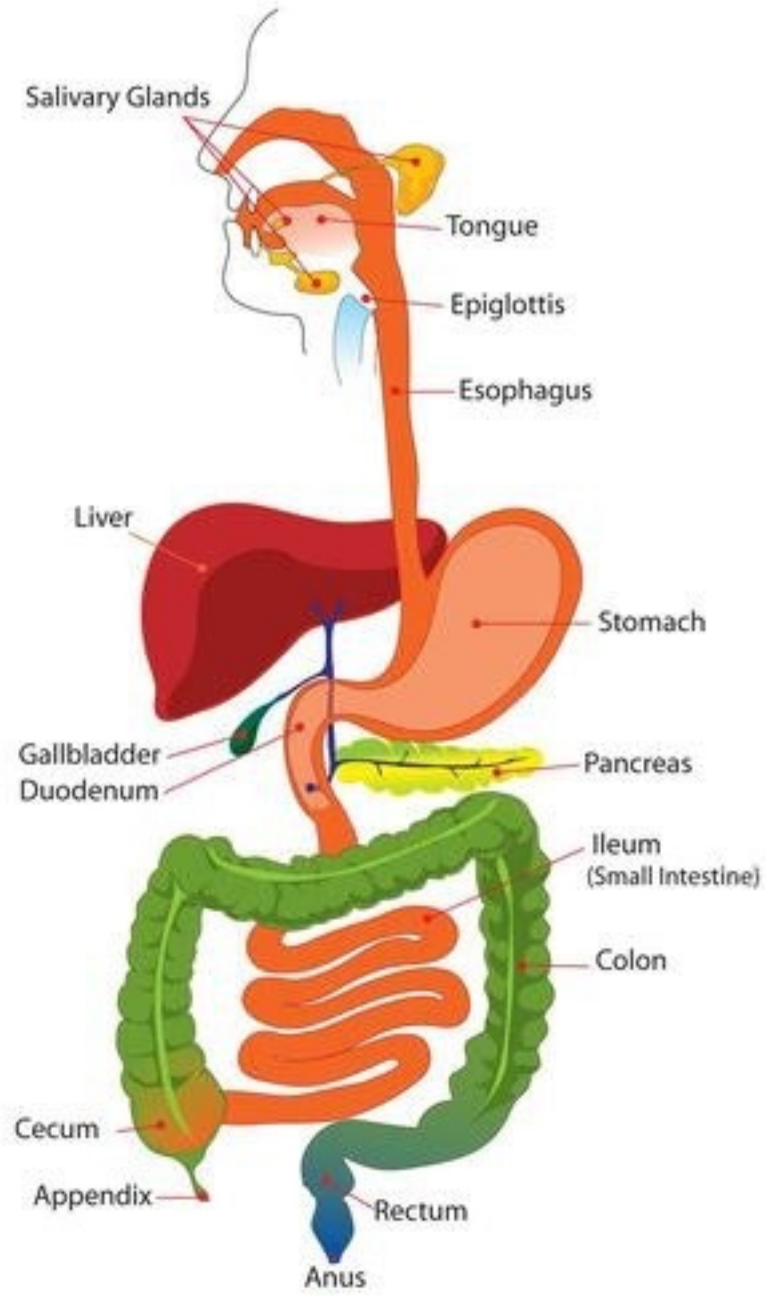


Figure 11.33

This drawing shows the liver, gallbladder, and pancreas. These organs are part of the digestive system. Food does not pass through them, but they secrete substances needed for chemical digestion.

The organs of the digestive system are lined with muscles. The muscles contract, or tighten, to push food through the system (**Figure** below). The muscles contract in waves. The waves pass through the digestive system like waves through a slinky. This movement of muscle contractions is called **peristalsis** . Without peristalsis, food would not be able to move through the digestive system. Peristalsis is an involuntary process, which means that it occurs without your conscious control.

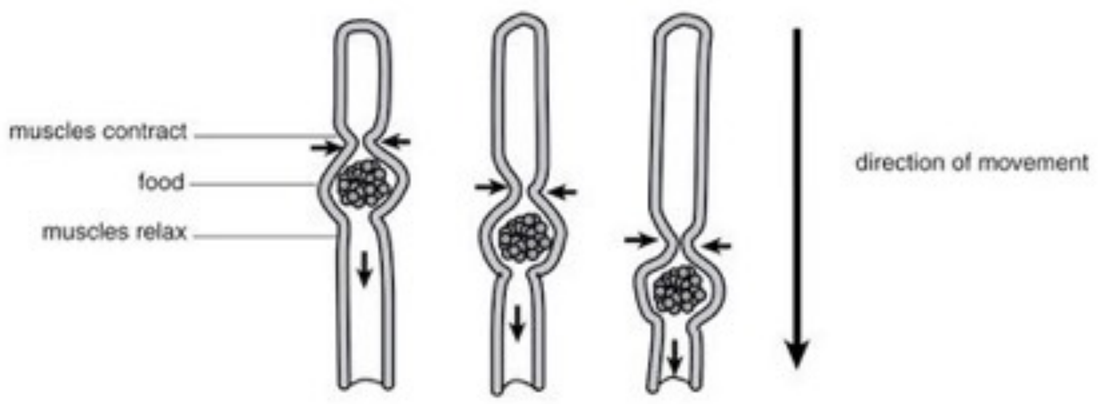


Figure 11.34

This diagram shows how muscles push food through the digestive system. Muscle contractions travel through the system in waves, pushing the food ahead of them. This is called peristalsis.

The liver, gallbladder, and pancreas are also organs of the digestive system (**Figure** above). Food does not pass through these three organs. However, these organs are important for digestion. They secrete or store enzymes or other chemicals that are needed to help digest food chemically.

Mouth, Esophagus, and Stomach

The mouth is the first organ that food enters. But digestion may start even before you put the first bite of food into your mouth. Just seeing or smelling food can cause the release of saliva and digestive enzymes in your mouth.

Once you start eating, saliva wets the food, which makes it easier to break up and swallow. Digestive enzymes, including the enzyme amylase, start breaking down starches into sugars. Your tongue helps mix the food with the saliva and enzymes.

Your teeth also help digest food. Your front teeth are sharp. They cut and tear food when you bite into it. Your back teeth are broad and flat. They grind food into smaller pieces when you chew. Chewing is part of mechanical digestion. Your tongue pushes the food to the back of your mouth so you can swallow it. When you swallow, the lump of chewed food passes down your throat to your esophagus.

The **esophagus** is a narrow tube that carries food from the throat to the stomach. Food moves through the esophagus because of peristalsis. At the lower end of the esophagus, a circular muscle controls the opening to the stomach. The muscle relaxes to let food pass into the stomach. Then the muscle contracts again to prevent food from passing back into the esophagus.

Some people think that gravity moves food through the esophagus. If that were true, food would move through the esophagus only when you are sitting or standing upright. In fact, because of peristalsis, food can move through the esophagus no matter what position you are in—even upside down! Just don't try to swallow food when you are upside down—you could choke!

The **stomach** is a sac-like organ at the end of the esophagus. It has thick muscular walls. The muscles contract and relax. This moves the food around and helps break it into smaller pieces. Mixing the food around with the enzyme pepsin and other chemicals helps digest proteins.

Water, salt, and simple sugars can be absorbed into the blood from the stomach. Most other substances are broken down further in the small intestine before they are absorbed. The stomach stores food until the small intestine is ready to receive it. A circular muscle controls the opening between the stomach and small intestine. When the small intestine is empty, the muscle relaxes. This lets food pass from the stomach into the small intestine.

Small Intestine

The **small intestine** a is narrow tube that starts at the stomach and ends at the large intestine (**Figure** above). In adults, the small intestine is about 23 feet long. Chemical digestion takes place in the first part of the small intestine. Many enzymes and other chemicals are secreted here. The small intestine is also where most nutrients are absorbed into the blood. The later sections of the small intestines are covered with tiny projections called **villi** (**Figure** below). Villi contain very tiny blood vessels. Nutrients are absorbed into the blood through these tiny vessels. There are millions of villi, so, altogether, there is a very large area for absorption to take place. In fact, villi make the inner surface area of the small intestine 1,000 times larger than it would be without them. The entire inner surface area of the small intestine is about as big as a basketball court!

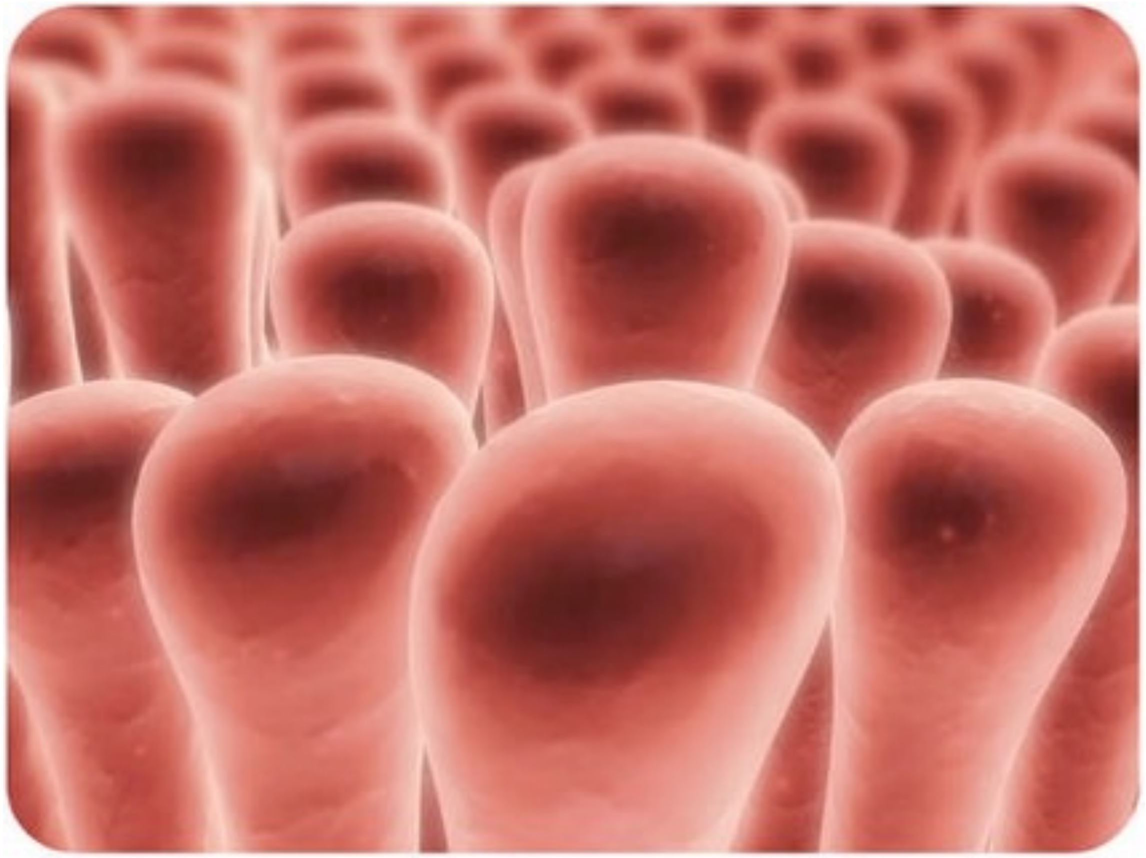


Figure 11.35

This is what the villi lining the intestine looks like when magnified. Each one is actually only about 1 millimeter long. Villi are just barely visible with the unaided eye.

The small intestine is much longer than the large intestine. So why is it called "small"? If you compare small and large intestines (**Figure** above), you will see the small intestine is smaller in width than the large intestine.

Large Intestine

The **large intestine** is a wide tube that connects the small intestine with the anus. In adults, it is about five feet long. Waste enters the large intestine from the small intestine in a liquid state. As the waste moves through the large intestine, excess water is absorbed from it. After the excess water is absorbed, the remaining solid waste is called feces.

Circular muscles control the anus. They relax to let the feces pass out of the body through the anus. After feces pass out of the body, they are called stool. Releasing the stool from the body is referred to as a bowel movement.

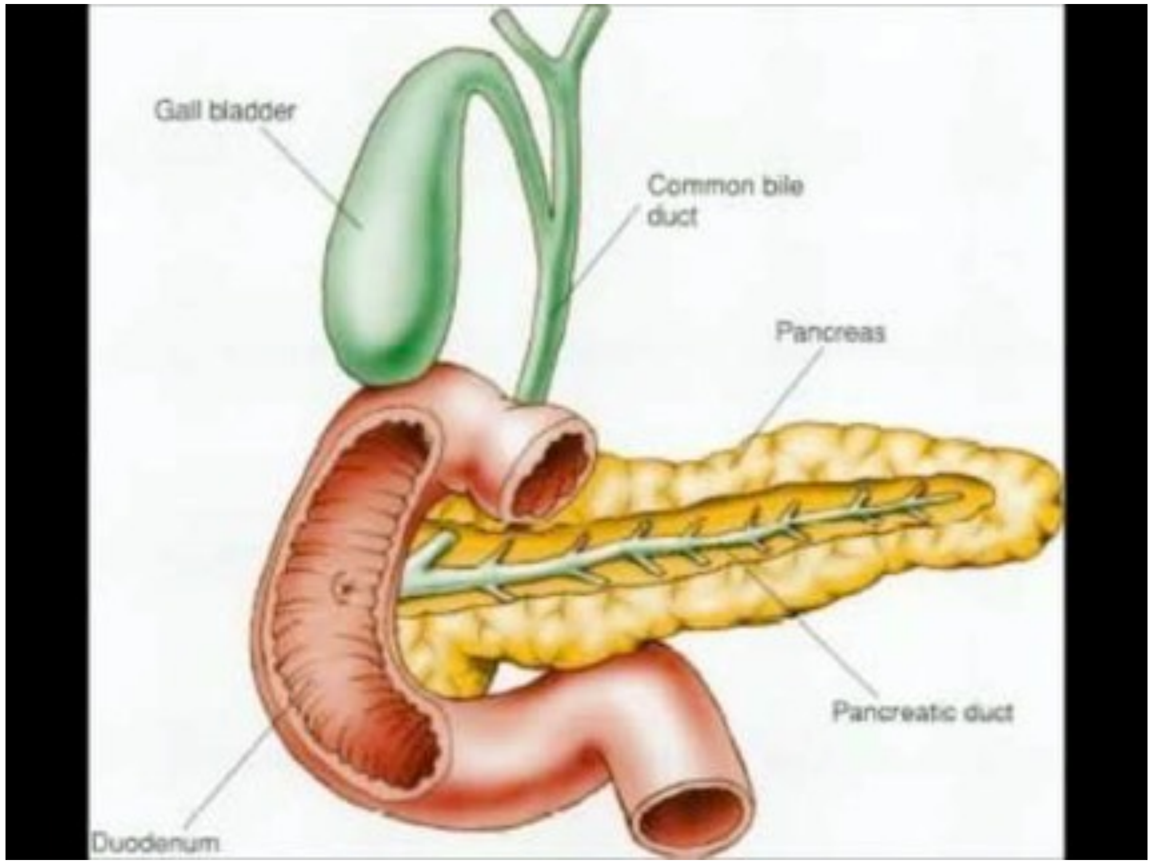
Summary

- The main organs of the digestive system are the mouth, esophagus, stomach, small intestine, and large intestine.
- The liver, gallbladder, and pancreas contribute chemicals that aid in digestion.

Explore More

Use the resource below to answer the questions that follow.

- **Functions of the Organs of the Digestive System** at http://www.youtube.com/watch?v=NtDTy6KLvYo (2:48)



Click on the image above for more content

1. What organ starts the digestion process? What does it do?
2. What function does the liver serve in digestion? How does the liver work together with the gallbladder?
3. What are the functions of the pancreas?

Review

1. List five organs of the digestive system.
2. Describe peristalsis, and explain why it is necessary for digestion.
3. Describe the stomach and its function.

4.In which organ of the digestive system does absorption of nutrients take place?

Section 19

Bacteria in the Digestive Sys-

Bacteria in the Digestive System

- Explain the roles of helpful bacteria in the digestive system.

Why eat yogurt?

Yogurt is a good source of calcium. Yogurt also contains active cultures of "good" bacteria. Foods that contain these beneficial bacteria are sometimes called "probiotic."

Bacteria in the Digestive System

Your large intestine is not just made up of cells. It is also an **ecosystem** , home to trillions of bacteria known as the "gut flora" (**Figure** below). But don't worry, most of these bacteria are helpful. Friendly bacteria live mostly in the large intestine and part of the small intestine. The acidic environment of the stomach does not allow bacterial growth.

Gut bacteria have several roles in the body. For example, intestinal bacteria:

- Produce **vitamin B** $_{12}$ and **vitamin K** .
- Control the growth of harmful bacteria.
- Break down poisons in the large intestine.
- Break down some substances in food that cannot be digested, such as fiber and some starches and sugars. Bacteria produce enzymes that digest carbohydrates in plant cell walls. Most of the nutritional value of plant material would be wasted without these bacteria. These help us digest plant foods like spinach.

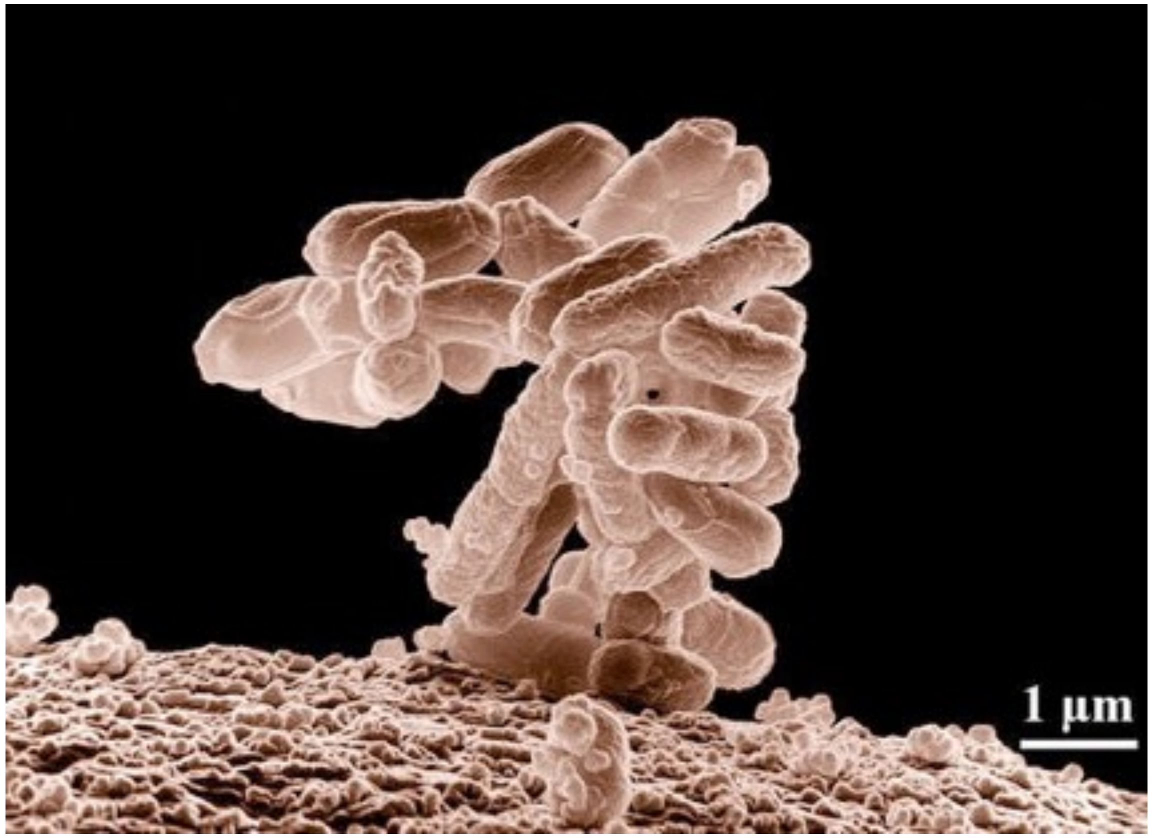


Figure 11.36

Your intestines are home to trillions of bacteria.

A wide range of friendly bacteria live in the gut. Bacteria begin to populate the human digestive system right after birth. Gut bacteria include *Lactobacillus* , the bacteria commonly used in probiotic foods such as yogurt, and *E. coli* bacteria. About a third of all bacteria in the gut are members of the *Bacteroides* species. *Bacteroides* are key in helping us digest plant food.

It is estimated that 100 trillion bacteria live in the gut. This is more than the human cells that make up you. It has also been estimated that there are more bacteria in your mouth than people on the planet. There are over 7 billion people on the planet.

The bacteria in your digestive system are from anywhere between 300 and 1000 species. As these bacteria are helpful, your body does not attack them. They actually appear to the body's immune system as cells of the digestive system. The bacteria actually cover themselves with sugar molecules removed from the actual cells of the digestive system. This disguises the bacteria and protects them from the immune system.

As the bacteria that live in the human gut are beneficial to us, and as the bacteria enjoy a safe environment to live, the relationship that we have with these tiny organisms is described as mutualism, a type of symbiotic relationship.

Lastly, keep in mind the small size of bacteria. Together, all the bacteria in your gut may weight just about 2 pounds.

Summary

- Your large intestine is home to trillions of bacteria.
- Bacteria in the large intestine have important roles, such as producing vitamins and controlling the growth of harmful bacteria.

Explore More

Use the resources below to answer the questions that follow.

Explore More I

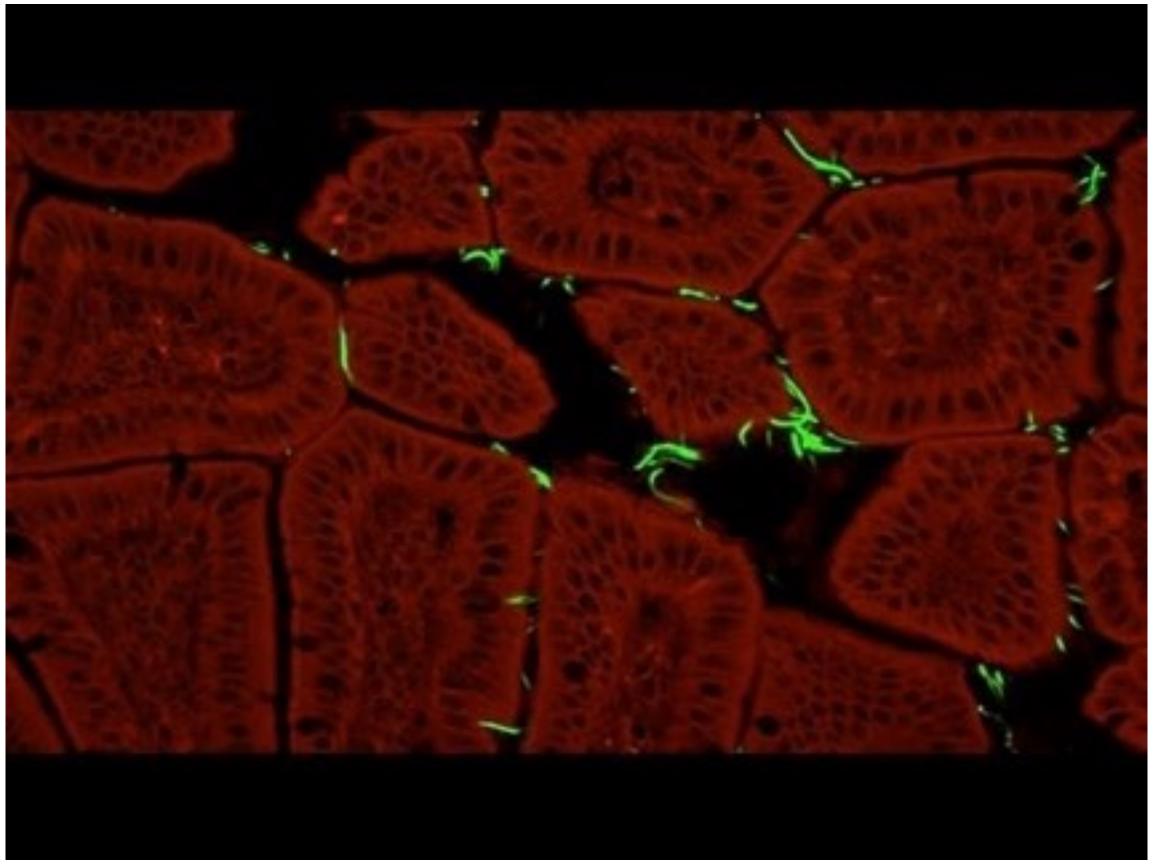
- **Gut Bacteria: We Are What We Eat** at http://www.youtube.com/watch?v=QwTOI5YoqrA (3:56)

Click on the image above for more content

1. How do bacteria influence our digestion?
2. What two categories, with regard to gut bacteria, have scientists identified?
3. What link do scientists believe may exist between gut bacteria and disease? Why is this an area of interest for scientists?

Explore More II

- **Our Microbes, Ourselves** at http://www.youtube.com/watch?v=zPO8-M_rcUo (3:07)



Click on the image above for more content

1. How may clean environments affect the microbes in our bodies?
2. How do gut microbes compare between host species (the species they live in)?
3. What do the findings presented here say about gut bacteria and their host?

Review

1. What is the gut flora?
2. Identify two roles of helpful bacteria in the intestine.
3. When you are sick, you might be given an antibiotic to kill harmful bacteria. Antibiotics cannot distinguish

between "good" and "bad" bacteria, however. Why might this be a problem?

4. What type of symbiotic relationship do we have with these bacteria?

Section 20

Health of the Digestive Sys-

Health of the Digestive System

- •Define foodborne illness.
- •List ways to avoid foodborne illnesses.
- •List common food allergies and symptoms.
- •Describe anaphylaxis and its symptoms.
- •Describe food intolerance.

Have you ever been sick to your stomach?

You may have even had to stay home from school because of a "stomach bug." It is possible that you caught a contagious illness, or you could have gotten sick from food you had eaten recently. The symptoms are very similar, so it's hard to pinpoint the cause.

Health of the Digestive System

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

Foodborne Illness

Harmful bacteria can enter your digestive system in food and make you sick. This is called **foodborne illness** or food poisoning. The bacteria, or the toxins they produce, may cause vomiting or cramping, in addition to the symptoms mentioned above. Foodborne illnesses can also be caused by viruses and parasites. The most common foodborne illnesses happen within a few minutes to a few hours, and make you feel really sick, but last for only about a day or so. Others can take longer for the illness to appear. Some people believe that the taste of food will tell you if it is bad. As a rule, you probably should not eat bad tasting food, but many contaminated foods can still taste good.

You can help prevent foodborne illness by following a few simple rules.

•Keep hot foods hot and cold foods cold. This helps prevent any bacteria in the foods from multiplying.
•Wash your hands before you prepare or eat food. This helps prevent bacteria on your hands from getting on the food. This is the easiest way to prevent foodborne illnesses.
•Wash your hands after you touch raw foods, such as meats, poultry, fish, or eggs. These foods often contain bacteria that your hands could transfer to your mouth.
•Cook meats, poultry, fish, and eggs thoroughly before eating them. The heat of cooking kills any bacteria the foods may contain, so they cannot make you sick.
•Refrigerate cooked food soon after a meal. Cooked food can be left out for up to two hours before they need to be placed in the cold. This will prevent the spread of bacteria. Cooked foods should not be left out all day.

Bacteria that cause foodborne illnesses include *Salmonella* , a bacterium found in many foods, including raw and undercooked meat, poultry, dairy products, and seafood. *Campylobacter jejuni* is found in raw or undercooked chicken and unpasteurized milk. Several strains of *E. coli* can cause illnesses, and are found in raw or undercooked hamburger, unpasteurized fruit juices and milk, and even fresh produce. *Vibrio* is a bacterium that may contaminate fish or shellfish. *Listeria* has been found in raw and undercooked meats, unpasteurized milk, soft cheeses, and ready-to-eat deli meats and hot dogs. Most of these bacterial illnesses can be prevented with proper cooking of food and washing of hands.

Common foodborne viruses include norovirus and hepatitis A virus. Norovirus, which causes inflammation of the stomach and intestines, has been a recent issue on cruise ships, infecting hundreds of passengers and crew on certain voyages. Hepatitis A causes inflammation of the liver, which is treated with rest and diet changes. Parasites are tiny organisms that live inside another organism. *Giardia* is a parasite spread through water contaminated with the stools of people or animals who are infected. Food preparers who are infected with parasites can also contaminate food if they do not thoroughly wash their hands after using the bathroom and before handling food. *Trichinella* is a type of roundworm parasite. People may be infected with this parasite by consuming raw or undercooked pork or wild game.

Food Allergies

Food allergies are like other allergies. They occur when the immune system reacts to harmless substances as though they were harmful. Almost ten percent of children have food allergies. Some of the foods most likely to cause allergies are shown below (**Figure** below).

Eating foods you are allergic to may cause vomiting, diarrhea, or skin rashes. Some people are very allergic to certain foods. Eating even tiny amounts of the foods causes them to have serious symptoms, such as difficulty breathing. If they eat the foods by accident, they may need emergency medical treatment.

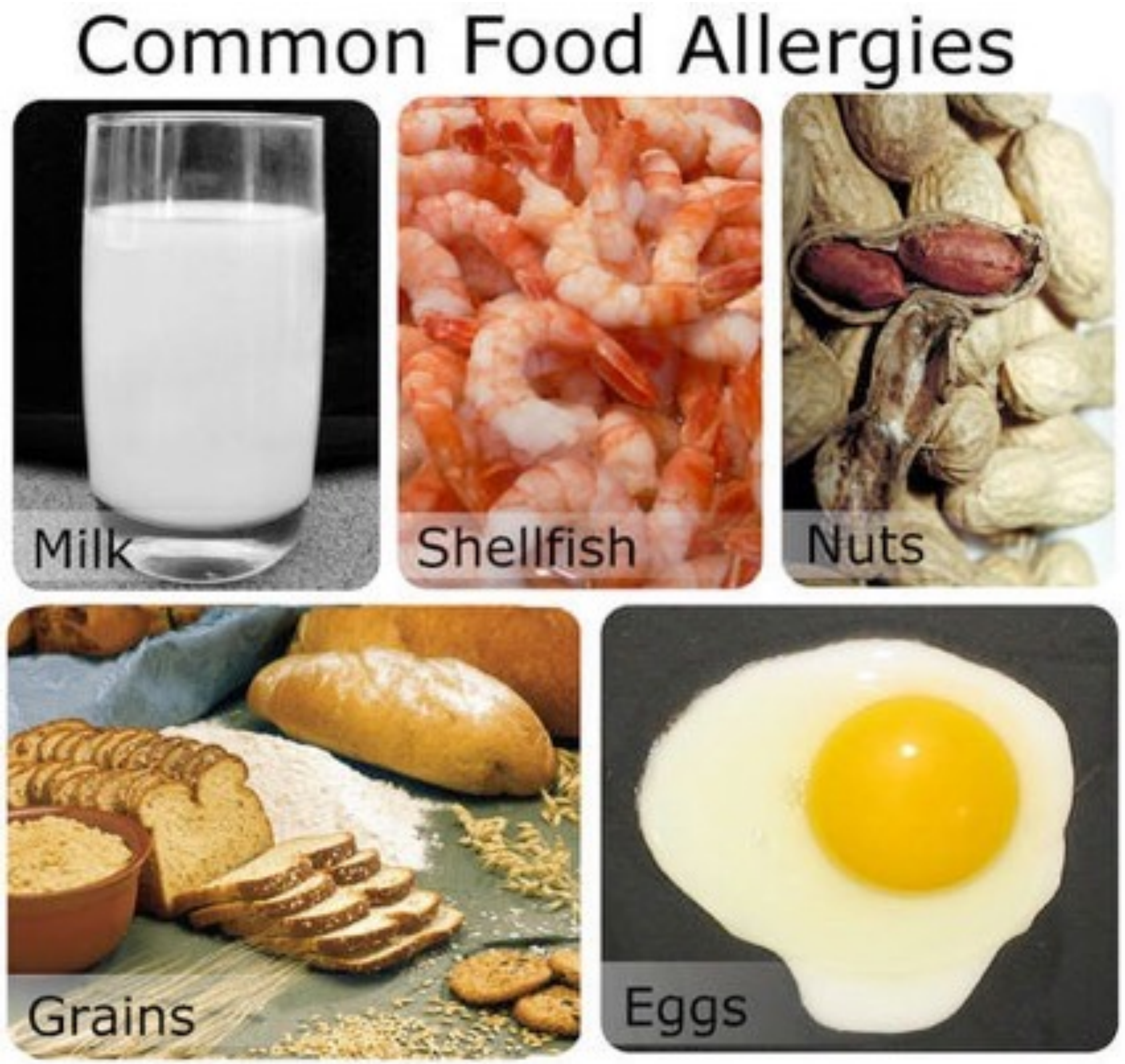


Figure 11.37

Some of the foods that commonly cause allergies are shown here. They include nuts, eggs, grains, milk, and shellfish. Are you allergic to any of these foods?

The most common food allergy symptoms include:

- tingling or itching in the mouth
- hives, itching or eczema,
- swelling of the lips, face, tongue and throat, or other parts of the body,

•wheezing, nasal congestion or trouble breathing,
•abdominal pain, diarrhea, nausea or vomiting,
•dizziness, lightheadedness or fainting.

In some people, a food allergy can trigger a severe allergic reaction called anaphylaxis. Emergency treatment is critical for anaphylaxis. Untreated, anaphylaxis can cause a coma or death. Anaphylaxis is vary rare. The vast majority of people will never have an anaphylactic reaction. The life-threatening symptoms of anaphylaxis include:

•constriction and tightening of the airway,
•a swollen throat or the sensation of a lump in your throat that makes it difficult to breathe,
•shock, with a severe drop in blood pressure,
•a rapid pulse,
•dizziness, lightheadedness or loss of consciousness.

Food Intolerance

A **food intolerance** , or food sensitivity, is different from a food allergy. A food intolerance happens when the digestive system is unable to break down a certain type of food. This can result in stomach cramping, diarrhea, tiredness, and weight loss. Food intolerances are often mistakenly called allergies. Lactose intolerance is a food intolerance. A person who is lactose intolerant does not make enough lactase, the enzyme that breaks down the milk sugar, lactose. Lactose intolerance may be as high as 75% in some populations, but overall the percentage of affected individuals is much less. Still, well over 10% of the world's population is lactose intolerant.

Summary

•Foodborne illness can be prevented by taking precautions during food preparation.
•Food allergies and food intolerance can upset your digestive system.

Explore More

Use the resources below to answer the questions that follow.

•**Introduction to Food Allergens** at http://www.youtube.com/watch?v=z7_Q7fI5uXA (4:27)

Click on the image above for more content

1. What is a food allergy? How does the body respond to food allergies?
2. What does the phrase "dose related" mean? How does this relate to food intolerance?
3. What are four common symptoms of food allergies?
4. What are the eight most common food allergens?
5. Do all people of all ages respond in the same way to foods?

Review

1. List two rules that can help prevent foodborne illness.
2. What's the difference between a food allergy and a food intolerance?
3. List three foods that commonly cause allergies.
4. List three common symptoms of food allergies.

Section 21

Cardiovascular System

Cardiovascular System

- List the components of the cardiovascular system.
- Explain the main function of the cardiovascular system.
- Describe additional functions of the cardiovascular system.

What do you do for "cardio"?

"Cardio" has become slang for exercise that raises your heart rate for an extended amount of time. Cardio can include biking, running, or swimming. Can you guess one of the main organs of the cardiovascular system? Yes, your heart.

Functions of the Cardiovascular System

Your cardiovascular system has many jobs. At times the cardiovascular system can work like a pump, a heating system, or even a postal carrier. To do these tasks, your cardiovascular system works with other organ systems, such as the respiratory, endocrine, and nervous systems.

The **cardiovascular system** (**Figure** below) is made up of the heart, the blood vessels, and the blood. It moves nutrients, gases (like oxygen), and wastes to and from your cells. Every cell in your body depends on your cardiovascular system. If your cells don't receive nutrients, they cannot survive. The main function of the cardiovascular system is to deliver oxygen to each of your cells. Blood receives oxygen in your lungs (the main organs of the respiratory system) and then is pumped, by your heart, throughout your body. The oxygen then diffuses into your cells, and carbon dioxide, a waste product of cellular respiration, moves from your cells into your blood to be delivered back to your lungs and exhaled. Each cell in your body needs oxygen, as oxygen is used in cellular respiration to produce energy in the form of ATP. Without oxygen, lactic acid fermentation would occur in your cells, which can only be maintained for a brief period of time. Arteries carry blood full of oxygen ("oxygen-rich") away from the heart and veins return oxygen-poor blood back to the heart.

The cardiovascular system also plays a role in maintaining body temperature. It helps to keep you warm by moving warm blood around your body. Your blood vessels also control your body temperature to keep you from getting too hot or too cold. When your brain senses that your body temperature is increasing, it sends messages to the blood vessels in the skin to increase in diameter. Increasing the diameter of the blood vessels increases the amount of blood and heat that moves near the skin's surface. The heat is then released from the skin. This helps you cool down. What do you think your blood vessels do when your body temperature is decreasing?

The blood also carries hormones, which are chemical messenger molecules produced by organs of the endocrine system, through your body. Hormones are produced in one area of your body and have an effect on another area. To get to that other area, they must travel through your blood. An example is the hormone adrenaline, produced by the adrenal glands on top of the kidneys. Adrenaline has multiple effects on the heart (it quickens the heart rate), on muscles and on the airway.

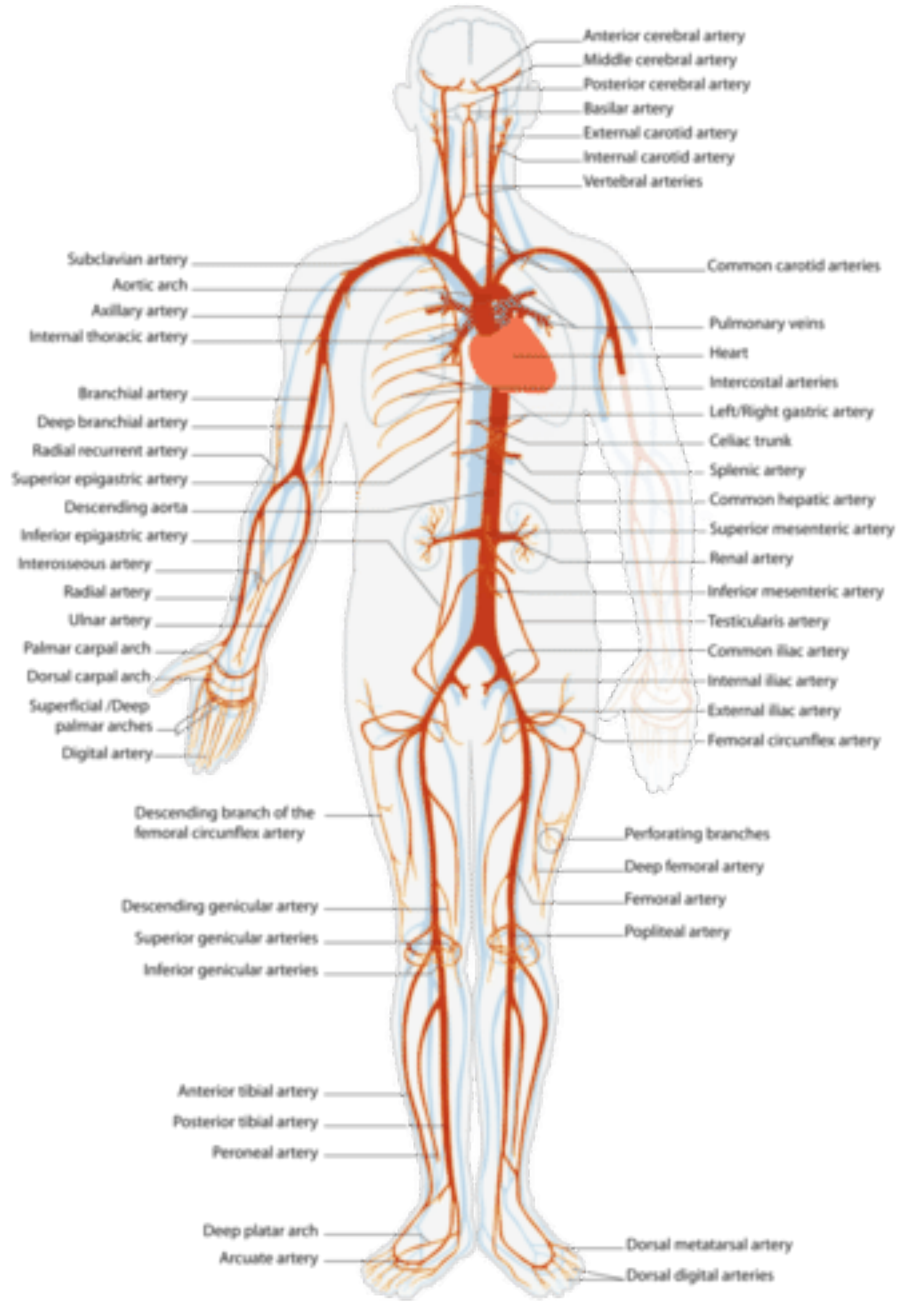


Figure 11.38

The cardiovascular system moves nutrients and other substances throughout the body.

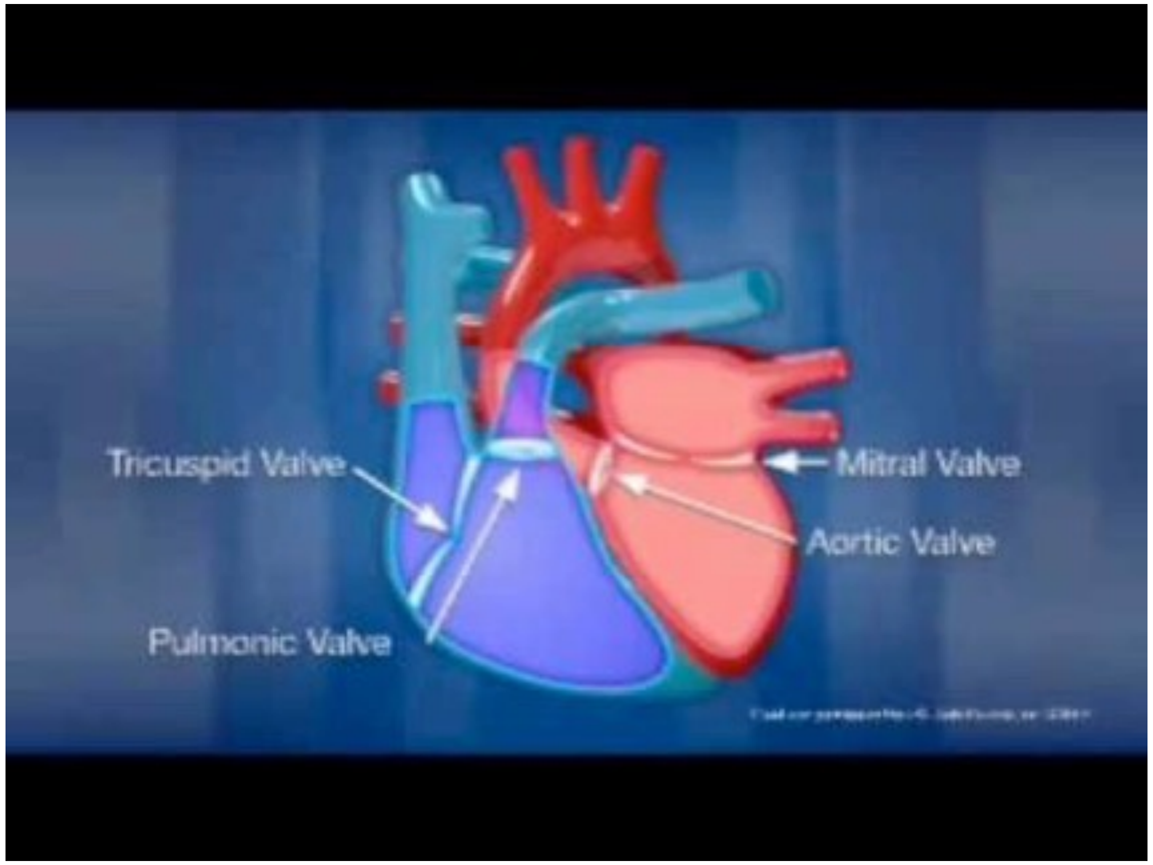
Summary

- The cardiovascular system is made up of the heart, the blood vessels, and the blood.
- The cardiovascular system moves nutrients, hormones, gases, and wastes to and from your cells.

Explore More

Use the resource below to answer the questions that follow.

- **Intro To The Cardiovascular System** at http://www.youtube.com/watch?v=DAXa4eR1s0M (4:04)



Click on the image above for more content

1. Where does blood enter the heart? Where does it exit the heart?
2. How does blood entering the right side of the heart differ from blood entering the left side of the heart?
3. Why is it important for the heart to have one-way valves? How do you think a leaky valve affects the functioning of the heart?
4. What are coronary arteries? What are their function? How are they involved in heart disease?

Review

1. List three components of the cardiovascular system.
2. List the main functions of the cardiovascular system.
3. Why does each cell in your body need oxygen?
4. Complete this sentence: _______ carry blood full of oxygen _______ from the heart and _______ return oxygen-poor blood back to the heart.

Section 22

Circulation and the Lym-

Circulation and the Lymphatic System

- •List the components of the lymphatic system.
- •Describe the functions of the lymphatic system.
- •Explain how the cardiovascular and the lymphatic systems work together.

Are your blood vessels leaky?

None of your blood vessels are leaking this badly, or you'd be in the hospital! But your blood vessels do leak a little bit. Water and solutes pass out of the blood vessels and help form the fluid that bathes your body's tissues. Ultimately the fluid that is lost from the blood vessels is returned through the lymphatic system.

The Lymphatic System and Circulation

The **lymphatic system** is a network of vessels and tissues that carry a clear fluid called **lymph.** The lymphatic system (**Figure** below) spreads all around the body and filters and cleans the lymph of any debris, abnormal cells, or pathogens. **Lymph vessels** are tube-shaped, just like blood vessels, with about 500-600 lymph nodes (in an adult) attached. The lymphatic system works with the cardiovascular system to return body fluids to the blood. The lymphatic system and the cardiovascular system are often called the body’s two "circulatory systems."

Organs of the lymphatic system include the tonsils, thymus gland and spleen. The thymus gland produces T cells or T-lymphocytes (see below) and the spleen and tonsils help in fighting infections. The spleen’s main function is to filter the blood. The spleen also detects viruses and bacteria and triggers the release of pathogen fighting cells.

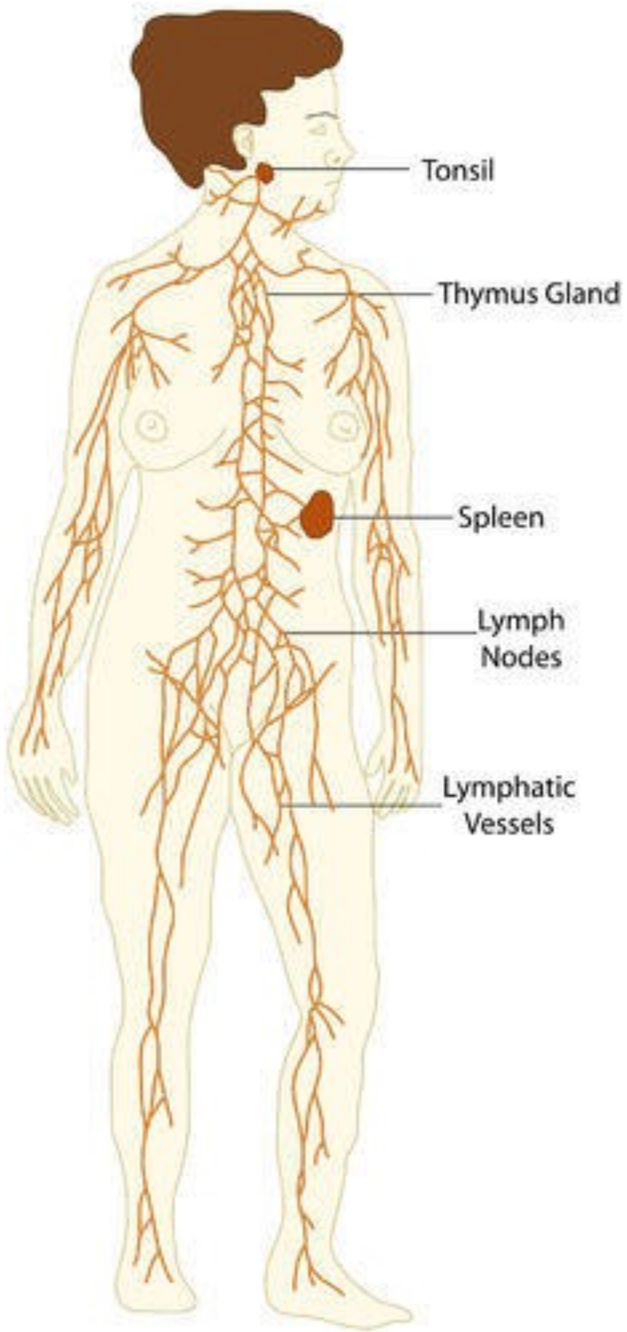


Figure 11.39

The lymphatic system helps return fluid that leaks from the blood vessels back to the cardiovascular system.

Role of the Lymphatic System in Circulation

You may think that your blood vessels have thick walls without any leaks, but that's not true. Blood vessels can leak just like any other pipe. The lymphatic system makes sure leaked blood returns back to the bloodstream.

When a small amount of fluid leaks out from the blood vessels, it collects in the spaces between cells and tissues. Some of the fluid returns to the cardiovascular system, and the rest is collected by the lymph vessels of the lymphatic system (**Figure** below). The fluid that collects in the lymph vessels is called lymph. The lymphatic system then returns the lymph to the cardiovascular system. Unlike the cardiovascular system, the lymphatic system is not closed (meaning it is an open circulatory system that releases and collects fluid) and has no central pump (or heart). Lymph moves slowly in lymph vessels. It is moved along in the lymph vessels by the squeezing action of smooth muscles and skeletal muscles.

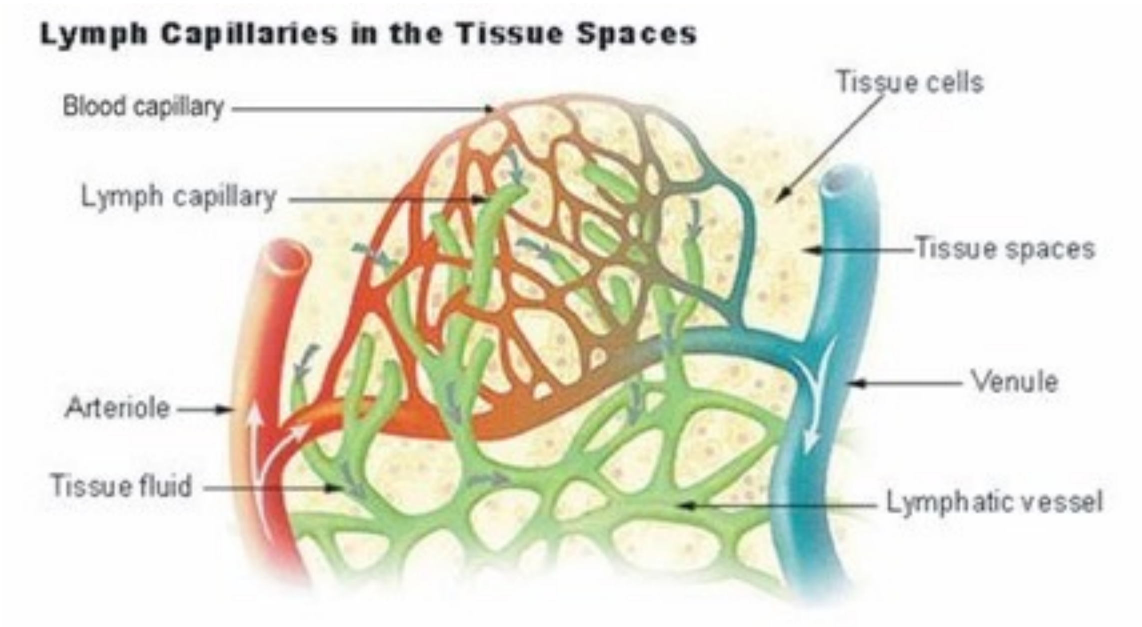


Figure 11.40

Lymph capillaries collect fluid that leaks out from blood capillaries.

Role of the Lymphatic System in the Body's Defenses

The lymphatic system also plays an important role in the immune system. For example, the lymphatic system makes white blood cells that protect the body from diseases. Cells of the lymphatic system produce two types of white blood cells, T cells and B cells, that are involved in fighting specific pathogens. Lymph nodes, which are scattered throughout the lymphatic system, act as filters or traps for foreign particles and are important in the proper functioning of the immune system. The role of the lymphatic system in the immune response is discussed in additional concepts.

Summary

- The lymphatic system works with the cardiovascular system to return body fluids to the blood.
- The lymph, the clear liquid found in the lymphatic system, is moved along in the lymph vessels by the squeezing action of smooth muscles and skeletal muscles.

Explore More

Use the resource below to answer the questions that follow.

- **Lymphatic System** at http://www.youtube.com/watch?v=BX8fBlme9vQ (10:35)

Click on the image above for more content

1. Where are lymphatic vessels found?
2. What are the functions of the lymphatic system?
3. What is interstitial fluid?
4. What causes circulation in the lymphatic system?
5. What are the functions of lymph nodes?
6. What effect does removing a person's spleen have on the functioning of the body?

Review

1. What is the role of the lymphatic system?
2. Describe the role of the spleen.
3. How does the lymph circulate through the body?

4.Where does lymph come from?

Section 23

Heart

Heart

- Describe the structure of the heart.
- Explain the function of each heart chamber.
- Summarize how blood moves through the heart.

Where is your heart?

Place your hand on your heart. Did you put your hand on the left side of your chest? Most people do, but the heart is actually located closer to the center of the chest.

The Heart

What does the heart look like? How does it pump blood? The heart is divided into four chambers (**Figure** below), or spaces: the left and right atria, and the left and right ventricles. An **atrium** (singular for atria) is one of the two small, thin-walled chambers on the top of the heart where the blood first enters. A **ventricle** is one of the two muscular V-shaped chambers that pump blood out of the heart. You can remember they are called ventricles because they are shaped like a "V."

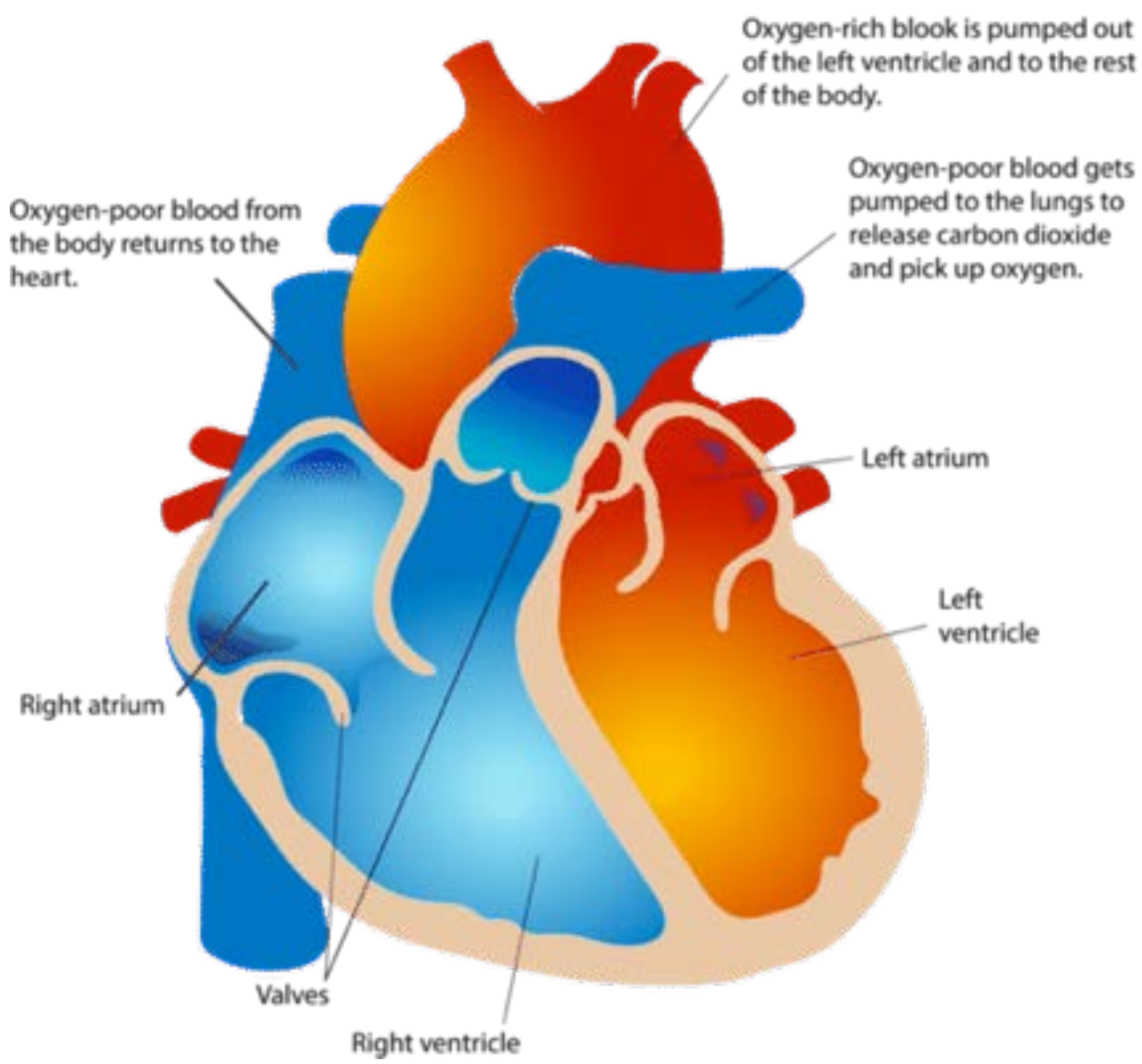


Figure 11.41

The atria receive blood and the ventricles pump blood out of the heart.

The atria receive the blood, and the ventricles pump the blood out of the heart. Each of the four chambers of the heart has a specific job.

- The right atrium receives oxygen-poor blood from the body.
- The right ventricle pumps oxygen-poor blood toward the lungs, where it receives oxygen.
- The left atrium receives oxygen-rich blood from the lungs.
- The left ventricle pumps oxygen-rich blood out of the heart to the rest of the body.

Blood Flow Through the Heart

Blood flows through the heart in two separate loops. You can think of them as a "left side loop" and a "right side loop." The right side of the heart collects oxygen-poor blood from the body and pumps it into the lungs, where it releases carbon dioxide and picks up oxygen. The left side carries the oxygen-rich blood back from the lungs into the left side of the heart, which then pumps the oxygen-rich blood to the rest of the body. The blood delivers oxygen to the cells of the body and returns to the heart oxygen-poor.

To move blood through the heart, the cardiac muscle needs to contract in an organized way. Blood first enters the atria (**Figure** below). When the atria contract, blood is pushed into the ventricles. After the ventricles fill with blood, they contract, and blood is pushed out of the heart. The heart is mainly composed of cardiac muscle. These muscle cells contract in unison, causing the heart itself to contract and generating enough force to push the blood out.

So how is the blood kept from flowing back on itself? **Valves** (**Figure** below) in the heart keep the blood flowing in one direction. The valves do this by opening and closing in one direction only. Blood only moves forward through the heart. The valves stop the blood from flowing backward. There are four valves of the heart.

•The two atrioventricular (AV) valves stop blood from moving from the ventricles to the atria.
•The two semilunar (SL) valves are found in the arteries leaving the heart, and they prevent blood from flowing back from the arteries into the ventricles.

Why does a heart beat? The “lub-dub” sound of the heartbeat is caused by the closing of the AV valves ("lub") and SL valves ("dub") after blood has passed through them.

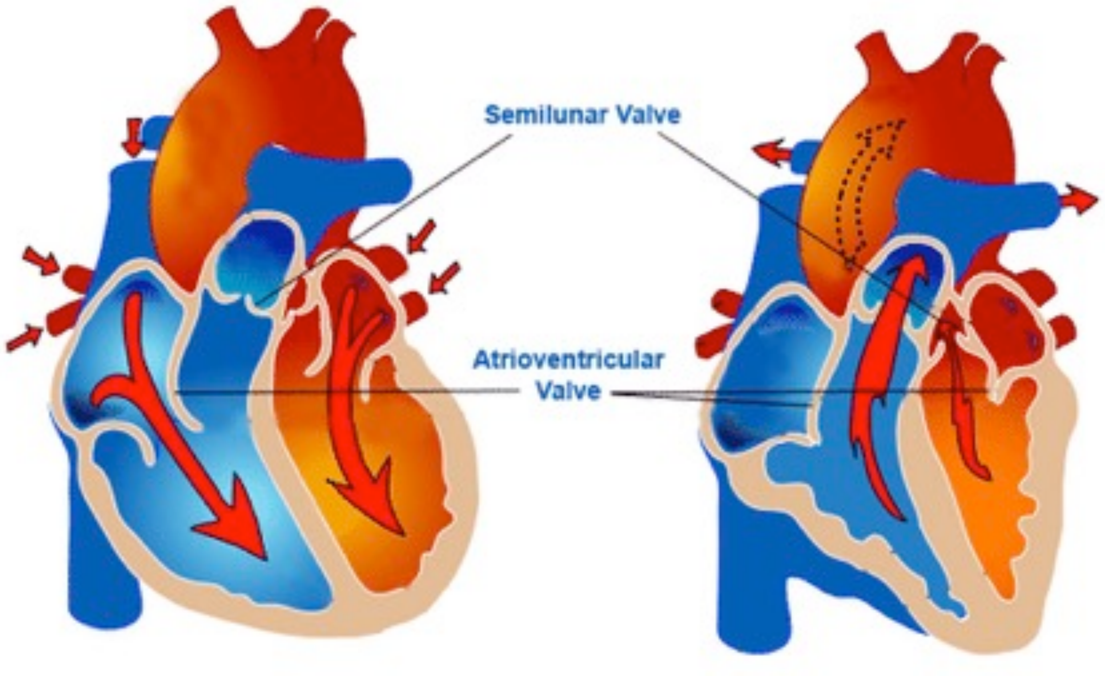


Figure 11.42

Blood flows in only one direction in the heart. Blood enters the atria, which contract and push blood into the ventricles. The atria relax and the ventricles fill with blood. Finally, the ventricles contract and push blood around the body.

Summary

•Blood enters the heart at the atria and then flows into the ventricles, which contract and push blood around the body.
•Valves in the heart keep the blood flowing in one direction.

Explore More

Use the resource below to answer the questions that follow.

•**Working of the Heart** at http://www.youtube.com/watch?v=NF68qhyfcoM (1:36)

Click on the image above for more content

1. How many chambers does a mammalian heart have? What are these chambers called?
2. What are the smallest blood vessels in the body?
3. What is the function of the circulatory system? What role does the heart play?
4. What passes from the cells into the capillaries? What passes into the cells from the capillaries?

Review

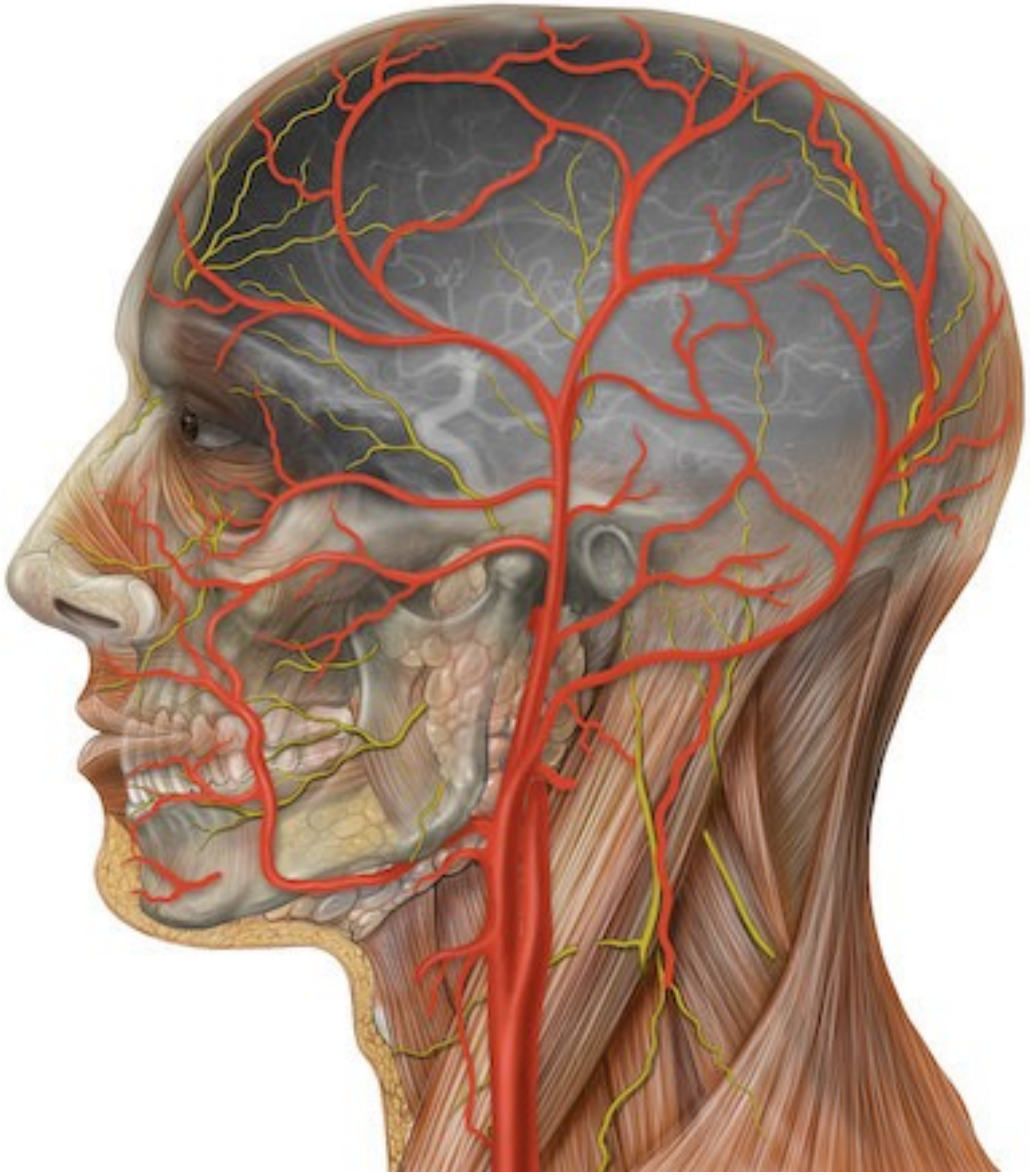
1. What are the ventricles?
2. Where does oxygen-poor blood first enter the heart?
3. What part of the heart pumps blood to the rest of the body?
4. What is the purpose of the valves in the heart?

Section 24

Blood Vessels

Blood Vessels

•List the three types of blood vessels.
•Describe the major arteries and veins.
•Distinguish between systemic circulation and pulmonary circulation.



Why are these arteries so important?

The major arteries of the neck are shown here in red. The heart pumps oxygen-rich blood through these arteries to the brain. Without oxygen, the brain cannot survive longer than just a few minutes. So these arteries in the neck are very important.

Blood Vessels and Blood Circulation

The blood vessels are an important part of the cardiovascular system. They connect the heart to every cell in the body. **Arteries** carry blood away from the heart, while **veins** return blood to the heart (**Figure** below).

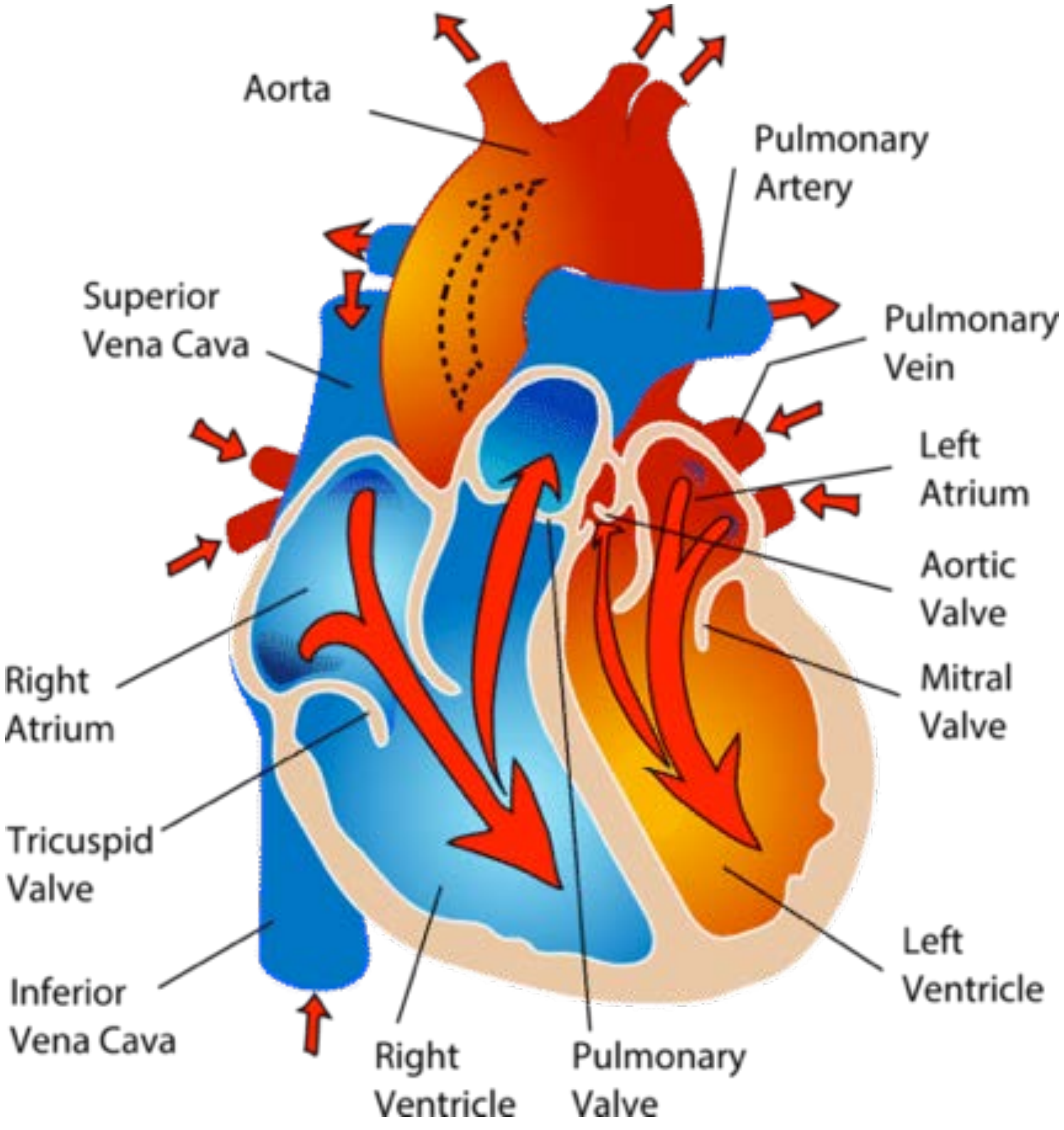


Figure 11.43

The right side of the heart pumps deoxygenated blood into pulmonary circulation, while the left side pumps oxygenated blood into systemic circulation.

Important Arteries and Veins

There are specific veins and arteries that are more significant than others. The **pulmonary arteries** carry oxygen-poor blood away from the heart to the lungs. These are the only arteries that carry oxygen-poor blood. The **aorta** is the largest artery in the body. It carries oxygen-rich blood away from the heart.

Further away from the heart, the aorta branches into smaller arteries, which eventually branch into capillaries. **Capillaries** are the smallest type of blood vessel; they connect very small arteries and veins. Gases and other substances are exchanged between cells and the blood across the very thin walls of capillaries.

The veins that return oxygen-poor blood to the heart are the **superior vena cava** and the **inferior vena cava** . The **pulmonary veins** return oxygen-rich blood from the lungs to the heart. The pulmonary veins are the only veins that carry oxygen-rich blood.

Pulmonary Circulation

Pulmonary circulation is the part of the cardiovascular system that carries oxygen-poor blood away from the heart and brings it to the lungs. Oxygen-poor blood returns to the heart from the body and leaves the right ventricle through the pulmonary arteries, which carry the blood to each lung.

Once at the lungs, the red blood cells release carbon dioxide and pick up oxygen when you breathe. The oxygen-rich blood then leaves the lungs through the pulmonary veins, which return it to the left side of the heart. This completes the pulmonary cycle. The oxygenated blood is then pumped to the body through systemic circulation, before returning again to pulmonary circulation.

Systemic Circulation

Systemic circulation is the part of the cardiovascular system that carries oxygen-rich blood away from the heart, to the body, and returns oxygen-poor blood back to the heart. Oxygen-rich blood leaves the left ventricle through the aorta. Then it travels to the body's organs and tissues. The tissues and organs absorb the oxygen through the capillaries. Oxygen-poor blood is collected from the tissues and organs by tiny veins, which then flow into bigger veins, and, eventually, into the inferior vena cava and superior vena cava. This completes systemic circulation. The blood releases carbon dioxide and gets more oxygen in pulmonary circulation before returning to systemic circulation. The inferior vena cava returns blood from the body. The superior vena cava returns blood from the head.

Summary

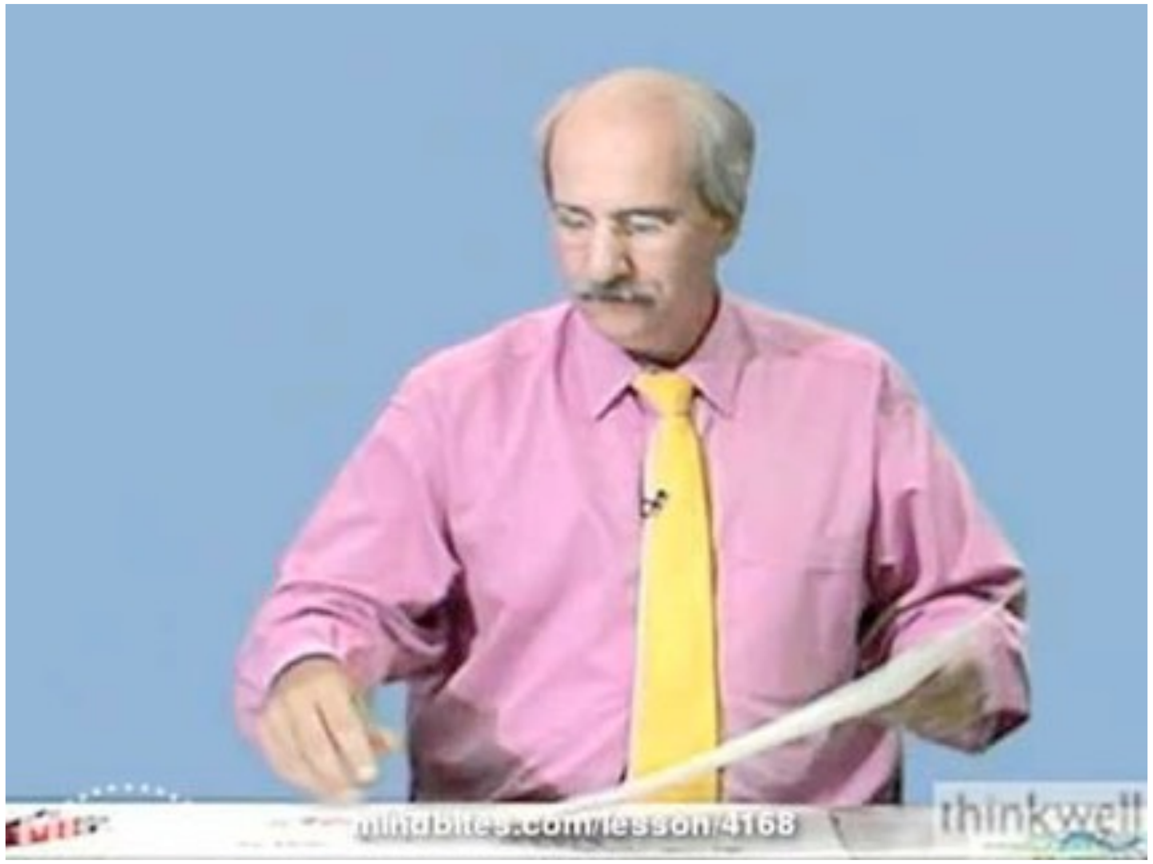
- Arteries carry blood away from the heart, while veins return blood to the heart.
- Pulmonary circulation carries blood between the heart and lungs, while systemic circulation carries blood between the heart and body.

Explore More

Use the resources below to answer the questions that follow. Food and oxygen pass through the thin walls of the capillaries and into living cells.

- **Human Circulation: Blood Vessels** at http://www.youtube.com/watch?v=oruunlHsXoQ (3:50)

Explore More I



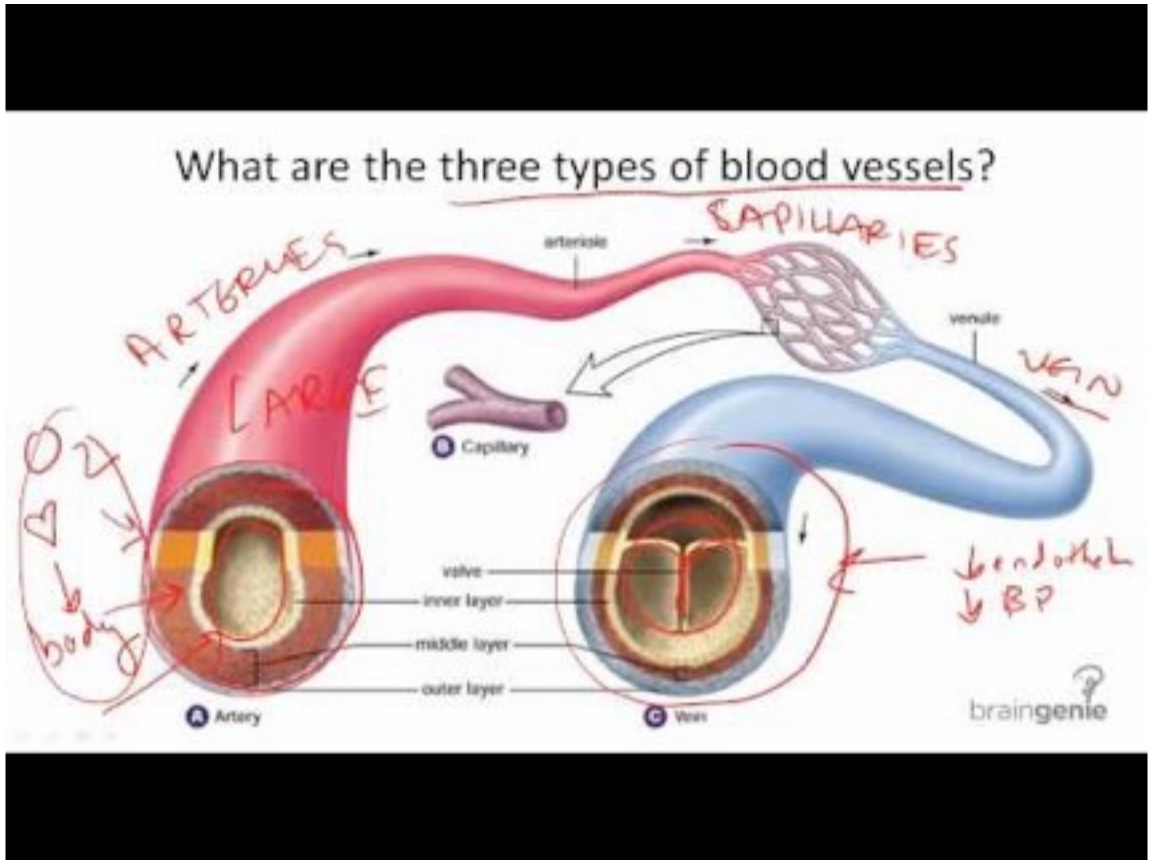
Click on the image above for more content

1. What is the difference between capillaries, veins, and arteries?

2.What is endothelium? What vessels have this tissue?
3.What do arteries and veins have that capillaries don't?

Explore More II

•Blood Vessel Structure and Function at http://www.youtube.com/watch?v=whtNDBIhczQ (3:16)

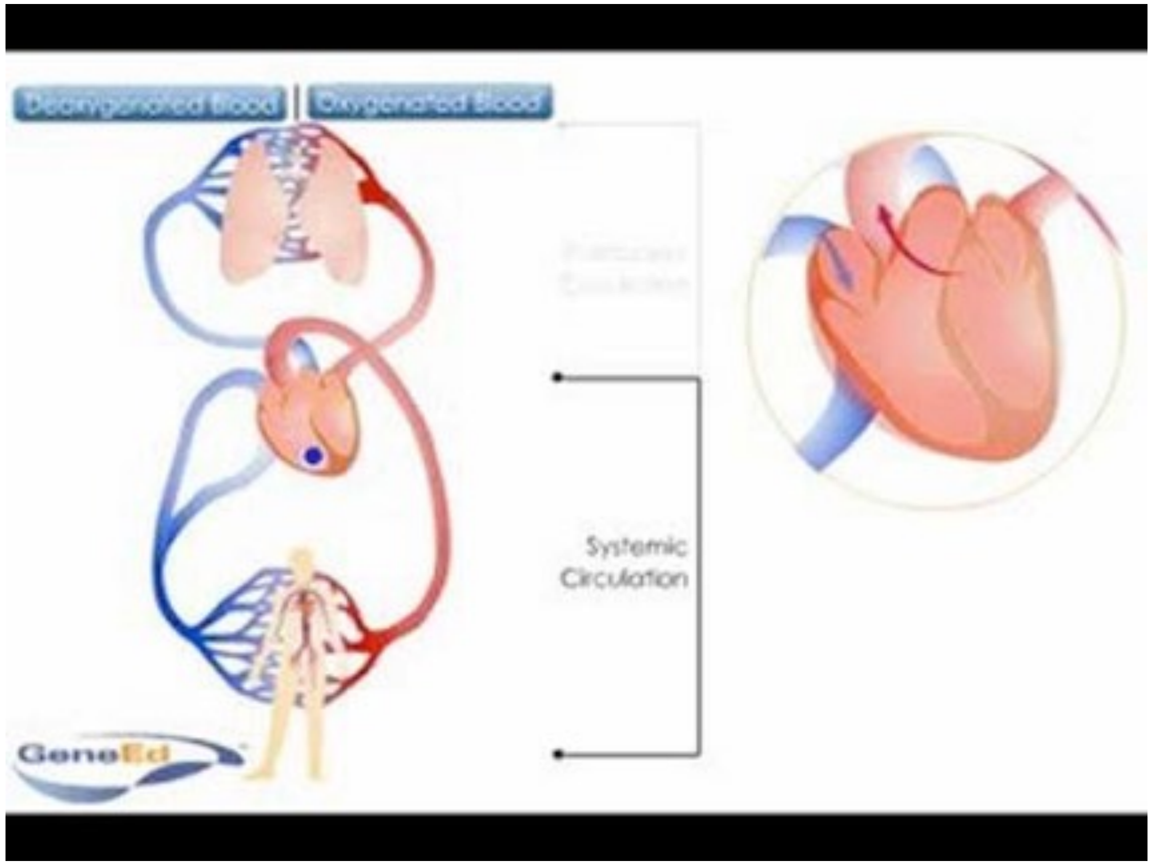


Click on the image above for more content

1.How does the structure of arteries differ from the structure of veins?
2.How is the structure of arteries related to their function?
3.How is the structure of veins related to their function?

Explore More III

•Systemic and Pulmonary Circulation at http://www.youtube.com/watch?v=0jznS5psypI (0:30)



Click on the image above for more content

1.What are the three types of circulation of the blood?
2.What is the function of the systemic circulation system?
3.What is the function of the pulmonary circulation system?

Review

1. What's the difference between veins and arteries?
2. Why can the heart be considered to be two separate pumps?
3. What is the systemic circulation?
4. What is the aorta?
5. What is a capillary? What happens in the capillaries?

Section 25

Components of Blood

Components of Blood

•List the components of the blood.
•Describe the main roles of red blood cells and white blood cells.
•List the types of white blood cells and explain their functions.
•Summarize the importance of platelets.

What's in your blood?

These bags of blood will be stored until they are needed for a transfusion. But what exactly is blood? What makes up the blood? Most of your blood is water. However, there are also many other important components of your blood.

Components of Blood

Did you know that blood is a tissue? Blood is a fluid connective tissue that is made up of red blood cells, white blood cells, platelets, and plasma. The cells that make up blood are pictured below (**Figure** below). The different parts of blood have different roles.

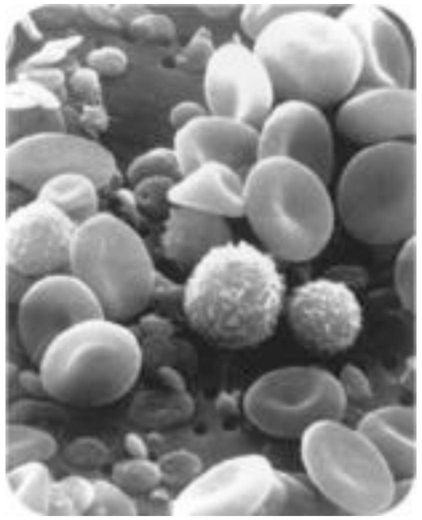


Figure 11.44

A scanning electron microscope (SEM) image of human blood cells. Red blood cells are the flat, bowl-shaped cells, the tiny disc-shaped pieces are platelets, and white blood cells are the round cells shown in the center.

Plasma

If you were to filter out all the cells in blood, a golden-yellow liquid would be left behind. **Plasma** is this fluid part of the blood. Plasma is about 90% water and about 10% dissolved proteins, glucose, ions, hormones, and gases. Blood is made up mostly of plasma.

Red Blood Cells

Red blood cells (RBCs) are flattened, disk-shaped cells that carry oxygen. They are the most common blood cell in the blood. There are about 4 to 6 million RBCs per cubic millimeter of blood. Each RBC has 200 million molecules of hemoglobin. **Hemoglobin** is the protein that carries oxygen. Hemoglobin also gives the red blood cells their red color.

Red blood cells (**Figure** below) are made in the red marrow of long bones, rib bones, the skull, and vertebrae. Each red blood cell lives for only 120 days (about four months). After this time, they are destroyed in the liver and spleen. Mature red blood cells do not have a nucleus or other organelles. Lacking these components allows the cells to have more hemoglobin and carry more oxygen.

Figure 11.45

The flattened shape of red blood cells helps them carry more oxygen than if they were rounded.

White Blood Cells

White blood cells (WBCs) are usually larger than red blood cells. They do not have hemoglobin and do not carry oxygen. White blood cells make up less than one percent of the blood's volume. Most WBCs are made in the bone marrow, and some mature in the lymphatic system. There are different WBCs with different jobs. WBCs defend the body against infection by bacteria, viruses, and other **pathogens** . WBCs do have a nucleus and other organelles.

- •Neutrophils are WBCs that can squeeze through capillary walls and swallow particles such as bacteria and parasites.
- •Macrophages are large WBCs that can also swallow and destroy old and dying cells, bacteria, or viruses. Below, a macrophage is attacking and swallowing two particles, possibly disease-causing pathogens (**Figure** below). Macrophages also release chemical messages that cause the number of WBCs to increase.
- •Lymphocytes are WBCs that fight infections caused by viruses and bacteria. Some lymphocytes attack and kill cancer cells. Lymphocytes called B-cells make antibodies.

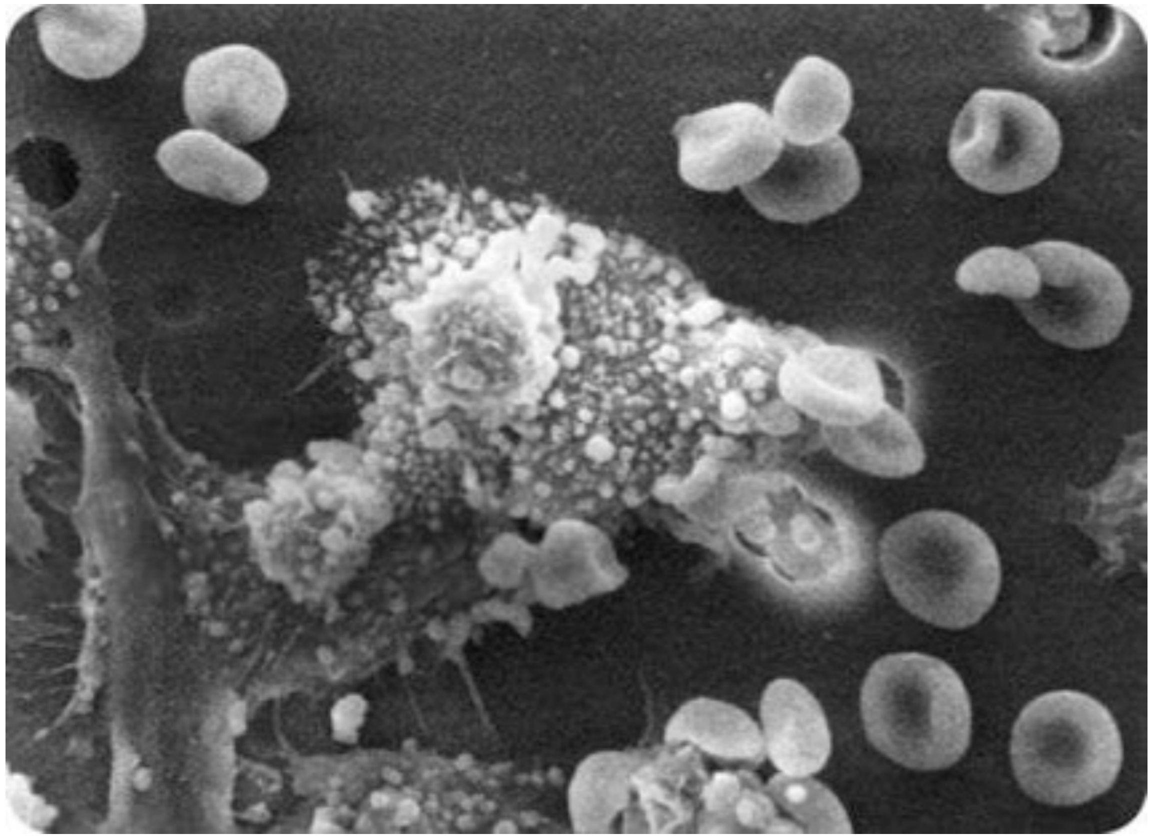


Figure 11.46

A type of white blood cell, called a macrophage, is attacking a cancer cell.

Platelets

Platelets (**Figure** below) are very small, but they are very important in blood clotting. Platelets are not cells. They are sticky little pieces of larger cells. Platelets bud off large cells that stay in the bone marrow. When a blood vessel gets cut, platelets stick to the injured areas. They release chemicals called clotting factors, which cause proteins to form over the wound. This web of proteins catches red blood cells and forms a clot. This clot stops more blood from leaving the body through the cut blood vessel. The clot also stops bacteria from entering the body. Platelets survive in the blood for ten days before they are removed by the liver and spleen.

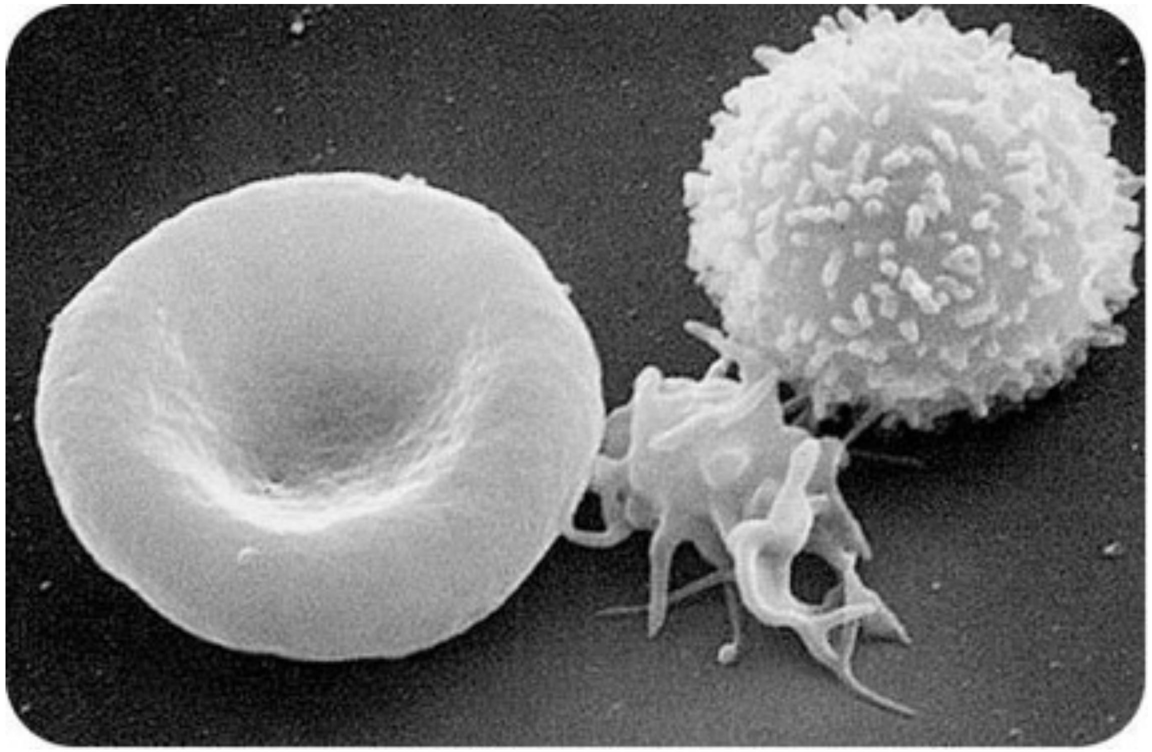


Figure 11.47

A platelet lies between a red blood cell, at left, and a white blood cell at right. Platelets are little pieces of larger cells that are found in the bone marrow.

Summary

- Plasma, the fluid part of the blood, is mostly made up of water but also contains dissolved proteins, glucose, ions, hormones, and gases.
- Red blood cells carry oxygen, while white blood cells defend the body against infection by bacteria, viruses, and other diseases.

Explore More

Use the resource below to answer the questions that follow.

- **The Components of Blood** at http://www.youtube.com/watch?v=C5qmKirdiic (2:01)

Click on the image above for more content

1. What is another name for red blood cells? What is the function of red blood cells?
2. Why are red blood cells red?
3. What is another name for white bloods cells? What is the function of white blood cells?
4. What is another name for platelets? What is the function of platelets?

Review

1. Is blood a tissue? Explain your answer.
2. What is the purpose of the white blood cells?
3. What is the purpose of the red blood cells?
4. What are macrophages?
5. What are platelets? What is the primary role of platelets?

Section 26

Blood Types

Blood Types

- •List blood types in humans.
- •Describe how blood type is determined.
- •Explain universal donors and universal recipients.

What's your type?

As this woman donates blood, you can see her blood collecting in a special bag. This bag is coded with her blood type. That makes it possible for doctors and nurses to match up the blood she is giving to a recipient that has the same blood type.

Blood Types

Do you know what your blood type is? Maybe you have heard people say that they have type A or type O blood. Blood type is a way to describe the type of **antigens** , or proteins, on the surface of red blood cells (RBCs). There are four blood types; A, B, AB, and O.

1. Type A blood has type A antigens on the RBCs in the blood.
2. Type AB blood has A and B antigens on the RBCs.
3. Type B has B antigens on the RBCs.
4. Type O does not have either A or B antigens.

The ABO blood group system is important if a person needs a blood transfusion. A **blood transfusion** is the process of putting blood or blood products from one person into the circulatory system of another person. The blood type of the recipient needs to be carefully matched to the blood type of the donor. That's because different blood types have different types of antibodies, or proteins, released by the blood cells. Antibodies attack strange substances in the body. This is a normal part of your defenses against disease.

For example, imagine a person with type O blood was given type A blood. First, what type of antibodies do people with type O blood produce? They produce anti-A and anti-B antibodies. This means, if a person with type O blood received type A blood, the anti-A antibodies in the person's blood would attack the A antigens on the RBCs in the donor blood (**Figure** below). The antibodies would cause the RBCs to clump together, and the clumps could block a blood vessel. This clumping of blood cells could cause death.

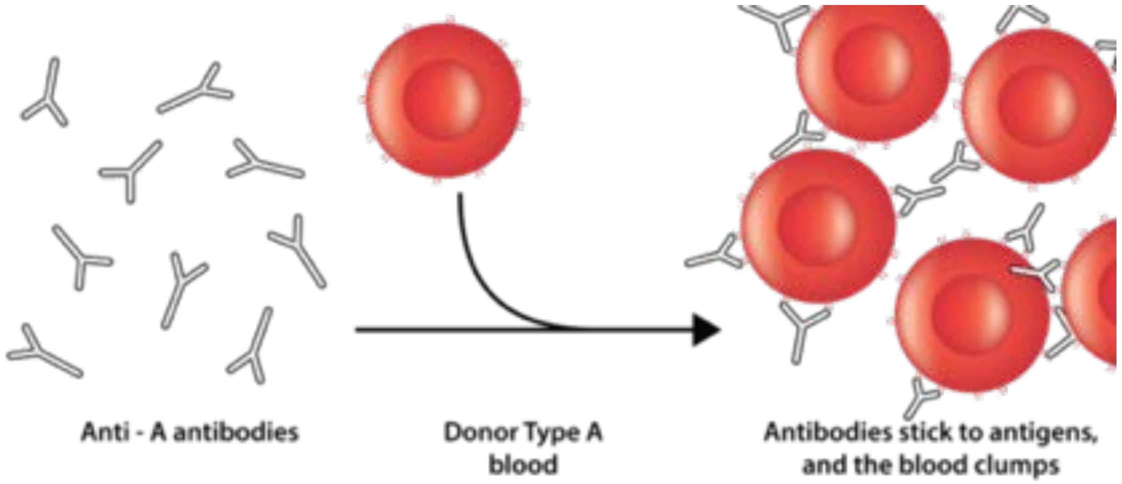


Figure 11.48

A person with type O blood has A and B antibodies in his/her plasma; if the person was to get type A blood instead of type O, his/her A antibodies would attach to the antigens on the RBCs and cause them to clump together.

People with type A blood produce anti-B antibodies, and people with type B blood produce anti-A antibodies. People with type AB blood do not produce either antibody.

The Rhesus Factor

The second most important blood group system in human blood is the **Rhesus (Rh) factor** . A person either has, or does not have, the Rh antigen on the surface of their RBCs. If they do have it, then the person is positive. If the person does not have the antigen, they are considered negative.

Blood Donors

Recall that people with type O blood do not have any antigens on their RBCs. As a result, type O blood can be given to people with blood types A, B, or AB. If there are no antigens on the RBCs, there cannot be an antibody reaction in the blood. People with type O blood are often called **universal donors** .

The blood plasma of AB blood does not contain any anti-A or anti-B antibodies. People with type AB blood can receive any ABO blood type. People with type AB blood are called **universal recipients** because they can receive any blood type. The antigens and antibodies that define blood type are listed as follows (**Table** below).

Blood Type	Antigen Type	Plasma Antibodies	Can Receive Blood from Types	Can Donate Blood to Types
A	A	anti-B	A,O	A, AB
B	B	anti-A	B,O	B, AB
AB	A and B	none	AB, A, B, O	AB
O	none	anti-A, anti-B	O	AB, A, B, O

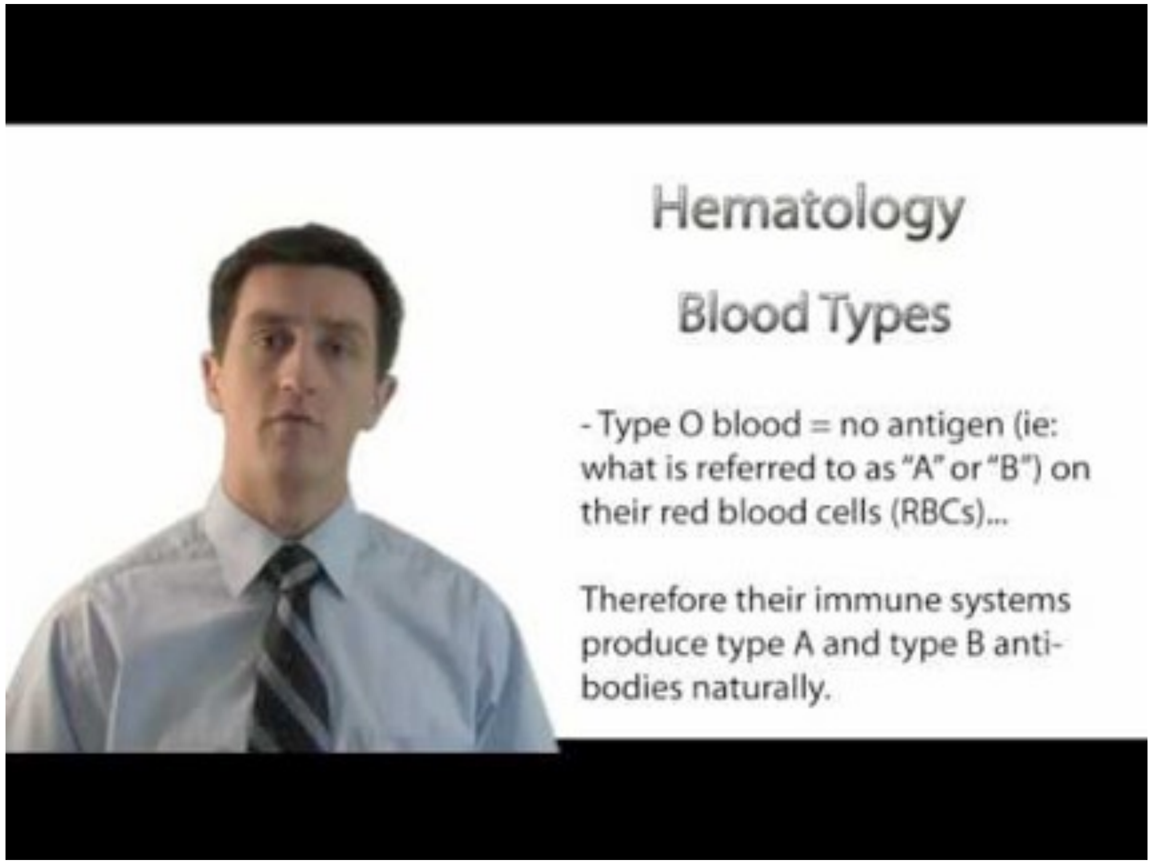
Summary

•Blood type, which can be A, B, AB, or O, is a way to describe the type of proteins on the surface of red blood cells.
•Another important aspect of blood type is the Rhesus (Rh) factor; a person either has, or does not have, the Rh antigen on the surface of his/her red blood cells.

Explore More

Use the resource below to answer the questions that follow.

•**Understanding Blood Types** at http://www.youtube.com/watch?v=G_-9_CF02qI (2:12)



Click on the image above for more content

1. What is an antigen? What are two examples of antigens?
2. What is an antibody?
3. What type of antigen are on type O red blood cells?
4. What antibodies do type O red blood cells produce?
5. What does type B blood have that type O blood does not?

Review

1. What is an antigen?
2. Why is it important to match blood types when giving a blood transfusion?
3. Why are people with type O blood called "universal donors"?
4. Who are universal recipients? Why?

Section 27

Blood Diseases

Blood Diseases

•Describe diseases of the blood.
•Describe causes of anemia.
•Explain sickle-cell anemia and hemophilia.
•Define leukemia.

What do these foods have in common?

Red meat, legumes, and spinach are all good sources of iron. Getting enough iron in your diet is important to prevent anemia. Anemia is a blood disease that causes you to feel weak and tired. Although anemia is caused by a nutrient deficiency, other blood diseases are genetic diseases, or forms of cancer.

Blood Diseases

Problems can occur with red blood cells, white blood cells, platelets, and other parts of the blood. Many blood disorders are genetic, meaning they are inherited from a parent. Some blood diseases are caused by not getting enough of a certain nutrient, while others are cancers of the blood.

Anemia

Anemia is a disease that occurs when there is not enough hemoglobin in the blood to carry oxygen to body cells. **Hemoglobin** is the blood protein that normally carries oxygen from the lungs to the tissues. Anemia leads to a lack of oxygen in organs.

Anemia is usually caused by one of the following:

•A loss of blood from a bleeding wound or a slow leak of blood.
•The destruction of red blood cells.
•A lack of red blood cell production.

Anemia may not have any symptoms. Some people with anemia feel weak or tired in general or during exercise. They also may have poor concentration. People with more severe anemia often get short of breath during times of activity. Iron-deficiency anemia is the most common type of anemia. It occurs when the body does not receive enough iron. Since there is not enough iron, hemoglobin, which needs iron to bind oxygen, cannot function properly.

In the United States, 20% of all women of childbearing age have iron-deficiency anemia, compared with only 2% of adult men. The most common cause of iron-deficiency anemia in young women is blood lost during menstruation. Iron deficiency anemia can be avoided by getting the recommended amount of iron in one's diet. Anemia is often treated or prevented by taking iron supplements.

Boys and girls between the ages of 9 and 13 should get 9 mg of iron every day. Girls between the ages of 14 and 18 should get 15 mg of iron every day. Boys between the ages of 14 and 18 should get 11 mg of iron every day. Pregnant women need the most iron—27 mg daily. Good sources of iron include shellfish, such as clams and oysters. Red meats, such as beef, are also a good source of iron. Non-animal sources of iron include seeds, nuts, and legumes. Breakfast cereals often have iron added to them in a process called fortification. Some good sources of iron are listed below (**Table** below). Eating vitamin C along with iron-containing food increases the amount of iron that the body can absorb.

Food	Milligrams (mg) of Iron
Canned clams, drained, 3 oz.	23.8
Fortified dry cereals, about 1 oz.	1.8 to 21.1
Roasted pumpkin and squash seeds, 1 oz.	4.2
Cooked lentils, ½ cup	3.3
Cooked fresh spinach, ½ cup	3.2
Cooked ground beef, 3 oz.	2.2
Cooked sirloin beef, 3 oz.	2.0

Sickle-Cell Anemia

Sickle-cell anemia is a blood disease that is caused by an abnormally shaped hemoglobin protein in red blood cells. Many of the red blood cells of a person with sickle-cell anemia are long and curved (sickle-shaped) (**Figure** below). The long, sickle shape of the cells can cause them to get stuck in narrow blood vessels. This clotting means that oxygen cannot reach the cells. People with sickle-cell anemia are most often well but can occasionally have painful attacks. The disease is not curable, but it can be treated with medicines.

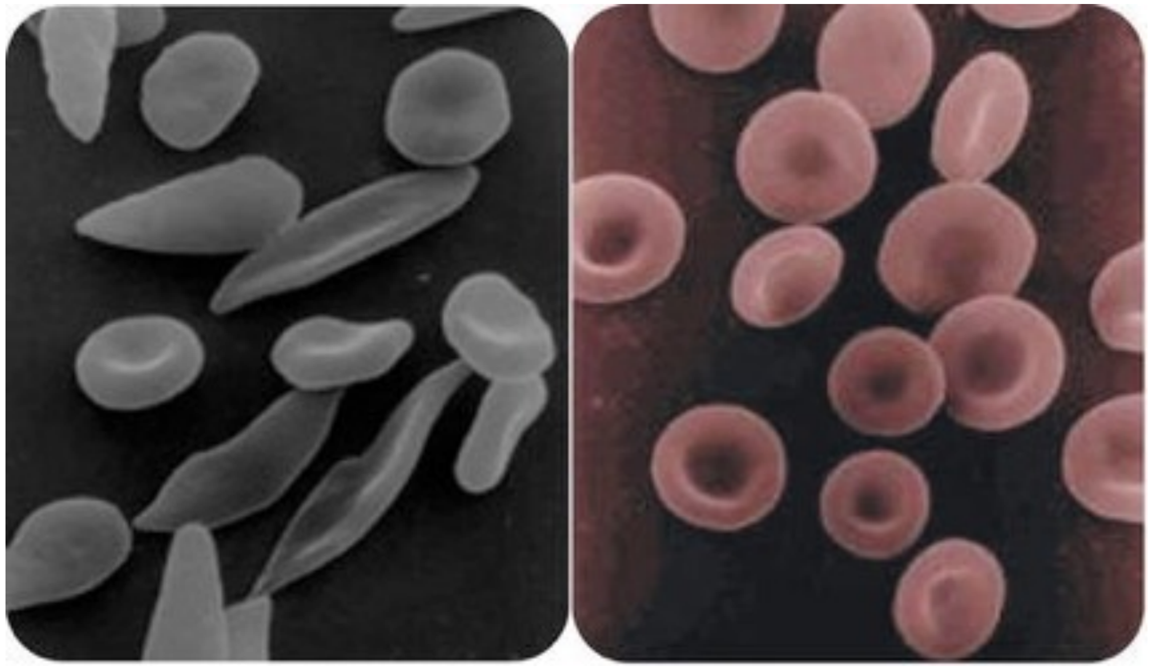


Figure 11.49

The red blood cells of a person with sickle-cell anemia (left) are long and pointed, rather than straight, like normal cells (right). The abnormal cells cannot carry oxygen properly and can get stuck in capillaries.

Blood Cancer

Blood cancers affect the production and function of your blood cells. Most of these cancers start in your bone marrow where blood is produced. In most blood cancers, the normal production of blood cells is replaced by uncontrolled growth of an abnormal type of blood cell. These abnormal blood cells are cancerous cells, and prevent your blood from performing many of its functions, like fighting off infections or preventing serious bleeding. **Leukemia** is a cancer of the blood or bone marrow. It is characterized by an abnormal production of blood cells, usually white blood cells. **Lymphoma** is a cancer of a type of white blood cell called lymphocytes. There are many types of lymphoma.

Hemophilia

Hemophilia is the name of a group of hereditary diseases that affect the body's ability to control blood clotting. Hemophilia is caused by a lack of clotting factors in the blood. Clotting factors are normally released by platelets. Since people with hemophilia cannot produce clots, any cut can put a person at risk of bleeding to death. The risk of internal bleeding is also increased in hemophilia, especially into muscles and joints. This disease affected the royal families of Europe.

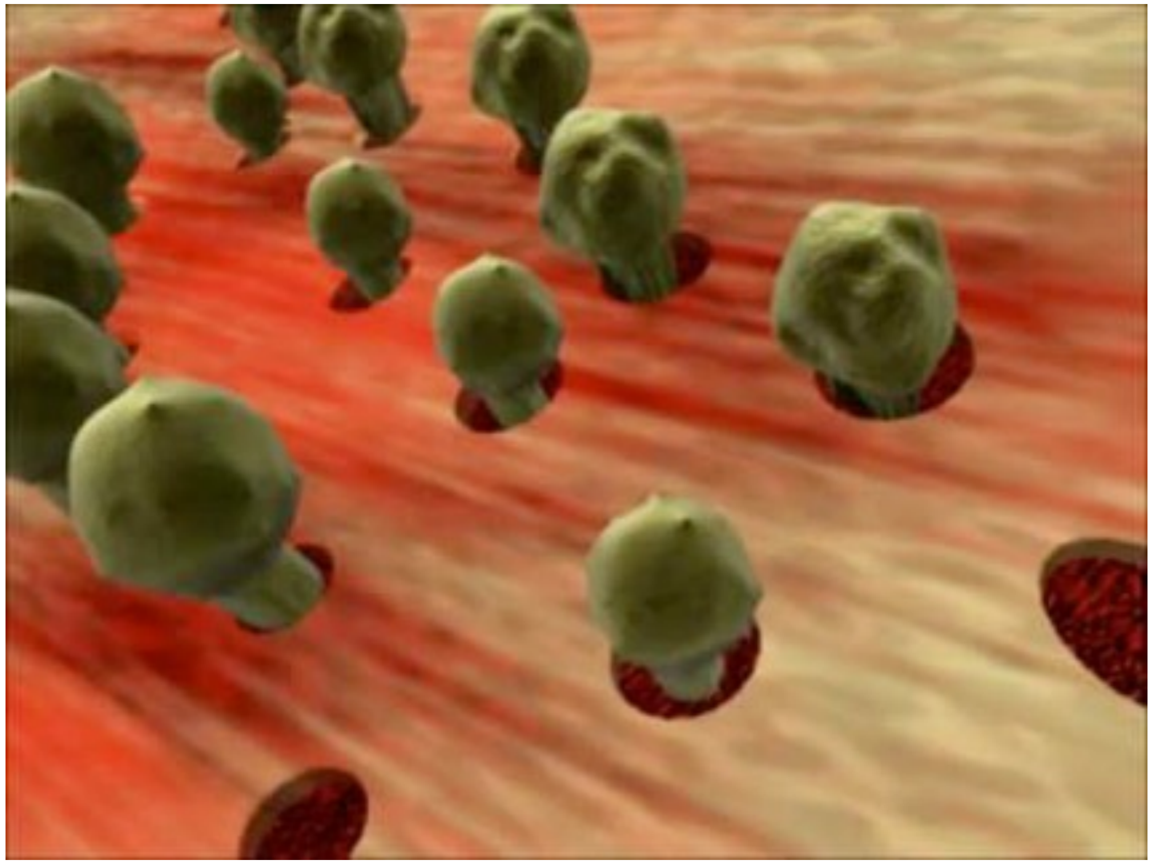
Summary

- Blood diseases can affect red blood cells, white blood cells, or platelets.
- Blood diseases include sickle-cell anemia, leukemia, lymphoma, and hemophilia.

Explore More

Use the resources below to answer the questions that follow.

- **Aplastic Anemia** at http://www.youtube.com/watch?v=w8-jx1dtg0U (2:41)



Click on the image above for more content

1. What causes aplastic anemia? Why is it considered an autoimmune disease?
2. Which blood cells are at reduced levels in someone with aplastic anemia?
3. Where are blood cells produced? What cells in this area make the blood cells?
4. How does "rebooting" the immune system treat aplastic anemia?

Review

1. Identify a blood disease that is inherited.
2. What is anemia?
3. List two good sources of iron in the diet.
4. What are the issues associated with sickle-cell anemia?

Section 28

Blood Pressure

Blood Pressure

•Define blood pressure.
•List healthy blood pressure ranges.
•Describe the effects of hypertension.

Why check your blood pressure?

It's a good idea to have a blood pressure test as part of a routine physical, especially in adulthood. High blood pressure is a risk factor for heart disease and stroke. It's important to know if you have high blood pressure, so it can be treated. A combination of medications and lifestyle changes can be successful in lowering your blood pressure.

Blood Pressure

The health of your whole body depends on the good health of your cardiovascular system. One measure of the health of your cardiovascular system is blood pressure. **Blood pressure** occurs when circulating blood puts pressure on the walls of blood vessels. Since blood pressure is primarily caused by the beating of your heart, the walls of the arteries move in a rhythmic fashion. Blood in arteries is under the greatest amount of pressure. The pressure of the circulating blood slowly decreases as blood moves from the arteries and into the smaller blood vessels. Blood in veins is not under much pressure.

Healthy Blood Pressure Ranges

Blood pressure is read as two numbers. The first number is the systolic pressure. The **systolic** pressure is the pressure on the blood vessels when the heart beats. This is the time when there is the highest pressure in the arteries. The **diastolic** pressure, which is the second number, is when your blood pressure is lowest, when the heart is resting between beats.

Healthy ranges for blood pressure are:

•Systolic: less than 120
•Diastolic: less than 80

Blood pressure is written as systolic/diastolic. For example, a reading of 120/80 is said as "one twenty over eighty." These measures of blood pressure can change with each heartbeat and over the course of the day. Pressure varies with exercise, emotions, sleep, stress, nutrition, drugs, or disease.

Studies have shown that people whose systolic pressure is around 115, rather than 120, have fewer health problems. Clinical trials have shown that people who have blood pressures at the low end of these ranges have much better long term cardiovascular health. Blood pressure is measured with a sphygmomanometer (**Figure** below).

Figure 11.50

A digital sphygmomanometer is made of an inflatable cuff and a pressure meter to measure blood pressure. This reading shows a blood pressure of 126/70.

Hypertension , which is also called "high blood pressure," occurs when a person's blood pressure is always high. Hypertension is said to be present when a person's systolic blood pressure is always 140 or higher, and/or if the person's diastolic blood pressure is always 90 or higher. Having hypertension increases a person's chance for developing heart disease, having a stroke, or suffering from other serious cardiovascular diseases. Hypertension often does not have any symptoms, so a person may not know that he or she has high blood pressure. For this reason, hypertension is often called the "silent killer." Treatments for hypertension include diet changes, exercise, and medication. Foods thought to lower blood pressure include skim milk, spinach, beans, bananas and dark chocolate.

Some health conditions, as well as a person's lifestyle and genetic background, can put someone at a higher risk for developing high blood pressure. As a person cannot alter their genetic background, lifestyle changes may be necessary to reduce the chance of developing high blood pressure. These changes include getting enough exercise, limiting the amount of sodium (salt) in the diet, not being overweight, not drinking alcohol to excess, and not smoking.

Low blood pressure is not usually a concern, as long as there are no problems associated with the low pressure. Symptoms associated with low blood pressure include dizziness or lightheadedness, fainting, dehydration and unusual thirst, lack of concentration, blurred vision, nausea, and fatigue.

Summary

- Blood pressure occurs when circulating blood puts pressure on the walls of blood vessels.
- Hypertension, or high blood pressure, can increase the risk of cardiovascular disease.

Explore More

Use the resource below to answer the questions that follow.

- **Blood Pressure** at http://www.youtube.com/watch?v=luppKLO74vg (1:42)

Click on the image above for more content

1. What causes your pulse?
2. What is systolic pressure?
3. What is diastolic pressure?
4. What does the first sound heard refer to when measuring blood pressure?

Review

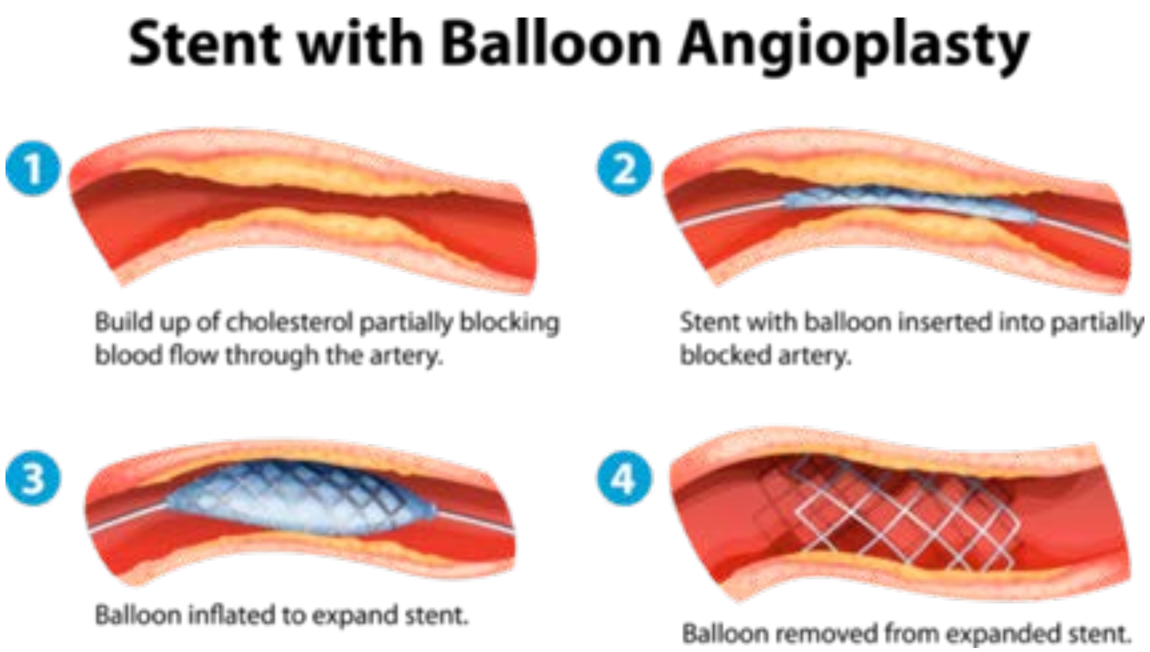
1. What is the healthy range for blood pressure?
2. What is the systolic pressure? What is the diastolic pressure?
3. Why is hypertension sometimes called the "silent killer"?

Section 29

Cardiovascular Diseases

Cardiovascular Diseases

•Describe the various types of cardiovascular disease.
•Define cardiovascular disease.
•Summarize the relationship between plaque, atherosclerosis, and coronary heart disease.
•Describe when a heart attack or stroke may occur.



How do you "fix" arteries?

When a blood vessel gets clogged, there is no medical equivalent of "Drano" that will clear it out. There is, however, a procedure known as angioplasty. A thin tube with a balloon is threaded through the blood vessels. Once in place, the balloon is inflated to compress the clog against the artery wall.

Cardiovascular Diseases

A **cardiovascular disease (CVD)** is any disease that affects the cardiovascular system. But the term is usually used to describe diseases that are linked to atherosclerosis.

Atherosclerosis (**Figure** below) is an inflammation of the walls of arteries that causes swelling and a buildup of material called plaque. **Plaque** is made of cell pieces, fatty substances, calcium, and connective tissue that builds up around the area of inflammation. As a plaque grows, it stiffens and narrows the artery, which decreases the flow of blood through the artery.

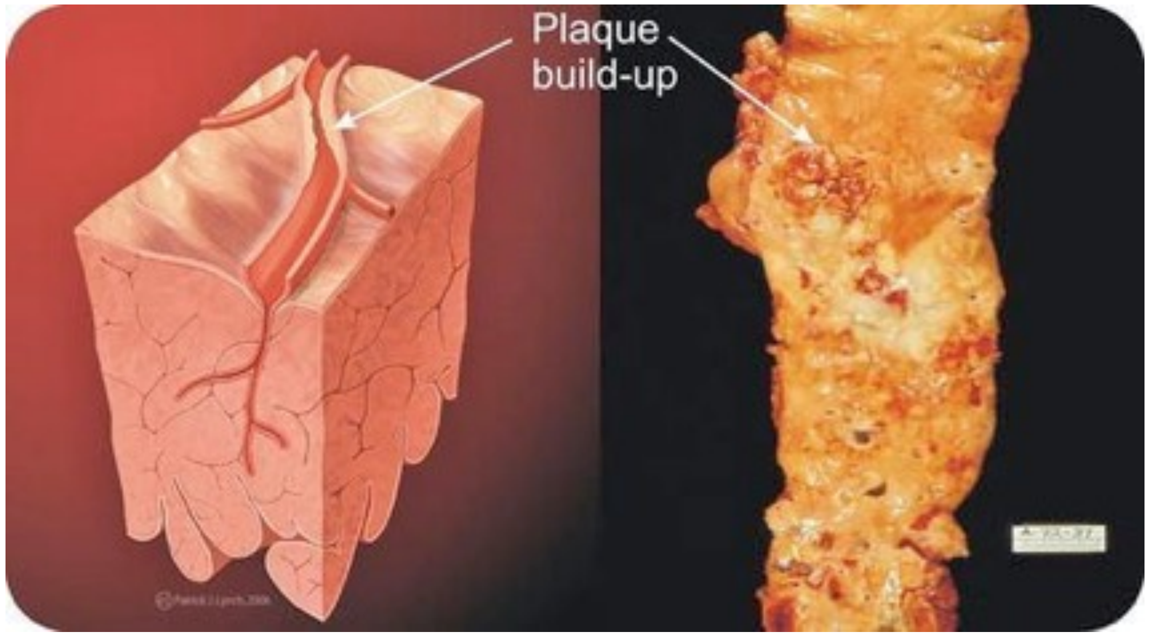


Figure 11.51

Atherosclerosis is sometimes referred to as hardening of the arteries; plaque build-up decreases the blood flow through the artery.

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

Ways to prevent atherosclerosis include eating healthy foods, getting plenty of exercise and not smoking. These three factors are not as hard to control as you may think. If you smoke, STOP. Start a regular exercise program and watch what you eat.

A diet high in saturated fat and cholesterol can raise your cholesterol levels, which makes more plaque available to line artery walls and narrow your arteries. Cholesterol and saturated fats are found mostly in animal products such as meat, eggs, milk, and other dairy products. Check food labels to find the amount of saturated fat in a product. Also, avoid large amounts of salt and sugar. Be careful with processed foods, such as frozen dinners, as they can be high in fat, sugar, salt and cholesterol. Eat lots of fresh or frozen fruits and vegetables, smaller portions of lean meats and fish, and whole grains such as oats and whole wheat. Limit saturated fats like butter, instead choose unsaturated vegetable oils such as canola oil.

Coronary Heart Disease

Like any other muscle, your heart needs oxygen. Hearts have arteries that provide oxygen through the blood. They are known as **coronary arteries** . **Coronary heart disease** is the end result of the buildup of plaque within the walls of the coronary arteries.

Coronary heart disease often does not have any symptoms. A symptom of coronary heart disease is chest pain. Occasional chest pain can happen during times of stress or physical activity. The pain of angina means the heart muscle fibers need more oxygen than they are getting. Most people with coronary heart disease often have no symptoms for many years until they have a heart attack.

A **heart attack** happens when the blood cannot reach the heart because a blood vessel is blocked. If cardiac muscle is starved of oxygen for more than roughly five minutes, it will die. Cardiac muscle cells cannot be replaced, so once they die, they are dead forever. Coronary heart disease is the leading cause of death of adults in the United States. The image below shows the way in which a blocked coronary artery can cause a heart attack and cause part of the heart muscle to die (**Figure** below). Maybe one day stem cells will be used to replace dead cardiac muscle cells.

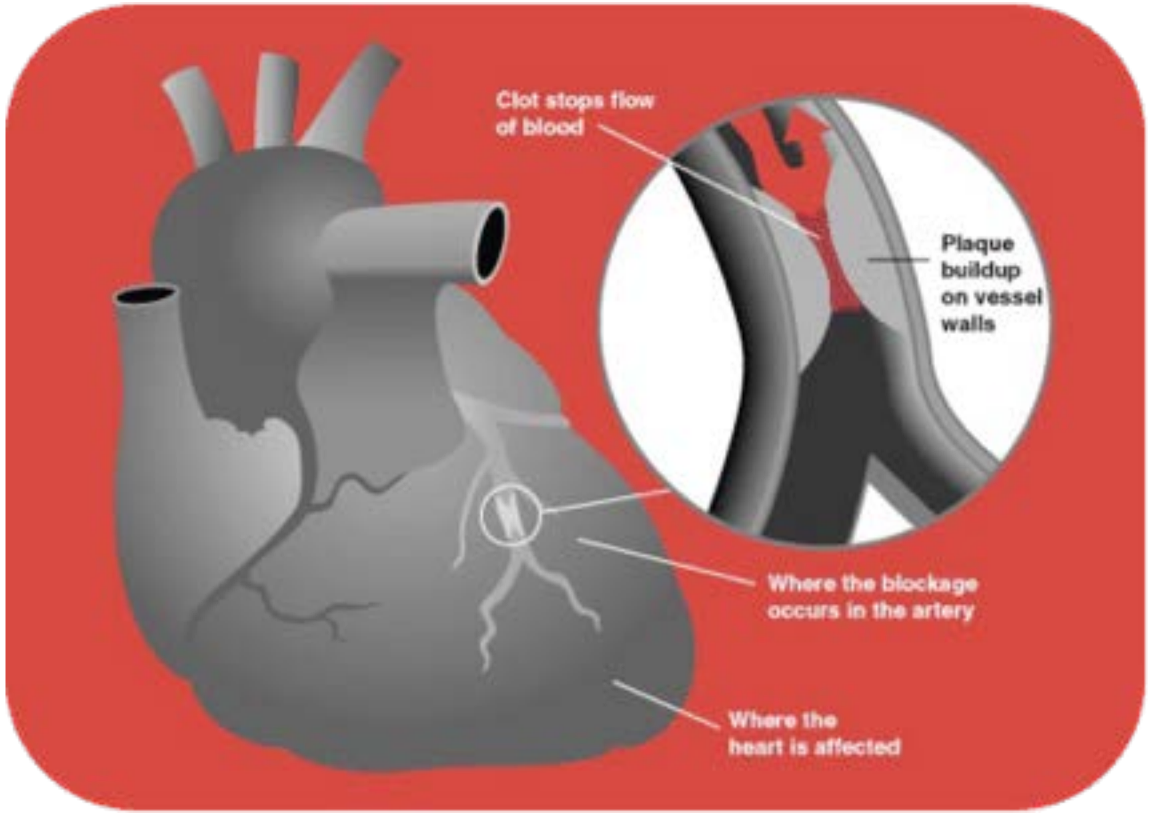


Figure 11.52

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

Stroke

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

Summary

- Atherosclerosis is a condition in which the inside of arteries become clogged with plaque, a deposit of fatty material.
- Atherosclerosis can be dangerous when it prevents blood circulation to the heart or the brain, causing a heart attack or stroke.

Explore More

Use the resource below to answer the questions that follow.

- **Understanding Heart Disease** at http://www.youtube.com/watch?v=3cW8__wFXDA (2:25)

Click on the image above for more content

1. What is coronary artery disease? What happens to someone who has coronary artery disease?
2. What is congestive heart failure? How does this affect your body?

Review

1. What is atherosclerosis?
2. What is the result of plaque growth?

3.How are strokes and heart attacks similar?
4.What are the causes of atherosclerosis?
5.What are three ways to prevent atherosclerosis?

Section 30

Cardiovascular System

Cardiovascular System Health

•Identify things you can do to avoid cardiovascular disease.
•Define risk factor.
•List risk factors for cardiovascular disease you cannot control.
•List controllable risk factors for cardiovascular disease.
•Define LDL and HDL.

Why is smoking bad for you?

Most people associate smoking with lung disease. But that is not the only health risk of smoking. Smoking is also a major cause of cardiovascular disease.

Keeping Your Cardiovascular System Healthy

There are many risk factors that can cause a person to develop cardiovascular disease. A **risk factor** is anything that is linked to an increased chance of developing a disease. Some of the risk factors for cardiovascular disease you cannot control, but there are many risk factors you can control.

Risk factors you cannot control include:

- *Age* : The older a person is, the greater their chance of developing a cardiovascular disease.
- *Gender* : Men under age 64 are much more likely to die of coronary heart disease than women, although the gender difference decreases with age.
- *Genetics* : Family history of cardiovascular disease increases a person's chance of developing heart disease.

Risk factors you can control include many lifestyle factors:

- *Tobacco smoking* : Giving up smoking or never starting to smoke is the best way to reduce the risk of heart disease.
- *Diabetes* : Diabetes can cause bodily changes, such as high cholesterol levels, which are are risk factors for cardiovascular disease.
- *High cholesterol levels* : High amounts of "bad cholesterol," increase the risk of cardiovascular disease.
- *Obesity* : Having a very high percentage of body fat, especially if the fat is mostly found in the upper body, rather than the hips and thighs, increases risk significantly.
- *High blood pressure* : If the heart and blood vessels have to work harder than normal, this puts the cardiovascular system under a strain.
- *Lack of physical activity* : Aerobic activities, such as the one pictured below (**Figure** below), help keep your heart healthy. To reduce the risk of disease, you should be active for at least 60 minutes a day, five days a week.
- *Poor eating habits* : Eating mostly foods that do not have many nutrients other than fat or carbohydrate leads to high cholesterol levels, obesity, and cardiovascular disease (**Figure** below).

Figure 11.53

60 minutes a day of vigorous aerobic activity, such as basketball, is enough to help keep your cardiovascular system healthy.

Figure 11.54

The USDA's MyPyramid recommends that you limit the amount of such foods in your diet to occasional treats.

What is bad cholesterol?

Cholesterol can't dissolve in the blood. It has to be transported to and from the cells by carriers called lipoproteins. Low-density lipoprotein, or LDL, is known as "bad" cholesterol. High-density lipoprotein (HDL) is known as good cholesterol. When too much LDL cholesterol circulates in the blood, it can slowly build up in the inner walls of the arteries that feed the heart and brain. Together with other substances, it can form plaque, and lead to atherosclerosis. If a clot forms and blocks a narrowed artery, a heart attack or stroke can result. Cholesterol comes from the food you eat as well as being made by the body. To lower bad cholesterol, a diet low in saturated fat and dietary cholesterol should be followed. Regular aerobic exercise also lowers LDL cholesterol and increases HDL cholesterol.

Summary

- A family history of cardiovascular disease increases a person's chance of developing heart disease.
- Having a poor diet and not getting enough exercise are two major causes of cardiovascular disease.

Explore More

Use the resource below to answer the questions that follow.

- **Healthy Heart For Life! - Mayo Clinic** at http://www.youtube.com/watch?v=TYGsqqzCMSE (2:10)

Click on the image above for more content

1. How many fruits and vegetables should be eaten daily to keep your heart healthy?
2. How much should you move a day to help prevent heart disease?
3. How much should you sleep a day to help prevent heart disease?
4. How much heart disease is preventable?

Review

1. What is a risk factor?
2. What are three risks factors for cardiovascular disease?
3. What are some steps you can take to avoid cardiovascular disease?
4. What is bad cholesterol?

Section 31

Respiration

Respiration

•Describe how breathing works.
•Define respiration, inhalation, and exhalation.
•Summarize how the lungs allow air in, and how inhaled oxygen enters the bloodstream.

Why do you breathe?

We breathe because we need oxygen. Breathing also releases carbon dioxide from our bodies into the air. The respiratory system is the body system that brings air containing oxygen into the body and releases carbon dioxide into the atmosphere. Recall that oxygen is needed to make ATP.

How We Breathe

Most of the time, you breathe without thinking about it. Breathing is mostly an involuntary action that is controlled by a part of your brain that also controls your heart beat. If you swim, do yoga, or sing, you know you can control your breathing, however. Taking air into the body through the nose and mouth is called **inhalation** . Pushing air out of the body through the nose or mouth is called **exhalation** . The woman pictured below is exhaling before she surfaces from the pool water (**Figure** below).

Figure 11.55

Being able to control breathing is important for many activities, such as swimming. The woman in the photograph is exhaling as she exits the water.

How do lungs allow air in? Air moves into and out of the lungs by the movement of muscles. The most important muscle in the process of breathing is the **diaphragm** , a sheet of muscle that spreads across the bottom of the rib cage. The diaphragm and rib muscles contract and relax to move air into and out of the lungs. During inhalation, the diaphragm contracts and moves downward. The rib muscles contract and cause the ribs to move outward. This causes the chest volume to increase. Because the chest volume is larger, the air pressure inside the lungs is lower than the air pressure outside. This difference in air pressures causes air to be sucked into the lungs. When the diaphragm and rib muscles relax, air is pushed out of the lungs. Exhalation is similar to letting the air out of a balloon.

How does the inhaled oxygen get into the bloodstream? The exchange of gasses between the lungs and the blood happens in tiny sacs called **alveoli** . The walls of the alveoli are very thin and allow gases to pass though them. The alveoli are lined with capillaries (**Figure** below). Oxygen moves from the alveoli to the blood in the capillaries that surround the alveoli. At the same time, carbon dioxide moves in the opposite direction, from capillary blood to the alveoli. The gases move by simple diffusion, passing from an area of high concentration to an area of low concentration. For example, initially there is more oxygen in the alveoli than in the blood, so oxygen moves by diffusion from the alveoli into the blood.

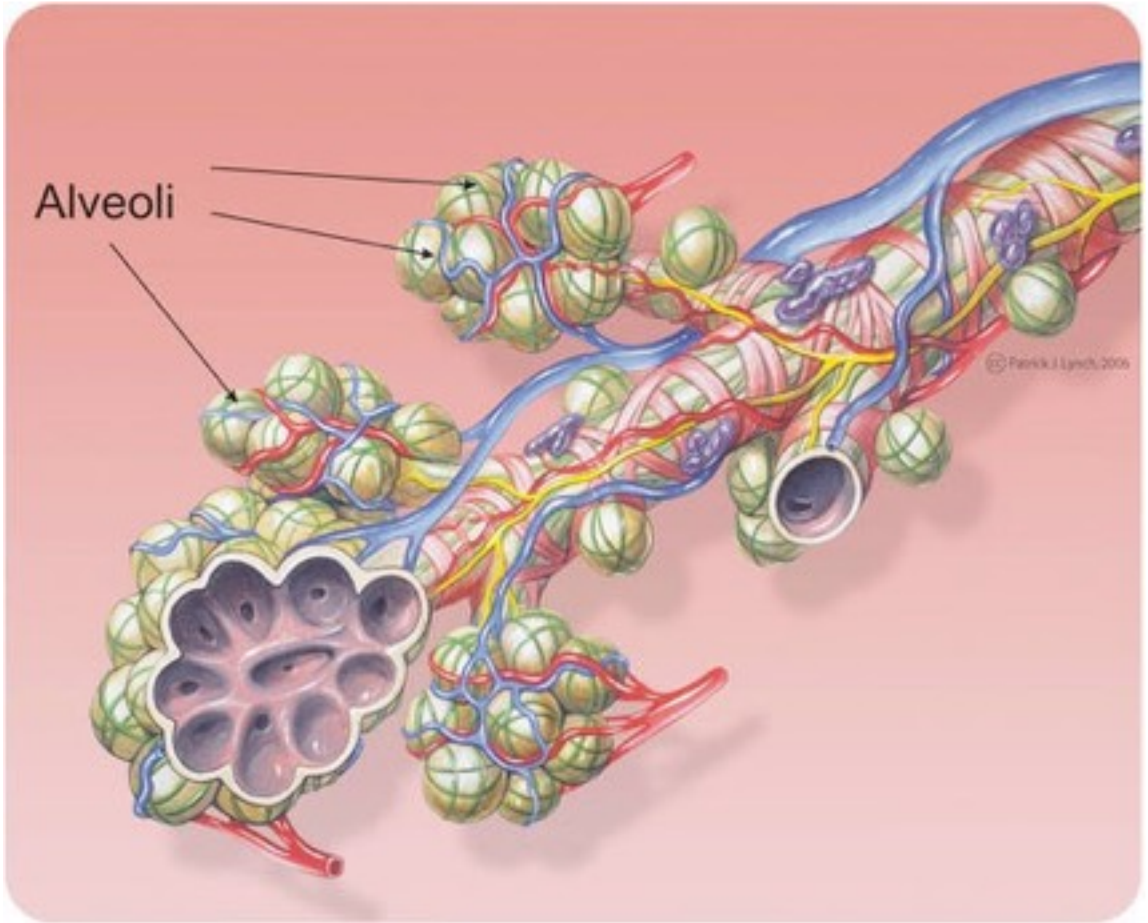


Figure 11.56

During respiration, oxygen gets pulled into the lungs and enters the blood by passing across the thin alveoli membranes and into the capillaries. The alveoli are at the end of the long air passages.

Breathing and Respiration

The process of getting oxygen into the body and releasing carbon dioxide is called **respiration** . Sometimes breathing is called respiration, but there is much more to respiration than just breathing. Breathing is only the movement of oxygen into the body and carbon dioxide out of the body.

The process of respiration also includes the exchange of oxygen and carbon dioxide between the blood and the cells of the body.

Summary

- The diaphragm and rib muscles contract when you inhale and relax when you exhale.
- The process of getting oxygen into the body and releasing carbon dioxide is called respiration.

Explore More

Use the resource below to answer the questions that follow.

- **Respiration-Ventilation** at http://www.youtube.com/watch?v=rzYFgT97tZw (1:44)

Click on the image above for more content

1. What happens to air as it enters the respiratory system? List three things.
2. What happens at the alveolar sacs? How does this occur?
3. What is the function of the epiglottis?

Review

1. In what part of the lung does gas exchange occur?
2. What causes the gases to move in the lungs during gas exchange?
3. What is the difference between breathing and respiration?

Section 32

Respiratory System Organs

Respiratory System Organs

- •Identify the organs of the respiratory system.
- •Summarize the functions of the larynx, pharynx, and trachea.
- •Describe the importance of the alveoli.
- •Explain the structure and function of the diaphragm.

What are the organs that help you breathe?

When you think of the processes of breathing, the lungs probably come to mind. The lungs are the main organ of the respiratory system. However, many other organs are also needed for the process of respiration to take place.

Organs of The Respiratory System

Your respiratory system is made up of the tissues and organs that allow oxygen to enter your body and carbon dioxide to leave your body. Organs in your respiratory system include your:

- •Nose.
- •Mouth.
- •Larynx.
- •Pharynx.
- •Lungs.
- •Diaphragm.

These structures are shown below (**Figure** below).

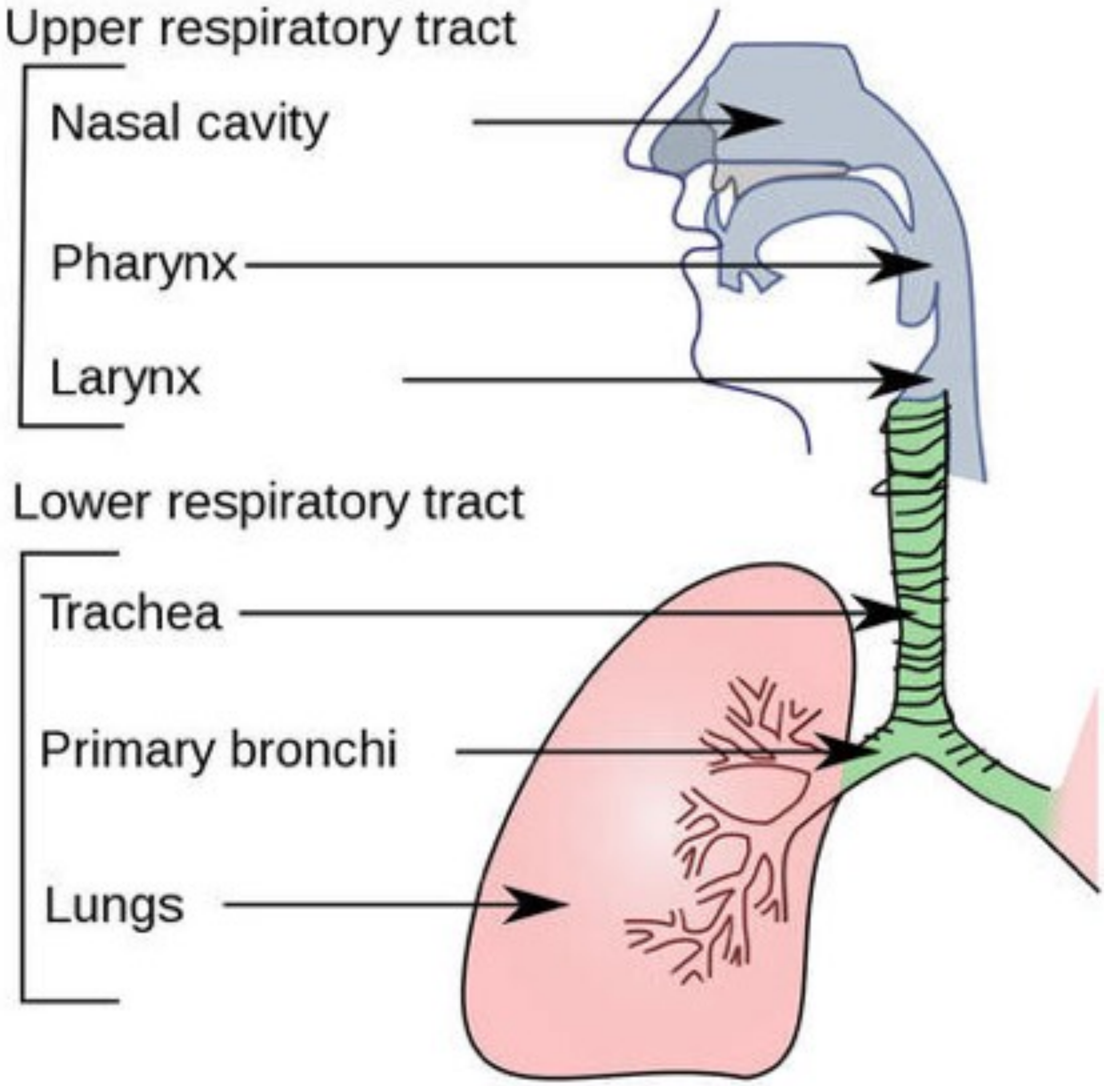


Figure 11.57

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

What do you think is the purpose of each of these organs?

•The nose and the nasal cavity filter, warm, and moisten the air you breathe. The nose hairs and the mucus produced by the cells in the nose catch particles in the air and keep them from entering the lungs.
•Behind the nasal cavity, air passes through the **pharynx** , a long tube. Both food and air pass through the pharynx.
•The **larynx** , also called the "voice box," is found just below the pharynx. Your voice comes from your larynx. Air from the lungs passes across thin tissues in the larynx and produces sound.
•The **trachea** , or windpipe, is a long tube that leads down to the lungs, where it divides into the right and left **bronchi** . The bronchi branch out into smaller bronchioles in each lung. There is small flap called the epiglottis that covers your trachea when you eat or drink. The muscle controlling the epiglottis is involuntary and prevents food from entering your lungs or wind pipe.
•The bronchioles lead to the alveoli. **Alveoli** are the little sacs at the end of the bronchioles (**Figure** below). They look like little bunches of grapes. Oxygen is exchanged for carbon dioxide in the alveoli. That means oxygen enters the blood, and carbon dioxide moves out of the blood. The gases are exchanged between the blood and alveoli by simple diffusion.
•The **diaphragm** is a sheet of muscle that spreads across the bottom of the rib cage. When the diaphragm contracts, the chest volume gets larger, and the lungs take in air. When the diaphragm relaxes,

the chest volume gets smaller, and air is pushed out of the lungs.

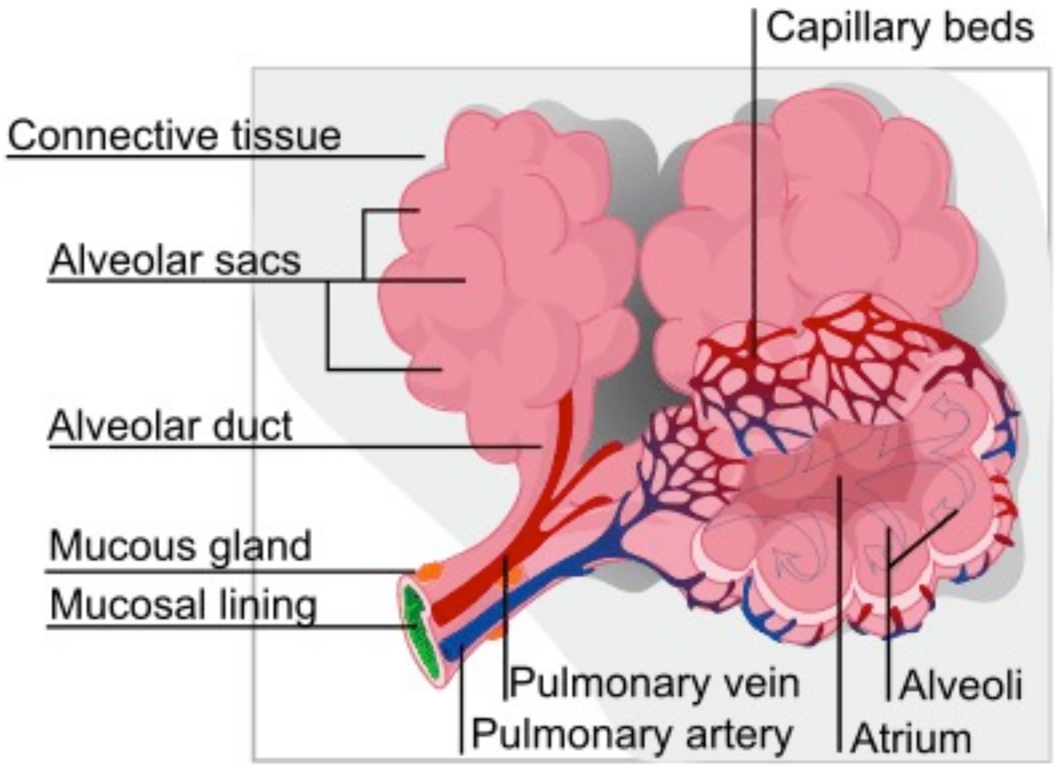


Figure 11.58

"Grape-like" alveoli in the lungs.

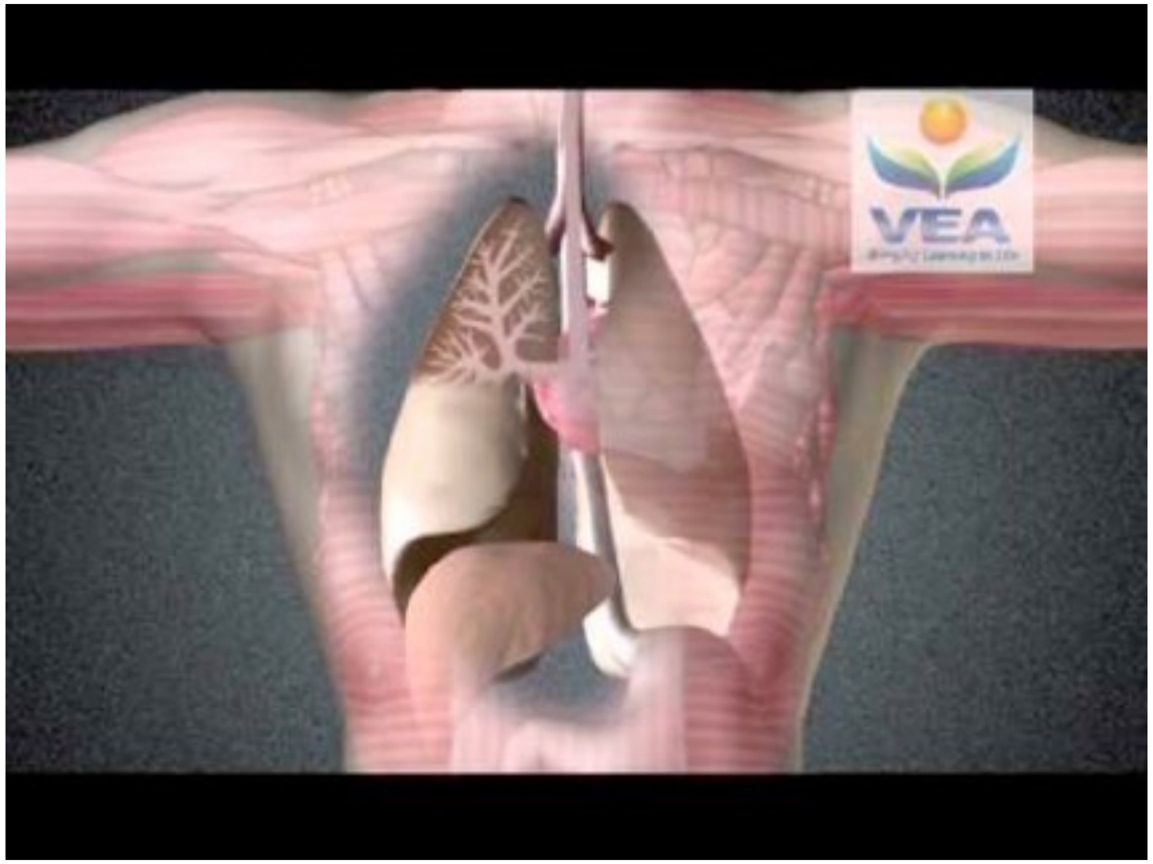
Summary

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

Explore More

Use the resource below to answer the questions that follow.

- **The Respiratory System** at http://www.youtube.com/watch?v=IWXAhe0w_CE (3:09)



Click on the image above for more content

1. Distinguish between inspiration and expiration. What muscle controls these processes?
2. Where is the trachea located and what is its function?
3. What is the relationship between the bronchi, bronchial tubes, and bronchioles? What function does this relationship serve?
4. Why does air funnel into smaller and smaller spaces within the lungs?

Review

1.Name four organs in the respiratory system.
2.What is the trachea? What does the trachea lead into?
3.What organ is known as the voice box?
4.What is the diaphragm? Why is the diaphragm important?

Section 33

Processes of Breathing

Processes of Breathing

•Describe the journey of oxygen through the body.
•Outline how the respiratory system and the cardiovascular system work together.
•Explain the importance of oxygen to each cell of the body.

Where does oxygen go in your body?

Once you take in a breath of air, the oxygen doesn't just stay there in your lungs. It has a lot of traveling to do! Oxygen has to reach each one of your cells. How do you think the oxygen is moved?

The Journey of a Breath of Air

Breathing is only part of the process of bringing oxygen to where it is needed in the body. After oxygen enters the lungs, what happens?

1. The oxygen enters the bloodstream from the **alveoli** , tiny sacs in the lungs where gas exchange takes place (**Figure** below). The transfer of oxygen into the blood is through simple diffusion.
2. The oxygen-rich blood returns to the heart.
3. Oxygen-rich blood is then pumped through the **aorta** , the large artery that receives blood directly from the heart.
4. From the aorta, oxygen-rich blood travels to the smaller arteries and, finally, to the **capillaries** , the smallest type of blood vessel.
5. The oxygen molecules move, by diffusion, out of the capillaries and into the body cells.
6. While oxygen moves from the capillaries and into body cells, carbon dioxide moves from the cells into the capillaries.
7. Carbon dioxide is brought, through the blood, back to the heart and then to the lungs. Then it is released into the air during exhalation.

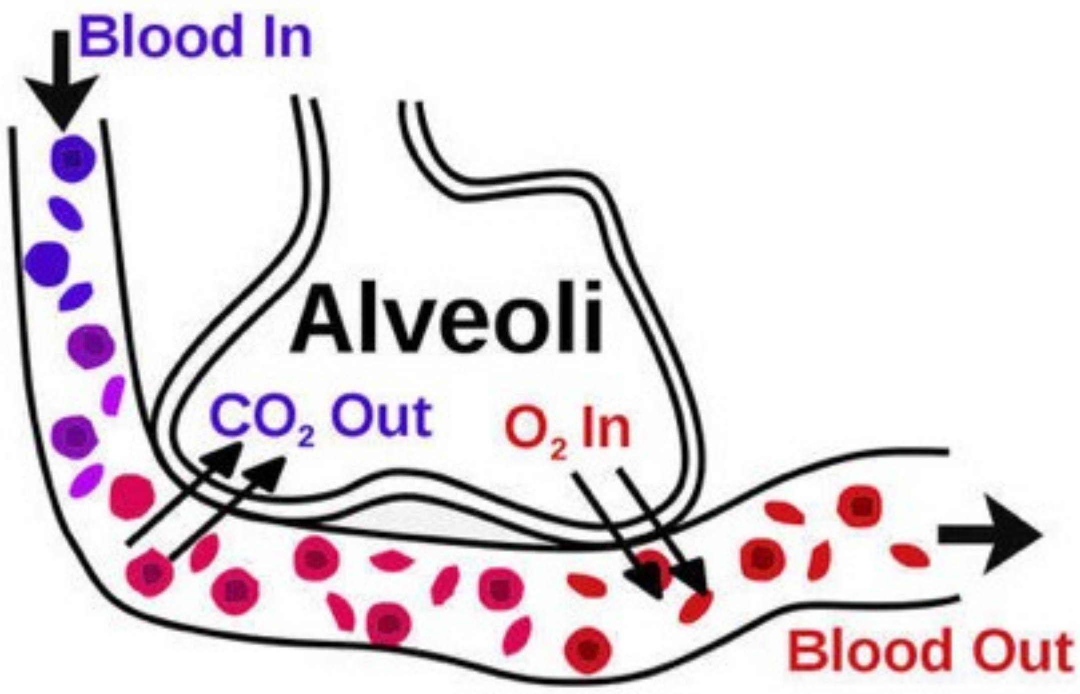


Figure 11.59

Gas exchange is the movement of oxygen into the blood and carbon dioxide out of the blood.

Why is oxygen needed by each cell in your body? To make ATP, the usable form of cellular energy. Oxygen is needed in the final stage of cellular respiration, which is the process of converting glucose into ATP. This process is much more efficient in the presence of oxygen. Without oxygen, much less ATP is produced. As ATP is needed for the cells to function properly, every cell in your body needs oxygen. Getting that oxygen begins with inhaling. The oxygen moves into your blood, where it travels to every cell in your body.

Summary

- •Oxygen enters the lungs, then passes through the alveoli and into the blood. The oxygen is carried around the body in blood vessels.
- •Carbon dioxide moves into the blood capillaries and is brought to the lungs to be released into the air during exhalation.

Explore More

Use the resource below to answer the questions that follow.

- •**Gaseous Exchange** at http://www.youtube.com/watch?v=AyUtdqiOgCA (3:09)

Click on the image above for more content

1. What molecule in blood cells carries oxygen?
2. What causes oxygen to enter the blood? Where does this occur?
3. How does hemoglobin carry oxygen through the blood?
4. How does oxygen enter the tissues of the body?

Review

1. How does oxygen enter the bloodstream?
2. What waste gas that is released during exhalation?
3. From the lungs, where does the oxygen go?
4. Why is oxygen needed by each cell in your body?

Section 34

Respiratory System Dis-

Respiratory System Diseases

•Describe common diseases and conditions affecting the respiratory system.
•List causes of asthma and pneumonia.
•Summarize facts about lung cancer and emphysema.

What's this boy doing?

This inhaler can help ease the symptoms of asthma. This girl may have felt an asthma attack coming on. Tightness in the chest and difficulty breathing are common signs of an asthma attack. She is fortunate that asthma can usually be controlled with medicine.

Diseases of the Respiratory System

Respiratory diseases are diseases of the lungs, bronchial tubes, trachea, nose, and throat (**Figure** below). These diseases can range from a mild cold to a severe case of pneumonia. Respiratory diseases are common. Many are easily treated, while others may cause severe illness or death. Some respiratory diseases are caused by bacteria or viruses, while others are caused by environmental pollutants, such as tobacco smoke. Some diseases are genetic and, therefore, are inherited.

Figure 11.60

This boy is suffering from whooping cough (also known as pertussis), which gets its name from the loud whooping sound that is made when the person inhales during a coughing fit.

Bronchitis

Bronchitis is an inflammation of the bronchi, the air passages that conduct air into the lungs. The bronchi become red and swollen with infection. Acute bronchitis is usually caused by viruses or bacteria, and may last several days or weeks. It is characterized by a cough that produces phlegm, or mucus. Symptoms include shortness of breath and wheezing. Acute bronchitis is usually treated with antibiotics.

Asthma

Asthma is a chronic illness in which the bronchioles, the tiny branches into which the bronchi are divided, become inflamed and narrow (**Figure** below). The muscles around the bronchioles contract, which narrows the airways. Large amounts of mucus are also made by the cells in the lungs. People with asthma have difficulty breathing. Their chests feel tight, and they wheeze. Asthma can be caused by different things, such as allergies. Asthma can also be caused by cold air, warm air, moist air, exercise, or stress. The most common asthma triggers are illnesses, like the common cold. Asthma is not contagious and cannot be passed on to other people. Children and adolescents who have asthma can still lead active lives if they control their asthma. Asthma can be controlled by taking medication and by avoiding contact with environmental triggers for asthma, like smoking.

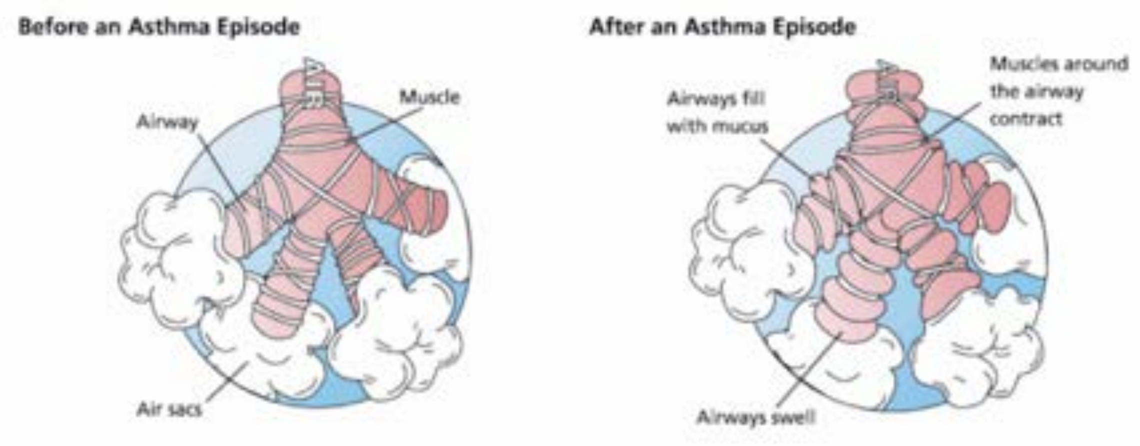


Figure 11.61

Asthma occurs when the bronchioles swell and the muscles around the bronchioles contract.

Pneumonia

Pneumonia is an illness that occurs when the alveoli, the tiny sacs in the lungs where gas exchange takes place, become inflamed and filled with fluid. When a person has pneumonia, gas exchange cannot occur properly across the alveoli. Pneumonia can be caused by many things. Infection by bacteria, viruses, fungi, or parasites can cause pneumonia. An injury caused by chemicals or a physical injury to the lungs can also cause pneumonia. Symptoms of pneumonia include cough, chest pain, fever, and difficulty breathing. Treatment depends on the cause of pneumonia. Bacterial pneumonia is treated with antibiotics.

Pneumonia is a common illness that affects people in all age groups. It is a leading cause of death among the elderly and people who are chronically and terminally ill.

Tuberculosis

Tuberculosis (TB) is a common and often deadly disease caused by a genus of bacterium called *Mycobacterium* . Tuberculosis most commonly attacks the lungs but can also affect other parts of the body. TB is a chronic disease, but most people who become infected do not develop the full disease. Symptoms include a cough, which usually contains mucus and coughing up blood.

The TB bacteria are spread in the air when people who have the disease cough, sneeze, or spit, so it is very contagious. To help prevent the spread of the disease, public health notices, such as the one pictured below (**Figure** below), remind people how to stop the spread of the disease.

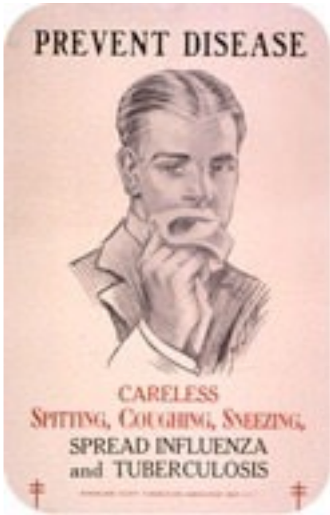


Figure 11.62

A public health notice from the early 20th century reminded people that TB could be spread very easily.

Lung Cancer

Lung cancer is a disease in which the cells found in the lungs grow out of control. The growing mass of cells can form a tumor that pushes into nearby tissues. The tumor will affect how these tissues work. Lung cancer is the most common cause of cancer-related death in men, and the second most common in women. It is responsible for 1.3 million deaths worldwide every year (**Figure** below). The most common symptoms are shortness of breath, coughing (including coughing up blood), and weight loss. The most common cause of lung cancer is exposure to tobacco smoke.

Figure 11.63

The inside of a lung showing cancerous tissue.

Emphysema

Emphysema is a chronic lung disease caused by the breakdown of the lung tissue. Symptoms of emphysema include shortness of breath, especially during exercise, and chronic cough, usually due to cigarette smoking, and wheezing, especially during expiration. Damage to the alveoli (**Figure** below), is not curable. Smoking is the leading cause of emphysema.

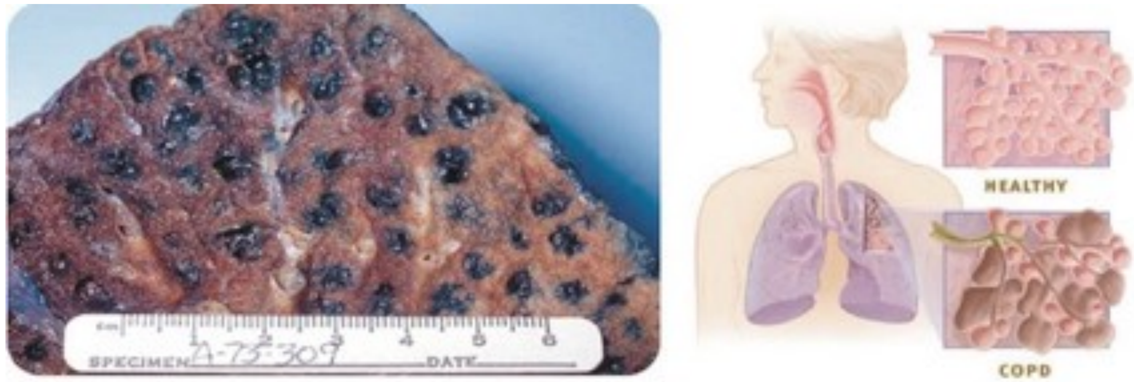


Figure 11.64

The lung of a smoker who had emphysema (left). Tar, a sticky, black substance found in tobacco smoke, is evident. Chronic obstructive pulmonary disease (right), is a tobacco-related disease that is characterized by emphysema.

Causes of Respiratory Diseases

Many respiratory diseases are caused by pathogens. A **pathogen** is an organism that causes disease in another organism. Certain bacteria, viruses, and fungi are pathogens of the respiratory system. The common cold and flu are caused by viruses. The influenza virus that causes the flu is pictured below (**Figure** below). Tuberculosis, whooping cough, and acute bronchitis are caused by bacteria. The pathogens that cause colds, flu, and TB can be passed from person to person by coughing, sneezing, and spitting. Illnesses caused by bacteria can be treated with antibiotics. Those caused by viruses cannot.

Figure 11.65

This represents the influenza virus that causes the swine flu, or H1N1. The Center for Disease Control and Prevention recommends that children between the ages of 6 months and 19 years get a flu vaccination each year.

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

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

Summary

- Common diseases and conditions affecting the respiratory system include asthma, bronchitis, lung cancer, tuberculosis, and emphysema.
- Pollution, smoking, and pathogens can also contribute to diseases of the respiratory system.

Explore More

Use the resource below to answer the questions that follow.

- **Respiratory Diseases** at http://www.youtube.com/watch?v=kcZO7h-NROo (1:30)

Click on the image above for more content

1. What is acute bronchitis? What causes acute bronchitis?
2. What is pneumonia? What is the effect of pneumonia on the body? What can cause this condition?
3. What can viral infections of the upper respiratory tract make you susceptible to?

4. Infections of the respiratory system can cause a decrease in the bodies ability to obtain oxygen. What effects can this have on other areas of the body?

Review

1. What parts of the body can be affected by respiratory system diseases?
2. How does asthma affect the lungs?
3. What is the most common cause of lung cancer?
4. Identify two things besides smoking that can cause a respiratory disease.

Section 35

Respiratory System Health

Respiratory System Health

•Identify what you can do to keep your respiratory system healthy.

Why sneeze into your elbow?

Sneezing into your elbow can help stop the spread of a respiratory illness, like the flu or common cold. If you sneeze into your hands, you may then spread germs when you touch a doorknob or other surfaces.

Keeping Your Respiratory System Healthy

We know that many respiratory illnesses are caused by bacteria or viruses. There are steps you can take to help the spread of these pathogens, and also to prevent you from catching one. Furthermore, many respiratory illnesses are caused by poor habits, such as smoking. Many of the diseases related to smoking are called **lifestyle diseases** . Lifestyle diseases are diseases that are caused by choices that people make in their daily lives. For example, the choice to smoke can lead to emphysema, cancer and heart disease in later life. But you can make healthy choices instead. There are many things you can do to keep yourself healthy.

Avoid Smoking

Cigarette smoking can cause serious diseases, so not smoking or quitting now are the most effective ways to reduce your risk of developing chronic respiratory diseases, such as lung cancer. Avoiding (or stopping) smoking is the single best way to prevent many respiratory and cardiovascular diseases. Also, do your best to avoid secondhand smoke.

Eat Well, Exercise Regularly, and Get Rest

Eating healthy foods, getting enough sleep, and being active every day can help keep your respiratory system, cardiovascular system and immune system strong. Getting enough exercise makes your lungs stronger and better at giving your body the oxygen it needs. It also helps to boost your body fight germs that could make you sick. These can also, of course, keep your skeletal and muscular systems strong.

Wash Your Hands

Washing your hands often, especially after sneezing, coughing, or blowing your nose, helps to protect you and others from diseases. Washing your hands for 20 seconds with soap and warm water can help prevent colds and flu. In one respect, you can think of hand washing as a survival skill. Some viruses and bacteria can live from 20 minutes to two hours or more on surfaces like cafeteria tables, doorknobs, and desks. Washing your hands often can remove many of these pathogens. Never touch your mouth, nose, or eyes without washing your hands.

Avoid Contact with Others When Sick

Do not go to school or to other public places when you are sick. You risk spreading your illness to other people. You may also get even sicker if you catch something else. Do not share food and other things that go in the mouth, as in guzzling milk from the carton or double dipping chips. You never know what pathogens can be lurking around. Cover your mouth with a tissue when you cough or sneeze and to dispose of the tissue yourself. No time to grab a tissue. Cough or sneeze into the inside of your elbow instead of your hands.

Visit Your Doctor

Getting the recommended vaccinations can help prevent diseases, such as whooping cough and flu. In fact, a yearly flu vaccine is recommended for everyone who is at least 6 months of age. The flu vaccine is especially important for people who are at high risk of developing serious complications (like pneumonia) if they get sick with the flu. People who have certain medical conditions including asthma, diabetes, and chronic lung disease, pregnant women, and people younger than 5 years (and especially those younger than 2), and people 65 years and older should also make sure they get the yearly flu vaccine.

Seeking medical help for diseases like asthma can help stop the disease from getting worse. If you are unsure if you should go to the doctor, call the doctor's office and ask.

Summary

- Avoid smoking, get enough exercise, and wash your hands to protect your respiratory system from illness.
- Getting the recommended vaccinations can help prevent diseases, such as whooping cough and flu.

Explore More

Use the resources below to answer the questions that follow.

Explore More I

- **The Genetics of Lung Health and Lung Disease** at http://www.youtube.com/watch?v=Pc8oWAzi1FI (2:57)

Click on the image above for more content

1. Why are scientists studying the genetics of lung disease?
2. What do scientists hope will come out of this research?
3. How many areas of the genome have scientists found that are associated with COPD?
4. Are these scientists engaged in basic or applied research? Explain your reasoning fully.

Explore More II

- **Smog and Health Effects** at http://www.youtube.com/watch?v=ROf4PeRlJsM (2:31)

Click on the image above for more content

1. How many days a year does Los Angeles have unhealthy air?
2. What are the potential health effects of this air? Who is most at risk? Why do you think risk is higher for these groups?
3. What are you supposed to do on days of unhealthy air?

Review

1. What are lifestyle diseases.
2. What is the relationship between smoking and lifestyle diseases?

3.What are two things you can do to keep your respiratory system healthy?
4.Explain how washing your hands can help you prevent catching a cold.

Section 36

Excretion

Excretion

•Define excretion.
•List organs of the excretory system.
•Identify the functions of the excretory system.

What happens to your body's waste?

There is no space for a landfill in your body to contain wastes. You must be able to expel wastes from your body. This is the role of the excretory system.

Excretion

So what happens to your body's wastes? Obviously, you must get rid of them. This is the job of the excretory system. You remove waste as a gas (carbon dioxide), as a liquid (urine and sweat), and as a solid. **Excretion** is the process of removing wastes and excess water from the body.

Recall that carbon dioxide travels through the blood and is transferred to the lungs where it is exhaled. In the large intestine, the remains of food are turned into solid waste for excretion. How is waste other than carbon dioxide removed from the blood? That is the role of the kidneys.

Urine is a liquid waste formed by the kidneys as they filter the blood. If you are getting plenty of fluids, your urine should be almost clear. But you might have noticed that sometimes your urine is darker than usual. Do you know why this happens? Sometimes your body is low on water and trying to reduce the amount of water lost in urine. Therefore, your urine gets darker than usual. Your body is striving to maintain **homeostasis** through the process of excretion.

Urine helps remove excess water, salts, and nitrogen from your body. Your body also needs to remove the wastes that build up from cell activity and from digestion. If these wastes are not removed, your cells can stop working, and you can get very sick. The organs of your **excretory system** help to release wastes from the body.

The organs of the excretory system are also parts of other organ systems. For example, your lungs are part of the respiratory system. Your lungs remove carbon dioxide from your body, so they are also part of the excretory system. More organs of the excretory system are listed below (**Table** below).

Organ(s)	Function	Component of Other Organ System
Lungs	Remove carbon dioxide.	Respiratory system
Skin	Sweat glands remove water, salts, and other wastes.	Integumentary system
Large intestine	Removes solid waste and some water in the form of feces.	Digestive system
Kidneys	Remove urea, salts, and excess water from the blood.	Urinary system

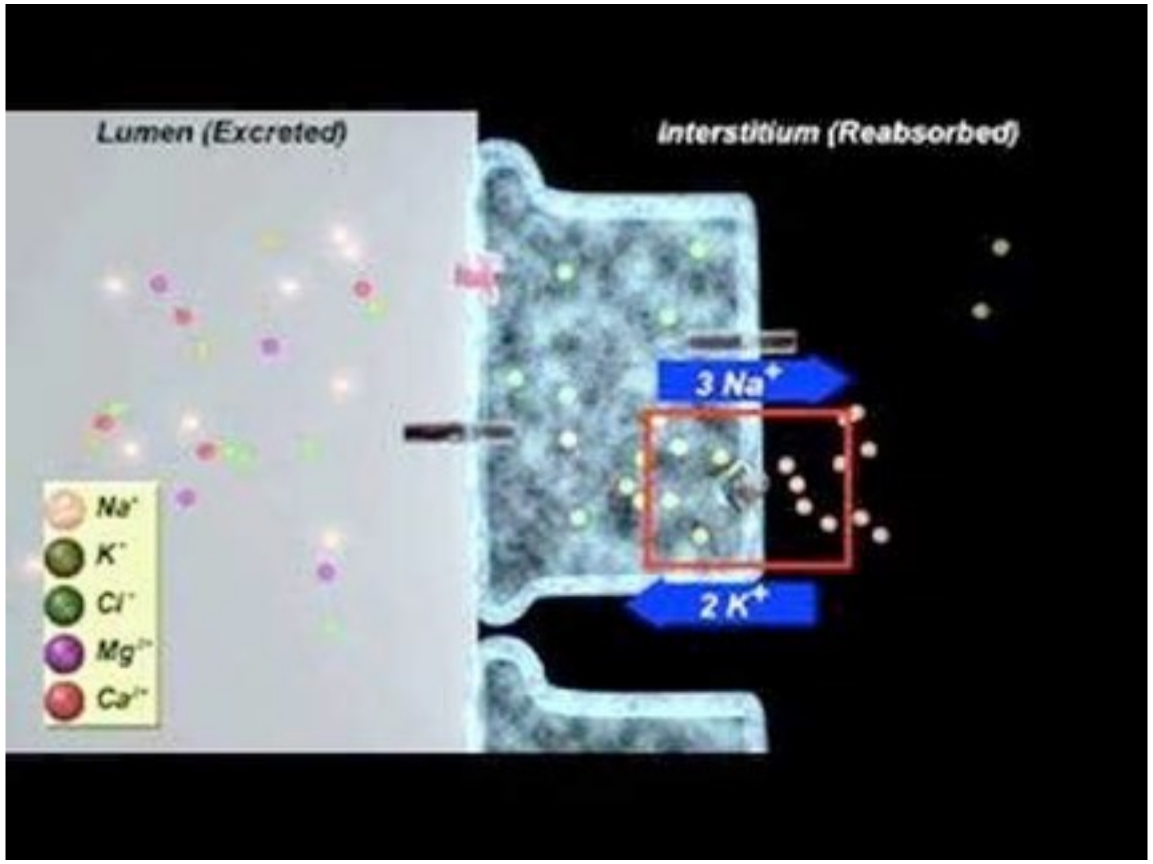
Summary

- Excretion is the process of removing wastes from the body.
- Organs of the excretory system include the kidneys, large intestine, skin, and lungs.

Explore More

Use the resource below to answer the questions that follow.

- **Excretion** at http://www.youtube.com/watch?v=DNJosKX_PmA (8:47)



Click on the image above for more content

1. What is filtered and excreted in the nephron?
2. What two mechanisms govern filtration in the glomerulus?
3. What is the name of the first section of the nephron?
4. What ions are removed from the blood?

Review

1. What is excretion?
2. List four organs involved in excretion.
3. How is the large intestine involved in excretion.
4. What does urine remove from your body?

Section 37

Urinary System

Urinary System

- •Describe the role of the urinary system.
- •List the parts of urinary system.
- •Explain the role of the kidneys.
- •Describe urine.

Why is urine important?

You might have had to give a urine sample when you've gone to the doctor for a check-up. Urine is basically your liquid waste. The contents of your urine can tell the doctor if you have certain illnesses.

The Urinary System

Sometimes, the urinary system (**Figure** below) is called the excretory system. But the urinary system is only one part of the excretory system. Recall that the excretory system is also made up of the skin, lungs, and large intestine, as well as the kidneys. The **urinary system** is the organ system that makes, stores, and gets rid of urine.

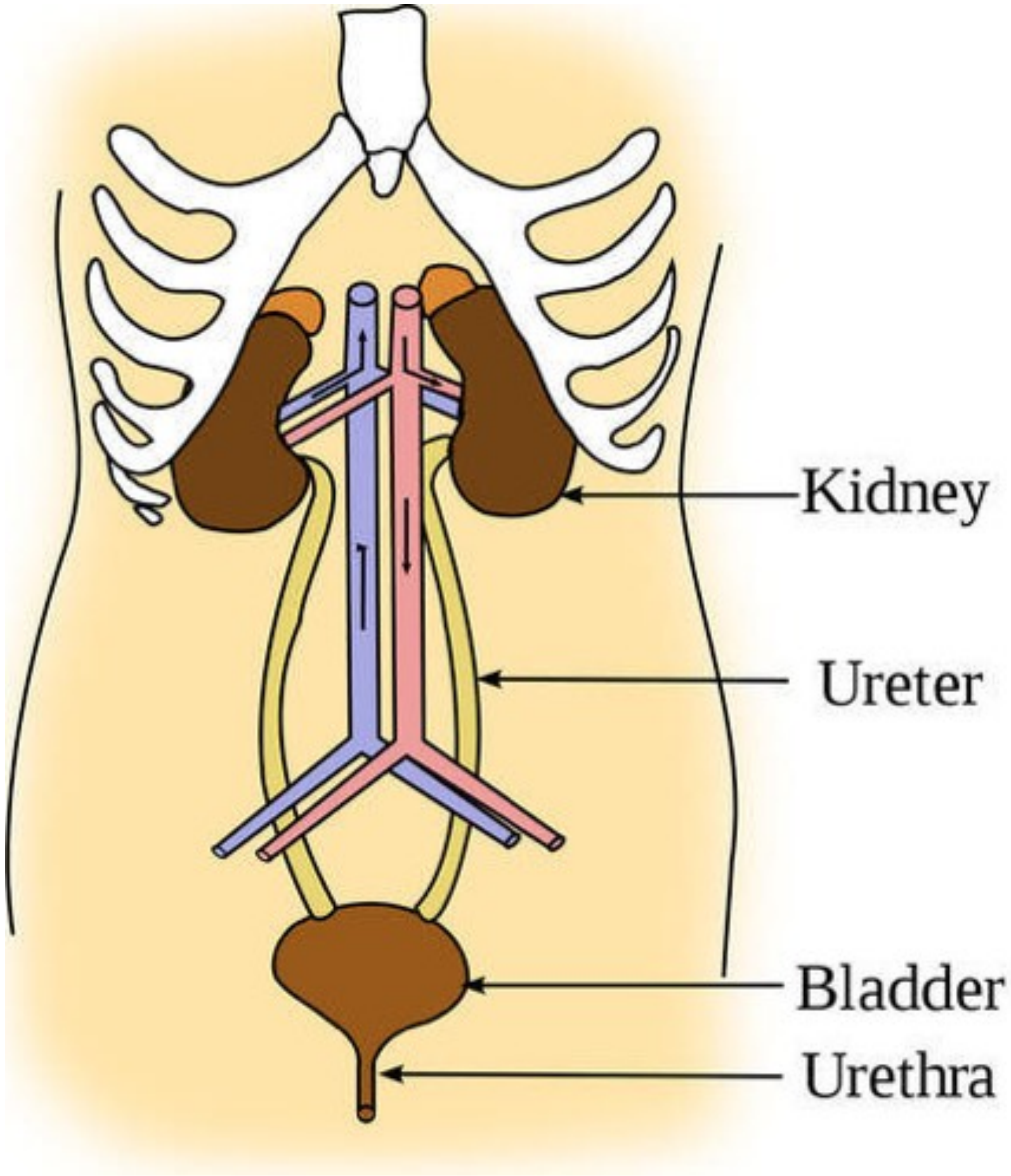


Figure 11.66

The kidneys filter the blood that passes through them, and the urinary bladder stores the urine until it is released from the body.

Organs of the Urinary System

1.As you can see above (**Figure** above), the kidneys are two bean-shaped organs. **Kidneys** filter and clean the blood and form urine. They are about the size of your fists and are found near the middle of the back, just below your ribcage.
2.**Ureters** are tube-shaped and bring urine from the kidneys to the urinary bladder.
3.The **urinary bladder** is a hollow and muscular organ. It is shaped a little like a balloon. It is the organ that collects urine.
4.Urine leaves the body through the **urethra** .

What is Urine?

Urine is a liquid that is formed by the kidneys when they filter wastes from the blood. Urine contains mostly water, but it also contains salts and nitrogen-containing molecules. The amount of urine released from the body depends on many things. Some of these include the amount of fluid and food a person consumes and how much fluid they have lost from sweating and breathing. Urine ranges from colorless to dark yellow but is usually a pale yellow color. Light yellow urine contains mostly water. The darker the urine, the less water it contains.

The urinary system also removes a type of waste called **urea** from your blood. Urea is a nitrogen-containing molecule that is made when foods containing protein, such as meat, poultry, and certain vegetables, are broken down in the body. Urea and other wastes are carried in the bloodstream to the kidneys, where they are removed and form urine.

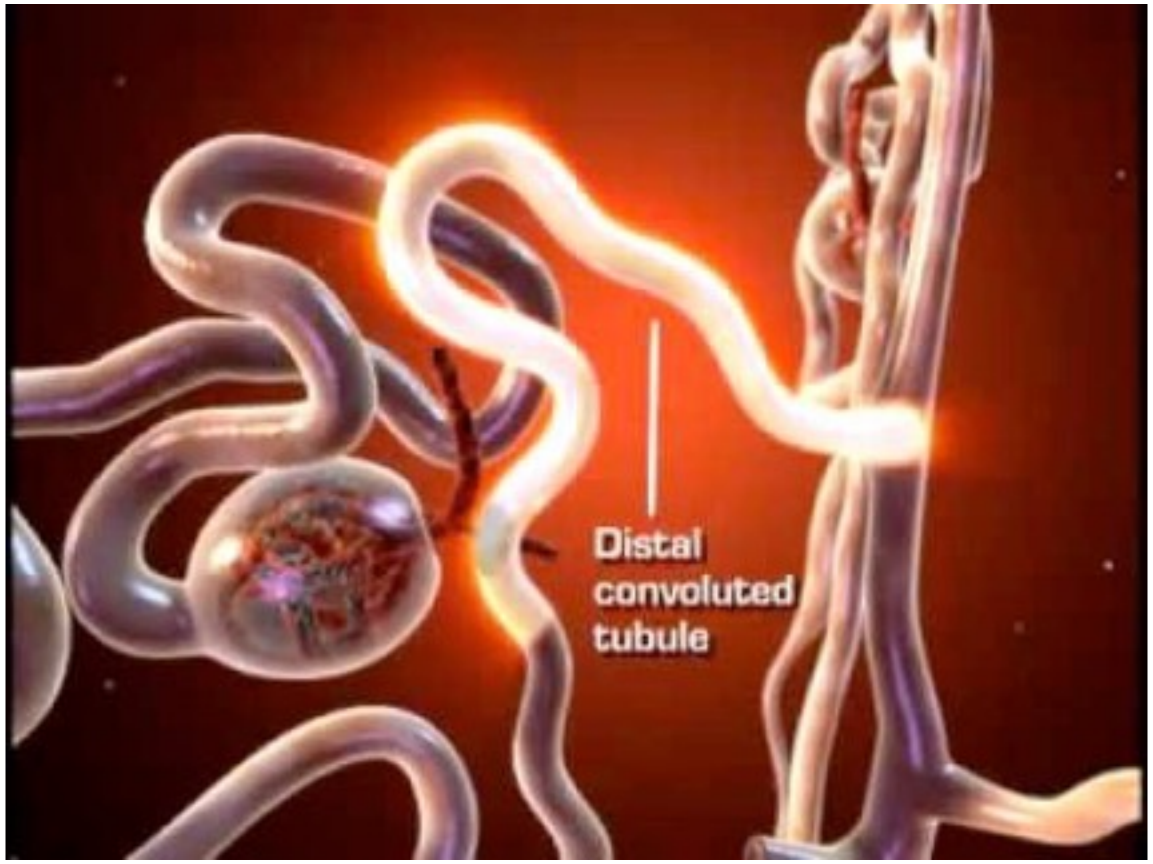
Summary

- The urinary system is made up of the kidneys, the ureters, the bladder, and the urethra.
- Urine is the liquid that is formed by the kidneys when they filter wastes from the blood. Urine contains water, salts, and nitrogen-containing molecules.

Explore More

Use the resource below to answer the questions that follow.

- **The Nephron** at http://www.youtube.com/watch?v=hiNEShg6JTI (5:46)



Click on the image above for more content

1. What are three components of the renal system? Which part of this system is the main excretory organ of the body?
2. What are three functions of the kidney?
3. What capsule surrounds the glomerulus? How many of the capsules are found in the entire kidney?

Review

1. What is the urinary system?
2. What is the main organ of the urinary system? What is the function of this organ?

3.What is the difference between the urinary system and the excretory system?
4.What is the purpose of the urinary bladder?

Section 38

Kidneys

Kidneys

•List the roles of the kidneys.
•Outline how the kidneys filter blood.
•Summarize the process of urine formation.
•Explain how urination is controlled.

Why are the kidneys important?

These kidney beans are named after a very important organ in your body. Though you probably can live without these beans, you can't live without at least one kidney. The kidneys have several essential functions. For example, kidneys filter your blood, removing wastes and regulating the amount of water in your body.

The Kidneys

The kidneys (**Figure** below) are important organs in maintaining **homeostasis** , the ability of the body to maintain a stable internal environment despite a changing environment. Kidneys perform a number of homeostatic functions.

•They maintain the volume of body fluids.
•They maintain the balance of salt ions in body fluids.
•They excrete harmful nitrogen-containing molecules, such as urea, ammonia, and uric acid.

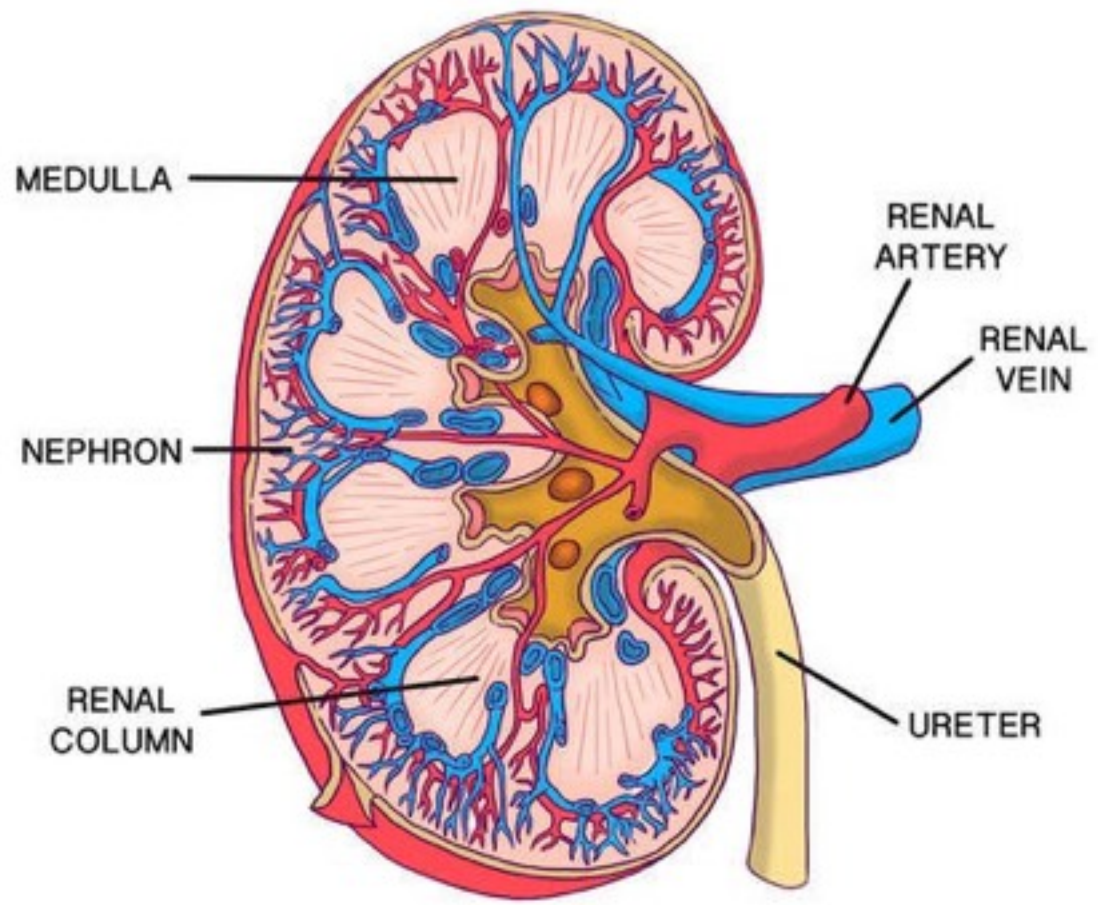


Figure 11.67

Structures of the kidney; fluid leaks from the capillaries and into the nephrons where the fluid forms urine then moves to the ureter and on to the bladder.

There are many blood vessels in the kidneys (**Figure** above). The kidneys remove urea and other wastes from the blood through tiny filtering units called nephrons. **Nephrons** (**Figure** below) are tiny, tube-shaped structures found inside each kidney. Each kidney has up to a million nephrons. Each nephron collects a small amount of fluid and waste from a small group of capillaries.

Nitrogen-containing wastes, together with water and other wastes, form the **urine** as it passes through the nephrons and the kidney. The fluid within nephrons is carried out into a larger tube in the kidney called a **ureter** , which carries it to the bladder (**Figure** below).

The kidneys never stop filtering waste products from the blood, so they are always producing urine. The amount of urine your kidneys produce is dependent on the amount of fluid in your body. Your body loses water through sweating, breathing, and urination. The water and other fluids you drink every day help to replace the lost water. This water ends up circulating in the blood because blood plasma is mostly water.

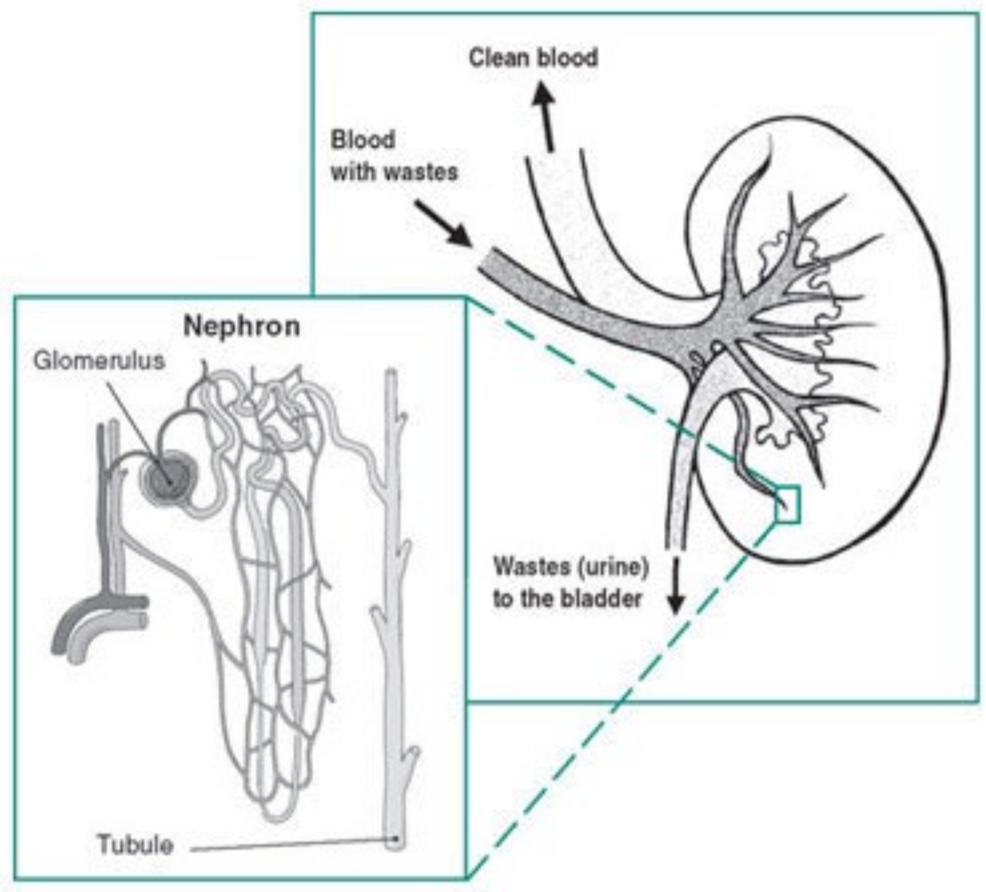


Figure 11.68

The location of nephrons in the kidney. The fluid collects in the nephron tubules and moves to the bladder through the ureter.

Formation of Urine

The process of urine formation is as follows:

1. Blood flows into the kidney through the renal artery. The renal artery connects to capillaries inside the kidney. Capillaries and nephrons lie very close to each other in the kidney.
2. The blood pressure within the capillaries causes water, salts, sugars, and urea to leave the capillaries and move into the nephron.
3. The water and salts move along through the tube-shaped nephron to a lower part of the nephron.
4. The fluid that remains in the nephron at this point is called urine.
5. The blood that leaves the kidney in the renal vein has much less waste than the blood that entered the kidney.
6. The urine is collected in the ureters and is moved to the urinary bladder, where it is stored.

Nephrons filter about ¼ cup of body fluid per minute. In a 24-hour period, nephrons filter 180 liters of fluid, and 1.5 liters of the fluid is released as urine. Urine enters the bladder through the ureters. Similar to a balloon, the walls of the bladder are stretchy. The stretchy walls allow the bladder to hold a large amount of urine. The bladder can hold about 1½ to 2½ cups of urine but may also hold more if the urine cannot be released immediately.

How do you know when you have to urinate? **Urination** is the process of releasing urine from the body. Urine leaves the body through the urethra. Nerves in the bladder tell you when it is time to urinate. As the bladder first fills with urine, you may notice a feeling that you need to urinate. The urge to urinate becomes stronger as the bladder continues to fill up.

Brain Control of Urination

The filtering action of the kidneys is controlled by the **pituitary gland** . The pituitary gland is about the size of a pea and is found below the brain (**Figure** below). The pituitary gland releases hormones that help the kidneys to filter water from the blood.

The movement of water back into blood is controlled by a hormone called **antidiuretic hormone** (ADH). ADH is one of the hormones released from the pituitary gland in the brain. One of the most important roles of ADH is to control the body's ability to hold onto water. If a person does not drink enough water, ADH is released. It causes the blood to reabsorb water from the kidneys. If the kidneys remove less water from the blood, what will the urine look like? It will look darker, because there is less water in it.

When a person drinks a lot of water, then there will be a lot of water in the blood. The pituitary gland will then release a lower amount of ADH into the blood. This means less water will be reabsorbed by the blood. The kidneys then produce a large volume of urine. What color will this urine be?

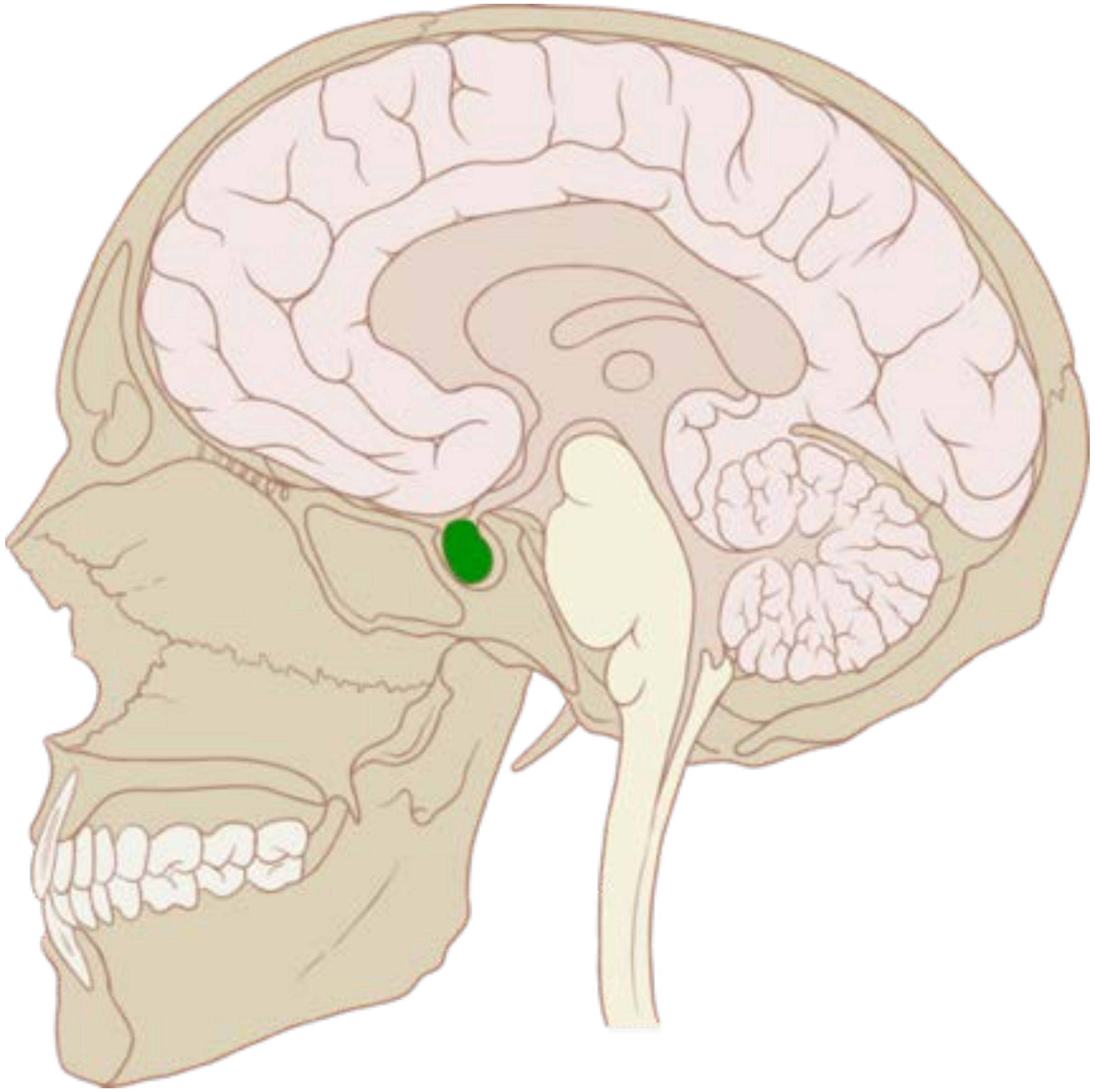


Figure 11.69

The pituitary gland (green) is found directly below the brain and releases hormones that control how urine is produced.

Summary

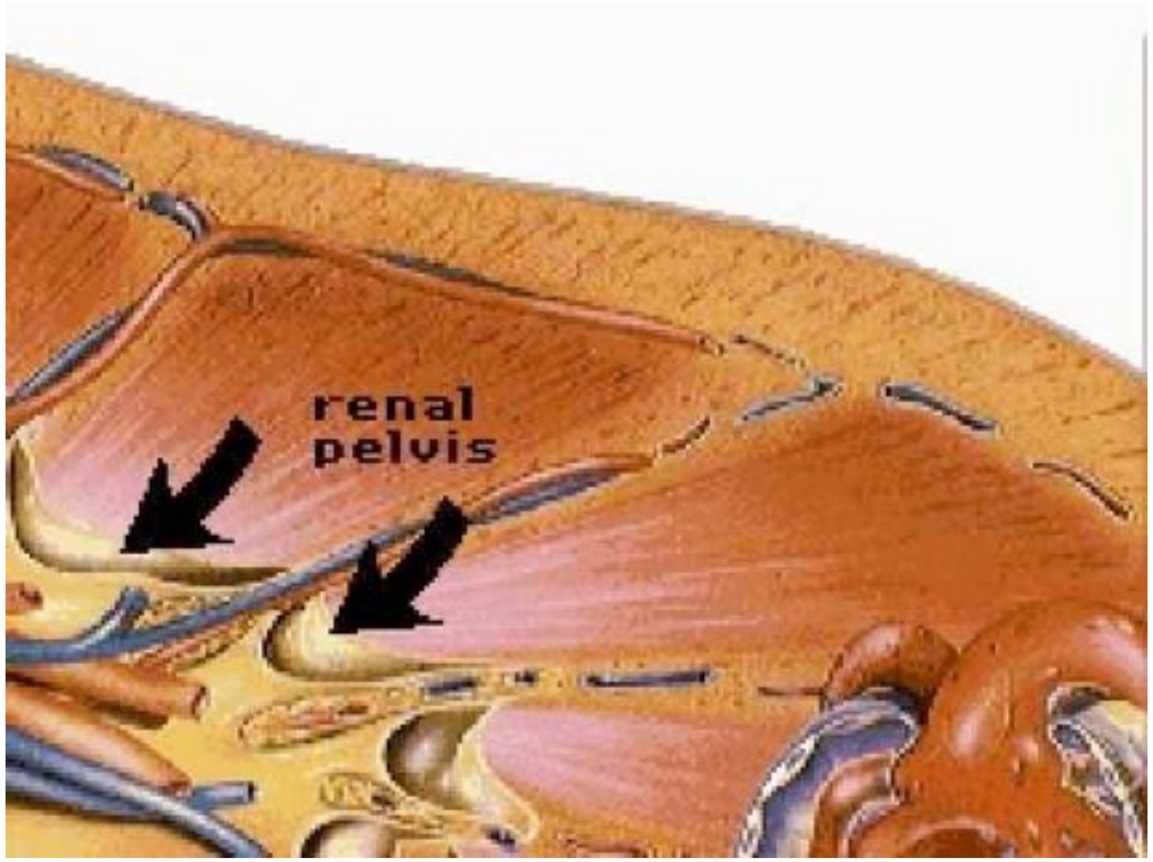
- Water and waste molecules move out of the blood capillaries and into the nephrons of the kidney to form the urine.
- ADH is the hormone released by the pituitary gland and controls how water is reabsorbed by the blood from the kidneys.

Explore More

Use the resources below to answer the questions that follow.

Explore More I

- **Anatomy of a Kidney** at http://www.youtube.com/watch?v=Pz5DHAv_Mw4 (1:46)

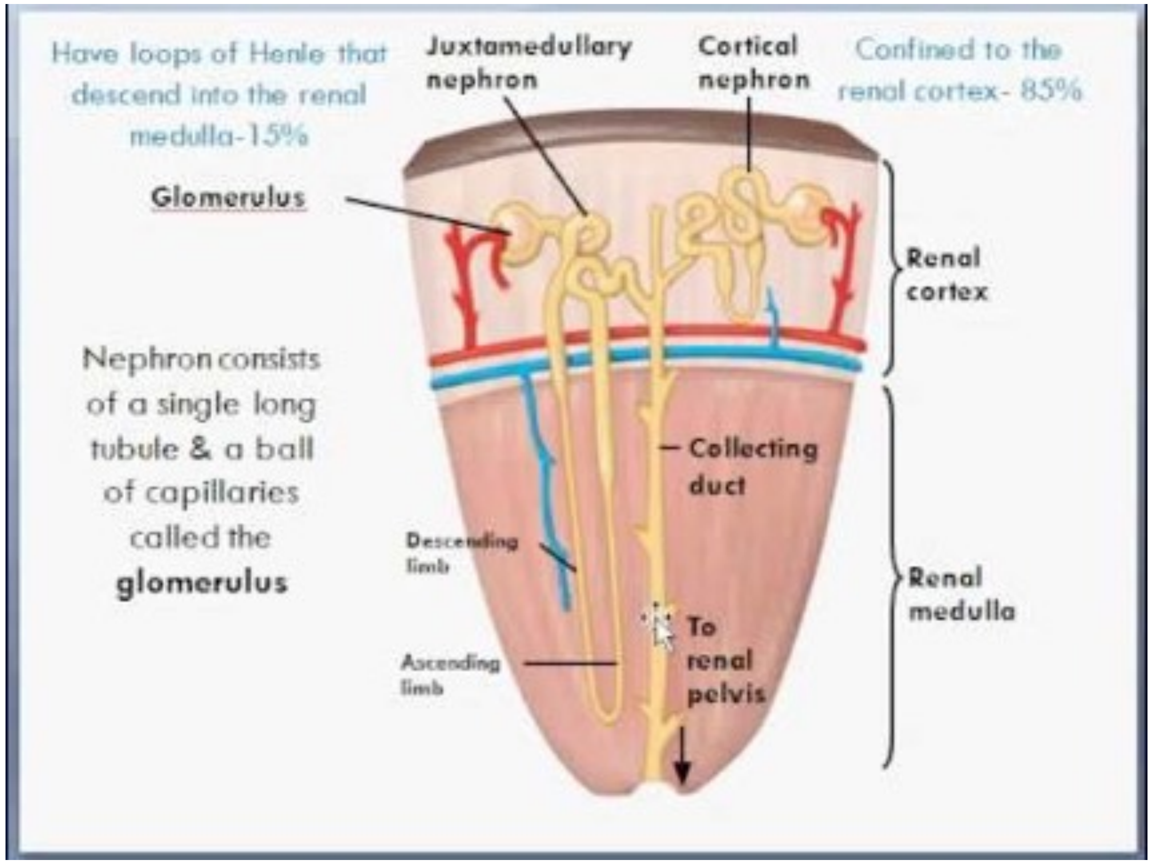


Click on the image above for more content

1.What is a nephron? What is its function in the kidney?
2.What happens in the coiled tubules in the kidney?
3.Where is the cortex of the kidney? What structures are located there?
4.Where is the medulla in the kidney? What structures are located there?

Explore More II

•**Kidney Anatomy and Physiology** at http://www.youtube.com/watch?v=7nesHuVEe8M (6:39)



Click on the image above for more content

1.Where does the ureter lead to?
2.What exits the tubules in the outer medulla? What effect does this have on the fluid moving through the tubules?
3.What exits the tubules on the ascending limb? What effect does this have on the fluid moving through the tubules?
4.What controls the permeability of the collecting ducts?

Review

1.What is the nephron?
2.Through what blood vessel does blood enter the kidney?
3.What causes wastes to leave the blood?
4.What is the difference between the blood that enters and leaves the kidney?
5.What does antidiuretic hormone (ADH) do?

Section 39

Excretory System Problems

Excretory System Problems

- •Identify disorders of the urinary system.
- •Explain the cause of kidney stones.
- •Describe kidney failure.
- •Describe the signs and symptoms of a urinary tract infection.

Why drink water?

It's always a good idea to drink plenty of fluids, especially when you have been exercising. Drinking plenty of water helps to flush away materials that might form kidney stones. Staying hydrated is the best way to prevent kidney stones.

Problems of the Excretory System

The urinary system controls the amount of water in the body and removes wastes. Any problem with the urinary system can also affect many other body systems.

Kidney Stones

In some cases, certain mineral wastes can form **kidney stones** (**Figure** below). Stones form in the kidneys and may be found anywhere in the urinary system. Often, stones form when the urine becomes concentrated, allowing minerals to crystallize and stick together. They can vary in size, from small stones that can flow through your urinary system, to larger stones that cannot. Some stones cause great pain, while others cause very little pain. Some stones may need to be removed by surgery or ultrasound treatments.

Figure 11.70

A kidney stone. The stones can form anywhere in the urinary system.

What are the symptoms of kidney stones? You may have a kidney stone if you have pain while urinating, see blood in your urine, and/or feel a sharp pain in your back or lower abdomen (the area between your chest and hips). The pain may last for a long or short time. You may also have nausea and vomiting with the pain. If you have a small stone that passes on its own easily, you may not experience any symptoms. If you have some of these symptoms, you should see your doctor.

Kidney failure

Kidney failure happens when the kidneys cannot remove wastes from the blood. If the kidneys are unable to filter wastes from the blood, the wastes build up in the body. Kidney failure can be caused by an accident that injures the kidneys, the loss of a lot of blood, or by some drugs and poisons. Kidney failure may lead to permanent loss of kidney function. But if the kidneys are not seriously damaged, they may recover.

Chronic kidney disease is the slow decrease in kidney function that may lead to permanent kidney failure. A person who has lost kidney function may need to get kidney dialysis. **Kidney dialysis** is the process of filtering the blood of wastes using a machine. A dialysis machine (**Figure** below) filters waste from the blood by pumping the blood through a fake kidney. The filtered blood is then returned to the patient's body.

Figure 11.71

During dialysis, a patient's blood is sent through a filter that removes waste products. The clean blood is returned to the body.

Urinary tract infections (UTIs)

Urinary tract infections (UTIs) are bacterial infections of any part of the urinary tract. When bacteria get into the bladder or kidney and produce more bacteria in the urine, they cause a UTI. The most common type of UTI is a bladder infection. Women get UTIs more often than men. UTIs are often treated with antibiotics.

Most UTIs are not serious, but some infections can lead to serious problems. Long lasting kidney infections can cause permanent damage, including kidney scars, poor kidney function, high blood pressure, and other problems. Some sudden kidney infections can be life threatening, especially if the bacteria enter the bloodstream, a condition called septicemia.

What are the signs and symptoms of a UTI?

- •a burning feeling when you urinate,
- •frequent or intense urges to urinate, even when you have little urine to pass,
- •pain in your back or side below the ribs,
- •cloudy, dark, bloody, or foul-smelling urine,
- •fever or chills.

You should see your doctor if you have signs of a UTI. Your doctor will diagnose a UTIs by asking about your symptoms and then testing a sample of your urine.

Summary

- •Disorders of the urinary system include kidney stones, kidney failure, and urinary tract infections.
- •Kidney dialysis is the process of filtering wastes from the blood using a machine.

Explore More

Use the resource below to answer the questions that follow.

- •**The Basics of Kidney Disease** at http://www.youtube.com/watch?v=wY4VvAjYLBU (6:24)

Click on the image above for more content

1. What is kidney disease? What is chronic kidney disease? How are they similar, and how do they differ?
2. What is kidney failure? How can people deal with kidney failure?

3. What are two causes of chronic kidney disease?
4. How can doctors test for kidney disease?
5. How can they treat kidney disease?

Review

1. Why do kidney stones form?
2. What is a urinary tract infection?
3. What is kidney failure?

Section 40

Nervous System

Nervous System

- •Define nerve.
- •Describe the role of a nerve.
- •Explain the functions of the nervous system.

What body system helps you learn?

As these girls are studying, many processes are taking place. Their eyes have to take in the words on the page, and their brains have to process the meaning of the words. The brain also has to assimilate the knowledge so it can be retrieved at a later time. All these processes are controlled by the nervous system.

Introduction to the Nervous System

Michelle was riding her scooter when she hit a hole in the street and started to lose control. She thought she would fall, but, in the blink of an eye, she shifted her weight and kept her balance. Her heart was pounding, but at least she didn't get hurt. How was she able to react so quickly? Michelle can thank her nervous system for that (**Figure** below).

Figure 11.72

Staying balanced when riding a scooter requires control over the body's muscles. The nervous system controls the muscles and maintains balance.

The **nervous system** , together with the **endocrine system** , controls all the other **organ systems** . The nervous system sends one type of signal around the body, and the endocrine system sends another type of signal around the body. The endocrine system makes and releases chemical messenger molecules, or hormones, which tell other body parts that a change or a reaction is necessary. So what type of signal does the nervous system send?

Controlling muscles and maintaining balance are just two of the roles of the nervous system. The nervous system also lets you:

- Sense your surroundings with your eyes and other sense organs.
- Sense the environment inside of your body, including temperature.
- Control your internal body systems and keep them in balance.
- Prepare your body to fight or flee in an emergency.
- Use language, think, learn, and remember.

The nervous system works by sending and receiving electrical signals. The main organs of the nervous system are the brain and the spinal cord. The signals are carried by **nerves** in the body, similar to the wires that carry electricity all over a house. The signals travel from all over the body to the spinal cord and up to the brain, as well as moving in the other direction. For example, when Michelle started to fall off her scooter, her nervous system sensed that she was losing her balance. It responded by sending messages from her brain to muscles in her body. Some muscles tightened while others relaxed. Maybe these actions moved her hips or her arms. The nervous system, working together with the muscular and skeletal systems, allowed Michelle to react to the situation. As a result, Michelle's body became balanced again. The messages released by the nervous system traveled through nerves. Just like the electricity that travels through wires, nerve quickly carry the electrical messages around the body.

Think about how quickly all this happens. It has to be really fast, otherwise Michelle would not have been able to react. What would happen if a car pulled out unexpectedly in front of Michelle? A signal would have to go from her eyes to her brain and then to her muscles. What allows the nervous system to react so fast. It starts with the special cell of the nervous system, the neuron.

Summary

- The nervous system sends electrical messages throughout the body and controls all other body systems.
- The nervous system allows you to think, learn, sense your surroundings, and control your internal body systems.

Explore More

Use the resource below to answer the questions that follow.

- **Nervous System** at http://www.getbodysmart.com/ap/nervoussystem/menu/menu.html

1. What are the major organs of the nervous system?
2. What does the somatic nervous system do? Why is a system like this useful to organisms?

3. What does the autonomic nervous system do? How does it differ from the somatic nervous system?

Review

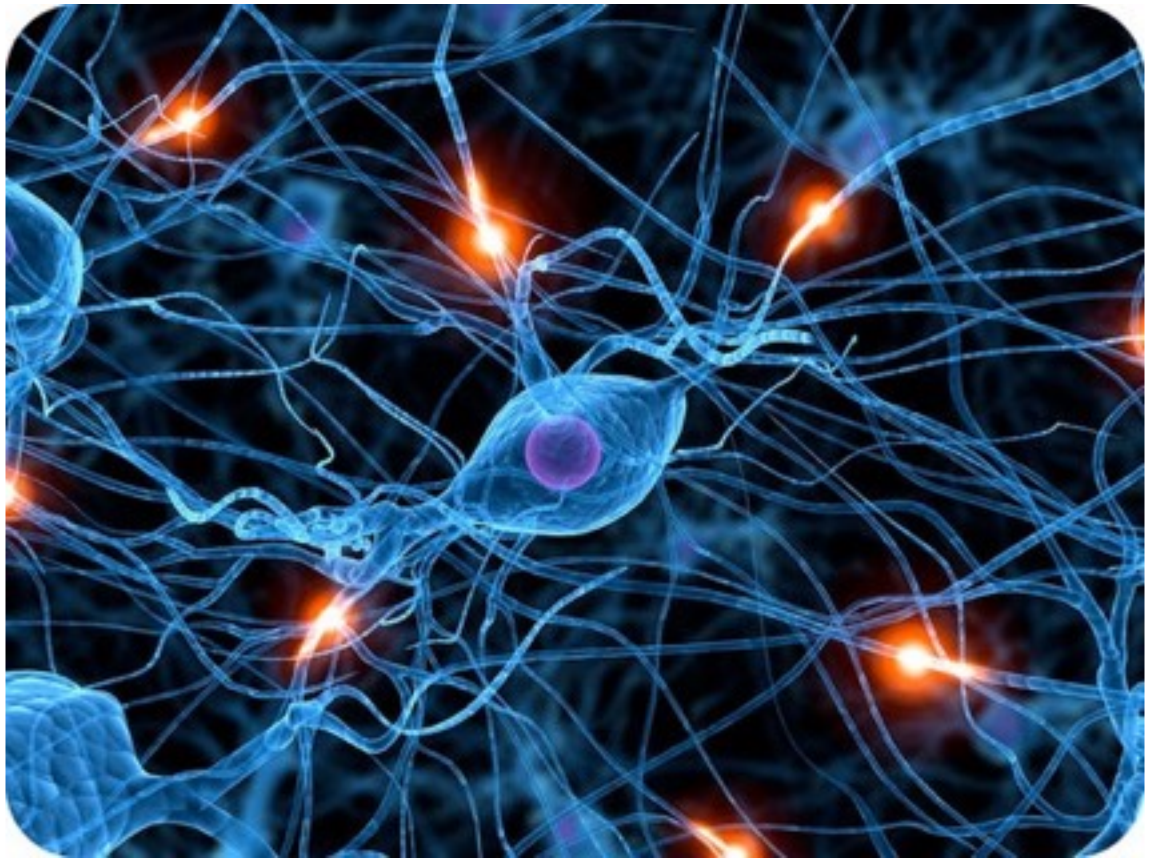
1. What are three functions of the nervous system?
2. What type of signals does the nervous system send? What carries these signals?
3. What are the main organs of the nervous system?

Section 41

Nerve Cells and Nerve Im-

Nerve Cells and Nerve Impulses

•Define neuron and synapse.
•Describe neuron structure.
•Explain the role of the dendrites and axon.
•Distinguish sensory neurons from motor neurons.
•Summarize what happens when a nerve impulse reaches the end of an axon.



What do nerve cells look like?

Note that like most other cells, these nerve cells have a nucleus. They also have other organelles. However, the long, threadlike extensions of the nerve cells are unique. This is where the nerve impulses are transmitted.

Neurons and Nerve Impulses

The nervous system is made up of nerves. A **nerve** is a bundle of nerve cells. A nerve cell that carries messages is called a **neuron** (**Figure** below). The messages carried by neurons are called **nerve impulses** . Nerve impulses can travel very quickly because they are electrical impulses.

Think about flipping on a light switch when you enter a room. When you flip the switch, the electricity flows to the light through wires inside the walls. The electricity may have to travel many meters to reach the light, but the light still comes on as soon as you flip the switch. Nerve impulses travel just as fast through the network of nerves inside the body.

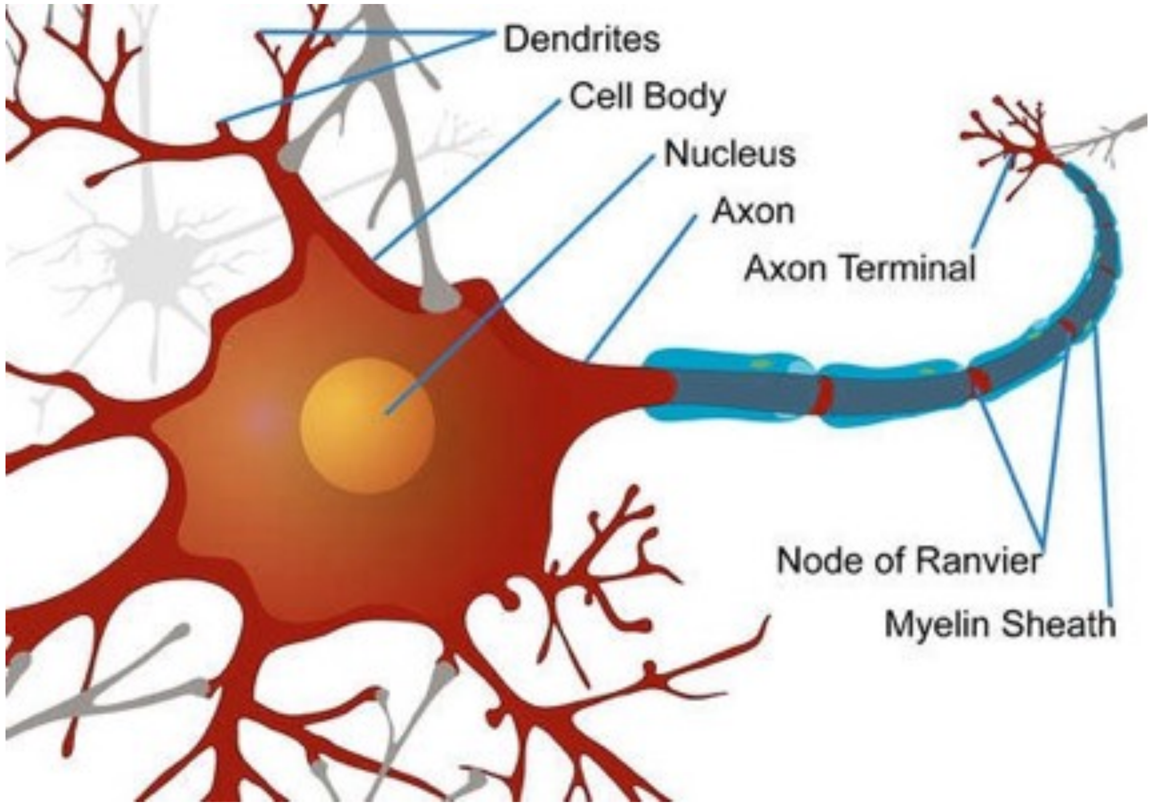


Figure 11.73

The axons of many neurons, like the one shown here, are covered with a fatty layer called myelin sheath. The sheath covers the axon, like the plastic covering on an electrical wire, and allows nerve impulses to travel faster along the axon. The node of Ranvier, shown in this diagram, is any gap in the myelin sheath; it allows faster transmission of a signal.

What Does a Neuron Look Like?

A neuron has a special shape that lets it pass signals from one cell to another. A neuron has three main parts (**Figure** above):

1. The cell body.
2. Many dendrites.
3. One axon.

The **cell body** contains the nucleus and other organelles. Dendrites and axons connect to the cell body, similar to rays coming off of the sun. **Dendrites** receive nerve impulses from other cells. **Axons** pass the nerve impulses on to other cells. A single neuron may have thousands of dendrites, so it can communicate with thousands of other cells but only one axon. The axon is covered with a **myelin sheath** , a fatty layer that insulates the axon and allows the electrical signal to travel much more quickly. The **node of Ranvier** is any gap within the myelin sheath exposing the axon, and it allows even faster transmission of a signal.

Types of Neurons

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

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

Both types of neurons work together. Sensory neurons carry information about the environment found inside or outside of the body to the central nervous system. The central nervous system uses the information to send messages through motor neurons to tell the body how to respond to the information.

The Synapse

The place where the axon of one neuron meets the dendrite of another is called a **synapse** . Synapses are also found between neurons and other types of cells, such as muscle cells. The axon of the sending neuron does not actually touch the dendrite of the receiving neuron. There is a tiny gap between them, the synaptic cleft (**Figure** below).

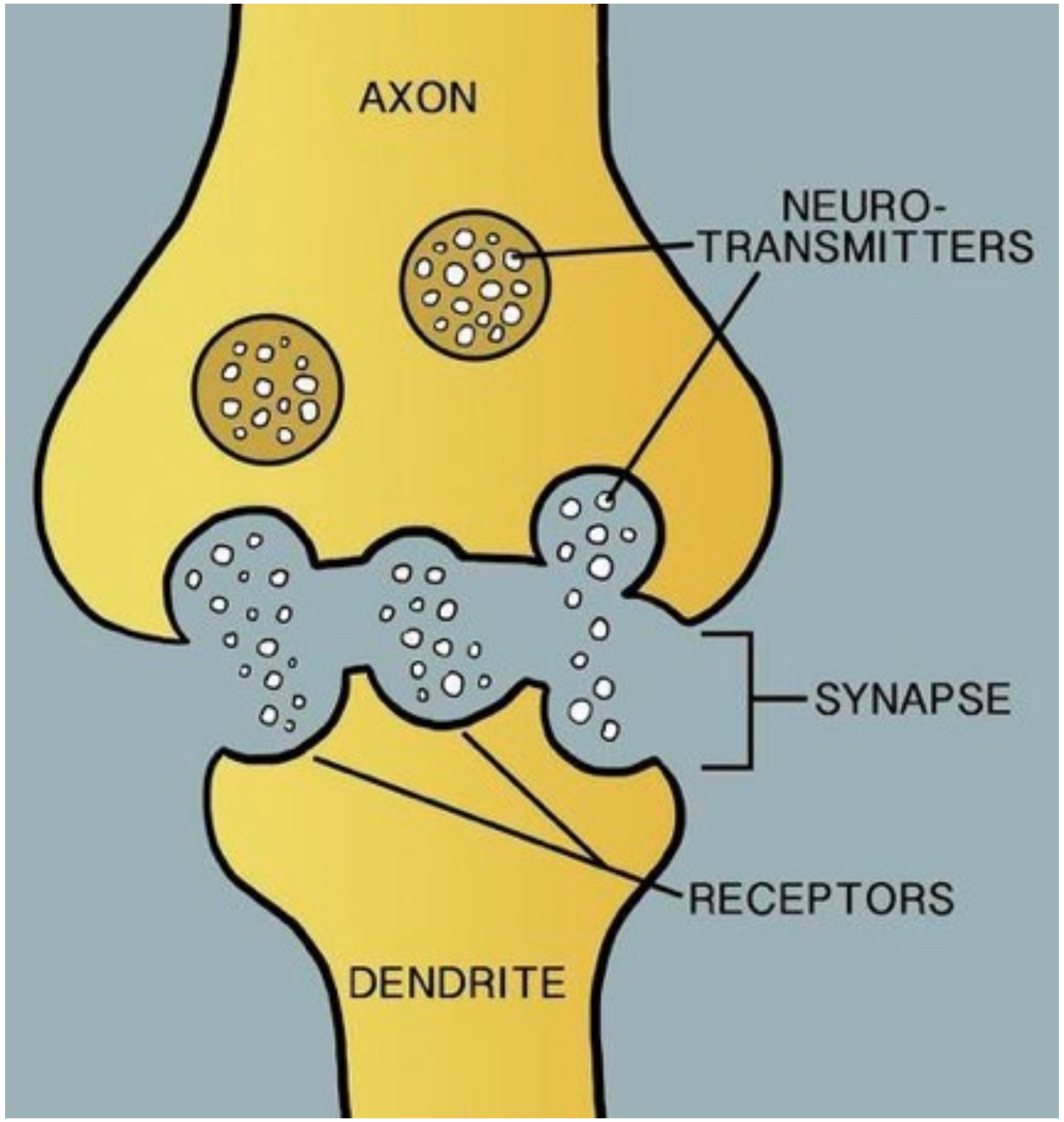


Figure 11.74

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

The following steps describe what happens when a nerve impulse reaches the end of an axon.

1. When a nerve impulse reaches the end of an axon, the axon releases chemicals called **neurotransmitters** .
2. Neurotransmitters travel across the synapse between the axon and the dendrite of the next neuron.
3. Neurotransmitters bind to the membrane of the dendrite.
4. The binding allows the nerve impulse to travel through the receiving neuron.

Did you ever watch a relay race? After the first runner races, he or she passes the baton to the next runner, who takes over. Neurons are a little like relay runners. Instead of a baton, they pass neurotransmitters to the next neuron. Examples of neurotransmitters are chemicals such as serotonin, dopamine, and adrenaline.

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

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

Summary

- Neurons, or nerve cells that carry nerve impulses, are made up of the cell body, the axon, and several dendrites.
- Signals move across the synapse, the place where the axon of one neuron meets the dendrite of another, using chemicals called neurotransmitters.

Explore More

Use the resource below to answer the questions that follow.

- **Neuroscience For Kids** at http://faculty.washington.edu/chudler/cells.html

1. What are the three types of neurons?
2. What neurons are most abundant in the central nervous system?
3. What is the function of sensory neurons?
4. What is the function of motor neurons?
5. What is the role of interneurons?

Review

1. Describe a neuron and identify its three main parts.
2. Distinguish between dendrites and the axon.
3. Distinguish between sensory and motor neurons.
4. Explain how one neuron transmits a nerve impulse to another neuron.

Section 42

Central Nervous System

Central Nervous System

- •Describe the structures of the central nervous system.
- •Identify sections of the brain.
- •Identify functions of the cerebral lobes.

What's the control center of your body?

Your brain is like the control center of your body. It controls your breathing and heartbeat. It helps you to think and learn. The brain is so "central" to all your body systems, it's not surprising that the brain and spinal cord are called the central nervous system.

The Central Nervous System

The **central nervous system** (CNS) (**Figure** below) is the largest part of the nervous system. It includes the **brain** and the **spinal cord** . The bony skull protects the brain. The spinal cord is protected within the bones of the spine, which are called **vertebrae** .

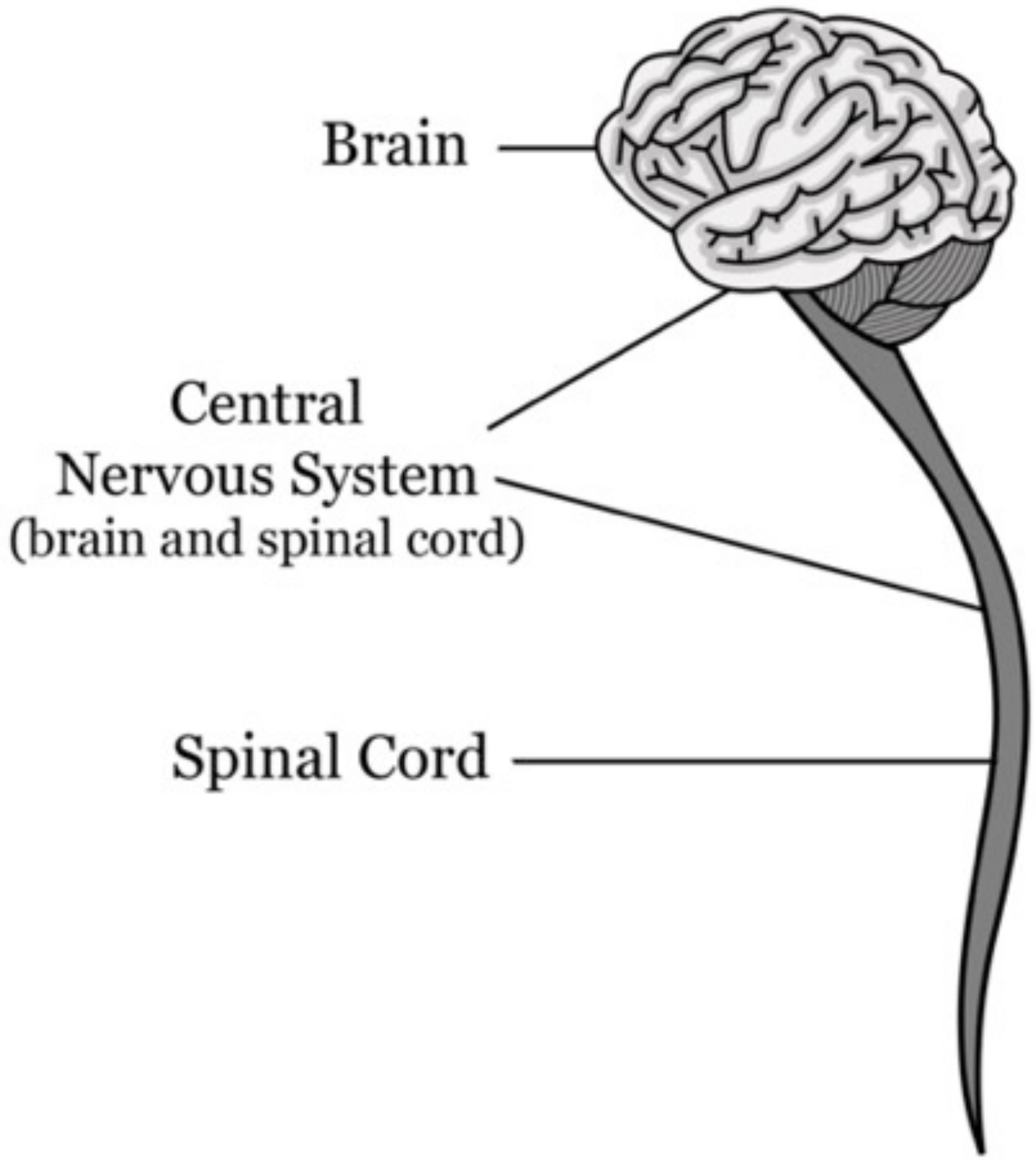


Figure 11.75

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

The Brain

What weighs about three pounds and contains up to 100 billion cells? The answer is the human brain. The brain is the control center of the nervous system. It's like the pilot of a plane. It tells other parts of the nervous system what to do.

The brain is also the most complex organ in the body. Each of its 100 billion neurons has synapses connecting it with thousands of other neurons. All those neurons use a lot of energy. In fact, the adult brain uses almost a quarter of the total energy used by the body. The developing brain of a baby uses an even greater amount of the body's total energy.

The brain is the organ that lets us understand what we see, hear, or sense in other ways. It also allows us to use language, learn, think, and remember. The brain controls the organs in our body and our movements as well. The brain consists of three main parts, the cerebrum, the cerebellum, and the brain stem (**Figure** below).

1. The **cerebrum** is the largest part of the brain. It sits on top of the brain stem. The cerebrum controls functions that we are aware of, such as problem-solving and speech. It also controls voluntary movements, like waving to a friend. Whether you are doing your homework or jumping hurdles, you are using your cerebrum.
2. The **cerebellum** is the next largest part of the brain. It lies under the cerebrum and behind the brain stem. The cerebellum controls body position, coordination, and balance. Whether you are riding a bicycle or writing with a pen, you are using your cerebellum.
3. The **brain stem** is the smallest of the three main parts of the brain. It lies directly under the cerebrum.

The brain stem controls basic body functions, such as breathing, heartbeat, and digestion. The brain stem also carries information back and forth between the cerebrum and spinal cord.

Figure 11.76

Side view of the brain (*right*). Can you find the locations of the three major parts of the brain? Top view of the brain (*left*).

The cerebrum is divided into a right and left half (**Figure** above). Each half of the cerebrum is called a hemisphere. The two hemispheres are connected by a thick bundle of axons called the **corpus callosum** . It lies deep inside the brain and carries messages back and forth between the two hemispheres.

Did you know that the right hemisphere controls the left side of the body, and the left hemisphere controls the right side of the body? By connecting the two hemispheres, the corpus callosum allows this to happen.

Each hemisphere of the cerebrum is divided into four parts, called lobes. The four lobes are the:

1. Frontal.
2. Parietal.
3. Temporal.
4. Occipital.

Each lobe has different jobs. Some of the functions are listed below (**Table** below).

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

The Spinal Cord

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

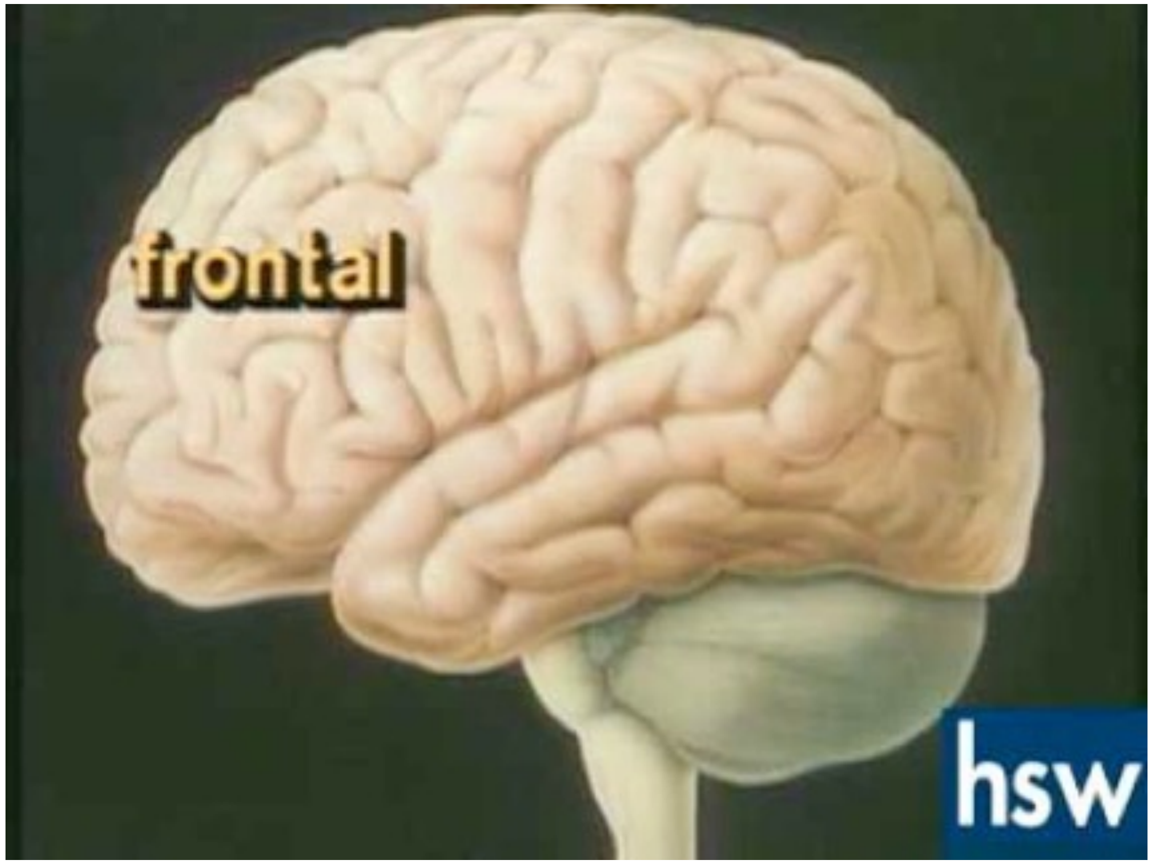
Summary

- The central nervous system is made up of the brain and the spinal cord.
- The brain consists of three main parts: the cerebrum, the cerebellum, and the brain stem.

Explore More

Use the resource below to answer the questions that follow.

- **The Human Brain** at http://www.youtube.com/watch?v=gVjpfPNpoGA (1:36)



Click on the image above for more content

1. What are two components of the central nervous system?
2. Describe the spinal cord.
3. What are the main division of the brain?
4. What are the four lobes of the cerebrum?

Review

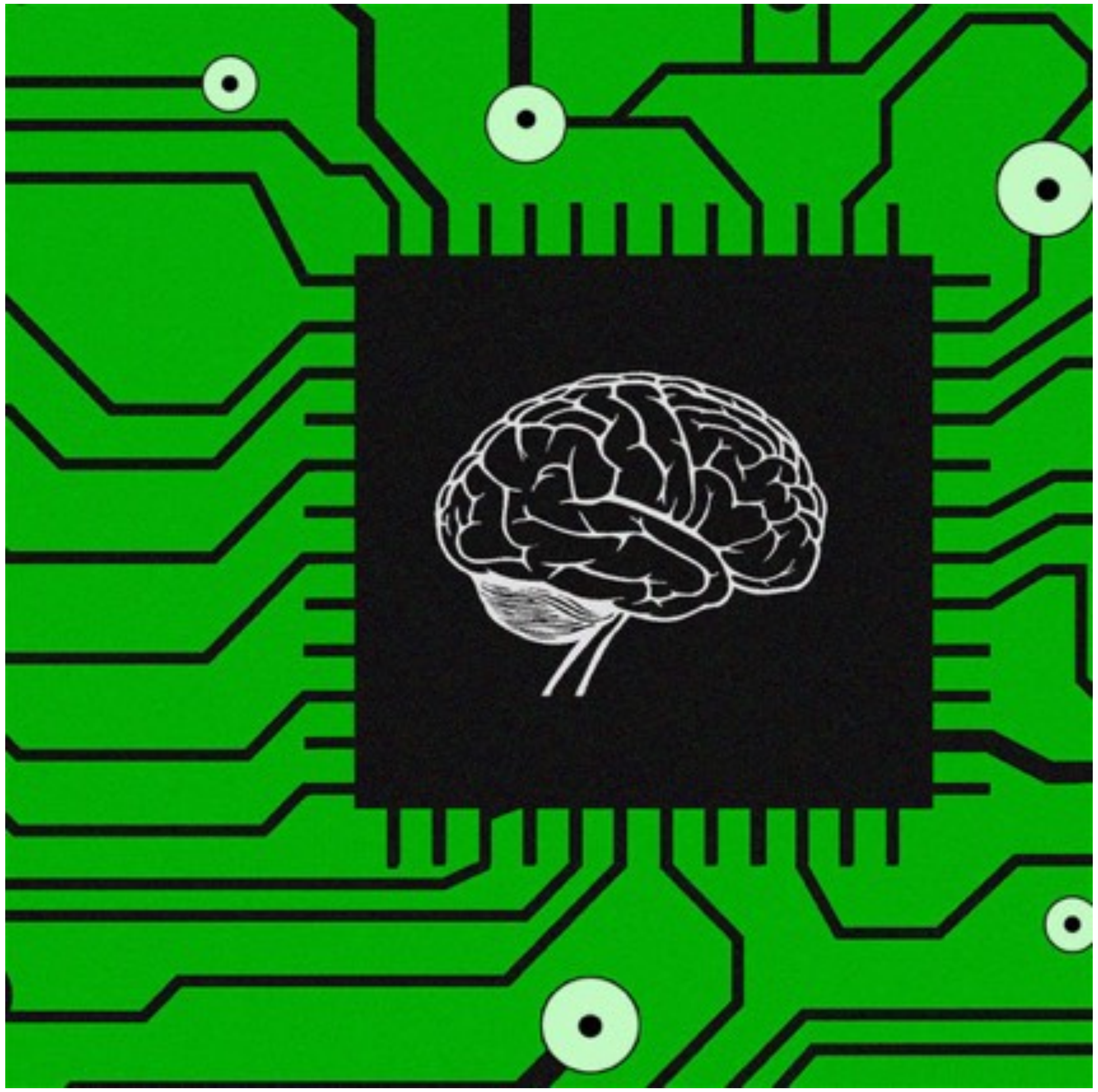
1. What two structures make up the central nervous system?
2. Compare and contrast the three main parts of the brain.
3. Describe the main function of the spinal cord.

Section 43

Peripheral Nervous System

Peripheral Nervous System

•Outline the divisions of the peripheral nervous system.
•Distinguish the sensory division from the motor division.
•Summarize responsibilities of the somatic nervous system and the autonomic nervous system.
•Explain the difference between the sympathetic division and the parasympathetic division.



How does your brain connect to the rest of your body?

You know you have nerves in your fingers and toes because you can feel them. But how does your brain know what's going on in these nerves? You have a network of nerves running from your brain and spinal cord to your fingers and toes and the rest of your body. This network is known as the peripheral nervous system.

The Peripheral Nervous System

There are other nerves in your body that are not found in the brain or spinal cord. The **peripheral nervous system** (PNS) (**Figure** below) contains all the nerves in the body that are found outside of the central nervous system. They include nerves of the hands, arms, feet, legs, and trunk. They also include nerves of the scalp, neck, and face. Nerves that send and receive messages to the internal organs are also part of the peripheral nervous system.

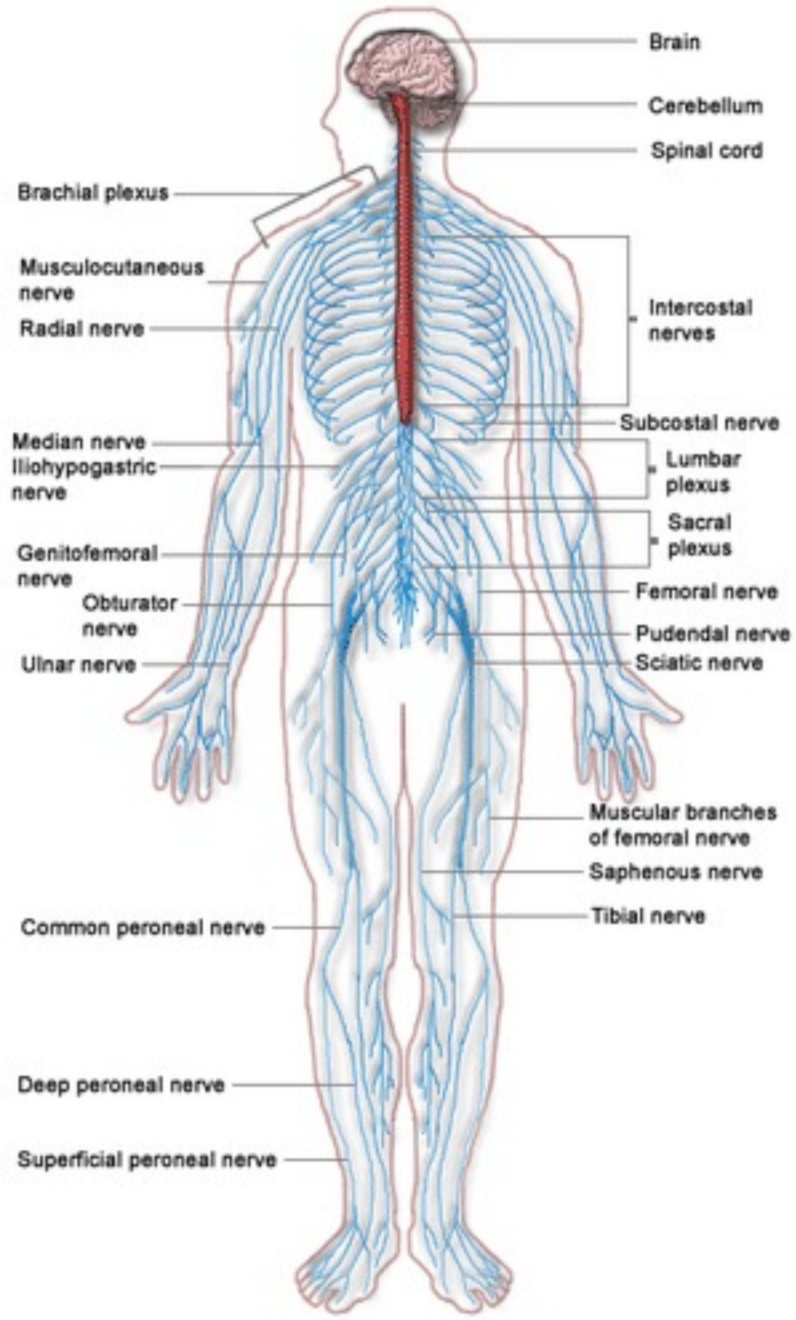


Figure 11.77

The blue lines in this drawing represent nerves of the peripheral nervous system. Every peripheral nerve is connected directly or indirectly to the spinal cord. Notice the thick sciatic nerve. It is the longest (and thickest) nerve in the body, running from the lower region of the spinal cord to just above the knee.

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

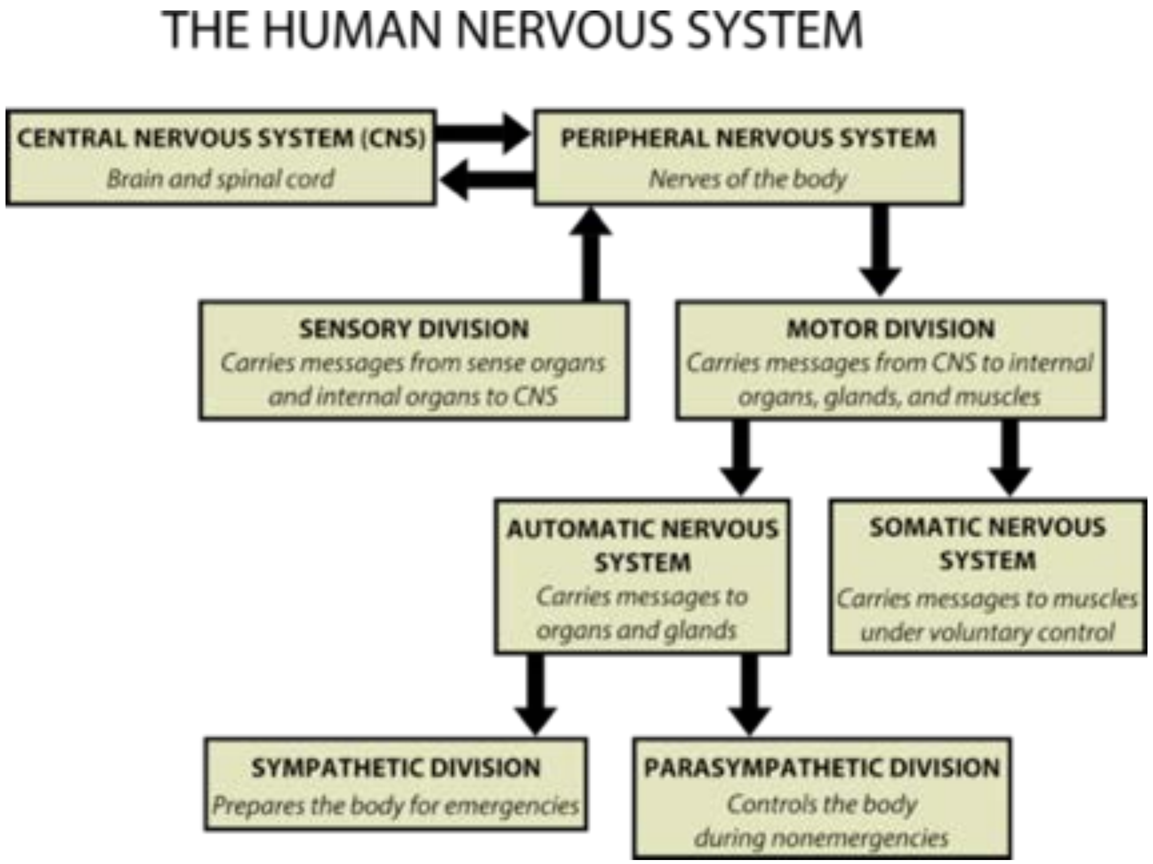


Figure 11.78

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

The Sensory Division

The **sensory division** carries messages from sense organs and internal organs to the central nervous system. Human beings have several senses. They include sight, hearing, balance, touch, taste, and smell. We have special sense organs for each of these senses. What is the sense organ for sight? For hearing?

Sensory neurons in each sense organ receive stimuli, or messages from the environment that cause a response in the body. For example, sensory neurons in the eyes send messages to the brain about light. Sensory neurons in the skin send messages to the brain about touch. Our sense organs recognize sensations, but they don't tell us *what* we are sensing. For example, when you breathe in chemicals given off by baking cookies, your nose does not tell you that you are smelling cookies. That's your brain's job. The sense organs send messages about sights, smells, and other stimuli to the brain (**Figure** below). The brain then reads the messages and tells you what they mean. A certain area of the brain receives and interprets information from each sense organ. For example, information from the nose is received and interpreted by the temporal lobe of the cerebrum.

Figure 11.79

Which senses would be stimulated by these raspberries?

The Motor Division

The **motor division** of the peripheral system carries messages from the central nervous system to internal organs and muscles. The motor division is also divided into two parts (**Figure** above), the somatic nervous system and the autonomic nervous system.

The **somatic nervous system** carries messages that control body movements. It is responsible for activities that are under your control, such as waving your hand or kicking a ball. The girl pictured below (**Figure** below) is using her somatic nervous system to control the muscles needed to play the violin. Her brain sends messages to motor neurons that move her hands so she can play. Without the messages from her brain, she would not be able to move her hands and play the violin.

Figure 11.80

These women's central nervous systems are controlling the movements of their hands and arms as they play the violin. Their brains send commands to their somatic nervous system, which controls the muscles of their hands and arms.

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

1. The **sympathetic division** controls internal organs and glands during emergencies. It prepares the body for fight or flight (**Figure** below). For example, it increases the heart rate and the flow of blood to the legs, so you can run away from danger.

2. The **parasympathetic division** controls internal organs and glands during the rest of the time. It controls processes like digestion, heartbeat, and breathing when there is not an emergency.

Figure 11.81

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

Have you ever become frightened and felt your heart start pounding? How does this happen? The answer is your autonomic nervous system. The sympathetic division prepared you to deal with a possible emergency by increasing your heart rate. The fact that this happened in the blink of an eye shows how amazing the nervous system is.

Summary

- The peripheral nervous system consists of all the nerves that are found outside the central nervous system.
- The peripheral nervous system is divided into the sensory and motor divisions, which are then divided into further systems and subdivisions.

Explore More

Use the resource below to answer the questions that follow.

- **PNS** at http://www.youtube.com/watch?v=3aiI2xt3crY (4:01)

Click on the image above for more content

1. What are the two parts of the peripheral nervous system? How do they differ?
2. What do the nerves of the autonomic nervous system connect to?
3. What is meant by a "rest and digest" response? What part of the nervous system is involved with this response?
4. What is meant by a "fight or flight" response? What part of the nervous system is involved with this response?

Review

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

Section 44

Human Vision

Human Vision

- •Describe how humans see and explain why vision is important.
- •Explain the importance of seeing in three dimensions and in color.

How have you used your vision today?

Maybe you were just doing some schoolwork. Or walking down the hallway. No matter what you were doing, you were probably using your sense of sight. You may depend on your sense of sight so much that it's hard to think of anything you do without it, except sleep. Why is sight so important?

The Nature of Human Vision

Think about all the ways that students use their sense of sight during a typical school day. As soon as they open their eyes in the morning, they might look at the clock to see what time it is. Then, they might look out the window to see what the weather is like. They probably look in a mirror to comb their hair. In school, they use their eyes to read the board, their textbooks, and the expressions on their friends' faces. After school, they might keep their eye on the ball while playing basketball (**Figure** below). Then, they might read their homework assignment and text messages from their friends.

Figure 11.82

All eyes are on the ball in this basketball game. Think about how we use the sense of sight in other games.

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

But humans do not have the best vision. You may think you see things fairly clearly. Imagine if you could see even better. How about 8 times better? Raptors, or birds of prey, including the eagles, hawks and falcons can see up to 8 times more clearly than the sharpest human eye. A golden eagle for example can see a rabbit from a mile away. Why do you think they have such a good sense of vision? Other animals also have much better night vision then us.

Seeing in Three Dimensions

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

Figure 11.83

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

We are able to see in three dimensions because we have two eyes facing the same direction but a few inches apart. As a result, we see objects and people with both eyes at the same time but from slightly different angles.

Hold up a finger a few inches away from your face, and look at it, first with one eye and then with the other. You'll notice that your finger appears to move. Now hold up your finger at arm's length, and look at it with one eye and then the other. Your finger seems to move less than it did when it was closer. Although you aren't aware of it, your brain constantly uses such differences to determine the distance of objects.

Seeing in Color

For animals like us that see in color, it may be hard to imagine a world that appears to be mainly shades of gray.

You can get an idea of how many other animals see the world by looking at a black-and-white picture of colorful objects. For example, look at the apple on the tree pictured below (**Figure** below). In the top picture, they appear in color, the way you would normally see them. In the bottom picture they appear without color, in shades of gray (**Figure** below).

Figure 11.84

Humans with color vision see the apple on this tree; the bright red color of the apple stands out clearly from the green background of leaves.

Figure 11.85

This black-and-white picture gives an idea of how many animals see the world. Dogs and cats would see the green and red colors as shades of gray; they are able to see blue, but red and green appear the same to them. Many animals see just one or two colors. Some see colors that we cannot see. Apes and chimps see the same colors as us.

But whereas many animals cannot see colors, some animals see colors that we cannot. The range of color vision of bees and butterflies for example, extends beyond the visible spectrum of light we can see. The leaves of the flowers they pollinate have special ultraviolet patterns which guide the insects deep into the flower.

Evolution and Primate Vision

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

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

Figure 11.86

With color vision, you can tell which cherries in this picture are ripe, because cherries turn red as they ripen.

Summary

- Vision depends on the eyes detecting light and forming images, and then the brain must make sense of the images.
- Humans can see in three dimensions and color.

Explore More

Use the resource below to answer the questions that follow.

- **How the Human Eye Works** at http://www.livescience.com/3919-human-eye-works.html

1. What is the cornea?
2. Why does the pupil expand or contract?
3. What cells are found in the retina?
4. What's the difference between the two main cells of the retina?
5. How do we determine what we see?

Review

1. What is vision?
2. Why were depth perception and color vision important for early primates?

Section 45

How the Eye Works

How the Eye Works

•Define retina, cornea, lens, and pupil.
•Distinguish rod cells from cone cells.
•Explain the steps involved in vision.

How do you see the board?

As you are sitting in the classroom, you may at first be focused on a paper directly in front of you. Then you may look to the front of the room to see a math problem worked out on the board. How can your eyes focus directly in front of you and then, a second later, at a distance? Your eyes are rather amazing!

How the Eye Works

The job of the eye is to focus light. The parts of the eye (**Figure** below) help it to carry out its job. Follow the path of light through the eye as you read about it below.

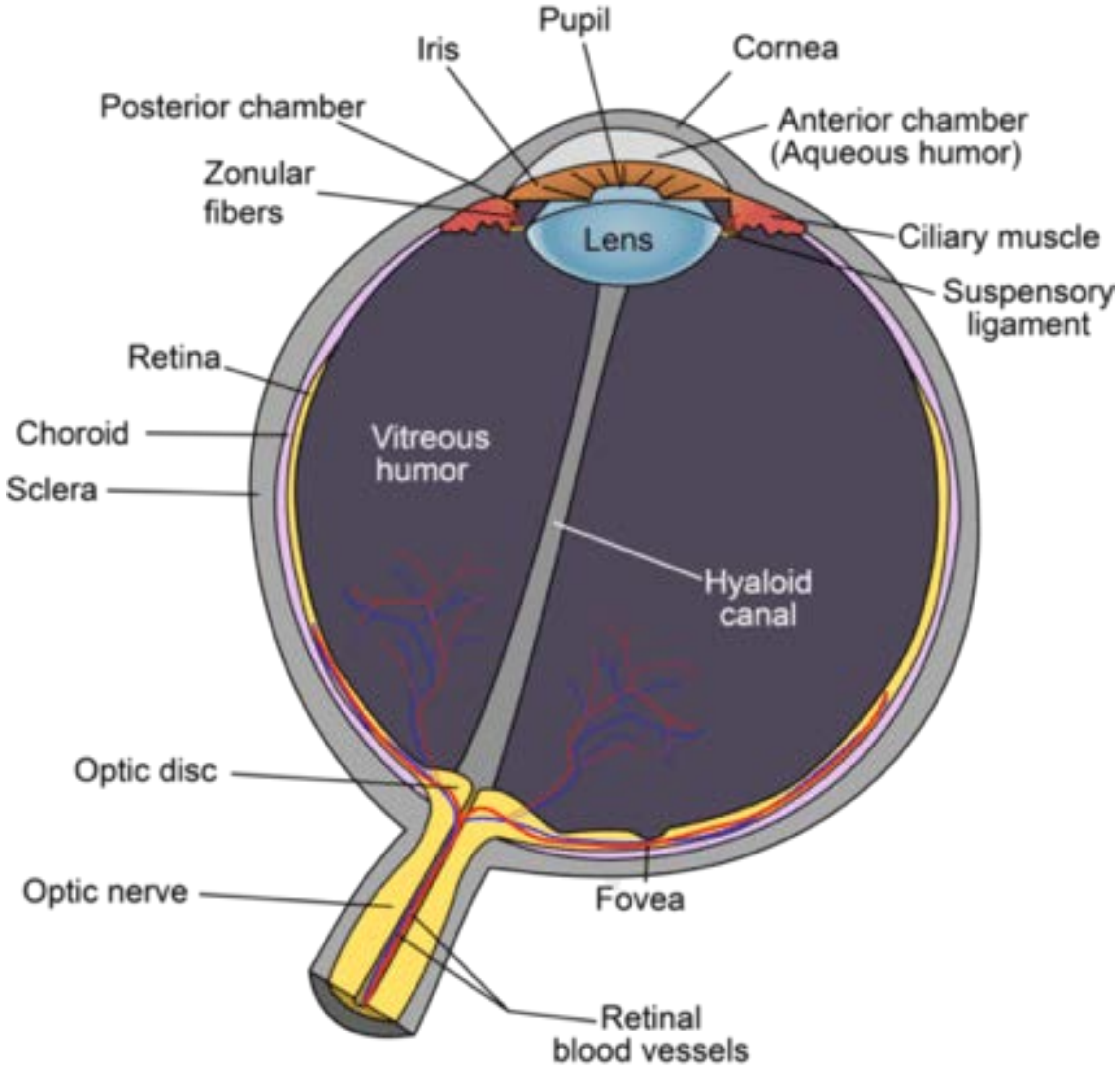


Figure 11.87

The human eye is a complex structure that senses light; the light passes through the cornea, pupil, and lens, and is focused on the retina. The vitreous humor is the clear gel that fills the space between the lens and the retina of the eye, and the hyaloid canal is a small transparent canal running through the vitreous humor from the optical disc to the lens.

Vision involves sensing and focusing light from people and objects. The steps involved are as follows:

1.First, light passes through the cornea of the eye. The **cornea** is a clear, protective covering on the outside of the eye.
2.Next, light passes through the pupil. The **pupil** is a black opening in the eye that lets light enter the eye.
3.After passing into the eye through the pupil, light passes through the lens. The **lens** of the eye is a clear, curved structure. Along with the cornea, the lens helps focus light at the back of the eye. This is pictured below (**Figure** below).
4.The lens must bend light from nearby objects more than it bends light from far-away objects. The lens changes shape to bend the light by just the right amount to bring objects into focus.
5.The lens focuses light on the **retina** , which covers the back of the inside of the eye. The retina has light-sensing photoreceptor cells called rods and cones. **Rods** let us see in dim light. **Cones** let us detect light of different colors.
6.When light hits rods and cones, it causes chemical changes. The chemical changes start nerve impulses. The nerve impulses travel to the brain through the **optic nerve** .
7.The brain makes sense of the nerve impulses and tells you what you are seeing.

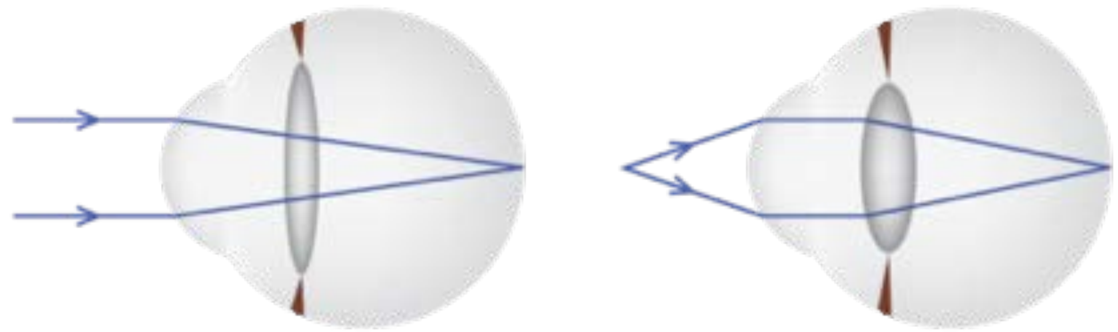


Figure 11.88

Light from objects at different distances is focused by the lens of the eye. Muscles in the eye control the shape of the lens so the light is focused on the back of the eye no matter how far the object is from the lens.

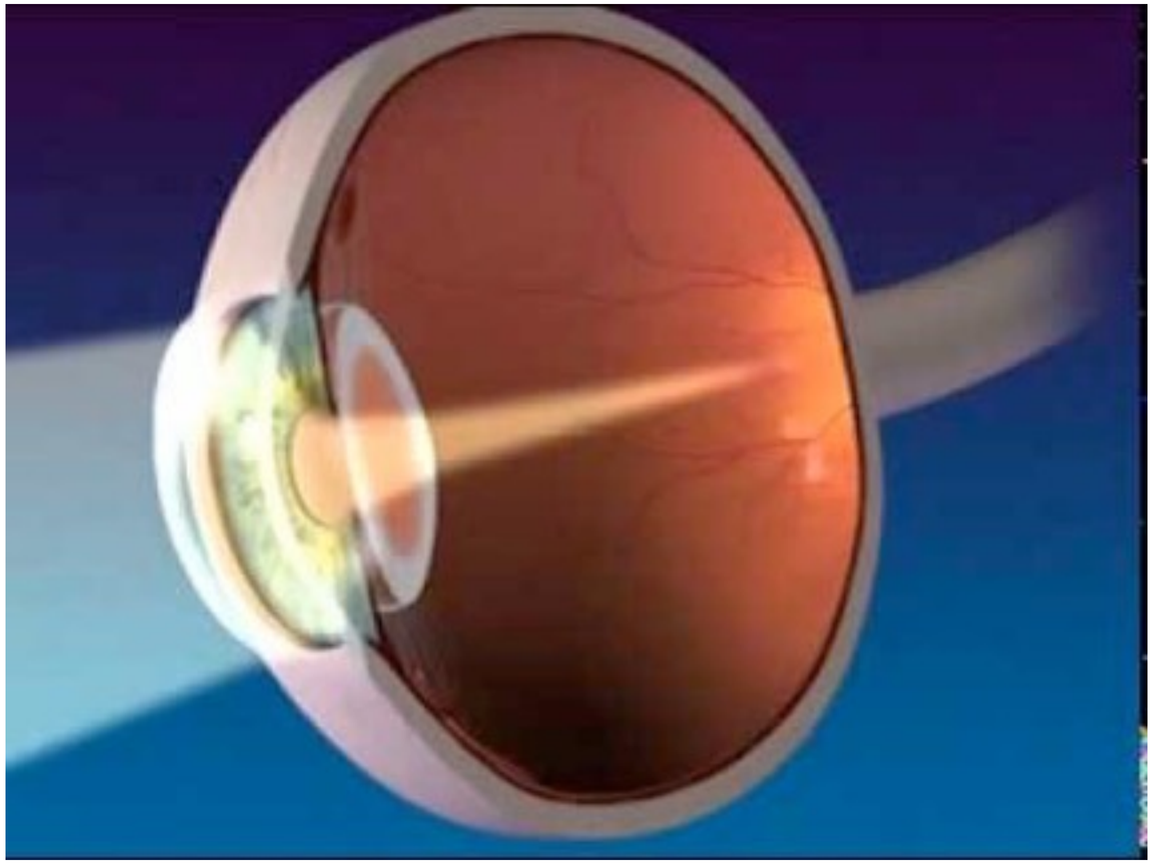
Summary

•Light entering the eye is focused by the lens on the retina, which sends messages to the brain through the optic nerve.
•Muscles in the eye control the shape of the lens so the light is focused on the back of the eye no matter how far the object is from the lens.

Explore More

Use the resource below to answer the questions that follow.

•**Anatomy and Function of the Eye** at http://www.youtube.com/watch?v=RE1MvRmWg7I (2:00)



Click on the image above for more content

1. What are the three layers of the eye? Which one acts to maintain the eyes shape?
2. Where does light enter the eye? How is the amount of light entering the eye controlled? Why is it valuable to organisms to control how much light enters the eye?
3. What structure contains the rods and cones in the eye? Where are they located?

Review

1. Outline the path of light through the eye.
2. What is the cornea?
3. Describe the role of the lens of the eye.
4. Distinguish between rods and cones.

Section 46

Vision Correction

Vision Correction

•Define myopia and hyperopia.
•Explain how lenses correct vision problems.

Why get an eye exam?

During a routine eye exam, your vision will be evaluated to see if you need glasses or contacts. Also, the eye doctor checks your eyes for diseases that could lead to vision loss.

Vision Correction

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

Myopia

Myopia is also called nearsightedness. It affects about one third of people. People with myopia can see nearby objects clearly, but distant objects appear blurry. The picture below shows how a person with myopia might see two boys that are a few meters away (**Figure** below).

Figure 11.89

On the left, you can see how a person with normal vision sees two boys. The right image shows how a person with myopia sees the boys.

In myopia, the eye is too long. Below, you can see how images are focused on the retina of someone with myopia (**Figure** below). Myopia is corrected with a **concave** lens, which curves inward like the inside of a bowl. The lens changes the focus, so images fall on the retina as they should.

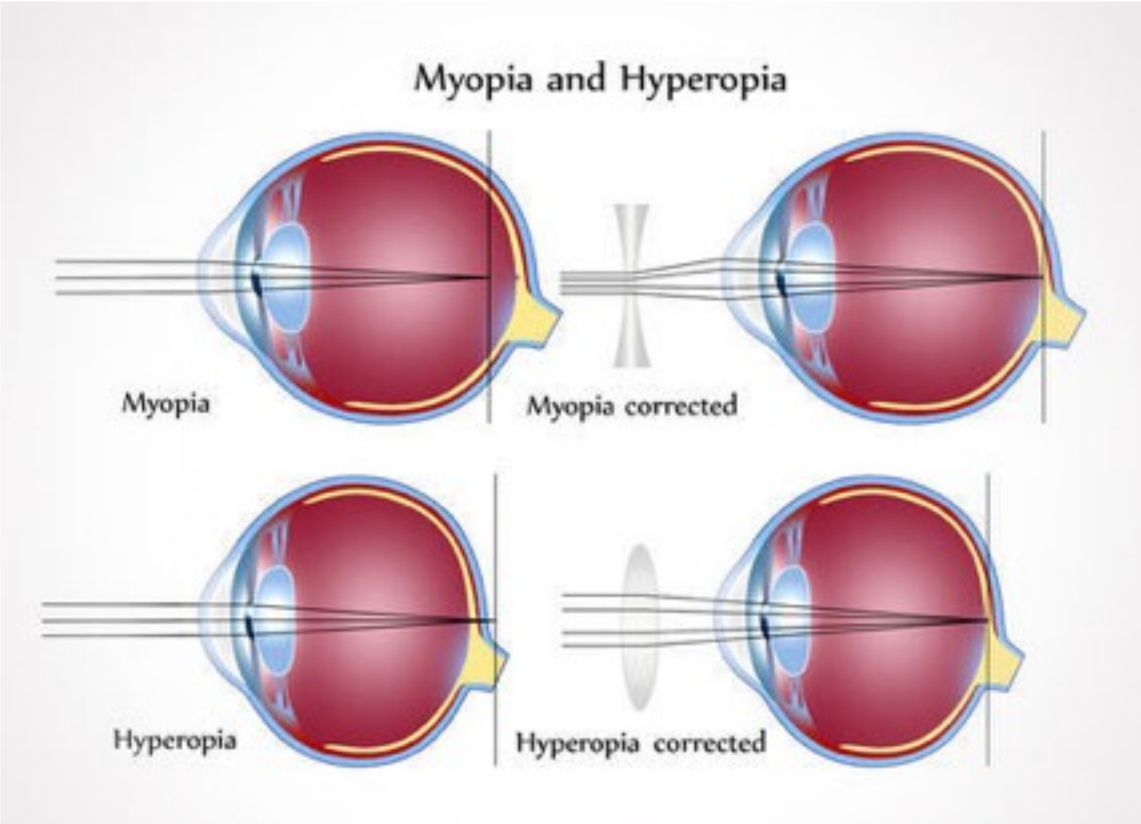


Figure 11.90

The eye of a person with myopia is longer than normal. As a result, images are focused in front of the retina (*top left*). A concave lens is used to correct myopia to help focus images on the retina (*top right*). Farsightedness, or hyperopia, occurs when objects are focused in back of the retina (*bottom left*). It is corrected with a convex lens (*bottom right*).

Generally, nearsightedness first occurs in school-age children. There is some evidence that myopia is inherited. If one or both of your parents need glasses, there is an increased chance that you will too. Individuals who spend a lot of time reading, working or playing at a computer, or doing other close visual work may also be more likely to develop nearsightedness. Because the eye continues to grow during childhood, myopia typically progresses until about age 20. However, nearsightedness may also develop in adults due to visual stress or health conditions such as diabetes. A common sign of nearsightedness is difficulty seeing distant objects like a movie screen or the TV, or the whiteboard or chalkboard in school. Eyeglasses or contact lenses can easily help with myopia. Depending on the amount of myopia, you may only need to wear glasses or contact lenses for certain activities, like watching a movie or driving a car. Or, if you are very nearsighted, they may need to be worn all the time.

Farsightedness

Farsightedness is also known as **hyperopia** . It affects about one fourth of people. People with hyperopia can see distant objects clearly, but nearby objects appear blurry. In hyperopia, the eye is too short. This results in images being focused in back of the retina (**Figure** above). Hyperopia is corrected with a **convex** lens, which curves outward like the outside of a bowl. The lens changes the focus so that images fall on the retina as they should. Common signs of farsightedness include difficulty in concentrating and maintaining a clear focus on close objects, eye strain, fatigue and headaches after close work, and aching or burning eyes, especially after intense concentration on close work. In addition to lenses, many cases of myopia and hyperopia can be corrected with surgery. For example, a procedure called LASIK (Laser-Assisted in situ Keratomileusis) uses a laser to permanently change the shape of the cornea so light is correctly focused on the retina.

Summary

- Vision problems such as myopia and hyperopia can be corrected with lenses that help focus light on the retina.
- Myopia is corrected with a concave lens, while hyperopia is corrected with a convex lens.

Explore More

Use the resources below to answer the questions that follow.

Explore More I

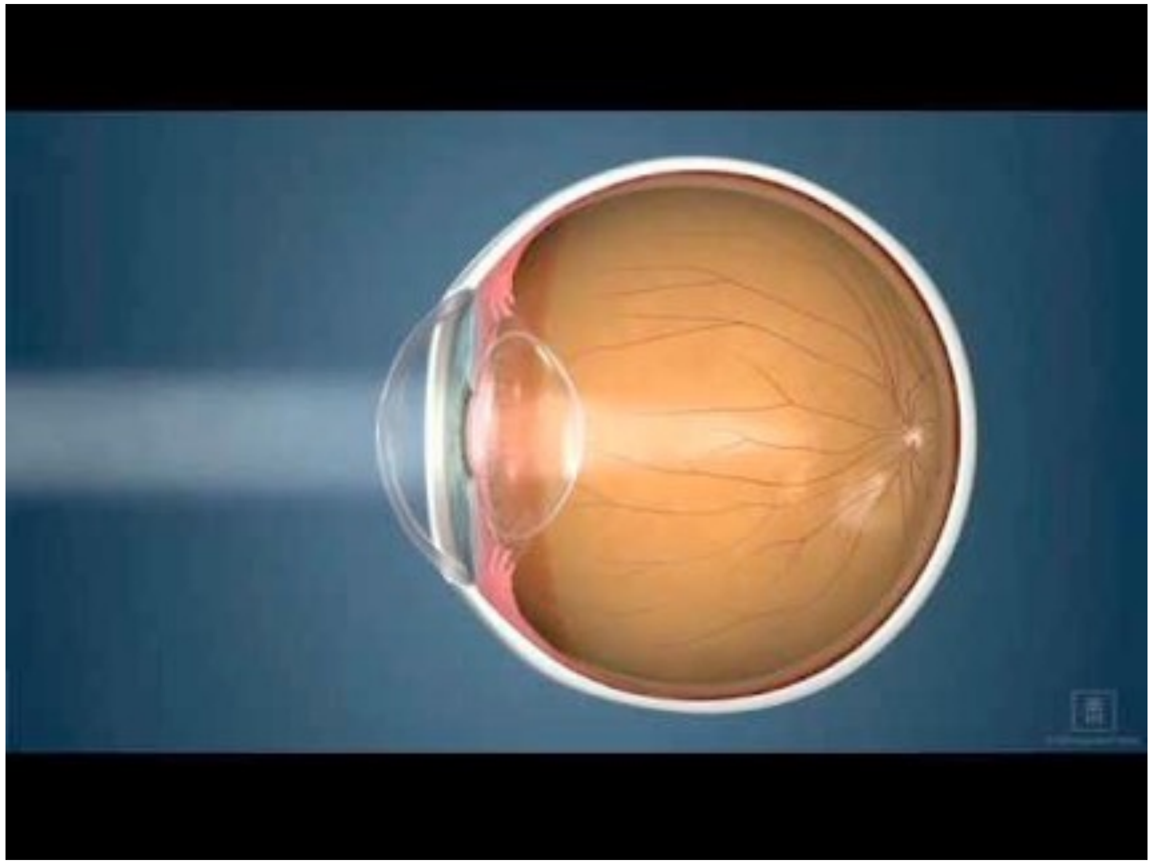
- **Myopia, Hyperopia, and Astigmatism Explained** at http://www.youtube.com/watch?v=6YxffFmi4Eo (1:55)

Click on the image above for more content

1. How can the shape of your eyeball cause you to be farsighted? How does this affect your focal point?
2. How can the shape of your eyeball cause you to be nearsighted? How does this affect your focal point?
3. How can an irregularly formed cornea affect your vision?

Explore More II

- **Nearsighted, Farsighted, and Reading Vision** at http://www.youtube.com/watch?v=iws1Mfu1k84 (1:39)



Click on the image above for more content

1. What is myopia? If you had this condition, when might you wear glasses?
2. What is hyperopia? If you had this condition, when might you wear glasses?
3. If you had an astigmatism, when might you wear glasses?
4. At what age do many people start needing reading glasses? What causes this condition?

Review

1. Describe vision in people with myopia.
2. What is hyperopia, and what type of lens corrects it?
3. What causes myopia, and what type of lens corrects it?
4. What are common signs of nearsightedness?
5. What are common signs of farsightedness?

Section 47

Hearing and Balance

Hearing and Balance

•Describe the hammer, anvil, and stirrup.
•Explain the steps involved in hearing.
•Describe how balance is maintained.

Feeling dizzy?

Have you ever gotten off a spinning ride at an amusement park and felt dizzy? Why does this happen? It actually all goes back to your ears! When you stop spinning, the fluid in the canals of your ears is still moving. Sensing the position of the liquid in the canals usually helps you keep balance, so spinning the fluid throws you off balance.

Hearing and Balance

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

Hearing

Hearing is the ability to sense sound. Sound travels through the air in waves, much like the waves you see in the water pictured below (**Figure** below). Sound waves in air cause vibrations inside the ears. The ears sense the vibrations.

Figure 11.91

Sound waves travel through the air in all directions away from a sound, like waves traveling through water away from where a pebble was dropped.

The human ear is pictured below (**Figure** below). As you read about it, trace the path of sound waves through the ear. Assume a car horn blows in the distance. Sound waves spread through the air from the horn. Some of the sound waves reach your ear. The steps below show what happens next. They explain how your ears sense the sound.

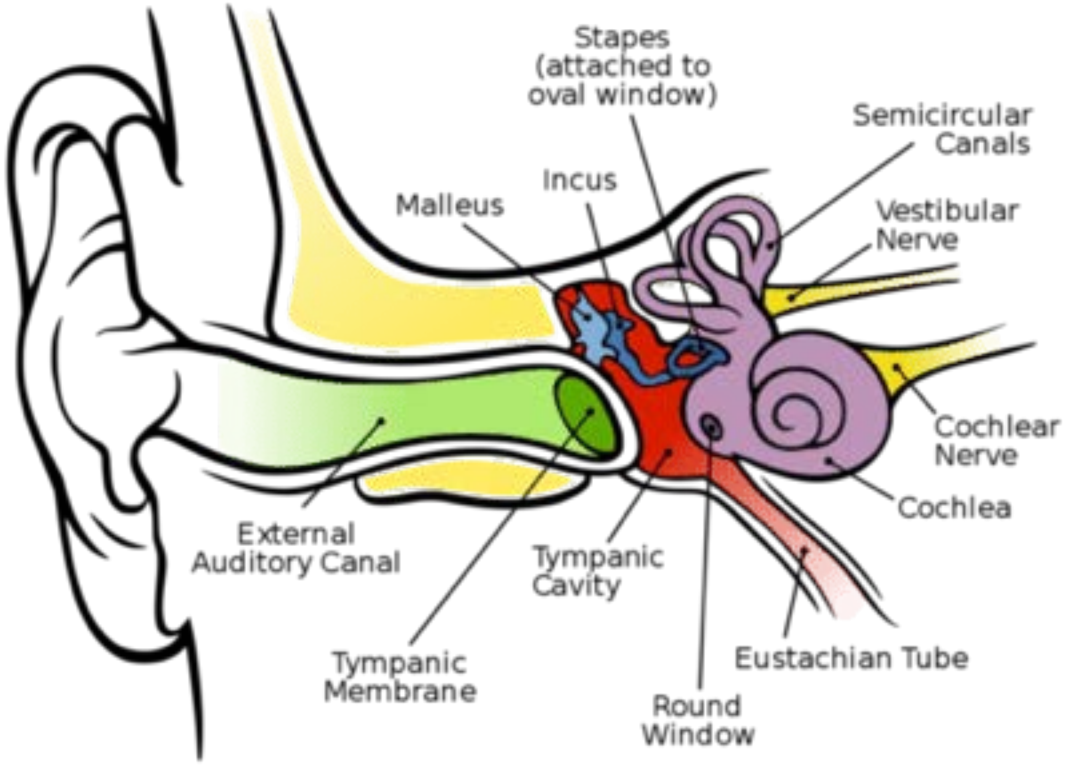


Figure 11.92

Read the names of the parts of the ear in the text; then find each of the parts in the diagram. Note that the round window is distinct from the oval window.

1.The sound waves travel to the **ear canal** (*external auditory canal* in the figure). This is a tube-shaped opening in the ear.
2.At the end of the ear canal, the sound waves hit the **eardrum** (*tympanic membrane*). This is a thin membrane that vibrates like the head of a drum when sound waves hit it.
3.The vibrations pass from the eardrum to the **hammer** (*malleus*). This is the first of three tiny bones that pass vibrations through the ear.

4. The hammer passes the vibrations to the **anvil** (*incus*), the second tiny bone that passes vibrations through the ear.
5. The anvil passes the vibrations to the **stirrup** (*stapes*), the third tiny bone that passes vibrations through the ear.
6. From the stirrup, the vibrations pass to the **oval window** . This is another membrane like the eardrum.
7. The oval window passes the vibrations to the **cochlea** . The cochlea is filled with liquid that moves when the vibrations pass through, like the waves in water when you drop a pebble into a pond. Tiny hair cells line the cochlea and bend when the liquid moves. When the hair cells bend, they release neurotransmitters.
8. The neurotransmitters trigger nerve impulses that travel to the brain through the auditory nerve (*cochlear nerve*). The brain reads the sound and "tells" you what you are hearing.

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

Balance

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

Figure 11.93

This gymnast is using the semicircular canals in her ears, along with the cerebellum in her brain, to help keep her balance on the balance beam.

The parts of the ears involved in balance are the **semicircular canals** . Above, the semicircular canals are colored purple (**Figure** above). The canals contain liquid and are like the bottle of water pictured below (**Figure** below). When the bottle tips, the water surface moves up and down the sides of the bottle. When the body tips, the liquid in the semicircular canals moves up and down the sides of the canals. Tiny hair cells line the semicircular canals. Movement of the liquid inside the canals causes the hair cells to send nerve impulses. The nerve impulses travel to the cerebellum in the brain along the vestibular nerve. In response, the cerebellum sends commands to muscles to contract or relax so that the body stays balanced.

Figure 11.94

This bottle of water models the semicircular canals in your ears. When you tip the bottle, the water moves up or down the sides of the bottle; when you tip your head, the liquid inside the semicircular canals moves up and down the sides of the canals. Tiny hair cells lining the canals sense the movement of liquid and send messages to the brain.

Summary

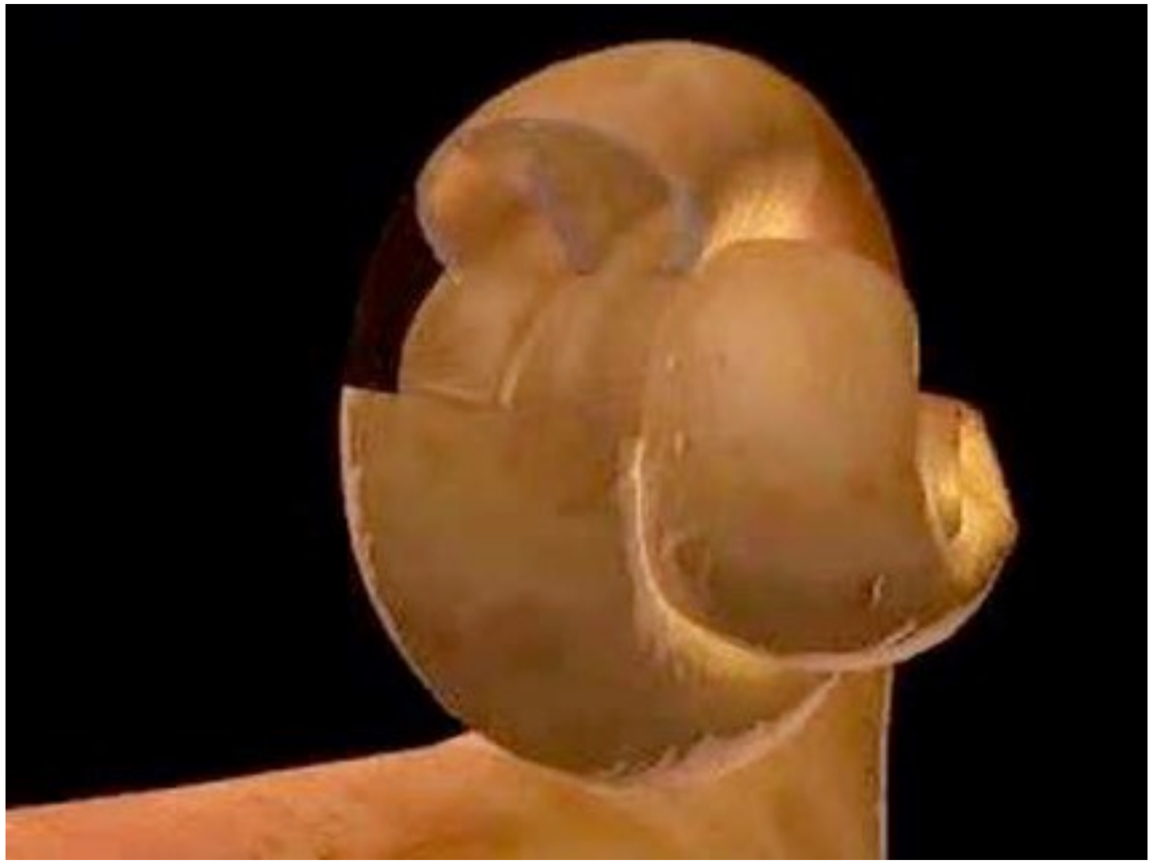
1.At the end of the ear canal, sound waves hit the eardrum, which passes vibrations through a series of bones to the cochlea.
2.The parts of the ears involved in balance are the semicircular canals.

Explore More

Use the resources below to answer the questions that follow.

Explore More I

•**Hearing and Balance** at http://www.youtube.com/watch?v=vTiGskc1o48 (1:02)

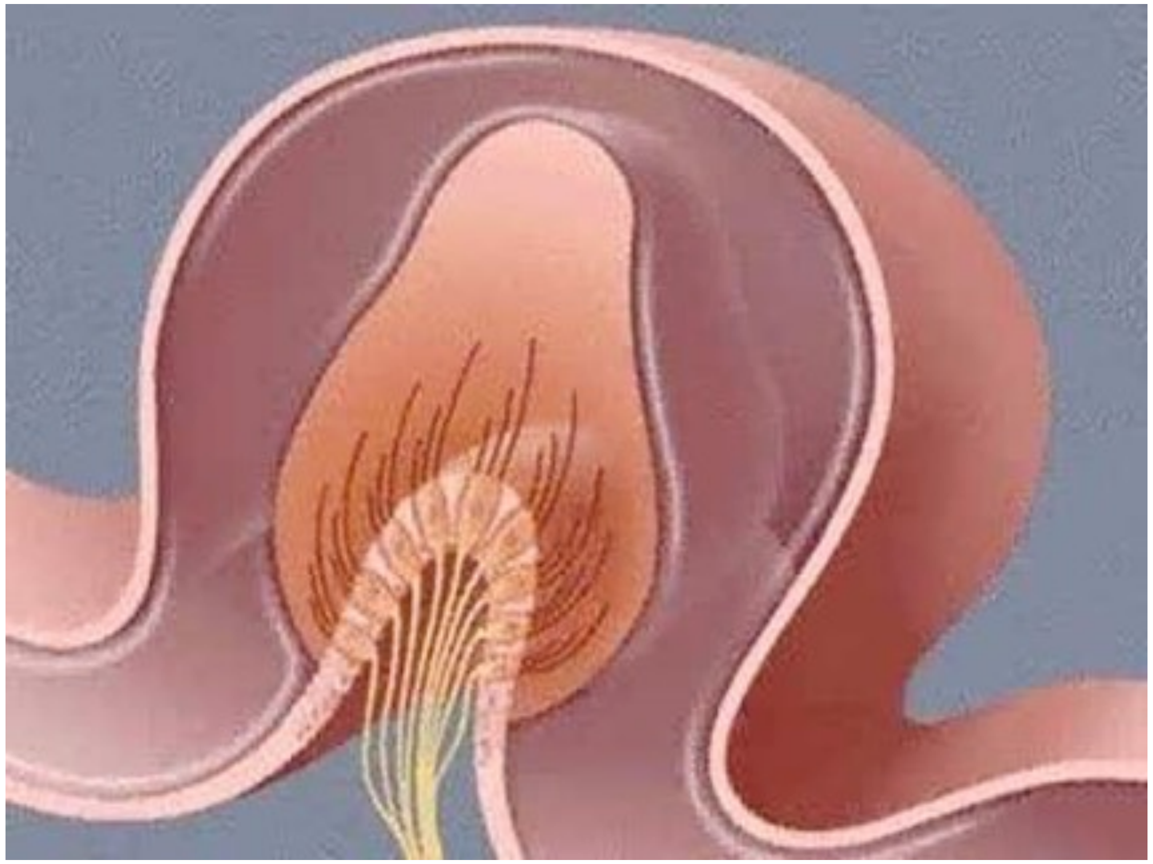


Click on the image above for more content

1. When sound enters your ear, it starts your eardrum vibrating. Where do the vibrations go next?
2. What part of your ear contains fluid?
3. Where are the nerve sensors that communicate with the brain located in your ear? What else is found in this same area of the ear?

Explore More II

- **The Sense of Balance** at http://www.youtube.com/watch?v=mmBB2bu1gEQ



Click on the image above for more content

1. What gives us our sense of balance?
2. What is a kinocilium? How is this involved in your sense of balance?

Review

1. How does sound travel through air?
2. Which structure in the ear changes sound waves in the air into vibrations?
3. What are the three tiny bones in the ear?
4. Which parts of the ear sense changes in the body's position? How do they do this?

5.Why does death of hair cells in the cochlea cause hearing loss?

Section 48

Touch

Touch

•Describe touch.
•Explain a reflex arc.
•Distinguish between mechanoreceptors, thermoreceptors, pain receptors, and proprioceptors.

What if you felt no pain?

It might sound good to you to have a condition where you feel no pain. But actually this type of condition would be very dangerous. What would happen if you strained your back but felt no pain? Instead of resting your back, you might injure it further.

Touch

When you look at the prickly cactus pictured below (**Figure** below), does the word "ouch" come to mind? Touching the cactus would be painful. **Touch** is the sense of pain, pressure, or temperature. Touch depends on sensory **neurons** , or nerve cells, in the skin. The skin on the palms of the hands, soles of the feet, and face has the most sensory neurons and is especially sensitive to touch. The tongue and lips are very sensitive to touch as well. Neurons that sense pain are also found inside the body in muscles, joints, and organs. If you have a stomach ache or pain from a sprained ankle, it's because of these sensory neurons found inside of your body.

Figure 11.95

The spines on this cactus are like needles; they help keep away animals that might want to eat the cactus.

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

In some cases, messages about pain or temperature don't travel all the way to and from the brain. Instead, they travel only as far as the spinal cord, and the spinal cord responds to the messages by giving orders to the muscles. This allows you to respond to pain more quickly. When messages avoid the brain in this way, it forms a **reflex arc** , like the one shown below (**Figure** below).

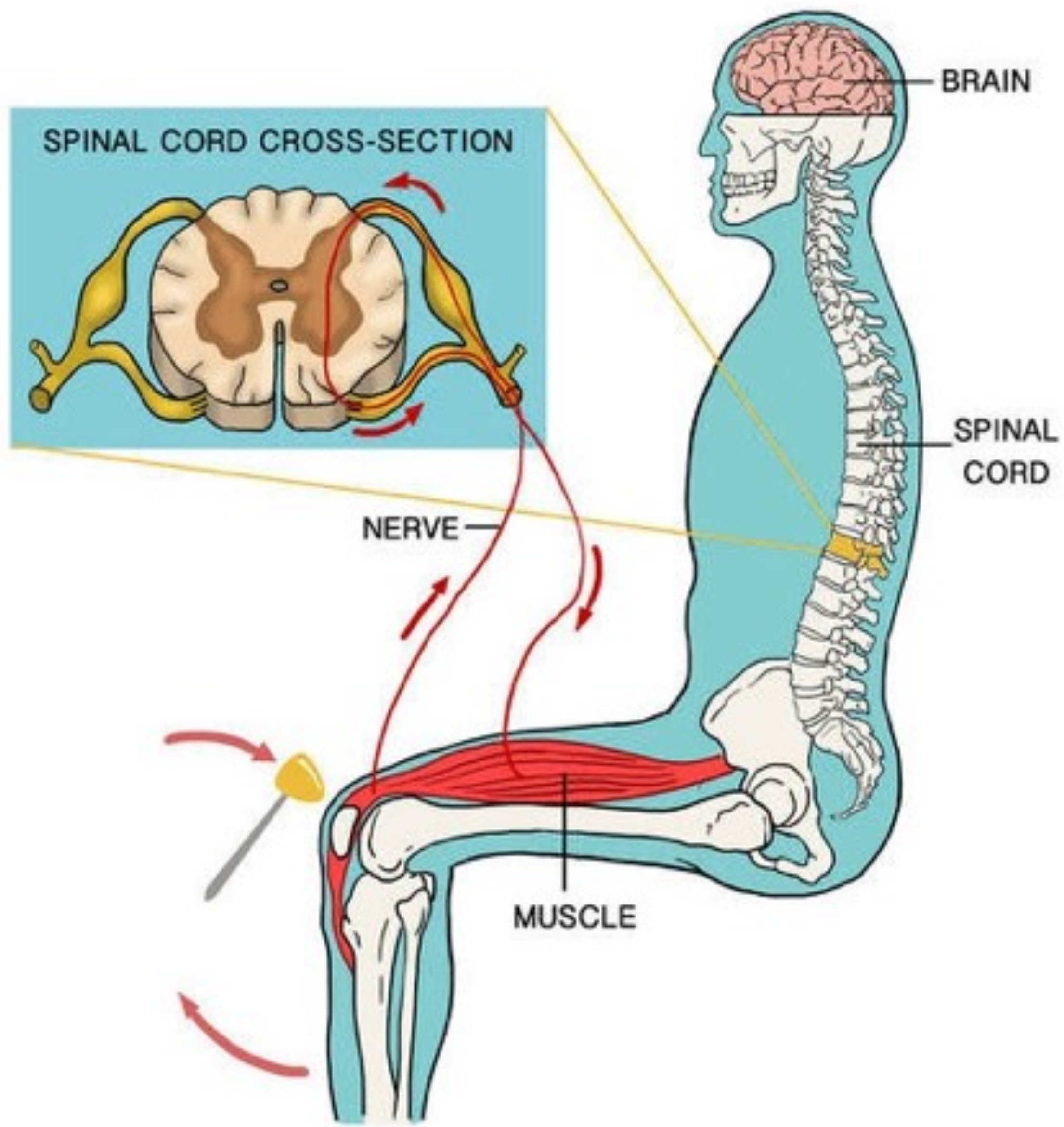


Figure 11.96

Reflex Arc: When a reflex hammer taps your knee, you may immediately kick your leg—without even thinking about it. The nerve impulse from your knee travels to the spinal cord, and the spinal cord sends a message to your muscles to kick your leg.

Touch Receptors

Our sense of touch is controlled by a huge network of nerve endings and touch receptors. This system is responsible for all the sensations we feel, including cold, hot, smooth, rough, pressure, tickle, itch, pain, vibrations, and more. There are four main types of receptors: mechanoreceptors, thermoreceptors, pain receptors, and proprioceptors.

•Mechanoreceptors perceive sensations such as pressure, vibrations, and texture. Your brain gets an enormous amount of information about the texture of objects through your fingertips because the ridges that make up your fingerprints are full of these sensitive receptors.
•Thermoreceptors perceive sensations related to the temperature of objects. There are two basic categories of thermoreceptors: hot receptors and cold receptors. The highest concentration of thermoreceptors can be found in the face and ears.
•Pain receptors, or nociceptor detect pain or stimuli that can or does cause damage to the skin and other tissues of the body. There are over three million pain receptors throughout the body, found in skin, muscles, bones, blood vessels, and some organs.
•Proprioceptors detect the position of different parts of the body in relation to each other and the surrounding environment. These receptors are found in joints, tendons and muscles, and allow us to do fundamental things such as feeding or clothing ourselves.

Summary

•Sensory neurons in the skin sense pain, pressure, and temperature.

•When sensory messages only travel as far as the spinal cord, and skip the brain, this is called a reflex arc.

Explore More

Use the resources below to answer the questions that follow.

•**Human Senses** at http://www.youtube.com/watch?v=Ajw_WJYxAAI (1:05)

Click on the image above for more content

1. What do touch receptors detect?
2. How do receptors communicate with the brain?
3. What happens in the somatic sensory system after a stimulus triggers a receptor?

Review

1. What is touch?
2. Where are touch neurons found?
3. Imagine you touch a smooth stone. How is this sensation transmitted to your brain?
4. How and why do reflex arcs occur?
5. What is the role of mechanoreceptors? Where are these receptors found?

Section 49

Taste and Smell

Taste and Smell

- Describe how we identify different tastes and smells.
- Describe the five tastes.

Why are your senses of taste and smell important?

Imagine you open a gallon of milk, and you suddenly smell a foul odor. Your sense of smell has informed you that the milk has spoiled. So you pour the spoiled milk down the kitchen sink. Your sense of smell has possibly kept you from getting sick!

Taste and Smell

The senses of taste and smell are more complicated than many people might think and have a surprisingly large impact on behavior, perception and overall health. Imagine your sense of smell disappearing as you age. Though this doesn't usually happen, it could provide clues about diseases of the nervous system. What about differences in taste? Do all foods taste the same to all people? Are there some foods you would never eat because you don't like the taste? Does this food taste good to other people? Genetic differences in taste could help predict what we eat, how well our metabolism works, and even whether or not we're overweight. These two senses actually work together to provide some of the basic sensations of everyday life.

Taste

Your sense of taste is controlled by sensory **neurons** , or nerve cells, on your tongue that sense the chemicals in food. The neurons are grouped in bundles within **taste buds** . Each taste bud actually has a pore that opens out to the surface of the tongue enabling molecules and ions taken into the mouth to reach the receptor cells inside. There are five different types of taste neurons on the tongue. Each type detects a different taste. The tastes are:

1. Sweet, which is produced by the presence of sugars, such as the common table sugar sucrose, and a few other substances.
2. Salty, which is produced primarily by the presence of sodium ions. Common salt is sodium chloride, NaCl. The use of salt can donate the sodium ion producing this taste.
3. Sour, which is the taste that detects acidity. The most common food group that contains naturally sour foods is fruit, such as lemon, grape, orange, and sometimes melon. Children show a greater enjoyment of sour flavors than adults, and sour candy such as Lemon Drops, Shock Tarts and sour versions of Skittles and Starburst, is popular. Many of these candies contain citric acid.
4. Bitter is an unpleasant, sharp, or disagreeable taste. Common bitter foods and beverages include coffee, unsweetened cocoa, beer (due to hops), olives, and citrus peel.
5. **Umami** , which is a meaty or savory taste. This taste can be found in fish, shellfish, cured meats, mushrooms, cheese, tomatoes, grains, and beans.

A single taste bud contains 50–100 taste cells representing all 5 taste sensations. A stimulated taste receptor cell triggers action potentials in a nearby sensory neuron, which send messages to the brain about the taste. The brain then decides what tastes you are sensing.

Smell

Your sense of smell also involves sensory neurons that sense chemicals. The neurons are found in the nose, and they detect chemicals in the air. Unlike taste neurons, which can detect only five different tastes, the sensory neurons in the nose can detect thousands of different odors. Have you ever noticed that you lose your sense of taste when your nose is stuffed up? That’s because your sense of smell greatly affects your ability to taste food. As you eat, molecules of food chemicals enter your nose (actually your nasal cavity). You experience the taste and smell at the same time. Being able to smell as well as taste food greatly increases the number of different flavors you are able to sense. For example, you can use your sense of taste alone to learn that a food is sweet, but you have to also use your sense of smell to learn that the food tastes like strawberry cheesecake.

Specific scents are often associated with our memories of places and events. That's because scents are more novel or specific than shapes or other things you might see. So an odor similar to that of your grandmother's kitchen or pantry might be more quickly associated with your memories of that place than a similar sight, which might be more generalized.

Summary

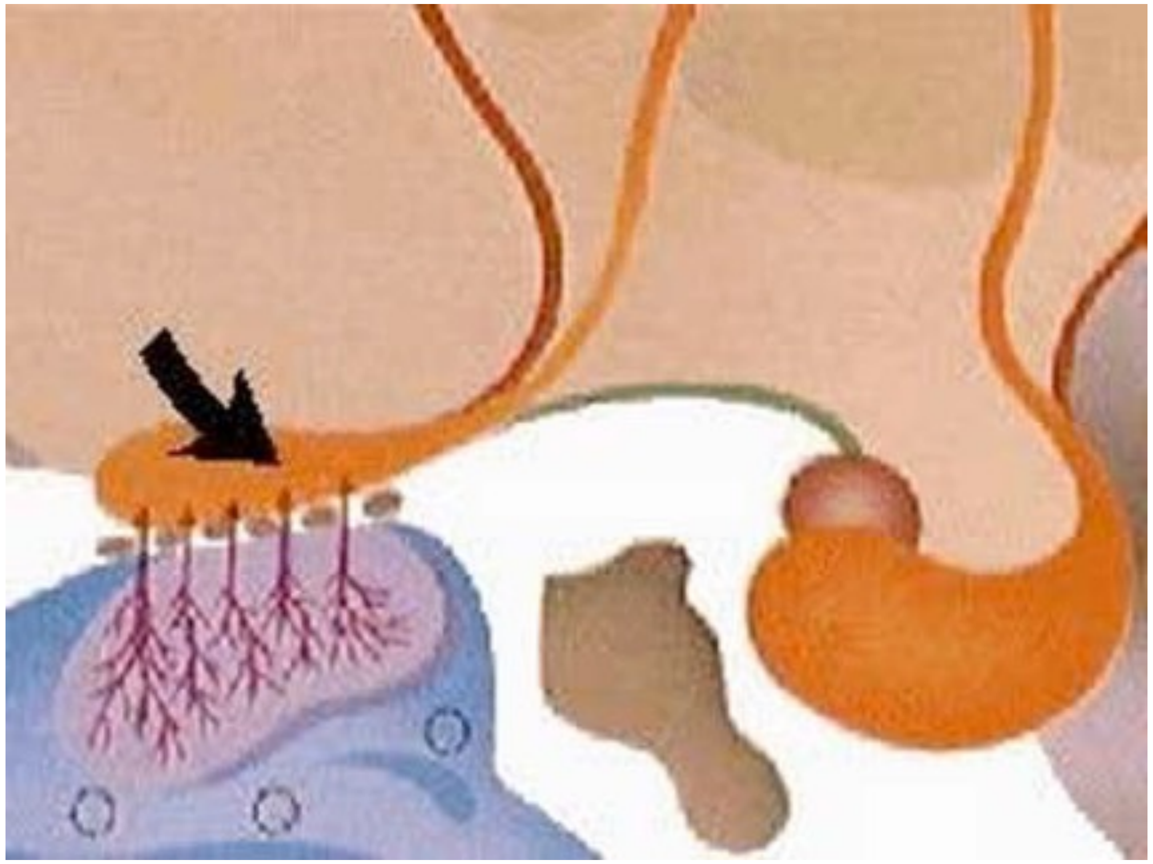
- •Sensory neurons on the tongue detect five types of tastes: sweet, salty, sour, bitter, and umami.
- •Sensory neurons that sense chemicals in your nose allow you to detect smells.

Explore More

Use the resources below to answer the questions that follow.

Explore More I

- •**The Olfactory Pathway** at http://www.youtube.com/watch?v=pM7H0Wud_Y0 (0:30)

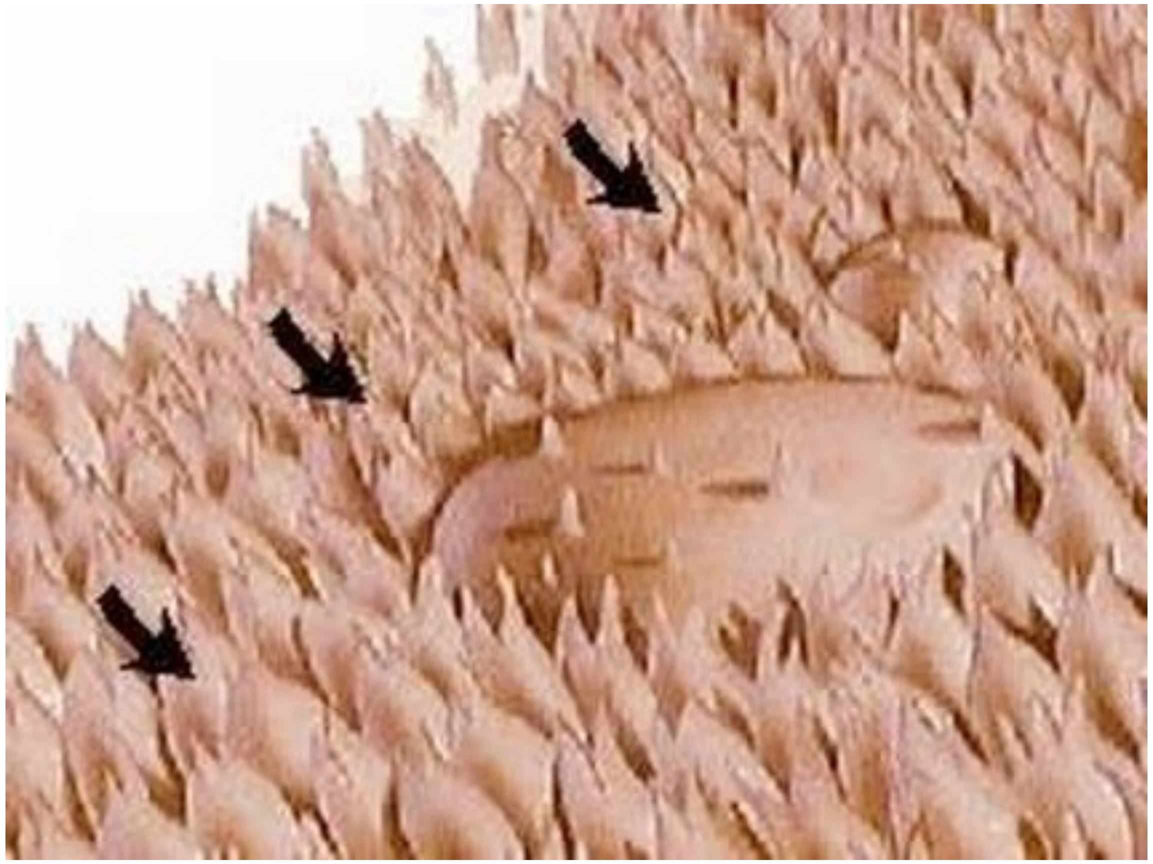


Click on the image above for more content

1. What is the function of the olfactory cortex?
2. What stimulates the olfactory sensors in the nose?

Explore More II

- •**Taste Centers** at http://www.youtube.com/watch?v=RIXtM2u--H8 (1:12)



Click on the image above for more content

1. What covers the surface of the tongue?
2. What four types of sensors can be found on the tongue? Are these distributed evenly over the tongue?
3. How does stimulation of the taste buds stimulate the salivary glands?

Explore More III

- **Sense of Taste and Smell** at http://www.youtube.com/watch?v=N42c52lCQNc (2:14)

Click on the image above for more content

1. What is the function of the taste pore?
2. What is at the end of the receptor cells for taste?
3. What do the olfactory receptors have that the taste receptors also have?

Review

1. What controls the sense of taste?
2. What are the five tastes sensed by neurons on the tongue?
3. Why is your sense of taste affected when you have a stuffy nose?

Section 50

Diseases of the Nervous Sys-

Diseases of the Nervous System

- •Describe diseases of the nervous system.
- •Explain encephalitis and meningitis.
- •Describe cerebral palsy and epilepsy.
- •Summarize causes and symptoms of multiple sclerosis, Parkinson's disease and Alzheimer's disease.

Why get vaccinations?

Like this girl, many people are a little afraid of needles. But this is no reason to avoid vaccinations. Vaccinations can help you avoid serious diseases. For example, a vaccination to prevent meningitis, a serious infection of the nervous system, is now available.

Diseases of the Nervous System

The nervous system controls sensing, feeling, and thinking. It also controls movement and just about every other body function. That's why problems with the nervous system can affect the entire body. Diseases of the nervous system include brain and spinal cord infections. Other problems of the nervous system range from very serious diseases, such as tumors, to less serious problems, such as tension headaches. Some of these diseases are present at birth. Others begin during childhood or adulthood.

Central Nervous System Infections

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

Encephalitis

Encephalitis is a brain infection (**Figure** below). If you have encephalitis, you are likely to have a fever and headache or feel drowsy and confused. The disease is most often caused by viruses. The immune system tries to fight off a brain infection, just as it tries to fight off other infections. But sometimes this can do more harm than good. The immune system's response may cause swelling in the brain. With no room to expand, the brain pushes against the skull. This may injure the brain and even cause death. Medicines can help fight some viral infections of the brain, but not all infections.

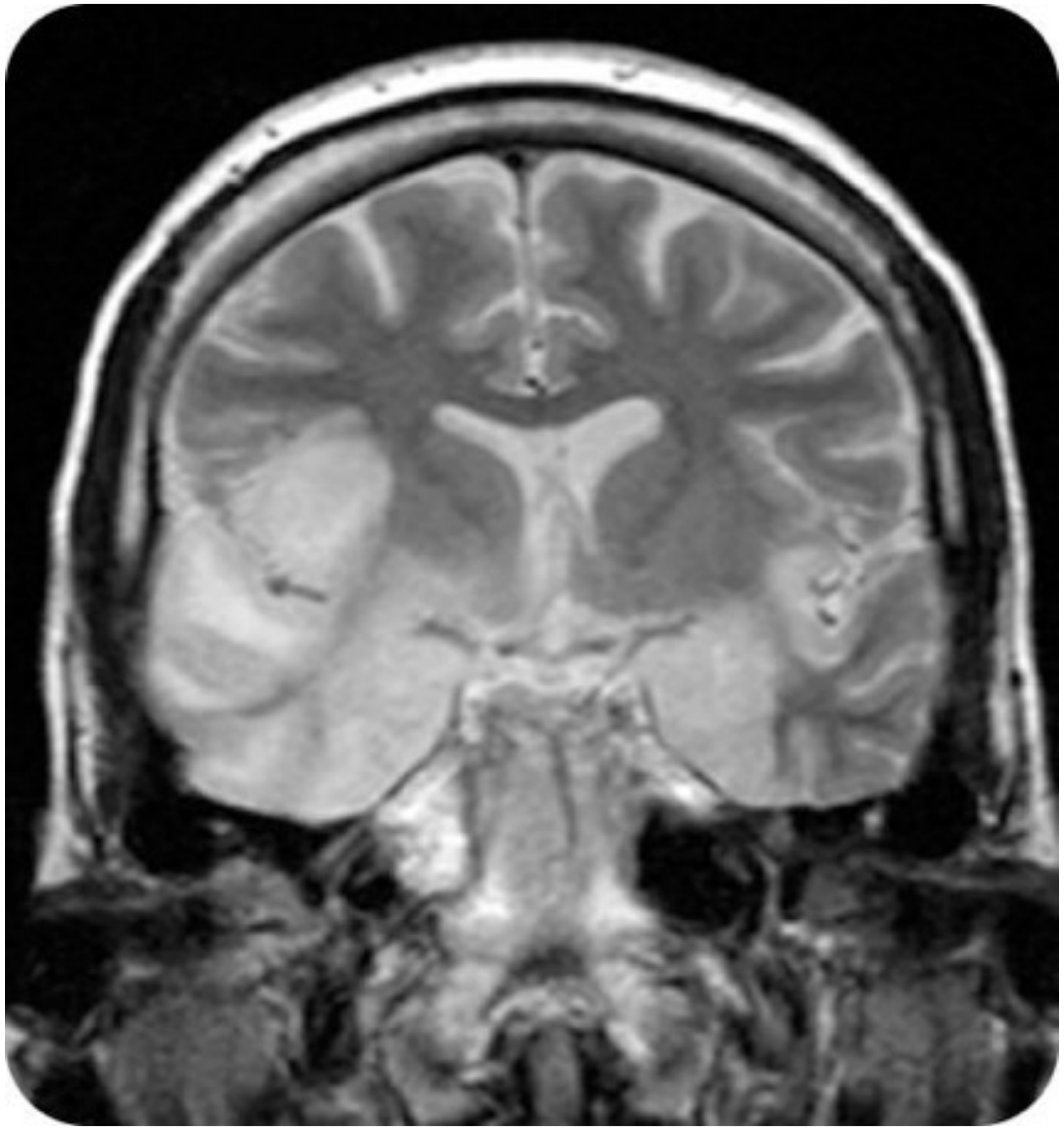


Figure 11.97

This scan shows a person with encephalitis.

Meningitis

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

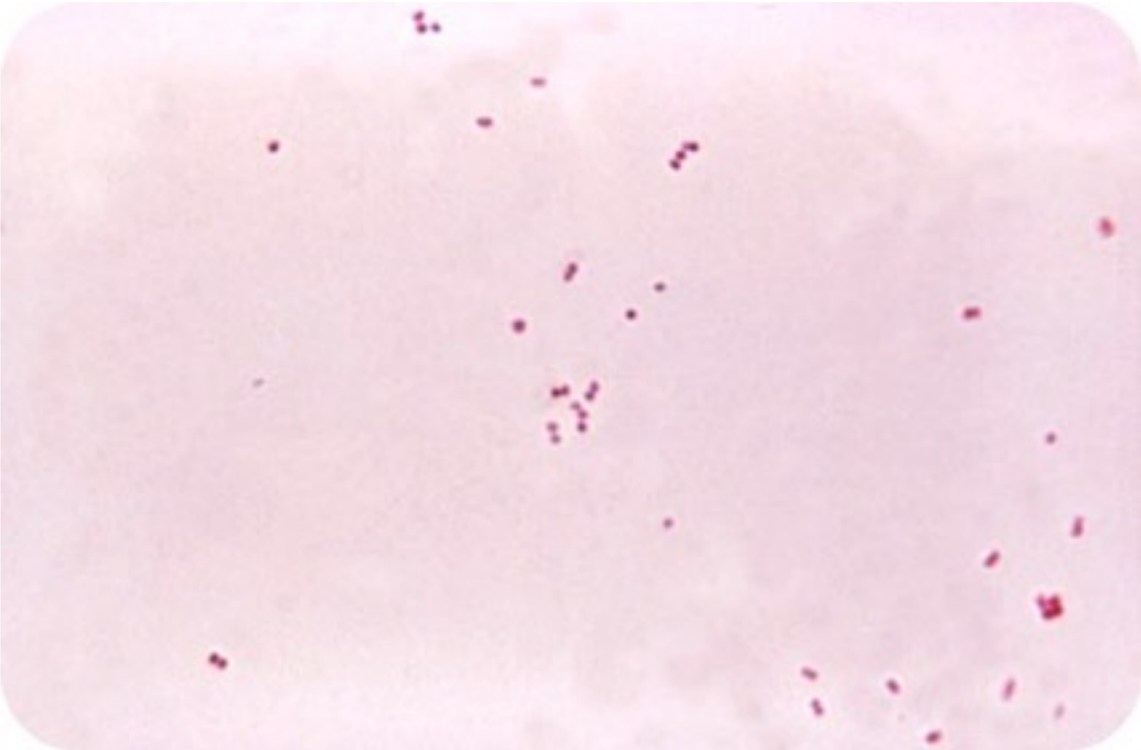


Figure 11.98

These bacteria, shown at more than 1,000 times their actual size, are the cause of bacterial meningitis. Despite their tiny size, they can cause very serious illness.

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

Reye's Syndrome

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

Figure 11.99

Since 1988, the U.S. Food and Drug Administration has required that all aspirin and aspirin-containing products carry a warning about Reye's syndrome.

Other Nervous System Diseases

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

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

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

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

Figure 11.100

Sometimes relaxation is the best "medicine" for a tension headache and to help muscles get rid of pain.

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

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

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

Summary

- The nervous system can be affected by infections, such as encephalitis or meningitis.
- Other nervous system diseases include tumors, cerebral palsy, epilepsy, and migraines.

Explore More

Use the resource below to answer the questions that follow.

- **Neurological Disorders** at http://www.youtube.com/watch?v=7ivWFEyiahg (9:14)

Click on the image above for more content

1. What are three examples of neurological disorders?
2. What kinds of deficits can neurological disorders cause?
3. How does blood supply affect strokes?
4. List three signs of a TIA.
5. What is the affect of multiple sclerosis? What body systems are involved?

Review

1. What is meningitis? What are the symptoms? What should you do if you have these symptoms?
2. What is cerebral palsy? What are its symptoms?
3. Compare and contrast tension headaches and migraine headaches.
4. Explain why young people should not take aspirin when they have the flu, which is caused by viruses.

Section 51

Injuries of the Nervous Sys-

Injuries of the Nervous System

•Explain how the nervous system can be injured.
•Define concussion.
•List symptoms of a severe brain injury.
•Describe what to do if you suspect that someone has a back or neck injury.

No diving?

Make sure you always heed the advice of signs that say "no diving." Diving in shallow water can lead to serious injuries to your nervous system.

Injuries of the Nervous System

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

Brain Injuries

Brain injuries can range from mild to extremely severe, but even mild injuries need medical attention. Brain injuries can result from falls, car accidents, violence, sports injuries, and war and combat. Falls are the most common cause of brain injuries, particularly in older adults and young children.

The mildest and most common type of brain injury is a **concussion** . This is a bruise on the surface of the brain. It may cause temporary problems such as headache, drowsiness, and confusion. Most concussions in young people occur when they are playing sports, especially contact sports like football. Other sports, like soccer, boxing, baseball, lacrosse, skateboarding, and hockey can also result in concussions. A concussion normally heals on its own in a few days.

A single concussion is unlikely to cause permanent damage. But repeated concussions may lead to lasting problems. People who have had two or more concussions may have life-long difficulties with memory, learning, speech, or balance. For this reason, concussions are treated very seriously among athletes and in professional sports. You can see an animation of how a concussion occurs by visiting http://www.pennmedicine.org/encyclopedia/em_DisplayAnimation.aspx?gcid=000034&ptid=17 .

A person with a serious brain injury usually suffers permanent brain damage. These brain injuries usually occur when an external mechanical force, such as a violent blow or jolt to the head or body, causes brain dysfunction. An object penetrating the skull, such as a bullet or a shattered piece of the skull, also can cause traumatic brain injury. As a result, the person may have trouble talking or controlling body movements. Symptoms depend on what part of the brain was injured. Serious brain injuries can also cause personality changes and problems with mental abilities such as memory. Medicines, counseling, and other treatments may help people with serious brain injuries recover from, or at least learn to cope with, their disabilities.

Symptoms of severe brain injuries include

- the loss of consciousness from several minutes to hours,
- profound confusion,
- slurred speech,
- the inability to awaken from sleep,
- seizures,
- loss of coordination,
- persistent headache or headache that worsens.

Spinal Cord Injuries

A spinal cord injury is damage to any part of the spinal cord or nerves at the end of the spinal canal. This injury often causes permanent changes in strength, sensation and other body functions below the site of the injury.

Spinal cord injuries make it difficult for messages to travel between the brain and body. They may cause a person to lose the ability to feel or move parts of the body. This is called **paralysis** . Whether paralysis occurs—and what parts of the body are affected if it does—depends on the location and seriousness of the injury. In addition to car crashes and sports injuries, diving accidents are a common cause of spinal cord injuries. Quadriplegia means your arms, hands, trunk, legs and pelvic organs are all affected by your spinal cord injury. Paraplegia means the paralysis affects all or part of the trunk, legs and pelvic organs. These people can still use their arms and hands.

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

Figure 11.101

Former "man of steel" *Superman* star Christopher Reeve (September 25, 1952 – October 10, 2004) was paralyzed from the neck down in a fall from a horse. The injury crushed his spinal cord so his brain could no longer communicate with his body.

If you suspect that someone has a back or neck injury:

- don't move the injured person as permanent paralysis and other serious complications may result,
- call 911 or your local emergency medical assistance number,
- keep the person very still,
- place heavy towels on both sides of the neck or hold the head and neck to prevent them from moving, until emergency care arrives,
- provide basic first aid, such as stopping any bleeding and making the person comfortable, without moving the head or neck.

Summary

- Mild brain injuries, such as a concussion, normally heal on their own, while serious brain injuries can cause permanent physical and mental disabilities.
- Spinal cord injuries can lead to paralysis, when a person loses the ability to feel or move parts of the body.

Explore More

Use the resource below to answer the questions that follow.

- **Nerve Pain and Nerve Damage** at http://www.webmd.com/brain/nerve-pain-and-nerve-damage-symptoms-and-causes

1. What are the symptoms of damage to motor nerves?
2. What are the symptoms of damage to sensory nerves?
3. List five causes of nerve pain or damage.

Review

1. What is the most common brain injury?
2. What are some possible consequences of a serious brain injury?
3. List three symptoms of a serious brain injury.
4. Explain what causes paralysis.

5.If a back or neck injury is expected, the most
important thing not to do to a person is __________.

Section 52

Keeping the Nervous Sys-

Keeping the Nervous System Healthy

•List ways to keep the nervous system healthy.
•List safe behaviors that will help keep your nervous system safe.

Do you like doing puzzles?

Activities that challenge your brain, such as working on a Sudoku puzzle, are good for the health of your nervous system. Just like you need to work out your body to stay in shape, your brain also needs a good work out regularly in order to stay sharp.

Keeping the Nervous System Healthy

The nervous system is such an important part of your body. You want it to work at its best so that you can be at your best. Your nervous system contains what is probably the most important part of your body, which, of course, is your brain. Your brain allows you to learn. It allows you to feel emotions like love, anger, and sadness. Your brain gives you the ability to see, hear, taste, touch, and smell. It works together with the nerves and spinal cord to send the signals that make your body move. Your nervous system lets you do things like run, jump, play sports, and do your homework.

There are many choices you can make to keep your nervous system healthy. One obvious choice is to avoid using alcohol or other drugs. Not only will you avoid the injury that drugs themselves can cause, but you will also be less likely to get involved in other risky behaviors that could harm your nervous system. Another way to keep the nervous system healthy is to eat a variety of healthy foods. The **minerals** sodium, calcium, and potassium, and **vitamins** B_1 and B_{12} are important for a healthy nervous system. Some foods that are good sources for these minerals and vitamins include milk, whole grains, beef steak, and kidney beans (shown in **Figure** below). Your brain also needs healthy fats like those in nuts and fish. Recall that fats insulate the axons of neurons. These fats help build new connections between nerves and brain cells. These fats may improve memory and increase learning and intelligence. Water is also important for the nervous system, so drink plenty of water and other fluids. This helps prevent dehydration, which can cause confusion and memory problems. And get plenty of rest. Your brain requires plenty of rest so it can strengthen circuits that help with memory. A good night's sleep will help keep your brain functioning at its best.

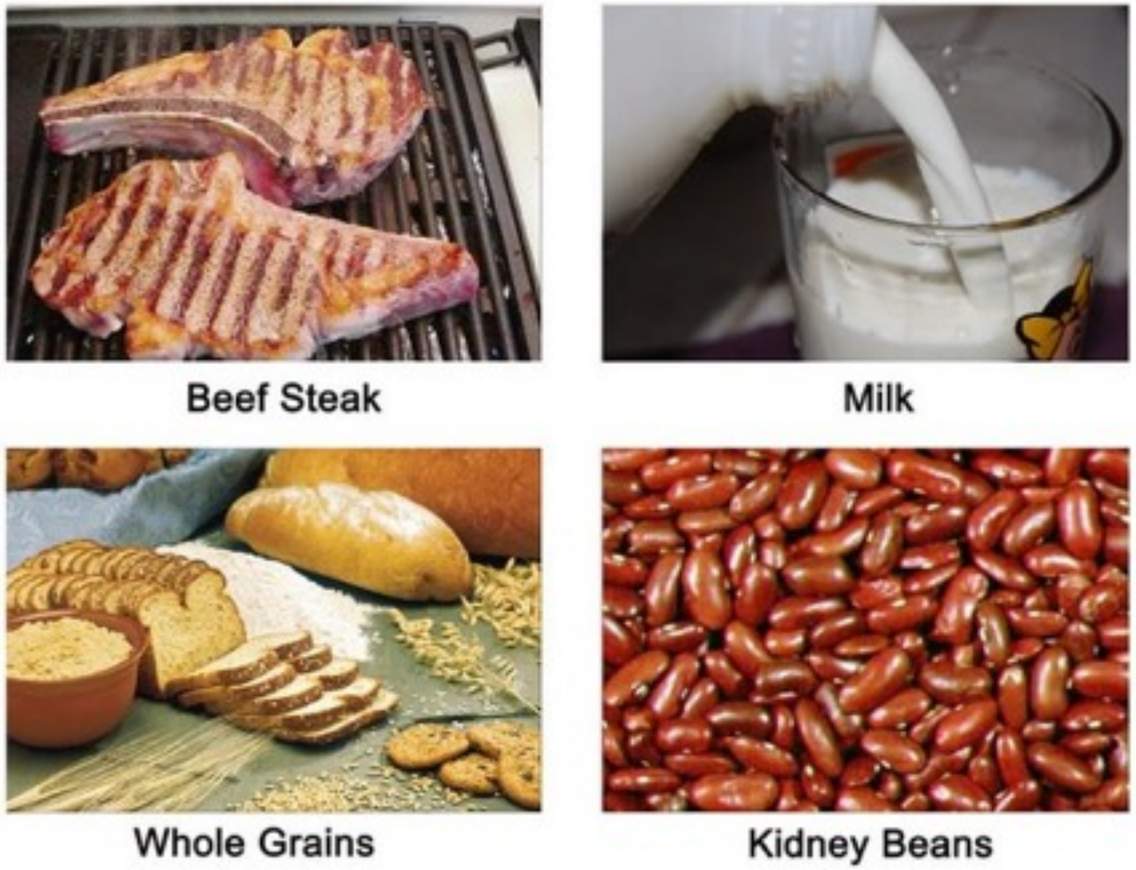


Figure 11.102

These foods are sources of nutrients needed for a healthy nervous system.

Daily physical activity is also important for nervous system health. Regular exercise makes your heart more efficient at pumping blood to your brain. As a result, your brain gets more oxygen, which it needs to function normally. The saying "use it or lose it" applies to your brain as well as your body. This means that mental activity, not just physical activity, is important for nervous system health. Doing crossword puzzles, reading, and playing a musical instrument are just a few ways you can keep your brain active.

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

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

Figure 11.103

Bicycle helmets help protect from head injuries. Making healthy choices like this can help prevent nervous system injuries that could cause lifelong disability.

Furthermore, make sure to exercise your nervous system on a daily basis. The simple act of writing requires that you use all the major components of your motor and sensory pathways. These include a number of different sensory receptors, peripheral nerves, synaptic connections within your spinal cord, major tracts within your spinal cord, and nerve tissue throughout your brain. All these components need to be utilized with great precision and coordination to produce neatly written words. What should you do? Spend a few minutes each day writing on paper as neatly as you can. This takes a lot more effort on the part of the nervous system than typing on a keyboard, as typing on a keyboard doesn't require as much fine motor control as writing on paper. If you don't want to write, then draw. Drawing with precision also requires use of all the major components of the sensory and motor divisions of the nervous system.

Summary

- The minerals, calcium and potassium, and vitamins B1 and B12 are important for a healthy nervous system.
- You can make choices that will help keep your nervous system healthy and safe, such as choosing to wear a bicycle helmet.

Explore More

Use the resource below to answer the questions that follow.

- **The First Key To Health—Your Nervous System** at http://www.youtube.com/watch?v=R6_CDcTLpVI (2:30)

Click on the image above for more content

1. How can the health of your nervous system affect all other body systems?
2. What kinds of problem might you experience if the nerve connection to your stomach were impaired?

Review

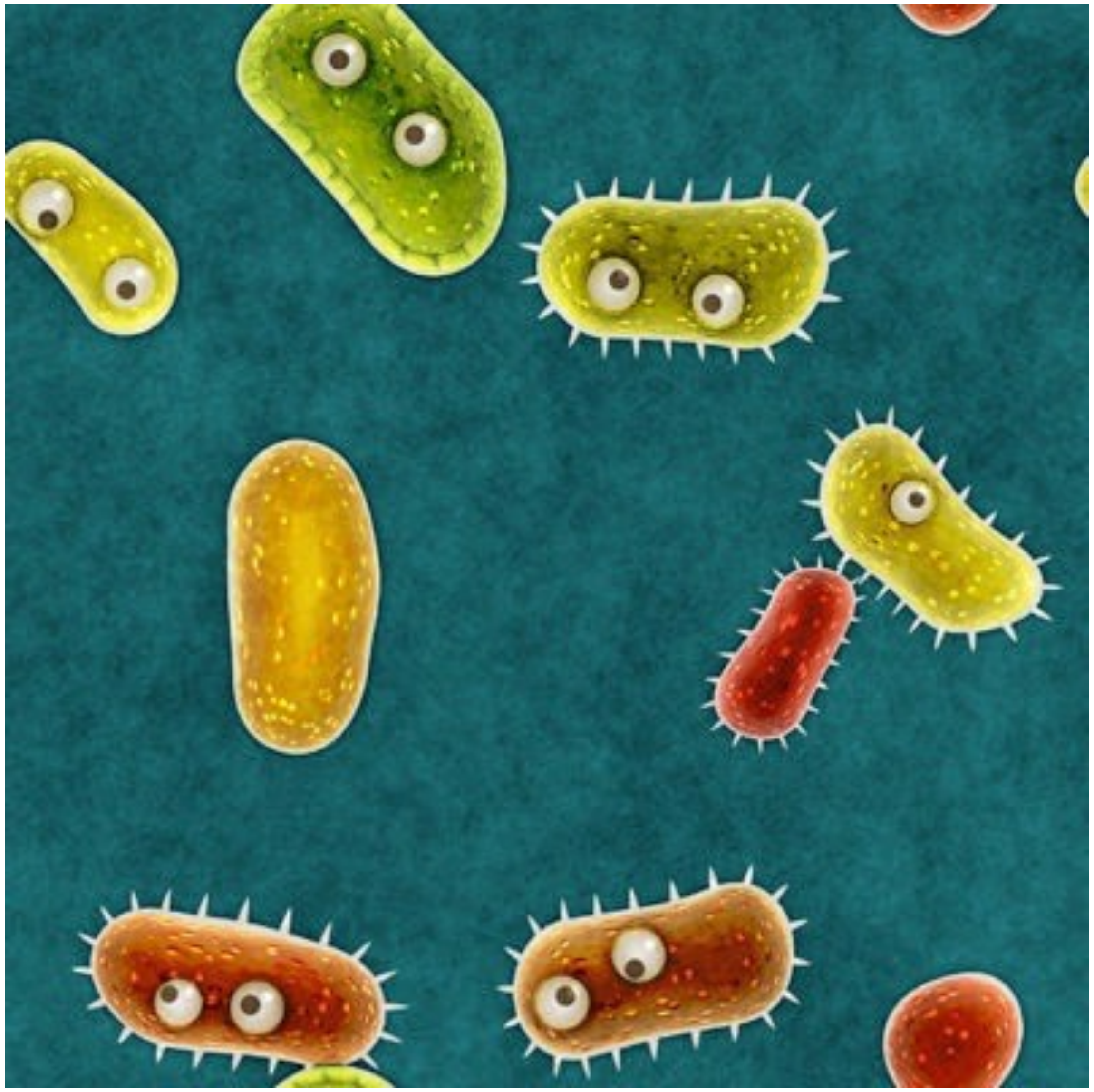
1. What types of foods are important for a healthy nervous system?
2. How do healthy fats help the nervous system?
3. Name two behaviors that protect your nervous system from injury.
4. How does an activity such as writing exercise the nervous system?

Section 53

Pathogens

Pathogens

•Define infectious disease and pathogen.
•List common causes of infectious diseases.
•Distinguish between a bacterium, a protozoa, and a fungi.
•Discuss how infectious diseases are spread.



What are germs?

You know germs can make you sick. They can live anywhere, from on your doorknob to in your food. A more scientific word for germ is pathogen.

Pathogens

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

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

Types of Pathogens

Living things that cause human diseases include bacteria, fungi, and protozoa. Most infectious diseases caused by these organisms can be cured with medicines. For example, medicines called antibiotics can cure most diseases caused by bacteria. Bacteria are one-celled organisms without a nucleus. Although most bacteria are harmless, some cause diseases.

Worldwide, the most common disease caused by bacteria is tuberculosis (TB). TB is a serious disease of the lungs. Another common disease caused by bacteria is strep throat. You may have had strep throat yourself. Bacteria that cause strep throat are shown below (**Figure** below). Some types of pneumonia and many cases of illnesses from food are also caused by bacteria.

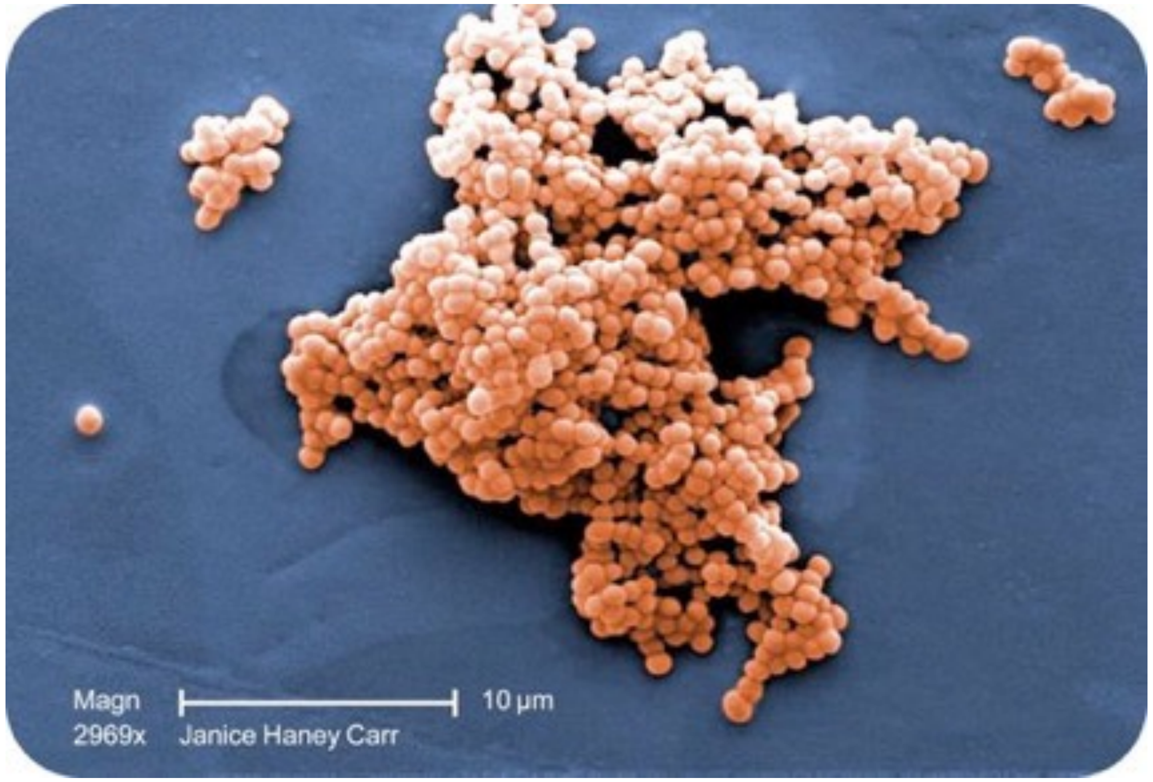


Figure 11.104

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

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

Figure 11.105

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

Protozoa are one-celled organisms with a nucleus. They cause diseases such as malaria. Malaria is a serious disease that is common in warm climates. The protozoa infect people when they are bit by a mosquito. More than a million people die of malaria each year. Other protozoa cause diarrhea. An example is *Giardia lamblia* (**Figure** below).

Figure 11.106

This picture shows a one-celled organism called *Giardia lamblia* . It is a protozoan that causes diarrhea.

Viruses are nonliving collections of protein and DNA that must reproduce inside of living cells. Viruses cause many common diseases. For example, viruses cause colds and the flu. Cold sores are caused by the virus *Herpes simplex* (**Figure** below). Antibiotics do not affect viruses, because antibiotics only kill bacteria. But medicines called antiviral drugs can treat many diseases caused by viruses.

Figure 11.107

The *Herpes simplex* virus, which is represented here, causes cold sores on the lips. Viruses are extremely small particles. This illustration is greatly magnified.

How Pathogens Spread

Different pathogens spread in different ways. Some pathogens spread through food. They cause food borne illnesses, which are discussed in a previous concept. Some pathogens spread through water. *Giardia lamblia* is one example. Water can be boiled to kill *Giardia* and most other pathogens.

Several pathogens spread through sexual contact. HIV is one example, which is discussed in the next concept. Other pathogens that spread through sexual contact are discussed in a separate concept.

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

Figure 11.108

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

Pathogens on Surfaces

Other pathogens spread when they get on objects or surfaces. A fungus may spread in this way. For example, you can pick up the fungus that causes athlete's foot by wearing shoes that an infected person has worn. You can also pick up this fungus from the floor of a public shower.

After acne, athlete's foot is the most common skin disease in the United States. Therefore, the chance of coming in contact with the fungus in one of these ways is fairly high.

Bacteria that cause the skin disease impetigo, which causes blisters, can spread when people share towels or clothes. The bacteria can also spread through direct skin contact in sports like wrestling.

Pathogens and Vectors

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

Figure 11.109

Some diseases are spread by insects. The type of mosquito shown here can spread West Nile virus. The virus doesn't make the mosquito sick. The mosquito just carries the virus from one person or animal to another. The mosquito is a vector.

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

Summary

- Infectious diseases are caused by bacteria, fungi, protozoa, or viruses that can travel from one person to another.
- Infectious diseases can be spread by a vector, an organism that carries pathogens from one person or animal to another.

Explore More

Use the resource below to answer the questions that follow.

- **Infectious Disease** at http://www.youtube.com/watch?v=oUMCKai3xp4 (5:00)

Click on the image above for more content

1. What is *Yersinia pestis* ? What disease does it cause?
2. What did Louis Pasteur discover about microorganisms?
3. What do pathogens have in common?
4. What are ectoparasites? How do they differ from endoparasites?
5. What group of fungi cause many diseases?

Review

1. What is a pathogen?
2. What is the most common disease caused by bacteria?
3. Give two examples of human diseases caused by fungi.
4. Name a serious disease caused by protozoa.
5. Explain why using insect repellent reduces your risk of developing Lyme disease.

Section 54

HIV and AIDS

HIV and AIDS

- •Explain how the virus known as HIV causes AIDS.
- •Discuss how HIV is spread.
- •Summarize the effects of HIV in the immune system.
- •Describe AIDS.

What does a red ribbon symbolize?

This red ribbon is a symbol for support of HIV-positive people and those living with AIDS. As of 2010, an estimated 34 million people are living with HIV worldwide.

HIV Infection and AIDS

HIV , or human immunodeficiency virus, causes AIDS. **AIDS** stands for "acquired immune deficiency syndrome." It is a condition that causes death and does not have a known cure. AIDS usually develops 10 to 15 years after a person is first infected with HIV. The development of AIDS can be delayed with proper medicines. The delay can be well over 20 years with the right medicines.

How HIV Spreads

HIV spreads through contact between an infected person's body fluids and another person's bloodstream or mucus membranes, which are found in the mouth, nose, and genital areas. Body fluids that may contain HIV are blood, semen, vaginal fluid, and breast milk. The virus can spread through sexual contact or shared drug needles. It can also spread from an infected mother to her baby during childbirth or breastfeeding. Saliva can carry the HIV virus, but it won't spread it, unless the saliva gets into the bloodstream. Other body fluids such as urine and sweat do not contain the virus.

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

HIV is not transmitted by day-to-day contact in the workplace, schools, or social settings. HIV is not transmitted through shaking hands, hugging, or a casual kiss. You cannot become infected from a toilet seat, a drinking fountain, a door knob, dishes, drinking glasses, food, or pets.

HIV and the Immune System

How does an HIV infection develop into AIDS? HIV destroys white blood cells called **helper T cells** . The cells are produced by the immune system. This is the body system that fights infections and other diseases.

HIV invades helper T cells and uses them to produce more virus particles (**Figure** below). Then, the virus kills the helper T cells. As the number of viruses in the blood rises, the number of helper T cells falls. Without helper T cells, the immune system is unable to protect the body. The infected person cannot fight infections and other diseases because they do not have T cells. This is why people do not die from HIV. Instead, they die from another illness, like the common cold, that they cannot fight because they do not have helper T cells.

Medications can slow down the increase of viruses in the blood. But the medications cannot remove the viruses from the body. At present, there is no cure for HIV infection. A vaccine against HIV could stop this disease, and such a vaccine is in development, though it could take many years before it can be given to prevent this virus.

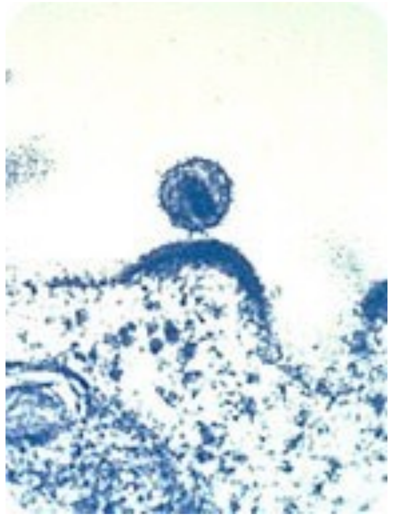


Figure 11.110

In this picture, the large structure on the bottom is a human immune cell. It is infected with HIV. A new HIV particle is shown budding out of the immune cell.

AIDS

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

The first known cases of AIDS occurred in 1981. Since then, AIDS has led to the deaths of more than 35 million people worldwide. Many of them were children. The greatest number of deaths occurred in Africa. It is also where medications to control HIV are least available. There are currently more people infected with HIV in Africa than any other part of the world. Well over 30 million people are living with HIV worldwide.

Summary

- •HIV causes AIDS by destroying disease-fighting cells produced by the immune system.
- •HIV spreads through contact between an infected person's body fluids and another person's bloodstream or mucus membranes; body fluids that may contain HIV include blood, semen, vaginal fluid, and breast milk.

Explore More

Use the resources below to answer the questions that follow.

Explore More I

•**HIV Replication** at http://www.youtube.com/watch?v=RO8MP3wMvqg (5:13)

Click on the image above for more content

1. What are the steps of HIV infection and replication?
2. How can understanding all the steps of infection help develop treatments to HIV?
3. What does HIV inject into a cell?
4. What enzymes does HIV supply to the host cell?

Explore More II

•**HIV Immunity** at http://www.pbs.org/wgbh/evolution/library/10/4/quicktime/l_104_06.html

1. Not all people show the same vulnerability to HIV infection. What did scientists do when they first found indications that this was the case?
2. How can studying people with natural resistance to HIV help develop treatments?

Review

1. How does an HIV infection develop into AIDS?
2. Explain why AIDS does not kill people but causes other illnesses to kill people infected with HIV.
3. What body fluids from an infected person may contain HIV?
4. What body fluids from an infected person do not contain HIV?

Preventing Infectious Dis-

Preventing Infectious Diseases

- State and describe how infectious diseases can be prevented.

What is this girl doing to prevent the spread of the flu?

Notice how this girl is covering her nose and mouth with a tissue as she sneezes. This is a good habit that helps prevent her from passing on the flu virus to other people. Notice she is also staying home and resting instead of going out and possibly infecting others with her illness.

Preventing Infectious Diseases

Infectious diseases are diseases that spread from person to person. They are caused by pathogens such as bacteria, viruses or fungi. What can you do to avoid infectious diseases? Eating right and getting plenty of sleep are a good start. These habits will help keep your immune system healthy. With a healthy immune system, you will be able to fight off many pathogens. The next best way is to avoid pathogens. Though this is difficult, there are steps you can take to limit your exposure to pathogens.

Here are the ten best ways to prevent the spread of infectious diseases.

1. Wash your hands frequently.
2. Don't share personal items.
3. Cover your mouth when you cough or sneeze.
4. Get vaccinated.
5. Use safe cooking practices.
6. Be a smart traveler.
7. Practice safe sex.
8. Don’t pick your nose (or your mouth or eyes either).
9. Exercise caution with animals.
10. Watch the news, and be aware of disease outbreaks.

Avoiding Pathogens

You can also take steps to avoid pathogens in the first place. The best way to avoid pathogens is to wash your hands often. You should wash your hands after using the bathroom or handling raw meat or fish. You should also wash your hands before eating or preparing food. In addition, you should also wash the food that your eat, and the utensils and countertop where food is prepared. In addition, you should wash your hands after being around sick people. The correct way to wash your hands is demonstrated below (**Figure** below). If soap and water aren't available, use some hand sanitizer.

Figure 11.111

This picture shows the proper way to wash your hands. Frequent hand washing helps prevent the spread of pathogens.

The best way to prevent diseases spread by vectors is to avoid contact with the vectors. Recall that a vector is an organism that carries pathogens from one person or animal to another. For example, ticks and mosquitoes are vectors, so you should wear long sleeves and long pants when appropriate to avoid tick and mosquito bites. Using insect repellent can also reduce your risk of insect bites.

Many infectious diseases can be prevented with vaccinations. Immunization can drastically reduce your chances of contracting many diseases. You will read more about vaccinations in another concept. Vaccinations can help prevent measles, mumps, chicken pox, and several other diseases.

If you do develop an infectious disease, try to avoid infecting others. Stay home from school until you are well. Also, take steps to keep your germs to yourself. Cover your mouth and nose with a tissue when you sneeze or cough, and wash your hands often to avoid spreading pathogens to other people. Don't go to work or school if you're vomiting, have diarrhea or are running a fever. Also, to avoid infectious diseases, don't share personal items; use your own toothbrush, comb, and razor. And avoid sharing drinking glasses or dining utensils.

Watching the news will allow you to make informed decisions. If an outbreak of bad beef due to a bacterial infection is in the news, don't buy beef for a while. If tomatoes are making people sick, don't eat tomatoes until the outbreak is over. If a place has an unhealthy water supply, boil the water or drink bottled water. Local news can tell you of restaurants to avoid due to unhealthy conditions. And so on.

Summary

- A healthy lifestyle and frequent hand washing can help reduce your risk of infectious diseases.
- To avoid infecting others when you are sick, stay home from school, cover your mouth and nose with a tissue when you sneeze or cough, and wash your hands often.

Explore More

Use the resources below to answer the questions that follow.

Explore More I

- **Preventing the Spread of Disease (1940)** at http://www.youtube.com/watch?v=uIATPuz12nc (10:49)

Click on the image above for more content

1. What is a communicable disease?
2. What are some pathways by which germs can pass from one person to another person?

Explore More II

- **Disease Prevention: It's in Your Hands** at http://www.youtube.com/watch?v=s0zCzuKiYu4 (2:32)

Click on the image above for more content

1. Why is hand washing effective in preventing the spread of some diseases?
2. How long should you wash your hands to help prevent the spread of disease?

Review

1. What are infectious diseases? What causes infectious diseases?
2. What is the single most important way to avoid pathogens?
3. How can you avoid infecting others when you are sick?

Section 56

Cancer

Cancer

•Define cancer, mutation, and tumor.
•Describe causes of cancer.
•List warning signs of cancer.

Why is tanning bad for your health?

It might be fun to lay out in the sun like these two girls are doing. But getting too much sun can be very dangerous. Overexposure to sunlight raises your risk for skin cancer.

Cancer

Cancer is a disease that causes cells to divide out of control. Normally, the body has systems that prevent cells from dividing out of control. But in the case of cancer, these systems fail. Cancer is usually caused by mutations. **Mutations** are random errors in genes. Mutations that lead to cancer usually happen to genes that control the cell cycle. Because of the mutations, abnormal cells divide uncontrollably. This often leads to the development of a tumor. A **tumor** is a mass of abnormal tissue. As a tumor grows, it may harm normal tissues around it. Anything that can cause cancer is called a **carcinogen** . Carcinogens may be pathogens, chemicals, or radiation.

Pathogens

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

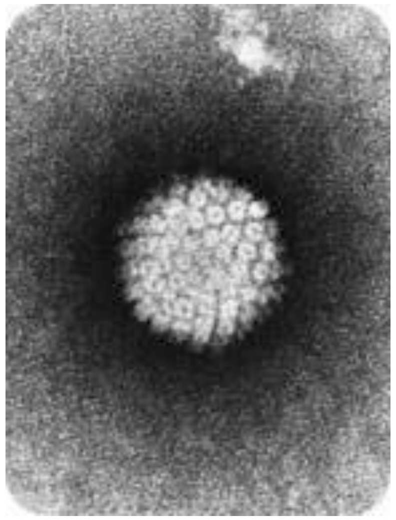


Figure 11.112

The mutations that cause cancer may occur when people are exposed to pathogens, such as the human papilloma virus (HPV), which is shown here.

Chemicals

Many different chemical substances cause cancer. Dozens of chemicals in tobacco smoke, including nicotine, have been shown to cause cancer (**Figure** below). In fact, tobacco smoke is one of the main sources of chemical carcinogens. Smoking tobacco increases the risk of cancer of the lung, mouth, throat, and bladder. Using smokeless tobacco can also cause cancer. Other chemicals that cause cancer include asbestos, formaldehyde, benzene, cadmium, and nickel.

Figure 11.113

The mutations that cause cancer may occur when people are exposed to chemical carcinogens, such as those in cigarettes.

Radiation

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

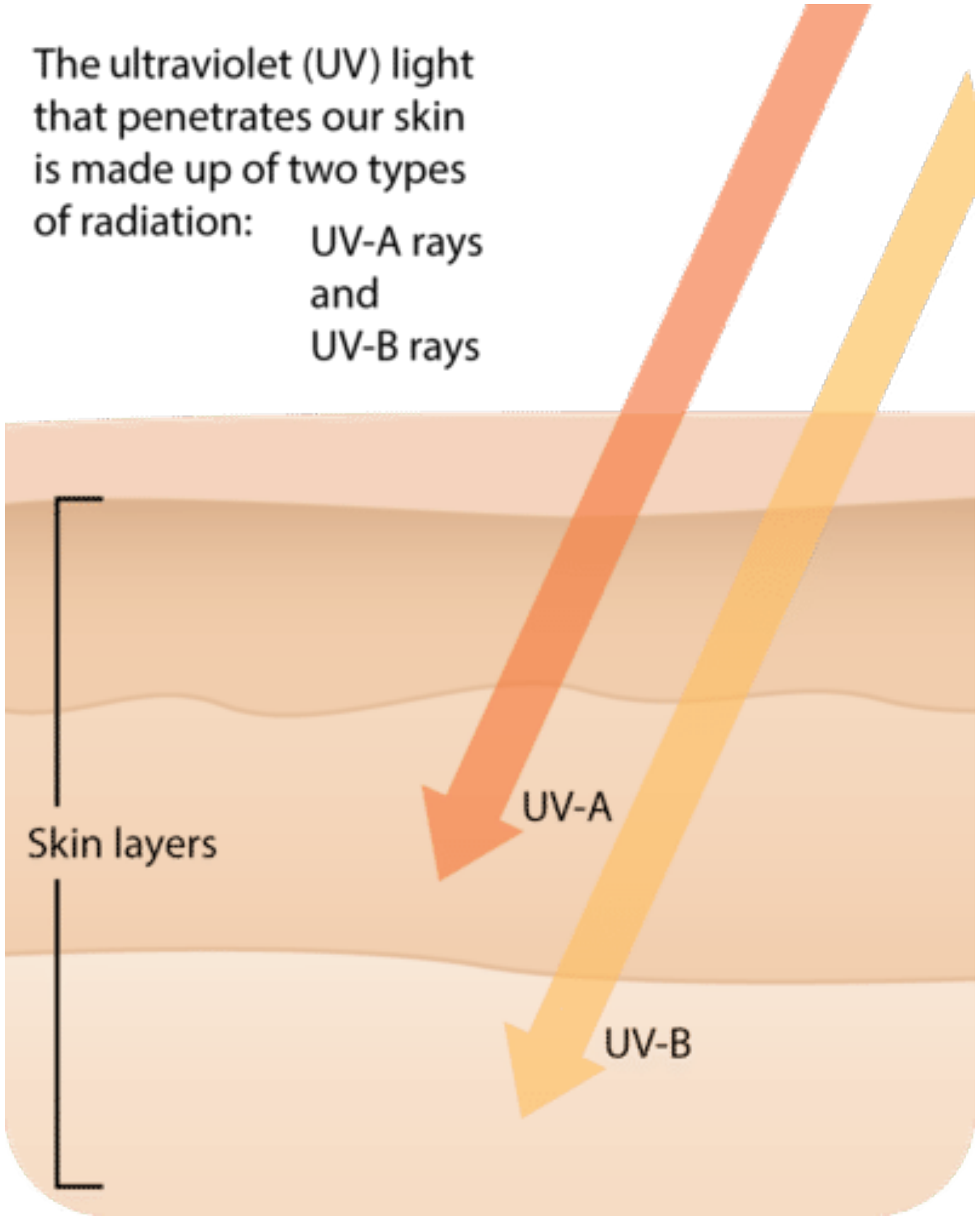


Figure 11.114

The mutations that cause cancer may occur when people are exposed to radiation, including the radiation from sunlight.

Common Types of Cancer

Cancer is usually found in adults, especially in adults over the age of 50. The most common type of cancer in adult males is cancer of the prostate gland. The prostate gland is part of the male reproductive system. Prostate cancer makes up about one third of all cancers in men. The most common type of cancer in adult females is breast cancer. It makes up about one third of all cancers in women. In both men and women, lung cancer is the second most common type of cancer. Most cases of lung cancer happen in people who smoke.

Cancer can also be found in children. But childhood cancer is rare. Leukemia is the main type of cancer in children. It makes up about one third of all childhood cancers. It happens when the body makes abnormal white blood cells.

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

Treating Cancer

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

The sooner cancer is treated, the greater the chances of a cure. This is why it is important to know the warning signs of cancer. Having warning signs does not mean that you have cancer. However, you should see a doctor to be sure. Everyone should know the warning signs of cancer. Detecting and treating cancer early can often lead to a cure. Some warning signs of cancer include:

- Change in bowel or bladder habits.
- Sores that do not heal.
- Unusual bleeding or discharge.
- Lump in the breast or elsewhere.
- Chronic indigestion.
- Difficulty swallowing.
- Obvious changes in a wart or mole.
- Persistent cough or hoarseness.

Summary

- Cancer is caused by mutations, which can be caused by pathogens, chemicals, or radiation.
- Cancer can be treated with surgery, drugs, and radiation.

Explore More

Use the resources below to answer the questions that follow.

Explore More I

- **How Cancer Cells Grow and Divide** at http://www.teachersdomain.org/asset/tdc02_vid_oncogene/

1. What is an oncogene?
2. How do receptors made by oncogenes differ from "normal" receptor cells?
3. How does cancer spread through the blood stream?

Explore More II

- **How Cancer Grows and Spreads** at http://www.pbs.org/wgbh/nova/body/how-cancer-grows.html

1. How are genetic mutations thought to affect the formation of cancer? What is the result of this process?
2. Cancer cells continuously divide. How does this affect the mutation rates of the cells?
3. What is angiogenesis? How does this help cancer spread?

Review

1. Define carcinogen and give three examples.
2. Explain how mutations can lead to cancer.
3. What type of cancers are associated with chemicals in cigarettes?
4. What type of cancer may be caused by UV radiation?
5. List four signs of cancer.

Section 57

Diabetes

Diabetes

- •Define diabetes.
- •Explain causes of diabetes.
- •Distinguish type 1 diabetes from type 2 diabetes.
- •List common symptoms and complications of diabetes.

What do these foods have in common?

These foods are all high in sugar. A person with diabetes has to avoid these types of foods.

Diabetes

Diabetes is a non-infectious disease in which the body is unable to control the amount of sugar in the blood. People with diabetes have high blood sugar, either because their bodies do not produce enough insulin, or because their cells do not respond to insulin. **Insulin** is a hormone that helps cells take up sugar from the blood. Without enough insulin, the blood contains too much sugar. This can damage blood vessels and other cells throughout the body. The kidneys work hard to filter out and remove some of the extra sugar. This leads to frequent urination and excessive thirst.

There are two main types of diabetes, type 1 diabetes and type 2 diabetes. Type 1 diabetes makes up about 5-10% of all cases of diabetes in the United States. Type 2 diabetes accounts for most of the other cases. Both types of diabetes are more likely in people that have certain genes. Having a family member with diabetes increases the risk of developing the disease.

Either type of diabetes can increase the chances of having other health problems. For example, people with diabetes are more likely to develop heart disease and kidney disease. Type 1 and type 2 diabetes are similar in these ways. However, the two types of diabetes have different causes.

Type 1 Diabetes

Type 1 diabetes occurs when the immune system attacks normal cells of the pancreas. Since the cells in the pancreas are damaged, the pancreas cannot make insulin. Type 1 diabetes usually develops in childhood or adolescence.

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

Figure 11.115

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

Type 2 Diabetes

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

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

Symptoms

Common symptoms of diabetes include the following:

- frequent urination
- feeling very thirsty
- feeling very hungry, even though you are eating
- extreme fatigue
- blurry vision
- cuts or bruises that are slow to heal
- weight loss, even though you are eating more (type 1)
- tingling, pain, or numbness in the hands or feet (type 2)

Complications

Complications of diabetes can include the following:

- •eye complications
- •foot complications
- •skin complications
- •high blood pressure
- •hearing issues
- •nerve damage
- •kidney disease
- •artery disease
- •stroke
- •stress

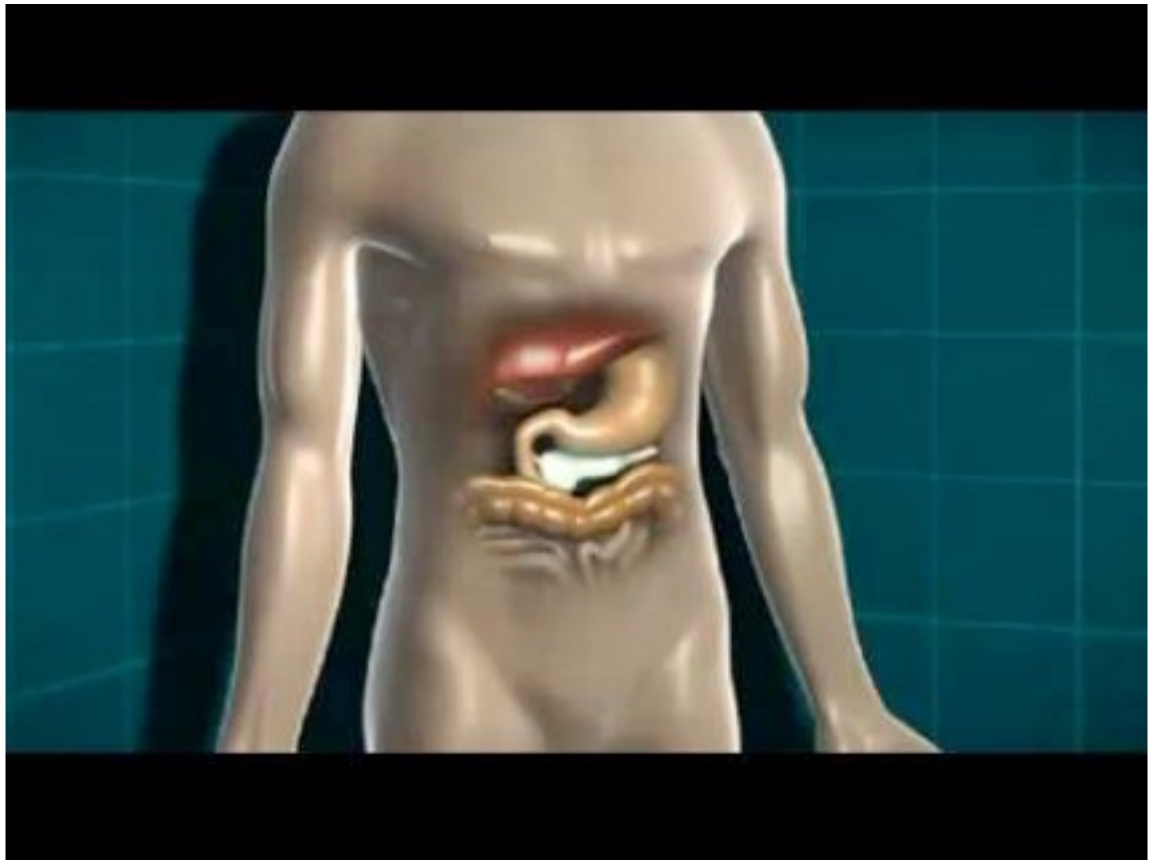
Summary

- •In type 1 diabetes, the pancreas cannot make enough insulin, the hormone that helps take up sugar from the blood.
- •In type 2 diabetes, the body cells cannot use insulin properly.

Explore More

Use the resource below to answer the questions that follow.

- •**Diabetes and the Body** at http://www.youtube.com/watch?v=jHRfDTqPzj4 (8:42)



Click on the image above for more content

1. How does a "normal" body respond when it senses that glucose levels in the blood stream are increasing?
2. How does insulin affect blood glucose levels? What mechanism does it act by?
3. What causes type 1 diabetes? How does this affect the body?
4. What causes type 2 diabetes? What are three symptoms of type 2 diabetes?
5. How can the liver make the situation worse with type 2 diabetes? Why does the liver respond this way?
6. Which type of diabetes is most likely to be influenced by dietary changes?

Review

1. What is diabetes?
2. Compare and contrast type 1 and type 2 diabetes.
3. What can increase your risk of developing type 2 diabetes?
4. List three common symptoms of diabetes.

Section 58

Autoimmune Diseases

Autoimmune Diseases

- Define autoimmune disease and allergy.
- Give examples of autoimmune diseases.
- List common allergies.

Does pollen make you sneeze?

If so, you are not alone. It is one of the most common allergies. The runny nose and sneezing associated with allergies results from the immune system working improperly.

Diseases of the Immune System

The immune system usually protects you from pathogens and other causes of disease. When the immune system is working properly, it keeps you from getting sick. But the immune system is like any other system of the body. It can break down or develop diseases.

AIDS is an infectious disease of the immune system caused by a virus. Some diseases of the immune system are noninfectious. They include autoimmune diseases and allergies.

Autoimmune Diseases

Does it make sense for an immune system to attack the cells it is meant to protect? No, but an immune system that does not function properly will attack its own cells. An **autoimmune disease** is a disease in which the immune system attacks the body's own cells.

One example is **type 1 diabetes** . In this disease, the immune system attacks cells of the pancreas. Other examples are multiple sclerosis and rheumatoid arthritis. In **multiple sclerosis** , the immune system attacks nerve cells. This causes weakness and pain. In **rheumatoid arthritis** , the immune system attacks the cells of joints. This causes joint damage and pain. These diseases cannot be cured. But they can be helped with medicines that weaken the immune system's attack on normal cells. Other autoimmune diseases include celiac disease (damages to the small intestine), inflammatory bowel disease (damage to the digestive tract), psoriasis (damage to the skin), and lupus (damage to the joints, skin, kidneys, heart, and lungs).

Allergies

An **allergy** occurs when the immune system attacks a harmless substance that enters the body from the outside. A substance that causes an allergy is called an allergen. It is the immune system, not the allergen, that causes the symptoms of an allergy.

Did you ever hear of hay fever? It's not really a fever at all. It's an allergy to plant pollens. People with this type of allergy have symptoms such as watery eyes, sneezing, and a runny nose. A common cause of hay fever is the pollen of ragweed. Many people are also allergic to poison ivy (**Figure** below). Skin contact with poison ivy leads to an itchy rash in people who are allergic to the plant.

Figure 11.116

Ragweed is a common roadside weed found throughout the United States. Many people are allergic to its pollen.

Figure 11.117

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

Some people are allergic to certain foods. Nuts and shellfish are common causes of food allergies. Other common causes of allergies include:

- Drugs such as penicillin.
- Mold.
- Dust.
- The dead skin cells of dogs and cats, called dander.
- Stings of wasps and bees.

Most allergies can be treated with medicines. Medicines used to treat allergies include antihistamines and corticosteroids. These medicines help control the immune system when it attacks an allergen. Sometimes, allergies cause severe symptoms, a condition known as anaphylaxis. For example, they may cause the throat to swell so it is hard to breathe. Severe allergies may be life threatening. They require emergency medical care.

Summary

- Autoimmune diseases occur when the immune system attacks normal body cells.
- Allergies occur when the immune system attacks harmless substances that enter the body from the outside.

Explore More

Use the resources below to answer the questions that follow.

Explore More I

- **Malfunction of the Immune System** at http://www.youtube.com/watch?v=YO_ph9wvFkI (2:06)

Click on the image above for more content

1. How does your immune system respond when you have allergies?
2. What happens when a person has Rheumatoid Arthritis? What sort of disease is this?

Explore More II

- **Problems of the Immune System** at http://kidshealth.org/parent/general/body_basics/immune.html

1. List the four categories of immune system disorders.
2. What is an immunodeficiency?
3. Describe SCID.

4. What type of immune disorder is lupus?
5. What are two cancers of the immune system?

Review

1. What is an autoimmune disease?
2. What causes rheumatoid arthritis?
3. What causes an allergy?

Section 59

Preventing Noninfectious

Preventing Noninfectious Diseases

•Define noninfectious disease.
•Describe how noninfectious diseases can be prevented.

How can you reduce your risk of developing cancer?

You can reduce your risk of developing cancer by staying away from certain hazards. For example, the use of tanning beds can lead to skin cancer.

Preventing Noninfectious Diseases

Noninfectious diseases can't be passed from one person to another. Instead, these types of diseases are caused by factors such as the environment, genetics, and lifestyle. Examples of inherited noninfectious conditions include cystic fibrosis and Down syndrome. If you're born with these conditions, you must learn how to manage the symptoms. Examples of conditions caused by environmental or lifestyle factors include heart disease and skin cancer. We can't change our genetic codes, but there are plenty of ways to prevent other noninfectious diseases. For example, cutting down on exposure to cigarette smoke and the sun's rays will prevent certain types of cancer.

It is a fact that most chronic noninfectious diseases can be prevented. The chronic noninfectious diseases that cause the most deaths in many developed countries are largely preventable. These diseases are heart disease, stroke, diabetes and cancer, and though they do have some genetic components, they also many lifestyle components. For example, some cancers have genetic risks, but people at high risk for cancers can have screening examinations to catch them early or sometimes can take other steps to prevent the cancers. Heart disease, stroke and diabetes are mostly linked to lifestyle choices, even when family history puts a person at higher risk for the diseases.

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

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

Making these healthy lifestyle choices can also help prevent some types of cancer. In addition, you can lower the risk of cancer by avoiding **carcinogens** , which are substances that cause cancer. For example, you can reduce your risk of lung cancer by not smoking. You can reduce your risk of skin cancer by using sunscreen. How to choose a sunscreen that offers the most protection is explained below (**Figure** below). Some people think that tanning beds are a safe way to get a tan. This is a myth. Tanning beds expose the skin to UV radiation. Any exposure to UV radiation increases the risk of skin cancer. It doesn't matter whether the radiation comes from tanning lamps or the sun.

Overall, people in many developed countries are contributing to higher rates of noninfectious diseases (heart disease, stroke, diabetes and cancer) by taking advantage of technology and social environments that encourage a less active lifestyle, and also encourages faster and cheaper meals. For example, many children now spend more time on their computer or watching TV then playing outdoors. The "faster and cheaper" meals are usually less healthy than other meals. Even though many people are living longer, they can choose to live more healthily by adopting regular exercise routines and healthy eating habits.

Figure 11.118

When you choose a sunscreen, select one with an SPF (sun protection factor) of 30 or higher. Also, choose a sunscreen that protects against both UVB and UVA radiation.

Summary

- A healthy lifestyle can help reduce your risk of developing many noninfectious diseases.
- You can lower your risk of cancer by avoiding habits that expose you to carcinogens, such as smoking and tanning beds.

Explore More

Use the resource below to answer the questions that follow.

- **What is a noninfectious disease?** at http://curiosity.discovery.com/question/what-is-noninfectious-disease

1. What is a noninfectious disease?
2. What are three examples of noninfectious diseases?
3. What are two ways to reduce you chance of developing heart disease?

Review

1. What are the chronic noninfectious diseases that cause the most deaths in many developed countries?
2. How can you reduce your risk of developing type 2 diabetes?
3. How can you reduce your risk of developing skin cancer?

Section 60

Barriers to Pathogens

Barriers to Pathogens

•Describe the body's first line of defense against pathogens.
•Discuss the role of skin and mucous membranes in the first line of defense.

What is your nose good for?

Your nose does a lot of work for you! Obviously, it helps you breathe and provides your sense of smell. But you might not realize that your nose also helps to fight off disease.

The Immune System's First Line of Defense

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

The first line of defence includes both physical and chemical barriers that are always ready and prepared to defend the body from infection. Pathogens must make it past this first line of defense to cause harm. If this defense is broken, the second line of defense within your body is activated.

Your body's first line of defense is like a castle's moat and walls. It keeps most pathogens out of your body. This is a non-specific type of defense, in that it tries to keep all pathogens out. The first line of defense includes different types of barriers. Being the "first line", it starts with the skin. The first line also includes tears, mucus, cilia, stomach acid, urine flow, and friendly bacteria.

Skin and Mucous Membranes

The skin is a very important barrier to pathogens. The skin is the body's largest organ. In adults, it covers an area of about 16-22 square feet! The skin is also the body's most important defense against disease. It forms a physical barrier between the body and the outside world. The skin has several layers that stack on top of each other (**Figure** below). The outer layer is tough and waterproof. It is very difficult for pathogens to get through this layer of skin.

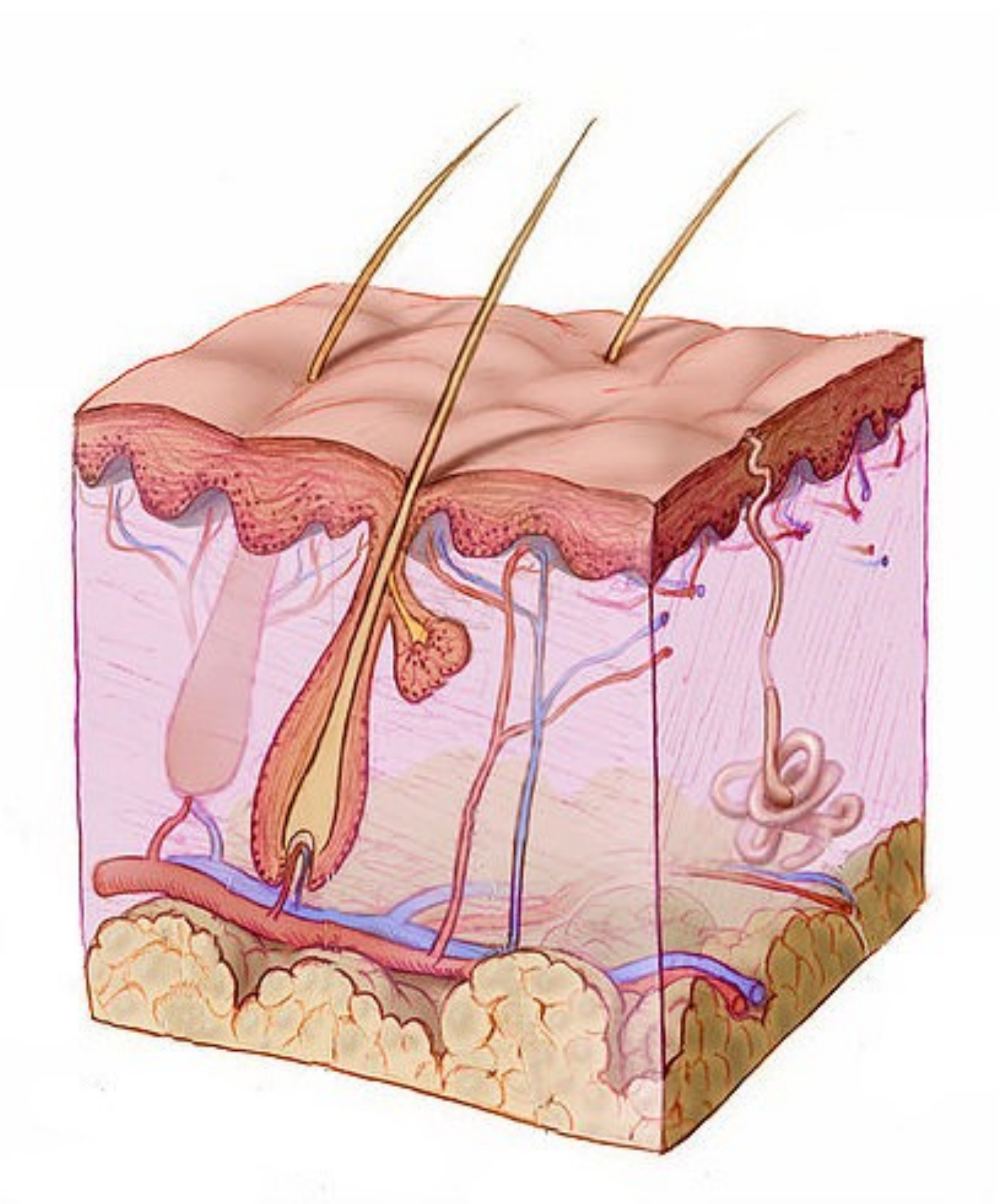


Figure 11.119

This drawing shows that the skin has many layers. The outer layer is so tough that it keeps out most pathogens.

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

One defense of mucous membranes is the mucus they release. **Mucus** is a sticky, moist substance that covers mucous membranes. Most pathogens get stuck in the mucus before they can do harm to the body. Many mucous membranes also have cilia. Cilia in the lungs are pictured below (**Figure** below). **Cilia** are tiny finger-like projections. They move in waves and sweep mucus and trapped pathogens toward body openings. When you clear your throat or blow your nose, you remove mucus and pathogens from your body.

Figure 11.120

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

Chemicals

Most body fluids that you release from your body contain chemicals that kill pathogens. For example, mucus, sweat, tears, and saliva contain enzymes called lysozymes that kill pathogens. These enzymes can break down the cell walls of bacteria to kill them.

The stomach also releases a very strong acid, called hydrochloric acid. This acid kills most pathogens that enter the stomach in food or water. Urine is also acidic, so few pathogens can grow in it.

Helpful Bacteria

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

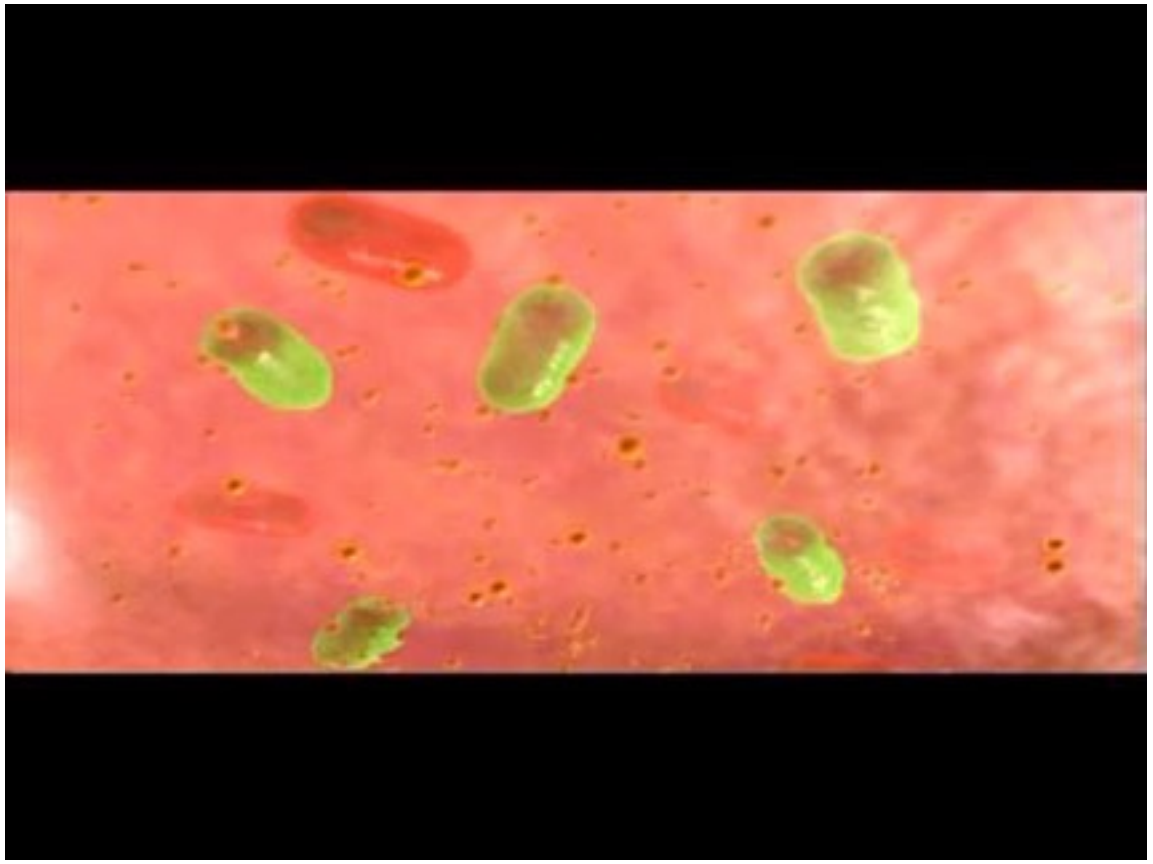
Summary

- Your body's first line of defense includes the skin and other barriers that keep pathogens out of your body.
- Most body fluids that you release from your body contain chemicals that kill pathogens.

Explore More

Use the resource below to answer the questions that follow.

- **Introduction To How The Immune System Works** at http://www.youtube.com/watch?v=IWMJIMzsEMg (3:16)



Click on the image above for more content

1. How do external barriers help our immune system?
2. Where is mucus used as a barrier?
3. How do some bacteria aid our immune system?

Review

1. How does your skin protect you from pathogens?
2. What is mucus? What are mucous membranes?
3. How is mucus helpful?
4. How are lysozymes helpful?
5. How do helpful bacteria defend your body?

Section 61

Inflammatory Response

Inflammatory Response

- •Summarize the body's second line of defense against pathogens.
- •Define inflammation.
- •Explain how inflammation helps protect you from pathogens.
- •Describe the roles of white blood cells.

Have you ever sprained your ankle?

Did you notice redness and swelling near the injury? These symptoms indicate that your body is attempting to fight off infection.

The Immune System's Second Line of Defense

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

Figure 11.121

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

Inflammation

The body's second line of defense against pathogens includes the inflammatory response. If bacteria enter the skin through a scrape, the area may become red, warm, and painful. These are signs of inflammation. **Inflammation** is one way the body reacts to infections or injuries. Inflammation is caused by chemicals that are released when skin or other tissues are damaged. The chemicals cause nearby blood vessels to dilate, or expand. This increases blood flow to the damaged area, which makes the area red and slightly warm. The chemicals also attract white blood cells called neutrophils to the wound and cause them to leak out of blood vessels into the damaged tissue.

White Blood Cells

What do these white blood cells do at the site of inflammation? The main role of white blood cells is to fight pathogens in the body. There are actually several different kinds of white blood cells. Some white blood cells have very specific functions. They attack only certain pathogens. Other white blood cells attack any pathogen they find. These white blood cells travel to areas of the body that are inflamed. They are called **phagocytes** , which means “eating cells.” Neutrophils are a type of phagocyte. In addition to pathogens, phagocytes “eat” dead cells. They surround the pathogens and destroy them. This process is called **phagocytosis** .

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

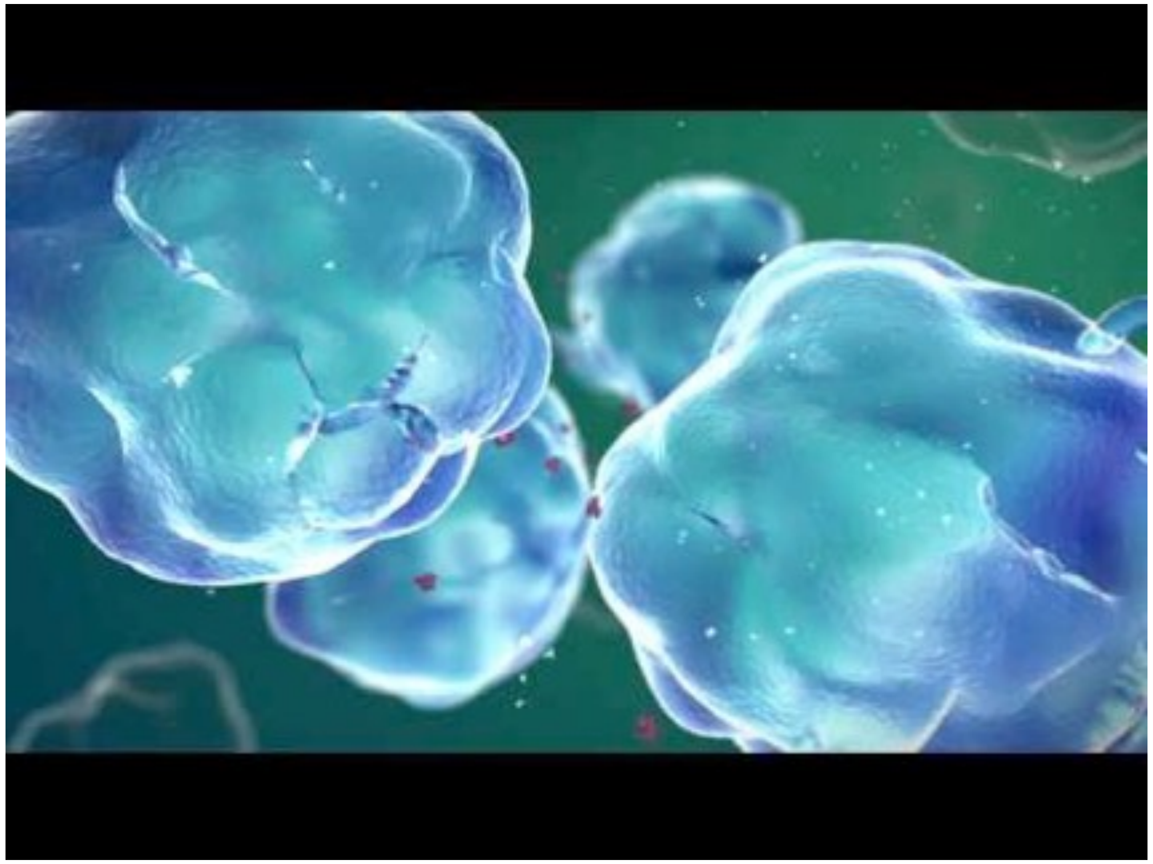
Summary

- If pathogens enter your body, inflammation occurs.
- White blood cells called phagocytes travel to areas of the body that are inflamed.

Explore More

Use the resource below to answer the questions that follow.

- **Our Immune System** at http://www.youtube.com/watch?v=MI-BLaj5nFk (4:53)



Click on the image above for more content

1. What is a macrophage? What does it do when it recognizes a "non-self" substance?
2. What are cytokines? What message do they send to the rest of the body's cells?
3. How do macrophages interact with T-cells? Where does this interaction occur?

Review

1. Describe inflammation.
2. What is the main role of white blood cells?
3. Describe phagocytosis.
4. A fever is a sign of infection. Why might it be considered a good sign?

Section 62

Lymphatic System

Lymphatic System

•Define immune response.
•Describe the role of the lymphatic system in the immune response.
•List the lymph organs.
•Explain the roles of the lymph and lymph vessels.
•Describe the two main types of lymphocytes.

Do you still have your tonsils?

Many people have their tonsils removed because they can hold on to germs that cause throat infections. Although sometimes they can do more harm than good, tonsils are there to help you. They trap pathogens so that they can be destroyed before they enter farther into your body.

The Lymphatic System and the Immune Response

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

The **immune system** (**Figure** below) is also part of the lymphatic system—named for **lymphocytes** , which are the type of white blood cells involved in an immune response. They include several lymph organs, lymph vessels, lymph, and lymph nodes.

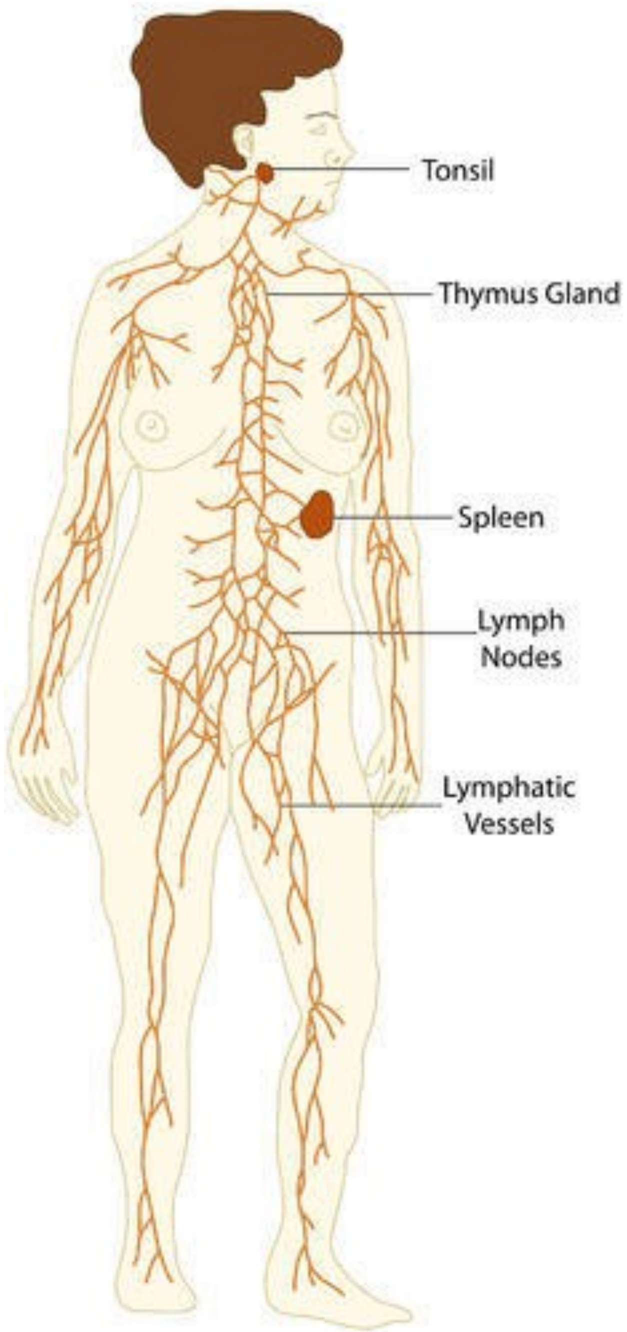


Figure 11.122

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

Lymph Organs

The lymph organs are the red **bone marrow** , **tonsils** , **spleen** , and **thymus gland** . They are described below (**Figure** below).

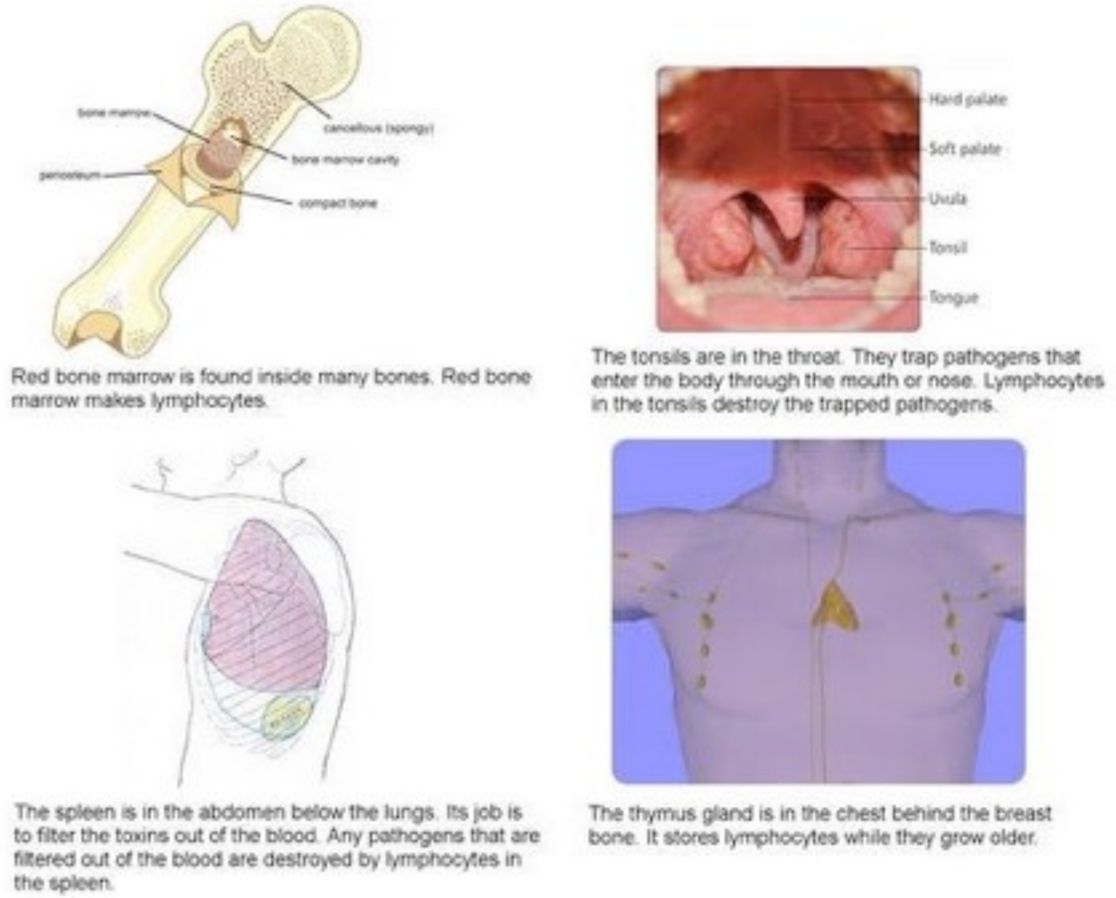


Figure 11.123

Each lymph organ has a different job in the immune system.

Lymph and Lymph Vessels

Lymph vessels make up a circulatory system that is similar to the cardiovascular system, which you can read about in a previous concept. Lymph vessels are like blood vessels, except they move lymph instead of blood. **Lymph** is a yellowish liquid that leaks out of tiny blood vessels into spaces between cells in tissues. Where there is more inflammation, there is usually more lymph in tissues. This lymph may contain many pathogens.

The lymph that collects in tissues slowly passes into tiny lymph vessels. It then travels from smaller to larger lymph vessels. Lymph is not pumped through lymph vessels like blood is pumped through blood vessels by the heart. Instead, muscles around the lymph vessels contract and squeeze the lymph through the vessels. The lymph vessels also contract to help move the lymph along. The lymph finally reaches the main lymph vessels in the chest. Here, the lymph drains into two large veins. This is how the lymph returns to the bloodstream.

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

Lymphocytes

Lymphocytes (**Figure** below), a type of white blood cell, are the key cells of an immune response. There are trillions of lymphocytes in the human body. They make up about one quarter of all white blood cells. Usually, fewer than half of the body's lymphocytes are in the blood. The rest are in the lymph, lymph nodes, and lymph organs.

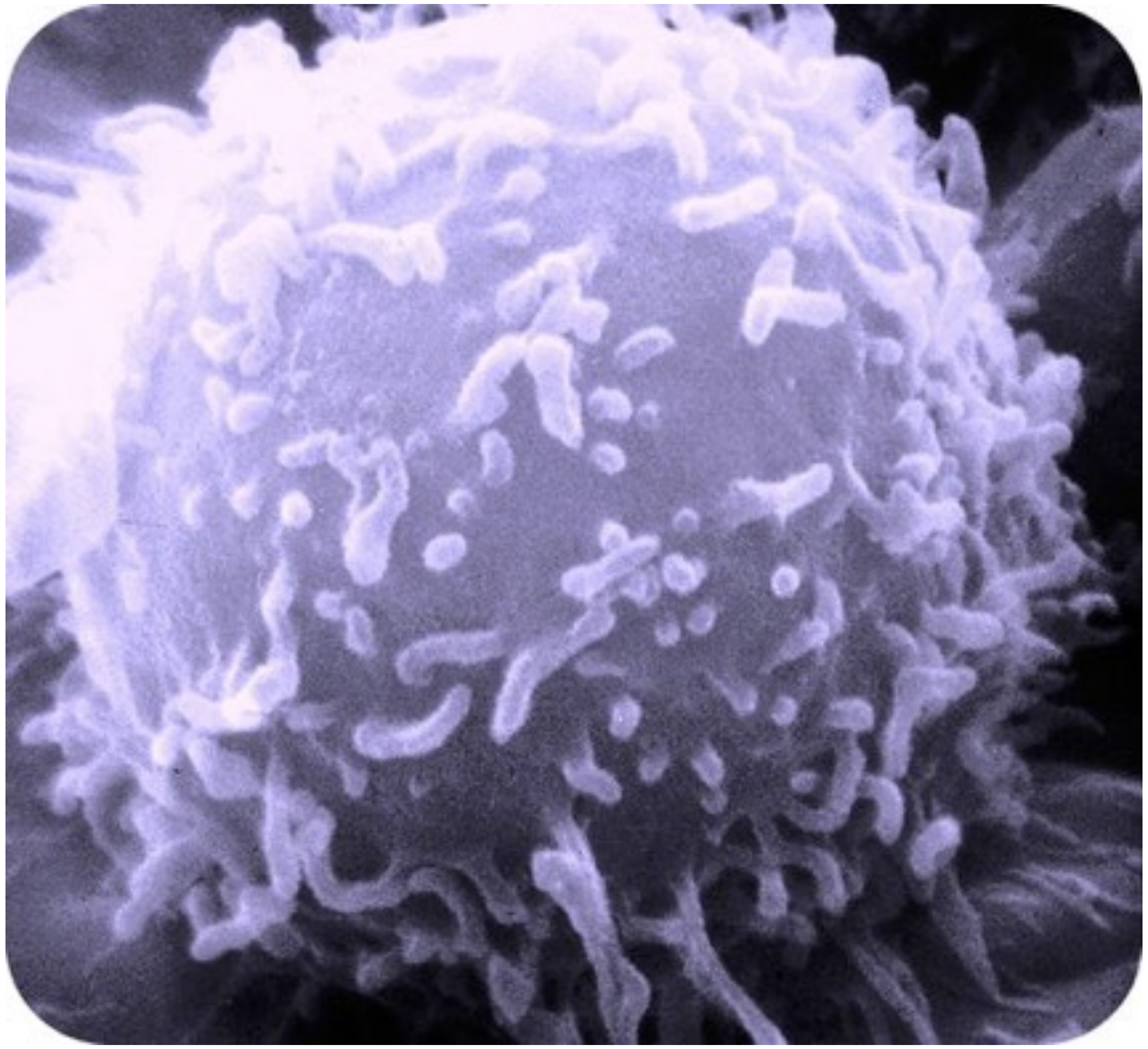


Figure 11.124

This image of a lymphocyte was made with an electron microscope. The lymphocyte is shown 10,000 times its actual size.

There are two main types of lymphocytes:

1. B cells.
2. T cells.

Both types of lymphocytes are produced in the red bone marrow. They are named for the sites where they grow larger. The "B" in B cells stands for “bone.” B cells grow larger in red bone marrow. The "T" in T cells stands for “thymus.” T cells mature in the thymus gland.

B and T cells must be “switched on” in order to fight a specific pathogen. Once this happens, they produce an army of cells ready to fight that particular pathogen. How can B and T cells recognize specific pathogens? Pathogens have proteins, often located on their cell surface. These proteins are called antigens. An **antigen** is any protein that causes an immune response, because it is unlike any protein that the body makes. Antigens are found on bacteria, viruses, and other pathogens. Your body sees these as foreign, meaning they do not belong in your body.

Summary

- The immune system includes lymph organs, lymph vessels, lymph, and lymph nodes.
- Lymph organs include the red bone marrow, thymus gland, spleen, and tonsils.
- Lymphocytes, including B cells and T cells, are key cells in the immune response.

Explore More

Use the resource below to answer the questions that follow.

- **Lymphatic System: Facts, Functions & Diseases** at http://www.livescience.com/26983-lymphatic-system.html

1. What is the main function of the lymphatic system?
2. What are the tonsils?
3. How do the lymph nodes act in the lymphatic system?

Review

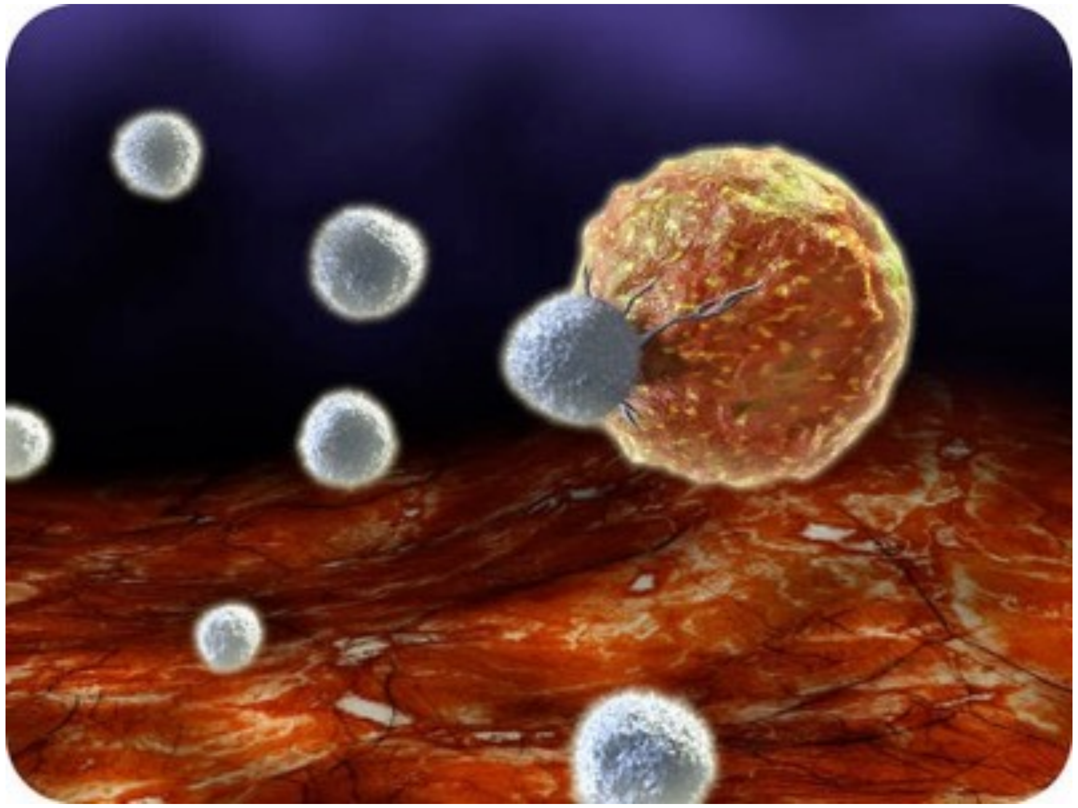
1. What are three examples of lymph organs?
2. What is the role of the tonsils?
3. What are lymph nodes? What is their function?
4. Distinguish between B and T lymphocytes.

Section 63

B and T Cell Response

B and T Cell Response

•Distinguish B cells from T cells.
•Define antibody and antigen.
•Explain how B cells and T cells respond to pathogens.
•Summarize the roles of killer T cells and helper T cells.



What happens when your body recognizes an invader?

When your immune system detects an invading pathogen, it goes on the attack! Notice how this T-cell is setting out to destroy a cancer cell.

B and T Cell Response

Some defenses, like your skin and mucous membranes, are not designed to ward off a specific pathogen. They are just general defenders against disease. Your body also has defenses that are more specialized. Through the help of your immune system, your body can generate an army of cells to kill that one specific pathogen.

There are two different types of specific immune responses. One type involves B cells. The other type involves T cells. Recall that **B cells** and **T cells** are types of white blood cells that are key in the immune response. Whereas the immune system's first and second line of defense are more generalized or non-specific, the immune response is specific. It can be described as a specific response to a specific pathogen, meaning it uses methods to target just one pathogen at a time. These methods involve B and T cells.

B Cell Response

B cells respond to pathogens and other cells from outside the body in the blood and lymph. Most B cells fight infections by making antibodies. An **antibody** is a large, Y-shaped protein that binds to an **antigen** , a protein that is recognized as foreign. Antigens are found on the outside of bacteria, viruses and other foreign microorganisms. Each antibody can bind with just one specific type of antigen

(**Figure** below). They fit together like a lock and key. Once an antigen and antibody bind together, they signal for a **phagocyte** to destroy them. Phagocytes are white blood cells that engulf targeted antigens by phagocytosis. As the antigen is on the outside of a pathogen, the pathogen is destroyed by this process.

At any one time the average human body contains antibodies that can react with 10^8 different antigens. This means that there can be up to 10^8 different antibody proteins in the body.

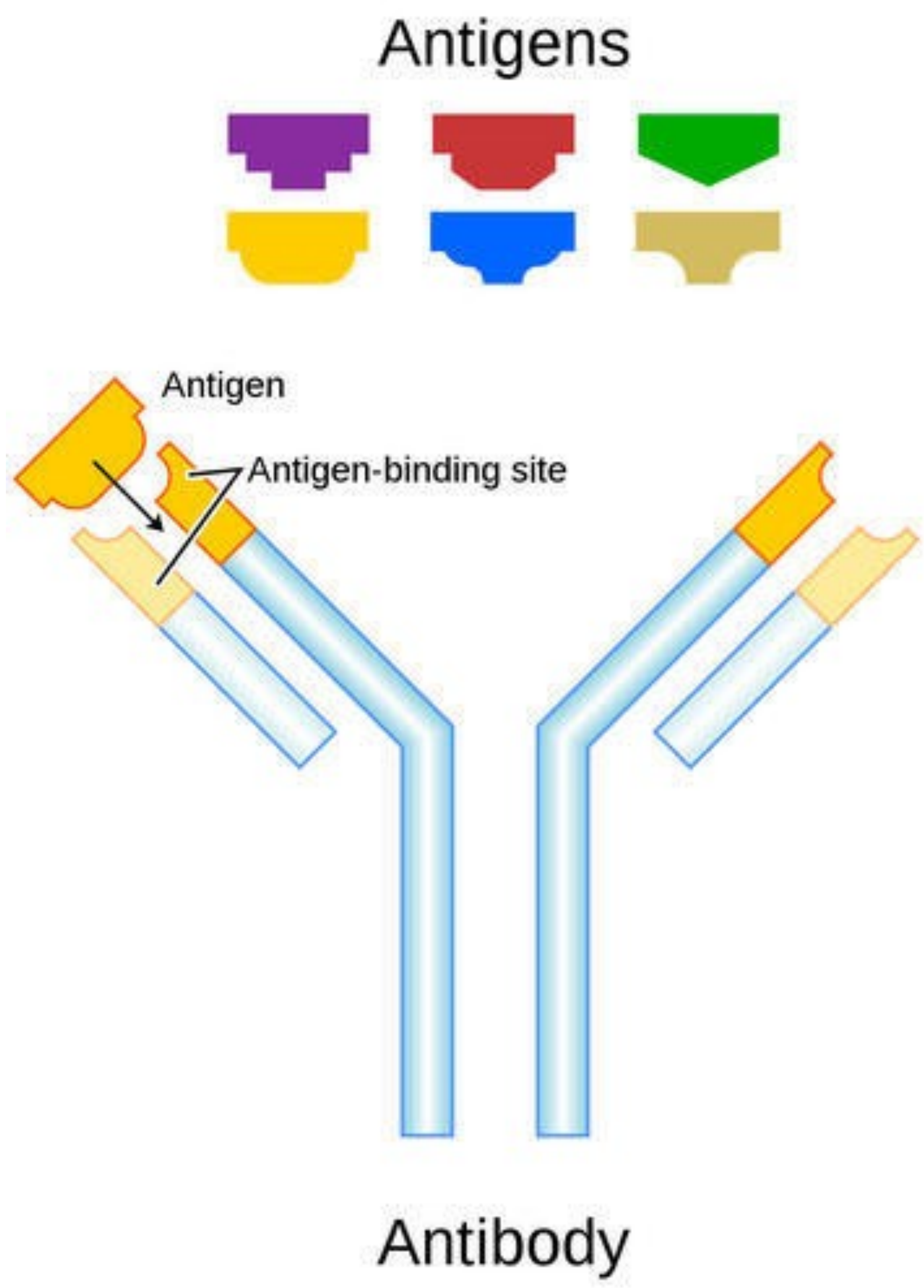


Figure 11.125

This diagram shows how an antibody binds with an antigen. The antibody was produced by a B cell. It binds with just one type of antigen. Antibodies produced by different B cells bind with other types of antigens. The antigen-binding sites can vary, such that they are specific for just one antigen.

T Cell Response

There are different types of T cells, including killer T cells and helper T cells. **Killer T cells** destroy infected, damaged, or cancerous body cells (**Figure** below). When the killer T cell comes into contact with the infected cell, it releases poisons. The poisons make tiny holes in the cell membrane of the infected cell. This causes the cell to burst open. Both the infected cell and the pathogens inside it are destroyed.

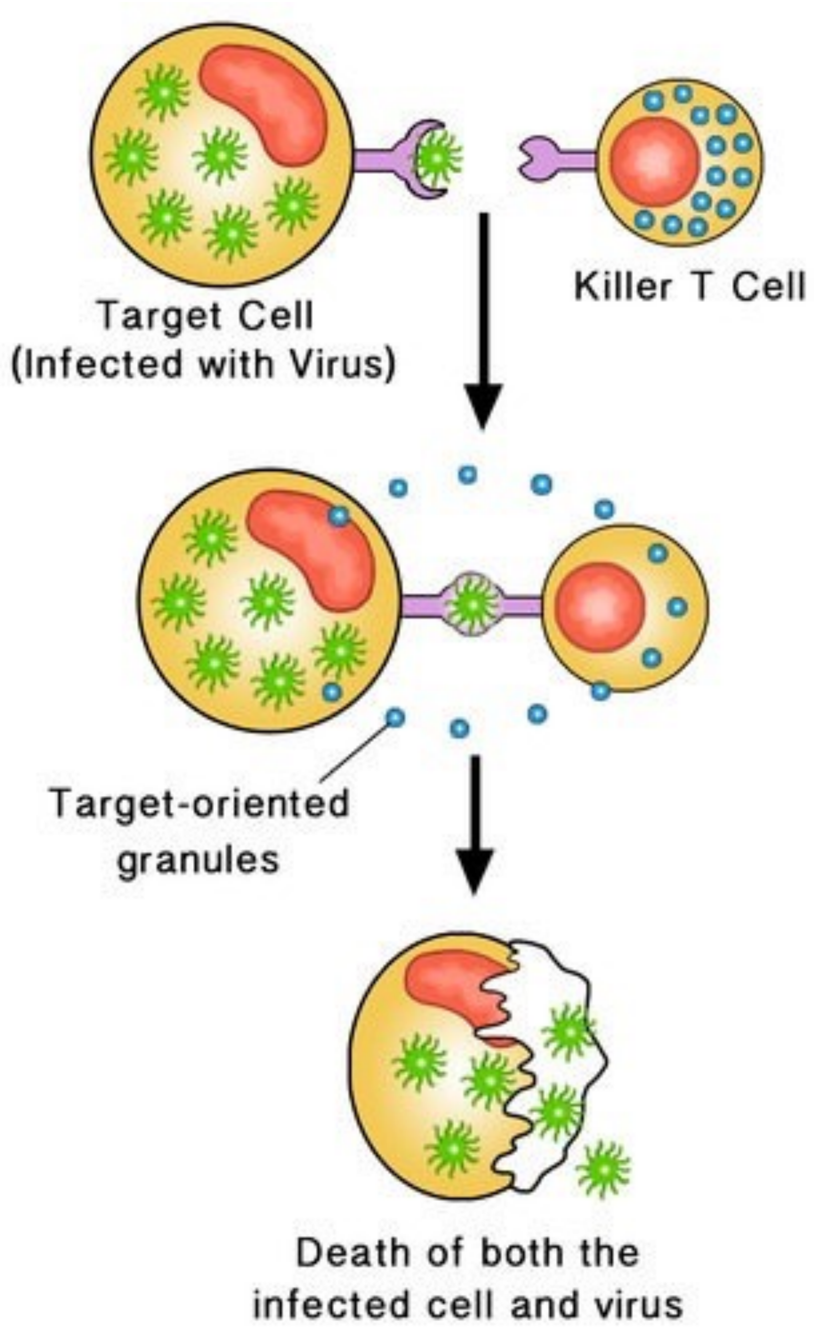


Figure 11.126

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

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

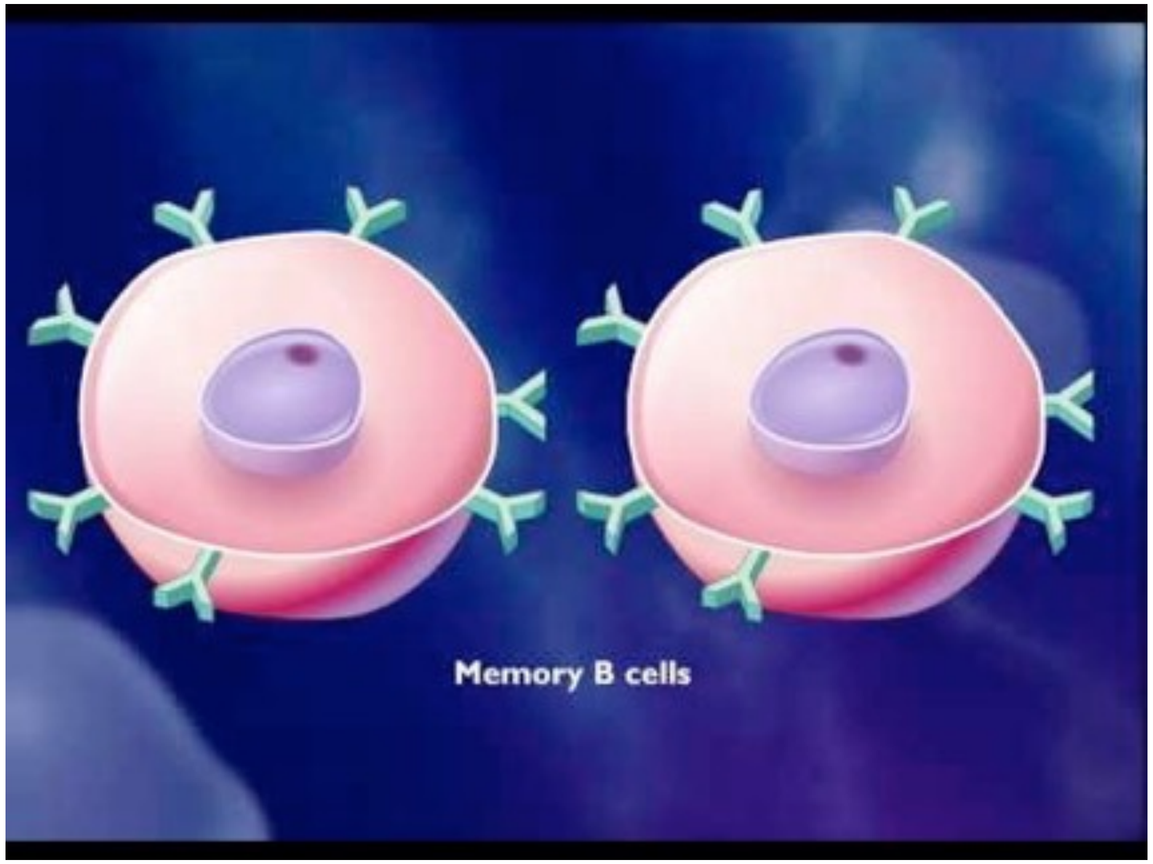
Summary

- •B cells produce antibodies against pathogens in the blood and lymph.
- •Killer T cells destroy body cells infected with pathogens.

Explore More

Use the resource below to answer the questions that follow.

- •**Specific Immunity** at http://www.youtube.com/watch?v=Bf2t8n1ibwQ



Click on the image above for more content

1. What starts an immune response?
2. How do killer T cells fight pathogens?
3. How do B cells fight pathogens?
4. Explain how long-term immunity comes about.

Review

1. Explain how B cells help fight infections.
2. Describe an antibody and its role.
3. How do killer T cells fight pathogens?
4. Describe the role of helper T cells.

Section 64
Immunity

Immunity

- Define immunity and vaccination.
- Describe immunity and how vaccinations work.

Is this child more fortunate than many children?

You may not feel lucky to get a shot. But you are very lucky to be able to get vaccinations. In many parts of the world, children do not get routine vaccinations. In 2008, the World Health Organization (WHO) estimated that 1.5 million children under the age of 5 died from diseases that are preventable with vaccinations.

Immunity and Vaccination

In previous concepts, you learned about B and T cells, special types of white blood cells that help your body to fight off a specific pathogen. They are necessary when the body is fighting off an infection. But what happens to them after the pathogen has been destroyed?

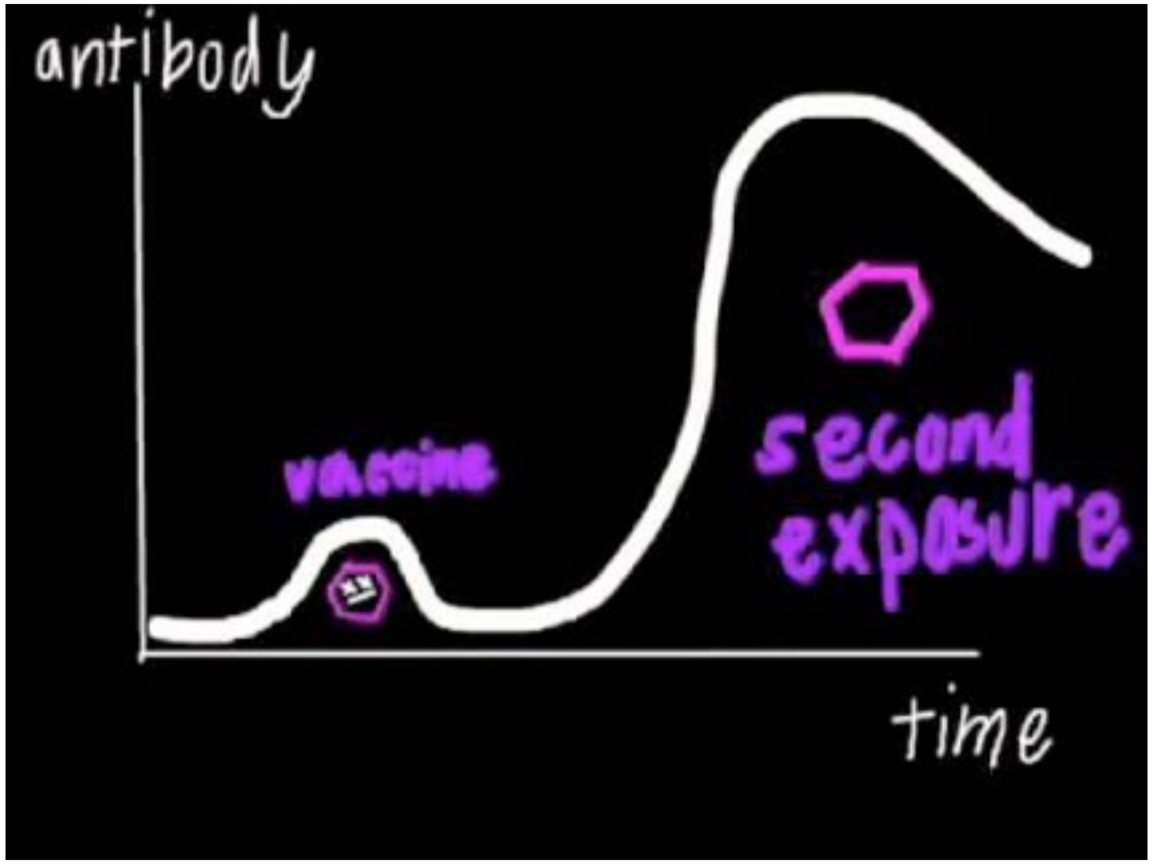
Most B and T cells die after an infection has been brought under control. But some of them survive for many years. They may even survive for a person's lifetime. These long-lasting B and T cells are called memory cells. They allow the immune system to "remember" the pathogen after the infection is over. If the pathogen invades the body again, the memory cells will start dividing in order to fight the pathogen or disease.

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

Immunity can also be caused by vaccination. **Vaccination** is the process of exposing a person to a pathogen on purpose in order to develop immunity. In vaccination, a modified pathogen is usually injected under the skin by a shot. Only part of the pathogen is injected, or a weak or dead pathogen is used. It sounds dangerous, but the shot prepares your body for fighting the pathogen without causing the actual illness. Vaccination triggers an immune response against the injected antigen. The body prepares "memory" cells for use at a later time, in case the antigen is ever encountered again. Essentially, a vaccine imitates an infection, triggering an immune response, without making a person sick.

In many countries, children receive their first vaccination at birth with the Hepatitis B shot, which protects infants from Hepatitis B, a serious liver disease. Before vaccines, many children died from diseases that vaccines now prevent, such as whooping cough, measles, and polio. Those same germs exist today, but because babies are now protected by vaccines, we do not see these diseases nearly as often. Diseases you have probably been vaccinated against include measles, mumps, and chicken pox.

How does a vaccine work? See *How a Vaccine Works* at https://www.youtube.com/watch?v=7MaiT5w5NWQ and *The History of Vaccines* at http://www.historyofvaccines.org/content/articles/top-20-questions-about-vaccination .



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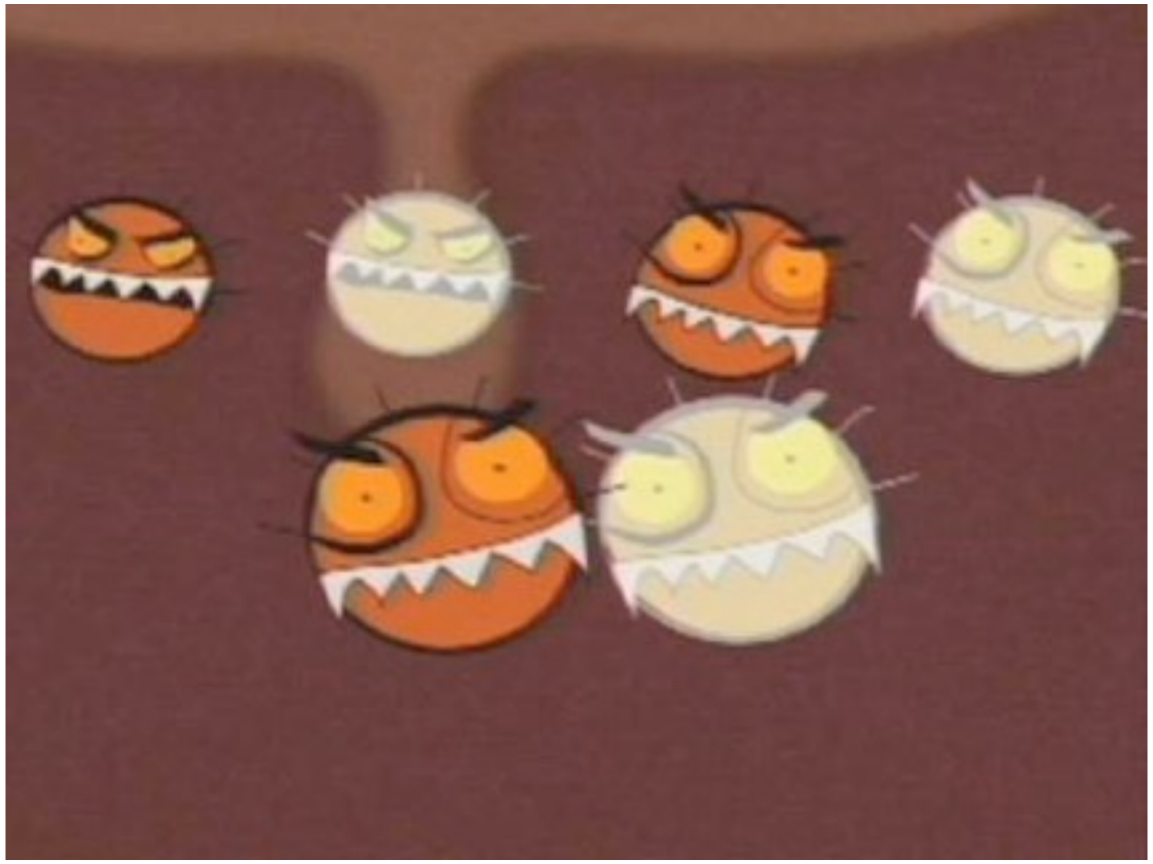
Summary

- Immunity is the ability to resist a particular pathogen.
- Vaccination is deliberate exposure to a pathogen in order to bring about immunity.

Explore More

Use the resource below to answer the questions that follow.

- **What Is Immunity?** at http://www.youtube.com/watch?v=vCBfiQnyiKw (1:23)



Click on the image above for more content

1. How do vaccines provide immunity? How is the immune response initiated by vaccines similar to the body's natural immune response?
2. Why do some people decide to take vaccines rather than letting the body develop natural immunity?

Review

1. Define immunity.
2. Define vaccination.
3. If you have been vaccinated against measles, you are unlikely to ever have the disease, even if you are exposed to the measles virus. How does this work?

Section 65

Male Reproductive System

Male Reproductive System

- List the functions of the male reproductive system.
- List the roles of testosterone.

Why do men and women look different?

The features that make men unique from women, such as this man's beard, are controlled by the sex hormones. The production of the sex hormones is a key role of the male reproductive system.

The Male Reproductive System Functions

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

The male reproductive system has two main functions:

1. Producing sperm.
2. Releasing testosterone into the body.

Sperm are male **gametes** , or reproductive cells. When a male gamete meets a female gamete, they can form a new organism. Sperm form when certain cells in the male reproductive system divide by **meiosis** , resulting in cells with half the amount of DNA as a regular "body" cell. More precisely, sperm cells are haploid sex cells, having one set of chromosomes. Regular body cells are diploid, having two set of chromosomes. As there are 46 chromosomes in a diploid human cell, how many are in a human sperm cell?

When males grow older, they produce millions of sperm each day. The male reproductive system also maintains and transports and delivers sperm and a protective fluid, known as semen.

Testosterone is the main sex hormone in males. Hormones are chemicals that control many body processes. Testosterone has two major roles:

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

When a hormone is released into the body, we say it is "secreted." Testosterone is secreted by males, but it is not the only sex hormone that males secrete. Males also secrete small amounts of estrogen. Even though estrogen is the main female sex hormone, scientists think that estrogen is needed for normal sperm production in males.

Figure 11.127

Testosterone, the main sex hormone in males, allows men to build larger muscles than women.

Summary

- •The main functions of the male reproductive system are to produce sperm and secrete testosterone.
- •Testosterone, the main sex hormone in males, causes the reproductive organs to mature and other male traits to develop.

Explore More

Use the resource below to answer the questions that follow.

- •**Male Reproductive System** at http://kidshealth.org/parent/general/body_basics/male_reproductive.html

1. In addition to the reproductive system, the testes are part of which other organ system? Why?
2. What composes the male genitals?
3. What occurs during the first stage of puberty in boys?

Review

1. What are the two main roles of the male reproductive system?
2. How many chromosomes are in a normal human sperm cell?
3. Explain the jobs of testosterone in males.

Section 66

Male Reproductive Struc-

Male Reproductive Structures

•Define testes, epididymis, and vas deferens.
•List the organs of the male reproductive system.
•Describe the functions of the male reproductive organs.

What organs are unique to the male body?

Men and women share most of the same organs. We all have skin, a heart, and lungs. Men and women differ only in their reproductive organs.

Male Reproductive Organs

The male reproductive organs include the penis, testes, and epididymis (**Figure** below). The figure also shows other parts of the male reproductive system.

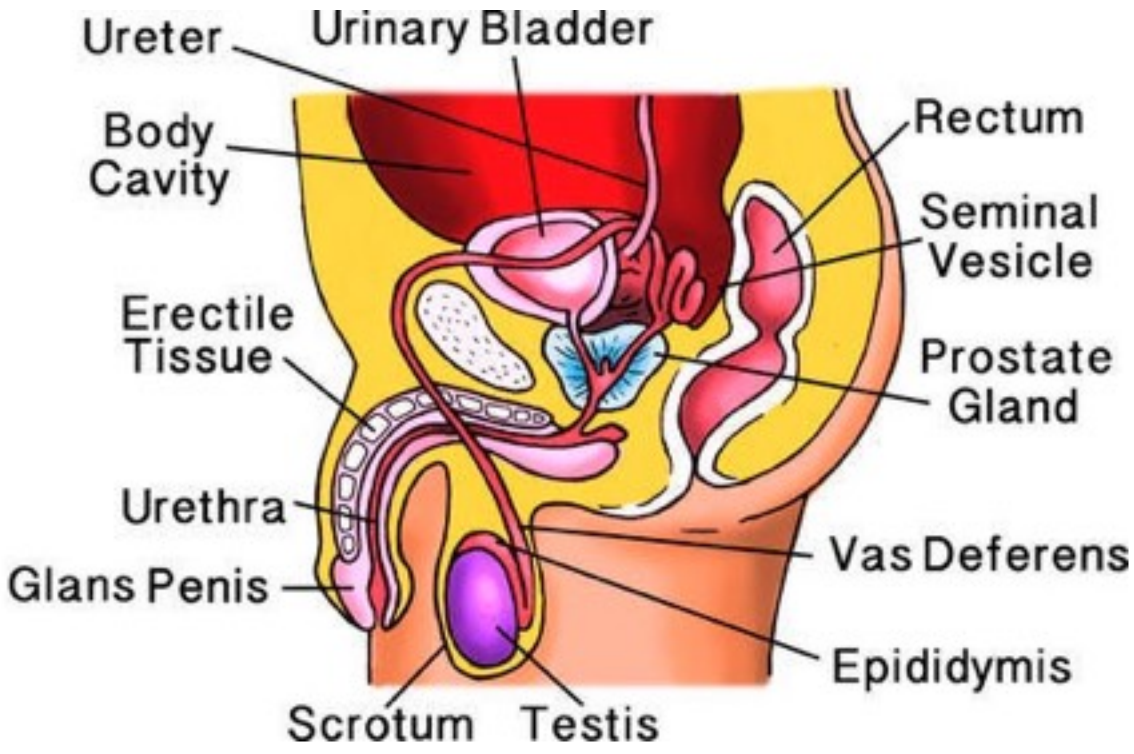


Figure 11.128

This drawing shows the organs of the male reproductive system. It shows the organs from the side. Find each organ in the drawing as you read about it in the text.

•The **penis** is a cylinder-shaped organ. It contains the urethra. The **urethra** is a tube that carries urine out of the body. The urethra also carries sperm out of the body.
•The two **testes** (singular, testis) are egg-shaped organs. They produce sperm and secrete testosterone. The testes are found inside of the scrotum. The **scrotum** is a sac that hangs down outside the body. The scrotum also contains the epididymis. The testes, being in the scrotum outside the body, allow the temperature of the sperm to be maintained at a few degrees lower than body temperature. This is necessary for the stability of these reproductive cells.
•The **epididymis** is a tube that is about six meters (20 feet) long in adults. It is tightly coiled, so it fits inside the scrotum. It rests on top of the testes. The epididymis is where sperm grow larger and mature. The epididymis also stores sperm until they leave the body.

Other parts of the male reproductive system include the vas deferens and the prostate gland. Both of these structures are pictured below (**Figure** above).

•The **vas deferens** is a tube that carries sperm from the epididymis to the urethra.
•The **prostate gland** secretes a fluid that mixes with sperm to help form semen. **Semen** is a "milky" liquid that carries sperm through the urethra and out of the body. In addition to sperm cells, semen contains sugars (fructose) which provide energy to the sperm cells, and enzymes and other substances which help the sperm survive.

Summary

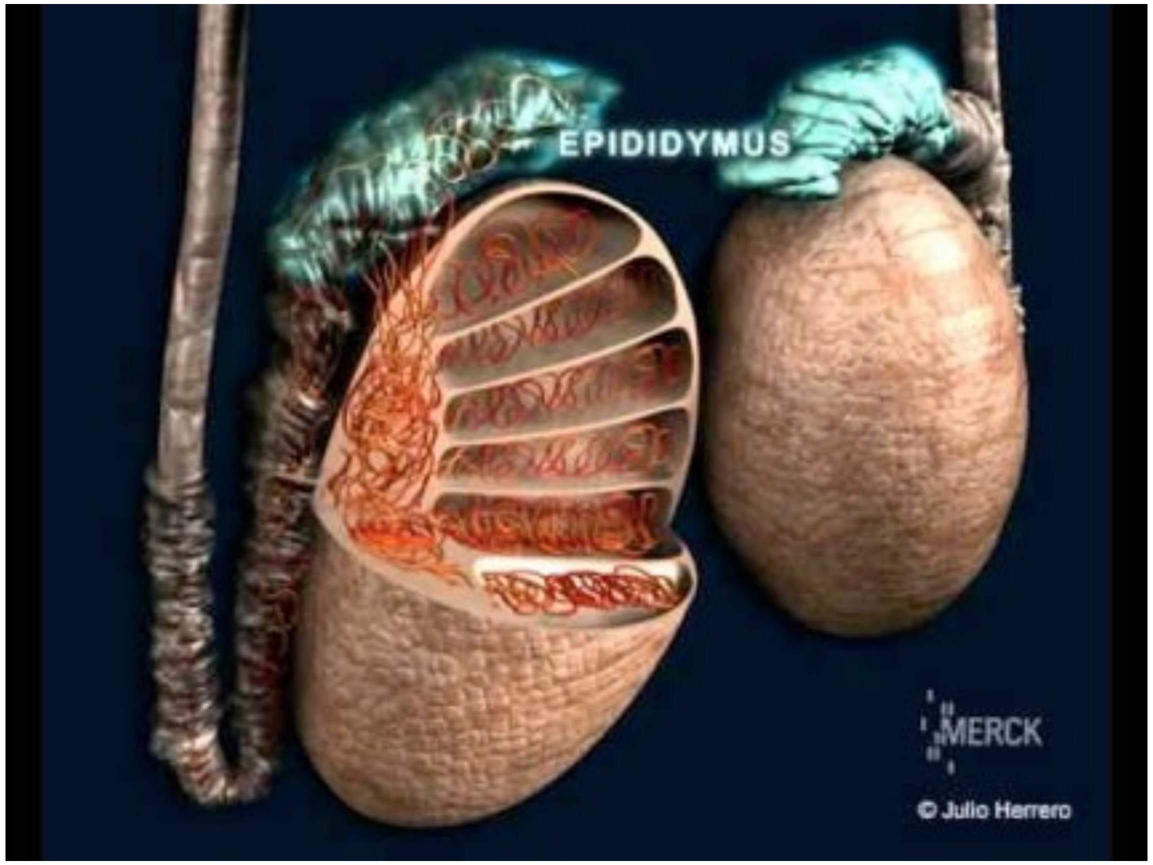
•Male reproductive organs include the penis, testes, and epididymis.
•The testes produce sperm and secrete testosterone.

Explore More

Use the resources below to answer the questions that follow.

Explore More I

- **The Male Reproductive System** at http://www.youtube.com/watch?v=yRNqsT_NRcY (1:21)



Click on the image above for more content

1. What are the two seminal tubules?
2. How long is sperm stored once it is produced? Where are sperm stored?
3. What two types of cells are found inside the seminiferous tubules?

Explore More II

- **Male Reproductive Organs** at http://www.innerbody.com/image_repmov/repo10-new3.html

1. What does the prostate gland do?
2. What is the epididymis? Where is it located? What is its function?

Review

1. Arrange the following structures in the order that sperm pass through them: urethra, epididymis, vas deferens.
2. Why is the epididymis needed for reproduction in males?
3. What is the composition of semen? What role do these components play?

Section 67

Human Sperm

Human Sperm

- •Define sperm.
- •Describe the three main parts of a sperm cell.
- •Summarize the steps of sperm production.

How many sperm does it take to fertilize an egg?

It might only take one sperm to fertilize an egg, but that sperm is not alone. Hundreds of millions of sperm can be released during sexual intercourse.

Sperm and Sperm Production

Sperm (**Figure** below), the male reproductive cells, are tiny. In fact, they are the smallest cells in the human body. What do you think a sperm cell looks like? Some people think that it looks like a tadpole. Do you agree?

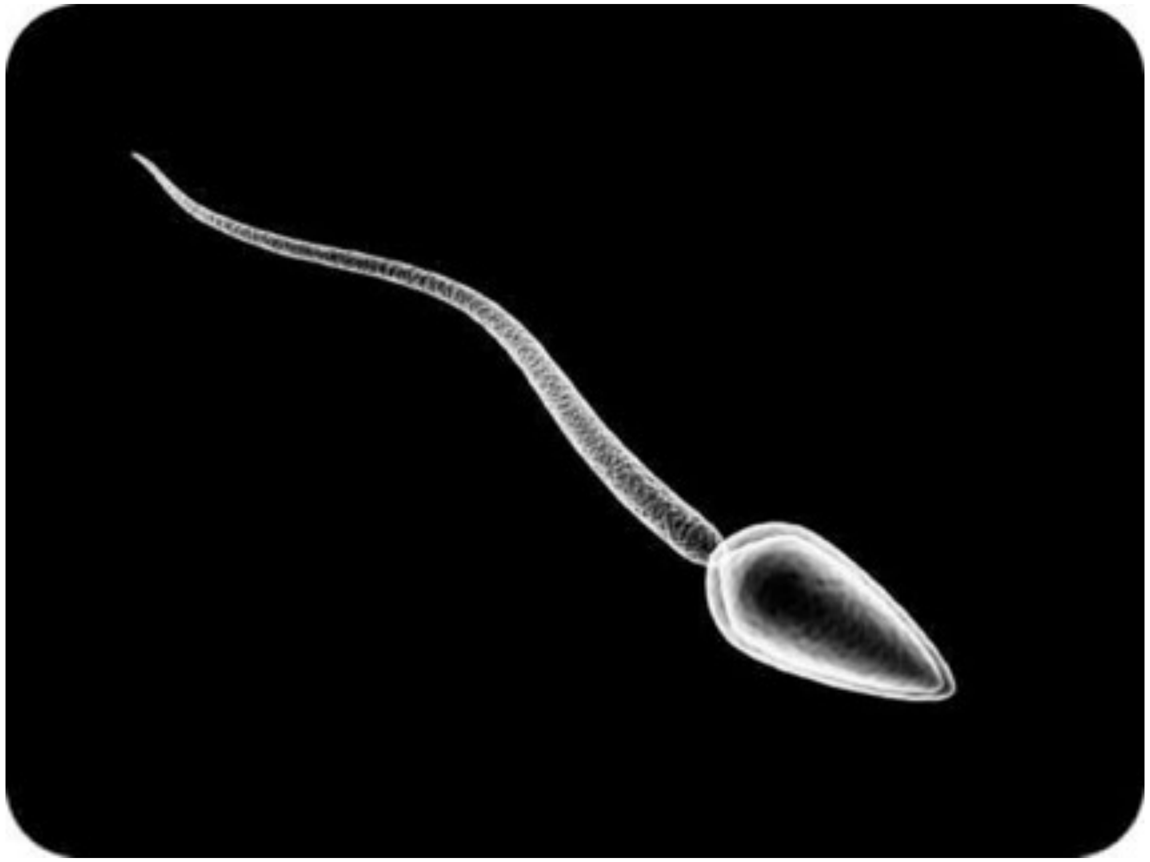


Figure 11.129

This drawing of a sperm shows its main parts. What is the role of each part? How do you think the shape of the sperm might help it swim?

Sperm

A sperm has three main parts:

1. The head of the sperm contains the nucleus. The **nucleus** holds the DNA of the cell. The head also contains enzymes that help the sperm break through the cell membrane of an egg.
2. The midpiece of the sperm is packed with mitochondria. **Mitochondria** are organelles in cells that produce energy. Sperm use the energy in the midpiece to move.
3. The tail of the sperm moves like a propeller, around and around. This tail is a long flagella that pushes the sperm forward. A sperm can travel about 30 inches per hour. This may not sound very fast, but don't forget how small a sperm is. For its size, a sperm moves about as fast as you do when you walk briskly.

Sperm Production

To make sperm, cells start in the testes and end in the epididymis. It takes up to two months to make sperm. The steps are explained below:

1. Special cells in the testes go through **mitosis** (cell division) to make identical copies of themselves.
2. The copies of the original cells divide by **meiosis** , producing cells called **spermatids** . The spermatids have half the number of chromosomes as the original cell. The spermatids are immature and cannot move on their own.
3. The spermatids are transported from the testes to the epididymis. Involuntary muscular contraction moves the spermatids along.
4. In the **epididymis** , spermatids slowly grow older and mature. They grow a tail. They also lose some of the cytoplasm from the head.
5. When sperm are mature, they can "swim." The mature sperm are stored in the epididymis until it is time for them to leave the body.

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

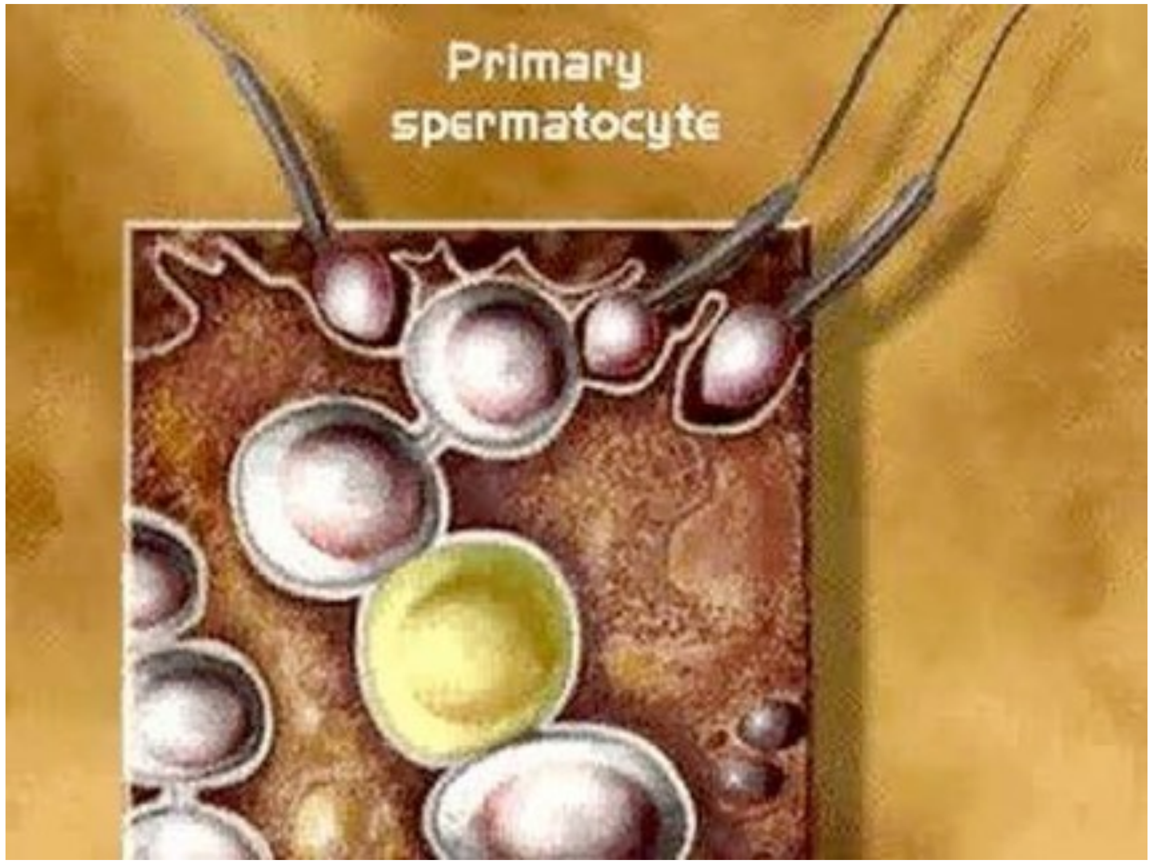
Summary

- Sperm are male gametes that form in the testes and mature in the epididymis.
- The head of the sperm contains the nucleus, the midpiece is packed with mitochondria, and the tail moves like a propeller.

Explore More

Use the resource below to answer the questions that follow.

- **Spermatogenesis** at http://www.youtube.com/watch?v=POpbN6RHOO0 (0:45)



Click on the image above for more content

1. What produces primary spermatocytes? How many chromosomes do primary spermatocytes have?
2. What produces secondary spermatocytes? How many chromosomes do secondary spermatocytes have?
3. What makes spermatids? How many chromosomes do spermatids have?
4. What happens to the spermatids?

Review

1. How many cells make up a sperm?
2. List the three main parts of a sperm.
3. What mostly make up the midpiece of a sperm? Why is this section important?
4. What is the function of the tail of a sperm?
5. Explain why sperm production is not completed when spermatids have been produced.

Section 68

Female Reproductive Sys-

Female Reproductive System

- •State the functions of the female reproductive system.
- •List the roles of estrogen.

What causes a girl to develop into a woman?

Adult female characteristics, such as breasts, develop during the teen years. What causes this to happen? The development of the female traits is caused by the hormones produced by the female reproductive system.

The Female Reproductive System Functions

Most of the male reproductive organs are outside of the body. But female reproductive organs are inside of the body. The male and female organs also look very different and have different jobs. Two of the functions of the female reproductive system are similar to the functions of the male reproductive system. The female system:

1. Produces **gametes** , the reproductive cells, which are called eggs in females.
2. Secretes a major sex hormone, estrogen.

One of the main roles of the female reproductive system is to produce eggs. **Eggs** (**Figure** below) are female gametes, and they are made in the ovaries. After puberty, females release only one egg at a time. Eggs are actually made in the body before birth, but they do not fully develop until later in life. Like sperm, eggs are produced by meiosis, so they contain half the number of chromosomes as the original cell.

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

1. During the teen years, estrogen causes the reproductive organs to develop. It also causes other

female traits to develop. For example, it causes the breasts to grow.
2.During adulthood, estrogen is needed for a woman to release eggs. On average, a woman releases one egg each month from her ovaries.

The female reproductive system has another important function. After puberty, the female reproductive system must prepare itself to accept a fertilized egg each cycle (about every month). This cycle is controlled by a well-planned and very complex interplay of hormones. If an egg is not fertilized, the system must prepare itself again the next cycle. The female reproductive system also supports a baby as it develops before birth, and it facilitates the baby's birth at the end of pregnancy.

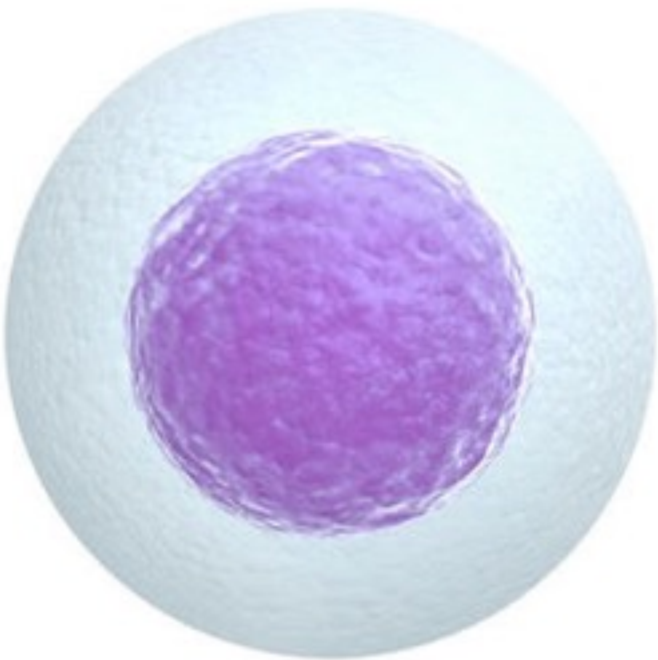


Figure 11.130

This represents a human egg, which is the gamete, or reproductive cell, in females. Notice that is does not have a distinct shape, like a sperm cell has. The egg is a round cell with a haploid nucleus in the center. The egg contains most of the cytoplasm and organelles present in the first cell of a new organism.

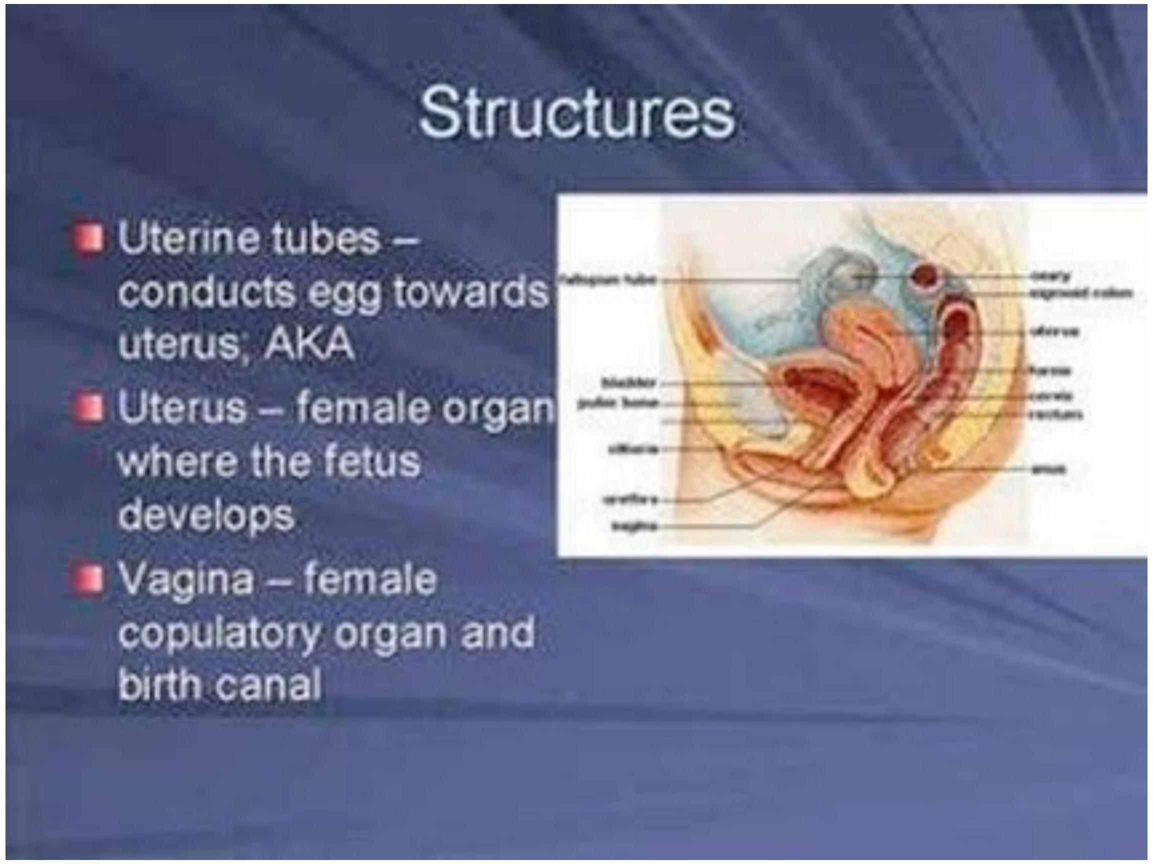
Summary

•The functions of the female reproductive system are to produce eggs, secrete estrogen, and support a baby as it develops before birth.
•Estrogen, the main sex hormone in females, causes the female traits and reproductive organs to develop and is needed for the release of eggs.

Explore More

Use the resource below to answer the questions that follow.

•**Female Reproductive System** at http://www.youtube.com/watch?v=SkcddD0LGIM (5:01)



Click on the image above for more content

1. What hormones are involved in the female reproductive process?
2. What are ovaries? What is their function?
3. What is an oocyte?
4. How many chromosomes are in a human egg cell?
5. What is the function of the follicles? Where are they located?
6. What is the function of the uterus?

Review

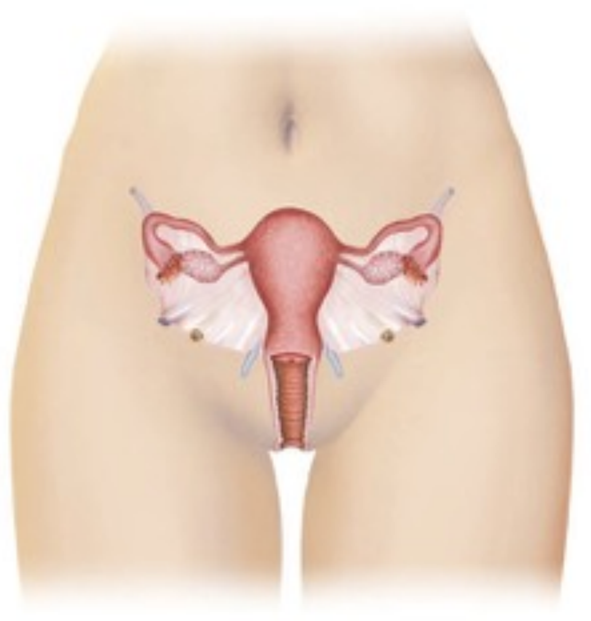
1. List the two major roles of estrogen in females.
2. What are the main roles of the female reproductive system?

Section 69

Female Reproductive Struc-

Female Reproductive Structures

•Define ovary, uterus, and fallopian tube.
•Identify the organs of the female reproductive system.
•Describe the functions of the female reproductive organs.



Where are the female reproductive organs?

Unlike the male reproductive organs, much of the female reproductive organs are internal. This allows them to be well-protected by the body.

Female Reproductive Organs

The female reproductive organs include the vagina, uterus, fallopian tubes, and ovaries (**Figure** below). The breasts are not shown in this figure. They are not considered reproductive organs, even though they are involved in reproduction. They contain mammary glands that give milk to feed a baby. The milk leaves the breast through the nipple when the baby sucks on it.

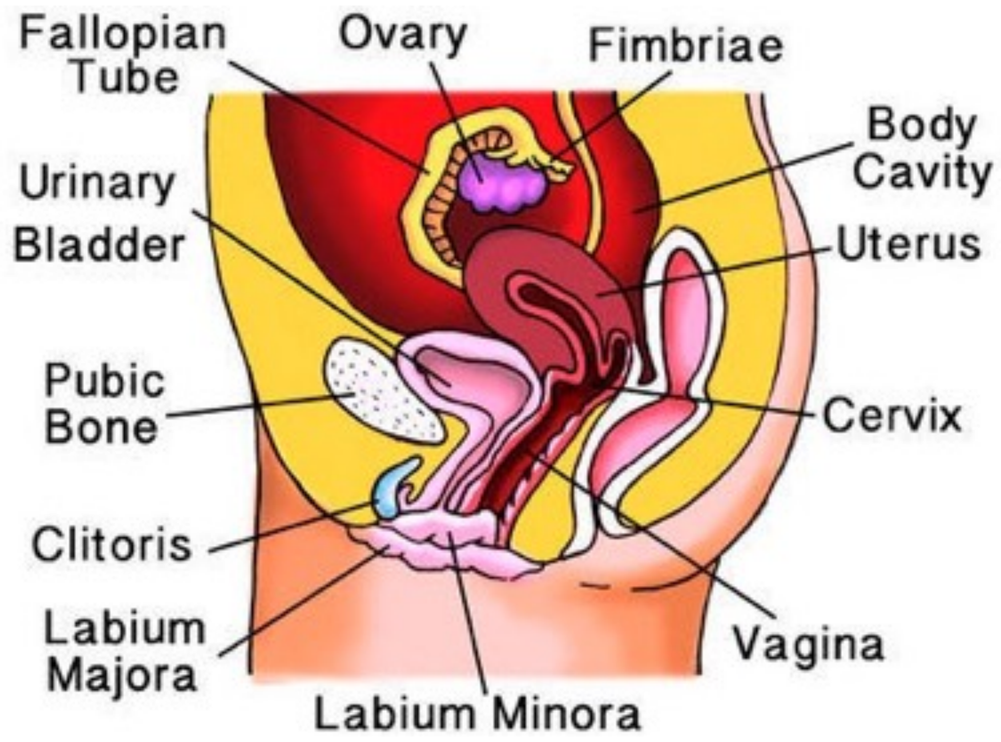


Figure 11.131

This drawing shows the organs of the female reproductive system. It shows the organs from the side. Find each organ in the drawing as you read about it in the text.

•The **vagina** is a cylinder-shaped organ found inside of the female body. One end of the vagina opens at the outside of the body. The other end joins with the uterus. During sexual intercourse, sperm may be released into the vagina. If this occurs, the sperm will move through the vagina and into the uterus. During birth, a baby passes from the uterus to the vagina to leave the body.

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

•The two **ovaries** are small, oval organs on either side of the uterus. Each ovary contains thousands of eggs, with about 1-2 million immature eggs present at birth and 40,000 immature eggs present at puberty, as most of the eggs die off. The eggs do not fully develop until a female has gone through puberty. About once a month, on average one egg completes development and is released by the ovary. The ovaries also secrete **estrogen** , the main female sex hormone.

•The two **fallopian tubes** are narrow tubes that open off from the uterus. Each tube reaches for one of the ovaries, but the tubes are not attached to the ovaries. The end of each fallopian tube by the ovary has "fingers" (**Figure** above). They sweep an egg into the fallopian tube. Then the egg passes through the fallopian tube to the uterus. If an egg is to be fertilized, this will occur in the fallopian tube. A fertilized egg then implants into the wall of the uterus, where it begins to develop. An unfertilized egg will flow through the uterus and be excreted from the body.

Summary

•Female reproductive organs include the vagina, uterus, ovaries, and fallopian tubes.
•The ovaries release the eggs and secrete estrogen.

Explore More

Use the resource below to answer the questions that follow.

•**Female Reproductive Organs** at http://www.innerbody.com/image/repfov.html

1.What is the vagina?
2.What is a fallopian tube? What commonly takes place here?
3.What are the functions of the ovaries?

Review

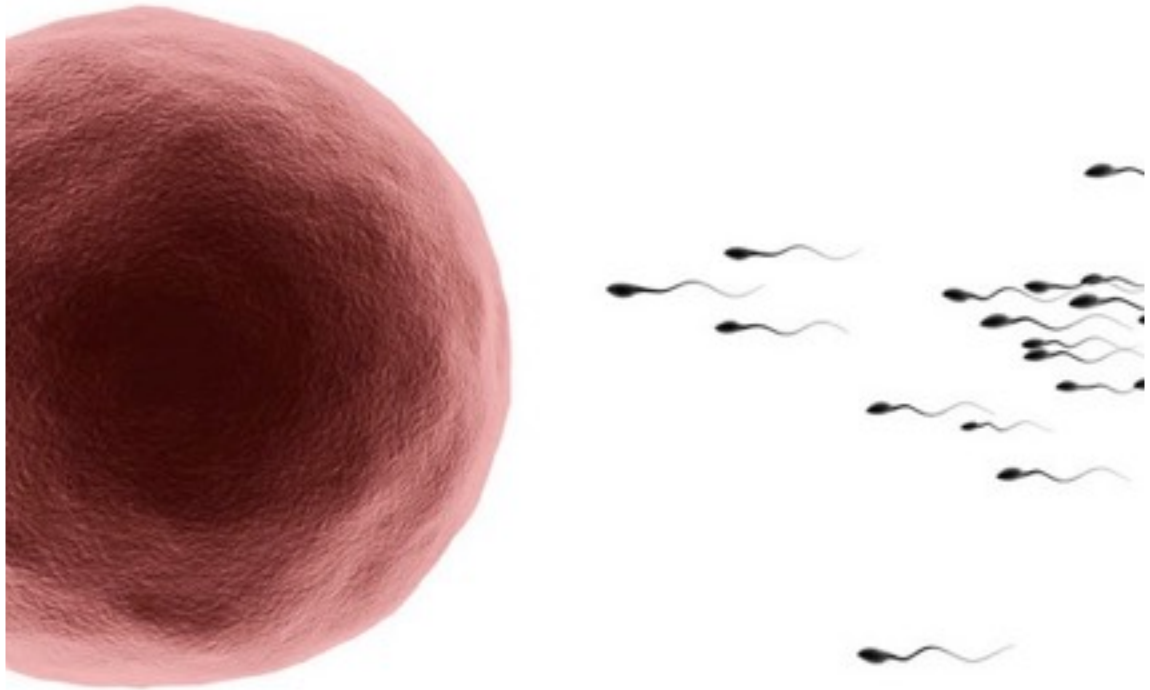
1.What are the functions of the ovaries in female reproduction?
2.What are the functions of the uterus in female reproduction?
3.What are the fallopian tubes? What may happen in the fallopian tube?

Section 70

Human Egg Cells

Human Egg Cells

- •State facts associated with the egg.
- •Summarize egg production.



How is egg different from sperm?

Egg and sperm are both gametes, or reproductive cells. Notice how different they are, however. The egg is much larger than the sperm. The egg also does not have a tail. And the female only releases one egg at time, while the male releases millions of sperm at a time.

Eggs and Egg Production

When a baby girl is born, her ovaries contain all of the eggs they will ever produce. But these eggs are not fully developed. They develop only after she starts having menstrual periods at about age 12 or 13. Just one egg develops each month. A woman will release an egg once each month until she is in her 40s. A girl is born with over a million eggs. They die off and by puberty about 40,000 remain.

Eggs

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

Egg Production

Egg production takes place in the ovaries. It takes several steps to make an egg:

1. Before birth, special cells in the ovaries go through **mitosis** (cell division), producing identical cells.

2.The daughter cells then start to divide by **meiosis** . But they only go through the first of the two cell divisions of meiosis at that time. They go through the second stage of cell division after the female goes through puberty.
3.In a mature female, an egg develops in an ovary about once a month. The drawing below shows how this happens (**Figure** below).

As you can see from the figure, the egg rests in a nest of cells called a **follicle** . The follicle and egg grow larger and go through other changes. After a couple of weeks, the egg bursts out of the follicle and through the wall of the ovary. This is called **ovulation** , which usually occurs at the midpoint of a monthly cycle. The moving fingers of the nearby **fallopian tube** sweep the egg into the tube. At this time, if sperm are present the egg can be fertilized.

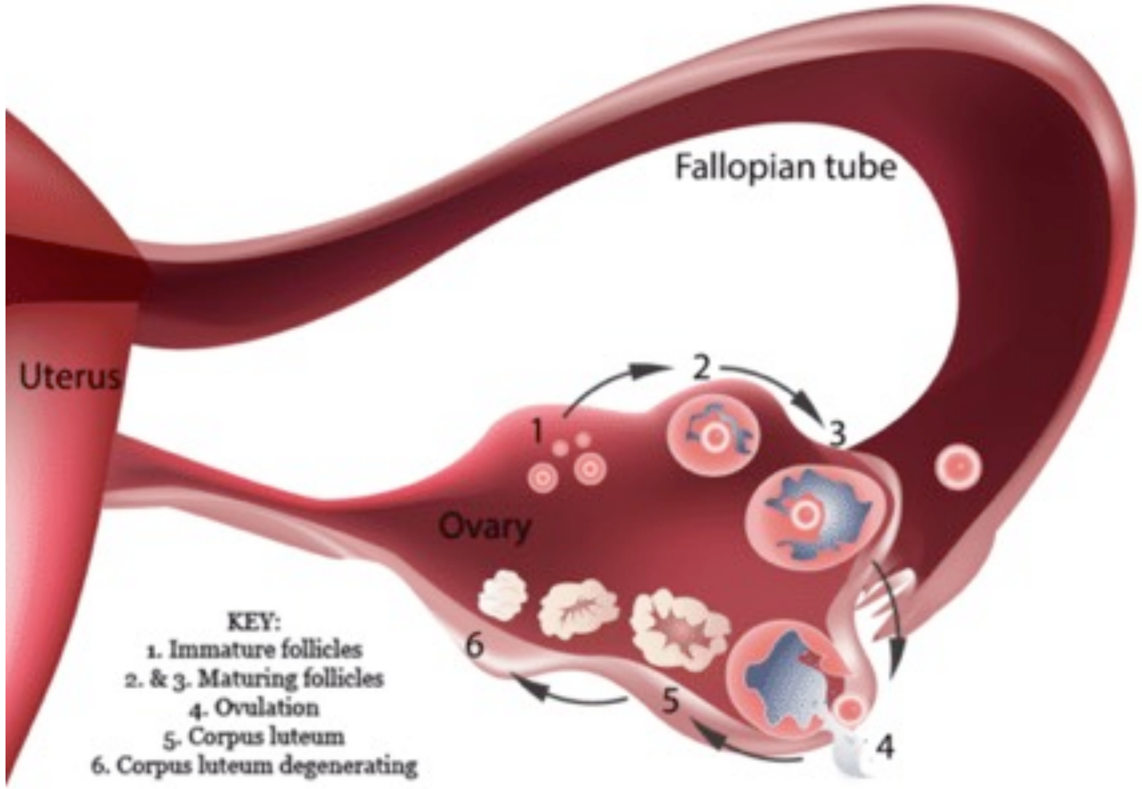


Figure 11.132

This diagram shows how an egg and its follicle develop in an ovary. After it develops, the egg leaves the ovary and enters the fallopian tube. (1) Undeveloped eggs, (2) Egg and follicle developing, (3) Egg and follicle developing, (4) Ovulation. After ovulation, what remains of the follicle is known as the corpus luteum, which degenerates (5, 6).

Fertilization occurs if a sperm enters the egg while it is passing through the fallopian tube. When this happens, the egg finally completes meiosis. This results in two daughter cells that are different in size. The smaller cell is called a **polar body** . It contains very little cytoplasm. It soon breaks down and disappears. The larger cell is the egg. It contains most of the cytoplasm. This will develop into a child.

Summary

- Eggs are female gametes that form in the ovaries and are released into the fallopian tubes.
- The eggs are formed before a baby girl is born, but these eggs are not fully developed.

Explore More

Use the resources below to answer the questions that follow.

Explore More I

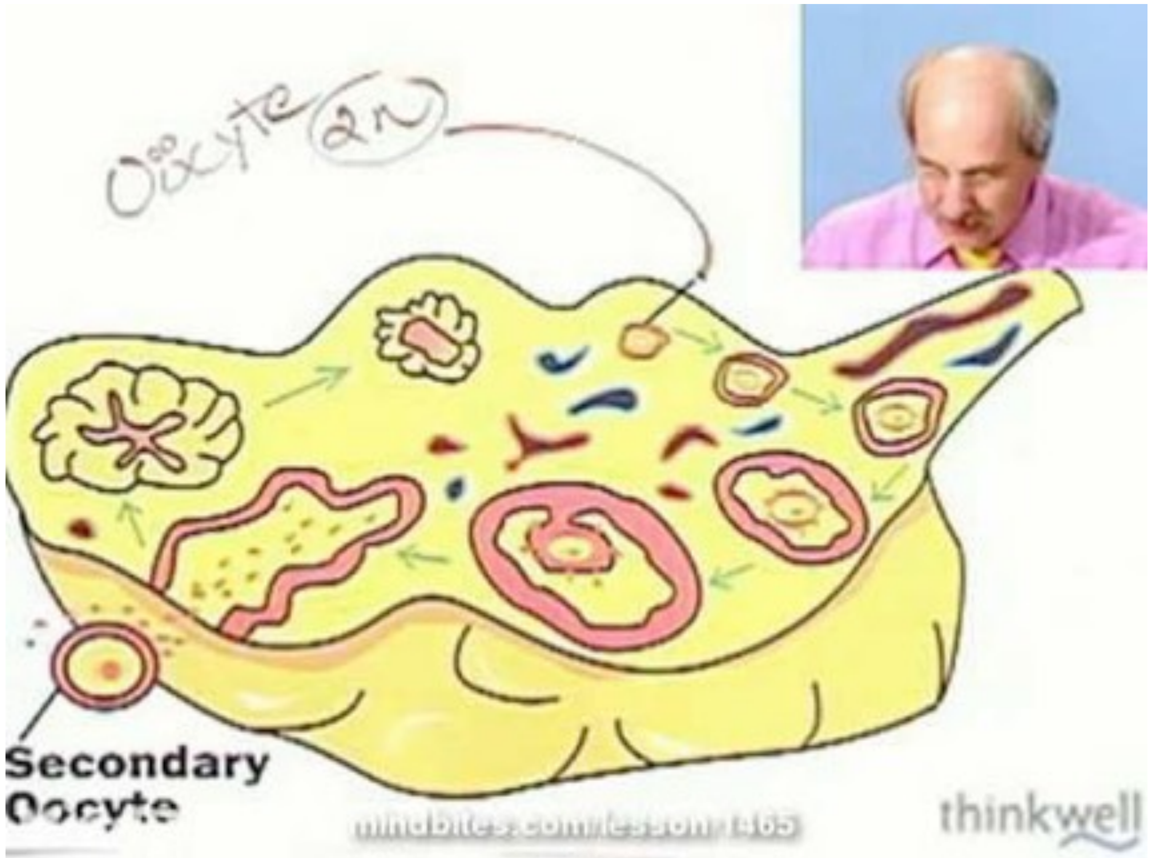
- **Follicle Development** at http://www.youtube.com/watch?v=dwtFYOLFeNw (1:56)

Click on the image above for more content

1. What happens during ovulation? What happens to an egg after ovulation?
2. At what point is a zygote formed? How many chromosomes does a human zygote normally have?
3. Where does implantation occur?

Explore More II

- **Biology: Oogenesis: Meiosis in Females** at http://www.youtube.com/watch?v=fyhl6Qcu5NQ (2:38)



Click on the image above for more content

1. How many chromosomes are in the primary oocyte?
2. What structure forms from the primary oocyte?

Review

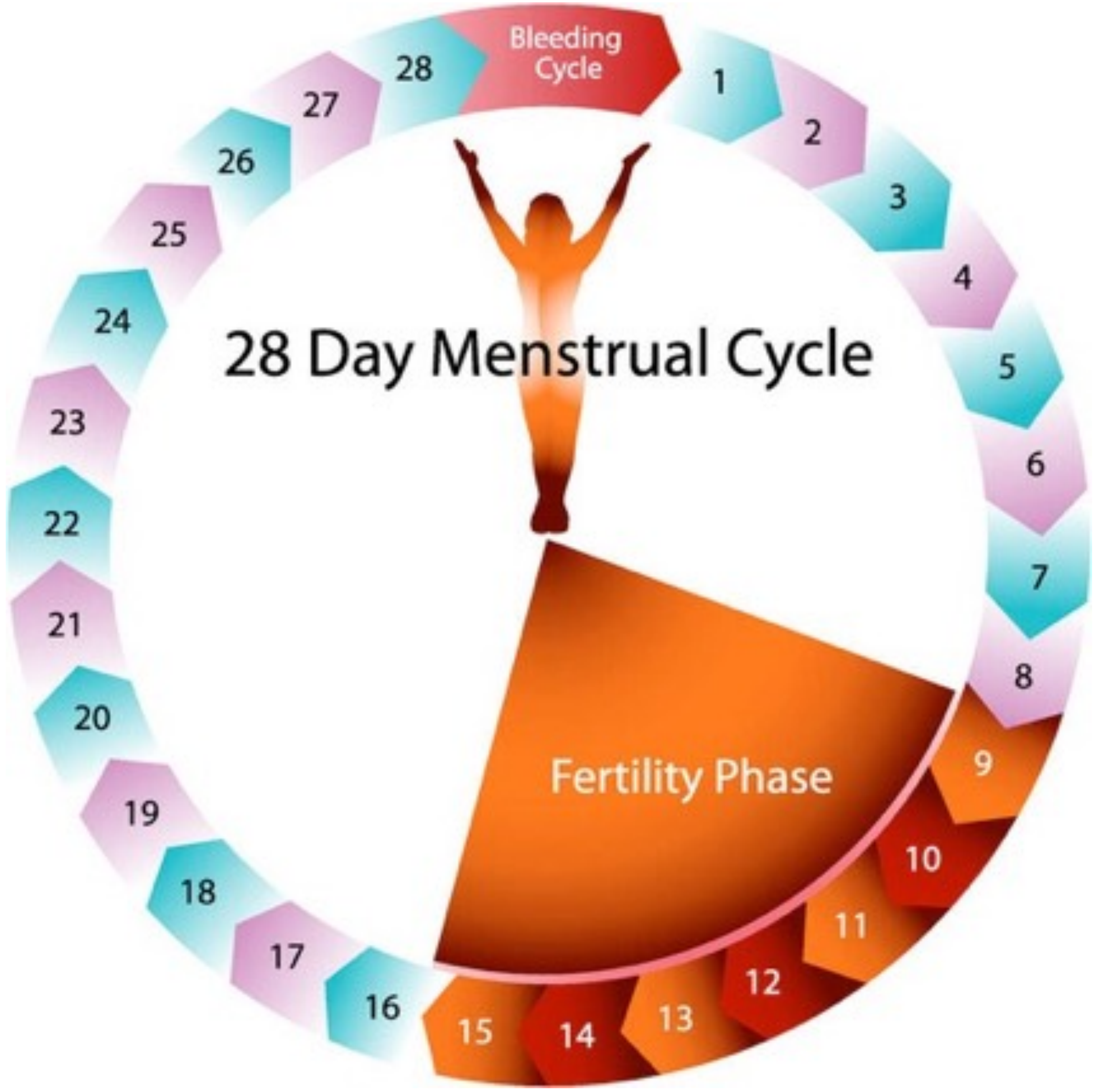
1. Describe what happens during ovulation. When does this occur?
2. After ovulation, where does the egg go?
3. Briefly describe egg production.
4. What is a polar body?

Section 71

Menstrual Cycle

Menstrual Cycle

•Define menstrual cycle and menstruation.
•Outline the monthly cycle of the female reproductive system.



What happens during the menstrual cycle?

When you think of the menstrual cycle, you probably think of the discharge of blood that happens during menstruation. This is only one small part of the female monthly cycle, however.

The Female Monthly Cycle

The **menstrual cycle** is a series of changes in the reproductive system of mature females that repeats every month. While the egg and follicle are developing in the ovary, tissues are building up inside the **uterus** , the reproductive organ where the baby would develop. The uterus develops a thick lining covered in tiny blood vessels. This prepares the uterus to receive an egg that could develop into a child. The occurs during the first part of the cycle. Ovulation, the release of an egg from the ovary, occurs at about the midpoint of the cycle. This would be around day 14 of a 28 day cycle. The egg is swept into the fallopian tube. If sperm is present, fertilization may occur. The fertilized egg makes its way through the fallopian tube into the uterus, where it imbeds into the thick lining. When this occurs, the monthly cycle stops. The monthly cycle does not resume until the pregnancy is over.

If a sperm *does not* enter an egg, the lining of the uterus breaks down. Blood and other tissues from the lining break off from the uterus. They pass through the vagina and out of the body. This is called **menstruation** . Menstruation is also called a menstrual period. It lasts about 4 days, on average. When the menstrual period ends, the cycle repeats. Some women feel discomfort during this process.

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

Figure 11.133

Some women experience cramping and pain before and during menstruation.

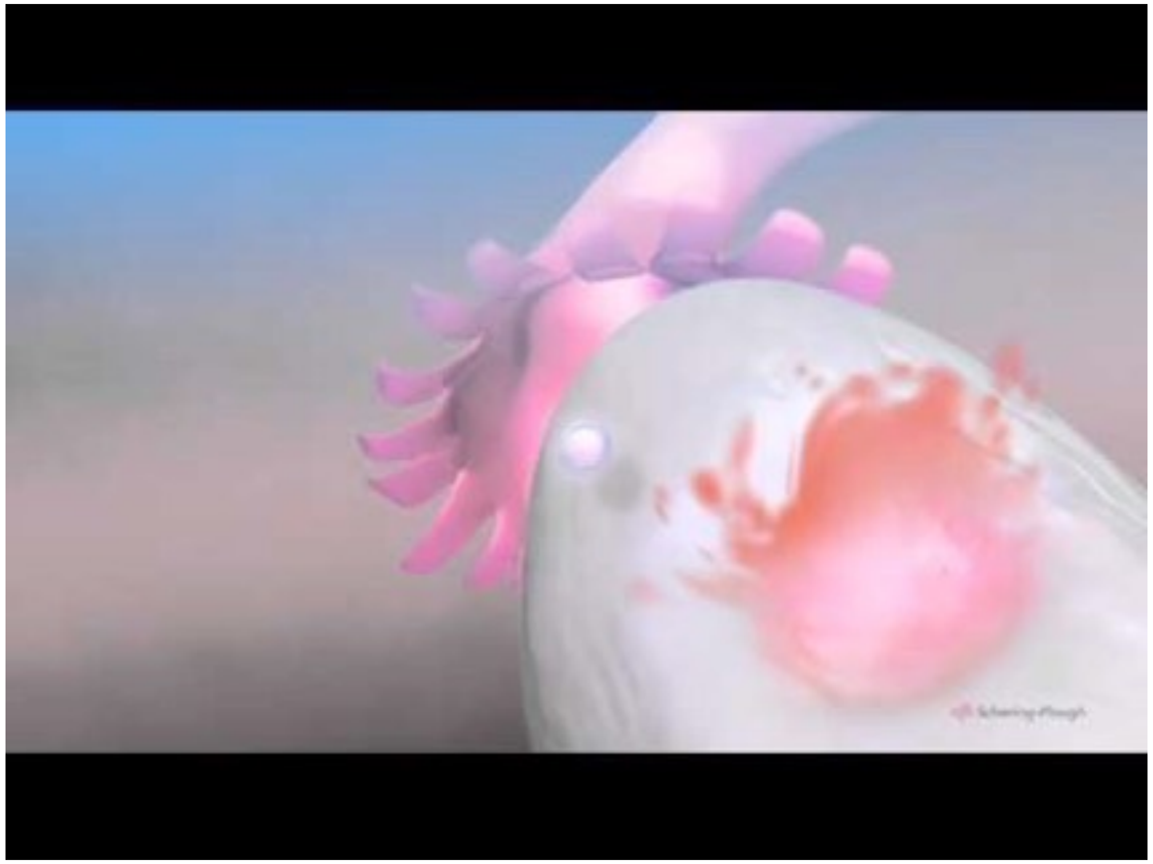
Summary

- The menstrual cycle is a monthly cycle of changes in the ovaries and uterus.
- During menstruation, blood and other tissues from the lining of the uterus are shed and exit the body.

Explore More

Use the resource below to answer the questions that follow.

•**Ovulation and the Menstrual Cycle** at http://www.youtube.com/watch?v=WGJsrGmWeKE (4:06)



Click on the image above for more content

1.What is ovulation?
2.What role does the pituitary gland play in menstruation? What controls the pituitary gland? What does this gland secrete?
3.How do the ovaries respond to a signal from the pituitary gland?
4.What does a peak in LH signal?
5.What role does progesterone play in the menstrual cycle? Where does the progesterone come from?

Review

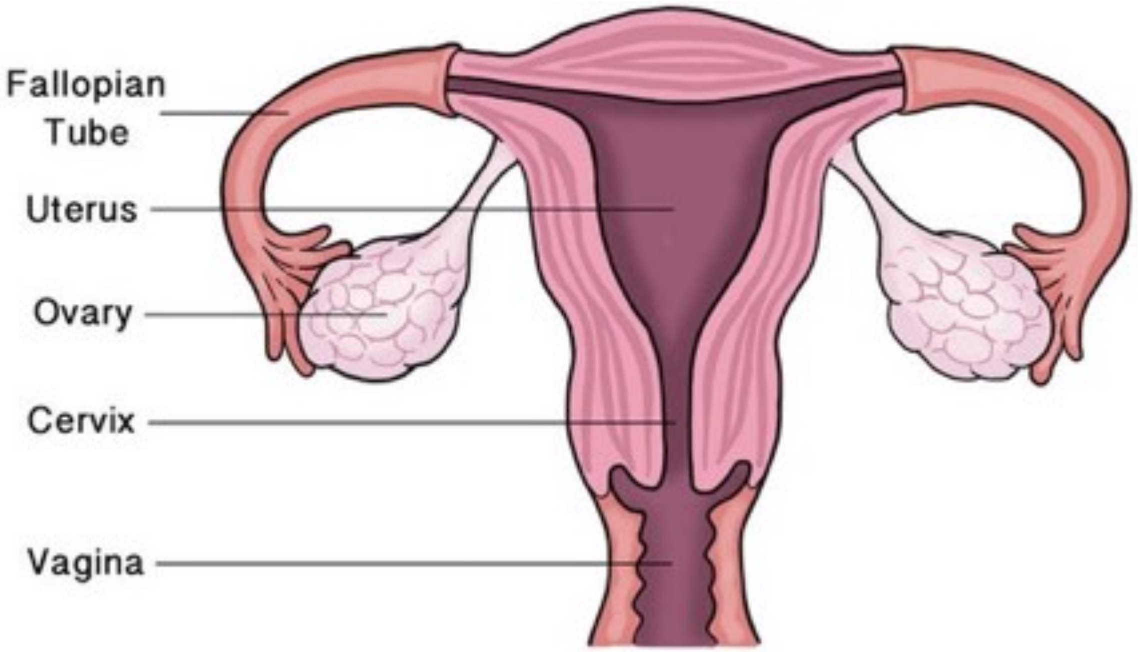
1.What happens in the uterus as the egg and follicle are developing in the ovary? Why is this necessary?
2.What happens to the uterus if the egg is not fertilized?
3.Explain what happens during menstruation.

Section 72

Fertilization

Fertilization

•Define fertilization and implantation.
•Explain the process of fertilization.
•Describe the events immediately after fertilization.



Where do sperm meet the egg?

You might guess that sperm meet the egg in the uterus, the organ where the baby develops. But that is incorrect. The sperm meet the egg in the fallopian tubes that carry the egg from the ovary to the uterus. Then the developing embryo travels to the uterus.

Fertilization and Implantation

The sperm and egg don't look anything like a human baby (**Figure** below). After they come together, they will develop into a human being. How does a single cell become a complex organism made up of billions of cells? Keep reading to find out.

Sexual reproduction happens when a sperm and an egg cell combine together. This is called **fertilization** . Sperm are released into the vagina during sexual intercourse. They "swim" through the uterus and enter a **fallopian tube** . This is where fertilization normally takes place.

A sperm that is about to enter an egg is pictured below (**Figure** below). If the sperm breaks through the egg's membrane, it will immediately cause changes in the egg that keep other sperm out. This ensures that only a single sperm can penetrate an egg. It will also cause the egg to go through meiosis. Recall that **meiosis** , cell division that creates the egg, begins long before an egg is released from an ovary. In fact, it begins prior to birth.

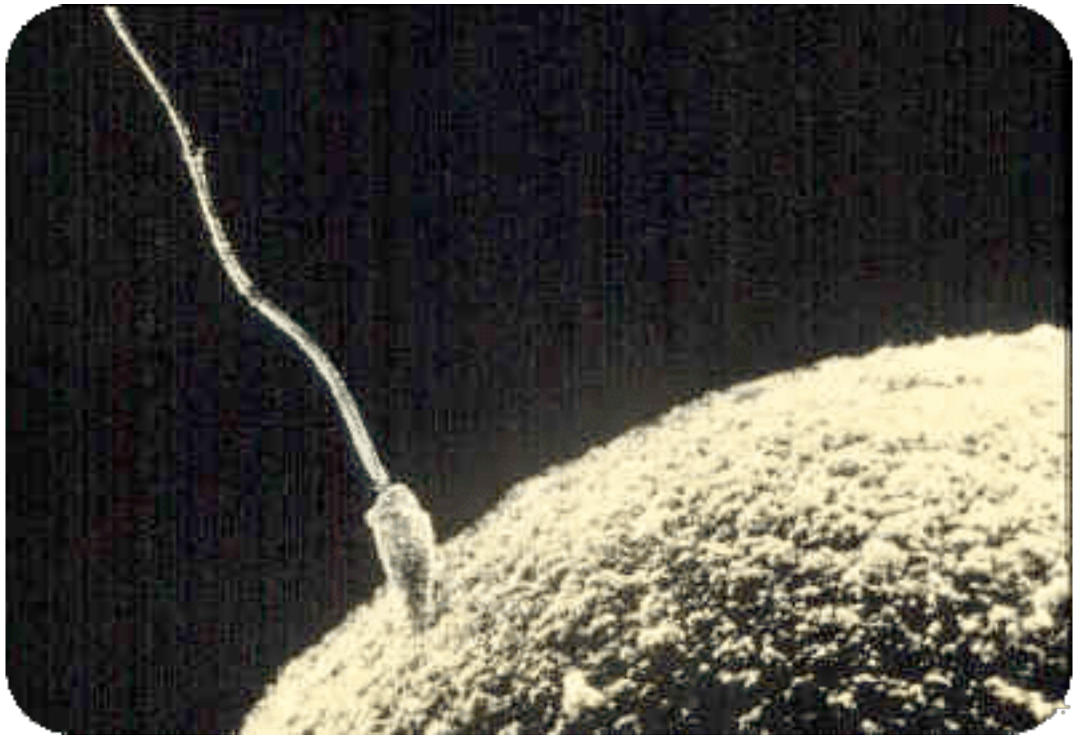


Figure 11.134

This sperm is ready to penetrate the membrane of this egg. Notice the difference in size of the sperm and egg. Why is the egg so much larger? The egg contributes all the cytoplasm and organelles to the zygote. The sperm only contributes one set of chromosomes.

The sperm and egg each have only half the number of chromosomes as other cells in the body. These cells are haploid, with a single set of chromosomes. This is because when they combine together, they form a cell with the full number of chromosomes. The cell they form is called a **zygote** . The zygote is diploid, with two sets of chromosomes, one from each parent. A human zygote has two sets of 23 chromosomes, for a total of 46 chromosomes. The zygote slowly travels down the fallopian tube to the uterus. As it travels, it divides by mitosis many times. It forms a hollow ball of cells.

After the ball of cells reaches the uterus, it fixes itself to the side of the uterus. This is called **implantation** . It usually happens about a week after fertilization. Now the implanted ball of cells is ready to continue its development into a baby boy or girl.

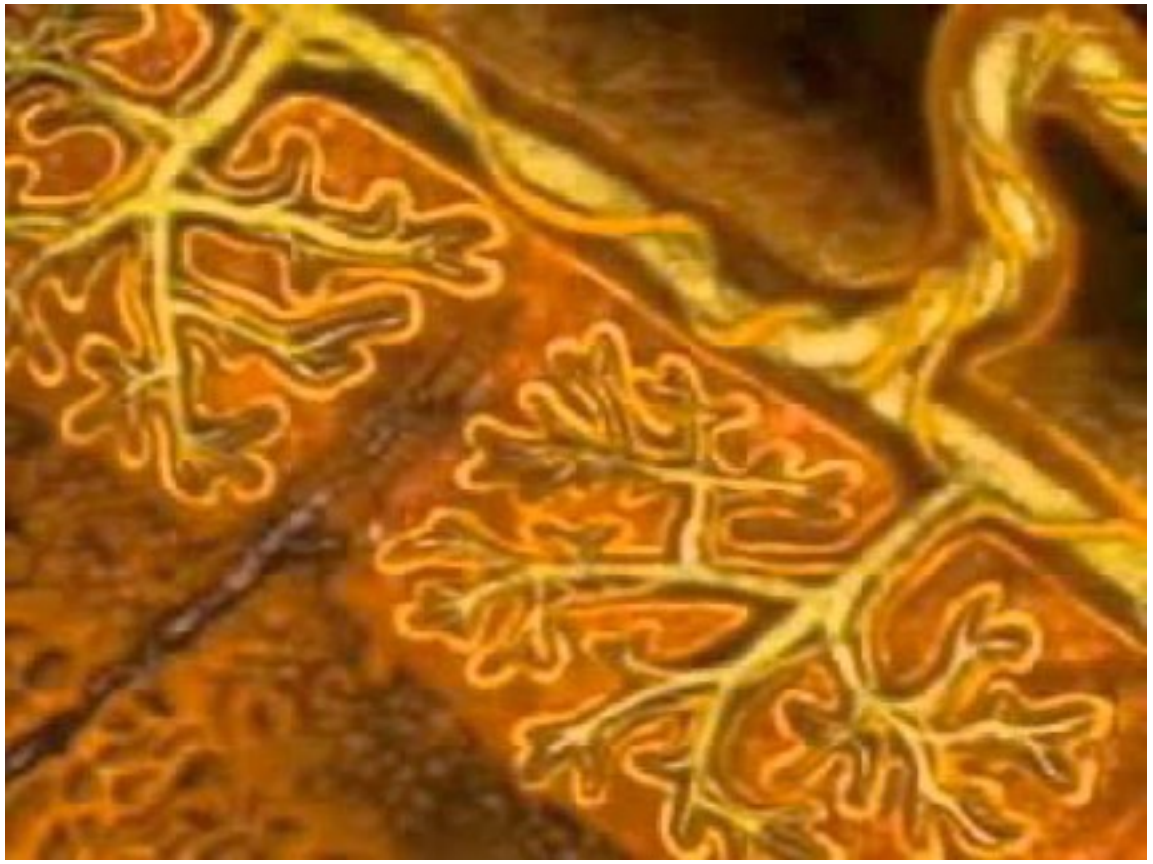
Summary

- Fertilization occurs when an egg and sperm come together to form a zygote.
- Implantation occurs when the developing embryo fixes itself to the side of the uterus.

Explore More

Use the resource below to answer the questions that follow.

- **Human Reproduction** at http://www.youtube.com/watch?v=VMGY9122ssE (3:01)



Click on the image above for more content

1. How long after fertilization does it take the zygote to reach the uterus?
2. About how many cells is the embryo at the time of implantation?
3. What prevents the uterine lining from being shed if an egg is fertilized?
4. How does the developing embryo receive nutrition?

Review

1. What is fertilization?
2. Where does fertilization take place?
3. What is a zygote? How many chromosomes does a human zygote normally have?
4. If the egg is fertilized, what immediately happens next?
5. Where does implantation take place?

Section 73

Pregnancy and Childbirth

Pregnancy and Childbirth

•Identify major events of pregnancy and childbirth.
•Summarize major developmental events between the third and eighth week after fertilization.
•Explain the roles of the amniotic sac, placenta, and umbilical cord.

Does a growing embryo always look like a tiny human?

The above picture shows the very early stages of human development. Notice that, at first, the embryo doesn't look very human! It takes time for the human features to take shape.

Pregnancy and Childbirth

While a woman is pregnant, the developing baby may be called an embryo or a fetus. Do these mean the same thing? No, in the very early stages the developing baby is called an embryo, while in the later stages it is called a fetus. When the ball of cells first implants into the uterus, it is called an **embryo** . The embryo stage lasts until the end of the 8th week after fertilization. After that point until birth, the developing baby is called a **fetus** .

Growth and Development of the Embryo

During the embryo stage, the baby grows in size.

- 3rd week after fertilization: Cells of different types start to develop. Cells that will form muscles and skin, for example, start to develop at this time.
- 4th week after fertilization: Body organs begin to form.
- 8th week after fertilization: All the major organs have started to develop.

Pictured below are some of the changes that take place during the 4th and 8th weeks (**Figure** below). Look closely at the two embryos in the figure. Do you think that the older embryo looks more human? Notice that it has arms and legs and lacks a tail. The face has also started to form, and it is much bigger.

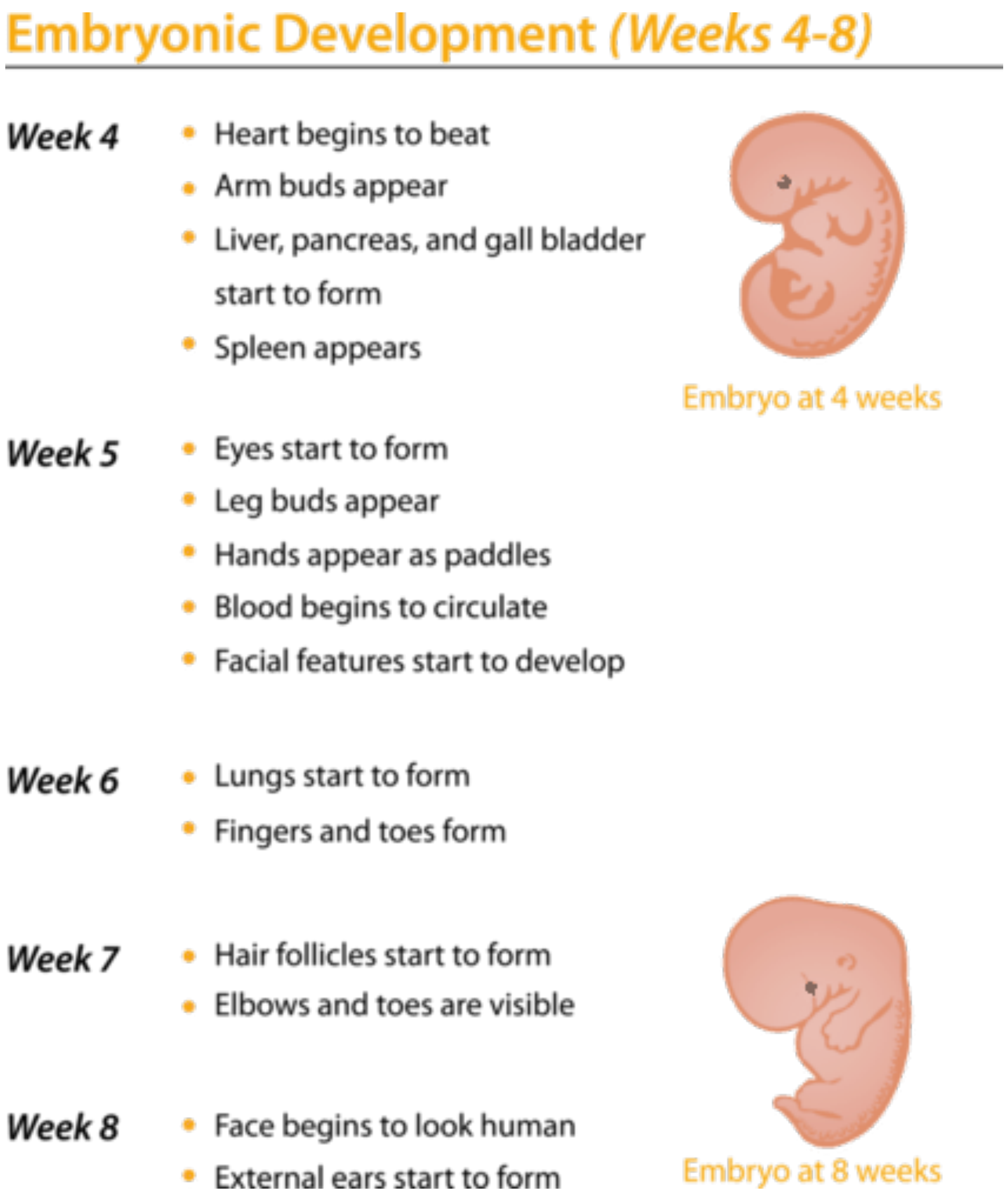


Figure 11.135

Embryonic Development (Weeks 4–8). Most organs develop in the embryo during weeks four through eight. (Note: the drawings of the embryos are not to scale.)

Growth and Development of the Fetus

There are also many changes that take place after the embryo becomes a fetus. Some of the differences between them are obvious. For example, the fetus has ears and eyelids. Its fingers and toes are also fully formed. The fetus even has fingernails and toenails. In addition, the reproductive organs have developed to make the baby a male or female. The brain and lungs are also developing quickly. The fetus has started to move around inside the uterus. This is usually when the mother first feels the fetus moving.

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

During the last several weeks of the fetal period, all of the organs become mature. The most obvious change, however, is an increase in body size. The fetus rapidly puts on body fat and gains weight during the last couple of months. By the end of the 38 th week, all of the organs are working, and the fetus is ready to be born. This is when birth normally occurs.

The Amniotic Sac and Placenta

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

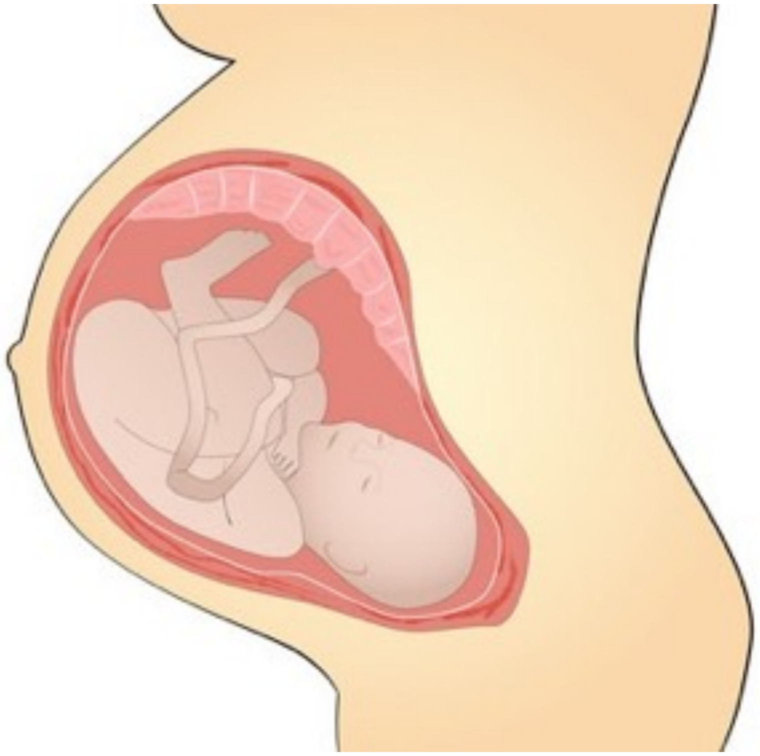


Figure 11.136

Surrounding the fetus is the fluid-filled amniotic sac. The placenta and umbilical cord are also shown here. They provide a connection between the mother's and fetus's blood for the transfer of nutrients and gases.

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

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

It is important for the mother to eat plenty of nutritious foods during pregnancy. She must take in enough nutrients for the fetus as well as for herself. She needs extra calories, proteins, and lipids. She also needs more vitamins and minerals.

In addition to eating well, the mother must avoid substances that could harm the embryo or fetus. These include alcohol, illegal drugs, and some medicines. It is especially important for her to avoid these substances during the first eight weeks after fertilization. This is when all the major organs are forming. Exposure to harmful substances during this time could damage the developing body systems.

Childbirth

During **childbirth** , a baby passes from the uterus, through the vagina, and out of the mother's body. Childbirth usually starts when the amniotic sac breaks.

Then, the muscles of the uterus start contracting. The contractions get stronger and closer together. They may go on for hours. Eventually, the contractions squeeze the baby out of the uterus. Once the baby enters the vagina, the mother starts pushing. She soon pushes the baby through the vagina and out of her body.

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

Summary

- A zygote develops into an embryo and then a fetus.
- During pregnancy, the amniotic sac, placenta, and umbilical cord develop inside the mother's uterus.

Explore More

Use the resource below to answer the questions that follow.

- **Anatomy of Childbirth** at http://www.pbs.org/wgbh/nova/body/anatomy-childbirth.html

1. What hormone does the mother secrete at the start of labor? What is the affect of this hormone
2. What signals the start of "active labor"?
3. What happens at the "pushing stage" of childbirth?
4. What is the leading cause of maternal death in developing countries?

Review

1. What's the difference between an embryo and a fetus?
2. What is the amniotic sac and amniotic fluid? Explain their roles.
3. What is the placenta and umbilical cord? Explain their roles.
4. What triggers a baby to start breathing after birth?

Section 74

Infancy and Childhood

Infancy and Childhood

•Define infancy and childhood.
•List important developments of infancy.
•List milestones that occur during the first few years of childhood.

Does a baby learn much during his first year?

The first years of life are full of important milestones as new skills are mastered. For example, at first this baby wasn't even able to roll over on his stomach or hold up his head!

Infancy and Childhood

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

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

Figure 11.137

This baby's teeth have started to come in. Babies often chew on toys or other objects when they are getting new teeth. They may even chew on their toes.

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

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

Figure 11.138

Children develop better motor skills as they get older.

Early Childhood Development

There are numerous milestones that occur during the first few years of childhood. These include

- the use of language,
- walking and running,
- understanding simple concepts,
- pretend play,
- the development of fine motor skills,
- the development of independence,
- having temper tantrums,
- demonstrating separation anxiety,
- becoming fully potty-trained,
- showing natural curiosity.

Summary

- The first year after birth is called infancy, after which childhood begins.
- An individual grows quickly and develops new abilities during infancy and childhood.

Explore More

Use the resource below to answer the questions that follow.

- **Infancy Studies Laboratory** at http://www.youtube.com/watch?v=t_Y6wNWbNuE (2:07)

Click on the image above for more content

1. At what age do the researchers like to see infants to study cognitive development?
2. Why is it important to establish a baseline in research of this nature?
3. How do researchers hope to use information they are collecting to help children with language problems?

Review

1. What is infancy?
2. What changes in size happen during infancy?
3. What is a toddler?

4.List three milestones of early childhood.

Section 75

Puberty and Adolescence

Puberty and Adolescence

- •Define puberty and adolescence.
- •Outline changes that occur during puberty and adolescence.

How do you know you are entering puberty?

The first signs of puberty appear at different times for different people. A boy might realize he's reached puberty when he starts needing to shave. A girl, on the other hand, starts getting her menstrual period during puberty.

Puberty and Adolescence

Puberty is the stage of life when a child becomes sexually mature. Puberty lasts from about 12 to 18 years of age in boys and from about 10 to 16 years of age in girls. The age when puberty begins is different from one child to another. Children that begin puberty much earlier or later than their peers may feel self-conscious. They may also worry that something is wrong with them. Usually, an early or late puberty is perfectly normal.

In boys, puberty begins when the pituitary gland tells the testes to secrete testosterone. Testosterone causes the following to happen:

1. The penis and testes grow.
2. The testes start making sperm.
3. Pubic and facial hair grow.
4. The shoulders broaden, and the voice becomes deeper.

In girls, puberty begins when the pituitary gland tells the ovaries to secrete estrogen. Estrogen causes the following to happen:

1. The uterus and ovaries grow.
2. The ovaries start releasing eggs.
3. The menstrual cycle begins.
4. Pubic hair grows.
5. The hips widen, and the breasts develop.

Boys and girls are close to the same height during childhood. In both boys and girls, growth in height and weight is very fast during puberty. But boys grow faster than girls during puberty. Their period of fast growth also lasts longer. By the end of puberty, boys are an average of 10 centimeters (4 inches) taller than girls.

Adolescence

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

- Teenagers develop new thinking abilities. For example, they can think about abstract ideas, such as freedom. They are also better at thinking logically. They are usually better at solving problems as well.
- Teenagers try to establish a sense of who they are as individuals. They may try to become more independent from their parents. Most teens also have emotional ups and downs. This is partly due to changing hormone levels.
- Teenagers usually spend much more time with peers than with family members.

Figure 11.139

These teens are good friends. Like most teens, they spend more time with one another than they do with family members. These teens are volunteering at a charity event. What do you enjoy doing with your friends?

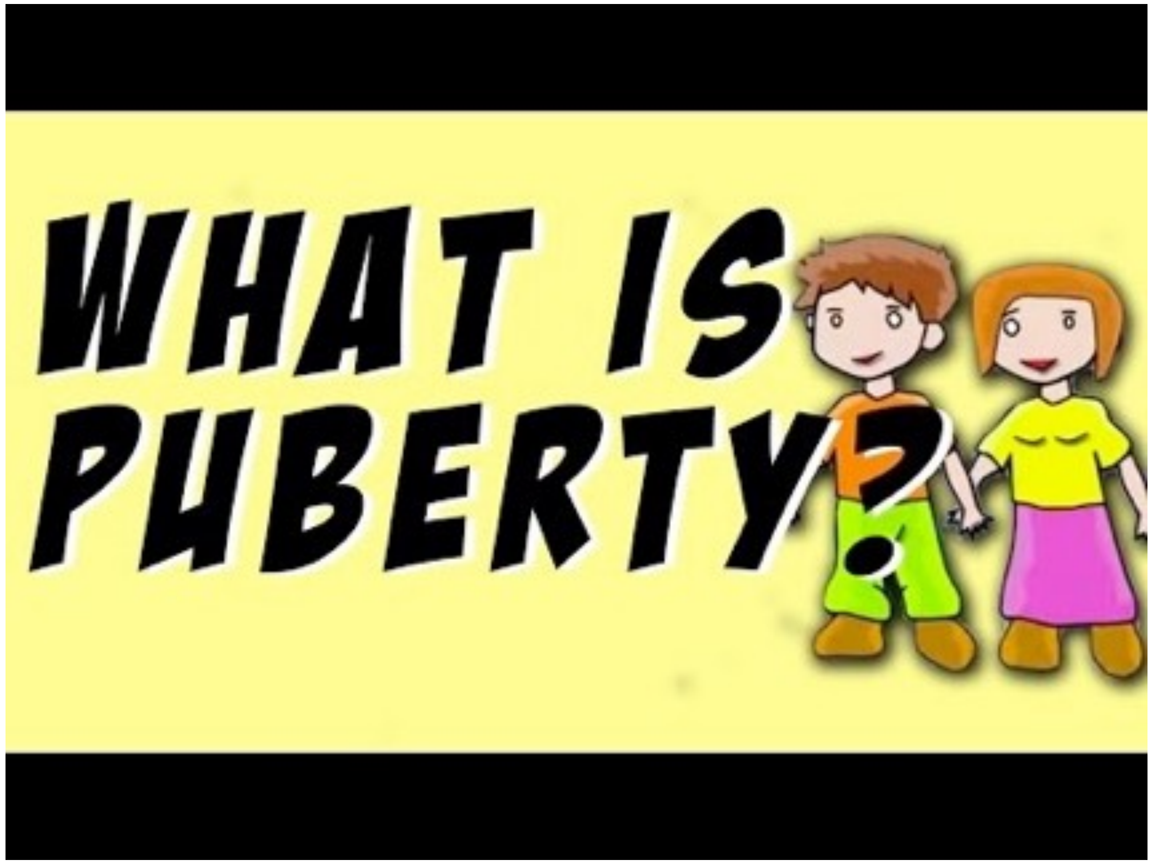
Summary

- A child becomes sexually mature during puberty.
- Adolescence includes the physical changes of puberty among other changes.

Explore More

Use the resource below to answer the questions that follow.

- **Puberty** at http://www.youtube.com/watch?v=TRyOcLSJDzk (3:04)



Click on the image above for more content

1. What is puberty? Are the first changes of puberty visible? What are they?
2. What is the average age that girls start puberty? When do physical changes usually appear?
3. What is the average age that boys start puberty? When do physical changes usually appear?
4. What kinds of non-physical changes may occur during puberty?

Review

1.When does puberty occur in boys? In girls?
2.What changes occur during puberty in boys?
3.What changes occur during puberty in girls?
4.What is adolescence?
5.Along with physical changes, what else changes during adolescence?

Section 76

Adulthood and Aging

Adulthood and Aging

•Distinguish early adulthood from middle adulthood and from late adulthood.
•Describe changes that begin in middle adulthood.
•Summarize issues associated with late adulthood.

What does adulthood mean to you?

You might think sometimes that you can't wait to be an adult! In adulthood you have greater freedom, but you also have greater responsibilities. Like this man, you might have a house and children to take care of.

Adulthood

When is a person considered an adult? That depends. Most teens become physically mature by the age of 16 or so. But they are not adults in a legal sense until they are older. For example, in the U.S., you must be 18 to vote. Once **adulthood** begins, it can be divided into three stages: (1) early, (2) middle, and (3) late adulthood.

Early Adulthood

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

Middle Adulthood

Middle adulthood begins in the mid-30s. It continues until the mid-60s.

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

Late Adulthood

Late adulthood begins in the mid-60s. It continues until death. This is the stage of life when most people retire from work. They are also likely to reflect on their life. They may focus on their grandchildren.

During late adulthood, people are not as physically able. For example, they usually have less muscle and slower reflexes. Their immune system also doesn't work as well as it used to. As a result, they have a harder time fighting diseases like the flu. The risk of developing diseases such as heart disease and cancer continues to rise. Arthritis is also common. In arthritis, joints wear out and become stiff and painful. As many as one in four late adults may develop Alzheimer's disease. In this disease, brain changes cause mental abilities to decrease.

Figure 11.140

This family picture shows females in each of the three stages of life. Which stage does each represent?

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

Summary

•Adulthood is divided into the stages of early, middle, and late adulthood.
•The risk of health problems increases in middle adulthood and late adulthood.

Explore More

Use the resources below to answer the questions that follow.

Explore More I

•**The Owner's Manual To Adulthood** at http://www.youtube.com/watch?v=VVwhMfWRfNA (5:25)

Click on the image above for more content

1. Why is it important to learn to prioritize activities?
2. What are some techniques people use to manage stress?
3. How can eating well, sleeping, and exercising help people with stress?
4. Do adults get to do whatever they want? Why or why not?

Explore More II

•**Late Adulthood** at http://www.youtube.com/watch?v=N6dn6LzdRkE (2:15)

Click on the image above for more content

1. Does reaching late adulthood mean you have to give up physical activity?
2. Do people in late adulthood still learn new things?

Review

1. How are early adulthood, middle adulthood, and late adulthood defined?
2. When are people at their physical peak?
3. What diseases are common in late adulthood?

Section 77

Sexually Transmitted Infec-

Sexually Transmitted Infections

•Define sexually transmitted infection.
•State common myths and facts about STIs.
•List common bacterial and viral STIs.
•Describe common sexually transmitted infections.

What is safe sex?

Safe sex is sexual activity engaged in by people who have taken precautions to protect themselves against sexually transmitted infections. Abstaining from sexual activity, however, is the only way to be absolutely sure that you won't get a sexually transmitted infection.

Sexually Transmitted Infections

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

STIs are more common in teens and young adults than in older people. One reason is that young people are more likely to take risks. They also may not know how STIs spread. They are likely to believe myths about STIs (**Table** below).

Myth	Fact
If you are sexually active with just one person, you can't get STIs.	The only way to avoid the risk of STIs is to practice abstinence from sexual activity.
If you don't have any symptoms, then you don't have an STI.	Many STIs do not cause symptoms, especially in females.

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

Bacterial STIs

In the U.S., **chlamydia** is the most common STI caused by bacteria. Females are more likely than males to develop the infection. Rates of chlamydia among U.S. females in 2006 are shown below (**Figure** below). Rates were much higher in teens and young women than in other age groups.

Chlamydia may cause a burning feeling during urination. It may also cause a discharge (leaking of fluids) from the vagina or penis. But in many cases it causes no symptoms. As a result, people do not know they are infected, so they don't go to the doctor for help. If chlamydia goes untreated, it may cause more serious problems in females. It may cause infections of the uterus, fallopian tubes, or ovaries. These infections may leave a woman unable to have children.

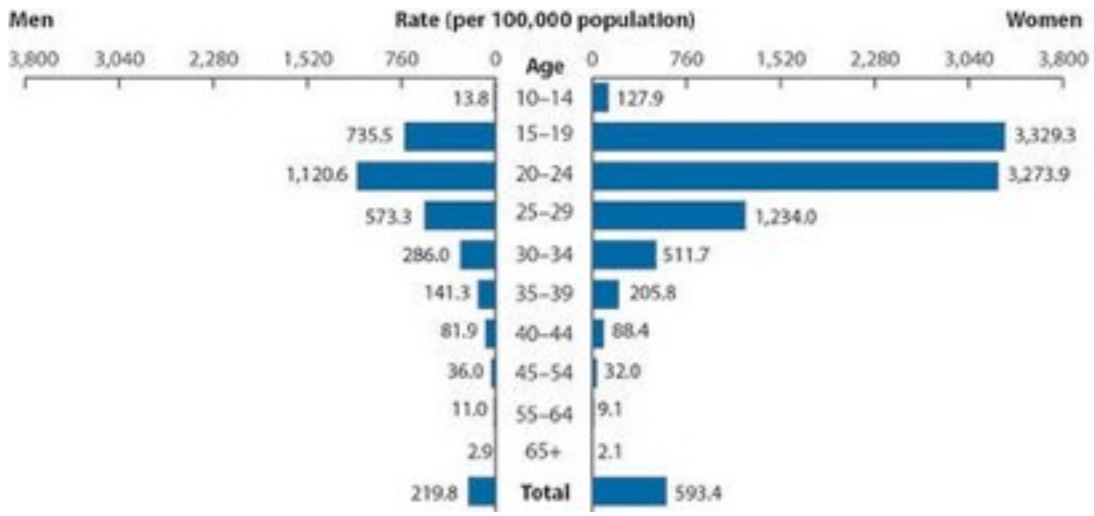


Figure 11.141

This graph shows data on the number of cases of chlamydia in U.S. males and females in 2009. Which two age groups had the highest rates of chlamydia? Why do you think rates were highest in these age groups?

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

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

Viral STIs

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

A related herpes virus causes cold sores on the lips (**Figure** below). Both viruses cause painful blisters. In the case of **genital herpes** , the blisters are on the penis or around the vaginal opening. The blisters go away on their own, but the virus remains in the body. The blisters may come back repeatedly, especially when a person is under stress. There is no cure for genital herpes. But drugs can help prevent or shorten outbreaks. Researchers are trying to find a vaccine to prevent genital herpes.

Figure 11.142

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

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

HIV stands for "human immunodeficiency virus." It is the virus that causes AIDS. HIV and AIDS are described in a previous concept. HIV can spread through sexual contact. It can also spread through body fluids such as blood. There is no cure for HIV infection, and AIDS can cause death, although AIDS can be delayed for several years with medication. Researchers are trying to find a vaccine to prevent HIV infection.

Summary

- Sexually transmitted infections (STIs) are caused by pathogens. They spread through sexual contact or other exchanges of body fluids.
- Examples of STIs caused by bacteria include chlamydia, gonorrhea, and syphilis.
- Examples of STIs caused by viruses include HPV, genital herpes, hepatitis B, and AIDS.

Explore More

Use the resource below to answer the questions that follow.

- **Sexually Transmitted Infections** at http://www.youtube.com/watch?v=OfGYFKxMCRg (4:57)

Click on the image above for more content

1. How many cases of sexually transmitted infections occur in the United States every year?
2. What can untreated chlamydial and gonococcal infection lead to? How can this have long term effects on people?
3. What does HPV cause?
4. What are two ways to minimize the risk of contracting a sexually transmitted infection?

Review

1. It is especially important for females to be protected from HPV infections. Why is this the case?

2. Explain why bacterial STIs are treated differently than viral STIs.
3. How is a viral STI cured?
4. What are the three common myths about STIs?

Section 78

Non-Infectious Reproductive

Non-Infectious Reproductive System Disorders

- •Identify and describe non-STI reproductive system disorders.
- •List facts associated with breast cancer.

Why should women perform a monthly breast self-exam?

If you are a young woman, getting in the habit of performing a monthly breast self-exam is a good idea. Lumps or other subtle changes in the breasts may indicate breast cancer. The outcome is typically better if breast cancer is caught and treated early.

Other Reproductive System Disorders

Many disorders of the reproductive system are not sexually transmitted infections. They are not caused by pathogens, so they don't spread from person to person. They develop for other reasons. The disorders are different between males and females. In both genders, the disorders could cause a little discomfort, or they could cause death.

Disorders in Males

Most common disorders of the male reproductive system involve the testes. For example, injuries to the testes are very common. In teenagers, injuries to the testes most often occur while playing sports. An injury such as a strike or kick to the testes can be very painful. It may also cause bruising and swelling. Such injuries do not usually last very long.

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

Disorders in Females

Disorders of the female reproductive system may affect the vagina, uterus, or ovaries. They may also affect the breasts.

One of the most common disorders is **vaginitis** . This is redness and itching of the vagina. It may be due to irritation by soap or bubble bath. Another possible cause of vaginitis is a yeast infection. Yeast normally grow in the vagina. A **yeast infection** happens when the yeast multiply too fast and cause symptoms. A yeast infection can be treated with medication.

Figure 11.143

Bubble baths may be fun, but for women and girls they can cause irritation to the vagina.

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

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

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

Summary

- In males, disorders of the reproductive system include injuries to the testes and cancer of the testes.
- In females, disorders of the reproductive system include vaginitis and breast cancer.

Explore More

Use the resources below to answer the questions that follow.

Explore More I

•**Testicular Cancer** at http://www.youtube.com/watch?v=o63hl15cgpI (4:20)

Click on the image above for more content

1. Testicular cancer is the most common form of cancer for what age group of men?
2. What is the most common sign of testicular cancer? What is it sometimes mistaken for?
3. How treatable is testicular cancer? What kinds of treatment are used?
4. What are the causes of testicular cancer?
5. What is the highest identified risk factor for contracting testicular cancer?

Explore More II

•**Ovarian Cysts** at http://www.medicinenet.com/ovarian_cysts/article.htm

1. What are ovarian cysts?
2. Are all ovarian cysts cancerous?
3. What is the most common type of ovarian cyst?
4. What symptoms can ovarian cysts cause?
5. Do most ovarian cysts need to be removed surgically?

Review

1. What is an example of a common disorder of the male reproductive system?
2. What is an example of a common disorder of the female reproductive system?
3. What is the most common cancer found in women?

Section 79

Reproductive System Health

Reproductive System Health

•List ways to maintain your overall health.
•List facts associated with toxic shock syndrome.

What protective equipment do these boys need?

Along with shin guards, a protective cup is useful in preventing injuries. A kicked ball or kick to the groin can really hurt. Wearing a protective cup also prevents a potentially serious injury to the testes.

Keeping the Reproductive System Healthy

As was discussed in previous concepts, both infectious and noninfectious diseases of the reproductive system can be very serious. But there are ways to keep your reproductive system healthy. What can you do to keep your reproductive system healthy? You can start by making the right choices for overall good health. To be as healthy as you can be, you should:

•Eat a balanced diet that is high in fiber and low in fat.
•Drink plenty of water.
•Get regular exercise.
•Maintain a healthy weight.
•Get enough sleep.
•Avoid using tobacco, alcohol, or other drugs.
•Manage stress in healthy ways.

Keeping your genitals clean is also very important. A daily shower or bath is all that it takes. Females do not need to use special feminine hygiene products. In fact, using them may do more harm than good because they can irritate the vagina or other reproductive structures.

You should also avoid other behaviors that can put you at risk. Do not get into contact with another person's blood or other body fluids. For example, never get a tattoo or piercing unless you are sure that the needles have not been used before. This is one of the most important ways to prevent an STI. Of course, the only way to be fully protected against STIs is to refrain from sexual activity.

If you are a boy, you should always wear a protective cup when you play contact sports. Contact sports include football, boxing, and hockey. Wearing a cup will help protect the testes from injury. You should also do a monthly self-exam to check for cancer of the testes.

If you are a girl and use tampons, be sure to change them every four to six hours. Leaving tampons in for too long can put you at risk of **toxic shock syndrome** . This is a serious condition. Signs and symptoms of toxic shock syndrome develop suddenly, and the disease can be fatal. The disease involves fever, shock, and problems with the function of several body organs.

Girls should also get in the habit of doing a monthly self-exam to check for breast cancer. Although breast cancer is rare in teens, it's a good idea to start doing the exam when you are young. It will help you get to know what is normal for you.

Summary

- To keep the reproductive system healthy, keep the genitals clean and avoid coming into contact with body fluids, like blood or semen.
- To check for cancer, women should perform monthly self-exams of their breasts, and men should perform monthly self-exams of their testes.

Explore More

Use the resource below to answer the questions that follow.

- **Ways to Keep Your Reproductive System Healthy** at http://www.usafitness.biz/ways-to-keep-your-reproductive-system-healthy/

1. Describe what is meant by each of the following:
    a. Screen for STDs Regularly
    b. Lead a Healthy Lifestyle
    c. Be Safe

Review

1. What is the purpose of a monthly self-exam of the testes?
2. Explain how girls can reduce their risk of developing toxic shock syndrome.
3. What is the purpose of a monthly self-exam of the testes breasts?

Summary

The human body. Made of numerous organ systems. Maybe one of the most complex structures ever. But all these systems and structures come together in an exquisite manner to make a fascinating organism. Currently, the end of the line of evolution. The most intelligent of all organisms. An organism that can protect itself from pathogens, has bones for support, muscles to help it move, systems that allow it to respond to the environment, systems to bring oxygen into and around the body, systems to extract nutrients from food and get rid of wastes, and systems to make the next generation. And all these systems and organs and tissues and cells work together to form one complete organism.

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103.Dana Beveridge. Bicycle helmets help protect against head injuries that can cause lifelong disability . CC BY 2.0
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Ecology

Ecology

Introduction

What do you get when you take energy, nutrients and other resources, biomes and their populations, and all the species and their relationships?

You get ecology. Understanding ecology is in part understanding the biology of our planet. And it can easily be argued that this is especially important today. We literally hold the future of our planet in our hands. The lessons in this concept discuss ecology, and all the related aspects that comprise the ecosystem.

Section 1

Introduction to Ecology

Introduction to Ecology

- •Define ecology.
- •Compare field studies to laboratory studies.
- •Distinguish between abiotic and biotic factors.

Do organisms live in isolation?

No, organisms are not separated from their environment or from other organisms. They interact in many ways with their surroundings. For example, these deer may be drinking from this stream or eating nearby plants. Ecology is the study of these interactions.

Introduction to Ecology

Life Science can be studied at many different levels. You can study small things like cells. Or you can study big things like a group of animals. You can also study the **biosphere,** which is any area in which organisms live. The study of the biosphere is part of **ecology** , the study of how living organisms interact with each other and with their environment.

Research in Ecology

Ecology involves many different fields, including geology, soil science, geography, meteorology, genetics, chemistry, and physics. You can also divide ecology into the study of different organisms, such as animal ecology, plant ecology, insect ecology, and so on.

Ecologists also study biomes. A **biome** is a large community of plants and animals that live in the same place. For example, ecologists can study the biomes as diverse as the Arctic, the tropics, or the desert (**Figure** below). They may want to know why different species live in different biomes. They may want to know what would make a particular biome or ecosystem stable. Can you think of other aspects of a biome or ecosystem that ecologists could study?

Figure 12.1

An example of a biome, the Atacama Desert, in Chile.

Ecologists do two types of research:

1. Field studies.
2. Laboratory studies.

Field studies involve collecting data outside in the natural world. An ecologist who completes a field study may travel to a tropical rainforest to study, count, and classify all of the insects that live in a certain area. Laboratory studies involve working inside, usually in a controlled environment. Sometimes, ecologists collect data from the field, and then they analyze that data in the lab. Also, they use computer programs to predict what will happen to organisms that live in a specific area. For example, they may make predictions about what happens to insects in the rainforest after a fire.

Organisms and Environments

All organisms have the ability to grow and reproduce. To grow and reproduce, organisms must get materials and energy from the environment. Plants obtain their energy from the sun through **photosynthesis** , whereas animals obtain their energy from other organisms. Either way, these plants and animals, as well as the bacteria and fungi, are constantly interacting with other species as well as the non-living parts of their ecosystem.

An organism’s environment includes two types of factors:

1. **Abiotic factors** are the parts of the environment that are not living, such as sunlight, climate, soil, water, and air.
2. **Biotic factors** are the parts of the environment that are alive, or were alive and then died, such as plants, animals, and their remains. Biotic factors also include bacteria, fungi and protists.

Ecology studies the interactions between biotic factors, such as organisms like plants and animals, and abiotic factors. For example, all animals (biotic factors) breathe in oxygen (abiotic factor). All plants (biotic factor) absorb carbon dioxide (abiotic factor) and need water (abiotic factor) to survive.

Can you think of another way that abiotic and biotic factors interact with each other?

Summary

- Ecology is the study of how living organisms interact with each other and with their environment.
- Abiotic factors are the parts of the environment that have never been alive, while biotic factors are the parts of the environment that are alive, or were alive and then died.

Explore More

Use the resource below to answer the questions that follow.

- **A Study in Stream Ecology** at USGS http://gallery.usgs.gov/videos/449#.UKWeJld9KSo (6:57)

Click on the image above for more content

1. What are some of the abiotic factors that scientists monitor when dealing with stream ecosystems?
2. What are some of the biotic factors that scientists monitor when dealing with stream ecosystems?
3. What is a "benchmark" in ecology? Why are they essential?
4. How does water pollution seem to be affecting diversity in some streams?

Review

1. What do ecologists study?
2. In a forest, what are five biotic factors present? Five abiotic factors?
3. What is a biome? Give an example.

Section 2

Levels of Ecological Organi-

Levels of Ecological Organization

•Define population, community, and biosphere.
•Describe the levels of organization in ecology.
•Explain the components of an ecosystem.

How is your school organized?

Your school is organized at several levels. Individual students and teachers are divided into classes. These classes are organized into an entire middle school. Your middle school and other nearby schools are organized into a school district. Just like schools are organized, ecosystems are also organized into several different levels, and an ecosystem can be studied at any one of the various levels of organization.

Levels of Ecological Organization

Ecosystems can be studied at small levels or at large levels. The levels of organization are described below from the smallest to the largest:

•A **species** is a group of individuals that are genetically related and can breed to produce fertile young. Individuals are not members of the same species if their members cannot produce offspring that can also have children. The second word in the two word name given to every organism is the species name. For example, in *Homo sapiens* , sapiens is the species name.
•A **population** is a group of organisms belonging to the same species that live in the same area and interact with one another.
•A **community** is all of the populations of different species that live in the same area and interact with one another. A community is composed of all of the biotic factors of an area.
•An **ecosystem** includes the living organisms (all the populations) in an area and the non-living aspects of the environment (**Figure** below). An ecosystem is made of the biotic and abiotic factors in an area.

Figure 12.2

Satellite image of Australia's Great Barrier Reef, an example of a marine ecosystem.

- The **biosphere** is the part of the planet with living organisms (**Figure** below). The biosphere includes most of Earth, including part of the oceans and the atmosphere.

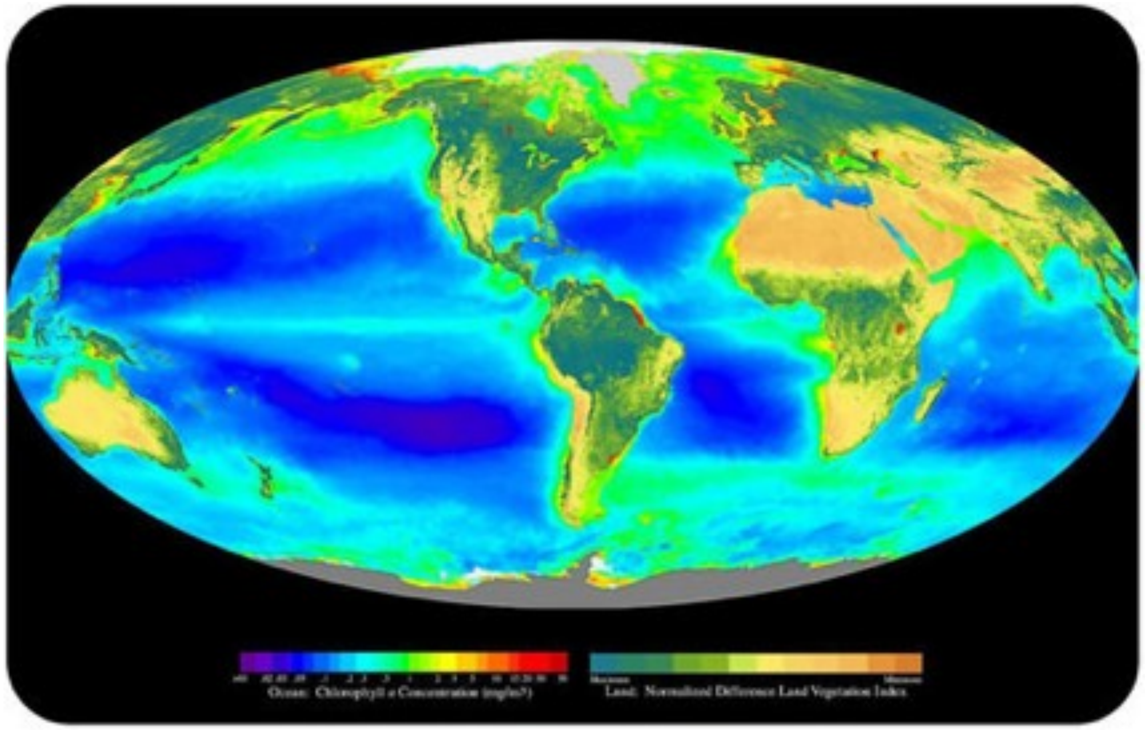


Figure 12.3

The global biosphere, which includes all areas that contain life, from the sea to the atmosphere.

Ecologists study ecosystems at every level, from the individual organism to the whole ecosystem and biosphere. They can ask different types of questions at each level. Examples of these questions are given in **Table** below , using the zebra (*Equus zebra*) as an example.

Ecosystem Level	Question
Individual	How do zebras keep water in their bodies?
Population	What causes the growth of a zebra populations?

Summary

- Levels of organization in ecology include the population, community, ecosystem, and biosphere.
- An ecosystem is all the living things in an area interacting with all of the abiotic parts of the environment.

Explore More

Use the resource below to answer the questions that follow.

- **Ecology Levels and Populations** at http://www.youtube.com/watch?v=1JSS8XIYcgU (5:31)

Click on the image above for more content

1. What is the relationship between an individual and a community?
2. What characteristics define a population?
3. Why is the distinction between a community and an ecosystem important to ecologists?

Review

1. Define species.
2. What is an ecosystem?
3. Define population. How is a population different from a community?

Section 3

Features of Populations

Features of Populations

•Define population.
•List ways in which a population can be described.
•Explain population density and dispersion.
•Explain how population growth is determined.

What is a population?

When you think of the word *population,* you might think of the number of people in your town or city. But humans are not the only species to have populations. Every species has a population. Or many populations. This group of penguins, which are all members of the same species and all living together in the same space, is a population.

What is a Population

A **population** is a group of organisms of the same species, all living in the same area and interacting with each other. Since they live together in one area, members of the same species reproduce together. Ecologists who study populations determine how healthy or stable the populations are. They also study how the individuals of a species interact with each other and how populations interact with the environment. If a group of similar organisms in the same area cannot reproduce with members of the other group, then they are members of two distinct species and form two populations.

Ecologists look at many factors that help to describe a population. First, ecologists can measure the number of individuals that make up the population, known as **population size** . They can then determine the **population density** , which is the number of individuals of the same species in an area. Population density can be expressed as *number per area* , such as 20 mice/acre, or 50 rabbits/square mile.

Ecologists also study how individuals in a population are spread across an environment. This spacing of individuals within a population is called **dispersion** . Some species may be clumped or clustered (**Figure** below) in an area.

Others may be evenly spaced (**Figure** below). Still others may be spaced randomly within an area. The population density and dispersion have an effect on reproduction and population size. What do you think the relationship is between population density, dispersion and size?

Figure 12.4

Clumped species are closer together. This may allow for easier reproduction.

Figure 12.5

A population of cacti in the Sonoran Desert generally shows even dispersion due to competition for water.

Ecologists also study the birth and death rates of the population. Together these give the growth rate (the birth rate minus the death rate), which tells how fast (or slow) the population size is changing. The **birth rate** is the number of births within a population during a specific time period. The **death rate** is the number of deaths within a population during a specific time period. Knowing the birth and death rates of populations gives you information about a population's health. For example, when a population is made up of mostly young organisms and the birth rate is high, the population is growing. A population with equal birth and death rates will remain the same size. Populations that are decreasing in size have a higher death rate than birth rate.

Summary

- A population is a group of organisms of the same species, all living in the same area and interacting with each other.
- Scientists can study many aspects of a population, including density, dispersion, and birth and death rates.

Explore More

Use the resource below to answer the questions that follow.

- **Population Distributions** at http://www.youtube.com/watch?v=BMsmDy-2jbA (3:51)

Click on the image above for more content

1. Is the distribution of organisms of a species constant with time?
2. What is the most common type of distribution? How does this distribution benefit the species?
3. What factors make a uniform distribution pattern a beneficial strategy for a species?
4. How do chemicals made by organisms help establish and maintain a uniform distribution pattern?
5. What factors contribute to a random distribution pattern? Why do animals not maintain this distribution pattern year round?

Review

1. Define population.
2. What is population dispersion? Describe the possible dispersion patterns for a population.
3. Would all the deer and mice living in a forest be a population? Why or why not?
4. What is the growth rate?

Section 4

Population Growth Patterns

Population Growth Patterns

- •Describe factors that affect population growth.
- •Distinguish immigration from emigration.
- •Compare exponential growth to logistic growth.
- •Explain carrying capacity.

What affects population growth in the United States?

One way the population of the United States has grown is through the movement of individuals into the United States from other parts of the world. The same effects can be seen in wildlife populations. Individuals move into a population and increase its size. This is just one of the many factors affecting population growth. Of course, individuals may also move away from a population.

Population Growth

What does population growth mean? You can probably guess that it means the number of individuals in a population is increasing. The **population growth rate** tells you how quickly a population is increasing or decreasing. What determines the population growth rate for a particular population?

Births, Deaths, and Migration

Population growth rate depends on birth rates and death rates, as well as migration. First, we will consider the effects of birth and death rates. You can predict the growth rate by using this simple equation: *growth rate = birth rate – death rate.*

If the birth rate is larger than the death rate, then the population grows. If the death rate is larger than the birth rate, what will happen to the population? The population size will decrease. If the birth and death rates are equal, then the population size will not change.

Factors that affect population growth are:

1. Age of organisms at first reproduction.
2. How often an organism reproduces.
3. The number of offspring of an organism.
4. The presence or absence of parental care.
5. How long an organism is able to reproduce.
6. The death rate of offspring.

For an ecosystem to be stable, populations in that system must be healthy, and that usually means reproducing as much as their environment allows. Do organisms reproduce yearly or every few years? Do organisms reproduce for much of their life, or just part of their life? Do organisms produce many offspring at once, or just a few, or even just one? Do many newborn organisms die, or do the majority survive? All these factors play a role in the growth of a population.

Organisms can use different strategies to increase their reproduction rate. **Altricial** organisms are helpless at birth, and their parents give them a lot of care. This care is often seen in bird species. (**Figure** below). Altricial birds are usually born blind and without feathers. Compared to precocial organisms, altricial organisms have a longer period of development before they reach maturity. **Precocial** organisms, such as the geese shown below, can take care of themselves at birth and do not require help from their parents (**Figure** below). In order to reproduce as much as possible, altricial and precocial organisms must use very different strategies.

Figure 12.6

(left) A hummingbird nest with young illustrates an altricial reproductive strategy, with a few small eggs, helpless young, and intensive parental care. (right) The Canada goose shows a precocial reproductive strategy. It lays a large number of large eggs, producing well-developed young.

Migration

Migration is the movement of individual organisms into, or out of, a population. Migration affects population growth rate. There are two types of migration:

1. **Immigration** is the movement of individuals into a population from other areas. This increases the population size and growth rate.
2. **Emigration** is the movement of individuals out of a population. This decreases the population size and growth rate.

The earlier growth rate equation can be modified to account for migration: *growth rate = (birth rate + immigration rate) – (death rate + emigration rate).*

One type of migration that you are probably familiar with is the migration of birds. Maybe you have heard that birds fly south for the winter. In the fall, birds fly thousands of miles to the south where it is warmer. In the spring, they return to their homes. (**Figure** below).

Monarch butterflies also migrate from Mexico to the northern U.S. in the summer and back to Mexico in the winter. These types of migrations move entire populations from one location to another.

Figure 12.7

A flock of barnacle geese fly in formation during the autumn migration.

Exponential Growth

Population growth can be described with two models, based on the size of the population and necessary resources. These two types of growth are known as exponential growth and logistic growth. If a population is given unlimited amounts of resources, such as food and water, land if needed, moisture, oxygen, and other environmental factors, it will grow exponentially. **Exponential growth** occurs as a population grows larger, dramatically increasing the growth rate. This is shown as a "J-shaped" curve below (**Figure** below). You can see that the population grows slowly at first, but as time passes, growth occurs more and more rapidly.

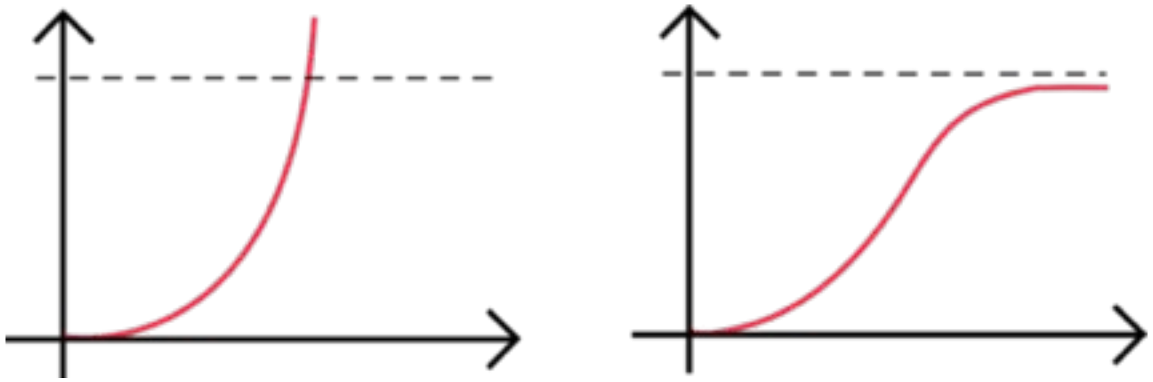


Figure 12.8

Growth of populations according to exponential (or J-curve) growth model (*left*) and logistic (or S-curve) growth model (*right*). Time is plotted on the x-axis, and population size is plotted on the y-axis.

In nature, organisms do not usually have ideal environments with unlimited food. In nature, there are limits. Sometimes, there will be plenty of food. Sometimes, a fire will wipe out all of the available nutrients. Sometimes a predator will kill many individuals in a population. How do you think these limits affect the way organisms grow?

Usually, populations first grow exponentially while resources are abundant. But as populations increase and resources become less available, rates of growth slow down and slowly level off, reaching the carrying capacity. The **carrying capacity** is the upper limit to the population size that the environment can support. This type of growth is shown as an "S-shaped" curve below (**Figure** above) and is called **logistic growth.** Why do you think occurs?

Summary

- •Population growth rate is affected by birth rates, death rates, immigration, and emigration.
- •If a population is given unlimited amounts of food, moisture, and oxygen, and other environmental factors, it will show exponential growth.

Explore More

Use the resource below to answer the questions that follow.

- •**Population Growth** at http://www.youtube.com/watch?v=sc4HxPxNrZ0 (2:58)

Click on the image above for more content

1. How many years did it take the human population to increase from 1 billion to 2 billion? Considering how long it took the human population to reach 1 billion, is this pattern consistent with an exponential growth model?
2. How fast is the human population currently increasing? What kind of growth does this indicate the human population is experiencing currently? Does this rate represent an increase or decrease from previous growth rates?
3. Is our current population level creating problems with available space? Why or why not?

Review

1. List three factors that affect population growth?
2. Compare altricial organisms to precocial organisms.
3. What is the overall equation for growth rate?
4. Does a typical population show exponential growth? Why or why not?
5. Define carrying capacity.

Section 5

Limiting Factors to Popula-

Limiting Factors to Population Growth

- •Give examples of limiting factors to population growth.
- •Explain how limiting factors affect population growth.

What happened during the Irish Potato Famine?

In the 1800s, a disease called potato blight destroyed much of the potato crop in Ireland. Since many Irish people depended on potatoes as their staple food, mass starvation and emigration resulted. This caused Ireland's population to dramatically decrease. Lack of food is one factor that can limit population growth.

Limiting Factors to Population Growth

For a population to be healthy, factors such as food, nutrients, water and space, must be available. What happens when there are not resources to support the population? **Limiting factors** are resources or other factors in the environment that can lower the population growth rate. Limiting factors include a low food supply and lack of space. Limiting factors can lower birth rates, increase death rates, or lead to emigration.

When organisms face limiting factors, they show **logistic growth** (S-shaped curve, curve B: **Figure** below). Competition for resources like food and space cause the growth rate to stop increasing, so the population levels off. This flat upper line on a growth curve is the carrying capacity. The **carrying capacity** (K) is the maximum population size that can be supported in a particular area without destroying the habitat. Limiting factors determine the carrying capacity of a population. Recall that when there are no limiting factors, the population grows exponentially. In **exponential growth** (J-shaped curve, curve A: **Figure** below), as the population size increases, the growth rate also increases.

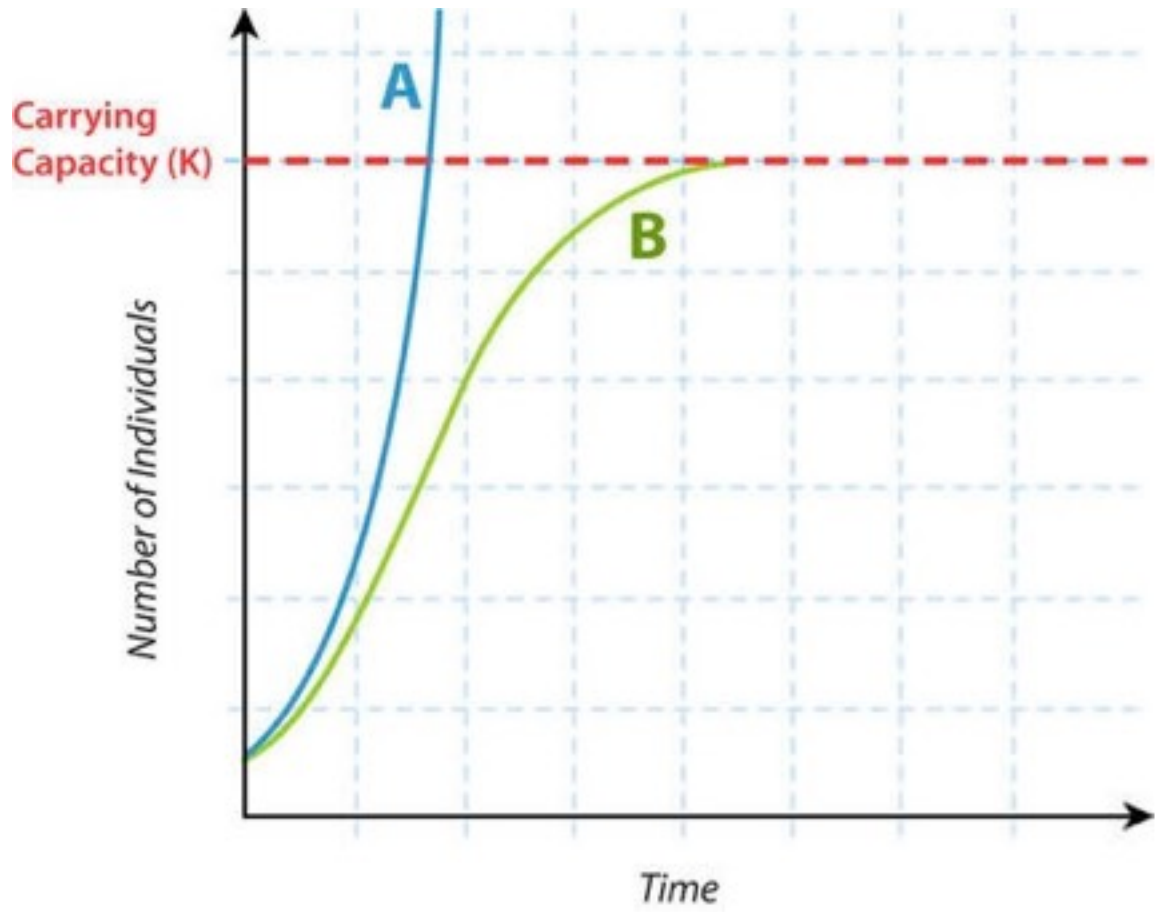


Figure 12.9

Exponential and Logistic Growth. Curve A shows exponential growth. Curve B shows logistic growth. Notice that the carrying capacity (K) is also shown.

Food Supply as Limiting Factor

If there are 12 hamburgers at a lunch table and 24 people sit down at a lunch table, will everyone be able to eat? At first, maybe you will split hamburgers in half, but if more and more people keep coming to sit at the lunch table, you will not be able to feed everyone. This is what happens in nature. But in nature, organisms that cannot get food will die or find a new place to live. It is possible for any resource to be a limiting factor, however, a resource such as food can have dramatic consequences on a population.

In nature, when the population size is small, there is usually plenty of food and other resources for each individual. When there is plenty of food and other resources, organisms can easily reproduce, so the birth rate is high. As the population increases, the food supply, or the supply of another necessary resource, may decrease. When necessary resources, such as food, decrease, some individuals will die. Overall, the population cannot reproduce at the same rate, so the birth rates drop. This will cause the population growth rate to decrease.

When the population decreases to a certain level where every individual can get enough food and other resources, and the birth and death rates become stable, the population has leveled off at its carrying capacity.

Other Limiting Factors

Other limiting factors include light, water, nutrients or minerals, oxygen, the ability of an ecosystem to recycle nutrients and/or waste, disease and/or parasites, temperature, space, and predation. Can you think of some other factors that limit populations?

Weather can also be a limiting factor. Whereas most plants like rain, an individual cactus-like *Agave americana* plant actually likes to grow when it is dry. Rainfall limits reproduction of this plant which, in turn, limits growth rate. Can you think of some other factors like this?

Human activities can also limit the growth of populations. Such activities include use of pesticides, such as DDT, use of herbicides, and habitat destruction.

Summary

- Limiting factors, or things in the environment that can lower the population growth rate, include low food supply and lack of space.
- When organisms face limiting factors, they show logistic type of growth (S-curve).

Explore More

Use the resource below to answer the questions that follow.

- **Biotic Potential** at http://www.youtube.com/watch?v=BSVbdaubxxg (2:58)

Click on the image above for more content

1. What type of growth is characterized by a consistent increase in growth rate? How often is this type of growth actually seen in nature?
2. What factors keep populations from reaching their carrying capacity?
3. How do you think the length of an organism's life span will affect the species' ability to reach carrying capacity?
4. What would the growth equation look like for sessile populations (i.e. populations where individuals are fixed in space)?

Review

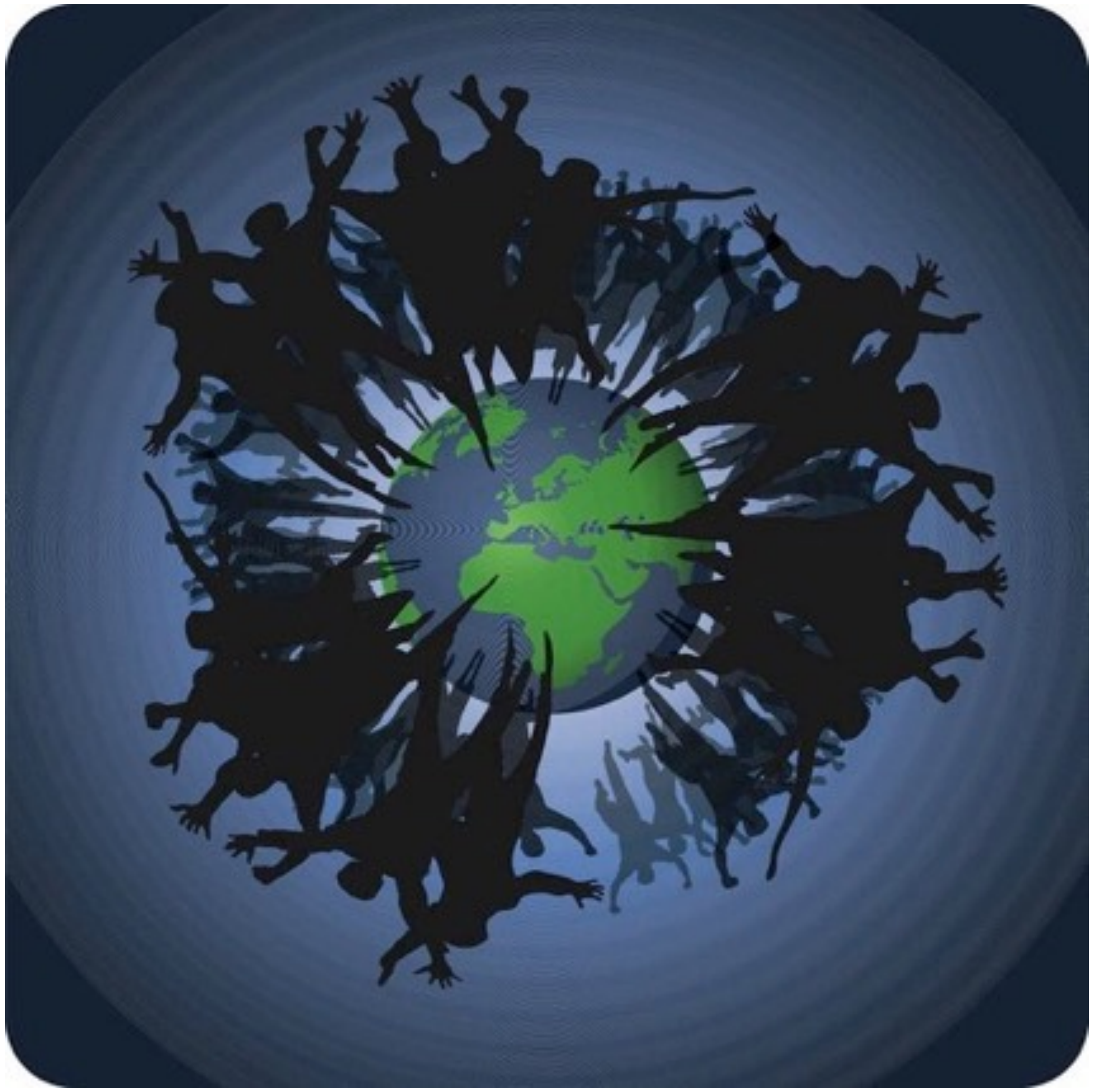
1. What is a limiting factor?
2. What are three examples of limiting factors?
3. When organisms face limiting factors, what type of growth do they show?

Section 6

Human Population

Human Population

•Describe how the human population has grown over the past 2,000 years.
•Discuss predictions for future human population growth.
•List the stages of human population growth.
•Compare Neo-Malthusians to Cornucopians.



Too many people?

In October 2011, the human population passed 7 billion people. What problems could result if the human population continues its rapid rise? One issue is that overpopulation makes many environmental issues more serious. More people on the planet means more food and water is needed and more pollution is generated. Is there a carrying capacity for the human population?

Human Population

How quickly is the human population growing? If we look at worldwide human population growth from 10,000 BCE through today, our growth looks like **exponential growth** . It increased very slowly at first, but later grew faster and faster as the population increased in size (**Figure** below). And recently, the human population has increased at a faster pace than ever before. It has taken only 12 years for the world's population to increase from six billion to seven billion. Considering that in the year 1804, there were just one billion people, and in 1927, there were just two billion people (that's 123 years to increase from 1 to 2 billion), the recent increase in the human population growth rate is characteristic of exponential growth. Does this mean there are unlimited resources?

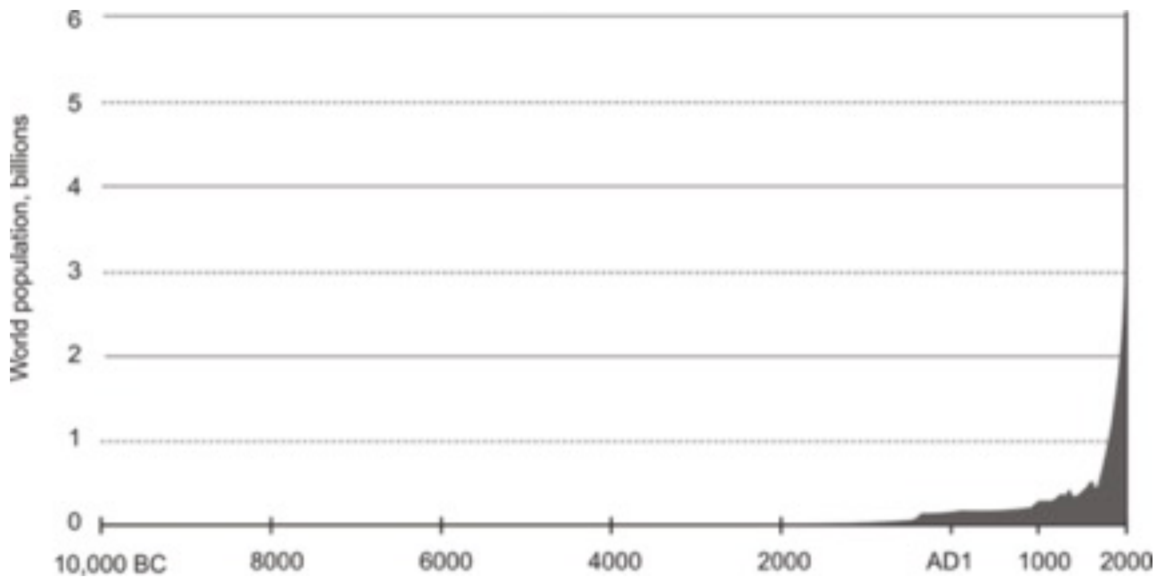


Figure 12.10

Worldwide human population growth from 10,000 BCE through today.

Five Stages

On the other hand, if you look at human population growth in specific countries, you may see a different pattern. On the level of a country, the history of human population growth can be divided into five stages, as described in **Table** below . Some countries have very high birth rates, in some countries the growth rate has stabilized, and in some countries the growth rate is in decline.

Stage	Description
1	Birth and death rates are high and population growth is stable. This occurred in early human history.
2	Significant drop in death rate, resulting in exponential growth. This occurred in 18th- and 19th-century Europe.
3	Population size continues to grow.
4	Birth rates equal death rates and populations become stable.
5	Total population size may level off.

The United Nations and the U.S. Census Bureau predict that by 2050, the Earth will be populated by 9.4 billion people. Other estimates predict 10 to 11 billion.

Future Growth

There are two different beliefs about what type of growth the human population will undergo in the future:

1. **Neo-Malthusians** believe that human population growth cannot continue without destroying the environment, and maybe humans themselves.
2. **Cornucopians** believe that the Earth can give humans a limitless amount of resources. They also believe that technology can solve problems caused by limited resources, such as lack of food.

The Cornucopians believe that a larger population is good for technology and innovation. The 5-stage model above predicts that when all countries are industrialized, the human population will eventually level out. But many scientists and other Neo-Malthusians believe that humans have already gone over the Earth's **carrying capacity** . That means, we may have already reached the maximum population size that can be supported, without destroying our resources and habitat. If this is true, then human overpopulation will lead to a lack of food and other resources. Overpopulation may also lead to increased disease, and/or war. These problems may cause the population of humans to crash. If these issues are not controlled, could the human population go extinct?

Which of the above theories makes sense to you? Why?

Summary

- The human population is undergoing exponential growth.
- Future outlooks on human population growth differ; some think we will have a limitless amount of resources, while others think we have already reached our carrying capacity.

Explore More

Use the resource below to answer the questions that follow.

- **Urban Sprawl: Phoenix** from the American Museum of Natural History at http://www.youtube.com/watch?v=rCYYf3igZuM (2:37)

Click on the image above for more content

1. How much land in the United States is lost to urban sprawl every year?
2. How has land use around Phoenix, Arizona changed since 1912?
3. How did urban areas change after agricultural expansion in Arizona?

4. How does urban growth affect water usage? What problems does this present for the sustainability of urban environments?

Review

1. Describe the rate of human population growth.
2. How long did it take for the world's population to grow from 6 billion to 7 billion?
3. What is the predicted human population by 2050?
4. How do the Cornucopians and Neo-Malthusians differ in their viewpoints?

Section 7

Competition

Competition

•Describe competition.
•Describe how competition affects the community.
•Compare intraspecific competition to interspecific competition.
•Summarize the competitive exclusion principle.

What does it mean to compete?

If you are in competition with someone, it usually means you are in a contest for a prize. The prize might just be bragging rights. In nature, the stakes are higher. Organisms must compete for resources necessary for life.

Competition

Recall that **ecology** is the study of how living organisms interact with each other and with their environment. But how do organisms *interact* with each other? Organisms interact with each other through various mechanisms, one of which is competition. **Competition** occurs when organisms strive for limited resources. Competition can be for food, water, light, or space. This interaction can be between organisms of the same species (intraspecific) or between organisms of different species (interspecific).

Intraspecific competition happens when members of the same species compete for the same resources. For example, two trees may grow close together and compete for light. One may out-compete the other by growing taller to get more available light. As members of the same species are usually genetically different, they have different characteristics, and in this example, one tree grows taller than the other. The organism that is better adapted to that environment is better able to survive. The other organism may not survive. In this example, it is the taller tree that is better adapted to the environment.

Interspecific competition happens when individuals of different species strive for a limited resource in the same area. Since any two species have different traits, one species will be able to out-compete the other. One species will be better adapted to its environment, and essentially "win" the competition. The other species will have lower reproductive success and lower population growth, resulting in a lower survival rate. For example, cheetahs and lions feed on similar prey. If prey is limited, then lions may catch more prey than cheetahs. This will force the cheetahs to either leave the area or suffer a decrease in population.

Looking at different types of competition, ecologists developed the **competitive exclusion principle** . The principle states that species less suited to compete for resources will either adapt, move from the area, or die out. In order for two species within the same area to coexist, they may adapt by developing different specializations. This is known as **character displacement** . An example of character displacement is when different birds adapt to eating different types of food. They can develop different types of bills, like Darwin's Finches (**Figure** below). Therefore, competition for resources within and between species plays an important role in **evolution** through **natural selection** .

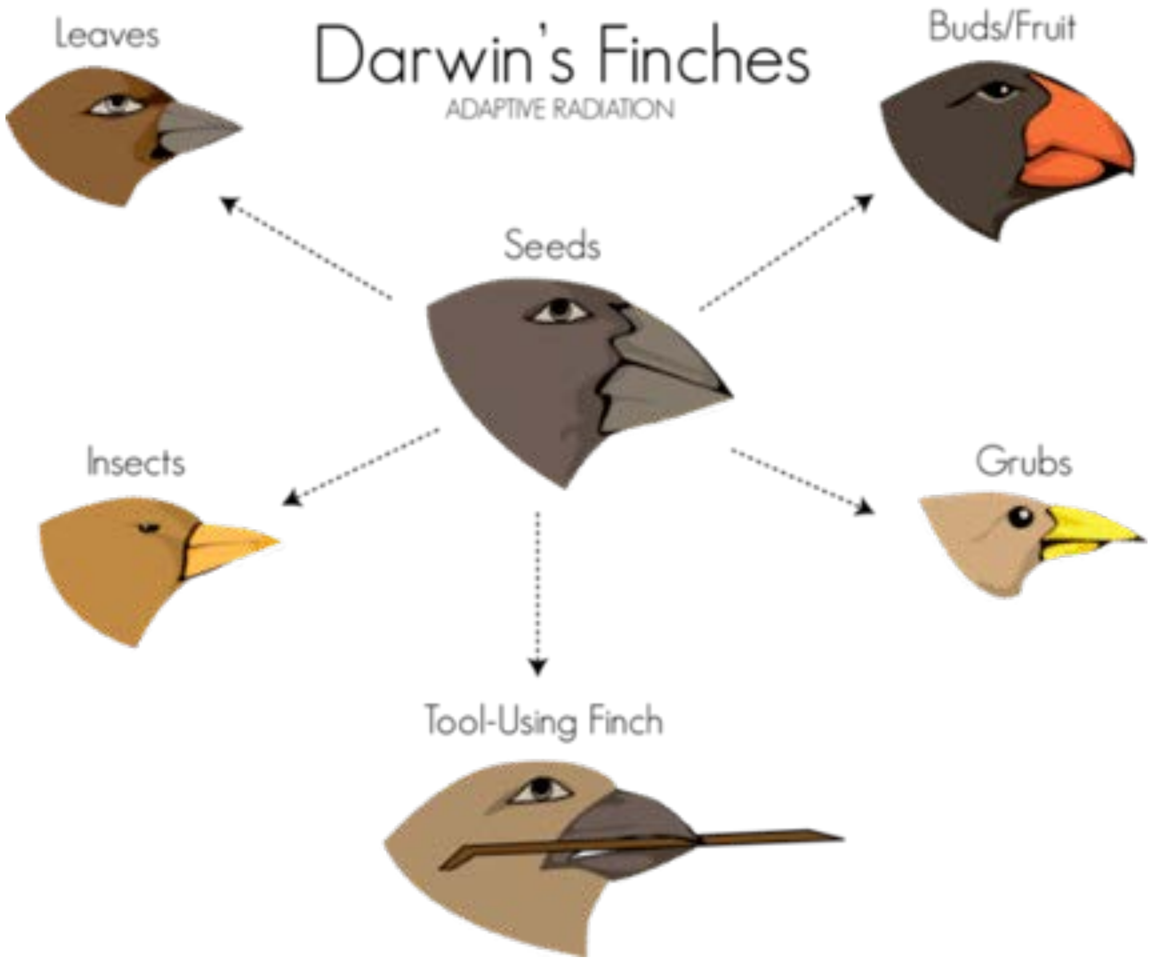


Figure 12.11

An example of character displacement, showing different types of bill for eating different types of foods, in Darwin's or Galapagos Finches.

Summary

- Competition, or when organisms strive for limited resources, can be between organisms of the same species (intraspecific) or organisms of different species (interspecific).
- In order for two species within the same area to coexist, they may develop different specializations; this is known as character displacement.

Explore More

Use the resource below to answer the questions that follow.

Anemones Attack at http://shapeoflife.org/video/behavior/cnidarians-anemones-fight (2:49)

Click on the image above for more content

1. What sort of competition are these anemones displaying?

2. Looking at the size of the sea anemones in this video, are you surprised by the amount of space they they feel they need? Explain your answer.
3. What must be true about the costs in energy of anemone fighting? What would happen to the population if this were not the case?

Review

1. What is the difference between intraspecific and interspecific competition?
2. What is the competitive exclusion principle?
3. How can competition contribute to evolution through natural selection?
4. What has to be true about available resources for competition to exist?

Section 8

Predation

Predation

•Define predation.
•Explain the different types of predation.
•Describe how predation affects the community.
•Explain the advantages of camouflage and mimicry.

Can insects hunt for food?

When you think of an animal hunting for its food, large animals such as lions may come to mind. But many tiny animals also hunt for their food. For example, this praying mantis is eating a fly. To eat the fly, the praying mantis first had to catch the fly, which is a form of hunting.

Predation

Predation is another mechanism in which species interact with each other. Predation is when a predator organism feeds on another living organism or organisms, known as **prey** . The predator always lowers the prey's **fitness** . It does this by keeping the prey from surviving, reproducing, or both. **Predator-prey relationships** are essential to maintaining the balance of organisms in an ecosystem. Examples of predator-prey relationships include the lion and zebra, the bear and fish, and the fox and rabbit.

There are different types of predation, including:

•true predation.
•grazing.
•parasitism.

Figure 12.12

This lion is an example of a predator on the hunt.

True predation is when a predator kills and eats its prey. Some predators of this type, such as jaguars, kill large prey. They tear it apart and chew it before eating it. Others, like bottlenose dolphins or snakes, may eat their prey whole. In some cases, the prey dies in the mouth or the digestive system of the predator. Baleen whales, for example, eat millions of plankton at once. The prey is digested afterward. True predators may hunt actively for prey, or they may sit and wait for prey to get within striking distance. Certain traits enable organisms to be effective hunters. These include camouflage, speed, and heightened senses. These traits also enable certain prey to avoid predators.

In **grazing** , the predator eats part of the prey but does not usually kill it. You may have seen cows grazing on grass. The grass they eat grows back, so there is no real effect on the population. In the ocean, kelp (a type of seaweed) can regrow after being eaten by fish.

Predators play an important role in an ecosystem. For example, if they did not exist, then a single species could become dominant over others. Grazers on a grassland keep grass from growing out of control. Predators can be **keystone species** . These are species that can have a large effect on the balance of organisms in an ecosystem. For example, if all of the wolves are removed from a population, then the population of deer or rabbits may increase. If there are too many deer, then they may decrease the amount of plants or grasses in the ecosystem. Decreased levels of **producers** may then have a detrimental effect on the whole ecosystem. In this example, the wolves would be a keystone species.

Prey also have adaptations for avoiding predators. Prey sometimes avoid detection by using camouflage (**Figure** below). **Camouflage** means that species have an appearance (color, shape, or pattern) that helps them blend into the background. **Mimicry** is a related adaptation in which a species uses appearance to copy or mimic another species. For example, a non-poisonous dart frog may evolve to look like a poisonous dart frog. Why do you think this is an adaptation for the non-poisonous dart frog? Mimicry can be used by both predators and prey (**Figure** below).

Parasitism is a type of **symbiotic** relationship and will be described in the *Symbiosis* concept.

Figure 12.13

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

Figure 12.14

An example of mimicry, where the Viceroy butterfly (*right*) mimics the unpleasant Monarch butterfly (*left*). Both butterfly species are avoided by predators to a greater degree than either one would be without mimicry.

Summary

- Predation happens when a predator organism feeds on another living organism or organisms, known as prey.
- Predators can be keystone species, a species that can have a large effect on the balance of organisms in an ecosystem.

Explore More

Use the resource below to answer the questions that follow.

- **Best Disguised Predator Fish?** at http://video.nationalgeographic.com/video/stonefish-predation (1:18)

1. What allows the stone fish to sneak up on prey?
2. What does the stone fish eat?
3. Where does the stone fish hide?

Review

1. What is predation?
2. What's the difference between grazing and true predation?
3. What sorts of adaptations do prey have for avoiding predators?
4. Predators can be a keystone species. What does this mean?

Section 9

Symbiosis

Symbiosis

•Define symbiosis.
•Distinguish mutualism from commensalism and parasitism.
•Give examples of the different kinds of symbiosis.

Is this little fish about to become lunch?

Actually, this big fish is not opening his mouth to munch on these little fish. He is opening his mouth to get his teeth cleaned! These small fish eat dead skin and parasites from his body. Both types of fish benefit from this relationship.

Symbiosis

Symbiosis describes a close and long-term relationship between different species. At least one species will benefit in a symbiotic relationship. These relationships are often necessary for the survival of one or both organisms. There are three types of symbiotic relationships: mutualism, communalism, and parasitism.

•**Mutualism** is a symbiotic relationship in which both species benefit.
•**Commensalism** is a symbiotic relationship in which one species benefits while the other is not affected.
•**Parasitism** is a symbiotic relationship in which the parasitic species benefits while the host species is harmed.

An example of a mutualistic relationship is between herbivores (plant-eaters) and the bacteria that live in their intestines. The bacteria get a place to live. Meanwhile, the bacteria help the herbivore digest food. Both species benefit, so this is a mutualistic relationship. The clownfish and the sea anemones also have a mutualistic relationship. The clownfish protects the anemone from anemone-eating fish, and the stinging tentacles of the anemone protect the clownfish from predators (**Figure** below). Another example of this type of symbiotic relationship is the relationship between the plover bird and the African crocodile. The tiny blackbird acts as a toothpick for the fierce crocodile, and helps by removing tiny morsels of food that are stuck between the crocodile's teeth. These food remains are the source of food for the bird. Another example is between the ostrich and the zebra. The ostrich always moves with the herd of zebras since it has a poor sense of hearing and smell, whereas the zebra has very sharp senses. The ostrich has a keen sense of sight, which the zebra lacks. Hence, these two species depend on each other to warn one another of any nearby imposing dangers.

Commensal relationships may involve an organism using another for transportation or housing. For example, spiders build their webs on trees. The spider gets to live in the tree, but the tree is unaffected. Other commensal relationships exist between cattle egrets and livestock. Cattle egrets are mostly found in meadows and grasslands are always seen near cattle, horses and other livestock. These birds feed on the insects that come out of the field due to the movement of the animals. They even eat ticks, fleas, and other insects off the back of animals. The relationship between tigers and golden jackals is also commensalism. The jackal alerts the tiger to a kill and feeds on the remains of the prey left by the tiger. This is not a mutualistic relationship as the tiger does not provide anything to the jackal.

Parasites may live either inside or on the surface of their host. An example of a parasite is a hookworm. Hookworms are roundworms that affect the small intestine and lungs of a host organism. They live inside of humans and cause them pain. However, the hookworms must live inside of a host in order to survive. Parasites may even kill the host they live on, but then they also kill their host organism, so this is rare. Parasites are found in animals, plants, and fungi. Hookworms are common in the moist tropic and subtropic regions. There is very little risk of getting a parasite in industrialized nations.

Figure 12.15

Clownfish in a sea anemone.

Summary

- •Symbiosis describes a close and long-term interaction between different species.
- •In a mutualism, both species benefit; in a commensalism, one species benefits while the other is not affected.
- •In a parasitism, the parasitic species benefits, while the host species is harmed.

Explore More

Use the resource below to answer the questions that follow.

- **Symbiosis: Mutualism, Commensalsim and Parasitism** at http://www.youtube.com/watch?v=zSmL2F1t81Q (5:17)

Click on the image above for more content

1. What defines a symbiotic relationship?
2. Is the benefit gained by each individual in a mutualistic relationship equal?
3. What could a mutualistic relationship, in which one organism receives little benefit, also be called?
4. What type of relationship exists between the clownfish and the sea anemone?
5. What are the two explanations for where a clownfish's protective mucus comes from?

Review

1. What is symbiosis?
2. Distinguish between mutualism and commensalism.
3. Describe an example of a symbiotic relationship.
4. What's an example of a parasite?

Section 10

Ecosystems

Ecosystems

•Define and describe an ecosystem.
•Give examples of biotic and abiotic factors.
•Explain the relationship between producers and consumers.
•Summarize the importance of biogeochemical cycles.

What nonliving things are essential for life?

Living organisms cannot exist without the nonliving aspects of the environment. For example: air, water, and sunlight, which are all nonliving, are all essential to living organisms. Both nonliving and living things make up an ecosystem.

What is an Ecosystem?

Ecology is the study of ecosystems. That is, ecology is the study of how living organisms interact with each other and with the nonliving part of their environment. An **ecosystem** consists of all the nonliving factors and living organisms interacting in the same **habitat** . Recall that living organisms are **biotic factors** . The biotic factors of an ecosystem include all the **populations** in a habitat, such as all the species of plants, animals, and fungi, as well as all the micro-organisms. Also recall that the nonliving factors are called **abiotic factors** . Abiotic factors include temperature, water, soil, and air.

You can find an ecosystem in a large body of fresh water or in a small aquarium. You can find an ecosystem in a large thriving forest or in a small piece of dead wood. Examples of ecosystems are as diverse as the rainforest, the savanna, the tundra, or the desert (**Figure** below). The differences in the abiotic factors, such as differences in temperature, rainfall, and soil quality, found in these areas greatly contribute to the differences seen in these ecosystems. Ecosystems can include well known sites, such as the Great Barrier Reef off the coast of Australia and the Greater Yellowstone Ecosystem of Yellowstone National Park, which actually includes a few different ecosystems, some with geothermal features, such as Old Faithful geyser.

Figure 12.16

Desert Botanical Gardens in Phoenix, Arizona.

Ecosystems need energy. Many ecosystems get their energy in the form of sunlight, which enters the ecosystem through **photosynthesis** . This energy then flows through the ecosystem, passed from **producers** to **consumers** . Plants are producers in many ecosystems. Energy flows from plants to the herbivores that eat the plants, and then to carnivores that eat the herbivores. The flow of energy depicts interactions of organisms within an ecosystem.

Matter is also recycled in ecosystems. **Biogeochemical cycles** recycle nutrients, like carbon and nitrogen, so they are always available. These nutrients are used over and over again by organisms. Water is also continuously recycled. The flow of energy and the recycling of nutrients and water are examples of the interactions between organisms and the interactions between the biotic and abiotic factors of an ecosystem.

Summary

•An ecosystem consists of all the living things and nonliving things interacting in the same area.
•Matter is also recycled in ecosystems; recycling of nutrients is important so they can always be available

Explore More

Use the resource below to answer the questions that follow.

•**How Ecosystems Work** at http://www.youtube.com/watch?v=o_RBHfjZsUQ (3:24)

Click on the image above for more content

1.How do land plants generate the energy they need for their metabolic energy? What do they do with excess energy?
2.Where do scavengers in an ecosystem obtain their energy from? How can scavenging be a beneficial strategy for an organism?
3.What is the role of decomposers?
4.What kind of problems can you foresee if every speck of carbon were turned into biomass? Why?
5.Complete this statement: Energy ___________ through an ecosystem, whereas nutrients are ____________.

Review

1.Define an ecosystem.
2.Distinguish between abiotic and biotic factors. Give examples of each.
3.Where does the energy come from for many ecosystems?
4.Name two nutrients that are recycled through an ecosystem.

Section 11

Habitat and Niche

Habitat and Niche

•Define habitat and niche.
•Describe the roles of the habitat and niche in an ecosystem.

What is your niche at school?

Are you on the basketball team? Are you a cheerleader? Do you play an instrument in the band? Your niche would be your role or place in the school. Organisms also each have their own niche in the ecosystem. Is an organism a producer or a consumer? How does the organism interact with other organisms? Is the organism involved in any symbiotic relationships?

Habitat and Niche

Niche

Each organism plays a particular role in its ecosystem. A **niche** is the role a species plays in the ecosystem. In other words, a niche is how an organism "makes a living." A niche will include the organism's role in the flow of energy through the ecosystem. This involves how the organism gets its energy, which usually has to do with what an organism eats, and how the organism passes that energy through the ecosystem, which has to do with what eats the organism. An organism's niche also includes how the organism interacts with other organisms, and its role in recycling nutrients.

Once a niche is left vacant, other organisms can fill that position. For example when the Tarpan, a small wild horse found mainly in southern Russia, became extinct in the early 1900s, its niche was filled by a small horse breed, the Konik (**Figure** below). Often this occurs as a new species evolves to occupy the vacant niche.

Figure 12.17

The Konik horse.

A species' niche must be specific to that species; no two species can fill the same niche. They can have very similar niches, which can overlap, but there must be distinct differences between any two niches. When plants and animals are introduced, either intentionally or by accident, into a new environment, they can occupy the existing niches of native organisms. Sometimes new species out-compete native species, and the native species may go extinct. They can then become a serious pest. For example, kudzu, a Japanese vine, was planted in the southeastern United States in the 1870s to help control soil loss. Kudzu had no natural predators, so it was able to out-compete native species of vine and take over their niches (**Figure** below).

Figure 12.18

Kudzu, a Japanese vine introduced intentionally to the southeastern United States, has out-competed the native vegetation.

Habitat

The **habitat** is the physical area where a species lives. Many factors are used to describe a habitat. The average amount of sunlight received each day, the range of annual temperatures, and average yearly rainfall can all describe a habitat. These and other **abiotic factors** will affect the kind of traits an organism must have in order to survive there. The temperature, the amount of rainfall, the type of soil and other abiotic factors all have a significant role in determining the plants that invade an area. The plants then determine the animals that come to eat the plants, and so on. A habitat should not be confused with an ecosystem: the habitat is the actual place of the ecosystem, whereas the ecosystem includes both the **biotic** and abiotic factors in the habitat.

Figure 12.19

Santa Cruz Island off the California coast has diverse habitats including a coastline with steep cliffs, coves, gigantic caves, and sandy beaches.

Figure 12.20

The above image shows wetland reeds, another type of habitat.

Habitat destruction means what it sounds like—an organism's habitat is destroyed. Habitat destruction can cause a population to decrease. If bad enough, it can also cause species to go extinct. Clearing large areas of land for housing developments or businesses can cause habitat destruction. Poor fire management, pest and weed invasion, and storm damage can also destroy habitats. National parks, nature reserves, and other protected areas all preserve habitats.

Summary

- The role a species plays in the ecosystem is called its niche.
- A habitat is the physical environment in which a species lives.

Explore More

Use the resource below to answer the questions that follow.

- **Competition, Predation, Symbiosis** at http://www.youtube.com/watch?v=D1aRSeT-mQE (3:20)

Click on the image above for more content

1. How do you think rapid changes in the chracteristics of habitats affect the niches of animals occupying that habitat?
2. Do you think rapid or gradual environmental changes have a greater potential to affect an organism's niche? Explain your answer.
3. On a very broad scale, how are the niches of a carnivore and an herbivore in the same geographic area similar? How do they differ?

Review

1. What is a niche?
2. Can two species share the same niche? Why or why not?
3. Name three factors that can be used to describe a habitat.
4. Distinguish between a habitat and an ecosystem.

Section 12

What are Biomes?

What are Biomes?

- •Define biome and describe how they are classified.
- •Explain what determines the differences among biomes.
- •Distinguish terrestrial biomes from aquatic biomes.

Where was this picture taken?

This scene is from Anza-Borrago California Desert Park. However, deserts exist around the globe. You might find a similar picture of a desert in Africa. The desert is one type of biome.

What are Biomes?

Tropical rainforests and deserts are two familiar types of biomes. A **biome** is an area with similar populations of organisms. This can easily be seen with a community of plants and animals. Remember that a **community** is all of the populations of different species that live in the same area and interact with one another. Different biomes, such as a forest (**Figure** below) or a desert, obviously have different communities of plants and animals. How are the plants and animals different in the rainforest than those in the desert? Why do you think they are so different?

The differences in the biomes are due to differences in the **abiotic factors** , especially climate. **Climate** is the typical weather in an area over a long period of time. The climate includes the amount of rainfall and the average temperature in the region. Obviously, the climate in the desert is much different than the climate in the rainforest. As a result, different types of plants and animals live in each biome.

Figure 12.21

Tropical rainforest landscape in Hawaii. Notice how the plants are different from those in the desert.

There are into two major groups of biomes:

1. **Terrestrial biomes** , which are land-based, such as deserts and forests.
2. **Aquatic biomes** , which are water-based, such as ponds and lakes.

The abiotic factors, such as the amount of rainfall and the temperature, are going to influence other abiotic factors, such as the quality of the soil. This, in turn, is going to influence the plants that migrate into the ecosystem and thrive in that biome. Recall that **migration** is the movement of an organism into or out of a population. It can also refer to a whole new species moving into a **habitat** . The type of plants that live in a biome are going to attract a certain type of animal to that habitat. It is the interaction of the abiotic and biotic factors that describe a biome and ecosystem. In aquatic biomes, abiotic factors such as salt, sunlight and temperature play significant roles.

For example, a hot dry biome is going to be completely different from a moderate wet biome. The soil quality will be different. Together, these will result in different plants being able to occupy each biome. Different plants will attract different animals (herbivores) to eat these plants. These animals, in turn, will attract different (carnivores) animals to eat the herbivores. So it is the abiotic factors that determine the biotic factors of an ecosystem, and together these define the biome.

Summary

- A biome is an area with similar climate that includes similar communities of plants and animals.
- Climate influences the types of plants and animals that inhabit a specific biome.

Explore More

Use the resources below to answer the questions that follow.

- **Biomes** at http://www.youtube.com/watch?v=ag5ATGEplbU (7:50)

Click on the image above for more content

1. Where do tundra biomes primarily occur? How much precipitation do these areas see annually?
2. What areas are best known for having Taiga biomes? What is the temperature range this biome experiences?
3. What is a behavioral adaptation that animals in desert biomes display?
4. List three characteristics of the rainforest.
5. How do the animals of a grassland adapt? Give two examples of animals of the grassland.

Review

1. What is a biome?
2. What causes differences in the biomes?
3. Give two examples of terrestrial biomes.
4. What influence does the soil quality have on a biome?

Section 13

Terrestrial Biomes

Terrestrial Biomes

•Describe the different types of terrestrial biomes.
•Summarize the roles of latitude, humidity, and elevation in a terrestrial biome.

Where could this picture have been taken?

This is an example of chaparral. This biome is usually characterized by dwarf trees and tangled shrubs. Although this is a picture along a Colorado road, you can also find this biome in southern California, the Mediterranean region in Europe, and many other places.

Terrestrial Biomes

A **terrestrial biome** is an area of land with a similar climate that includes similar communities of plants and animals. Different terrestrial biomes are usually defined in terms of their plants, such as trees, shrubs, and grasses.

Factors such as latitude, humidity, and elevation affect biome type:

•**Latitude** means how far a biome is from the equator. Moving from the poles to the equator, you will find (in order) Arctic, boreal, temperate, subtropical, and tropical biomes.
•**Humidity** is the amount of water in the air. Air with a high concentration of water will be called humid. Moving away from the most humid climate, biomes will be called semi-humid, semi-arid, or arid (the driest).
•**Elevation** measures how high land is above sea level. It gets colder as you go higher above sea level, which is why you see snow-capped mountains.

Terrestrial biomes include grasslands, forests, deserts, and tundra. **Grasslands** are characterized as lands dominated by grasses rather than large shrubs or trees and include the savanna and temperate grasslands. Forests are dominated by trees and other woody vegetation and are classified based on their latitude. **Forests** include tropical, temperate, and boreal forests (taiga). **Deserts** cover about one fifth of the Earth's surface and occur where rainfall is less than 50 cm (about 20 inches) each year. **Tundra** is the coldest of all the biomes. The tundra is characterized for its frost-molded landscapes, extremely low temperatures, little precipitation, poor nutrients, and short growing seasons. There are two main types of tundra, Arctic and Alpine tundras. Terrestrial biomes (**Figure** below) lying within the Arctic and Antarctic Circles do not have very much plant or animal life. Biomes with the highest amount of **biodiversity** , that is the most variation in plant and animal life, are near the equator (**Figure** below).

Figure 12.22

One of the terrestrial biomes, taiga, is an evergreen forest of the subarctic, covering extensive areas of northern North America and Eurasia. This taiga is along the Denali Highway in Alaska.

Figure 12.23

Another terrestrial biome is tropical rainforest. The one pictured here is located in Costa Rica.

Summary

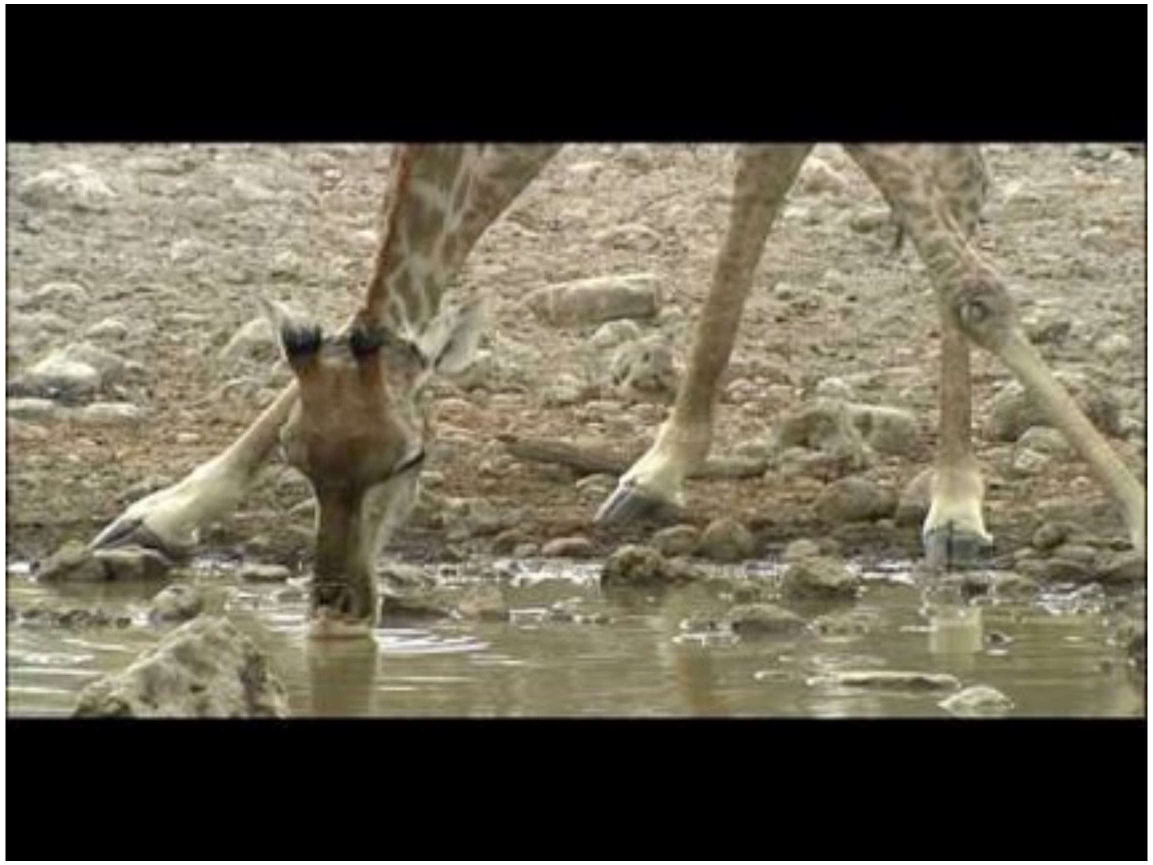
- Factors affecting biome type include latitude, humidity, and elevation.
- Terrestrial biomes include the tropical rainforest, chaparral, and taiga.

Explore More

Use the resources below to answer the questions that follow.

Explore More I

- **Terrestrial Biomes** at http://www.youtube.com/watch?v=RFEV-hiP2gQ (3:39)



Click on the image above for more content

1. Where are two locations at which tropical rainforests occur?
2. What four physical characteristics are necessary for life to persist? Of these four, which two explain the pattern of terrestrial biomes?
3. What adaptations do all desert plants share regardless of the specific desert they inhabit?

Explore More II

- **Savannas** at http://www.youtube.com/watch?v=Tuk-JW-wng0 (2:37)

Click on the image above for more content

1. How much precipitation do savannas receive annually? Over what period of time do they receive

this precipitation? How does this affect the animals living in this biome?
2. How do the physical characteristics of savannas lead to their dominance by grasses?

Review

1. How are terrestrial biomes defined?
2. Give four examples of terrestrial biomes.
3. What defines a desert?
4. Where is biodiversity the highest?

Section 14

Aquatic Biomes

Aquatic Biomes

•Give examples of marine biomes.
•Define freshwater biome.
•Distinguish the photic zone from the aphotic zone.
•Explain dissolved oxygen and nutrient distribution in aquatic biomes.

Is there life deep in the ocean?

Yes, there is life even at great depths in the ocean. One example of deep ocean life is this deep-sea chimaera. Chimaeras are related to sharks and resemble them somewhat. But most chimaeras are adapted for life thousands of feet under the ocean surface. This is one example of an organism that lives in an aquatic biome.

Aquatic Biomes

Recall that terrestrial biomes are defined by their climate. That's because plants and animals are adapted for certain amounts of temperature and moisture. However, would **aquatic biomes** be classified in the same way? No, that wouldn't make much sense—all parts of an aquatic environment have plenty of water. Aquatic biomes can be generally classified based on the amount of salt in the water. **Freshwater biomes** have less than 1% salt and are typical of ponds and lakes, streams and rivers, and wetlands. **Marine biomes** have more salt and are characteristic of the oceans, coral reefs, and estuaries.

Most aquatic organisms do not have to deal with extremes of temperature or moisture. Instead, their main limiting factors are the availability of sunlight and the concentration of dissolved oxygen and nutrients in the water.

Marine Biomes

Aquatic biomes in the ocean are called marine biomes. Organisms that live in marine biomes must be adapted to the salt in the water. For example, many have organs for excreting excess salt. Marine biomes include the oceans, coral reefs, and estuaries (**Figure** below). The oceans are the largest of all the ecosystems. They can be divided into four separate zones based on the amount of sunlight. Ocean zones are also divided based on their depth and their distance from land. Each zone has a great diversity of species. Within a **coral reef** , the dominant organisms are corals. **Corals** consist partially of algae, which provide nutrients via photosynthesis. Corals also extend tentacles to obtain plankton from the water. Coral reefs include several species of microorganisms, invertebrates, fishes, sea urchins, octopuses, and sea stars. **Estuaries** are areas where freshwater streams or rivers merge with the ocean.

Figure 12.24

An example of a marine biome, a kelp forest, from Anacapa Island in the Channel Islands National Marine Sanctuary.

Freshwater Biomes

Freshwater biomes are defined by their low salt concentration, usually less than 1%. Plants and animals in freshwater regions are adjusted to the low salt content and would not be able to survive in areas of high salt concentration, such as the ocean. There are different types of freshwater biomes: ponds and lakes (**Figure** below), streams and rivers, and wetlands. Ponds and lakes range in size from just a few square meters to thousands of square kilometers. Streams and rivers are bodies of flowing water moving in one direction. They can be found everywhere. They get their starts at **headwaters** , which may be springs, melting snow, or even lakes, and then travel all the way to their **mouths** , emptying into another water channel or the ocean. **Wetlands** are areas of standing water that support aquatic plants. Wetlands include marshes, swamps, and bogs.

Figure 12.25

Lake Tahoe in Northern California is a freshwater biome.

Aquatic Biomes and Sunlight

In large bodies of water, such as the ocean and lakes, the water can be divided into zones based on the amount of sunlight it receives:

1. The **photic zone** extends to a maximum depth of 200 meters (656 feet) below the surface of the water. This is where enough sunlight penetrates for **photosynthesis** to occur. Algae and other photosynthetic organisms can make food and support food webs.
2. The **aphotic zone** is water deeper than 200 meters. This is where too little sunlight penetrates for photosynthesis to occur. As a result, producers must make "food" by **chemosynthesis** , or the food must drift down from the water above.

Aquatic Biomes and Dissolved Substances

Water in lakes and the ocean also varies in the amount of dissolved oxygen and nutrients it contains:

1. Water near the surface of lakes and the ocean usually has more dissolved oxygen than does deeper water. This is because surface water absorbs oxygen from the air above it.
2. Water near shore generally has more dissolved nutrients than water farther from shore. This is because most nutrients enter the water from land. They are carried by runoff, streams, and rivers that empty into a body of water.
3. Water near the bottom of lakes and the ocean may contain more nutrients than water closer to the surface. When aquatic organisms die, they sink to the bottom. Decomposers near the bottom of the water

break down the dead organisms and release their nutrients back into the water.

Summary

- Aquatic biomes are distinguished by the availability of sunlight and the concentration of dissolved oxygen and nutrients in the water.
- The photic zone extends to a maximum depth of 200 meters, while the aphotic zone is deeper than 200 meters.
- Aquatic biomes in the ocean are called marine biomes.

Explore More

Use the resources below to answer the questions that follow.

Explore More I

- **Freshwater Biomes** at http://www.youtube.com/watch?v=tU2F36Y3AdU (2:04)

Click on the image above for more content

1. What factors determines the distribution of life in lakes?
2. What is a main entry point for nutrients in the littoral zone in lakes? How does this affect the biomass of this zone? How does it affect the species diversity?

Explore More II

- **Wetlands** at http://www.youtube.com/watch?v=1ILtfbde16A (3:07)

Click on the image above for more content

1. What effect do wetlands have on water quality? How does this work?
2. What is an estuary? How and why does the salinity of estuaries vary?

Review

1. Aquatic biomes are defined by what factor(s)?
2. Distinguish between freshwater and marine biomes.
3. How do producers in the aphotic zone differ from those in the photic zone?

Section 15

The Biosphere

The Biosphere

- Describe the biosphere and its importance in ecology.
- Distinguish the lithosphere from the hydrosphere and from the atmosphere.
- Discuss the Gaia hypothesis.

Is Earth a living organism?

Most scientists agree that the Earth itself is not a living thing. However, the Earth does have some aspects of life. Some scientists argue that the Earth maintains homeostasis, a stable state, just like a living organisms.

The Biosphere

The highest level of ecological organization is the **biosphere** . It is the part of Earth, including the air, land, surface rocks, and water, where life is found. Parts of the lithosphere, hydrosphere, and atmosphere make up the biosphere. The **lithosphere** is the outermost layer of the Earth's crust; essentially land is part of the lithosphere. The **hydrosphere** is composed of all the areas that contain water, which can be found on, under, and over the surface of Earth. The **atmosphere** is the layer of gas that surrounds the planet. The biosphere includes the area from about 11,000 meters below sea level to 15,000 meters above sea level. It overlaps with the lithosphere, hydrosphere, and atmosphere. Land plants and animals are found on the lithosphere, freshwater and marine plants and animals are found in the hydrosphere, and birds and other flying animals are found in the atmosphere. Of course, there are countless bacteria, protists, and fungi that are also found in the biosphere.

Is the Biosphere Living?

The **Gaia hypothesis** states that the biosphere is its own living organism. The hypothesis suggests that the Earth is self-regulating and tends to achieve a stable state, known as **homeostasis** . For example the composition of our atmosphere stays fairly consistent, providing the ideal conditions for life. When carbon dioxide levels increase in the atmosphere, plants grow more quickly. As their growth continues, they remove more carbon dioxide from the atmosphere. In this way, the amount of carbon dioxide stays fairly constant without human intervention.

For a better understanding of how the biosphere works and various dysfunctions related to human activity, scientists have simulated the biosphere in small-scale models.

Biosphere 2 (**Figure** below) is a laboratory in Arizona that contains 3.15 acres of closed ecosystems. Ecosystems of Biosphere 2 are an ocean ecosystem with a coral reef, mangrove wetlands, a tropical rainforest, a savannah grassland and a fog desert. See http://www.b2science.org/ for additional information.

Additional biosphere projects include BIOS-3, a closed ecosystem in Siberia, and Biosphere J, located in Japan.

Figure 12.26

Biosphere 2, in Arizona, contains 3.15 acres of closed ecosystem and is a small-scale model of the biosphere.

Summary

- The biosphere is the part of the Earth, including the air, land, surface rocks, and water, where you can find life.
- The Gaia hypothesis states that the biosphere is its own living organism

Explore More

Use the resource below to answer the questions that follow.

- **Biosphere** at http://www.eoearth.org/view/article/150667/

1. What is the biosphere?
2. What is the ecological definition of the biosphere?
3. What is the result of humans releasing carbon dioxide back into the atmosphere?
4. What is the Anthropocene?

Review

1. What is the biosphere?
2. Distinguish between the lithosphere, atmosphere and hydrosphere.
3. Give an example of how Earth is self-regulating.

Section 16

Producers

Producers

•Explain where all the energy in an ecosystem originates.
•Define photosynthesis and chemosynthesis.
•Describe how energy enters an ecosystem.
•Explain the role of a producer.

Where does all the bear's energy come from?

Bears get their energy from their food. Brown bears eat a varied diet, from nuts and berries to fish and other animals. When bears eat a berry, they are obtaining energy that the plant originally captured from the sun. Even when a bear eats another animal, the energy in that animal ultimately came from eating a producer that captured the sun's energy.

Producers

Energy is the ability to do work. In organisms, this work can be physical work, like walking or jumping, or it can be the work used to carry out the chemical processes in their cells. Every biochemical reaction that occurs in an organism's cells needs energy. All organisms need a constant supply of energy to stay alive.

Some organisms can get the energy directly from the sun. Other organisms get their energy from other organisms. Through **predator-prey relationships** , the energy of one organism is passed on to another. Energy is constantly flowing through a community. With just a few exceptions, all life on Earth depends on the sun's energy for survival.

The energy of the sun is first captured by **producers** (**Figure** below), organisms that can make their own food. Many producers make their own food through the process of **photosynthesis** . The "food" the producers make is the sugar, **glucose** . Producers make food for the rest of the ecosystem. As energy is not recycled, energy must consistently be captured by producers. This energy is then passed on to the organisms that eat the producers, and then to the organisms that eat those organisms, and so on.

Recall that the only required ingredients needed for photosynthesis are sunlight, carbon dioxide (CO_2), and water (H_2O). From these simple inorganic ingredients, photosynthetic organisms produce the carbohydrate glucose ($C_6H_{12}O_6$), and other complex organic compounds. Essentially, these producers are changing the energy from the sunlight into a usable form of energy. They are also making the oxygen that we breathe. Oxygen is a waste product of photosynthesis.

The survival of every ecosystem is dependent on the producers. Without producers capturing the energy from the sun and turning it into glucose, an ecosystem could not exist. On land, plants are the dominant producers. **Phytoplankton** , tiny photosynthetic organisms, are the most common producers in the oceans and lakes. Algae, which is the green layer you might see floating on a pond, are an example of phytoplankton.

There are also bacteria that use chemical processes to produce food. They get their energy from sources other than the sun, but they are still called producers. This process is known as **chemosynthesis** , and is common in ecosystems without sunlight, such as certain marine ecosystems.

Figure 12.27

Producers include (a) plants, (b) algae, and (c) diatoms.

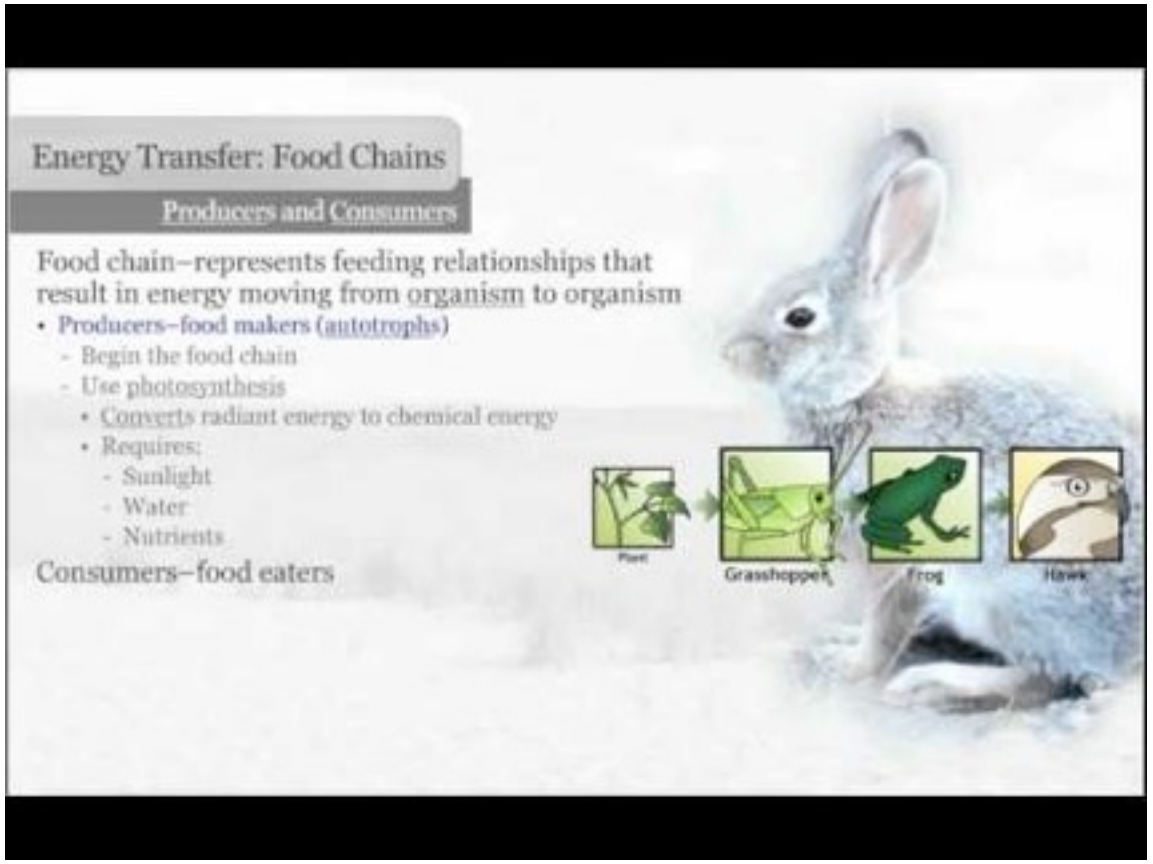
Summary

•With just a few exceptions, all life on Earth depends on the sun's energy for survival.
•Producers make food for the rest of the ecosystem through the process of photosynthesis, where the energy of the sun is used to convert carbon dioxide and water into glucose.

Explore More

Use the resource below to answer the questions that follow.

•**Producers and Consumers** at http://www.youtube.com/watch?v=P0a97kS_3SA (1:59)



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1.Can producers function without sunlight? Why or why not?
2.What are some examples of producers? Why are they called autotrophs?
3.How do some producers use sunlight to make "food"? What other resources do they require?

Review

1.Where does all the "food" in an ecosystem ultimately come from?
2.What is the most common method of producing energy for an ecosystem? What is the energy that is made?
3.What "ingredients" are needed for the process of photosynthesis?
4.Why are producers important to an ecosystem?

Section 17

Consumers and Decompos-

Consumers and Decomposers

•Explain the roles of consumers and decomposers in an ecosystem.
•Distinguish herbivores from carnivores and omnivores.
•Classify organisms on the basis of how they obtain energy and describe examples of each.

What is breaking down this leaf?

Notice how this leaf is slowly being broken down. This process can be carried out by fungi and bacteria on the ground. Breaking down old leaves is an important process since it releases the nutrients in the dead leaves back into the soil for living plants to use.

Consumers and Decomposers

Recall that **producers** make their own food through photosynthesis. But many organisms are not producers and cannot make their own food. So how do these organisms obtain their energy? They must get their energy from other organisms. They must eat other organisms, or obtain their energy from these organisms some other way. The organisms that obtain their energy from other organisms are called **consumers** . All animals are consumers, and they eat other organisms. Fungi and many protists and bacteria are also consumers. But, whereas animals eat other organisms, fungi, protists, and bacteria "consume" organisms through different methods.

The consumers can be placed into different groups, depending on what they consume.

•**Herbivores** are animals that eat producers to get energy. For example, rabbits and deer are herbivores that eat plants. The caterpillar pictured below (**Figure** below) is a herbivore. Animals that eat phytoplankton in aquatic environments are also herbivores.
•**Carnivores** feed on animals, either herbivores or other carnivores. Snakes that eat mice are carnivores.

Hawks that eat snakes are also carnivores (**Figure** below).

•**Omnivores** eat both producers and consumers. Most people are omnivores, since they eat fruits, vegetables, and grains from plants, and also meat and dairy products from animals. Dogs, bears, and raccoons are also omnivores.

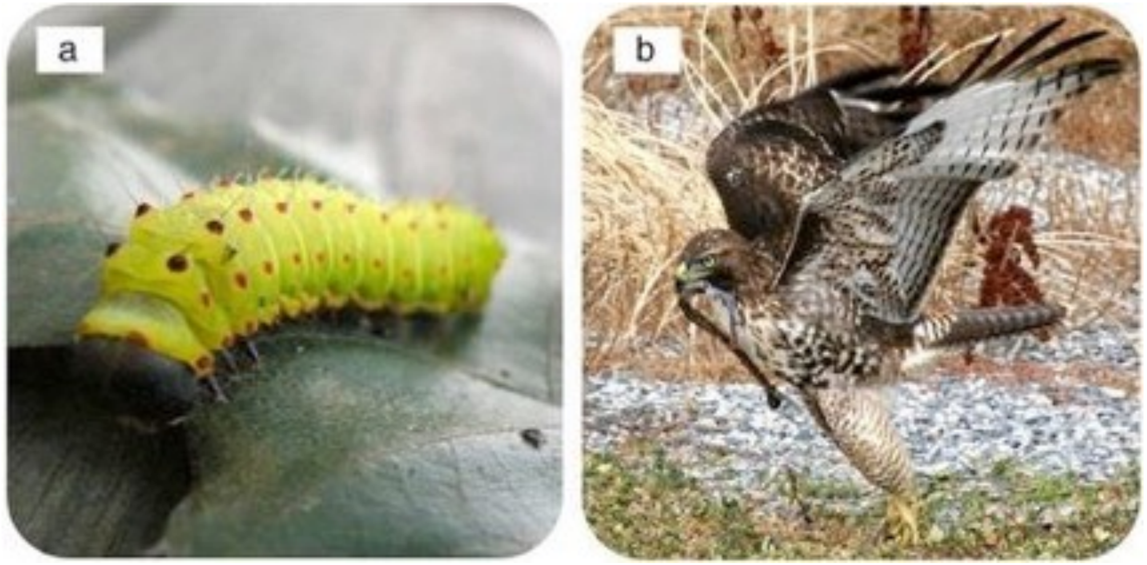


Figure 12.28

Examples of consumers are caterpillars (herbivores) and hawks (carnivore).

Decomposers and Stability

Decomposers (**Figure** below) get nutrients and energy by breaking down dead organisms and animal wastes. Through this process, decomposers release nutrients, such as carbon and nitrogen, back into the environment. These nutrients are recycled back into the ecosystem so that the producers can use them. They are passed to other organisms when they are eaten or consumed. Many of these nutrients are recycled back into the soil, so they can be taken up by the roots of plants.

The stability of an ecosystem depends on the actions of the decomposers. Examples of decomposers include mushrooms on a decaying log. Bacteria in the soil are also decomposers. Imagine what would happen if there were no decomposers. Wastes and the remains of dead organisms would pile up and the nutrients within the waste and dead organisms would not be released back into the ecosystem. Producers would not have enough nutrients. The carbon and nitrogen necessary to build organic compounds, and then cells, allowing an organism to grow, would be insufficient. Other nutrients necessary for an organism to function properly would also not be sufficient. Essentially, many organisms could not exist.

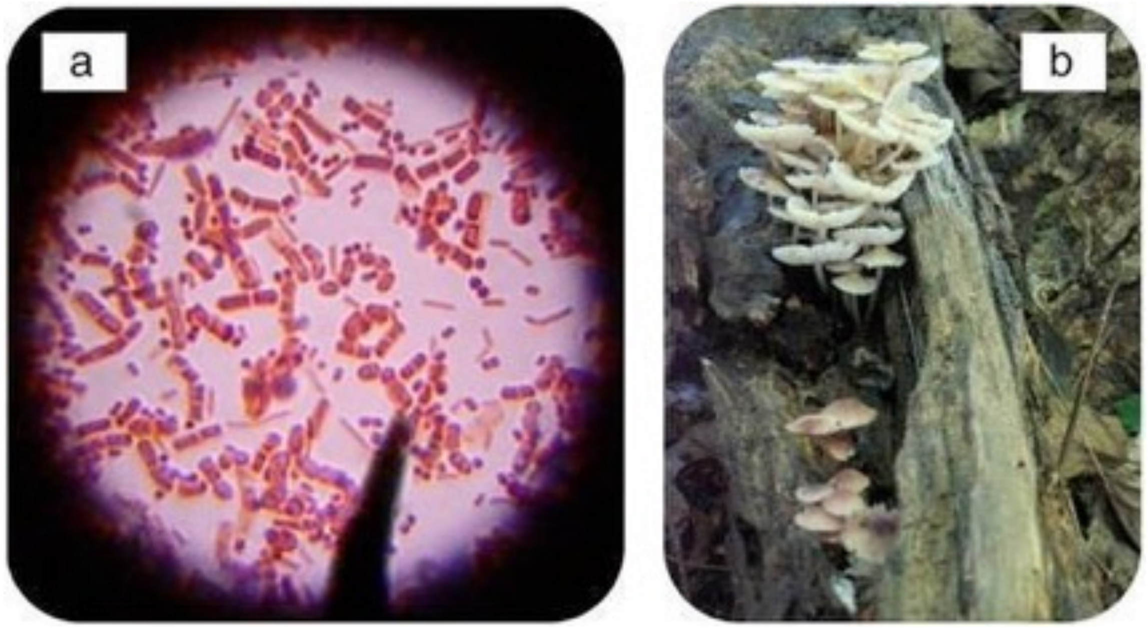


Figure 12.29

Examples of decomposers are (a) bacteria and (b) fungi.

Summary

- Consumers must obtain their nutrients and energy by eating other organisms.
- Decomposers break down animal remains and wastes to get energy.
- Decomposers are essential for the stability and survival of an ecosystem.

Explore More

Use the resource below to answer the questions that follow.

- **Decomposers** at http://www.youtube.com/watch?v=Z6V0a_7N1Mw (3:19)

Click on the image above for more content

1. What is the role of decomposers in an ecosystem? What is the source of the matter which is decomposed?
2. How do the actions of earthworms improve soil quality? How does this impact the amount of biomass an ecosystem can support?
3. How do gastropods function as decomposers?

Review

1. What is a consumer?
2. What's the term for a consumer that eats both leaves and fish?
3. What are the different types of consumers?
4. Why are decomposers important in the ecosystem?

Section 18

Food Webs

Food Webs

•Distinguish a food chain from a food web.
•Be able to draw and interpret a food web.
•Summarize the roles of producers, herbivores, and carnivores in a food web.

How do the grasshopper and the grass interact?

Grasshoppers don't just hop on the grass. They also eat the grass. Other organisms also eat the grass, and some animals even eat the grasshopper. These interactions can be visualized by drawing a food web.

Food Webs

Energy must constantly flow through an ecosystem for the system to remain stable. What exactly does this mean? Essentially, it means that organisms must eat other organisms. **Food chains** (**Figure** below) show the eating patterns in an ecosystem. Food energy flows from one organism to another. Arrows are used to show the feeding relationship between the animals. The arrow points from the organism being eaten to the organism that eats it. For example, an arrow from a plant to a grasshopper shows that the grasshopper eats the leaves. Energy and nutrients are moving from the plant to the grasshopper. Next, a bird might prey on the grasshopper, a snake may eat the bird, and then an owl might eat the snake. The food chain would be:

plant → grasshopper → bird → snake → owl.

A food chain cannot continue to go on and on. For example the food chain could not be:

plant → grasshopper → spider → frog → lizard → fox → hawk.

Food chains only have 4 or 5 total levels. Therefore, a chain has only 3 or 4 levels for energy transfer.

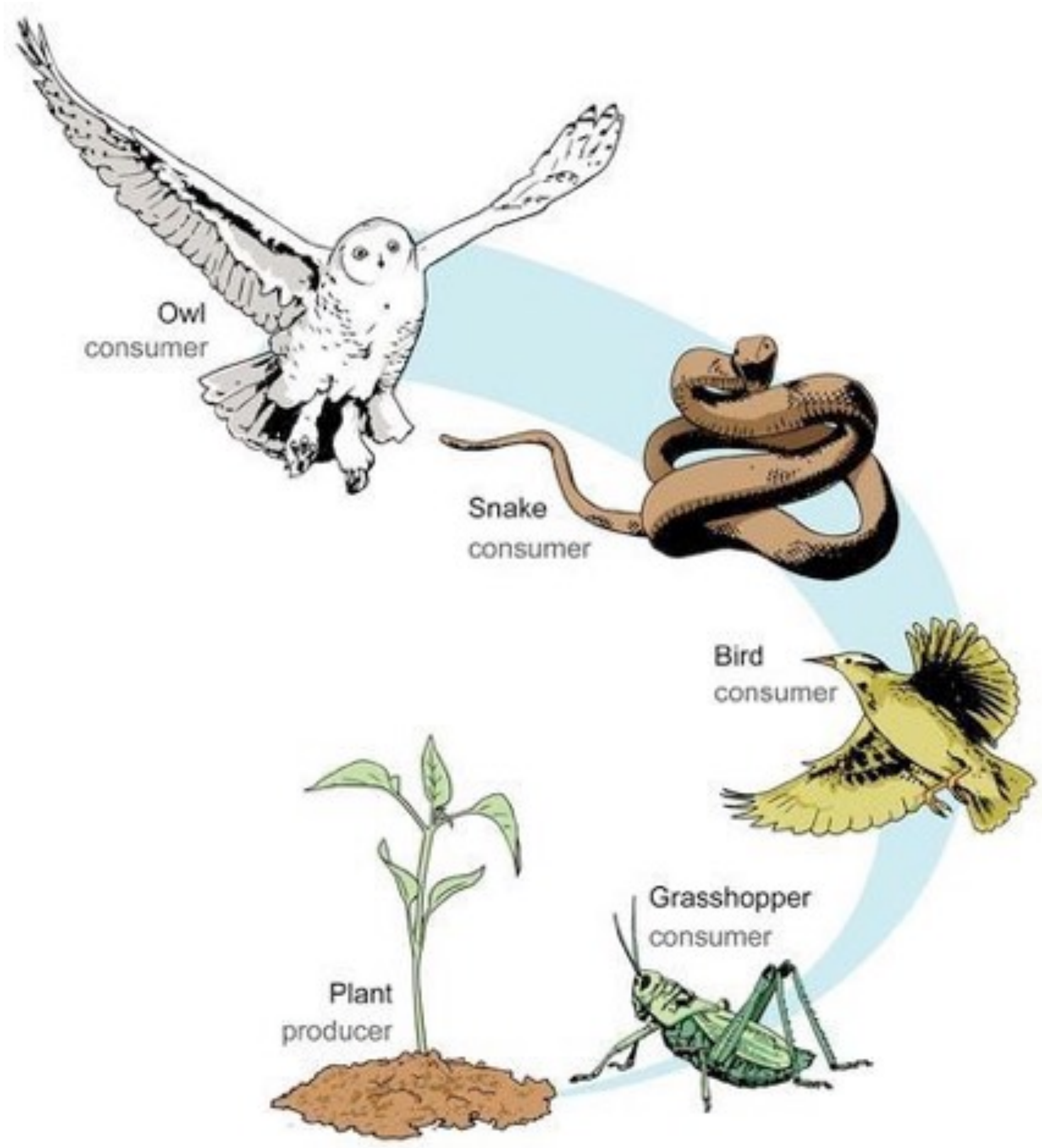


Figure 12.30

This food chain includes producers and consumers. How could you add decomposers to the food chain?

In an ocean ecosystem, one possible food chain might look like this: phytoplankton → krill → fish → shark. The **producers** are always at the beginning of the food chain, bringing energy into the ecosystem. Through photosynthesis, the producers create their own food in the form of glucose, but also create the food for the other organisms in the ecosystem. The **herbivores** come next, then the **carnivores** . When these **consumers** eat other organisms, they use the glucose in those organisms for energy. In this example, phytoplankton are eaten by krill, which are tiny, shrimp-like animals. The krill are eaten by fish, which are then eaten by sharks. Could **decomposers** be added to a food chain?

Each organism can eat and be eaten by many different types of organisms, so simple food chains are rare in nature. There are also many different species of fish and sharks. So a food chain cannot end with a shark; it must end with a distinct species of shark. A food chain does not contain the general category of "fish," it will contain specific species of fish. In ecosystems, there are many food chains.

Since feeding relationships are so complicated, we can combine food chains together to create a more accurate flow of energy within an ecosystem. A **food web** (**Figure** below) shows the feeding relationships between many organisms in an ecosystem. If you expand our original example of a food chain, you could add deer that eat clover and foxes that hunt chipmunks. A food web shows many more arrows, but still shows the flow of energy. A complete food web may show hundreds of different feeding relationships.

For more information on food chains, see *A Million Sharks* at https://www.youtube.com/watch?v=QXMTzXaWJyk .

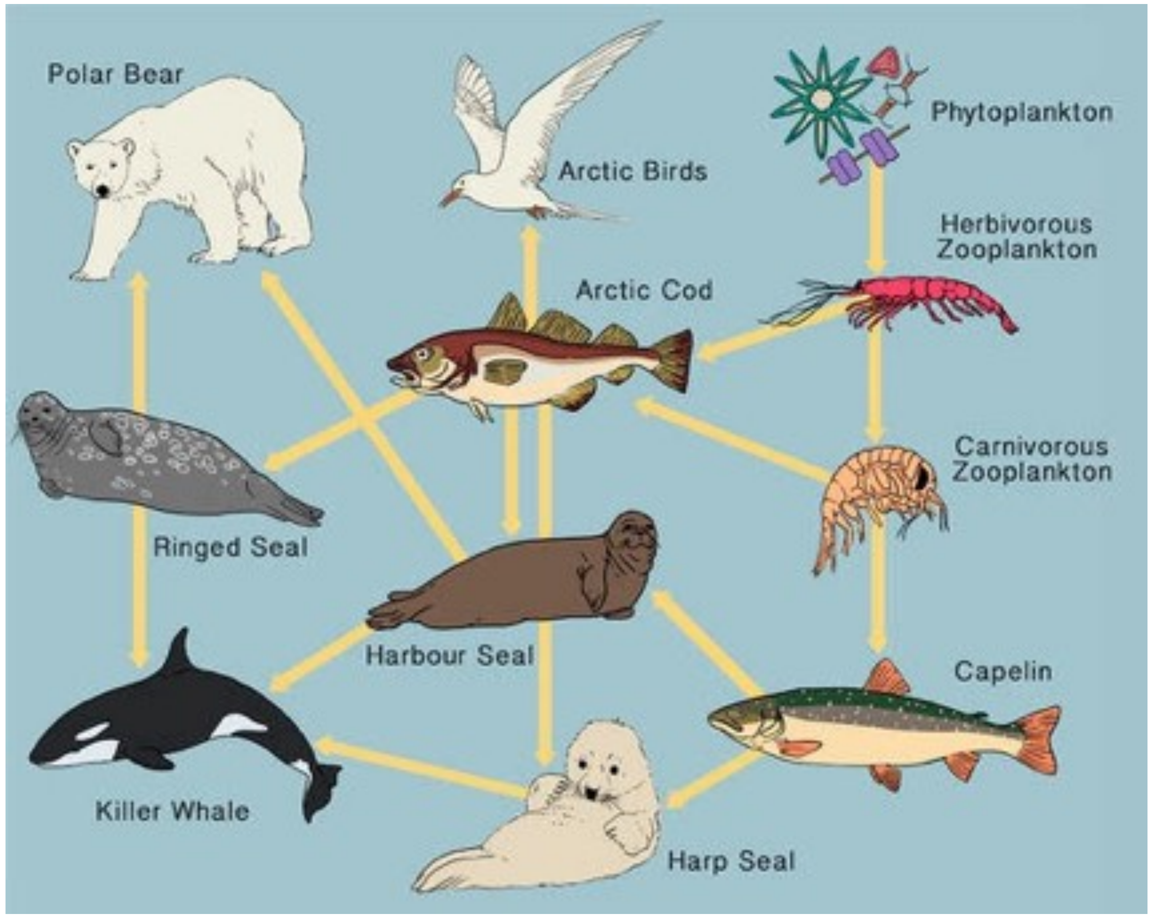


Figure 12.31

Food web in the Arctic Ocean.

Summary

- A food chain is a diagram that shows feeding interactions in an ecosystem through a single pathway.
- A food web is a diagram that shows feeding interactions between many organisms in an ecosystem through multiple intersecting pathways.

Explore More

Use the resource below to answer the questions that follow.

- **Build A Food Web** at http://www.sciencesource2.ca/resources/SS_active_art/active_art/SEinteractive_gr09_ch01_pg31/index.html

1. What do the Loons and Arctic Tern have in common in the food web?
2. What do the Beluga and the sea duck have in common in the food web?
3. What species in the food web feed on zooplankton (animal plankton)?
4. When you build your own food web what must it contain to be healthy? How many healthy food webs could you build?

Review

1. What is the difference between a food chain and a food web?
2. Food chains always begin with what type of organism? Why?
3. What is the herbivore in the following food chain: algae → fish → herons?

Section 19

Energy Pyramids

Energy Pyramids

- •Define energy and energy pyramid.
- •Explain the flow of energy through an ecosystem using an energy pyramid.
- •Describe a trophic level.
- •Explain the maximum number of trophic levels in an ecosystem.

How much energy could be gained from the warthog?

If the cheetah is successful in capturing the warthog, it would gain some energy by eating it. But would the cheetah gain as much energy as the warthog has ever consumed? No, the warthog has used up some of the energy it has consumed for its own needs. The cheetah will only gain a fraction of the energy that the warthog has consumed throughout its lifetime.

Energy Pyramids

When an herbivore eats a plant, the **energy** in the plant tissues is used by the herbivore. But how much of that energy is transferred to the herbivore? Remember that plants are **producers** , bringing the energy into the ecosystem by converting sunlight into glucose. Does the plant use some of the energy for its own needs? Recall the energy is the ability to do work, and the plant has plenty or "work" to do. So of course it needs and uses energy. It converts the glucose it makes into **ATP** through **cellular respiration** just like other organisms. After the plant uses the energy from glucose for its own needs, the excess energy is available to the organism that eats the plant.

The herbivore uses the energy from the plant to power its own life processes and to build more body tissues. However, only about 10% of the total energy from the plant gets stored in the herbivore’s body as extra body tissue. The rest of the energy is used by the herbivore and released as heat. The next consumer on the food chain that eats the herbivore will only store about 10% of the total energy from the herbivore in its own body. This means the carnivore will store only about 1% of the total energy that was originally in the plant. In other words, only about 10% of energy of one step in a food chain is stored in the next step in the food chain. The majority of the energy is used by the organism or released to the environment.

Every time energy is transferred from one organism to another, there is a loss of energy. This loss of energy can be shown in an **energy pyramid** . An example of an energy pyramid is pictured below (**Figure** below). Since there is energy loss at each step in a food chain, it takes many producers to support just a few carnivores in a community.

Each step of the food chain in the energy pyramid is called a **trophic level** . Plants or other photosynthetic organisms (**autotrophs**) are found on the first trophic level, at the bottom of the pyramid. The next level will be the herbivores, and then the carnivores that eat the herbivores. The energy pyramid (**Figure** below) shows four levels of a food chain, from producers to carnivores. Because of the high rate of energy loss in food chains, there are usually only 4 or 5 trophic levels in the food chain or energy pyramid. There just is not enough energy to support any additional trophic levels. **Heterotrophs** are found in all levels of an energy pyramid other than the first level.

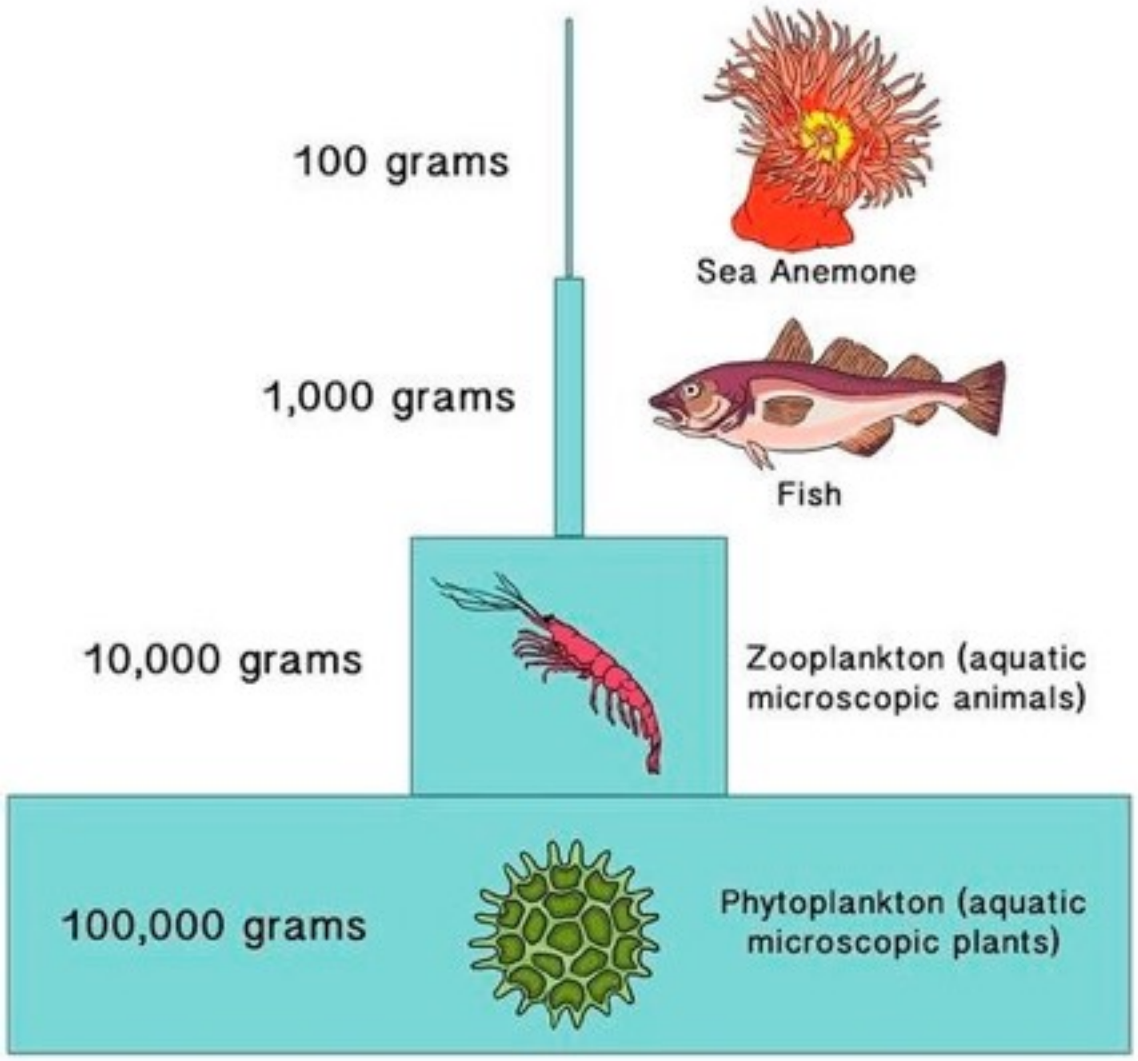


Figure 12.32

As illustrated by this ecological pyramid, it takes a lot of phytoplankton to support the carnivores of the oceans. This energy pyramid has four trophic levels, which signify the organisms place in the food chain from the original source of energy.

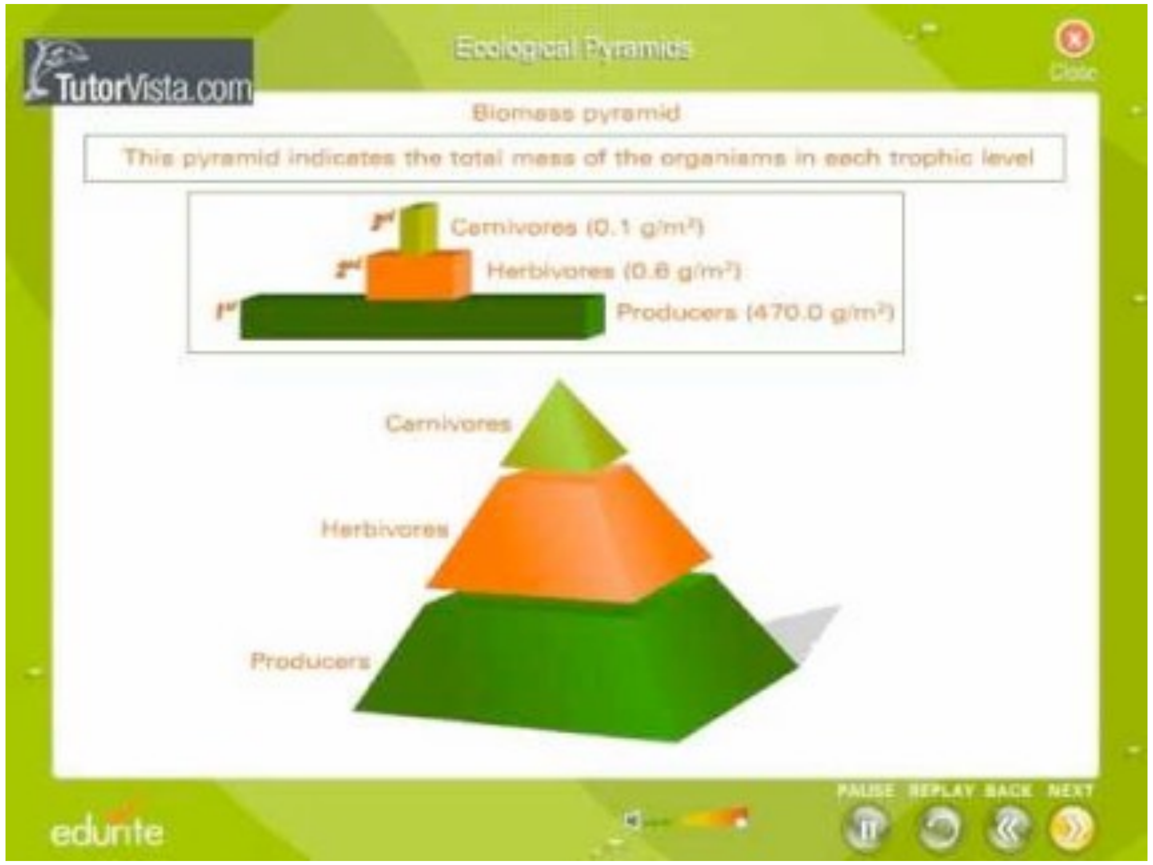
Summary

•As energy is transferred along a food chain, energy is lost as heat.
•Only about 10% of energy of one step in a food chain is stored in the next step in the food chain.

Explore More

Use the resource below to answer the questions that follow.

•**Ecological Pyramids** at http://www.youtube.com/watch?v=NJplkrliUEg (4:03)



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1.What are three types of ecological pyramids? How do their shapes compare?
2.Do you think it would be possible to construct a pyramid where the number of carnivores was more than the number of herbivores? Why or why not?
3.Do you think it would be possible to construct a pyramid where the biomass of carnivores was more than the biomass of herbivores? How does this compare to a numbers pyramid.
4.What consumes energy at each trophic level? How does this contribute to energy loss between trophic levels?

Review

1.When an herbivore eats a plant, what happens to 90% of the energy obtained from that plant?
2.What is a trophic level?
3.Why are the number of trophic levels limited?
4.In a forest community, caterpillars eat leaves, and birds eat caterpillars. Draw an energy pyramid using this information.

Section 20

The Water Cycle

The Water Cycle

- •Define biogeochemical cycle.
- •Describe the key features of the water cycle.
- •Distinguish condensation from precipitation.
- •Distinguish evaporation from transpiration.

Could you be drinking the same water as George Washington?

Water is recycled constantly through the ecosystem. That means any water you drank today has been around for millions of years. You could be drinking water that was once drunk by George Washington, the first humans, or even the dinosaurs.

The Water Cycle

Whereas energy flows through an ecosystem, water and elements like carbon and nitrogen are recycled. Water and nutrients are constantly being recycled through the environment. This process through which water or a chemical element is continuously recycled in an ecosystem is called a **biogeochemical cycle** . This recycling process involves both the living organisms (biotic components) and nonliving things (abiotic factors) in the ecosystem. Through biogeochemical cycles, water and other chemical elements are constantly being passed through living organisms to non-living matter and back again, over and over. Three important biogeochemical cycles are the **water cycle** , **carbon cycle** , and **nitrogen cycle** .

The biogeochemical cycle that recycles water is the water cycle. The water cycle involves a series of interconnected pathways involving both the biotic and abiotic components of the biosphere. Water is obviously an extremely important aspect of every ecosystem. Life cannot exist without water. Many organisms contain a large amount of water in their bodies, and many live in water, so the water cycle is essential to life on Earth. Water continuously moves between living organisms, such as plants, and non-living things, such as clouds, rivers, and oceans (**Figure** below).

The water cycle does not have a real starting or ending point. It is an endless recycling process that involves the oceans, lakes and other bodies of water, as well as the land surfaces and the atmosphere. The steps in the water cycle are as follows, starting with the water in the oceans:

1. Water evaporates from the surface of the oceans, leaving behind salts. As the water vapor rises, it collects and is stored in clouds.
2. As water cools in the clouds, condensation occurs. **Condensation** is when gases turn back into liquids.
3. Condensation creates precipitation. **Precipitation** includes rain, snow, hail, and sleet. The precipitation allows the water to return again to the Earth's surface.
4. When precipitation lands on land, the water can sink into the ground to become part of our underground water reserves, also known as **groundwater** . Much of this underground water is stored in **aquifers** , which are porous layers of rock that can hold water.

Run-off

Most precipitation that occurs over land, however, is not absorbed by the soil and is called **runoff** . This runoff collects in streams and rivers and eventually flows back into the ocean.

Transpiration

Water also moves through the living organisms in an ecosystem. Plants soak up large amounts of water through their roots. The water then moves up the plant and evaporates from the leaves in a process called **transpiration** . The process of transpiration, like evaporation, returns water back into the atmosphere.

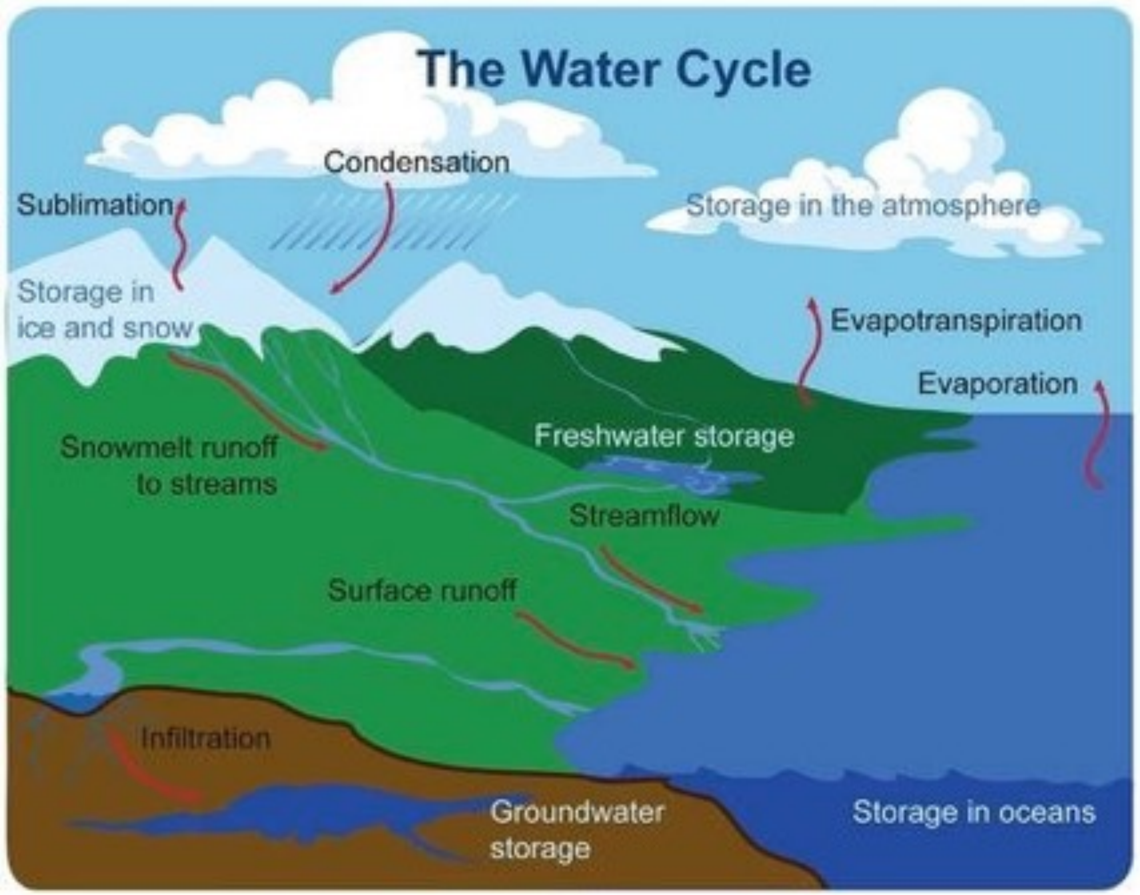


Figure 12.33

The water cycle.

Summary

- Chemical elements and water are constantly recycled in the ecosystem through biogeochemical cycles.
- During the water cycle, water enters the atmosphere by evaporation and transpiration, and water returns to land by precipitation.

Explore More

Use the resource below to answer the questions that follow.

- **The Water Cycle** at http://www.youtube.com/watch?v=IncMhop-4Jc (2:48)

Click on the image above for more content

1. What is a fundamental difference between the water cycle and other nutrient cycles?
2. What drives the water cycle? Where does this process primarily occur?
3. What happens to most of the water taken up by plants? How does this compare to most of the water taken up by animals?

4. How does water's role in photosynthesis explain increased biological productivity in areas of heavy precipitation?

Review

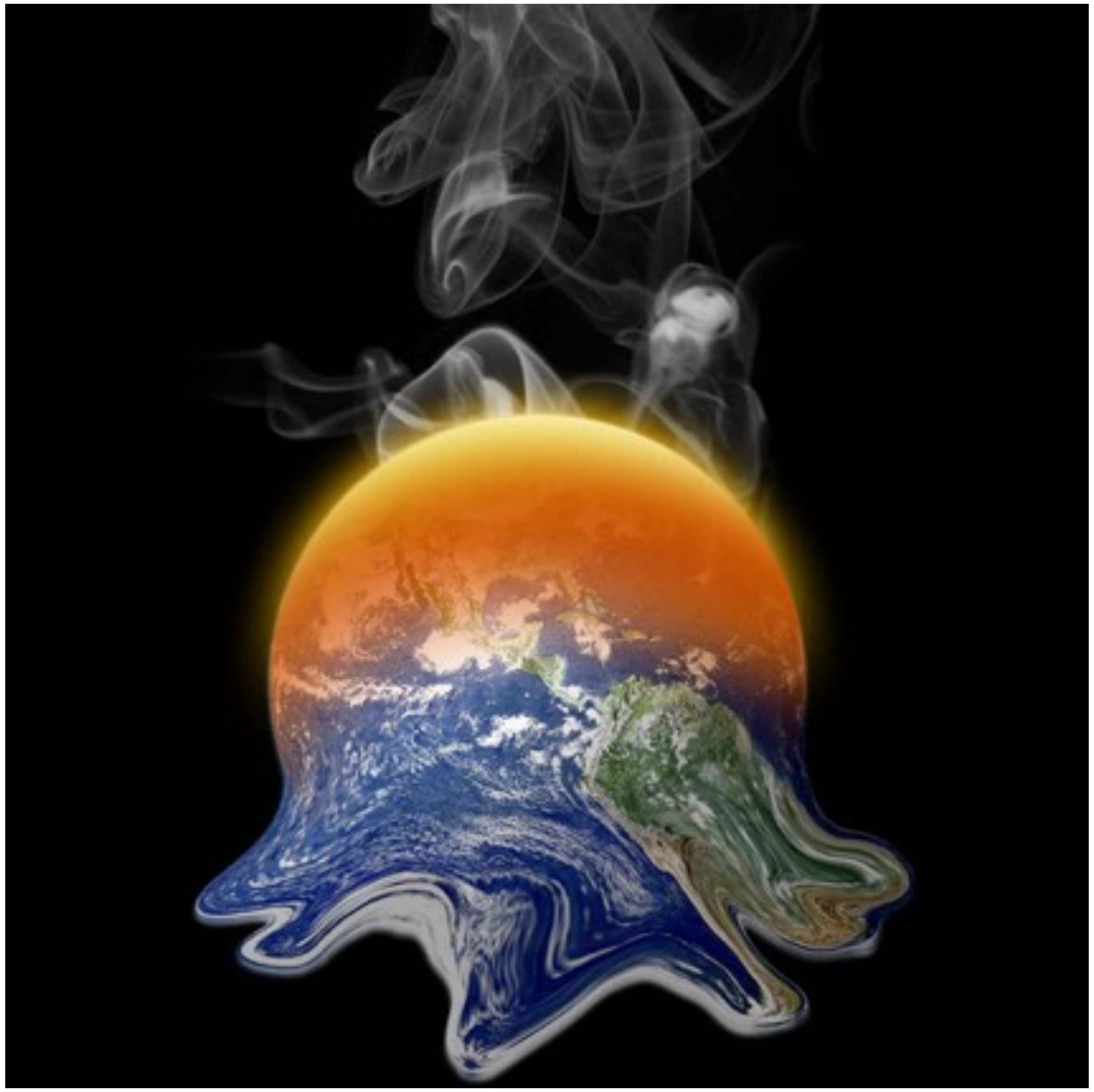
1. What is the water cycle?
2. What are two ways water returns to the atmosphere?
3. How does water get from the atmosphere back to land? What are the various forms of this process?
4. What is the relationship between groundwater and aquifers?

Section 21

The Carbon Cycle

The Carbon Cycle

- •Describe the key features of the carbon cycle.
- •Describe the relationship between photosynthesis and cellular respiration.
- •Define fossil fuels.
- •Explain the role of fossil fuels in global climate change.



Why is Earth getting warmer?

What happens if carbon is not removed from the atmosphere? The excess carbon dioxide in the atmosphere is contributing to a global rise in Earth's temperature, known as global warming. Where does this carbon dioxide come from? Burning gas to power our cars and burning coal to generate electricity are two main sources of the excess carbon dioxide.

The Carbon Cycle

Carbon is one of the most common elements found in living organisms. Chains of carbon molecules form the backbones of many organic molecules, such as carbohydrates, proteins, and lipids. Carbon is constantly cycling between living organisms and the atmosphere (**Figure** below). The cycling of carbon occurs through the **carbon cycle** .

Living organisms cannot make their own carbon, so how is carbon incorporated into living organisms? In the atmosphere, carbon is in the form of carbon dioxide gas (CO_2). Recall that plants and other producers capture the carbon dioxide and convert it to glucose ($C_6H_{12}O_6$) through the process of **photosynthesis** . Then as animals eat plants or other animals, they gain the carbon from those organisms.

The chemical equation of photosynthesis is $6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$.

How does this carbon in living things end up back in the atmosphere? Remember that we breathe out carbon dioxide. This carbon dioxide is generated through the process of **cellular respiration** , which has the reverse chemical reaction as photosynthesis. That means when our cells burn food (glucose) for energy, carbon dioxide is released. We, like all animals, exhale this carbon dioxide and return it back to the atmosphere. Also, carbon is released to the atmosphere as an organism dies and decomposes.

Cellular respiration and photosynthesis can be described as a cycle, as one uses carbon dioxide (and water) and makes oxygen (and glucose), and the other uses oxygen (and glucose) and makes carbon dioxide (and water).

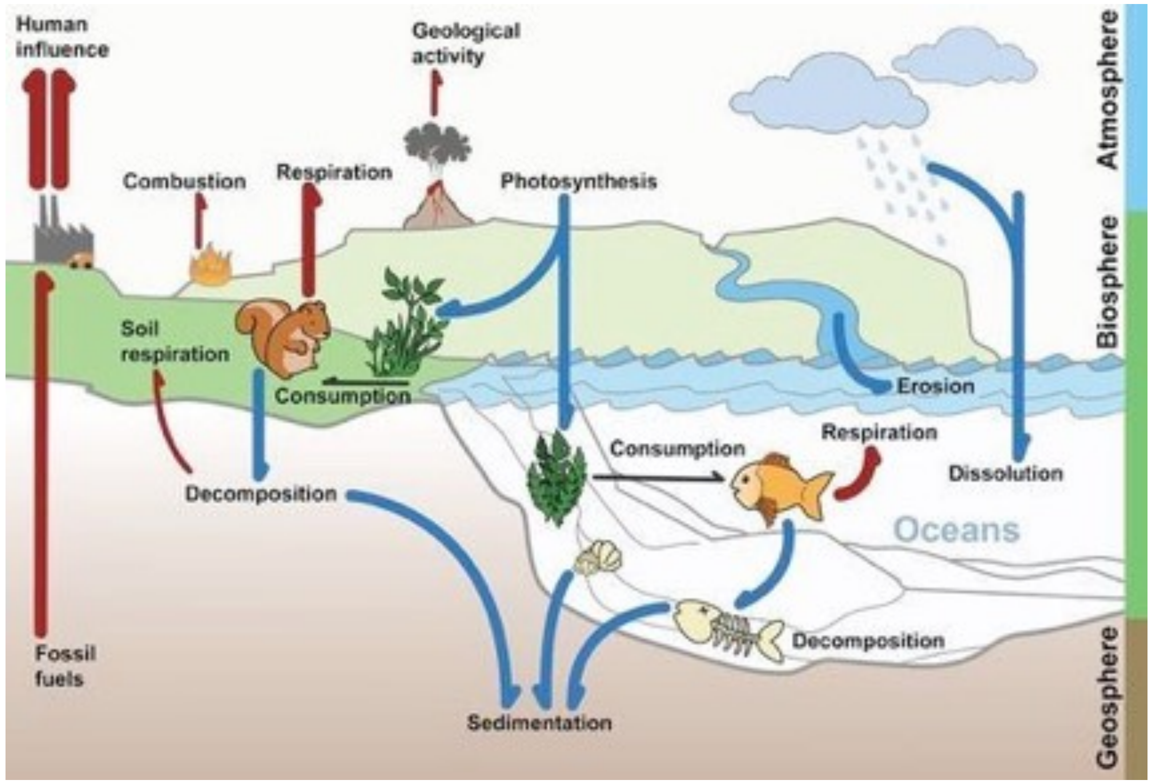


Figure 12.34

The carbon cycle. The cycling of carbon dioxide in photosynthesis and cellular respiration are main components of the carbon cycle. Carbon is also returned to the atmosphere by the burning of organic matter (combustion) and fossil fuels and decomposition of organic matter.

Formation of Fossil Fuels

Millions of years ago, there were so many dead plants and animals that they could not completely decompose before they were buried. They were covered over by soil or sand, tar or ice. These dead plants and animals are organic matter made out of cells full of carbon-containing organic compounds (carbohydrates, lipids, proteins and nucleic acids). What happened to all this carbon? When organic matter is under pressure for millions of years, it forms **fossil fuels.** Fossil fuels are coal, oil, and natural gas.

When humans dig up and use fossil fuels, we have an impact on the carbon cycle (**Figure** below). This carbon is not recycled until it is used by humans. The burning of fossil fuels releases more carbon dioxide into the atmosphere than is used by photosynthesis. So, there is more carbon dioxide entering the atmosphere than is coming out of it. Carbon dioxide is known as a **greenhouse gas** , since it lets in light energy but does not let heat escape, much like the panes of a greenhouse. The increase of greenhouse gasses in the atmosphere is contributing to a global rise in Earth's temperature, known as **global warming** or global climate change.

Figure 12.35

Human activities like burning gasoline in cars are contributing to a global change in our climate.

Summary

- During the carbon cycle, animals and plants add carbon dioxide to the atmosphere through cellular respiration, and plants remove carbon dioxide through photosynthesis.
- The burning of fossil fuels releases more carbon dioxide into the atmosphere, contributing to global warming.

Explore More

Use the resource below to answer the questions that follow.

- **Organic Carbon and the World Around Us** from USGS http://gallery.usgs.gov/videos/571#.UKWjAId9KSo (7:11)

Click on the image above for more content

1. What are two types of carbon? What type is carbon dioxide (CO_2)? What is an example of the other type?
2. How can carbon aid the spread of toxic substances?
3. Why are the reactivity and binding capabilities of carbon crucial to life?

Review

1. What biological process releases carbon back into the atmosphere?
2. What human activities have thrown the carbon cycle off balance?
3. Why is carbon dioxide a greenhouse gas?
4. What is the outcome of the increase of greenhouse gasses?

Section 22

The Nitrogen Cycle

The Nitrogen Cycle

- Describe the key features of the nitrogen cycle.
- Define nitrogen fixation.
- Explain assimilation and denitrification.

What can bean plants do that most other plants can't?

No, they don't grow giant stalks to the clouds. Bean plants and other legumes (plants that have their seeds in pods) can use the nitrogen in the air to grow. It takes the help of special bacteria friends in the soil, and this relationship is unique to the legumes.

The Nitrogen Cycle

Like water and carbon, nitrogen is also repeatedly recycled through the biosphere. This process is called the **nitrogen cycle** . Nitrogen is one of the most common elements in living organisms. It is important for creating both proteins and nucleic acids, like DNA. The air that we breathe is mostly nitrogen gas (N_2), but, unfortunately, animals and plants cannot use the nitrogen when it is a gas. In fact, plants often die from a lack of nitrogen even through they are surrounded by plenty of nitrogen gas. Nitrogen gas (N_2) has two nitrogen atoms connected by a very strong triple bond. Most plants and animals cannot use the nitrogen in nitrogen gas because they cannot break that triple bond.

In order for plants to make use of nitrogen, it must be transformed into molecules they can use. This can be accomplished several different ways (**Figure** below).

- Lightning: When lightening strikes, nitrogen gas is transformed into nitrate (NO_3^-) that plants can use.
- **Nitrogen fixation** : Special nitrogen-fixing bacteria can also transform nitrogen gas into useful forms. These bacteria live in the roots of plants in the pea family. They turn the nitrogen gas into ammonium (NH_4^+) (a process called ammonification). In water

environments, bacteria in the water can also fix nitrogen gas into ammonium. Ammonium can be used by aquatic plants as a source of nitrogen.

- Nitrogen also is released to the environment by decaying organisms or decaying wastes. These wastes release nitrogen in the form of ammonium.

Ammonium in the soil can be turned into nitrate by a two-step process completed by two different types of bacteria. In the form of nitrate, nitrogen can be used by plants through the process of **assimilation** . It is then passed along to animals when they eat the plants.

Sending Nitrogen back to the Atmosphere

Turning nitrate back into nitrogen gas, the process of **denitrification** , happens through the work of denitrifying bacteria. These bacteria often live in swamps and lakes. They take in the nitrate and release it back to the atmosphere as nitrogen gas.

Just like the carbon cycle, human activities impact the nitrogen cycle. These human activities include the burning of fossil fuels, which release nitrogen oxide gasses into the atmosphere. Releasing nitrogen oxide back into the atmosphere leads to problems like **acid rain** .

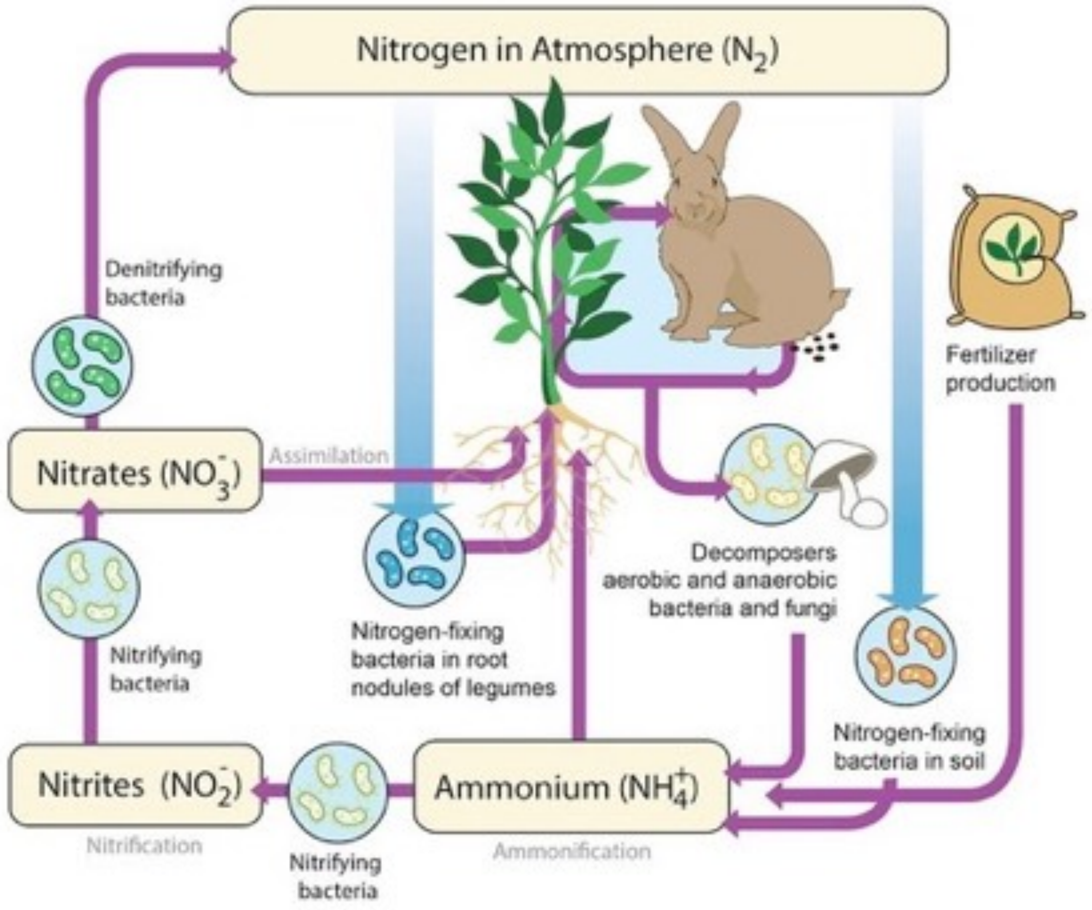


Figure 12.36

The nitrogen cycle includes assimilation, when plants absorb nitrogen; nitrogen-fixing bacteria that make the nitrogen available to plants in the form of nitrates; decomposers that transform nitrogen in dead organisms into ammonium; nitrifying bacteria that turn ammonium into nitrates; and denitrifying bacteria that turn nitrates into gaseous nitrogen.

Summary

- Gaseous nitrogen is converted into forms that can be used by plants during the process of nitrogen fixation.

•Denitrifying bacteria turn nitrate back into gaseous nitrogen.

Explore More

Use the resources below to answer the questions that follow.

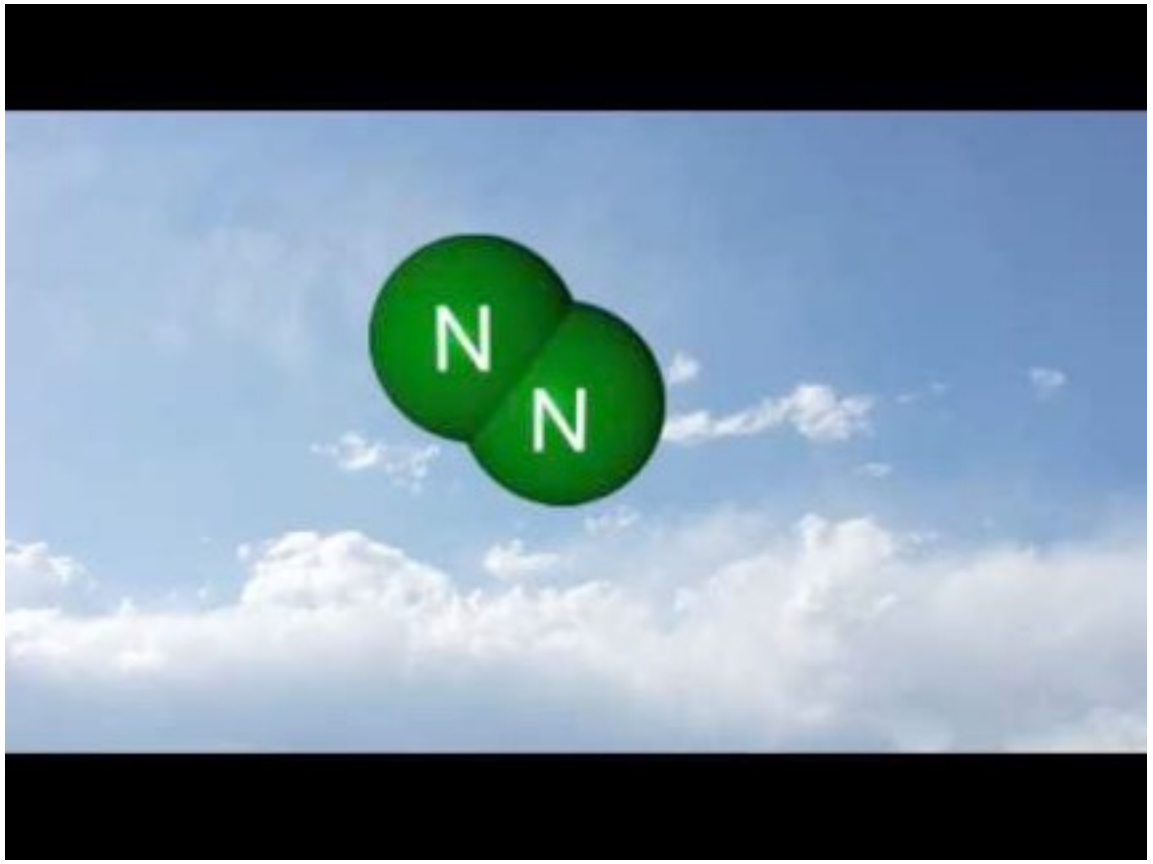
Explore More I

- **The Nitrogen Cycle** at http://www.teachersdomain.org/asset/lsps07_int_nitrogen/

1. What is the largest source of nitrogen on Earth? How does this nitrogen enter the food web?
2. What kind of relationship exists between nitrogen-fixing bacteria and the plants whose roots they live around?
3. What is assimilation? Describe the "loop" in the Nitrogen Cycle that involves assimilation by animals?
4. At what step in the Nitrogen Cycle do bacteria assimilate nitrogen?

Explore More II

- **The Nitrogen Cycle** at http://www.youtube.com/watch?v=XU3QMYfOdCM (4:18)



Click on the image above for more content

1. What metabolic processes do organisms use nitrogen (N) for?
2. What sorts of molecules are made using nitrogen?

Review

1. How do living organisms use nitrogen?
2. What is nitrogen fixation? Describe how it happens.
3. How is nitrate in the soil converted back to nitrogen gas?
4. How does acid rain form?

Succession

Succession

•Explain types of ecological succession and replacement within a community.
•Distinguish primary succession from secondary succession.
•Explain the role of a pioneer species.
•Define lichen.
•Summarize what is meant by a climax community.

What will happen to this land?

Since this land was clearcut, there is little life left behind. However, that does not mean that this land will stay barren forever. First little seedlings will establish themselves, and with time a forest could thrive here once again.

Succession

When you see an older forest, it's easy to picture that the forest has been there forever. This is not the case. Ecosystems are "dynamic." This means that ecosystems change over time. That forest may lie on land that was once covered by an ocean millions of years ago. Lightning may have sparked a fire in a forest, destroying much of the plant life there. Or the forest may have been cut down at one point for agricultural use, then abandoned and allowed to re-grow over time. During the ice ages, glaciers once covered areas that are tropical rainforests today. Both natural forces and human actions cause ecosystems to change.

If there is a big ecosystem change caused by natural forces or human actions, the plants and animals that live there may be destroyed. Or they may be forced to leave. Over time, a new **community** will develop, and then that community may be replaced by another. You may see several changes in the plant and animal composition of the community over time. **Ecological succession** is the constant replacement of one community by another. It happens after a big change in the ecosystem. And, of course, succession occurs on brand new land.

Primary Succession

Primary succession is the type of ecological succession that happens on new lands—lands where life has not yet existed. Primary succession can take place after lava flow cools and hardens into new land, or a glacier recedes exposing new land. Since the land that results from these processes is completely new land, soil must first be produced. How is soil produced?

Primary succession always starts with a **pioneer species** . This is the species that first lives in the habitat. If life is to begin on barren rock, which is typical of new land, the pioneer species would be an organism such as a lichen (**Figure** below). A **lichen** is actually an organism formed from two species. It results from a symbiotic relationship between a fungus and an algae or cyanobacteria. The lichen is able to thrive as both the fungus and the algae or bacteria contribute to the relationship. The fungus is able to absorb minerals and nutrients from the rock, while algae supplies the fungus with sugars through **photosynthesis** . Since lichens can photosynthesize and do not rely on soil, they can live in environments where other organisms cannot. As a lichen grows, it breaks down the rock, which is the first step of soil formation.

Figure 12.37

Primary succession on a rock often begins with the growth of lichens. What do lichens help create?

The pioneer species is soon replaced by other populations. Abiotic factors such as soil quality, water, and climate will determine the species that continue the process of succession. Mosses and grasses will be able to grow in the newly created soil. During early succession, plant species like grasses that grow and reproduce quickly will take over the landscape. Over time, these plants improve the soil and a few shrubs can begin to grow. Slowly, the shrubs are replaced by small trees. Small trees then are succeeded by larger trees. Since trees are more successful at competing for resources than shrubs and grasses, a forest may be the end result of primary succession.

Secondary Succession

Sometimes ecological succession occurs in areas where life has already existed. These areas already have soil full of nutrients. **Secondary succession** is the type of succession that happens after something destroys the habitat, such as a flood or other natural disaster. Abandoning a field that was once used for agriculture can also lead to secondary succession (**Figure** below). In this case, the pioneer species would be the grasses that first appear. Lichen would not be necessary as there is already nutrient-rich soil. Slowly, the field would return to its natural state.

Figure 12.38

This land was once used for growing crops. Now that the field is abandoned, secondary succession has begun. Pioneer species, such as grasses, appear first, and then shrubs begin to grow.

A forest fire can alter a habitat such that secondary succession occurs (**Figure** below and **Figure** below). Although the area will look devastated at first, the seeds of new plants are underground. They are waiting for their chance to grow. Just like primary succession, the burned forest will go through a series of communities, starting with small grasses, then shrubs, and finally bigger trees.

Figure 12.39

The early stages of succession after a forest fire are shown in these pictures. Taken four years after the fire, they show the charred remains of the original forest as well as the small grasses and shrubs that are beginning to grow back in the area.

Figure 12.40

In 1988, a forest fire destroyed much of Yellowstone National Park. This photo, taken 17 years later, shows that the forest is gradually growing back. Small grasses first grew here and are now being replaced by small trees and shrubs. This is an example of the later stages of secondary succession.

Climax Communities

A **climax community** (**Figure** below) is the end result of ecological succession. The climax community is a stable balance of all organisms in an ecosystem, and will remain stable unless a disaster strikes. After the disaster, succession will start all over again. Depending on the climate of the area, the climax community will look different.

In the tropics, the climax community might be a tropical rainforest. At the other extreme, in northern parts of the world, the climax community might be a coniferous forest. Though climax communities are stable, are they truly the final community of the habitat? Or is it likely that sometime in the future, maybe a long time in the future, the community of populations will change, and another stable, climax community will thrive?

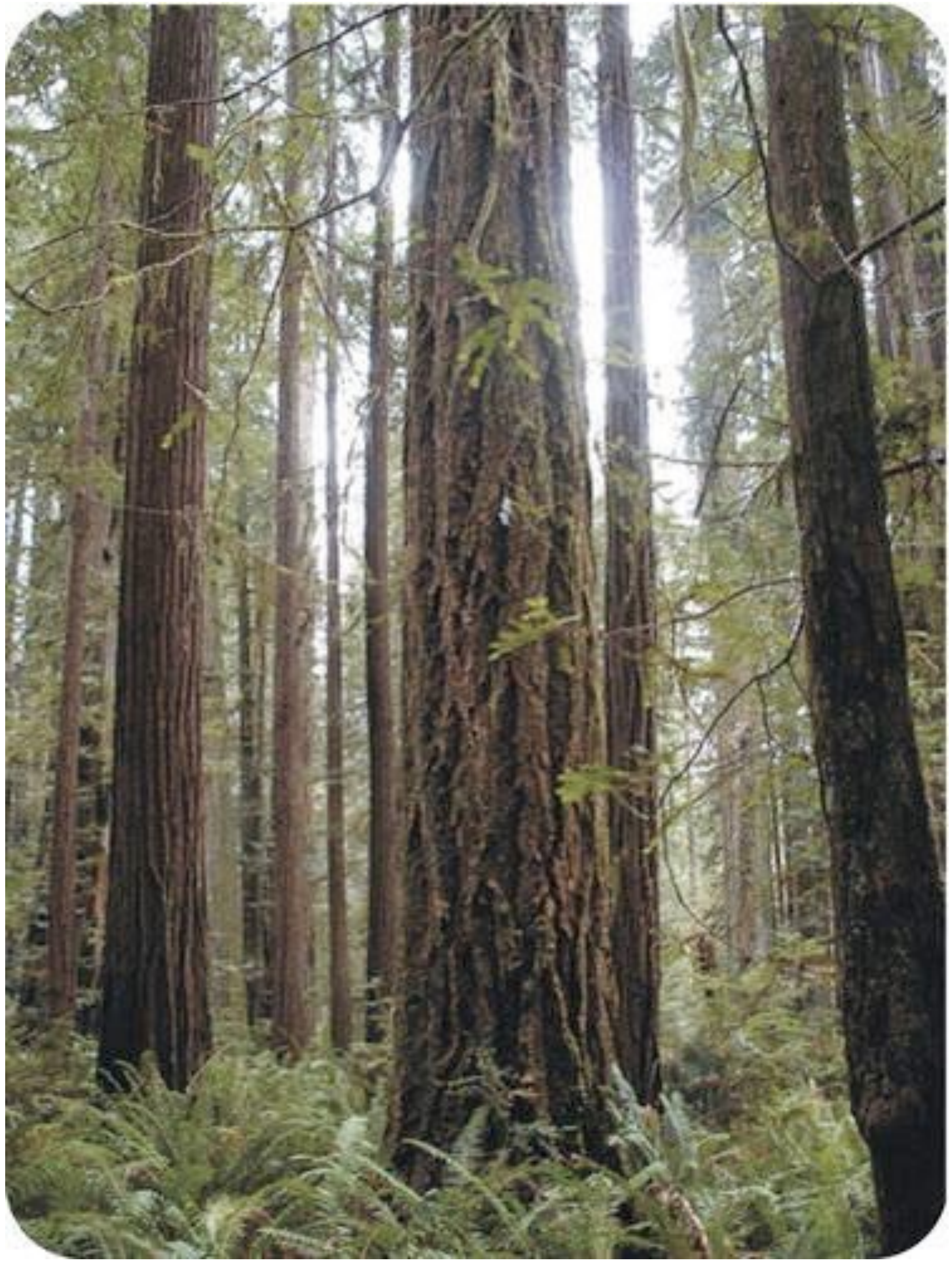


Figure 12.41

These ancient redwood trees are part of a climax community, the end result of a series of community replacements during succession.

Summary

- Ecological succession is the constant replacement of one community by another.
- Primary succession occurs in an area that has never before been colonized by plants and animals, while secondary succession occurs in an established area that was disturbed.

Explore More

Use the resource below to answer the questions that follow.

- **Climax Communities** at http://www.youtube.com/watch?v=iZA5yfrzLV8 (2:52)

Click on the image above for more content

1. How do climax communities relate to biomes?
2. What factors affect the characteristics of climax communities?
3. How has cattle grazing affected the ecological balance between sage brush and grasses in the American Midwest?
4. How did fire aid the spread of the American Praire? What was the source of this fire?
5. What is a sub-climax community? How are they maintained?
6. If people maintained the American Prairies through the use of fire, what kind of community does this make the American Prairie?

Review

1. Define ecological succession.
2. What type of succession occurs in areas where there is no soil?
3. Imagine a forest fire destroyed a forest. The forest will slowly reestablish itself, which is an example of what kind of succession? Why?
4. How does primary succession usually begin? Give an example.
5. What is the end result of succession? Do these communities truly exist? Why or why not?

Section 24

Outdoor Air Pollution

Outdoor Air Pollution

- •Discuss the types of outdoor air pollution and their causes.
- •Define primary pollutant and give examples.
- •Define secondary pollutant and give examples.
- •Summarize the effects of acid rain.
- •Explain the relationship between greenhouse gases, deforestation, and global climate change.

What is this haze?

This picture shows a thick layer of smog and dust over a very polluted city (Singapore). Smog in the air is a serious health hazard for people living in many big cities around the globe. Smog is one example of air pollution.

Outdoor Air Pollution

Air is all around us. Air is essential for life. Sometimes, humans can pollute the air. For example, releasing smoke and dust from factories and cars can cause **air pollution** . Air pollution is due to chemical substances and particles released into the air mainly by human actions. This pollution affects entire ecosystems around the world. Pollution can also cause many human health problems, and it can also cause death. Air pollution can be found both outdoors and indoors.

Outdoor air pollution is made of chemical particles. When smoke or other pollutants enter the air, the particles found in the pollution mix with the air. Air is polluted when it contains many large toxic particles. Outdoor air pollution changes the natural characteristics of the atmosphere. **Primary pollutants** are added directly to the atmosphere. Fires add primary pollutants to the air. Particles released from the fire directly enter the air and cause pollution (**Figure** below). Burning of **fossil fuels** such as oil and coal is a major source of primary pollutants (**Figure** below).

Secondary pollutants are formed when primary pollutants interact with sunlight, air, or each other. They do not directly cause pollution. However, when they interact with other parts of the air, they do cause pollution. For example, **ozone**

is created when some pollutants interact with sunlight. High levels of ozone in the atmosphere can cause problems for humans.

Figure 12.42

Wildfires, either natural or human-caused, release particles into the air, one of the many causes of air pollution.

Figure 12.43

A major source of air pollution is the burning of fossil fuels from factories, power plants, and motor vehicles.

Sources of Outdoor Air Pollution

Most air pollutants can be traced to the burning of fossil fuels. Fossil fuels are burned during many processes, including in power plants to create electricity, in factories to make machinery run, in power stoves and furnaces for heating, and in waste facilities. Perhaps one of the biggest uses of fossil fuels is in transportation. Fossil fuels are used in cars, trains, and planes.

Air pollution can also be caused by agriculture, such as cattle ranching and the use of fertilizers and pesticides.

Other sources of air pollution include the production of plastics, refrigerants, and aerosols, in nuclear power and defense, from landfills and mining, and from biological warfare.

Acid Rain

One result of air pollution is acid rain. **Acid rain** is precipitation with a low (acidic) pH. This rain can be very destructive to wildlife. When acid rain falls in forests, freshwater habitats, or soils, it can kill insects and aquatic life. It causes this damage because of its very low pH. Sulfur oxides and nitrogen oxides in the air both cause acid rain to form (**Figure** below). Sulfur oxides are chemicals that are released from coal-fired power plants. Nitrogen oxides are released from motor vehicle exhaust.

Figure 12.44

A forest in the Jizera Mountains of the Czech Republic shows effects caused by acid rain. What do you observe?

Global Warming

Pollutants also affect the atmosphere through their contribution to global warming. **Global warming** is an increase in the Earth’s temperature. It is thought to be caused mostly by the increase of **greenhouse gases** like carbon dioxide. Greenhouse gases can be released by factories that burn fossil fuels. Over the past 20 years, burning fossil fuels has produced about three-quarters of the carbon dioxide from human activity. The rest of the carbon dioxide in the atmosphere is there because of deforestation, or cutting down trees (**Figure** below). Trees absorb carbon dioxide during cellular respiration, so when trees are cut down, they cannot remove carbon dioxide from the air.

Figure 12.45

Deforestation, shown here as a result of burning for agriculture in southern Mexico, has produced significant increases in carbon dioxide emissions over the past 20 years.

This increase in global temperature will cause the sea level to rise. It is also expected to produce an increase in extreme weather events and change the amount of precipitation. Global warming may also cause food shortages and species extinction.

Summary

- Air pollution is caused by chemical substances and particles released into the air, mainly by human activities.
- The major cause of outdoor air pollution is the burning of fossil fuels.
- Problems caused by the burning of fossil fuels include acid rain and global warming.

Explore More

Use the resource below to answer the questions that follow.

- **Human Pollution** at http://www.youtube.com/watch?v=HRJ6njStTec (2:15)

Click on the image above for more content

1. What are pollutants?
2. What are three sources of pollutants?
3. What are the two main categories of pollutants?

Review

1. What is air pollution?
2. What's the difference between primary and secondary pollutants? Give examples of each.
3. What are three ways that polluting fossil fuels are burned?
4. Why is acid rain dangerous.

Section 25

Indoor Air Pollution

Indoor Air Pollution

•Discuss the sources of indoor air pollutants.
•Distinguish biological from chemical air pollutants.
•Give examples of biological and chemical air pollutants.
•Explain ways to decrease your exposure to indoor air pollution.

How do you paint safely?

If you are painting indoors, there are more important concerns than just getting messy. You should also be concerned about breathing in the fumes from the paints. Making sure to get plenty of fresh air while painting is very important. Paint fumes can have serious health effects. Paint fumes are just one example of indoor air pollution.

Indoor Air Pollution

Recall that **air pollution** is due to chemical substances and particles released into the air mainly by human actions. When most people think of air pollution, they think of the pollution outdoors. But it is just as easy to have **indoor air pollution.** Your home or school classroom probably doesn't get much fresh air. Sealing up your home reduces heating and cooling costs. But this also causes air pollution to stay trapped indoors. And people today usually spend a majority of their time indoors. So exposure to indoor air pollution can become a significant health risk.

Indoor air pollutants include both chemical and biological pollutants. Chemical pollutants include the following:

•**Radon** , a radioactive gas released from the Earth in certain locations. It can become trapped inside buildings and increase your risk of cancer.
•Formaldehyde, a toxic gas emitted from building materials, such as carpeting and plywood.
•**Volatile organic compounds** (VOCs), which are given off by paint and solvents as they dry. They can cause cause long-term health effects.
•**Secondhand smoke** , which comes from breathing the smoke release from tobacco products. Secondhand smoke is also the smoke exhaled by a

cigarette smoker. This smoke is extremely dangerous to human health.
•**Carbon monoxide** (CO), a toxic gas released by burning fossil fuels. It is often released indoors by faulty chimneys, gas-powered generators, or burning charcoal; it can be extremely dangerous.
•Dry cleaning fluids, such as tetrachloroethylene, which can be released from clothing days after dry cleaning.
•The past use of **asbestos** in factories and in homes. Asbestos is a very dangerous material, and it was used in many buildings (**Figure** below). Asbestos can cause cancer and other lung diseases. The use of asbestos is not allowed today.

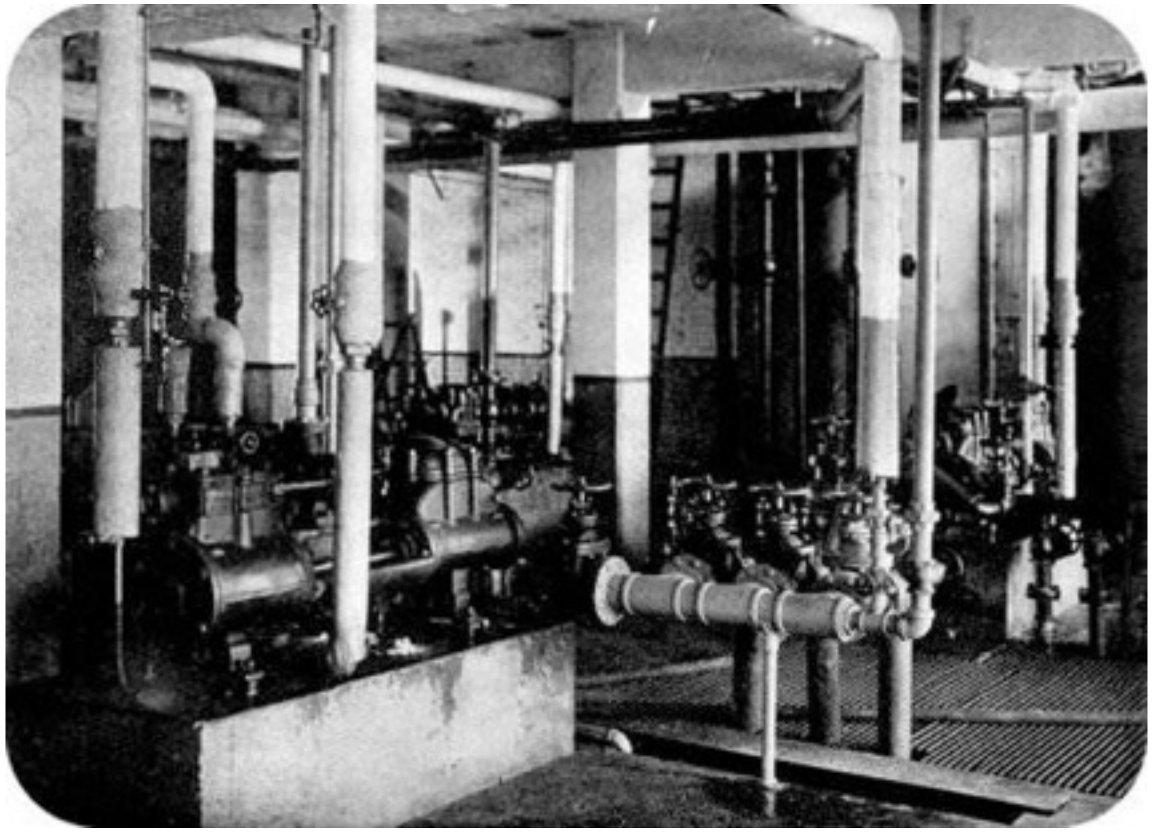


Figure 12.46

The use of asbestos in industry and domestic environments in the past, as in the asbestos-covered pipes in the oil-refining plant pictured here, has left a potentially very dangerous material in many businesses.

Biological sources of air pollution are also found indoors. These are produced from:

•Pet dander.
•Dust from tiny skin flakes and decomposed hair.
•Dust mites.
•Mold from walls, ceilings, and other structures.
•Air conditioning systems that can incubate certain bacteria and mold.
•Pollen, dust, and mold from houseplants, soil, and surrounding gardens.

Limiting Exposure

Can you avoid indoor air pollution? You can't go to school outside. But it is possible to reduce your exposure to air pollution. Some tips to decrease your exposure to indoor air pollution include:

•Using less toxic chemicals when possible.
•Limiting your exposure to pesticides and cleaning fluids by keeping them in a garage or shed.
•When using toxic chemicals, allowing fresh air to circulate through open windows and doors.
•Having detectors for radon and carbon monoxide in your home.

What else could you do to reduce your exposure to air pollution?

Summary

•Sources of indoor air pollution can include radon gas, carbon monoxide, and volatile organic compound (VOCs).
•Biological sources of air pollution include molds, pollen, and pet dander.

Explore More

Use the resource below to answer the questions that follow.

•**Indoor Air Quality Investigation** at http://www.youtube.com/watch?v=TAavBk2HISc (4:52)

Click on the image above for more content

1.How does the way most Americans spend their time make indoor air quality a pertinent health concern? What other countries do you think share this problem?
2.What are the four "Ps" in indoor air quality investigations? How does this information help solve problems with indoor air quality?
3.Give three examples of pollutant sources.

Review

1.What are three sources of indoor air pollution?
2.List two things you could do to minimize your exposure indoor air pollution.

Section 26

Health Hazards of Air Pollu-

Health Hazards of Air Pollution

- Describe the health hazards of indoor air pollution.
- Explain the relationship between ozone and smog.
- List ways to protect yourself from air pollution.

Why is this woman wearing a mask?

In many cities around the world, the air quality is so poor that people are often told to stay indoors when possible. When there is poor air quality in a city, some people choose to wear face masks when they have to be outdoors. Lowering exposure to air pollutants with a face mask is especially important for people with existing heart or lung conditions.

Health Hazards of Air Pollution

The World Health Organization (WHO) reports that 2.4 million people die each year from causes directly related to **air pollution** . This includes both outdoor and indoor air pollution. Worldwide, there are more deaths linked to air pollution each year than to car accidents. Research by the WHO also shows that the worst air quality is in countries with high poverty and population rates, such as Egypt, Sudan, Mongolia, and Indonesia.

Respiratory system disorders are directly related to air pollution. These disorders have severe effects on human health, some leading to death directly related to air pollution. Air pollution related respiratory disorders include asthma, bronchitis, and emphysema. **Asthma** is a respiratory disorder characterized by wheezing, coughing, and a feeling of constriction in the chest. **Bronchitis** is inflammation of the membrane lining of the bronchial tubes of the lungs. **Emphysema** is a deadly lung disease characterized by abnormal enlargement of air spaces in the lungs and destruction of the lung tissue. Additional lung and heart diseases are also related to air pollution, as are respiratory allergies.

Air pollution can also indirectly cause other health issues and even deaths. Air pollutants can cause an increase in cancer including lung cancer, eye problems, and other conditions. For example, using certain chemicals on farms, such as the insecticide DDT (dichlorodiphenyltrichloroethane) and toxic PCBs (polychlorinated biphenyl), can cause cancer. Indoors, pollutants such as radon or asbestos can also increase your cancer risk. Lastly, air pollution can lead to heart disease, including heart attack and stroke.

Air Pollution in Cities

Certain respiratory conditions can be made worse in people who live closer to or in large cites. Some studies have shown that people in urban areas suffer lower levels of lung function and more chronic bronchitis and emphysema. If you live in a city, you have seen **smog** . It is a low-hanging, fog-like cloud that seems to never leave the city (**Figure** below). Smog is caused by coal burning and by **ozone** produced by motor vehicle exhaust. Smog can cause eye irritation and respiratory problems.

Figure 12.47

A layer of smog is typical for Cairo, Egypt.

Protecting Yourself from Air Pollution

After reading about the effects of air pollution, both indoors and outdoors, you may wonder how you can avoid it. As for outdoor air pollution, if you hear in the news that the outdoor air quality is particularly bad, then it might make sense to wear a mask outdoors or to stay indoors. Because you have more control over your indoor air quality than the outdoor air quality, there are some simple steps you can take indoors to make sure the air quality is less polluted. These include:

1. Make sure that vents and chimneys are working properly, and never burn charcoal indoors.
2. Place carbon monoxide detectors in the home.
3. Keep your home as clean as possible from pet dander, dust, dust mites, and mold.
4. Make sure air conditioning systems are working properly.

Are there any other ways you can think of to protect yourself from air pollution?

Summary

- Air-pollution can directly cause deaths due to illnesses like asthma and emphysema or indirectly cause deaths by increasing your risk of cancer.
- There are steps you can take to decrease your exposure to indoor air pollution, such as having carbon monoxide detectors in your home and keeping your home as clean as possible from pet dander, dust, dust mites, and mold.

Explore More

Use the resource below to answer the questions that follow.

- **State of the Air - Health Effects of Air Pollution** at http://www.youtube.com/watch?v=sf3kOa3csys (5:24)

Click on the image above for more content

1. How has air quality improved in Southern California since the 1960s?
2. What health issues are associated with poor air quality?
3. Is the air quality that people currently experience in Southern California healthy?
4. What is believed to be the primary source of cancer caused from air pollution? Where does this substance come from?

Review

1.What are direct and indirect causes of air pollution related deaths?
2.What causes smog? What issues are associated with smog?
3.How can you protect yourself from indoor air pollution? Give two methods.

Section 27

Sources of Water Pollution

Sources of Water Pollution

- •Describe examples of water pollution.
- •Distinguish point source pollution from nonpoint source pollution.

Is the ocean a good dumping ground?

Unfortunately some people think so. A lot of garbage ends up washing ashore, and some garbage stays floating out in the ocean. Animals can be strangled by floating trash or mistake inedible trash for food. Not only is the pollution of our oceans a problem, but also our precious freshwater resources are often polluted.

Sources of Water Pollution

While to many people clean water may seem limitless and everywhere, to many others this is not so. **Water pollution** is a serious issue facing hundreds of millions of people world-wide, having harmful effects on the lives of those people. Water is not in unlimited supply and cannot just be made fresh when it is wanted. Water is actually a limited resource, and for many people, fresh, unpolluted water is hard to find. A **limited resource** is one that we use faster than we can remake it. It is a resource that can be used up.

Water pollution happens when contaminants enter water bodies. **Contaminants** are any substances that harm the health of the environment or humans. Most contaminants enter the water because of humans. Surface water (river or lake) can be exposed to and contaminated by acid rain, storm water runoff, pesticide runoff, and industrial waste. This water is cleaned somewhat by exposure to sunlight, aeration, and microorganisms in the water. **Groundwater** (private wells and some public water supplies) generally takes longer to become contaminated, but the natural cleaning process also may take much longer. Groundwater can be contaminated by disease-producing pathogens, careless disposal of hazardous household chemical-containing products, agricultural chemicals, and leaking underground storage tanks.

Figure 12.48

Water pollution can cause harmful effects to ecology and human health. Shown is the pollution in Jakarta, Indonesia.

Natural events, like storms, volcanic eruptions and earthquakes can cause major changes in water quality. But human-caused contaminants have a much greater impact on the quality of the water supply. Water is considered polluted either when it does not support a human use, like clean drinking water, or a use for other animals and plants. The overgrowth of algae, known as an **algal bloom** , can result from the runoff of fertilizer into bodies of water. This excess of nutrients allows the algae to grow beyond control, bring harm to the rest of the ecosystem.

The main sources of water pollution can be grouped into two categories:

- **Point source pollution** results from the contaminants that enter a waterway or water body through a single site. Examples of this include untreated sewage, wastewater from a sewage treatment plant, and leaking underground tanks.
- **Nonpoint source pollution** is contamination that does not come from a single point source. Instead, it happens when there is a buildup of small amounts of contaminants that collect from a large area. Examples of this include fertilizer runoff from many farms flowing into groundwater or streams.

Summary

- Water is a limited resource, but it is often polluted by humans.
- Sources of water pollution can be grouped as point source pollution (large amounts entering through a single site) or nonpoint source pollution (small amounts entering from many sites.)

Explore More

Use the resource below to answer the questions that follow.

- **Water Pollution** at http://www.youtube.com/watch?v=ACgv19b-n5E (4:42)

Click on the image above for more content

1. How can human sewage throw ecosystems out of balance? What nutrient cycle(s) are involved?
2. How does agriculture run-off effect ecosystems? How does this change move through the food web? What can the result be?
3. How can drugs excreted by humans affect aquatic organisms? How does this affect the ecosystem?
4. What is heat pollution? What affect can this have on aquatic ecosystems? Explain your answer as fully as possible.

Review

1. Why is fresh water a limited resource?
2. What is water pollution?
3. What are two main sources of pollution of surface water?
4. What are two main sources of groundwater pollution?
5. What's the difference between a point source and nonpoint source of water pollution?

Section 28

Effects of Water Pollution

Effects of Water Pollution

•Describe the effects of water pollution on the environment.
•Define eutrophication and explain how this may lead to an algal bloom.
•Summarize the effects of an algal bloom.
•Explain ocean acidification and its effects.
•Summarize the effects of waterborne diseases.

Can water have too many nutrients?

Excess nutrients can cause algae to grow like crazy. Too much algae causes the green slime on the water that you see in this picture. These excess nutrients come from fertilizers that were carried by the runoff from farmland. This type of water pollution can have serious consequences for the other forms of life trying to survive here.

Effects of Water Pollution

Water pollutants can have an effect on both the ecology of ecosystems and on humans. As a result of water pollution, humans may not be able to use a waterway for recreation and fishing. Drinking water can also be affected if a toxin enters the groundwater.

Eutrophication

In a marine ecosystem, algae are the producers. Through photosynthesis, they provide glucose for the ecosystem. So, can too much algae be a bad thing? **Eutrophication** is an over-enrichment of chemical nutrients in a body of water. Usually these nutrients are the nitrogen and phosphorous found in fertilizers. Run-off from lawns or farms can wash fertilizers into rivers or coastal waters.

Plants are not the only things that grow more quickly with added fertilizers. Algae like the excess nutrients in fertilizers too. When there are high levels of nutrients in the water, algae populations will grow large very quickly. This leads to overgrowths of algae called **algal blooms** . However, these algae do not live very long. They die and begin to decompose. This process uses oxygen, removing the oxygen from the water. Without oxygen, fish and shellfish cannot live, and this results in the death of these organisms (**Figure** below).

Certain types of algal blooms can also create toxins. These toxins can enter shellfish. If humans eat these shellfish, then they can get very sick. These toxins cause neurological problems in humans.

Figure 12.49

Lake Valencia, Venezuela, showing green algal blooms. How did the algal bloom form? What will it do to the lake over time?

Ocean Acidification

Ocean acidification occurs when excess carbon dioxide in the atmosphere causes the oceans to become acidic. Burning fossil fuels has led to an increase in carbon dioxide in the atmosphere. This carbon dioxide is then absorbed by the oceans, which lowers the pH of the water. Ocean acidification can kill corals and shellfish. It may also cause marine organisms to reproduce less, which could harm other organisms in the food chain. As a result, there also may be fewer marine organisms for humans to consume.

Aquatic Debris

Aquatic debris is trash that gets into fresh- and saltwater waterways. It comes from shipping accidents, landfill erosion, or the direct dumping of trash. Debris can be very dangerous to aquatic wildlife. Some animals may swallow plastic bags, mistaking them for food. Other animals can be strangled by floating trash like plastic six-pack rings. Wildlife can easily get tangled in nets (**Figure** below).

Figure 12.50

Marine trash can harm different types of aquatic life. Pictured here is a marine turtle entangled in a net. How can you keep this from happening?

Waterborne Diseases

Unsafe water supplies have drastic effects on human health. **Waterborne diseases** are diseases due to microscopic **pathogens** in fresh water. These diseases can be caused by protozoa, viruses, bacteria, and intestinal parasites. In many parts of the world there are no water treatment plants. If sewage or animal manure gets into a river, then people downstream will get sick when they drink the water. According to the World Health Organization (WHO), diarrheal disease is responsible for the deaths of 1.8 million people every year. It was estimated that 88% of the cases of diarrheal disease are caused by unsafe water supplies.

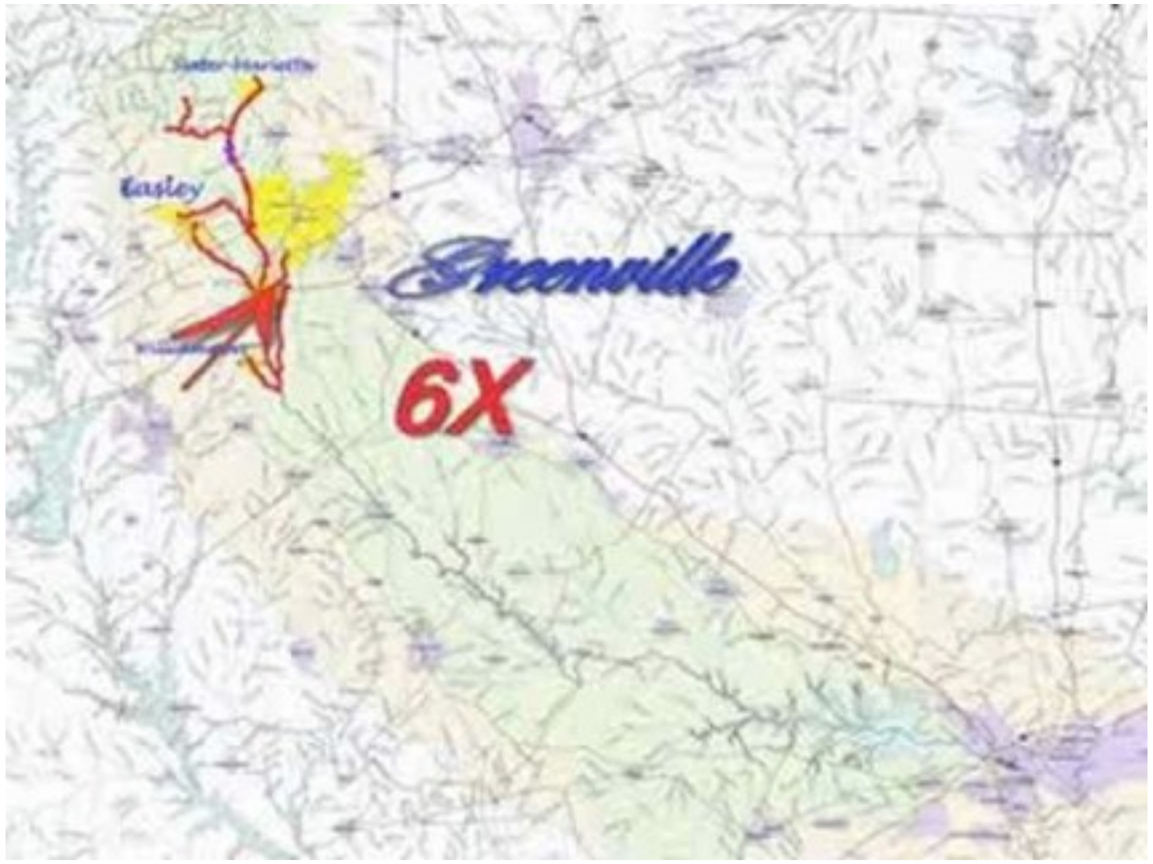
Summary

- High levels of nutrients, called eutrophication, can cause conditions that deprive fish of oxygen.
- Ocean acidification occurs when excess carbon dioxide in the atmosphere causes the oceans to become acidic, which harms corals and shellfish.
- Debris can be dangerous to aquatic wildlife.

Explore More

Use the resource below to answer the questions that follow.

- **Water Pollution and the Public Health Risk Engulfing Greenville, NC, USA** at http://www.youtube.com/watch?v=0PgQi0w1m3s (10:01)



Click on the image above for more content

1. What are some of the problems causing poor water quality around Greenville, North Carolina?
2. Can you gauge the health of a river by just looking at it? Why or why not?
3. What pollutants are causing issues in these rivers?
4. What can happen to a person who goes swimming in a bacteria-rich stream?

Review

1. What is eutrophication?
2. Explain what causes eutrophication and how it affects the ecosystem.
3. Explain what causes ocean acidification and how it affects the ecosystem.
4. What are waterborne diseases? What causes waterborne diseases?

Section 29

Preserving Water Sources

Preserving Water Sources

- Explain why water is a limited resource.
- Explain the Clean Water Act.
- Discuss how water pollution can be prevented.
- Summarize benefits of wastewater treatment.

Do we have an infinite supply of drinkable water?

No. In fact, in many parts of the world, finding clean drinkable water is difficult. This can lead to various serious health issues. Hundreds of millions of people world-wide are thought to live in areas where obtaining safe water is difficult. This makes preserving water resources an important global issue.

Preserving Water Sources

It might seem like there is plenty of water on Earth, but that's not really the case. Water is a **limited resource.** That means that it is used faster than it is replaced. Theoretically, at some point in time, the supply of fresh water could run out. Though this is unlikely, it is possible. But it is a significant issue in parts of the world with large populations. As these populations continue to grow, the supply of water becomes an increasingly important issue.

Even though we have lots of water in our oceans, we cannot use that water whenever we want. It takes special equipment, such as a desalination plant, and a lot of energy (and money) to convert salt water into fresh water. Of all the water on Earth, only about 1% can be used for drinking water. Almost all of the rest of the water is either salt water in the ocean or ice in glaciers and ice caps. As a result, there are water shortages many places in the world. Since we have such a limited supply of water, it is important to preserve our water supplies. Therefore, steps have been taken to prevent water pollution. Technologies have also been developed to conserve water and prevent **water pollution** .

Sub-Saharan African countries have the most vulnerable water supplies. Some scientists believe of a potential future crisis in both Asia and Africa from pollution and depletion of natural water resources. Many countries in the Middle East are at an extreme risk of water shortages. Diminished water supplies could increase the risk of both internal conflicts or wars between countries.

Preventing Water Pollution

In the U.S., concern over water pollution has resulted in many federal laws. Some of these laws go all the way back to the 1800s! The laws prohibit the disposal of any waste into the nation's rivers, lakes, streams, and other bodies of water, unless a person first has a permit. Growing concern for controlling water pollutants led to the enactment of the Clean Water Act in 1972. The **Clean Water Act** set water quality standards. It also limits the pollution that can enter the waterways. Other countries are also actively preventing water pollution and purifying water (**Figure** below).

Figure 12.51

A water purification station in France. Contaminants are removed to make clean water.

Wastewater Treatment

Fresh water is also preserved by purifying wastewater. **Wastewater** is water that has been used for washing, flushing, or manufacturing. It includes the water that goes down your shower drain and that is flushed down your toilet. Instead of dumping wastewater directly into rivers, wastewater can be purified at a water treatment plant (**Figure** below). When wastewater is recycled, **waterborne diseases** caused by **pathogens** in sewage can be prevented. What are some ways you can save water in your own house?

Figure 12.52

Sewage treatment plant.

Summary

- The United States, as well as other countries, have passed laws to preserve water quality and prevent water pollution.
- In the U.S., we also preserve our freshwater sources by purifying our wastewater.

Explore More

Use the resource below to answer the questions that follow.

- **What's In Our Water** from USGS http://gallery.usgs.gov/videos/524#.UKWpdod9KSo (7:15)

Click on the image above for more content

1. What kind of material can be found in our water?
2. What kinds of problems can algae cause to our water resources? How is algae good?
3. What is turbidity?
4. How is the pH of the Clackamas River related to river flow?

Review

1. Of all the water on Earth, how much can be uses as drinking water?

2.How has the United States government tried to preserve water sources?
3.Why is wastewater treatment important?

Section 30

Renewable Resources and

Renewable Resources and Alternative Energy Sources

- •Distinguish renewable resources from nonrenewable resources.
- •Give examples of sustainable resources.
- •Describe renewable resources.
- •Describe and give examples of alternative energy sources.

Can we use up all of our sunlight?

No, we have a limitless supply of sunlight. That makes it a renewable resource. Products derived from fossil fuels, like the gasoline we use to drive our cars, are not renewable resources. We will eventually run out of fossil fuels.

Renewable Resources and Alternative Energy Sources

A resource is *renewable* if it is remade by natural processes at the same rate that humans use it up. Sunlight and wind are **renewable resources** because they will not be used up (**Figure** below). The rising and falling of ocean tides is another example of a resource in unlimited supply. A **sustainable resource** is a resource that is used in a way that meets the needs of the present without keeping future generations from meeting their needs. People can sustainably harvest wood, cork, and bamboo. Farmers can also grow crops sustainably by not planting the same crop in their soil year after year. Planting the same crop each year can remove nutrients from the soil. This means that wood, cork, bamboo, and crops can be sustainable resources.

Figure 12.53

Wind power, a renewable resource, shown here in a modern wind energy farm.

Alternative Energy Sources

A **nonrenewable resource** is one that cannot be replaced as easily as it is consumed. Fossil fuels are an example of nonrenewable resources. They take millions of years to form naturally, and so they cannot be replaced as fast as they are consumed. To take the place of fossil fuel use, alternative energy resources are being developed. These alternative energy sources often utilize renewable resources. The following are examples of sustainable alternative energy resources:

•**Solar power** , which uses solar cells to turn sunlight into electricity (**Figure** below). The electricity can be used to power anything that uses normal coal-generated electricity.

Figure 12.54

These solar panels convert sunlight into electricity.

•**Wind power** , which uses windmills to transform wind energy into electricity. It is used for less than 1% of the world's energy needs. But wind energy is growing fast. Every year, 30% more wind energy is used to create electricity.
•**Hydropower** (**Figure** below), which uses the energy of moving water to turn turbines (similar to windmills)

or water wheels, that create electricity. This form of energy produces no waste or pollution. It is a renewable resource.

Figure 12.55

Hydropower plant.

•**Geothermal power** , which uses the natural flow of heat from the Earth's core to produce steam. This steam is used to turn turbines which create electricity.
•**Biomass** is the mass of biological organisms. It is usually used to describe the amount of organic matter in a trophic level of an ecosystem. **Biomass production** involves using organic matter ("biomass") from plants to create electricity. Using corn to make ethanol fuel is an example of biomass generated energy. Biomass is generally renewable.

•Tides in the ocean can also turn a turbine to create electricity. This energy can then be stored until needed (**Figure** below).

Figure 12.56

Dam of the tidal power plant in the Rance River, Bretagne, France

Turning Trash Into Treasure

Scientists at the Massachusetts of Technology are turning trash into coal, which can readily be used to heat homes and cook food in developing countries. This coal burns cleaner than that from fossil fuels. It also save a tremendous amount of energy. See http://youtu.be/GzhFgEYiVyY?list=PLzMhsCgGKd1hoofiKuifwy6qRXZs7NG6a for more information.

Click on the image above for more content

Summary

- Renewable resources can be replaced by natural processes as quickly as they are used.
- Alternative energy sources include wind power, solar power, hydropower, and geothermal power.

Explore More

Use the resource below to answer the questions that follow.

- **20% Renewable Energy by 2020** at http://www.youtube.com/watch?v=1cysaOnlv_E (3:54)

Click on the image above for more content

1. How much of the energy needs of the European Union in 2005 was supplied from renewable resources?
2. What energy producing techniques can be used to produce electricity? What techniques can be used to produce heat?
3. Why is biomass based energy known as the "Sleeping Giant"?

Review

1. What is a renewable resource? Give two examples.
2. What does sustainable mean?
3. What are three ways that renewable resources can be used to generate energy?

Section 31

Nonrenewable Resources

Nonrenewable Resources

•Describe and give examples of nonrenewable resources.
•Explain why nuclear power is a nonrenewable resource.

Could we all run out of gasoline?

Yes, we will use up all our gasoline eventually. Gasoline is derived from oil. Oil deposits were formed over hundreds of millions of years. They cannot be quickly replenished. Oil is an example of a nonrenewable resource.

Nonrenewable Resources

A **nonrenewable resource** is a natural resource that is consumed or used up faster than it can be made by nature. Two main types of nonrenewable resources are fossil fuels and nuclear power. **Fossil fuels** , such as petroleum, coal, and natural gas, formed from plant and animal remains over periods from 50 to 350 million years ago. They took millions of years to form. Humans have been consuming fossil fuels for less than 200 years, yet remaining reserves of oil can supply our needs only until around the year 2055. Natural gas can only supply us until around 2085. Coal will last longer, until around the year 2250. That is why it is so important to develop alternate forms of energy, especially for our cars. Today, electric cars are becoming more and more common. What would happen if we ran out of gasoline? Alternative use of energy, especially in transportation, must become a standard feature of all cars and trucks and planes by the middle of the century.

Nuclear power is the use of nuclear energy (**nuclear fission**) to create energy inside of a nuclear reactor (**Figure** below). Nuclear power is developed from atoms in certain elements, such as uranium. Currently, there are limited uranium fuel supplies, which will last to about the year 2100 (or longer) at current rates of use. However, new technologies could make some uranium fuel reserves more useful.

Figure 12.57

Aerial photo of the Bruce Nuclear Generating Station near Kincardine, Ontario.

Population growth, especially in developing countries, should make people think about how fast they are consuming resources. Governments around the world should seriously consider these issues. Developing nations will also increase demands on natural resources as they build more factories (**Figure** below). Improvements in technology, conservation of resources, and controls in population growth could all help to decrease the demand on natural resources.

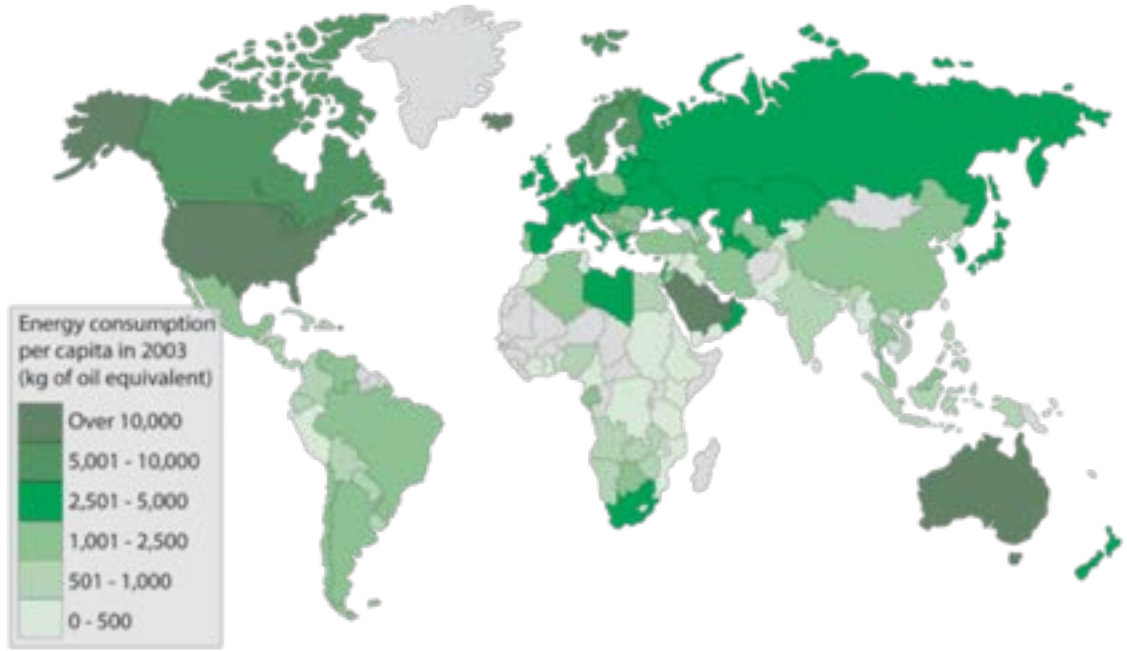


Figure 12.58

Per capita energy consumption (2003) shows the unequal distribution of wealth, technology, and energy use.

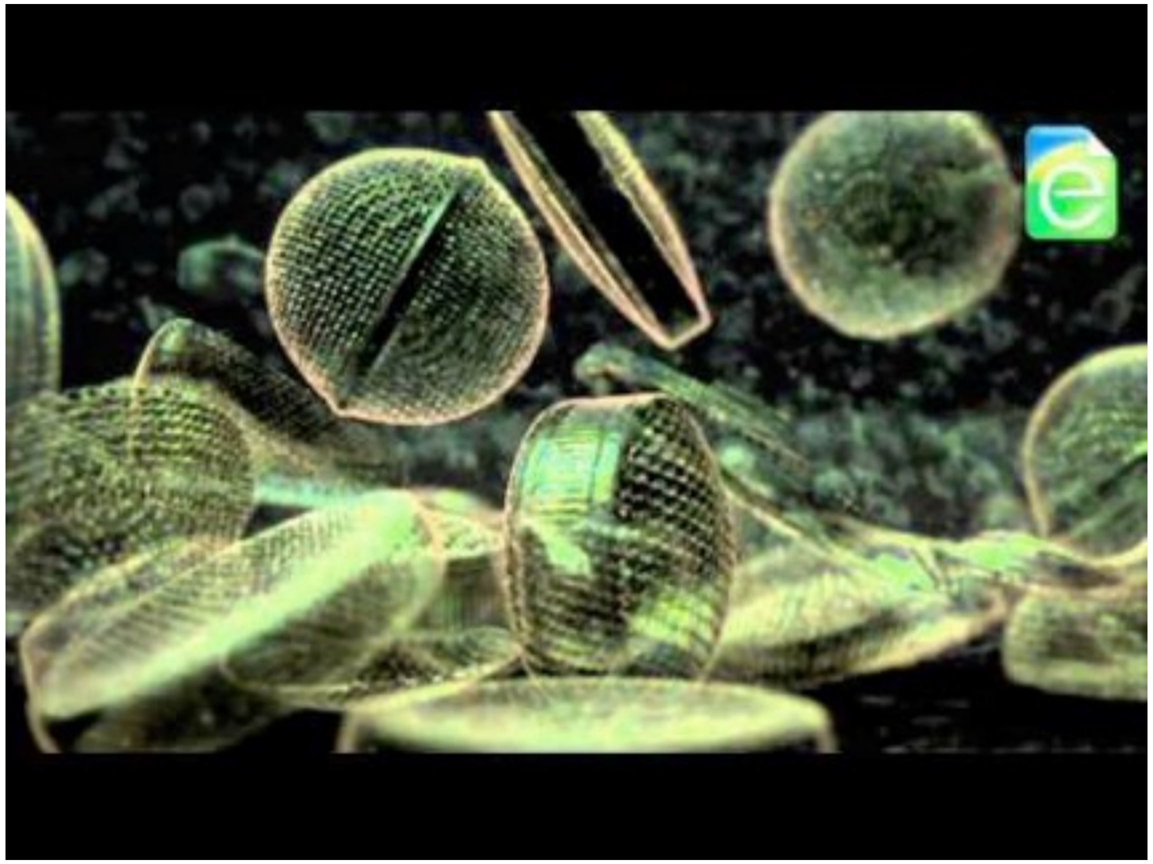
Summary

- Nonrenewable resources are being used up faster than they can be made by nature.
- Nonrenewable resources include fossil fuels and nuclear power.

Explore More

Use the resource below to answer the questions that follow.

- **Formation of Fossil Fuels** at http://www.youtube.com/watch?v=_8VqWKZIPrM (2:26)



Click on the image above for more content

1. How does the formation of coal differ from the formation of oil? How are these processes the same?
2. Why are researchers looking for ways to speed up the production of fuel from plant matter?
3. Where does natural gas come from?
4. When you burn fossils fuels, they release $C0_2$ into the atmosphere. Based on how long it takes fossil fuels to form, when was the last time that the carbon molecule in the $C0_2$ was in the atmosphere? How does this situation differ from someone cutting down a ten-year-old tree and burning it in his/her fireplace? What are the consequences for the atmosphere.

Review

1. What is a nonrenewable resource? What are two main types?
2. When did fossil fuels form?
3. Why is nuclear power considered a nonrenewable resource?

Section 32

Reduce, Reuse, and Recy-

Reduce, Reuse, and Recycle

•Discuss how reducing, reusing, and recycling can help conserve resources.
•Give examples of reducing the use of resources.
•Give examples of of reusing resources.
•Give examples of things that are commonly recycled.

How can you help conserve our natural resources?

Reduce, reuse, and recycle. There are steps that you personally can take to conserve our natural resources and reduce waste. The waste that an individual creates is small in proportion to all the waste produced by society. Yet all small contributions, when added up, make a difference.

Reduce, Reuse, and Recycle

Why conserve resources? During your lifetime, it is possible that the world may run out of some **nonrenewable**

resources , especially as the population passes 8 then 9 billion people. So it is necessary to try to make these resources last as long as possible. You may have heard people say, "Reduce, Reuse, Recycle." You may know that this is the slogan of the campaign to conserve resources. But what do each one of those words truly mean?

Reduce

What exactly does it mean to **reduce** ? Reducing means decreasing the amount of waste we create. That could also mean cutting down on use of natural resources. Minimizing of waste may be difficult to achieve for individuals and households, but here are some starting points that you can include in your daily routine to reduce the use of resources:

- •Turn lights off when not using them.
- •Turn the television off when no one is watching.
- •Replace burned out bulbs with ones that are more energy-efficient (**Figure** below).
- •Reduce water use by turning off faucets when not using water.
- •Use low-flow shower heads, which save on water and use less energy.
- •Use low-flush and composting toilets.
- •Put kitchen and garden waste into a compost pile.
- •In the summer, change filters on your air conditioner and use as little air conditioning as possible. The use of air conditioning uses a lot of energy.
- •In winter, make sure your furnace is working properly and make sure there is enough insulation on windows and doors.
- •Mend broken or worn items instead of buying new ones.
- •When you go shopping for items, buy quantities you know you will use without waste.
- •Walk or bicycle instead of using an automobile, in order to save on fuel usage and costs, and to cut down on pollution.
- •When buying a new vehicle, check into hybrid, semi-hybrid, or electric models to cut down on gas usage and air pollution.

Figure 12.59

These fluorescent light bulbs are much more energy efficient than standard light bulbs.

Reuse

Let's now look at what we can **reuse** . Reusing includes using the same item again for the same function and also using an item again for a new function. Reuse can have both economic and environmental benefits. New packaging regulations are helping society to move towards these goals. Some ways of reusing resources include:

- Use reusable bags when shopping.
- Use gray water. Water that has been used for laundry, for example, can be used to water the garden or flush toilets.
- At the town level, purified sewage water can be used for fountains, watering public parks or golf courses, fire fighting, and irrigating crops.
- Rain can be caught in rain barrels and used to water your garden.

What are some other ways to reuse resources?

Recycle

Now we move on to **recycle.** Sometimes it may be difficult to understand the differences between reusing and recycling. Recycling involves processing used materials in order to make them suitable for other uses. That usually means taking a used item, breaking it down, and reusing the pieces. Even though recycling requires extra energy, it does often make use of items which are broken, worn out, or cannot be reused.

The things that are commonly recycled include:

- Batteries.
- Biodegradable waste.
- Electronics.
- Iron and steel.
- Aluminum (**Figure** below).
- Glass.
- Paper.
- Plastic.
- Textiles, such as clothing.
- Timber.
- Tires.

Figure 12.60

These aluminum cans are packed together in a recycling plant to be reused.

Each type of recyclable requires a different recycling technique. Here are some things you can do to recycle in your home, school, or community:

- If you have recycling in your community, make sure you separate aluminum, plastics, glass, and paper products.
- See if your school recycles. If not, you and some friends could start a recycling club, or organize efforts to better recycling goals.

Laws can also be created to make sure people and companies reduce, reuse, and recycle. Individuals can vote for leaders who stand for sustainable ecological practices. They can also tell their leaders to make wise use of **natural resources** . You can also influence companies. If you and your family only buy from companies and restaurants that support recycling or eco-friendly packaging, then other companies will also change to be more environmentally friendly.

Summary

- Reducing waste, as well as reusing and recycling resources, can help save natural resources
- Consumers can influence companies to become more environmentally friendly.

Explore More

Use the resource below to answer the questions that follow.

- **In Cairo Slum, the Poor Spark Environmental Change** at http://www.npr.org/templates/story/story.php?storyId=89956754

1. What are the Zabaleen?
2. Why are solar water heaters beneficial?

See **Cairo puts its faith in ragpickers to manage the city's waste problem** at http://www.theguardian.com/world/2013/nov/19/cairo-ragpickers-zabaleen-egypt-recycling for additional information on the Zabaleen.

Review

1. What are four examples of recyclable materials?
2. What are two ways you can reduce the amount of waste you create?
3. What are two ways of reusing materials?

Section 33

Habitat Destruction

Habitat Destruction

•Define habitat destruction.
•Give examples of habitat destruction.
•Discuss what causes the destruction of habitats.
•Explain the effects of slash-and-burn agriculture.
•Give examples of invasive species.
•Describe the effects of non-native species.

What's happening to this land?

This picture, taken in southern Mexico, shows land being cleared for agriculture. The forest has been cut down and burned to make room for a a farm. In the process, homes to many plants and animals were destroyed. This is an example of habitat destruction.

Habitat Destruction

From a human point of view, a habitat is where you live, go to school, and go to have fun. Your habitat can be altered, and you can easily adapt. Most people live in a few different places and go to a number of different schools throughout their life. But a plant or animal may not be able to adapt to a changed habitat. A **habitat** is the natural home or environment of an organism. Humans often destroy the habitats of other organisms. Habitat destruction can cause the extinction of species. **Extinction** is the complete disappearance of a species. Once a species is extinct, it can never recover. Some ways humans cause habitat destruction are by clearing land and by introducing non-native species of plants and animals.

Land Loss

Clearing land for agriculture and development is a major cause of habitat destruction. Within the past 100 years, the amount of total land used for agriculture has almost doubled. Land used for grazing cattle has more than doubled. Agriculture alone has cost the United States half of its wetlands (**Figure** below) and almost all of its tallgrass prairies. Native prairie ecosystems, with their thick fertile soils, deep-rooted grasses, diversity of colorful flowers, burrowing prairie dogs, and herds of bison and other animals, have virtually disappeared (**Figure** below).

Figure 12.61

Wetlands such as this one in Cape May, New Jersey, filter water and protect coastal lands from storms and floods.

Figure 12.62

The Flint Hills contain some of the largest remnants of tallgrass prairie habitat remaining in North America.

Figure 12.63

Herds of bison also made up part of the tallgrass prairie community.

Slash-and-Burn Agriculture

Other habitats that are being rapidly destroyed are forests, especially tropical rainforests. The largest cause of deforestation today is **slash-and-burn agriculture** (shown in the opening image). This means that when people want to turn a forest into a farm, they cut down all of the trees and then burn the remainder of the forest. This technique is used by over 200 million people in tropical forests throughout the world.

As a consequence of slash-and-burn agriculture, nutrients are quickly lost from the soil. This often results in people abandoning the land within a few years. Then the top soil erodes and desertification can follow. **Desertification** turns forest into a desert, where it is difficult for plants to grow. Half of the Earth's mature tropical forests are gone. At current rates of deforestation, all tropical forests will be gone by the year 2090.

Non-native Species

One of the main causes of extinction is introduction of exotic species into an environment. These exotic and new species can also be called **invasive species** or **non-native species** . These non-native species, being new to an area, may not have natural predators in the new habitat, which allows their populations to easily adapt and grow. Invasive species out-compete the native species for resources. Sometimes invasive species are so successful at living in a certain habitat that the native species go extinct (**Figure** below).

Recently, cargo ships have transported zebra mussels, spiny waterfleas, and ruffe (a freshwater fish) into the Great Lakes (**Figure** below). These invasive species are better at hunting for food. They have caused some of the native species to go extinct.

Invasive species can disrupt food chains, carry disease, prey on native species directly, and out-compete native species for limited resources, like food. All of these effects can lead to extinction of the native species.

Figure 12.64

An exotic species, the brown tree snake, hitchhiked on an aircraft to the Pacific Islands, causing the extinctions of many bird and mammal species which had evolved in the absence of predators.

Figure 12.65

These zebra mussels, an invasive species, live on most man-made and natural surfaces. Here they have infested the walls of the Arthur V. Ormond Lock on the Arkansas River. They have caused significant damage to American waterways, locks, and power plants.

Other Causes

Other causes of habitat destruction include poor fire management, overfishing, mining (**Figure** below), pollution, and storm damage. All of these can cause irreversible changes to a habitat and ecosystem.

Figure 12.66

Strip coal mining, pictured here, has destroyed the entire ecosystem.

Examples of Habitat Destruction

A habitat that is quickly being destroyed is the **wetland** . By the 1980s, over 80% of all wetlands in parts of the U.S. were destroyed. In Europe, many wetland species have gone extinct. For example, many **bogs** in Scotland have been lost because of human development.

Another example of species loss due to habitat destruction happened on Madagascar's central highland plateau. From

1970 to 2000, slash-and-burn agriculture destroyed about 10% of the country's total native plants. The area turned into a wasteland. Soil from erosion entered the waterways. Much of the river ecosystems of several large rivers were also destroyed. Several fish species are almost extinct. Also, some coral reef formations in the Indian Ocean are completely lost.

Summary

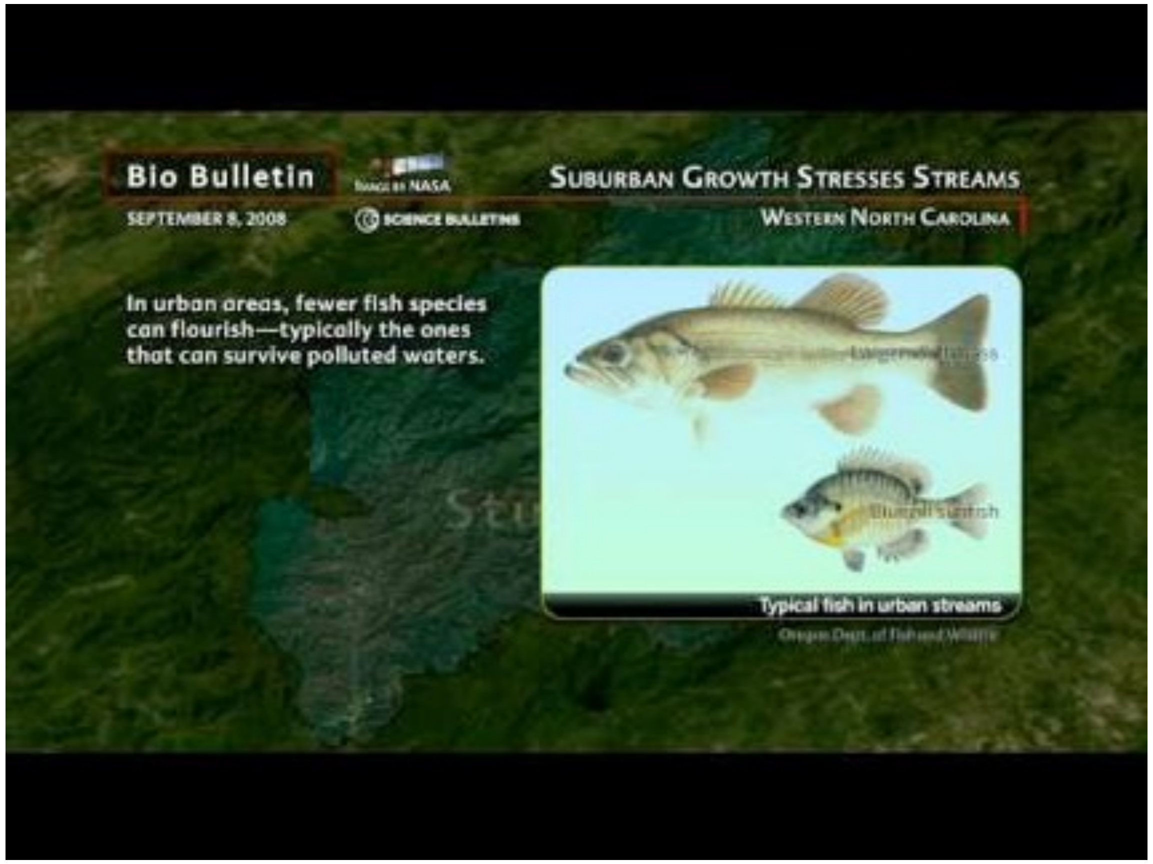
- There are many causes of habitat destruction, including clearing of land and introduction of invasive species.
- Slash-and-burn agriculture can lead to desertification, meaning the fertile top soil is lost.

Explore More

Use the resource below to answer the questions that follow.

Explore More I

- **Suburban Growth Stresses Streams** at http://www.youtube.com/watch?v=54k5vaWIRdA



Click on the image above for more content

1. How does the loss of trees along streams affect steam ecosystems?
2. Loss of trees has destabilized some stream banks. How are aquatic insects affected by this situation?
3. How have urban areas affected the diversity of fish in streams? What types of fish are being selected for?

Explore More II

- **The Ecology of Climate Change** at http://www.youtube.com/watch?v=isPGjChdby8 (8:07)

Click on the image above for more content

1. What types of trees dominate boreal forests?
2. How is climate change affecting the amount of fires occurring in Alaska? How is this affecting the ecosystem?
3. How do conifer forests differ from deciduous forest in their effect on carbon? How may this feed into climate change?
4. How may the thawing of permafrost affect the Global Carbon Cycle? How is the carbon in the permafrost similar to the carbon in fossil fuel?

Review

1. What is a habitat?
2. What are the primary ways that humans destroy habitats?
3. Why may invasive species thrive in a new area? Why is this an issue?
4. Describe slash-and-burn agriculture.

Section 34

Human Causes of Extinction

Human Causes of Extinction

- •Describe the effects of global warming on habitats.
- •Summarize associations between pollution and species extinction.
- •Discuss issues associated with human overpopulation.

Why are these polar bears threatened?

These polar bears are threatened because of global warming. They depend on the sea ice for their hunting grounds, and this ice is melting away. Plus bears have to make a longer and more hazardous journey to get to the remaining ice.

Other Causes of Extinction

In addition to habitat destruction, other human-caused problems are also threatening many species. These include issues associated with climate change, pollution, and over-population.

Global Warming

Another major cause of extinction is **global warming** , which is also known as global climate change. During the past century, the Earth's average temperature has risen by almost 1°C (about 1.3°F). You may not think that is significant, but to organisms that live in the wild and are constantly adapting to their environments, any **climate** change can be hazardous. Recall that burning **fossil fuels** releases gasses into the atmosphere that warm the Earth. Our increased use of fossil fuels, such as coal and oil, is changing the Earth's climate. Any long-term change in the climate can destroy the habitat of a species. Even a brief change in climate may be too stressful for an organism to survive. For example, if the seas increase in temperature, even briefly, it may be too warm for certain types of fish to reproduce.

Pollution

Pollution adds chemicals, noise, heat, or even light to an environment. This can have many different harmful effects on all kinds of organisms. For example, the pesticide DDT nearly eliminated the peregrine falcon in some parts of the world. This pesticide caused falcons to lay eggs with thinner shells. As a result, fewer falcon eggs survived to hatching. Populations of peregrine falcons declined rapidly. DDT was then banned in the U.S. and peregrine falcon populations have recovered.

Water pollution threatens vital freshwater and marine resources throughout the world (**Figure** below). Specifically, industrial and agricultural chemicals, waste, and **acid rain** threaten water. As water is essential for all ecosystems, water pollution can result in the extinction of species.

Figure 12.67

A bird that was the victim of an oil spill. About 58,000 gallons of oil spilled from a South Korea-bound container ship when it struck a tower supporting the San Francisco-Oakland Bay Bridge in dense fog in November, 2007.

Finally, soil contamination can also result in extinction. Soil contamination can come from toxic industrial and municipal wastes (**Figure** below), salts from irrigation, and pesticides from agriculture. These all degrade the soil as well. As soil is the foundation of terrestrial ecosystems, this can result in extinction.

Figure 12.68

Soil contamination caused by petrochemical products.

Human Overpopulation

Human populations are on the rise. The human population passed the 7 billion mark in October of 2011, and will pass 8 and 9 billion probably before the middle of the century. All these people will need resources such as places to live, food to eat, and water to drink, and they will use energy and create waste. Essentially, human population growth can effect all other causes of extinction. For example, more people on the Earth means more people contributing to global warming and pollution. More people also means more clearing of land for agriculture and development. Recall that development by humans often causes habitats to be destroyed. This destruction can force species to go extinct, or move somewhere else.

Summary

- Global climate change is a major cause of extinctions.
- Pollution of chemicals, noise, heat, or even light to an environment can be harmful to organisms.

Explore More

Use the resource below to answer the questions that follow.

- **Causes of Extinction** at http://www.eoearth.org/view/article/150962/

1. What is the primary cause of human-induced extinctions?
2. What is considered the greatest contributor to the extinction of many species?
3. What was the effect effect of the introduction of mammalian predators to New Zealand?

Review

1. Define global warming. Why is global warming an issue to organisms?
2. How could the high human population growth rate drive further extinctions of plants and animals?
3. Give an example of how pollution can threaten organisms.

Section 35

Importance of Biodiversity

Importance of Biodiversity

- •Define biodiversity.
- •Discuss the ecological and economic importance of biodiversity.
- •Define and discuss biomimicry (bionics).

Why is preserving the rainforest important?

Preserving the rainforest is important for many reasons. But one reason conservation efforts have focused here is that the rainforest is home to more species of insects, amphibians, and birds than anywhere else on the planet. This wide diversity of life is called biodiversity.

Importance of Biodiversity

Biodiversity is a measurement of the amount of variation of the species in a given area. More specifically, biodiversity can be defined as the variety of life and its processes, including the variety of living organisms, the genetic differences among them, and the communities and ecosystems in which they occur.

A place such as a coral reef has many different species of plants and animals. That means the coral reef is a ecosystem with high biodiversity (**Figure** below). Because of its biodiversity, the rainforest shown above is an ecosystem with extreme importance. Why is biodiversity so important? In addition to maintaining the health and stability of the ecosystem, the diversity of life provides us with many benefits.

Extinction is a threat to biodiversity. Does it matter if we are losing thousands of species each year? The answer is yes. It matters even if we consider not only the direct benefits to humans, but also the benefits to the ecosystems. The health and survival of ecosystems is related to that ecosystem's biodiversity.

Figure 12.69

Coral reefs are one of the biomes with the highest biodiversity on Earth.

Economic Importance

Economically, there are many direct benefits of biodiversity. As many as 40,000 species of fungi, plants, and animals provide us with many varied types of clothing, shelter, medicines and other products. These include poisons, timber, fibers, fragrances, papers, silks, dyes, adhesives, rubber, resins, skins, furs, and more. According to one survey, 57% of the most important prescription drugs come from nature. Specifically, they come from bacteria, fungi, plants, and animals (**Figure** below). But only a small amount of species with the ability to give us medicines have been explored. The loss of any species may mean the loss of new medicines, which will have a direct effect on human health.

Figure 12.70

Aspirin originally came from the bark of the white willow tree, pictured here.

Biodiversity and Technology

Nature has inspired many technologies in use today. **Bionics** , also known as biomimetics or biomimicry, uses organisms to inspire technology or engineering projects. By studying animals and their traits, we are able to gain valuable information that we can put to use to help us. For example, rattlesnake heat-sensing pits helped inspire the development of infrared sensors. Zimbabwe's Eastgate Centre (**Figure** below) was inspired by the air-conditioning efficiency of a termite mound (**Figure** below).

Figure 12.71

Design of the Eastgate Centre (brown building), in Zimbabwe, which requires just 10% of the energy needed for a conventional building of the same size, was inspired by a biological design.

Figure 12.72

The air-conditioning efficiency of this termite mound was the inspiration for the Eastgate Centre.

Ecological Importance

Biodiversity also has many benefits to ecosystems. High biodiversity makes ecosystems more stable. What can happen to an ecosystem if just one species goes extinct? What if that one species was a **producer** or **decomposer** ? Would the loss of a producer have an effect on all the organisms that relied on that producer? If a decomposer vanishes, are there other decomposers to fill the void? Maybe the resulting species will adapt. Other species may fill in the **niche** left by the extinct species. But the extinction of one species could have a "domino" effect, resulting in the extinction of other species. This could greatly effect the stability of the whole ecosystem.

One important role of biodiversity is that it helps keep the nutrients, such as nitrogen, in the soil. For example, a diversity of organisms in the soil allows **nitrogen fixation** and nutrient recycling to happen. Biodiversity also allows plants to be pollinated by different types of insects. And of course, different species of fungi are necessary to recycle wastes from dead plants and animals. These are just a few of the many examples of how biodiversity is important for ecosystems.

Summary

- Biodiversity is a measurement of the amount of variation of the species in a given area.
- Biodiversity is important because it directly benefits humans and ecosystems.

Explore More

Use the resource below to answer the questions that follow.

- **In Search of Wild Variety** from American Museum of Natural History http://www.youtube.com/watch?v=Pbg_pGZv3CQ (1:52)

Click on the image above for more content

1. As of November 2010, about how many species have been identified on the Earth? How close do

scientist feel this number is to the total number of species which exist?
2.In what kinds of locations are new species being found?
3.Can different species be identified by just looking at them? What techniques are scientists using to identify new species?

Review

1.What is biodiversity?
2.What does it mean if a place has high biodiversity?
3.What is an economic impact of biodiversity?
4.How does high biodiversity help the stability of an ecosystem?

Summary

Ecology is the study of ecosystems. An ecosystem consists of all the living and nonliving components of the habitat. Whereas nutrients and certain elements are recycled through ecosystems, energy moves in just one direction. Many interactions among species within an ecosystem are centered around the flow of energy. The formation of ecosystems, from new land to current habitats, is usually based on the pioneer species, and these species are able to live in an area due to the nonliving factors, such as the climate, the soil and the amount of rainfall, of that area. The populations within an ecosystem also determine the stability of the system. Recent tremendous increases in the human population have raised many important ecological issues.

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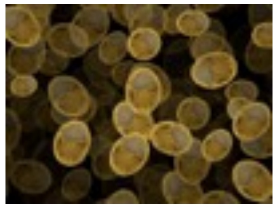

Type of Fungi	Examples
Molds	Penicillium

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