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# CK-12 Life Science
## Middle School

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# Contents

# CHAPTER 1 MS Studying the Life Sciences

## Chapter Outline



How many questions can you ask about the sun? Why does the sun shine? How does it move across the sky? How does it help plants grow? What would happen to life on Earth if the sun failed to rise tomorrow? You could ask all of these questions, and probably many more. When scientists observe the physical world, they ask questions like these and then try to answer them.

Before science, these types of questions were answered by beliefs and myths. For example, ancient Aztec societies believed the sun would not rise unless they performed human sacrifices. Science teaches us that we need evidence that can explain our observations. In this chapter, we will explore how science can help us ask and answer the questions we have about our physical world.

# 1.1 Scientific Ways of Thinking

## Lesson Objectives

- Describe the role of a scientist.
- Understand that science is a system based on evidence, testing, and reasoning.

## Vocabulary

- evidence
- experiment

## Modern Science

Modern science is:

1. A way of understanding the physical world, based on observable evidence, reasoning, and repeated testing.
2. A body of knowledge that is based on observable evidence, experimentation, reasoning, and repeated testing.

## Thinking Like a Scientist

How can you think like a scientist?

- **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 will ask, "What differs between the two environments where the chimpanzees live?" and "Are there differences in behavior between the two chimps that allow one group to survive over another?"
- **Scientists make detailed observations:** A person untrained in the sciences may observe, "The chimps on one side of the jungle are dying, while chimps on the other side of the jungle are healthy." Can you think of ways to make this observation more detailed? What about the number of chimps? Are they male of female? Young or old? A good scientist may observe, "While all seven females and three 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 have died." Detailed observations can ultimately help scientists to design their experiments and answer their questions. See a photo of chimpanzees in **Figure** 1.1.

FIGURE 1.1
An adult and child chimpanzee.

- **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 a hypothesis 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.

# 1.2 What Are the Life Sciences?

## Lesson Objectives

- Define Life Science.
- Describe how evidence is used to create and support scientific theories.

## Vocabulary

- cell theory
- life science
- scientific theory
- theory of evolution

## Fields in the Life Sciences

The **life sciences** are the study of living organisms, and how they interact with each other and their environment. Life sciences deal with every aspect of living organisms.

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. Look at **Table** 1.1, **Table** 1.2, and **Table** 1.3. If you want to study the nervous system, what life sciences field is right for you?

TABLE 1.1: **Subspecialties that focus on one type of organism**

| Subspecialty | Studies | Subspecialty | Studies |
|---|---|---|---|
| **Botany** | plants | **Zoology** | animals |
| **Marine biology** | organisms living in and around oceans, and seas | **Fresh water biology** | organisms living in and around freshwater lakes, streams, rivers, ponds, etc. |
| **Microbiology** | microorganisms | **Bacteriology** | bacteria |
| **Virology** | viruses ( see **Figure** 1.2) | **Entomology** | insects |
| **Taxonomy** | the classification of organisms | | |

**TABLE 1.2: Fields of life sciences that examine the structure, function, growth, development and/or evolution of living things**

| Life Science | What it Examines | Life Science | What it Examines |
|---|---|---|---|
| **Cell biology** | cells and their structures (see **Figure** 1.2) | **Anatomy** | the structures of animals |
| **Morphology** | the form and structure of living organisms | **Physiology** | the physical and chemical functions of tissues and organs |
| **Immunology** | the mechanisms inside organisms that protect them from disease and infection | **Neuroscience** | the nervous system |
| **Developmental biology and embryology** | the growth and development of plants and animals | **Genetics** | the genetic make up of all living organisms (heredity) |
| **Biochemistry** | the chemistry of living organisms | **Molecular biology** | biology at the molecular level |
| **Epidemiology** | how diseases arise and spread | | |

**TABLE 1.3: Fields of biology that examine the distribution and interactions between organisms and their environments**

| Life Science | What it Examines |
|---|---|
| **Ecology** | how various organisms interact with their environments |
| **Biogeography** | the distribution of living organisms (see **Figure** 1.3) |
| **Population biology** | the biodiversity, evolution, and environmental biology of populations of organisms |

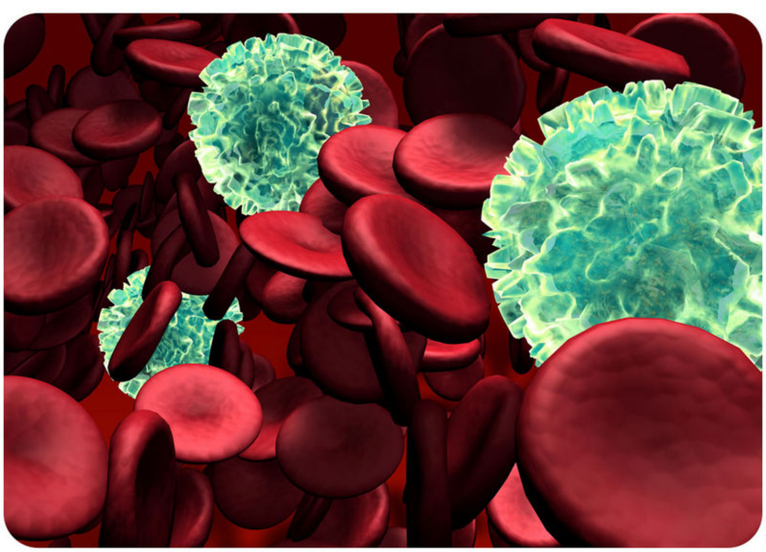


FIGURE 1.2
This illustration shows red blood cells and a virus. Virology is the study of viruses. Cell biology is the study of cells. Though virology can be considered a life science, are viruses in fact living?

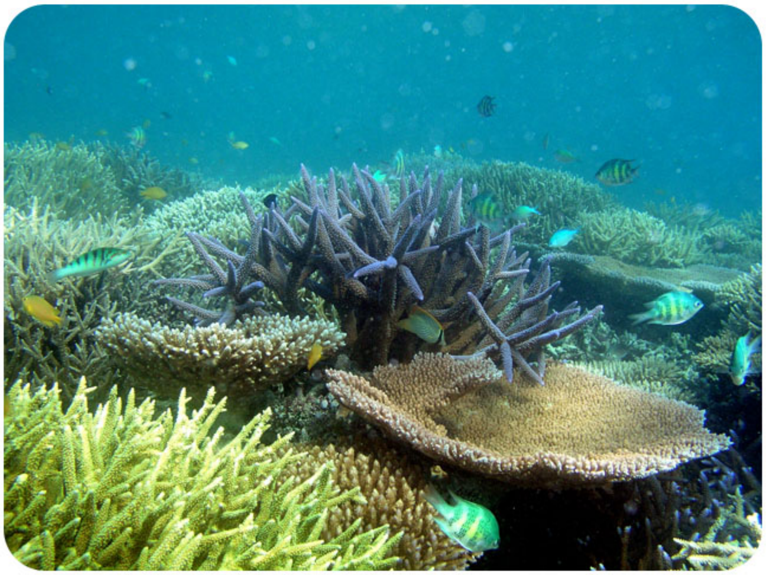


FIGURE 1.3
Biogeography looks at the variation of life forms within a given ecosystem, biome, or for the entire Earth. In other words, it tries to explain where organisms live and at what abundance.

## Scientific Evidence and Theories in the Life Sciences

Scientists perform experiments and collect evidence. Evidence is:

1. A direct, physical observation of a thing, a group of things, 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 theory of gravity ( **Figure** 1.4). A bear skeleton in the woods would be evidence of the presence of bears.

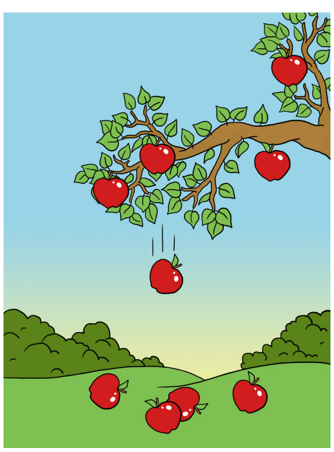


FIGURE 1.4
An apple falls from a tree to the ground, instead of floating in space. This is evidence for the theory of gravity.

**Scientific theories** are well established and tested explanations of observations or evidence. Scientific theories are produced through repeated experiments. Theories are usually tested and confirmed by many different people.

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.

The following are links to information about the nature of science:

- http://www.project2061.org/publications/bsl/online/index.php?chapter=1
- http://evolution.berkeley.edu/evosite/nature/index.shtml

## Two Important Life Science Theories

In the many life sciences, there are possibly hundreds or thousands of theories. The field of modern biology, however, really depends on two especially significant theories. They are:

1. **The Cell Theory**
2. **The Theory of Evolution.**

### The Cell Theory

The Cell Theory states that:

1. All organisms are composed of cells ( **Figure** 1.5).
2. Cells are the basic units of structure and function in an organism.
3. Cells only come from preexisting cells; life comes from life.

The development of the microscope in the mid 1600s made it possible for scientists to develop this theory ( **Figure** 1.6).

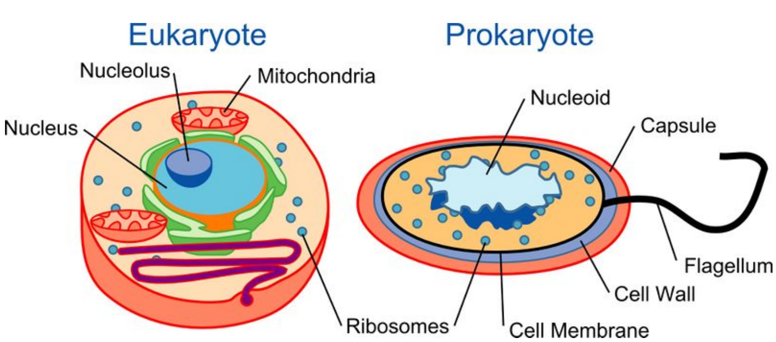



FIGURE 1.5
The two types of cells, eukaryotic (left) and prokaryotic (right).

### The Theory of Evolution

The Theory of Evolution explains how populations of organisms can change over time. It also explains why there are many different types of organisms on Earth. This theory is often called the "great unifier" of biology, because it applies to every field of biology. It also explains how all living organisms on Earth come from common ancestors ( **Figure** 1.7). You will learn more about the details of the theory of evolution in later chapters.

An introduction to evolution and natural selection can be viewed at http://www.youtube.com/watch?v=GcjgWov7mTM .

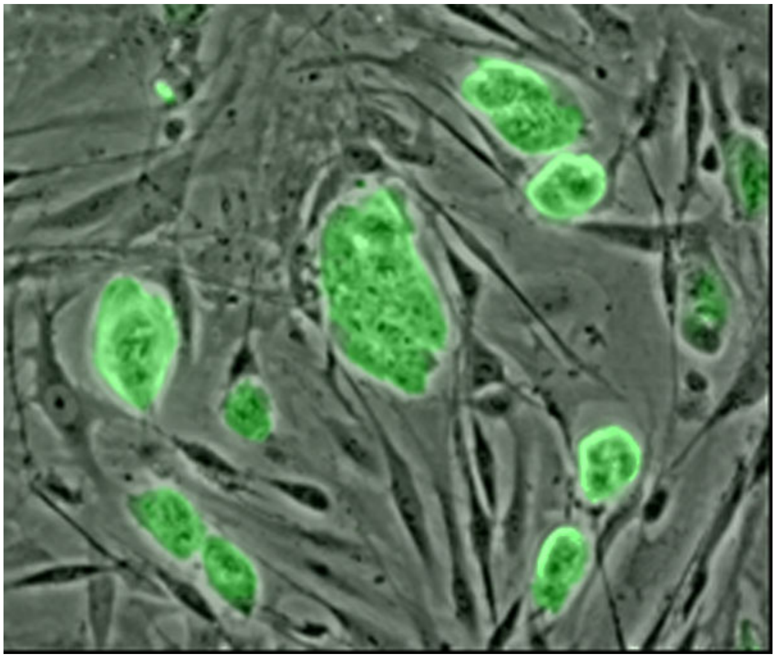
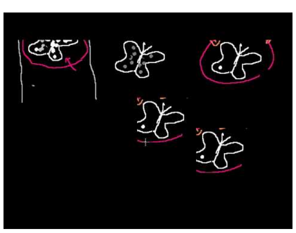


FIGURE 1.6
A mouse cell viewed through a microscope.

FIGURE 1.7
Evolution explains the millions of varieties of organisms on Earth.



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## Lesson Summary

- Science is a way of understanding about the physical world.
- Science is based on evidence, reasoning, and testing predictions.
- Information that has been thoroughly tested can still undergo further testing and revisions, as new evidence and questioning are raised.
- Science differs from other ways of knowing because it is entirely based on observable evidence.
- Scientific explanations are constantly questioned and tested.
- Science produces theories and general knowledge.
- Science allows us to better understand the world.
- Science allows us to apply this knowledge to solve problems.

## Review Questions

### Recall

1. What do all fields of life science have in common?
2. What are the three characteristics of evidence?
3. What is the goal of science?

### Apply Concepts

4. What would you study if you were a biogeographer?
5. Why do you think the development of microscopes led to the development of the Cell Theory?

### Think Critically

6. What do you think the difference is between a theory and a set of observations?
7. If all cells come from pre-existing cells, where do you think the first cells came from?

## Further Reading / Supplemental Links

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## Points to Consider

Next we discuss the scientific method.

- How does thinking like a scientist allow us to answer questions about life?
- What is the difference between science completed in a laboratory and science completed outside?

# 1.3 The Scientific Method

## Lesson Objectives

- Describe the scientific method as a process.
- Explain why the scientific method allows scientists and others to examine the physical world more objectively than other ways of knowing.
- Describe the steps involved in the scientific method.

## Vocabulary

- applied science
- basic science
- hypothesis
- scientific method

## The Scientific Method

The **scientific method** is a process used to investigate the unknown. 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. Why do you think it is important that scientists reproduce each other's experiments?

Almost all versions of the scientific method include the following steps, though not always in the same order:

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
7. Communicate your results

### Making Observations

Imagine that you are scientist. While collecting water samples at a local pond, you notice a frog with five legs instead of four ( **Figure** 1.8). 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.

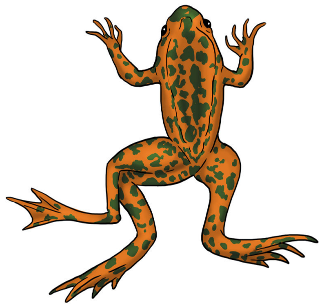

FIGURE 1.8
A frog with an extra leg.

### Identify a Question Based on Your Observations

The next step is to ask a question about the frogs ( **Figure** 1.9). You may ask, "Why are so many frogs are 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 1.9
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.

### Construct a Hypothesis

A **hypothesis** is an educated guess 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."

### Test Your Hypothesis

To test the hypothesis, 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. Here is an example of a hypothesis that is not testable: "The frogs are deformed because someone cast a magic spell on them." You cannot test a magic hypothesis or measure any results of magic. 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.

### 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. See **Table** 1.4 for the experimental results.

**TABLE 1.4: Deformed Frog Data**

| 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 tell whether your hypothesis is true or false. If a hypothesis is true, scientists will often continuing 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.

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 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.

## 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 cell or a whole ecosystem. Basic science is the source of most scientific theories and new knowledge. For example, a scientist that tries to find the right drug to treat brain injuries is performing basic science.

**Applied science** is using scientific discoveries to solve practical problems. Applied science also creates new technologies. For example, medicine and all that is known about how to treat patients is applied science based on basic research ( **Figure** 1.10). A doctor administering a drug or performing surgery on a patient is an example of applied science.

FIGURE 1.10

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

## Lesson Summary

- The scientific method is a process used to investigate questions.
- The scientific method uses observable evidence and testing.
- A hypothesis is a proposed explanation of an observation; it is used to test an idea.

- A hypothesis must be written in a way that can be tested, can be proved false, can be measured, and will help answer the original question.
- Basic research produces knowledge and theories.
- Applied research uses knowledge and theories from basic research to develop solutions to practical problems.

## Review Questions

### Recall

1. What does a hypothesis need to include?

2. What does "falsifiable" mean?

3. List the steps of the Scientific Method.

### Apply Concepts

4. How is a hypothesis different from a theory?

5. A doctor treats a patient with HIV with a new anti-viral drug. Is this an example of basic or applied science?

### Think Critically

6. What does a scientist do if their research contradicts previous theories or popular knowledge?

7. A field scientist studies mice and observes that mice in the desert have fewer offspring (children) than mice in the forest. She hypothesizes that mice in the desert have access to less water and therefore have fewer offspring to conserve the much-needed resource. Is this a testable hypothesis? Why or why not?

## Further Reading / Supplemental Links

- William Souder, A Plague of Frogs: The Horrifying True Story. Hyperion Press, 2000.

## Points to Consider

- How do you think scientific “tools” can help scientists?
- What do you think is one of the more common tools of the life scientist?

# 1.4 Tools of Science

## Lesson Objectives

- Describe the growing number of tools available to investigate different features of the physical world.
- Describe how microscopes have allowed humans to view increasingly small tissues and organisms that were never visible before.

## Vocabulary

- electron microscope
- microscope
- microscopy
- optical (light) microscope
- scanning acoustic microscope
- scanning electron microscope (SEM)
- transmission electron microscope (TEM)

## Using Microscopes

Microscopes, tools that you may get to use in your class, are some of the most important tools in biology ( **Figure** 1.11). 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?

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. That was the forerunner of the compound microscope and of the telescope. Later, the father of microscopy, Dutch scientist Antoine van Leeuwenhoek taught himself to make one of the first microscopes ( **Figure** 1.12). A **microscope** is a tool used to make things that are too small to be seen by the human eye look bigger. **Microscopy** is a technology for studying small objects using microscopes.

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. Inside of cork, he discovered the smallest building blocks of life, or **cells** ( **Figure** 1.13 and **Figure** 1.14). 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.

In one of his early experiments, van Leeuwenhoek took a sample of scum from his own teeth and used his microscope to discover bacteria, one of the tiniest living organisms on the planet. Using microscopes, van Leeuwenhoek also discovered one-celled organisms (protists) and sperm.

Some modern microscopes use light, as Hooke's and van Leeuwenhoek's did, but others may use electron beams or sound waves.

Researchers now use these types of microscopes:

FIGURE 1.11

Basic light microscopes opened up a new world to curious people. See if you can identify the following parts of the microscope: 1, ocular lens or eyepiece; 2, objective turret; 3, objective lenses; 4, coarse adjustment knob; 5, fine adjustment knob; 6, object holder or stage; 7, mirror or light (illuminator); 8, diaphragm and condenser.

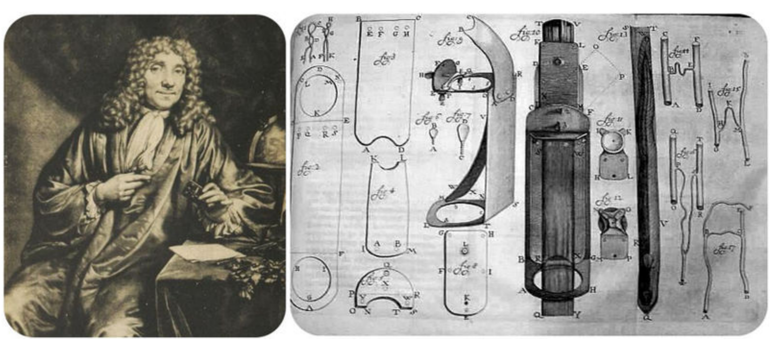

FIGURE 1.12

Antoine van Leeuwenhoek, a Dutch cloth merchant with a passion for microscopy (left), discovered bacteria in 1683 when he used a microscope (right) he built to look at the plaque on his own teeth.

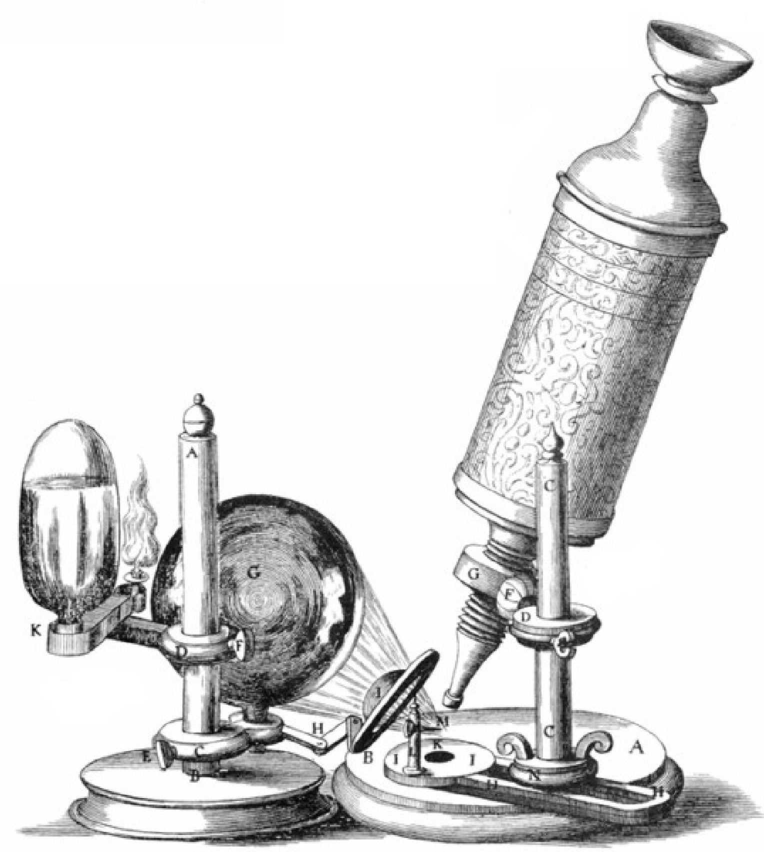


FIGURE 1.13
Robert Hooke's early microscope.

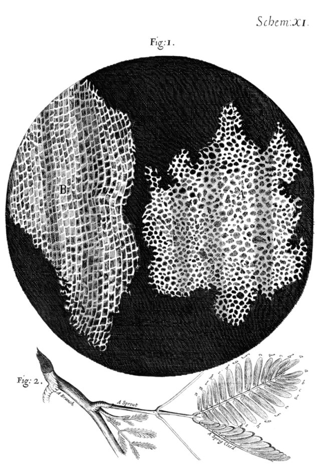


FIGURE 1.14
Cell structure of cork by Hooke.

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 refractive 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 ("high resolution").
3. **Scanning electron microscopes (SEM)** ( **Figure** 1.15 and **Figure** 1.16) 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 shapes of objects. Visit the following site to see incredible images of tiny organisms and objects using an electron scanning microscope: http://www.mos.org/sln/sem/sem.html

4. **Scanning acoustic microscopes** use sound waves to scan a specimen. These microscopes are useful in biology and medical research.

FIGURE 1.15
A scanning electron microscope.

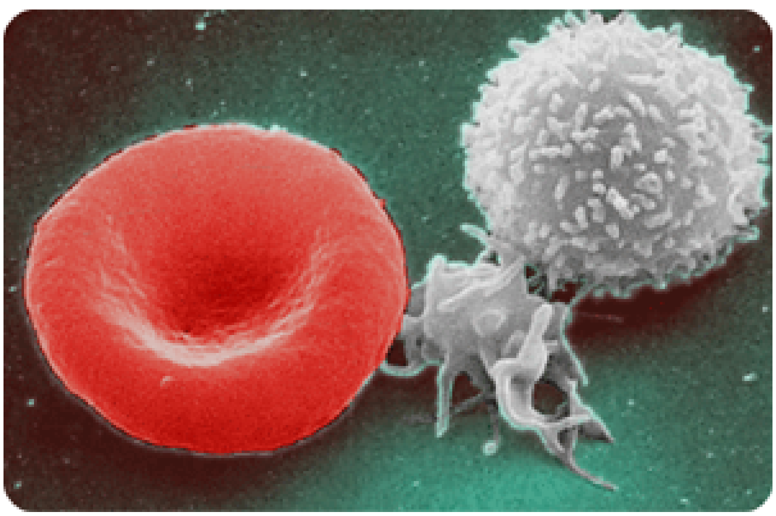

FIGURE 1.16
A scanning electron microscope image of blood cells.

## Other Life Science Tools

What other kinds of tools and instruments would you expect to find in a biologist's laboratory or field station? Other than computers and lab notebooks, biologists use very different instruments and tools for the wide range of life science specialties. For example, a medical research laboratory and a marine biology field station might not use any of the same tools.

Tools such as a radio telemetry devices, thermocyclers, and inoculation (sterile) hoods ( **Figure** 1.17) are all biological equipment.

FIGURE 1.17
(Left) A radio telemetry device used to track the movement of falcons in the wild. (Center) A thermocycler used for molecular biological and genetic studies. (Right) A sterile laboratory chamber. This laboratory inoculation hood allows researchers to conduct experiments in sterile environments.

## Using Maps and Other Models

People use models for many purposes. We use street maps to help us find our way around. A model of the solar system may show the relationship between the planets in space. Life scientists often use maps to show where different organisms live, or to learn about the climate of an area. Scientists use maps and models to explain observations and to make predictions. For example, if a scientist wants to study the effect of temperature on coral reefs, he or she would first consult a map of coral reef locations and then measure the temperature in those specific areas ( **Figure** 1.18).

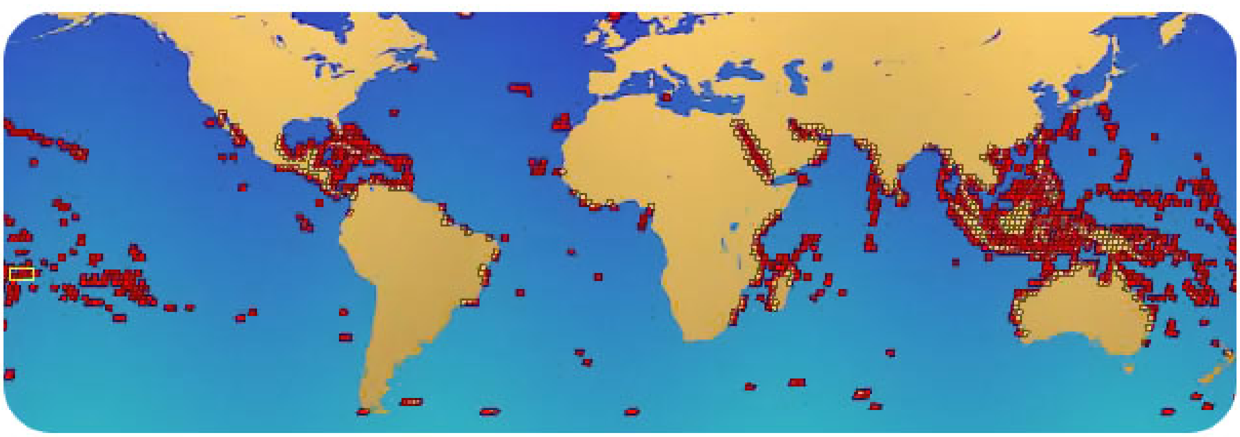

FIGURE 1.18
The above map shows where you can find coral reefs around the world. Coral reefs are shown in red.

Some models are used to show the relationship between different parts of an experiment, or variables. For example, the model in **Figure** 1.19 says that when there are few coyotes, there are many rabbits (left side of the graph) and when there are only a few rabbits, there are many coyotes (right side of the graph). You could make a prediction, based on this model, that removing all the coyotes from the ecosystem would result in an increase in rabbits. This is a good scientific prediction because it can be tested.

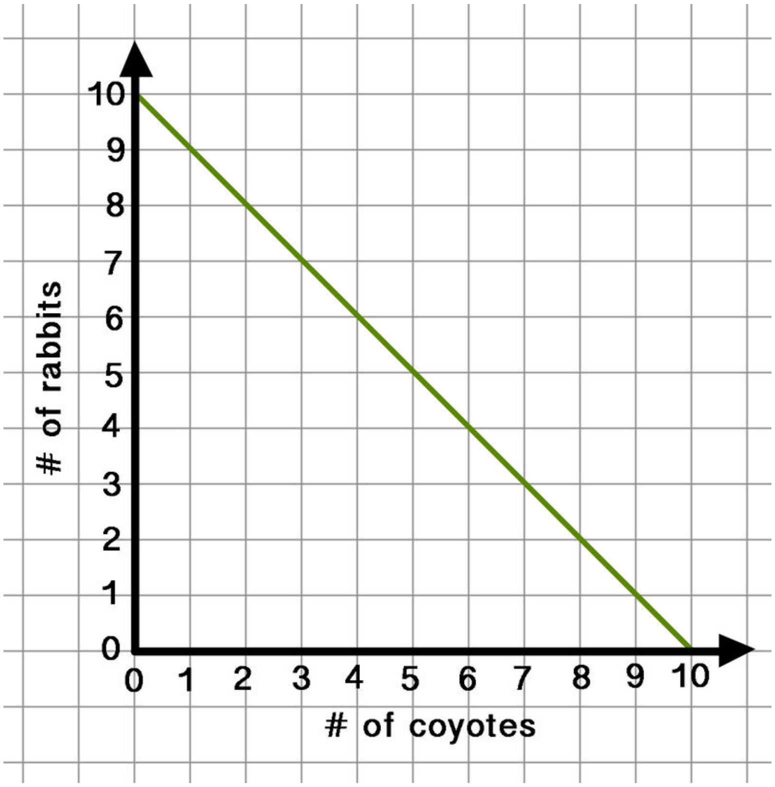


FIGURE 1.19
This graph shows a model of a relationship between a population of coyotes (the predators) and a population of rabbits, which the coyotes eat (the prey).

## Lesson Summary

- From the time that the first microscope was built, over four hundred years ago, microscopes have been used to make major discoveries.
- Life science is a vast field; different kinds of research usually require very different tools.
- Scientists use maps and models to understand how features of real events or processes work.

## Review Questions

### Recall

1. What did van Leeuwenhoek discover when he looked at scum from his own teeth under the microscope?

2. What does the symbol 10X on the side of a microscope mean?

3. What is a scientific model?

### Apply Concepts

4. Look at the predator/prey (coyote/rabbit) model in **Figure** 1.19. What does the model predict would happen to the rabbit population if you took away all of the coyotes?

### Think Critically

5. If you want to describe all of the places on the planet where ants can survive, how would you display this information?

6. What tool might you use to keep track of where a wolf travels?

## Points to Consider

- What hazards may biologists face in the laboratory?
- What could be risks may biologists face who complete research outside?
- What do you think biologists do to protect themselves?

# 1.5 Safety in Scientific Research

## Lesson Objectives

- Recognize how the kind of hazards that a scientist faces depends on the kind of research they do.
- Identify some potential risks associated with scientific research.
- Identify how safety regulations protect scientists and the environment.

## Vocabulary

- biohazard
- carcinogen
- field scientist
- teratogen

## Types of Safety Hazards

There are some very serious safety risks in scientific research. When studying a science like chemistry, scientists need to make sure that they do not mix two explosive chemicals together. Since the life sciences deal with living organisms, some research may have risks not found in other fields. Safety practices must be followed when working with the following hazardous things:

- Disease-causing viruses, bacteria or fungi
- Parasites
- Wild animals
- Radioactive materials
- Pollutants in air, water, or soil
- Toxins
- Teratogens
- Carcinogens
- Radiation

The kinds of risks that scientists face depend on the kind of research they perform. For example, a bacteriologist working with bacteria in a laboratory faces different risks than a zoologist studying the behavior of lions in Africa.

Think back to the deformed frogs discussed earlier. If there is something in the frogs' environment causing these deformities, could there be a risk to a researcher in that environment? A chemical in the pond that could cause such deformities is called a **teratogen**. If the chemical is causing deformities in frogs, could it cause deformities in humans? A scientist would most likely wear gloves and maybe even a mask when dealing with polluted water.

Or perhaps a disease is causing the deformities. Viruses and bacteria are called **biohazards**. **Figure** 1.20 shows laboratory safety and chemical hazard signs. Biohazards include any biological material that could make someone sick. A used needle or laboratory bacteria are also biohazards.


FIGURE 1.20
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, as shown in **Figure** 1.21.

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 doing labs:

- Be sure to obey all safety guidelines given in lab instructions and your teacher.
- Follow directions carefully.
- Tie back long hair.
- Wear closed 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 and the lab supervisor must know if any materials are damaged or discarded.

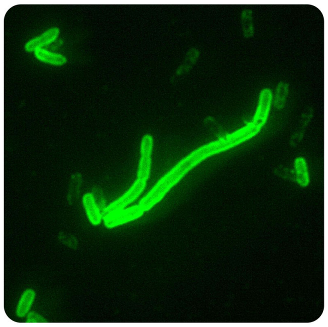

FIGURE 1.21
Scientists studying dangerous organisms such as *Yersinia pestis*, the cause of bubonic plague, use special equipment that helps keep the organism from escaping the lab.

## Field Research Safety

Scientists who work outdoors, called **field scientists**, are also required to follow safety regulations designed to prevent harm to themselves, other humans, to animals, and the environment. In fact, 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** 1.22) migrations between the United States and Mexico must follow regulations in both countries.

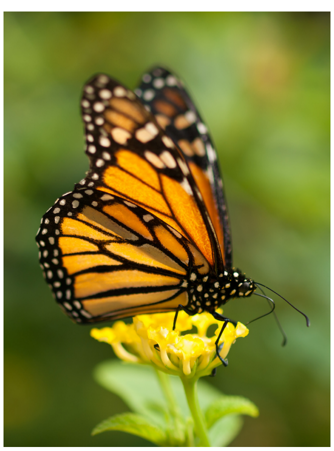

FIGURE 1.22
A Monarch butterfly.

Field scientists are also required to follow laws to protect the environment. Before biologists can study protected wildlife or plant species, they must apply for permission to do so, and obtain a research permit. For example, if scientists collect butterflies without a permit, they may unknowingly disturb the balance of the organism's habitat.

## Lesson Summary

- Research of any kind may have safety risks. Because life scientists study organisms as diverse as bacteria and bears, they deal with risks that other scientists may never encounter.
- The risks scientists face depend on the kind of research they are doing.
- Scientists are required by federal, state, and local institutions to follow strict regulations designed to protect the safety of themselves, the public, and the environment.

## Review Questions

### Recall

1. What kinds of hazards might be found in biology laboratories, but not physics laboratories?

2. Who has more freedom to do whatever research they want? Laboratory scientists or field biologists?

3. What is a biohazard?

4. What is a research permit?

### Apply Concepts

5. What are some of the precautions you might take if you were collecting frogs in water you think might be polluted?

6. Name some possible hazards to field biologists.

### Think Critically

7. You want to complete field research on the border between the United States and Mexico. Before you begin, what precautions should you take?

## Further Reading / Supplemental Links

- Biosafety in Microbiological and Biomedical Laboratories (National Research Council, 1999).
- Chemical Classification Signs: http://www.howe.k12.ok.us/~jimaskew/nfpa.htm
- NFPA Chemical Hazard Labels: http://www.atsdr.cdc.gov/NFPA/nfpa_label.html
- Where to Find MSDS's on the Internet: http://www.ilpi.com/msds/index.html
- MSDS Power Point: http://www.tenet.edu/teks/science/safety/pdf/hazcom/msds.ppt http://www.research.northwestern.edu/ors/biosafe/index.htm

## Points to Consider

- What do you think makes something "alive?"
- What does a blade of grass, a fly, and a human have in common?

# 1.6 References


1. Neil McIntosh. An adult and child chimp . CC BY 2.0
2. Image copyright Jiri Flogel, 2014. http://www.shutterstock.com . Used under license from Shutterstock.com
3. Courtesy of the U.S. Forest Service. http://www.fs.fed.us/rm/boise/rmrs_sai/sai_subjects/geography.shtml . Public Domain
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6. National Science Foundation. http://commons.wikimedia.org/wiki/File:Mouse_embryonic_stem_cells.jpg . Public Domain
7. Butterfly: Flickr:whologwhy; Owl: Marie Hale; Monkey: Julie Langford; Tiger: Keith Roper; Frog: Anthony Masi; Snail: Brooke Anderson; Spider: John Fowler; Seal: Northwest Power and Conservation Council; Raccoon: Neil McIntosh; Fish: Taras Kalapun. Evolution explains the millions of varieties of organisms on Earth . CC BY 2.0
8. Laura Guerin. A frog with an extra leg. . CC BY-NC 3.0
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# CHAPTER 2 MS What is a Living Organism?

## Chapter Outline



How do we tell the difference between a living thing and a non-living thing? Think about your own body. How do you know that you are alive? Your heart beats. You breathe in air. Do all living things need to do be like you in order to be "alive"?

The above image represents bacteria. Do these bacteria look like they could be alive? They do not have hands or feet or a heart or a brain, but they are actually more similar to you than you may think. Scientists found that all living things share certain characteristics. In this chapter, we will discover how to precisely define living things.

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# 2.1 Characteristics of Living Organisms

## Lesson Objectives

- List the defining characteristics of living things.
- List the needs of all living things.

## Vocabulary

- cell
- embryo
- homeostasis
- organism

## 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 things in common. Living things are similar to each other because all living things evolved from the same common ancestor that lived billions of years ago. See http://vimeo.com/15407847 for a powerful introduction to life.

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 ( **homeostasis**).

### Living Things Need Resources and Energy

Why do you eat everyday? To get energy. The work you do each day, from walking to writing and thinking, is fueled by energy. But you are not the only one. In order to grow and reproduce, all living things 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 plants or other animals in order to obtain energy and 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** 2.1).

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 2.1

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 ( **Figure** 2.2). **Cells** are the smallest unit of living things. 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** 2.3 are made of just one cell. Other organisms have millions of cells. On the other hand, eggs are some of the biggest cells around. A chicken egg is just one huge cell.

All cells share at least some structures. Although the cells of different organisms are built differently, they all function much the same way. Every cell must get energy from food, be able to grow and reproduce, and respond to its environment.

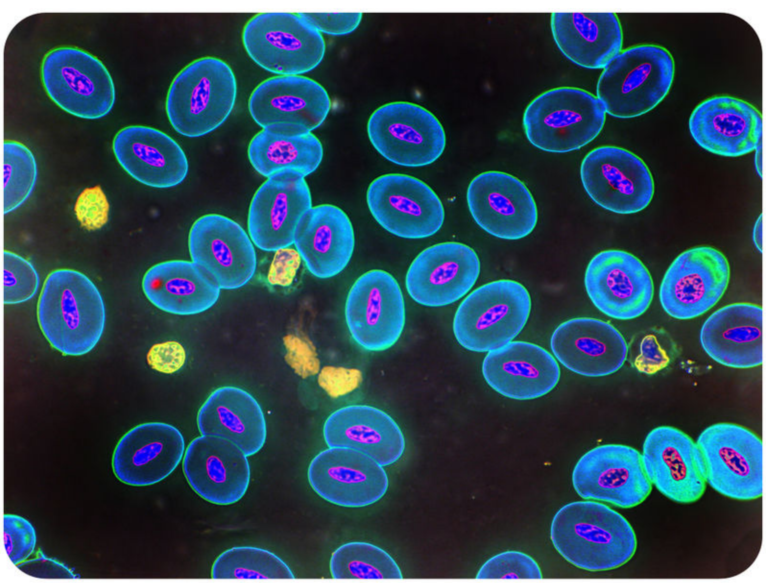

FIGURE 2.2

Reptilian blood cell showing the characteristic nucleus. A few smaller white blood cells are visible. This image has been magnified 1000 times its real size.

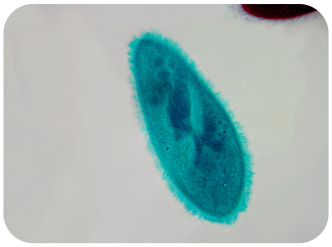

FIGURE 2.3
This paramecium is a single-celled organism.

### Living Things Respond to their Environment

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

### 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** 2.4).

FIGURE 2.4
Like all living things, cats reproduce themselves and make a new generation of cats. When animals and plants reproduce they make tiny undeveloped versions of themselves called **embryos**, which grow up and develop into adults. A kitten is a partly developed cat.

### 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 thing gets thrown off balance, its body or cells help them return to normal. In other words, living things 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** 2.5).

## Lesson Summary

- All living things grow, reproduce, and maintain a stable internal environment.
- All organisms are made of cells.
- All living things need energy and resources to survive.

FIGURE 2.5
A bird fluffs its feathers to stay warm (keep from losing energy) and to maintain homeostasis.

## Review Questions

### Recall

1. Define the word organism.
2. What are three characteristics of living things?

### Apply Concepts

3. What are a few ways organisms can get the energy they require?
4. What is a cell?

### Think Critically

5. Think about fire. Can fire be considered a living thing? Why or why not?

## Points to Consider

- DNA is considered the "instructions" for the cell. What do you think this means?
- What kinds of chemicals do you think are necessary for life?
- Do you expect that the same chemicals can be in non-living and living things?

# 2.2 Chemicals of Life

## Lesson Objectives

- Define matter, element, and atom.
- Name the four main classes of organic molecules that are building blocks of life.

## Vocabulary

- atom
- atomic number
- carbohydrate
- chemical reaction
- compound
- electron
- element
- enzyme
- lipid
- macromolecule
- matter
- molecule
- neutron
- nucleic acid
- organic compound
- Periodic Table
- product
- protein
- proton
- reactant

## Check Your Understanding

- What are the main properties of all living things?
- What is homeostasis?

## The Elements

If you pull a flower petal from a plant and break it in half, and 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? Scientists have broken down **matter**, or anything that takes up space and has mass, into the smallest pieces that cannot be broken down anymore. Rocks, animals, flowers, and your body are all made up of matter (see **Figure** 2.6).

FIGURE 2.6
Life on a rocky peak in the Waitakere Ranges.

Matter is made up 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.

Each element has a different type of atom, and is represented with a one or two letter symbol. For example, the symbol for oxygen is O and the symbol for helium is He.

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** 2.7), 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**.

*The Element Song* can be heard at http://www.youtube.com/watch?v=DYW50F42ss8 (1:25)

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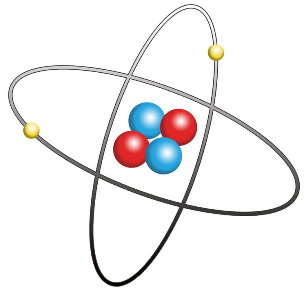


FIGURE 2.7
An atom of Helium (He) contains two positively charged protons (red), two uncharged neutrons (blue), and two negatively charged electrons (yellow).

## 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 (see **Figure** 2.8). Each element has a one or two letter symbol. For example, H stands for hydrogen and Au 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.

## 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. 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 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.

For example, hydrogen and oxygen bind together to form water. The molecules that come together to start a chemical reaction are the **reactants**. So hydrogen and oxygen are reactants. The **product** is the end result of a reaction. In this example, water is the product.

## Organic Compounds

The 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. Our body gets the organic molecules we need from the food we eat ( **Figure** 2.9). Which organic molecules do you recognize from the list below?

The four main macromolecules found in living things, shown in **Table** 2.1, are:

1. Proteins
2. Carbohydrates
3. Lipids

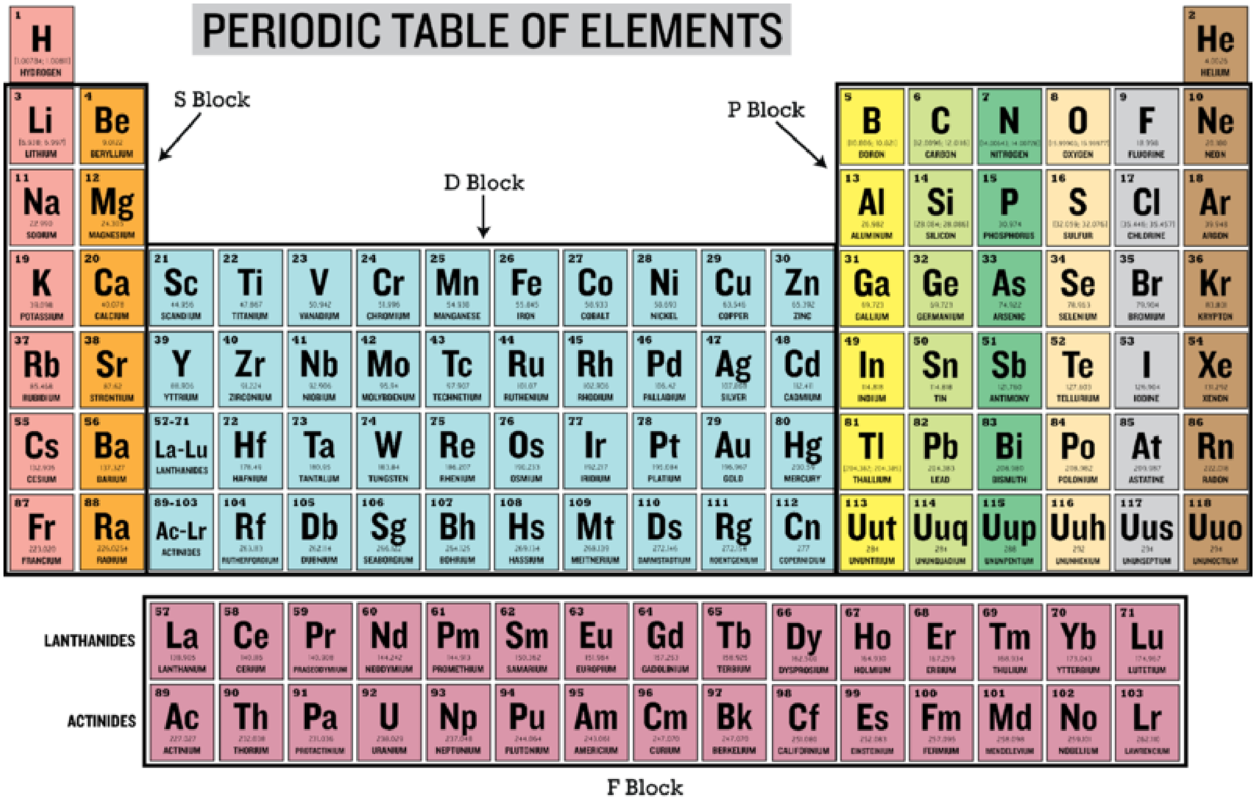



FIGURE 2.8

The periodic table groups the elements based on their properties.

4. Nucleic Acids

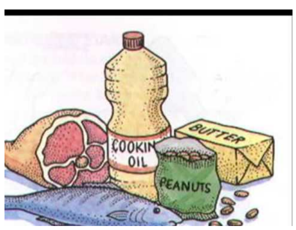
*What are proteins and what do they do?* can be seen at http://ghr.nlm.nih.gov/handbook/howgeneswork/protein . *What is DNA?* can be viewed at http://ghr.nlm.nih.gov/handbook/basics/dna .

**TABLE 2.1: The Four Main Classes of Organic Molecules**

| | Proteins | Carbohydrates | Lipids | Nucleic Acids |
|---|---|---|---|---|
| Elements | C,H,O,N,S | C,H,O | C,H,O,P | C,H,O,P,N |
| Examples | Enzymes, muscle fibers, antibodies | Sugar, Starch, Glycogen, Cellulose | Phospholipids in membranes, fats, oils, waxes, steroids | DNA, RNA, ATP |
| Monomer (small building block molecule) | Amino acids | Monosaccharides (simple sugars) | Often include fatty acids | Nucleotides |

FIGURE 2.9
A healthy diet includes protein, fat, and carbohydrate, providing us with organic molecules.

The *Molecules of Cells,* an overview of the molecules of the cell, can be viewed at http://www.youtube.com/watch?v=Q1dRmbCCO4Y (6:09).

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## Carbohydrates

**Carbohydrates** are sugars or long chains of sugars. An important role of carbohydrates is to store energy. Glucose ( **Figure** 2.10) is a simple sugar molecule with the chemical formula $C_6H_{12}O_6$.

Carbohydrates also include long chains of connected sugar molecules. Plants store sugar in long chains called starch, whereas animals store sugar in long chains 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.

## Proteins

**Proteins** are molecules that have many different functions in living things. All proteins are made of small molecules called amino acids that connect together like beads on a necklace ( **Figure** 2.11 and **Figure** 2.13). There are only 20 common amino acids needed to build proteins. These amino acids form in thousands of different combinations, making 100,000 or more unique proteins in humans. Proteins can differ in both the number and order of amino acids. Small proteins have just a few hundred amino acids. The largest proteins have more than 25,000 amino acids.

Many important molecules in your body are proteins. **Enzymes** are a type of protein that speed up chemical reactions. 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** 2.12).

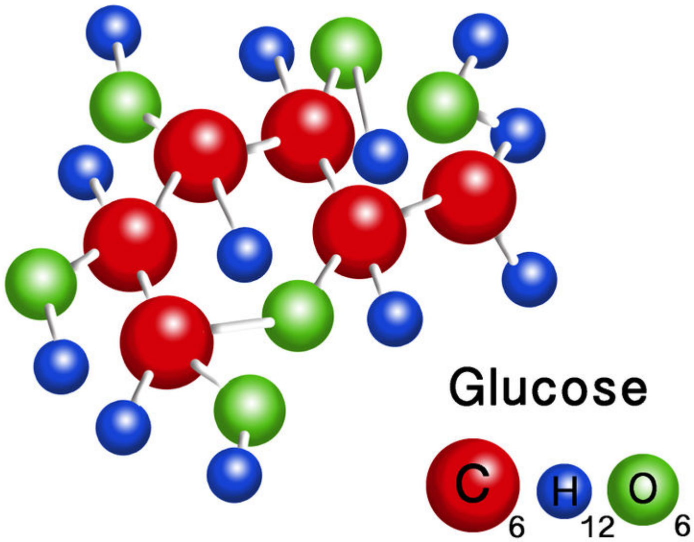



FIGURE 2.10
A molecule of glucose (a carbohydrate).


FIGURE 2.11
Amino acids connect together like beads on a necklace.

FIGURE 2.12
Muscle fibers are made mostly of protein.

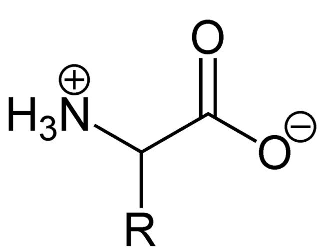



FIGURE 2.13
General Structure of Amino Acids. This model shows the general structure of all amino acids. Only the side chain, R, varies from one amino acid to another. KEY: H = hydrogen, N = nitrogen, C = carbon, O = oxygen, R = variable side chain.

It's important for you and other animals to eat food with protein because we cannot make some amino acids ourselves. 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 (see the chapter titled *Cell Functions*) that make up the protective outer membrane of all cells ( **Figure** 2.14).

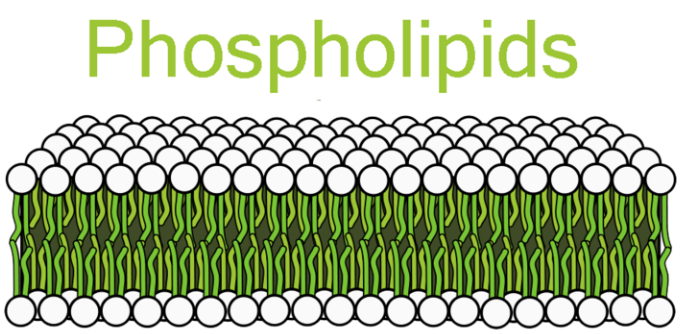
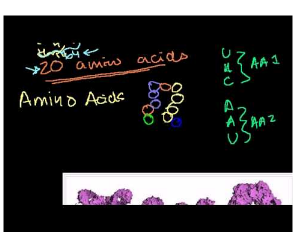



FIGURE 2.14
Phospholipids in a membrane.

## 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 the molecule that stores our genetic information ( **Figure** 2.15). RNA is involved in making proteins. ATP (adenosine triphosphate), known as the "energy currency" of the cell, is also a nucleic acid.

An overview of DNA can be seen at http://www.youtube.com/watch?v=_-vZ_g7K6P0 .



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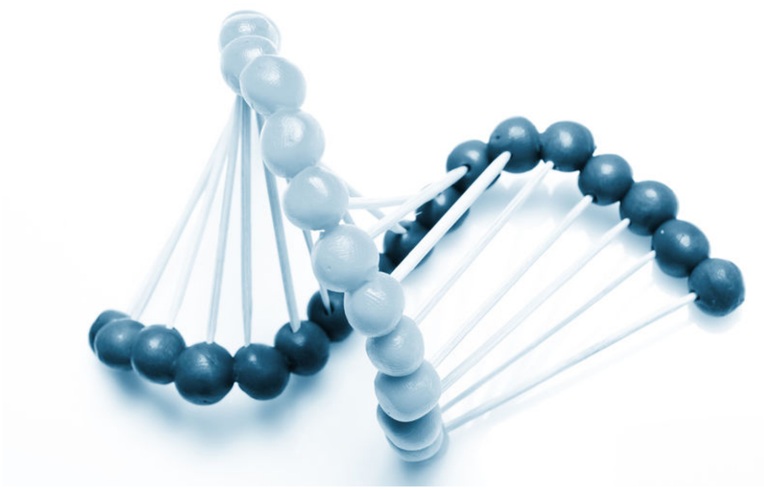

FIGURE 2.15
DNA, a nucleic acid.

### Arsenic in Place of Phosphorus?

In late 2010, scientists proposed that the notion that the elements essential for life - carbon, hydrogen, oxygen, nitrogen, phosphorus and sulfur - may have additional members. Scientists have trained a bacterium to eat and grow on a diet of arsenic, in place of phosphorus. Phosphorus chains form the backbone of DNA, and ATP is the principal molecule in which energy in the cell is stored. Arsenic is directly under phosphorus in the Periodic Table, so the two elements have similar chemical bonding properties. This finding raises the possibility that organisms could exist on Earth or elsewhere in the universe using biochemicals not currently known to exist. These results will expand the notion of what life could be and where it could be. It could be possible that life on other planets may have formed using biochemicals with other elements.

See http://www.nytimes.com/2010/12/03/science/03arsenic.html?pagewanted=1&_r=3 for further information.

## Lesson 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.
- Enzymes can speed up a chemical reaction.
- Living things are made of just four classes of macromolecules: proteins, carbohydrates, lipids, and nucleic acids.

## Review Questions

### Recall

1. What are the 4 main classes of organic compounds?

2. Sugar is what kind of organic compound?
3. What is an atom?
4. Name a few examples of proteins.
5. Name a few examples of lipids in organisms.
6. What are two nucleic acids?

### Apply Concepts

7. Would water, with the symbol $H_2O$, be considered an element or a compound?
8. How many types of atoms make up gold?

### Think Critically

9. Why do you think you need fats in your diet?

## Points to Consider

- Do you expect the genetic information in the DNA of a cow to be the same or different from that in a crow?
- If we are all composed of the same chemicals, how do all organisms look so different?
- What characteristics would you use to distinguish and classify living things?

# 2.3 Classification of Living Things

## Lesson Objectives

- Explain what makes up a scientific name.
- Explain what defines a species.
- List the information scientists use to classify organisms.
- List the three domains of life and the chief characteristics of each.

## Check Your Understanding

- What are the basic characteristics of life?
- What are the four main classes of organic molecules that are building blocks of life?

## Vocabulary

- Archaea
- bacteria
- binomial nomenclature
- classify
- domain
- Eukarya
- genus
- species
- taxonomy

## Classifying Organisms

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 in 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. 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.

Carl Linnaeus (1707-1778) ( **Figure** 2.16) built on Aristotle's work to create his own classification system. He invented the way we name organisms today. Linnaeus is considered the inventor of modern **taxonomy**, the science of naming and grouping organisms. See http://www.ucmp.berkeley.edu/history/linnaeus.html for additional information.

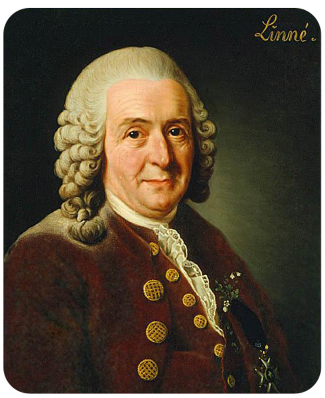


FIGURE 2.16

In the $18^{th}$ 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. Each species 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** 2.17). 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 they are written in a language called Latin.

FIGURE 2.17

These leaves(left and center) are from one of two different species of trees in the Acer, or maple, genus. One of the characteristics of the maple genus is winged seeds (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** 2.18). See http://www.pbs.org/wgbh/nova/orchid/classifying.html for further information.

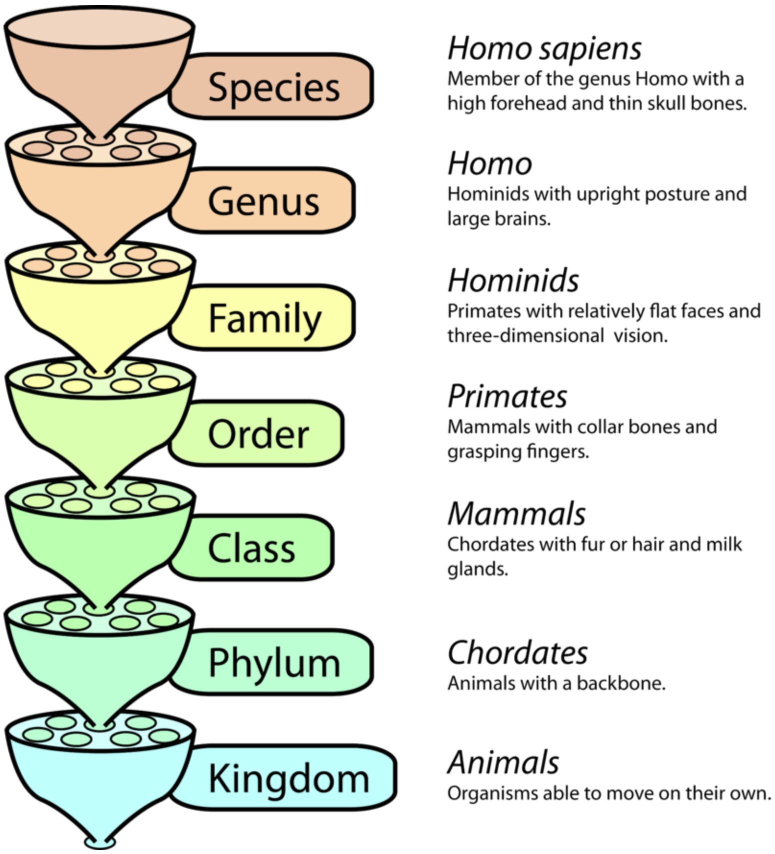


FIGURE 2.18
This diagram illustrates the classification categories for organisms, with the broadest category (Kingdom) at the bottom, and the most specific category (Species) at the top.

The *Classification Rap* can be heard at http://www.youtube.com/watch?v=6jAGOibTMuU (3:18).

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## Difficulty Naming 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** 2.19).

So how is a species defined? A **species** is group of individuals that can interbreed with one another and produce fertile offspring; a species does not interbreed with other groups. By this definition, two species of animals or plants that do not interbreed are not the same species. See *Biological Classification of Organisms* for additional information: http://www.physicalgeography.net/fundamentals/9b.html .

FIGURE 2.19
These children are all members of the same species, Homo sapiens.

## Domains of Life

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

All of life can be divided into 3 domains, which tell you the type of cell inside of an organism:

1. **Bacteria**: Single-celled organisms that do not contain a nucleus
2. **Archaea**: Single-celled organisms that do not contain a nucleus; have a different cell wall from bacteria
3. **Eukarya**: Organisms with cells that contain a nucleus.

### Archaea and Bacteria

Archaea and Bacteria ( **Figure** 2.20 and **Figure** 2.21) seem very similar, but they also have significant differences.

Similarities:

- Do not have a nucleus
- Small cells
- One-celled
- Can reproduce without sex by dividing in two

Differences:

- Cell walls made of different material

- Archaea often live in extreme environments like hot springs, geysers, and salt flats while bacteria can live almost everywhere.

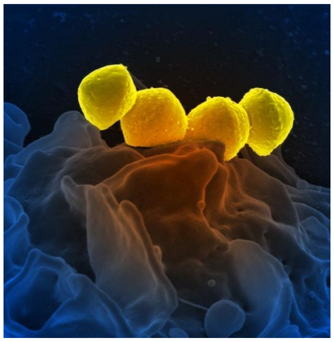

FIGURE 2.20
The Group A Streptococcus organism is in the domain Bacteria, one of the three domains of life.

FIGURE 2.21
The Halobacterium is in the domain Archaea, one of the three domains of life.

### 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.
3. Animalia: Animals survive by eating other organisms or the remains of other organisms. Animals range from tiny ants to the largest dinosaurs (reptiles) and whales (mammals), including all sizes in between. ( **Figure** 2.22).
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 (an alga protist is shown in **Figure** 2.23).

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. The main characteristics of the three domains of life are summarized in **Table** 2.2.

FIGURE 2.22
The Western Gray Squirrel is in the domain Eukarya, one of the three domains of life.

FIGURE 2.23
This microscopic alga is a protist in the domain Eukarya.

**TABLE 2.2: Three domains of life: Bacteria, Archaea, and Eukarya**

| | **Archaea** | **Bacteria** | **Eukarya** |
|---|---|---|---|
| Multicelluar | No | No | Yes |
| Cell Wall | Yes, without peptidoglycan | Yes, with peptidoglycan | Varies. Plants and fungi have a cell wall; animals do not. |
| Nucleus (DNA inside a membrane) | No | No | Yes |
| Organelles inside a membrane | No | No | Yes |

## Viruses

We have all heard of viruses. The flu and many other diseases are caused by viruses. But what is a virus? Based on the material presented in this chapter, do you think viruses are living?

The answer is actually "no." A virus is essentially DNA or RNA surrounded by a coat of protein ( **Figure** 2.24). It is not a cell and does not maintain homeostasis. Viruses also cannot reproduce on their own –they need to infect a host cell to reproduce. Viruses do, however, change over time, or evolve. So a virus is very different from any of the organisms that fall into the three domains of life.

- Scientists classify organisms according to their evolutionary histories and how related they are to one another - by looking at their physical features, the fossil record, and DNA sequences.
- All life can be classified into three domains: Bacteria, Archaea, and Eukarya.

## Review Questions

### Recall

1. Who designed modern classification and invented the two-part species name?

2. Define a species.

3. What kingdoms make up the domain Eukarya?

4. What is the name for the scientific study of naming and classifying organisms?

5. How are organisms given a scientific name?

### Apply Concepts

6. In what domain are humans?

7. *Quercus rubra* is the scientific name for the red oak tree. What is the red oak's genus?

8. In what domain are mushrooms?

9. What information do scientists use to classify organisms?

### Think Critically

10. Is it possible for organisms in two different classes to be in the same genus?

11. If molecular data suggests that two organisms have very similar DNA, what does that say about their evolutionary relatedness?

12. Can two different species ever share the same scientific name?

13. If two organisms are in the same genus, would you expect them to look much alike?

## Points to Consider

- This Section introduced the diversity of life on Earth. Do you think it is possible for cells from different organisms to be similar even though the organisms look different?
- Do you think human cells are different from bacterial cells?
- Do you think it is possible for a single cell to be a living organism?

# 2.4 References


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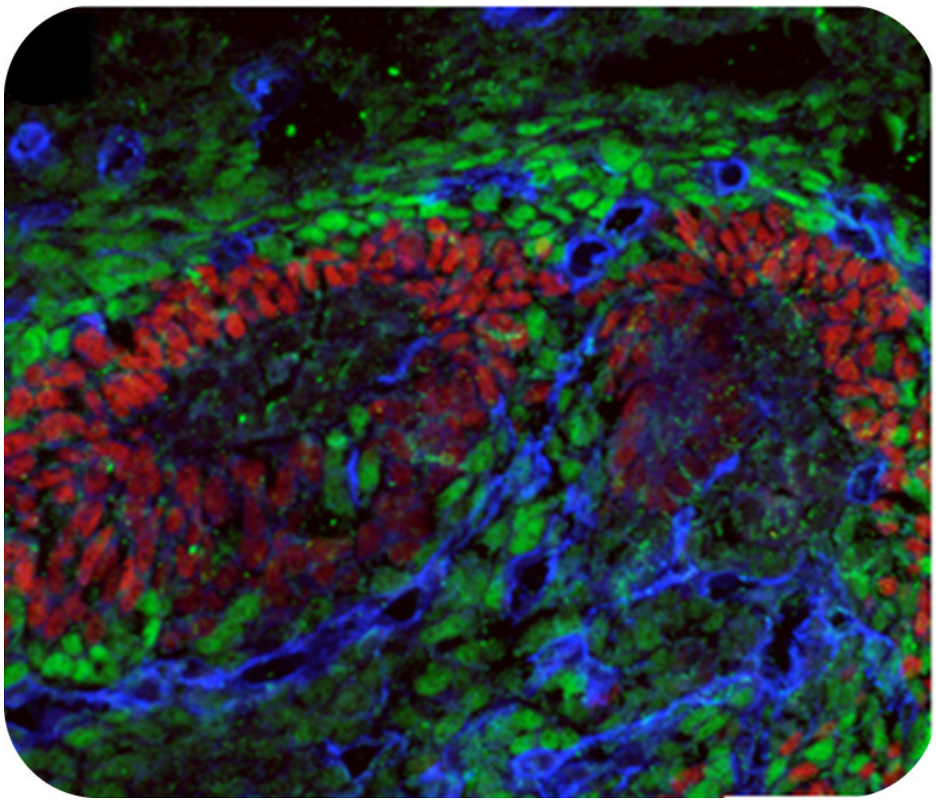
# CHAPTER 3 MS Cells and Their Structures

## Chapter Outline





Look carefully at the above image. What do you see? What colors? What shapes? Can you guess what it is?

These are actually cells from a mouse's kidney. Cells are the smallest units of living things. You are made of cells. Plants are made of cells. So are mice, chickens, bees, and mushrooms. Our cells even look very similar to the above mouse cells.

But the cells of a kidney are not actually bright green, red, and blue. Scientists remove cells from organisms, dye them with different colors, and look at them under strong microscopes. The above image is an example of what scientists see under these microscopes. Now, we will explore what different types of cells look like and what they do.

*Sims−Lucas S, Schaefer C, Bushnell D, Ho J, Logar A, et al. www.plosone.org/article/info%3Adoi%2F10.1371%2Fjournal.pone.0065993. CC BY 2.5.*

# 3.1 Introduction to Cells

## Lesson Objectives

- Explain how cells are observed.
- Define the three main parts of the cell theory.
- Explain the levels of organization in an organism.

## Check Your Understanding

- What are the five main characteristics of living things?
- Name the four main classes of organic molecules that are building blocks of life.

## Vocabulary

- organ
- organ system
- tissue

## What are cells?

In the chapter *What is a Living Organism?*, you learned that living things are made of big molecules called proteins, lipids, carbohydrates, and nucleic acids. When these big molecules come together, they form a cell. A **cell** is the smallest unit of an organism that is still considered living (see the onion cells in **Figure** 3.1). 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 tiny 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. 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?

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

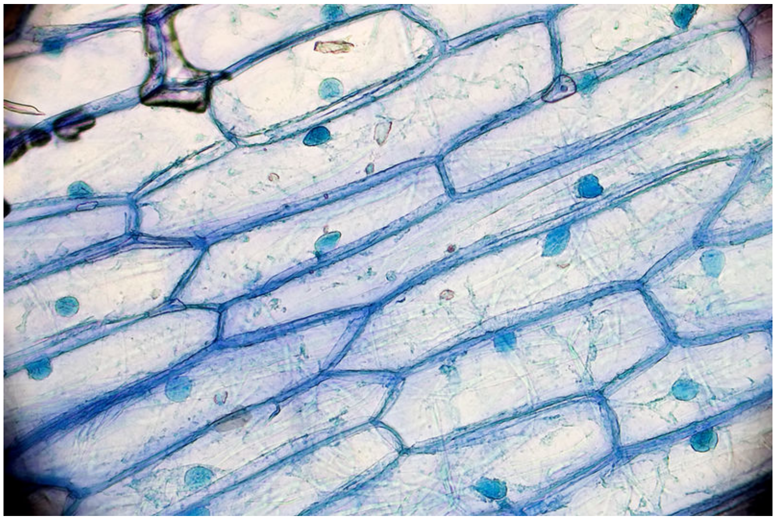


FIGURE 3.1
The outline of onion cells are visible under a light microscope.

beam of electrons through the specimen. Sending electrons through a cell allows us to see its tiniest parts ( **Figure** 3.2).

Without electron microscopes, we would not know what the inside of a cell looked like. The only problem with using an electron microscope is that it only works with dead cells. Scientists and students still use light microscopes to study living cells.

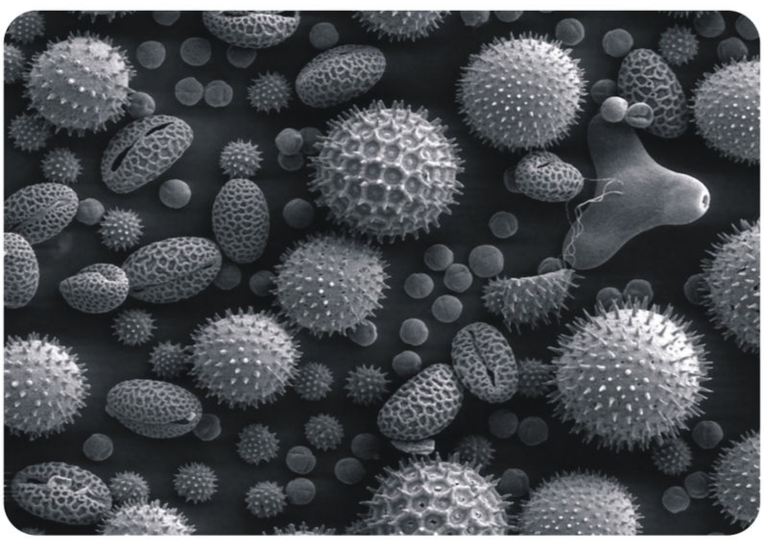


FIGURE 3.2
An electron microscope allows scientists to see much more detail than a light microscope, as with this sample of pollen. But a light microscope allows scientists to study living cells.

*How to Correctly Use a Microscope* can be viewed at http://www.youtube.com/watch?v=jP9HtcAvGDk (1:43).

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Click image to the left for more content.

## 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 are composed of only one cell ( **Figure** 3.3) and divide in half 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, 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 contradicted it.

FIGURE 3.3
Bacteria (pink) are an example of an organism consisting of only one cell.

## Levels of Organization

Although cells share many of the same features and structures, they also can be very different. Each cell in your body is designed for a specific task.

For example:

- Red blood cells ( **Figure** 3.4) are shaped with a pocket that traps oxygen and brings it to other body cells.

- Nerve cells, which can quickly send the feeling of touching a hot stove to your brain, are long and stringy in order to form a line of communication with other nerve cells, like a wire ( **Figure** 3.5).
- Skin cells ( **Figure** 3.6) are flat and fit tightly together to protect your body.

An animation comparing the size of red blood cells and skin cells to other structures can be found at http://learn.genetics.utah.edu/content/begin/cells/scale/.

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.

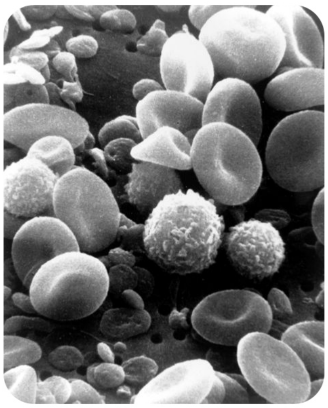

FIGURE 3.4
Red blood cells are specialized to carry oxygen in the blood.

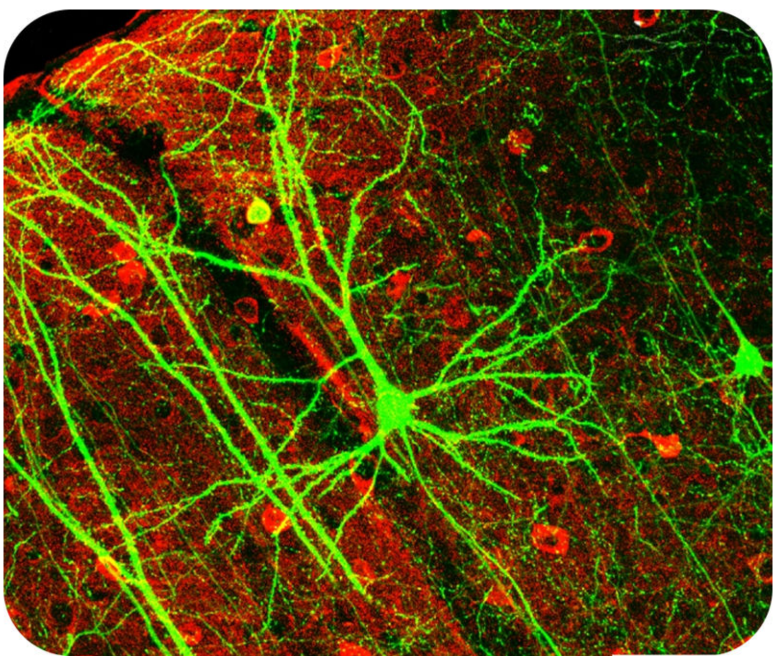

FIGURE 3.5
Neurons are shaped to conduct electrical impulses to many other nerve cells.

While cells are the basic units of an organism, groups of cells can be specialized, or perform a specific job. Specialized cells can be organized into tissues. For example, your liver cells are organized into liver tissue, which is organized into an organ, your liver. Organs are formed from two or more specialized tissues working together to perform a job that helps your body work. All organs, from your heart to your liver, are made up of an organized group of tissues.

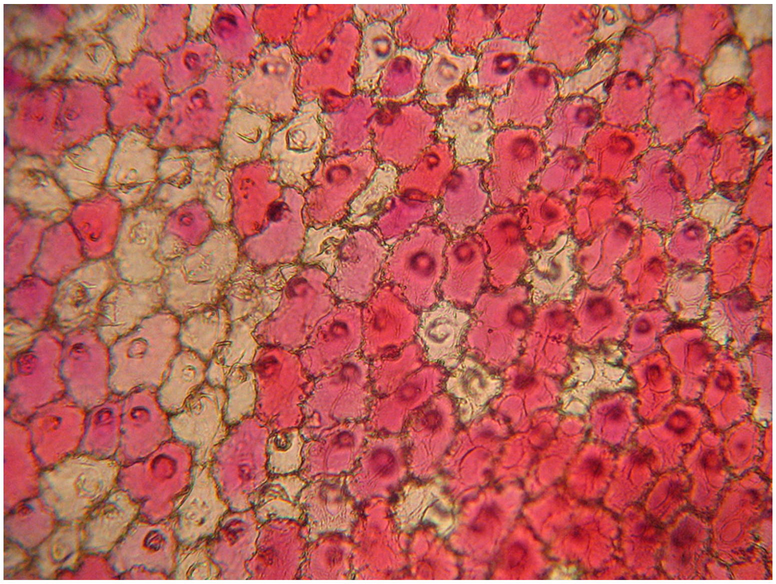

FIGURE 3.6
These epidermal cells make up the "skin" of plants. Note how the cells fit tightly together.

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. As you can see ( **Figure** 3.7), there are many levels of organization in living things.

## Lesson 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; and
  - 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.

## Review Questions

### Recall

1. What scientific tool was used to first observe cells?
2. What are the three main parts of the cell theory?

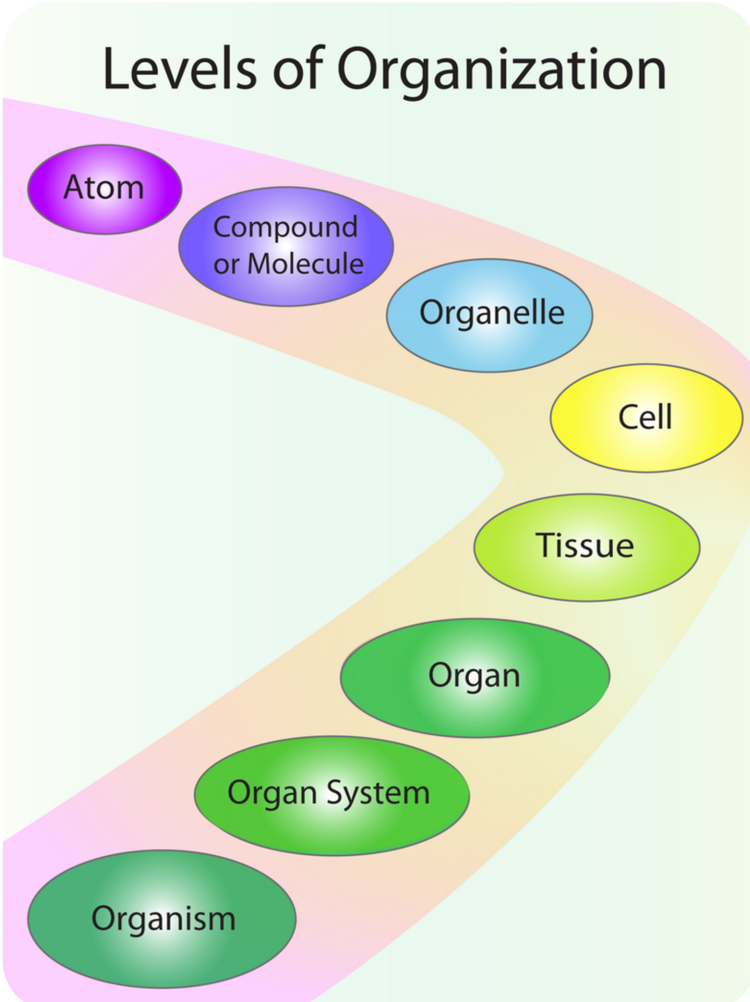


FIGURE 3.7
Levels of Organization, from the atom to the organism.

#### Apply Concepts

3. Put the following in the correct order from simplest to most complex: organ, cell, tissue, organ system.

4. What type of microscope would be best for studying the structures found inside of cells?

#### Think Critically

5. According to the cell theory, can we create a new cell in laboratory by putting different molecules together? Why or why not?

## Further Reading / Supplemental Links


- Baeuerle, Patrick A. and Landa, Norbert. *The Cell Works: Microexplorers.* Barron's; 1997, Hauppauge, New York.
- Sneddon, Robert. *The World of the Cell: Life on a Small Scale.* Heinemann Library; 2003, Chicago.
- Wallace, Holly. *Cells and Systems.* Heinemann Library; 2001, Chicago.

## Points to Consider

- Do you think there would be a significant difference between bacterial cells and your brain cells? What might they be?
- Do you think a bacterial cell and a brain cell have some things in common? What might they be?
- Do you think cells have organs like we do? How would that benefit cells?

# 3.2 Cell Structures

## Lesson Objectives

- Compare prokaryotic and eukaryotic cells.
- List the organelles of the cell and their functions.
- Discuss the structure and function of the cell membrane and cytosol.
- Describe the structure and function of the nucleus.
- Distinguish between plant and animal cells.

## Check Your Understanding

- What is a cell?
- How do we visualize cells?

## Vocabulary

- cell wall
- central vacuole
- chloroplast
- chromosome
- cytoplasm
- cytoskeleton
- cytosol
- endoplasmic reticulum (ER)
- eukaryote
- Golgi apparatus
- lysosome
- mitochondria
- nuclear envelope
- nucleus
- organelle
- plasma membrane
- prokaryote
- ribosome
- rough endoplasmic reticulum
- semipermeable
- smooth endoplasmic reticulum
- vesicle

## Prokaryotic and Eukaryotic Cells

There are two basic types of cells, prokaryotic cells ( **Figure** 3.8), found in organisms called **prokaryotes**, and eukaryotic cells ( **Figure** 3.9), found in organisms called **eukaryotes**.

The main difference between eukaryotic and prokaryotic cells is that eukaryotic cells have a **nucleus**, where they store their DNA, or genetic material. The nucleus is membrane-bound, which means it is surrounded by a phospholipid membrane. Prokaryotic cells do not have a "membrane-bound" nucleus. Instead, their DNA floats around inside the cell.

Here are some other key features of eukaryotic cells:

1. They have membrane-bound structures called **organelles**. A list of the main eukaryotic organelles is located in **Table** 3.2.
2. Eukaryotic cells include the cells of fungi, animals, protists, and plants.
3. These cells are more specialized than prokaryotic cells.

Key features of prokaryotic cells include:

1. The cells are usually smaller and simpler than eukaryotic cells.
2. Prokaryotic cells do not have membrane-bound structures.
3. The DNA, or genetic material, forms a single large circle that coils up on itself.
4. Prokaryotic cells belong to the domains Bacteria or Archaea. These two domains were discussed in the *What is a Living Organism?* chapter.

From the above information, are the cells found in your body prokaryotic cells or eukaryotic cells? **Table** 3.1 compares prokaryotic and eukaryotic cells.

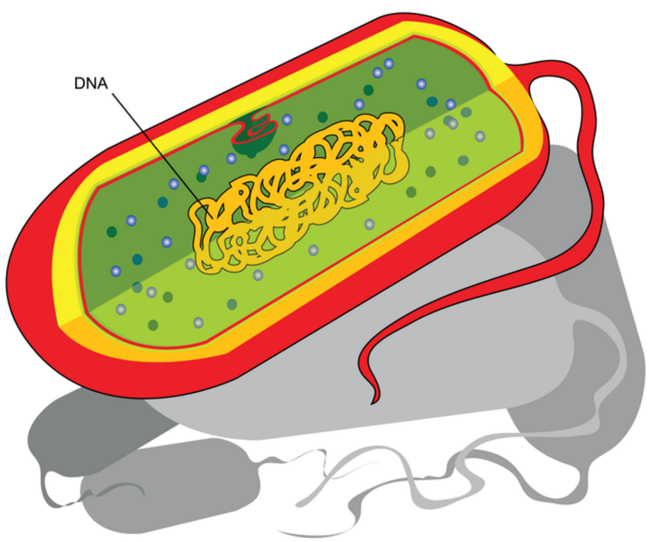


FIGURE 3.8

Prokaryotes do not have a nucleus. Instead, their genetic material is a simple loop of DNA.

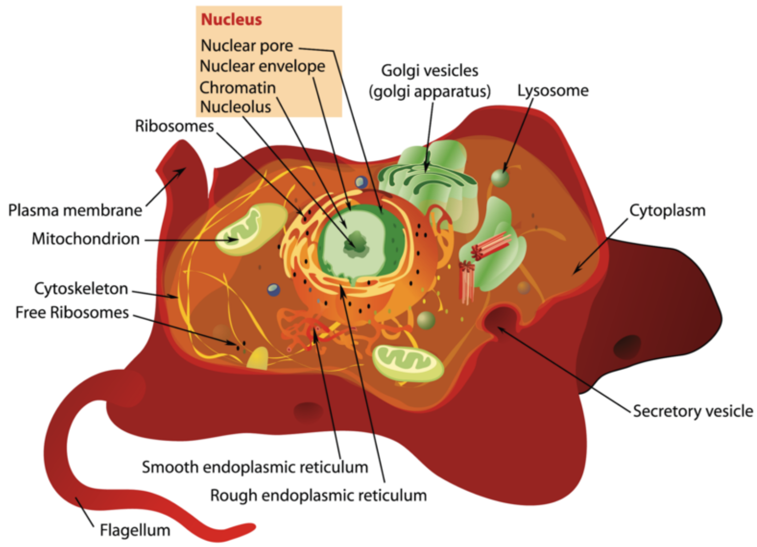


FIGURE 3.9
Eukaryotic cells contain a nucleus (where the DNA lives, and surrounded by a membrane) and various other special compartments surrounded by membranes, called organelles. For example, notice in this image the mitochondria, lysosomes, and peroxisomes.

TABLE 3.1: **Comparison of Prokaryotic and Eukaryotic Cells**

| Feature | Prokaryotic cells | Eukaryotic cells |
|---|---|---|
| DNA | Single “naked” circle; plasmids | In membrane-enclosed nucleus |
| Membrane-enclosed organelles | No | Yes |
| Examples | Bacteria | Plants, animals, fungi |

## The Plasma Membrane and Cytosol

Both eukaryotic and prokaryotic cells have walls around them that separate them from other cells and make sure the parts of the cell do not just float away. This wall is called a plasma membrane. The **plasma membrane** is made of a double layer of lipids, known as phospholipids. The function of the plasma membrane, also known as the cell membrane, is to control what goes in and out of the cell.

Some molecules can go through the cell membrane and enter and leave the cell, but some cannot. "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.

The inside of eukaryotic and prokaryotic cells also both contain a jelly-like substance called **cytosol**. Cytosol is composed of water and other molecules, including enzymes that speed up the cell’s chemical reactions. Everything in the cell - the nucleus and the organelles - sit in the cytosol, like fruit in a Jell-o mold. The term **cytoplasm** refers to the cytosol and all of the organelles, but not the nucleus.

TABLE 3.2: **Some Eukaryotic Organelles**

| Organelle | Function |
|---|---|
| Ribosomes | Involved in making proteins |
| Golgi apparatus | Packages proteins and some polysaccharides |
| Mitochondria | Where ATP is made |
| Smooth Endoplasmic Reticulum | Makes lipids |
| Chloroplast | Makes sugar (photosynthesis) |
| Lysosomes | Digests macromolecules |

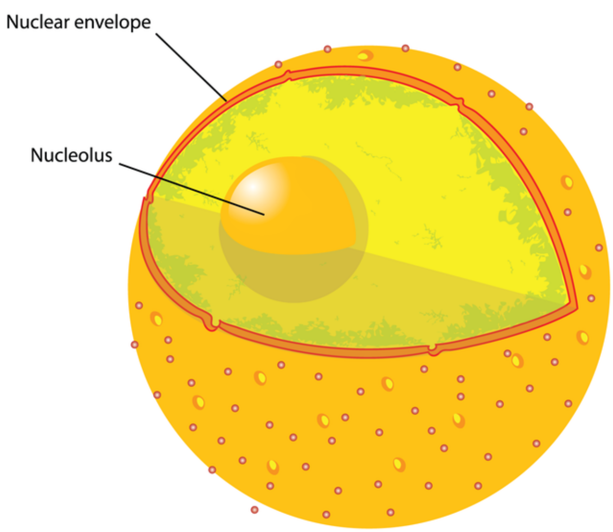


FIGURE 3.10

In eukaryotic cells, the DNA is kept in a nucleus. The nucleus is surrounded by a double plasma membrane called the nuclear envelope. Within the nucleus is the *nucleolus* (smaller yellow ball).

## Organelles in the Cytoplasm: The Cell Factory

A cell is like a factory. Just as a factory is made up of many people and machines, a cell has many different parts, each with a special role. The different parts of the cell are called **organelles**, which means "small organs." All organelles are found in eukaryotic cells, but most are NOT found in prokaryotic cells. Pay attention to which ones are included in prokaryotic cells.

Below are the main organelles found in cells:

1. The nucleus of a cell is like a safe containing the factory's trade secrets, including information about how to build thousands of proteins.
2. The **mitochondria** are powerhouses that create ATP (adenosine triphosphate), which provides the energy needed to power chemical reactions. Plant cells have special organelles called **chloroplasts** that capture energy from the sun and store it in the bonds of sugar molecules, using a process called photosynthesis ( **Figure** 3.11). (The cells of animals and fungi do not photosynthesize and do not have chloroplasts.)
3. The **vacuoles** are like storage centers. Plant cells have larger ones than animal cells because they need to store water and other nutrients.
4. The **lysosomes** are like the recycling trucks that carry waste away from the factory. Inside lysosomes are enzymes that break down old molecules into parts that can be recycled into new ones.
5. Eukaryotic cells also contain a skeleton-like structure called the **cytoskeleton**. Like our bony skeleton, a cell's cytoskeleton gives the cell its shape and helps the cell to move. What part of a factory would act like a cytoskeleton?
6. In both eukaryotes and prokaryotes, **ribosomes** are 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). If the ER is covered with ribosomes, it looks bumpy and is called **rough endoplasmic reticulum**. If the ER does not contain ribosomes, it is smooth and called the **smooth endoplasmic reticulum**. Proteins are made on the rough ER. Lipids are made on the smooth ER.
8. The **Golgi apparatus**, works like a mail room. The Golgi apparatus receives the proteins from the rough ER,

puts "shipping addresses" on the proteins, packages them up in vesicles, and then sends them to the right place in the cell.

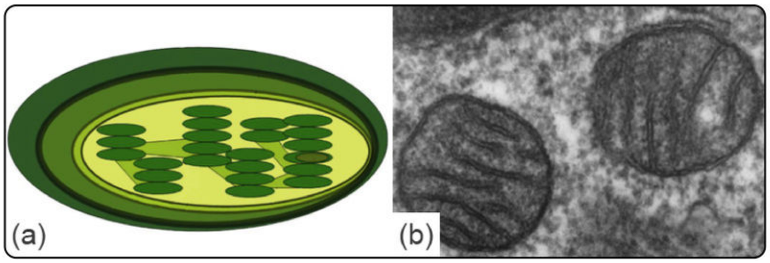


FIGURE 3.11
Diagram of chloroplast (a) and electron microscope image of two mitochondria (b). Chloroplasts and mitochondria provide energy to cells. If the bar at the bottom of the electron micrograph image is 200 nanometers, what is the diameter of one of the mitochondria?

## Differences between Plant and Animal Cells

Even though plants and animals are both eukaryotes, plant cells differ in some ways from animal cells. 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. In animal cells, vacuoles are much smaller.

Second, plant cells have a cell wall, while animal cells do not. A **cell wall** gives the plant cell strength and protection.

A third difference between plant and animal cells is that plants have several kinds of organelles called **plastids**. There are several kinds of plastids, including chloroplasts, needed for photosynthesis; **leucoplasts**, which store starch and oil; and brightly colored **chromoplasts**, which give some flowers and fruits their yellow, orange, or red color. You will learn more about chloroplasts and photosynthesis in the chapter titled *Cell Functions*. Under a microscope one can see plant cells more clearly ( **Figure** 3.12 and **Figure** 3.13).

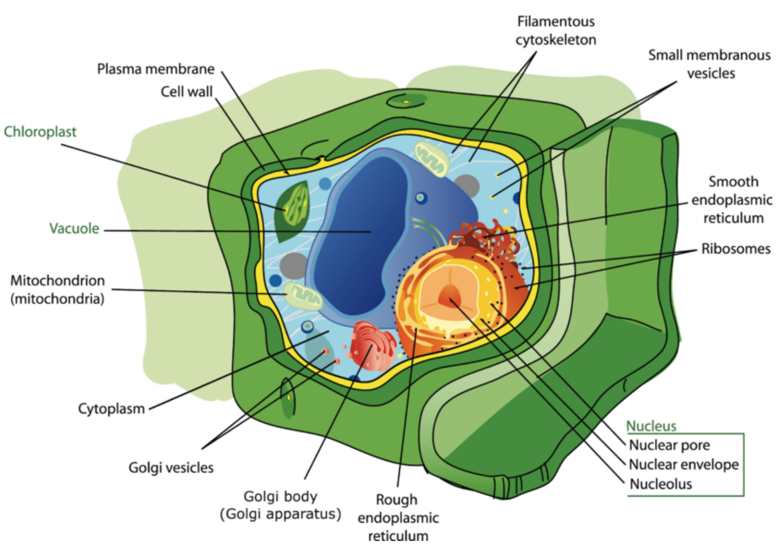


FIGURE 3.12
A plant cell has several features that make it different from an animal cell, including a cell wall, huge vacuoles, and several kinds of plastids, including chloroplasts (which photosynthesize).

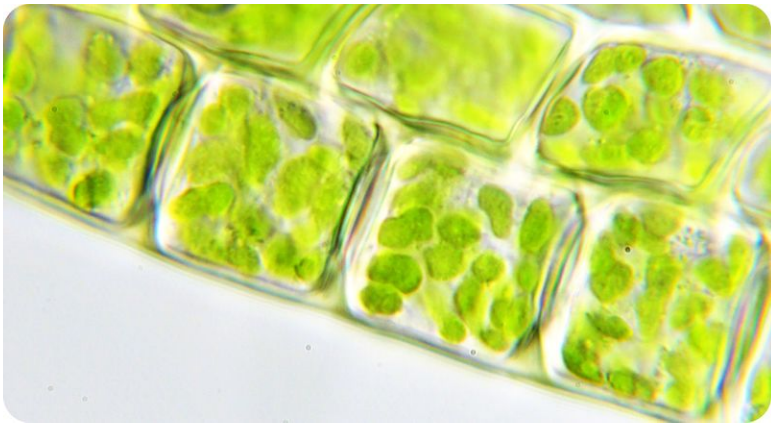

FIGURE 3.13
This photo of plant cells taken with a light microscope shows green chloroplasts, as well as a cell wall around each cell.

## Lesson Summary

- Prokaryotic cells lack a nucleus; eukaryotic cells have a nucleus.
- Each component of a cell has a specific function.
- Plant cells are different from animal cells. For example, plant cells contain plastids, cell walls, and large vacuoles.

## Review Questions

### Recall

1. What are the two basic types of cells?
2. What are organelles?
3. Discuss the main differences between prokaryotic cells and eukaryotic cells.

### Apply Concepts

4. What is the plasma membrane and what is its role?
5. Why is the mitochondria known as the powerhouse of the cell?

### Think Critically

6. Why does photosynthesis not occur in animal cells?

## Further Reading / Supplemental Links

- Baeuerle, Patrick A. and Landa, Norbert. *The Cell Works: Microexplorers.* Barron's; 1997, Hauppauge, New York.

- Sneddon, Robert. *The World of the Cell: Life on a Small Scale.* Heinemann Library; 2003, Chicago.
- Wallace, Holly. *Cells and Systems.* Heinemann Library; 2001, Chicago.


## Points to Consider

- Think about what molecules would need to be transported into cells.
- Discuss why you think it would be important for some molecules to be kept out of a cell.

# 3.3 References


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3. Courtesy of Rocky Mountain Laboratories, NIAID, NIH. http://commons.wikimedia.org/wiki/File:SalmonellaNIAID.jpg . Public Domain
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9. Mariana Ruiz Villarreal (User:LadyofHats/Wikimedia Commons). http://commons.wikimedia.org/wiki/File:Animal_cell_structure.svg . Public Domain
10. Mariana Ruiz Villarreal (User:LadyofHats/Wikimedia Commons). http://commons.wikimedia.org/wiki/File:Diagram_human_cell_nucleus.svg . Public Domain
11. (a) User:It'sJustMe/Wikipedia; (b) Louisa Howard. (a) http://commons.wikimedia.org/wiki/File:Chloroplast-new.jpg; (b) http://commons.wikimedia.org/wiki/File:Mitochondria%2C_mammalian_lung_-_TEM_%282%29.jpg . Public Domain
12. Mariana Ruiz Villarreal (User:LadyofHats/Wikimedia Commons). http://commons.wikimedia.org/wiki/File:Plant_cell_structure_svg.svg . Public Domain
13. Kelvin Song. http://commons.wikimedia.org/wiki/File:Moss_chloroplasts_100%C3%97_objective_oblique.jpg . CC BY 3.0

# Chapter 4 MS Cell Functions

## Chapter Outline



Multi-celled organisms, like dolphins, are made up of trillions of cells. How do you think they work together to move an organism? How do the cells of a tree allow it to absorb water and produce leaves? How are the cells interacting with the world inside of the body and outside of the body? Do small one-celled organisms function the same way as the cells in big organisms like dolphins? We need to know how cells function, so we can understand how entire organisms, both large and small, function.

# 4.1 Transport

## Lesson Objectives

- Describe methods of transporting molecules into and out of the cell.
- Distinguish between active and passive transport.
- Explain how diffusion and osmosis work.

## Check Your Understanding

- What structure surrounds the cell?
- What is the primary part of the cell membrane?
- What does homeostasis mean?

## Vocabulary

- active transport
- concentration
- diffusion
- hypertonic solution
- hypotonic solution
- isotonic solution
- osmosis
- passive transport
- phospholipid
- selectively permeable

## Introduction

Cells are found in all different types of environments, and these environments are constantly changing. One-celled organisms, like bacteria, can be found on your skin, or in the ground, or in all different types of water. The cells of your body interact with the food you eat, and also with other cells in your body. All cells need a way to protect themselves. This job is done by the cell membrane.

The cell membrane is semipermeable, or **selectively permeable**, which means that only some molecules can get 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 degrees F, and it is freezing outside, your cells will maintain homeostasis if the temperature of the cells stays the same and does not drop.

How does the cell ensure it is semipermeable? How does the cell control what molecules enter and leave the cell? The ways that cells control what passes through the cell membrane will be the focus of this lesson.

## What is Transport?

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** 4.1). 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.

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. An interesting quality of the plasma membrane is that it is constantly moving, like a soap bubble. Water and small molecules such as oxygen and carbon dioxide can pass freely through the membrane, but larger molecules cannot easily pass through the plasma membrane. Some molecules need a special way to get across the membrane.

## 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** 4.2). The amount of a substance in relation to the total volume is the **concentration**.

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.

How do marine animals keep their cells from shrinking? How do blood cells keep from bursting? Both have to do with the cell membrane and transport of materials. 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 secrete salt by active transport, which will be discussed later in this lesson. 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. This is represented in **Figure** 4.3.

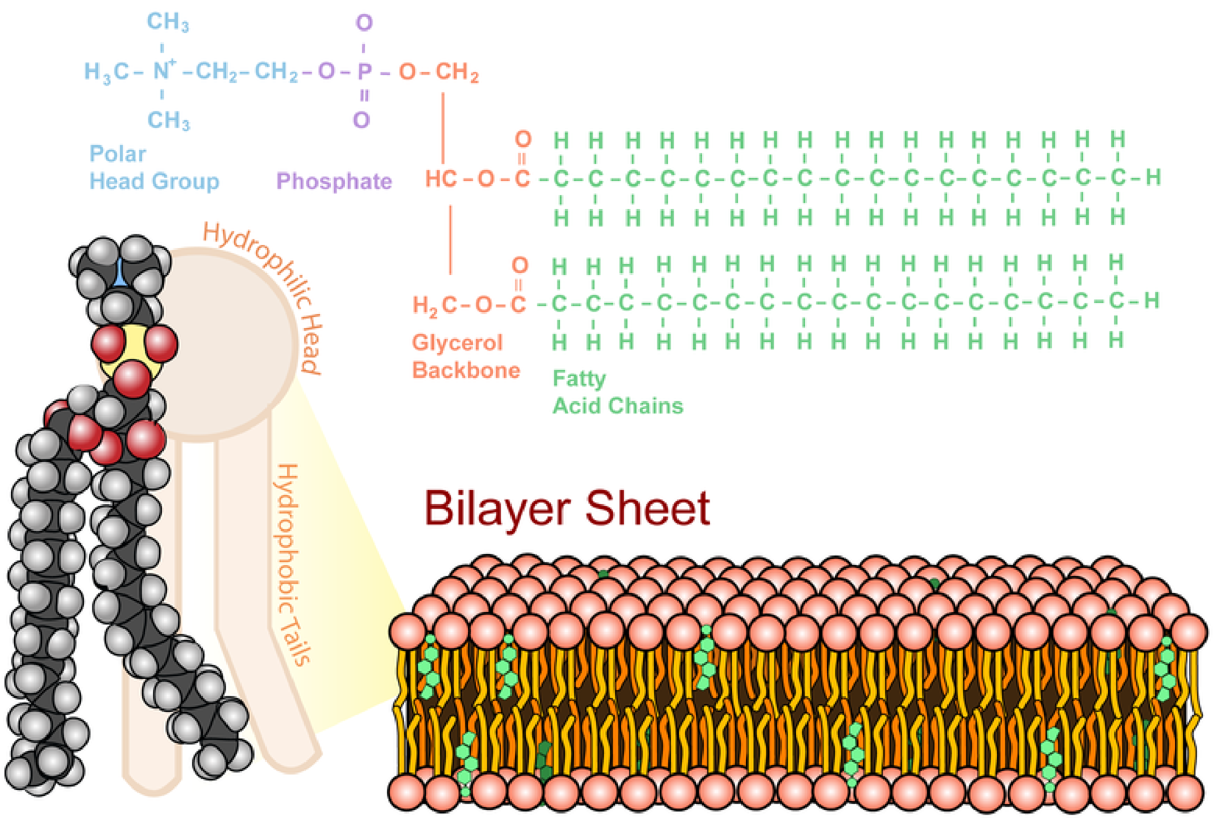



FIGURE 4.1
The cell membrane is made up of a phospholipid bilayer, two layers of phospholipid molecules.

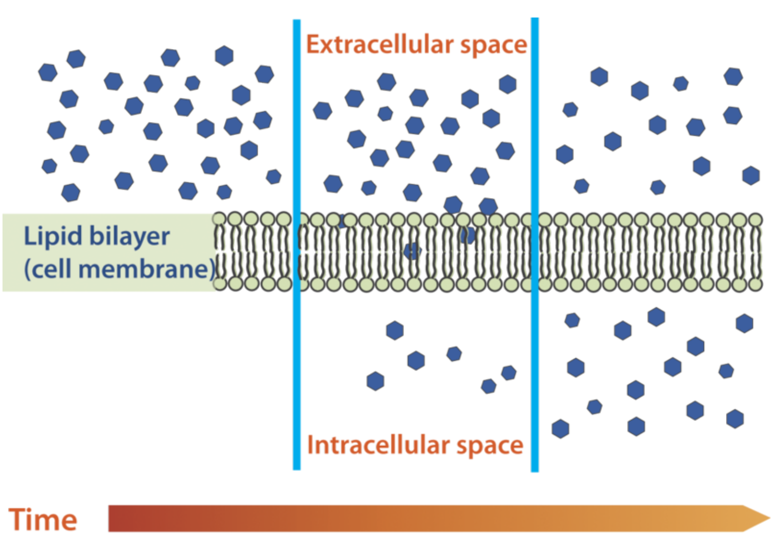



FIGURE 4.2
Diffusion is the movement of a substance from an area of a higher amount towards an area of lower amount. Equilibrium is reached when there is an equal amount on both sides of the membrane.

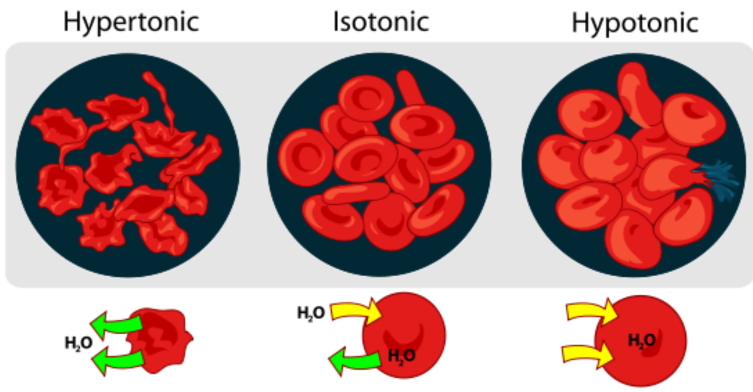



FIGURE 4.3
Osmosis causes these red blood cells to change shape by losing or gaining water.

## Passive Transport

Diffusion is called **passive transport**. This means it does not require energy to move molecules. 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. Sometimes, special proteins are needed to help molecules move across the membrane. These are called channel proteins or carrier proteins ( **Figure** 4.4).

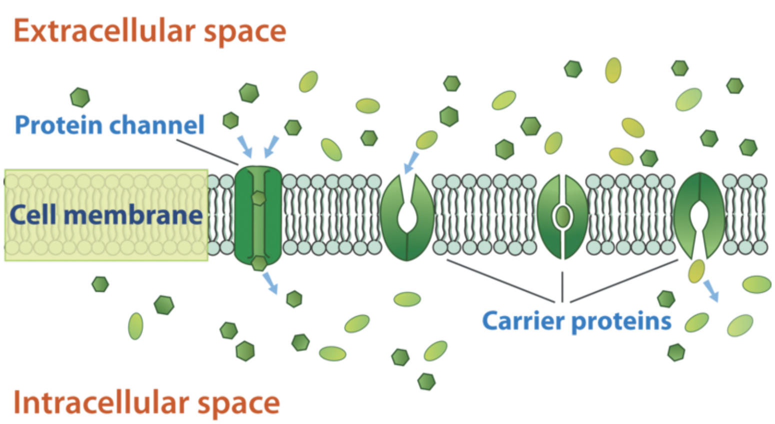
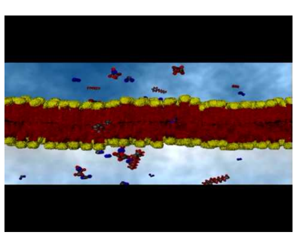



FIGURE 4.4
Protein channels and carrier proteins are involved in passive transport.

*Diffusion Across Cell Membranes: Passive Transport* can be viewed at http://www.youtube.com/watch?v=JShwXBWGMyY (4:41).



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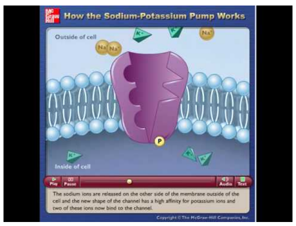
## Active Transport

During **active transport,** molecules move from an area of low concentration to high concentration. This is the opposite of diffusion. Active transport is called "active" because this type of transport requires energy to move molecules. A protein in the membrane carries the molecules across the membrane. These proteins are often called "pumps", because like other pumps they use energy to move molecules. There are many cells in your body that use pumps to move molecules. For example, your nerve cells would not send messages to your brain unless you had protein pumps moving molecules by active transport. The sodium-potassium pump ( **Figure** 4.5) is an example of an active transport pump.

An overviewof active transport can be viewed at http://www.youtube.com/watch?v=yz7EHJFDEJs (1:26).

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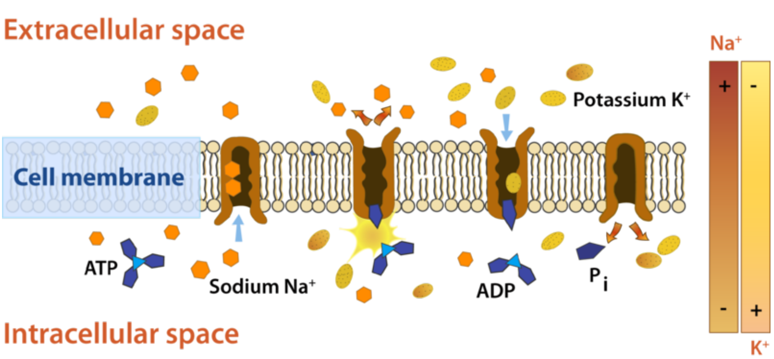



FIGURE 4.5
The sodium-potassium pump moves sodium ions to the outside of the cell and potassium ions to the inside of the cell. ATP is required for the protein to change shape. As ATP adds a phosphate group to the protein, it leaves behind adenosine diphosphate (ADP).

## Lesson Summary

- The plasma membrane is semipermeable, meaning that some molecules can move through the membrane easily, while others cannot.
- Passive transport, such as diffusion and osmosis, does not require energy.
- Active transport moves molecules in the direction of the higher concentration and requires energy and a carrier protein.

## Review Questions

### Recall

1. What's the main difference between active and passive transport?

2. List the two types of passive transport.

3. Why is the plasma membrane considered semipermeable?

4. What is diffusion?

### Apply Concepts

5. What happens when a cell is placed in a hypotonic solution?

6. What happens when a cell is placed in a hypertonic solution?

### Critical Thinking

7. 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?

8. If a there are 100 $X$ molecules on the outside of a cell and 10 $X$ molecules inside of the cell, will $X$ molecules flow into or out of the cell? Explain why.

## Points to Consider

The next lesson discusses photosynthesis.

- It is often said that plants make their own food. What do you think this means?
- What substances do you think would need to move into a leaf cell for the cell to make its own food?
- What substances would need to move out of a leaf cell?

# 4.2 Photosynthesis

## Lesson Objectives

- Explain the importance of photosynthesis.
- Write and interpret the chemical equation for photosynthesis.
- Describe what happens during the light reactions and the Calvin Cycle.

## Check Your Understanding

- How are plant cells different from animal cells?
- In what organelle does photosynthesis take place?

## Vocabulary

- chlorophyll
- photosynthesis
- stomata
- stroma
- thylakoid

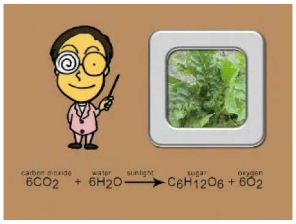
## What is Photosynthesis?

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? **Photosynthesis** is the process plants use to make their own "food" from the sun's energy, carbon dioxide and water.

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 is indirectly getting energy that began with the "food" formed through photosynthesis. Therefore, the process of photosynthesis is central to sustaining life on Earth.

During photosynthesis, carbon dioxide and water combine with solar energy to create glucose and oxygen. Glucose is a sugar that acts as the "food" source for plants. Oxygen, which is necessary for animal life, is the waste of photosynthesis.

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



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## The Process of Photosynthesis

Photosynthesis takes place in chloroplasts. Chloroplasts are one of the main differences between plant and animal cells. There are two separate parts of a chloroplast ( **Figure** 4.6).

- The inner compartments formed by the flattened sacs, or **thylakoids,** are called the thylakoid space. Energy from sunlight is absorbed by the pigment chlorophyll in the thylakoid membrane.
- The interior space that surrounds the thylakoids is filled with a fluid called **stroma.** This is where carbon dioxide is used to produce glucose.

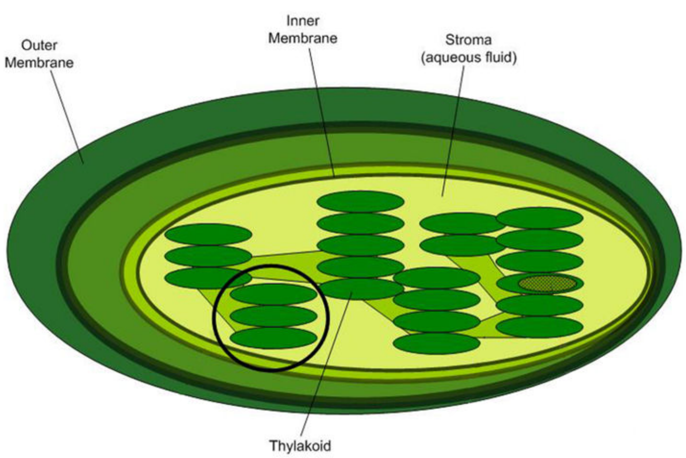



FIGURE 4.6

The chloroplast is the photosynthesis factory of the plant.

### The Reactants

What goes into the plant cell? The reactants of photosynthesis are carbon dioxide and water, and the energy from sunlight. This means that carbon dioxide, water, and the sun's energy are necessary for the chemical reactions of photosynthesis.

- **Chlorophyll** is the green pigment in leaves that captures energy from the sun.
- 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** 4.7).

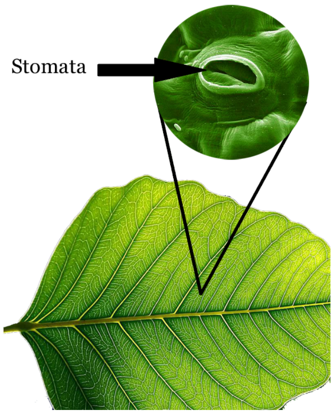



FIGURE 4.7
Stomata are special pores that allow gasses to enter and exit the leaf.

### The Products

What is produced by the plant cell? 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 for later in the form of carbohydrate molecules.
- Oxygen is a plant waste product. 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

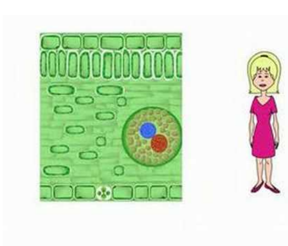
The overall chemical reaction for photosynthesis is 6 molecules of carbon dioxide ($CO_2$) and 6 molecules of water ($H_20$), with the addition of solar energy. This produces 1 molecule of glucose ($C_6H_{12}O_6$) and 6 molecules of oxygen ($O_2$) ( **Figure** 4.8). Using chemical symbols the equation is represented as follows:

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

## Lesson Summary

- The net reaction for photosynthesis is that carbon dioxide and water, together with energy from the sun, produce glucose and oxygen.

A review of photosynthesis can be viewed at http://www.youtube.com/watch?v=mpPwmvtDjWw (2:41).



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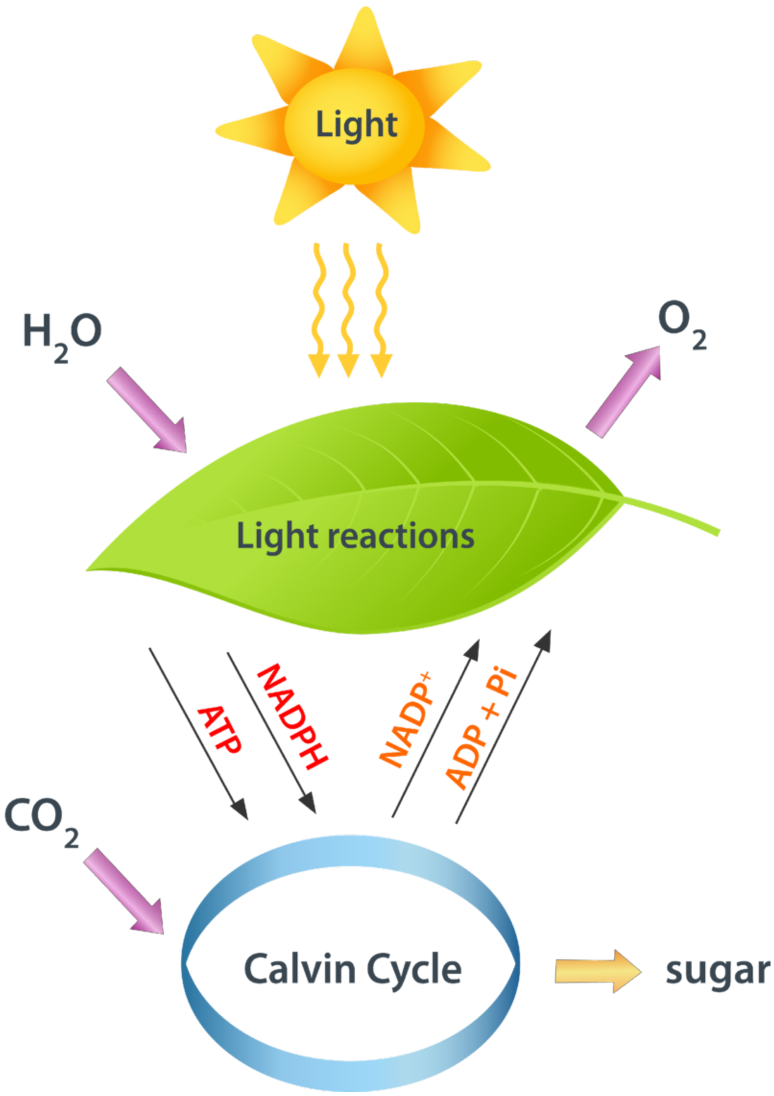


FIGURE 4.8
As is depicted here, the energy from sunlight is needed to start photosynthesis. The initial steps are called the light reactions as they occur only in the presence of light. During these initial reactions, water is used and oxygen is released. The energy from sunlight is converted into a 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.

## Review Questions

### Recall

1. What are the reactants required for photosynthesis?
2. What are the products of photosynthesis?

### Apply Concepts

3. What happens to the glucose produced from photosynthesis?
4. Why is it important to animals that oxygen is released during photosynthesis?
5. Describe the structures of the chloroplast where photosynthesis takes place.

### Critical Thinking

6. 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?

## Points to Consider

The next lesson is about Cellular Respiration.

- How do you gain energy from the food you eat?
- Which do you think provides more energy- a bowl of pasta or a small piece of candy?
- What "waste" gas do you exhale?

# 4.3 Cellular Respiration

## Lesson Objectives

- Write and explain the chemical formula for cellular respiration.
- Explain the two states of cellular respiration.
- Compare photosynthesis with cellular respiration.

## Check Your Understanding

- Where does the energy captured at the beginning of photosynthesis originate from?
- What is the form of chemical energy produced by photosynthesis?
- What occurs in oxidation and reduction reactions?

## Vocabulary

- aerobic respiration
- alcoholic fermentation
- anaerobic respiration
- ATP
- cellular respiration
- fermentation
- lactic acid fermentation

## 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. In other words, glucose and oxygen are converted into ATP, carbon dioxide, and water. **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.

## The Process of Cellular Respiration

What happens inside of the cell? Glucose is broken down in the cytoplasm of the cells and then transported to the mitochondria, the organelles known as the energy "powerhouses" of the cells ( **Figure** 4.9). Inside the mitochondria, the "broken-down" glucose is broken down again to release ATP. 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.

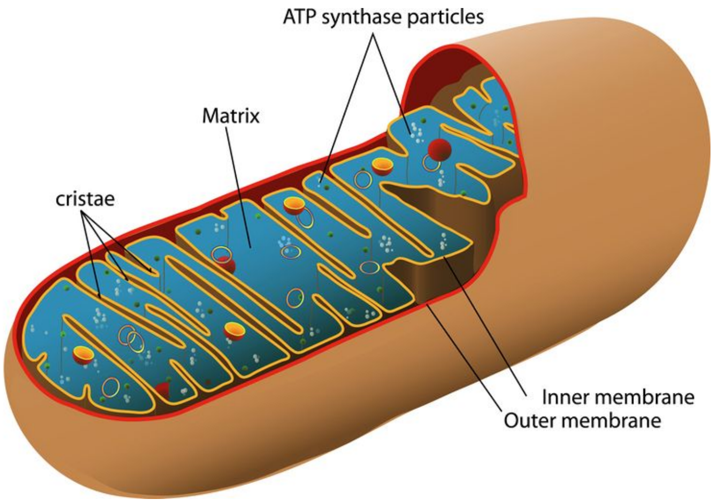


FIGURE 4.9
Most of the reactions of cellular respiration are carried out in the mitochondria.

### The Reactants

What goes into the cell? Oxygen and glucose are both reactants in the process 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 main product of cellular respiration is ATP. Waste products include 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.

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 1 molecule of glucose ($C_6H_{12}O_6$) and 6 molecules of oxygen ($O_2$) yields 6 molecules of carbon dioxide ($CO_2$) and 6 molecules of water ($H_20$). Using chemical symbols the equation is represented as follows:

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

## Connecting Cellular Respiration and Photosynthesis

Notice that the equation for cellular respiration is the direct opposite of photosynthesis ( **Figure** 4.10). While water was 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. This exchange of carbon dioxide and oxygen in all the organisms that use photosynthesis or cellular respiration worldwide helps to keep atmospheric oxygen and carbon dioxide at stable levels.

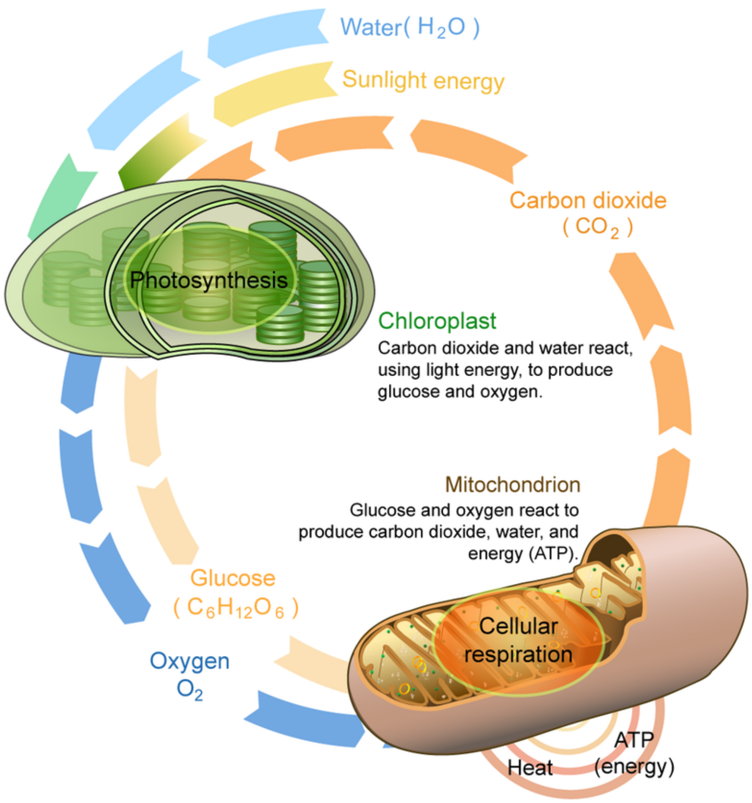


FIGURE 4.10
Cellular respiration and photosynthesis are direct opposite reactions. Some of the ATP made in the mitochondria is used as energy for work, and some is lost to the environment as heat. Can you explain what is depicted in this diagram?

## Fermentation

Sometimes cellular respiration is **anaerobic**, occurring in the absence of oxygen. In this process, called **fermentation**, no additional ATP is produced, so the organism only obtains the two ATP molecules per glucose molecule from the initial step of this process (compare that to 36-38 ATP produced with oxygen!).

Yeasts (single-celled eukaryotic organisms) perform **alcoholic fermentation** in the absence of oxygen, making 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 the alcohol evaporates. In wine making, the sugars of grapes are fermented to produce the 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, when oxygen cannot be delivered to the muscles quickly enough. The buildup of lactic acid is what makes your muscles sore after exercise.

Bacteria that produce lactic acid are used to make cheese and yogurt ( **Figure** 4.11). Tooth decay is also increased by lactic acid from the bacteria that use the sugars in your mouth for energy.

FIGURE 4.11
Products of fermentation include cheese (lactic acid fermentation) and wine (alcoholic fermentation).

## Lesson Summary

- Cellular respiration is the breakdown of glucose to release energy in the form of ATP.
- If oxygen is not available, the process of fermentation can break down glucose without the presence of oxygen.

A summary of cellular respiration can be viewed at http://www.youtube.com/watch?v=wqqYIgY40OE (8:50).

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## Review Questions

### Recall

1. What is the purpose of cellular respiration?
2. Where is glucose broken down to form ATP?

### Apply Concepts

3. What are the products of alcoholic fermentation?
4. Write the chemical reaction for the overall process of cellular respiration.
5. What produces more ATP, aerobic or anaerobic cellular respiration? What is the purpose of fermentation?

### Critical Thinking

6. Why do your muscles get sore after vigorous exercise?
7. Why is the cellular respiration equation the opposite of the photosynthesis equation?

## Supplemental Links

- http://biology.clc.uc.edu/Courses/bio104/cellresp.htm
- http://www.emc.maricopa.edu/faculty/farabee/BIOBK/BioBookGlyc.html
- http://biology.clc.uc.edu/Courses/bio104/cellresp.htm
- http://www.science.smith.edu/departments/Biology/Bio231/glycolysis.html

## Points to Consider

- What do you think could happen if your cells divide uncontrollably?
- When new life is formed, do you think it receives all the DNA of the mother and the father?
- Why do you think you might need new cells throughout your life?

# 4.4 References

1. Mariana Ruiz Villarreal (LadyofHats) for the CK-12 Foundation. CK-12 Foundation . CC BY-NC 3.0
2. Mariana Ruiz Villarreal (User:LadyofHats/Wikimedia Commons), modified by Hana Zavadska. http://commons.wikimedia.org/wiki/File:Scheme_simple_diffusion_in_cell_membrane-en.svg . Public Domain
3. Mariana Ruiz Villarreal (User:LadyofHats/Wikimedia Commons). http://commons.wikimedia.org/wiki/File:Osmotic_pressure_on_blood_cells_diagram.svg . Public Domain
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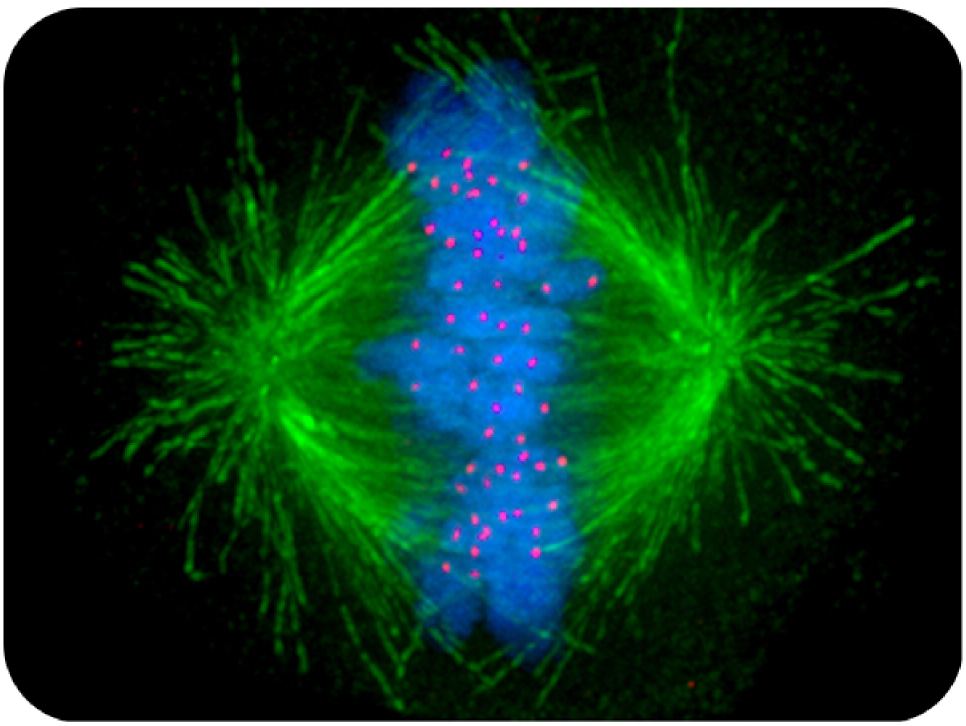
# CHAPTER 5 MS Cell Division, Reproduction, and DNA

## Chapter Outline





What has to happen for a cell to divide? Plenty. The above image shows the mitotic spindle in a human cell. The mitotic spindle separates DNA in cells that are dividing. But that is just one step in the process. Why do you think cells need to divide? Do all cells divide the same way? How do cells help us reproduce? What would happen to living things if their cells failed to divide? What happens if cells divide uncontrollably? Think about these questions as you begin to understand why and how cells divide and how cell division helps the reproduction of all living things.

*User:Afunguy/Wikipedia. commons.wikimedia.org/wiki/File:Kinetochore.jpg. Public Domain.*

# 5.1 Cell Division

## Lesson Objectives

- Explain why cells need to divide.
- List the stages of the cell cycle and explain what happens at each stage.
- List the stages of mitosis and explain what happens at each stage.

## Check Your Understanding

- What is the cell theory?
- In what part of your cells is the genetic information located?

## Vocabulary

- anaphase
- cancer
- cell cycle
- chromosome
- cytokinesis
- daughter cell
- interphase
- metaphase
- mitosis
- parent cell
- prophase
- sister chromatids
- spindle
- telophase

## Why Cells Divide

Imagine the first stages of life. In humans, 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 cell theory, all cells must come from existing cells. From that one cell, an entire baby will develop.

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** 5.1).

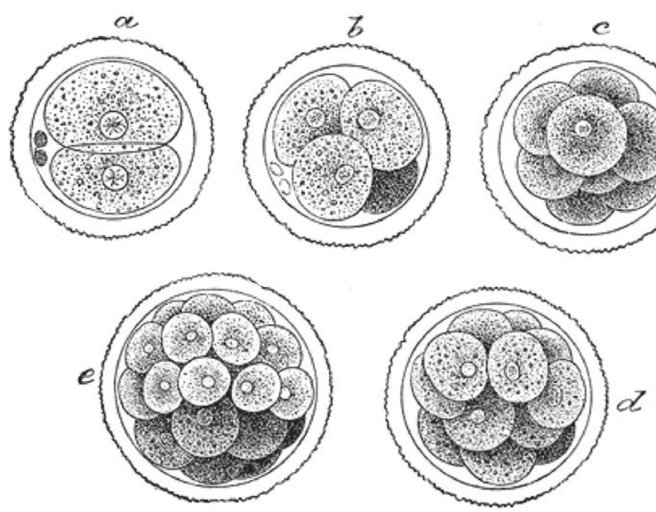


FIGURE 5.1

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.
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.

## The Cell Cycle

The process of cell division in eukaryotic cells is carefully controlled. The **cell cycle** is the lifecycle of a cell, with cell division at the end of the cycle. Like a human lifecycle that is made up of different phases, like childhood, adolescence, and adulthood, there are a series of steps that lead to cell division ( **Figure** 5.2).

These steps can be divided into two main components, interphase and mitosis.

1. Interphase: 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.
2. Mitosis: The stage when the cell prepares to become two cells.

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. DNA replication will be further discussed in lesson 5.3.

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.

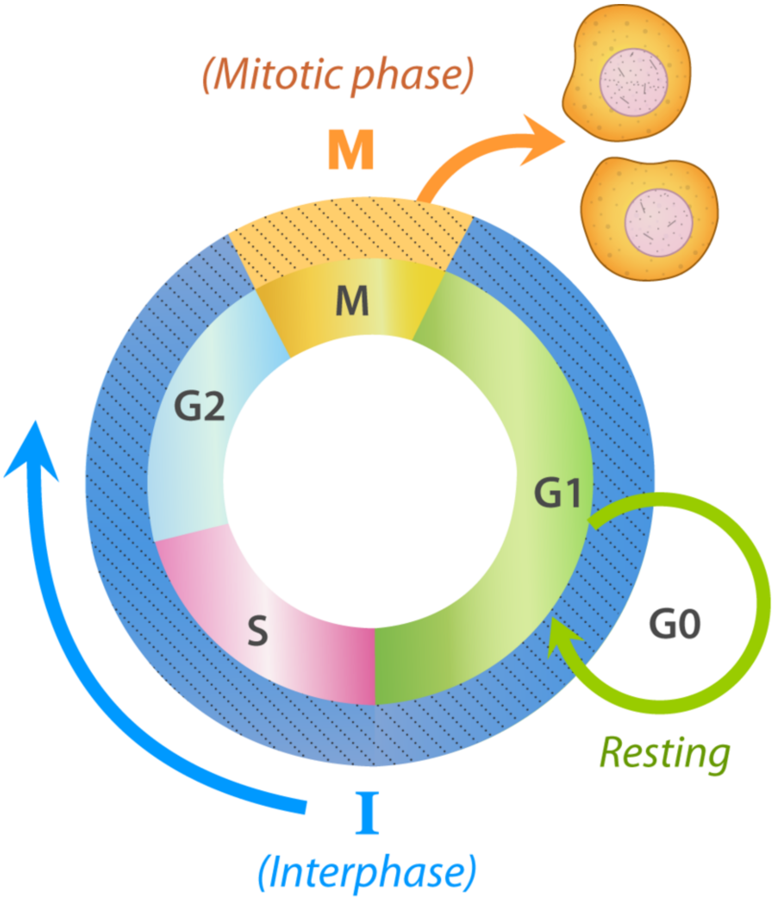
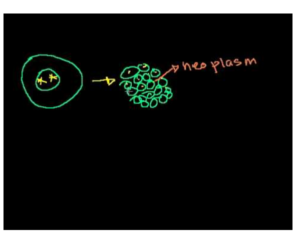



FIGURE 5.2
The cell cycle is the repeated process of growth and division. Notice that most of the cell cycle is spent in interphase (G1, S, and G2) (I). G0 is a resting state of the cell cycle.

During **mitosis**, the nucleus divides. Mitosis is followed by **cytokinesis**, when the cytoplasm divides, resulting in two cells. After cytokinesis, cell division is complete. Scientists say that one **parent cell**, or the dividing cell, forms two genetically identical **daughter cells,** or 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**, which causes cell division to happen too fast. A tumor can result from this kind of growth.

Cancer is discussed in the video at http://www.youtube.com/watch?v=RZhL7LDPk8w . (12:36).

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Two animations of the cell cycle are available at the following links. See if you can explain what is happening in these animations.

- http://www.wisc-online.com/objects/index_tj.asp?objID=AP13604

- http://www.cellsalive.com/cell_cycle.htm

## 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. The DNA inside of the nucleus is also copied. The copied DNA needs to be moved into the nucleus, so each cell can have a correct set of genetic instructions.

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. After the DNA is replicated during the S stage of interphase, each chromosome has two identical molecules of DNA, called **sister chromatids**, forming the "X" shaped molecule depicted in **Figure** 5.3.

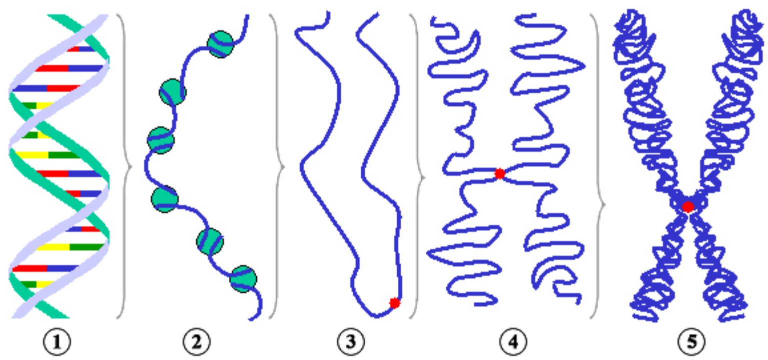


FIGURE 5.3
The DNA double helix wraps around proteins (2) and tightly coils a number of times to form a chromosome (5). This figure shows the complexity of the coiling process. The red dot shows the location of the centromere, where the microtubules attach during mitosis and meiosis.

### The Four Phases of Mitosis

During mitosis, the two sister chromatids must be split apart. Each resulting chromosome is made of *1/2* of the "X". Through this process, each daughter cell receives one copy of each chromosome. Mitosis is divided into four phases ( **Figure** 5.4):

1. **Prophase**: The chromosomes "condense," or become so tightly wound that you can see them under a microscope. The wall 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 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, resulting in two sets of identical chromosomes.
4. **Telophase**: The spindle dissolves and nuclear envelopes form around the chromosomes in both cells.

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." The cells separate, producing two genetically identical cells, each with its own nucleus. **Figure** 5.5 is a representation of dividing plant cells.

The phases of mitosis are discussed in the video: http://www.youtube.com/watch?v=LLKX_4DHE3I (20:42).

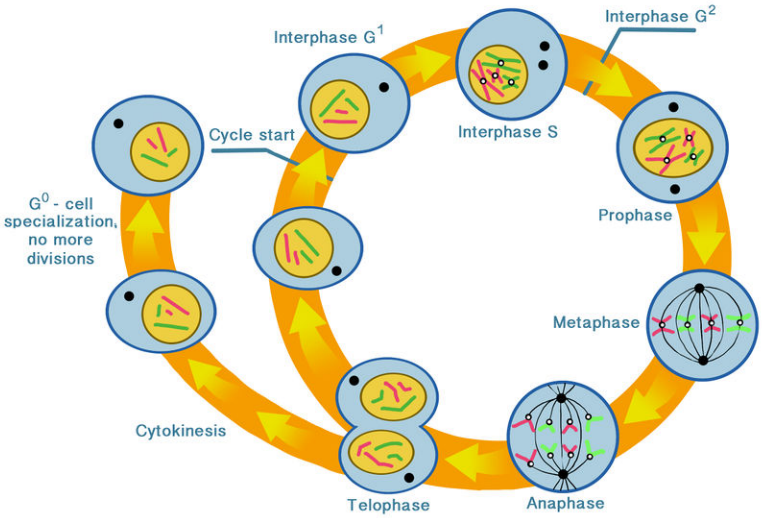
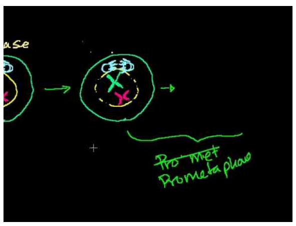



FIGURE 5.4
An overview of the cell cycle and mitosis: during prophase the chromosomes condense, during metaphase the chromosomes line up, during anaphase the sister chromatids are pulled to opposite sides of the cell, and during telophase the nuclear envelope forms.



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Additional animations of mitosis can be viewed at the following links:

- http://www.cellsalive.com/mitosis.htm
- http://www.youtube.com/watch?v=7hQ5xXJSmK4

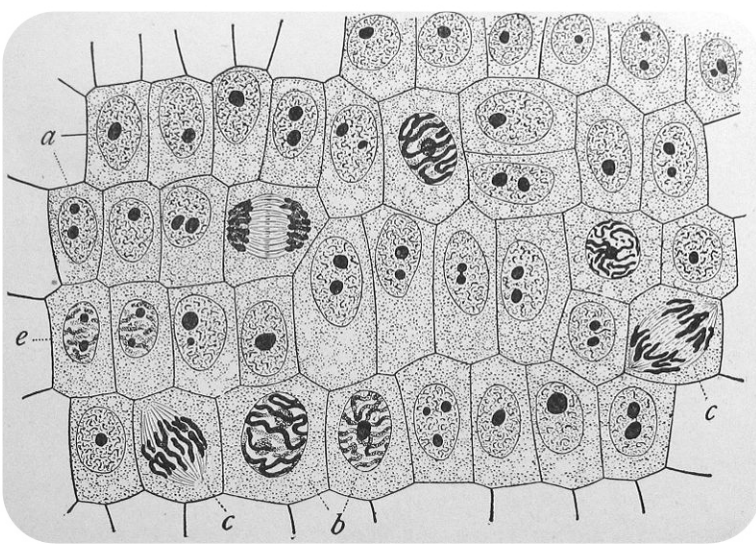
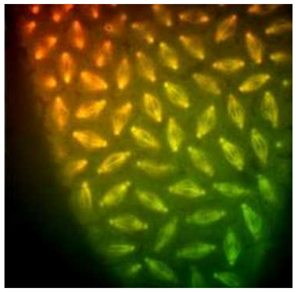



FIGURE 5.5
This is a representation of dividing plant cells. Cell division in plant cells differs slightly from animal cells as a cell wall must form. Note that most of the cells are in interphase. Can you find examples of the different stages of mitosis?

*Mitosis in Real Time* can be viewed at http://www.youtube.com/watch?v=m73i1Zk8EA0 (0:19).



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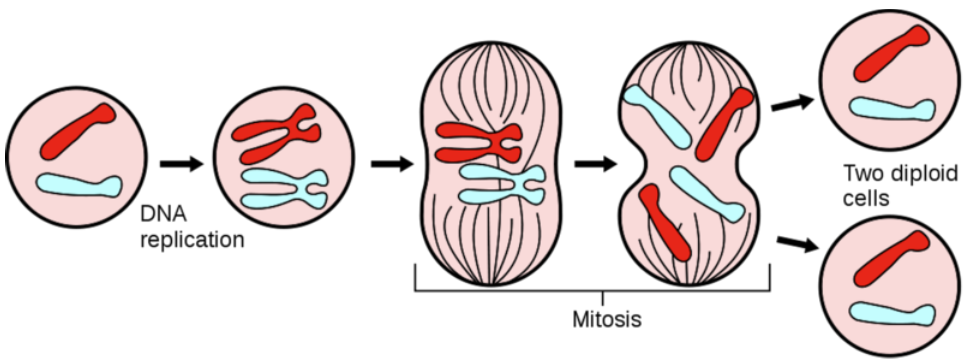
## Lesson Summary

- Cells divide for growth, development, reproduction and replacement of injured or worn-out cells.
- The cell cycle is a series of controlled steps by which a cell divides.
- During mitosis, the newly duplicated chromosomes are divided into two daughter nuclei.
- This summary diagram depicts one cell dividing into two genetically identical cells. Mitosis occurs after DNA replication. A diploid cell has two sets of chromosomes, as is shown here.




## Review Questions

### Recall

1. In what phase of mitosis are chromosomes moving toward opposite sides of the cell?

2. In what phase of mitosis do the duplicated chromosomes condense?

3. What step of the cell cycle is the longest?

4. What is the term for the division of the cytoplasm?

5. What happens during the S stage of interphase?

### Apply Concepts

6. Interphase used to be considered the "resting" stage of the cell cycle. Why is this not correct?

7. What are some reasons that cells divide?

8. During what stage of the cell cycle does the cell double in size?
9. Why must cell division be tightly regulated?

### Critical Thinking

10. What would happen if the cells in your liver stopped going through the process of mitosis?
11. What do you think might happen if mitosis could NOT stop happening to the cells in your brain?

## Further Reading / Supplemental Links

- http://www.biology.arizona.edu/Cell_bio/tutorials/cell_cycle/cells3.html
- http://biology.clc.uc.edu/courses/bio104/mitosis.htm

## Points to Consider

- How might a cell without a nucleus divide?
- How are new cells made that include the DNA of two parents?

# 5.2 Reproduction

## Lesson Objectives

- Name the types of asexual reproduction.
- Explain the advantage of sexual reproduction.
- List the stages of meiosis and explain what happens in each stage.

## Check Your Understanding

- Can something that does not reproduce still be considered living?
- What stores the genetic information that is passed on to offspring?
- How many chromosomes are in the human nucleus?

## Vocabulary

- allele
- asexual reproduction
- binary fission
- crossing-over
- cross-pollination
- diploid
- external fertilization
- gamete
- gonad
- haploid
- internal fertilization
- meiosis
- ovaries
- parthenogenesis
- sexual reproduction
- testes
- zygote

## What is Reproduction?

What does reproduction mean? Can an organism be considered alive if it cannot make the next generation? Since individuals cannot live forever, they must reproduce for the species to survive. Reproduction is the ability to make the next generation.

Two methods of reproduction are:

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

For humans to reproduce, DNA must be passed from the mother and father to the child. Humans cannot reproduce with just one parent, but it is possible in other organisms, like bacteria, some insects and some fish. These organisms can reproduce asexually, meaning that the offspring (children) have a single parent and share the exact same genetic material as the parent. This is very different from humans.

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 cannot mix beneficial traits from both parents. An organism that is born through asexual reproduction only has the DNA from the one parent, and it is the exact copy of that parent. This can cause problems for the individual. For example, if the parent organism has a gene that causes cancer, the offspring will also have the gene that causes cancer. Organisms produced sexually may or may not inherit the cancerous gene because there are two parents mixing up their 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** 5.6). First, their chromosome replicates (bacteria only have one chromosome) and the cell enlarges. After cell division, the two new cells each have one identical chromosome (mitosis is not necessary because bacteria do not have nuclei). Then, new membranes form to separate the two cells. This simple process allows bacteria to reproduce very rapidly.
2. Flatworms, an animal species. Flatworms divide in two, then each half regenerates into a new flatworm identical to the original.
3. Different types of insects, fish, and lizards. These organisms can reproduce asexually through a process called parthenogenesis ( **Figure** 5.7). **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.

## 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, a **zygote,** the first cell of a new organism, is formed ( **Figure** 5.8). The zygote will divide and grow into the embryo.

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,** which produce the sperm, and the female gonads are the **ovaries,** which produce the eggs. Sperm and egg, the two sex cells, are known as **gametes**, and can combine two different ways:

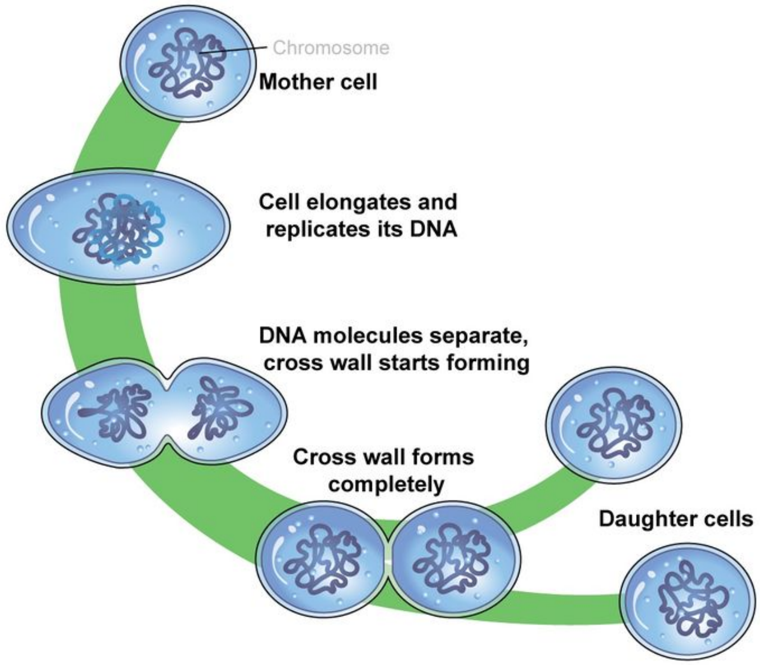



FIGURE 5.6
Bacteria reproduce by binary fission. Shown is one bacterium reproducing and becoming two bacteria.

FIGURE 5.7
This Komodo dragon was born by parthenogenesis.

1. Fish and other aquatic animals release their gametes in the water, which is called **external fertilization.** These gametes will combine by chance ( **Figure** 5.9).
2. Animals that live on land reproduce by **internal fertilization**. Typically males have a penis that deposits

FIGURE 5.8
During sexual reproduction, a sperm fertilizes an egg.

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.

FIGURE 5.9
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** 5.10) carry the pollen from flower to flower.

- 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.

FIGURE 5.10
Butterflies receive nectar when they deposit pollen into flowers, resulting in cross-pollination.

## Meiosis and Gametes

**Meiosis** is a process of cell division that produces sex cells, or gametes. 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 information from the mother and from the father, so the gametes must contain half of the chromosomes found in normal body cells.

In humans, our 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. The homologous chromosomes are separated when gametes are formed. Therefore, gametes have only 23 chromosomes, not 23 pairs.

**Alleles** are alternate forms of genes found on chromosomes. Since the separation of chromosomes into gametes is random, it 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 in a gamete.

### Haploid vs. Diploid

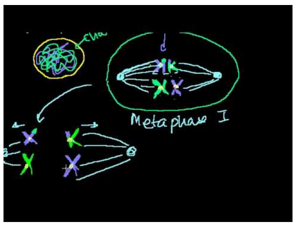
A cell with two sets of chromosomes is **diploid**, referred to as $2n$, where $n$ is the number of sets of chromosomes. Most of the cells in a human body are diploid. A cell with one set of chromosomes, such as a gamete, is **haploid,** referred to as $n$. Sex cells are haploid. When a haploid sperm ($n$) 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.

### Meiosis

Before meiosis begins, DNA replication occurs, so each chromosome contains two sister chromatids that are identical to the original chromosome.

Meiosis is divided into two divisions: Meiosis I and Meiosis II. Each division is similar to mitosis and can be divided into the same phases: prophase, metaphase, anaphase, and telophase. Between the two divisions, DNA replication does not occur. Through this process, one diploid cell will divide into four haploid cells.

The phases of meiosis are discussed at http://www.youtube.com/watch?v=ijLc52LmFQg (27:23).

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### Meiosis I

During meiosis I, the pairs of homologous chromosomes are separated from each other.

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** 5.11), which is the exchange of DNA between homologous chromosomes. Crossing-over increases the new combinations of alleles in the gametes. Without crossing-over, the offspring would always inherit all of the many 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 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 separate.
4. Telophase I: The spindle fibers dissolves, but a new nuclear envelope does not need to form. This is because the nucleus will divide again. No DNA replication happens between meiosis I and meiosis II because the chromosomes are already duplicated.

### Meiosis II

During meiosis II, the sister chromatids are separated and the gametes are generated.

The steps are outlined below:

1. Prophase II: The chromosomes condense.
2. Metaphase II: The chromosomes line up one on top of the next along the middle of the cell.
3. Anaphase II: The sister chromatids separate.
4. Telophase II: Nuclear envelopes form around the chromosomes in all four cells.

After cytokinesis, each cell has divided again. Therefore, meiosis results in four daughter cells with half the DNA of the parent cell ( **Figure** 5.12). In human cells, the parent cell has 46 chromosomes, so the cells produced by meiosis have 23 chromosomes. These cells will become gametes.

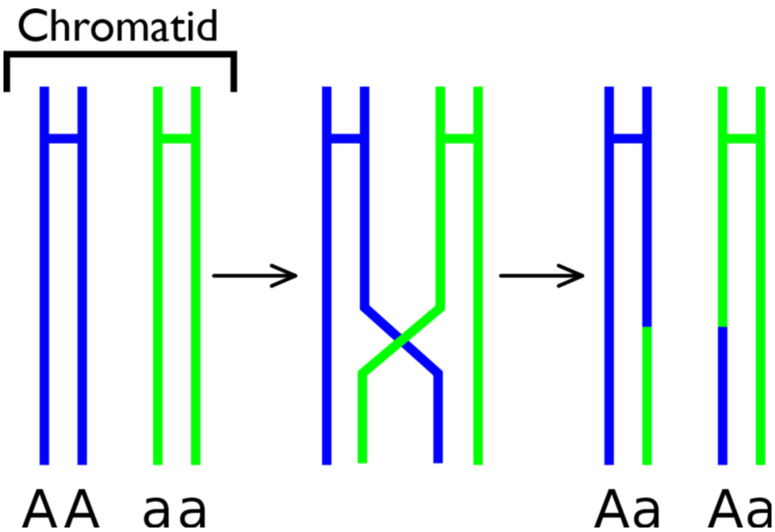


FIGURE 5.11
During crossing-over, segments of DNA are exchanged between non-sister chromatids of homologous chromosomes. Notice how this can result in an allele (A) on one chromatid being moved onto the other non-sister chromatid.

## Mitosis vs. Meiosis: A Comparison

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

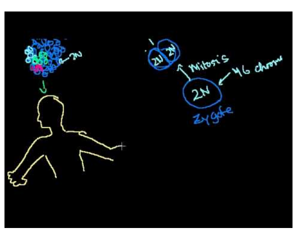

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**Figure** 5.13 is a comparison between binary fission, mitosis, and meiosis. Mitosis and meiosis are also compared in **Table** 5.1.

Animations of meiosis can be found at the following sites:

- http://www.cellsalive.com/meiosis.htm
- http://www.youtube.com/watch?v=MqaJqLL49a0

TABLE 5.1: **Mitosis vs. Meiosis: A Comparison**

| | **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 |
| Daughter cells identical to parent cells? | Yes | No |
| Daughter cells identical to each other? | Yes | No |

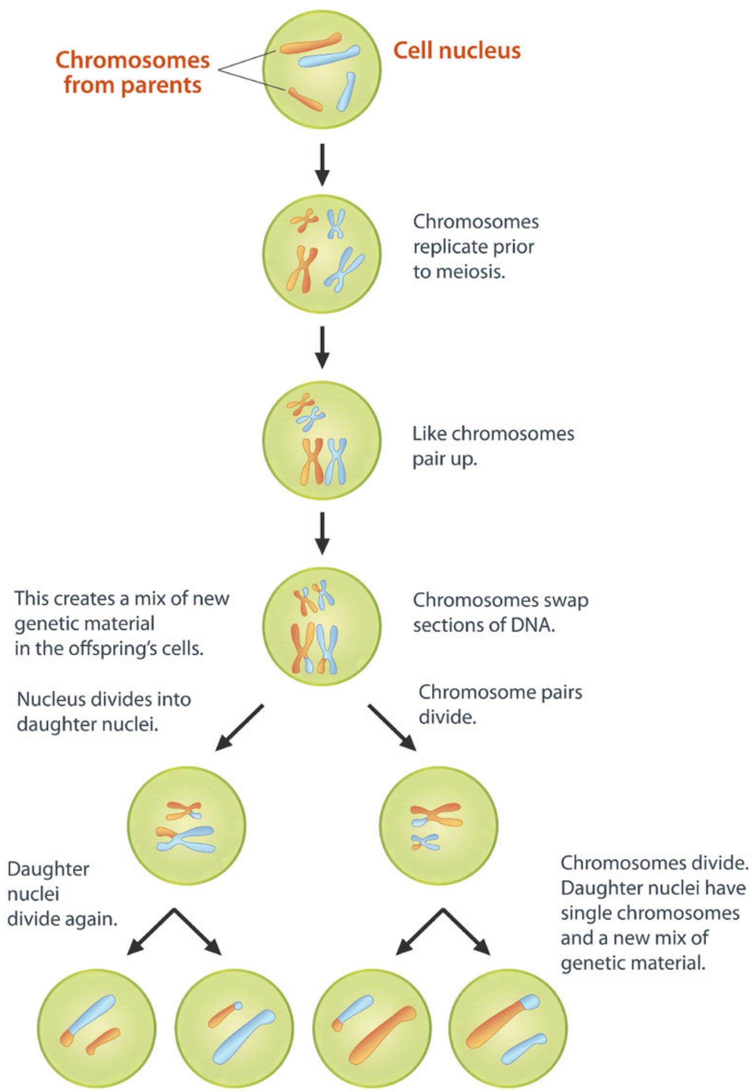



FIGURE 5.12
An overview of meiosis.

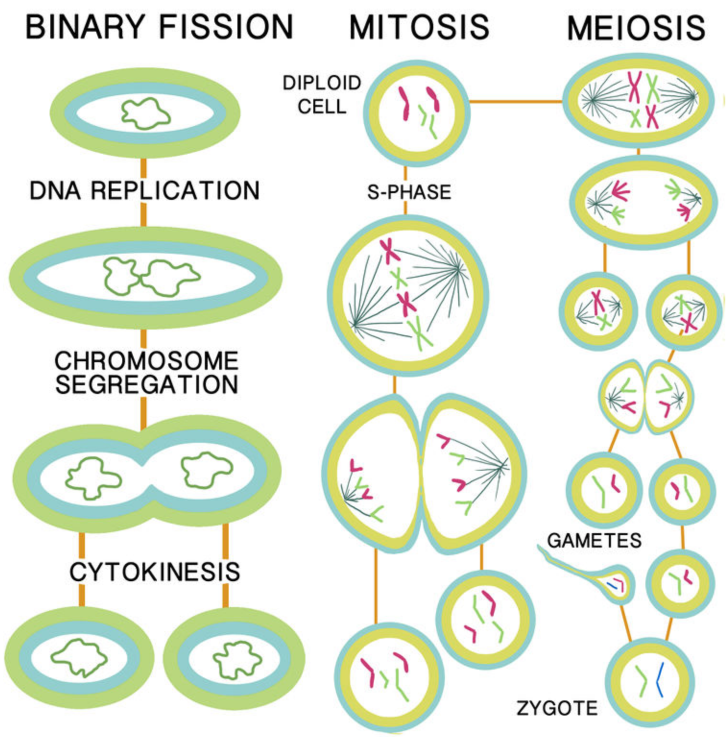



FIGURE 5.13

A comparison between binary fission, mitosis, and meiosis.

## Lesson Summary

- Organisms can reproduce sexually or asexually.
- The gametes in sexual reproduction must have half the DNA of the parent.
- Meiosis is the process of nuclear division that forms gametes.

## Review Questions

### Recall

1. What is parthogenesis?
2. During what phase of meiosis do homologous chromosomes separate?
3. What is the purpose of meiosis?
4. In what phase of meiosis do homologous chromosomes pair up?

### Apply Concepts

5. Explain how organisms reproduce asexually.
6. Explain how birds fertilize their eggs.
7. How do most plants reproduce sexually?
8. Compare and contrast the process of mitosis and the process of meiosis.

### Critical Thinking

9. How would sexual reproduction in a lizard be different than in a fish?
10. What is the advantage of sexual reproduction over asexual reproduction?
11. If an organism has 12 chromosomes in its cells, how many chromosomes will be in its gametes?

## Further Reading / Supplemental Links

- http://www.emc.maricopa.edu/faculty/farabee/BIOBK/BioBookmeiosis.html
- http://www.biology.arizona.edu/Cell_BIO/tutorials/meiosis/page3.html

## Points to Consider

- What must be replicated prior to mitosis?
- How do you think DNA might be replicated?
- What might happen if there is a mistake during DNA replication?

# 5.3 DNA, RNA, and Protein Synthesis

## Lesson Objectives

- Explain the chemical composition of DNA.
- Explain how DNA synthesis works.
- Explain how proteins are coded for and synthesized.
- Describe the three types of RNA and the functions of each.

## Check Your Understanding

- What is the purpose of DNA?
- When is DNA replicated?

## Vocabulary

- amino acid
- DNA
- DNA replication
- double helix
- gene
- mutagen
- mutation
- nucleotide
- RNA
- semiconservative replication
- transcription
- translation

## 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 long chain of nucleotides.

**Nucleotides** are composed of 3 main parts:

1. Phosphate group
2. 5-carbon sugar
3. 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 various sequences of these four 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** 5.14 and **Figure** 5.15).

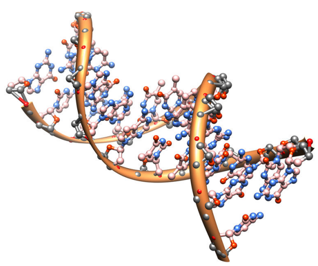
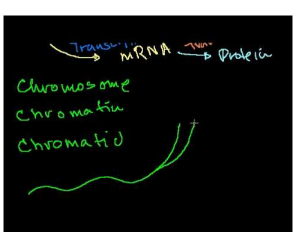


FIGURE 5.14
DNA's three-dimensional structure is a double helix. The hydrogen bonds between the bases at the center of the helix hold the helix together.

## 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. For example, if one DNA strand reads ATGCCAGT, the other strand will be made up of the complementary bases: TACGGTCA.

The vocabulary of DNA, including chromosomes, chromatids, chromatin, transcription, translation, and replication, is discussed at http://www.youtube.com/watch?v=s9HPNwXd9fk (18:23).

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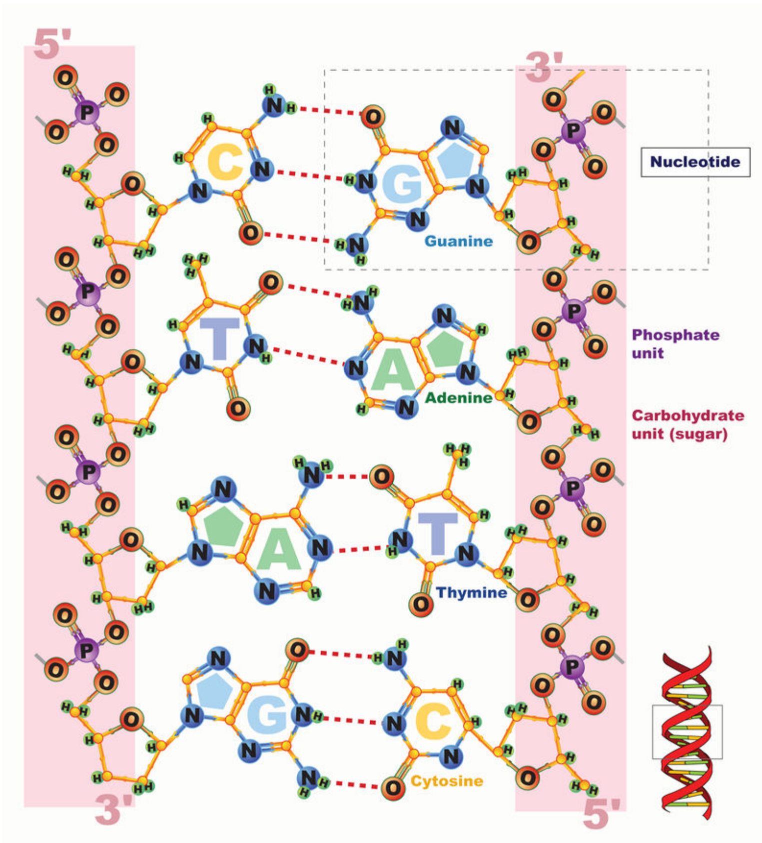


FIGURE 5.15
The chemical structure of DNA includes a chain of nucleotides consisting of a 5-carbon sugar, a phosphate group, and a nitrogen base. Notice how the sugar and phosphate form the backbone of DNA (one strand in blue), with the hydrogen bonds between the bases joining the two strands.

## DNA Replication

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. DNA replication happens before cell division. Below are the steps involved in DNA replication:

1. The DNA helix unwinds like a zipper, as the bonds between the base pairs are broken.
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 the bases are placed in the right order because of the base pairing rules. If ATG is on the "template strand," then TAC will be on the new DNA strand.
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** 5.16).

## Protein Synthesis

The DNA sequence contains the instructions to make units called amino acids, which are assembled in a specific order to make proteins. In short, DNA contains the instructions to create proteins. Each strand of DNA has many

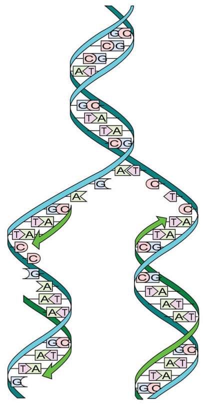

FIGURE 5.16

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.

separate sequences that code for a specific protein. Units of DNA that contain code for the creation of one protein are called **genes.** An overview of protein synthesis can be seen at this animation: http://www.biostudio.com/demo_freeman_protein_synthesis.htm

### 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 use the same genes to 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.

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, giving different cell types different functions.

### Three Types of RNA

DNA contains the instructions to create proteins, but it does not make proteins itself. DNA is located in the nucleus, 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.

All three RNAs are nucleic acids, made of nucleotides, similar to DNA. 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.

## Transcription

mRNA is created by using DNA as a template. The process of constructing an mRNA molecule from DNA is known as **transcription** ( **Figure** 5.17 and **Figure** 5.18). The double helix of DNA unwinds and the nucleotides follow basically the same base pairing rules to form the correct sequence in the mRNA. This time, however, U pairs with each A in the DNA. In this manner, the genetic code is passed on to the mRNA.

Two multimedia links of protein synthesis are provided below.

- http://www-class.unl.edu/biochem/gp2/m_biology/animation/gene/gene_a2.html

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

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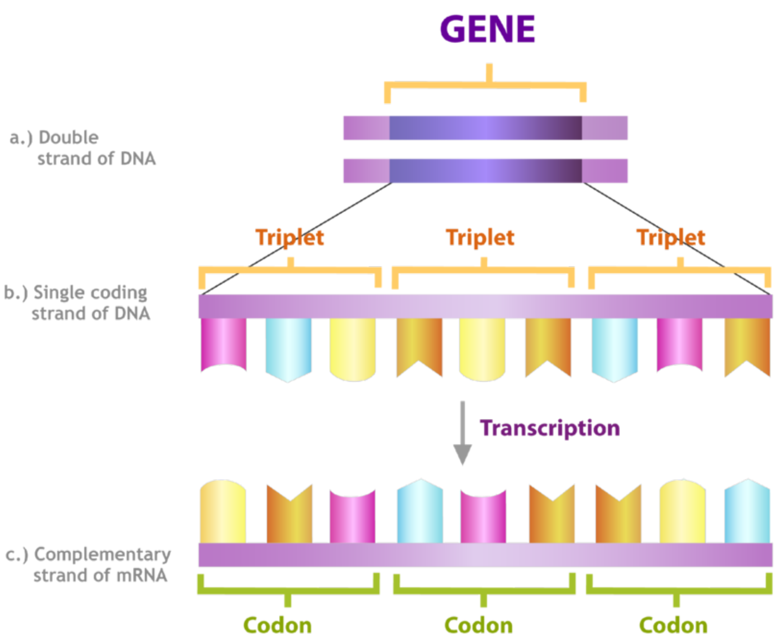


FIGURE 5.17

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

## Translation

The mRNA is directly involved in the protein-making process. mRNA tells the ribosome ( **Figure** 5.19) how to create a protein. The process of reading the mRNA code in the ribosome to make a protein is called **translation** ( **Figure** 5.20). Sets of three bases, called codons, are read in the ribosome, the organelle responsible for making proteins.

The following are the steps involved in translation:

1. mRNA travels to the ribosome from the nucleus.


FIGURE 5.18
Base-pairing ensures the accuracy of transcription. Notice how the helix must unwind for transcription to take place.

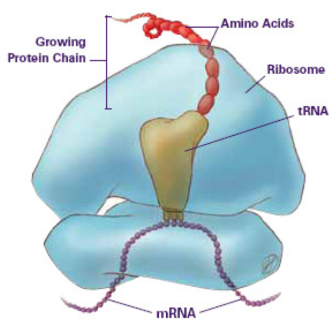


FIGURE 5.19
Ribosomes translate RNA into a protein with a specific amino acid sequence. The tRNA binds and brings to the ribosome the amino acid encoded by the mRNA. Ribosomes are made of rRNA and proteins.

2. 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 and different codons code for different ones. For example, GGU codes for the amino acid glycine, while GUC codes for valine.
3. tRNA reads the mRNA code and brings a specific amino acid to attach to the growing chain of amino acids. Each tRNA carries only one type of amino acid and only recognizes one specific codon.
4. tRNA is released from the amino acid.
5. 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.

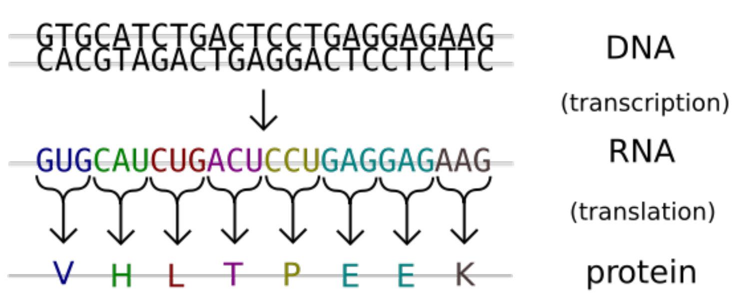


FIGURE 5.20
This summary of how genes are expressed shows that DNA is transcribed into RNA, which is translated in turn to protein.

The chart in **Figure** 5.21 is used to determine which amino acids correspond to which codons. An interactive activity for transcribing and translating a gene can be found at http://learn.genetics.utah.edu/units/basics/transcribe/ .

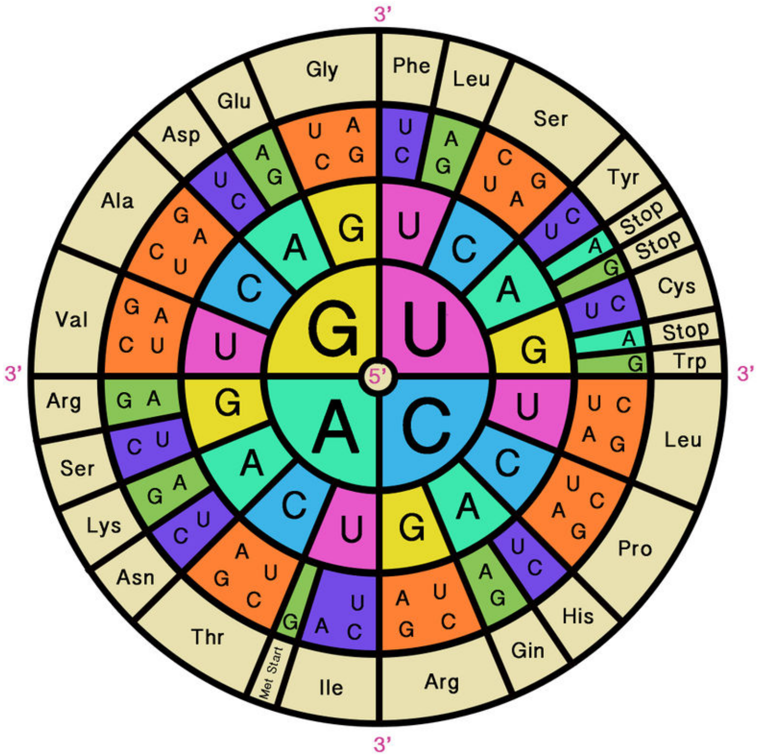


FIGURE 5.21
This chart shows the genetic code used by all organisms. For example, an RNA codon reading GUU would encode for a valine (Val) according to this chart. Start at the center for the first base of the three base codon, and work your way out. Notice for valine, the second base is a U and the third base of the codon may be either a G, C, A, or U. Similarly, glycine (Gly) is encoded by a GGG, GGA, GGC, and GGU.

## Mutations

The process of DNA replication is not always 100% accurate, and sometimes the wrong base is inserted in the new strand of DNA. 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. Sometimes, a mutation can cause the protein to be made incorrectly, which 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.

However, in rare circumstances, 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.

Mutations may also occur in chromosomes. Possible types of mutations in chromosomes ( **Figure** 5.22) include:

1. Deletion: When a segment of DNA is lost, so there is a missing segment in the chromosome.
2. Duplication: When a segment of DNA is repeated, creating a longer chromosome.
3. Inversion: When a segment of DNA is flipped and then reattached to the 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.

If a single base is deleted (called a point mutation), there can be huge effects on the organism because this may cause

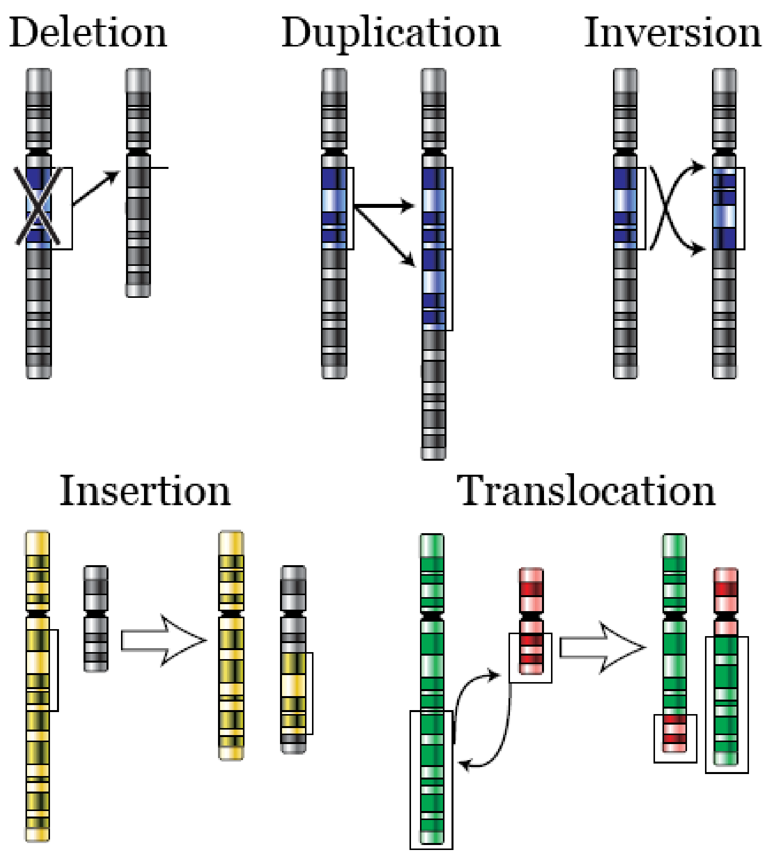


FIGURE 5.22
Mutations can arise in DNA through deletion, duplication, inversion, insertion, and translocation within the chromosome.

a "frameshift mutation." Remember that the bases are read in groups of three by the tRNA. If the reading frame gets off by 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 you wrote "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.

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.

## Lesson Summary

- DNA stores the genetic information of the cell in the sequence of its 4 bases: adenine, thymine, guanine, and cytosine.
- The information in a small segment of DNA, a gene, is sent by mRNA to the ribosome to synthesize a protein.
- Within the ribosome, tRNA reads the mRNA in sets of three bases (triplets), called codons, which encode for the specific amino acids that make up the protein.
- A mutation is a permanent change in the sequence of bases in DNA.

## Review Questions

### Recall

1. What is a nucleotide made out of?
2. Describe the process of DNA replication.
3. What is made in the process of transcription?
4. What is made in the process of translation?
5. Name a mutagen.

### Apply Concepts

6. Translate the following segment of DNA into RNA: AGTTC
7. Write the complimentary DNA nucleotides to this strand of DNA: GGTCCA
8. Nucleotides are subunits of which two macromolecules?
9. Amino acids are subunits that make up what macromolecule?
10. How does RNA encode for proteins?

### Critical Thinking

11. How does a mutation in a strand of DNA affect translation and transcription?
12. Given the DNA sequence, ATGTTAGCCTTA, what is the mRNA sequence? What is the amino acid sequence?

## Further Reading / Supplemental Links

- http://nobelprize.org/educational_games/medicine/dna_double_helix/readmore.html
- http://learn.genetics.utah.edu/units/basics/builddna/
- http://sickle.bwh.harvard.edu/scd_background.html

## Points to Consider

- Your cells have "proofreaders" that replace mismatched pairs that occurred during DNA synthesis. How would that affect the rate of mutation in your body?
- There are many diseases due to mutations in the DNA. These are known as genetic diseases, and many can be passed onto the next generation. Think about how a single base change cause a huge medical problem.
- Your DNA contains the instructions to make you. So is everyone's DNA different? Can it be used to distinguish individuals, like a fingerprint?

# 5.4 References


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# Chapter 6 MS Genetics

## Chapter Outline



The above puppies are offspring from the same parents. Why don't the puppies look identical to each other? Do you think they are identical to their parents? Or do you think they have some traits from their mother and some from their father?

Just as you don't look exactly like your parents, neither do these puppies. Has anyone ever told you, "You have your father's eyes"? or, "You have red hair like your grandmother; it must have skipped a generation." You don't look identical to your parents or to your grandparents. But many of their traits are passed down to you.

Genetics seeks to answer why and how we, and all living things, inherit traits from the previous generation.

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# 6.1 Gregor Mendel and the Foundations of Genetics

## Lesson Objectives

- Explain Mendel's law of segregation.
- Draw a Punnett square to make predictions about the traits of the offspring of a simple genetic cross.

## Check Your Understanding

- What is the genetic material of our cells?
- How does meiosis affect the chromosome number in gametes?

## Vocabulary

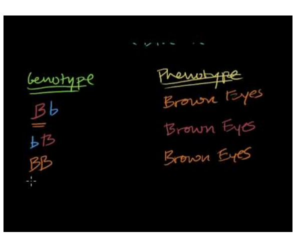
- dominant
- F1 generation
- F2 generation
- genetics
- Punnett square
- recessive

## 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. If you inherit a trait from your parents, you can be inheriting their 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.

An introduction to heredity can be seen at http://www.youtube.com/watch?v=eEUvRrhmcxM (17:27).

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In the late 1850s, an Austrian monk named Gregor Mendel ( **Figure** 6.1) performed the first genetics experiments. To study genetics, Mendel chose to work with pea plants because they have easily identifiable traits ( **Figure** 6.2). For example, pea plants are either tall or short, which are easily identifiable traits. Pea plants grow quickly, so he could complete many experiments in a short period of time.

FIGURE 6.1
Gregor Mendel

Mendel also used pea plants because they can either self-pollinate or be cross-pollinated by hand, by moving pollen from one flower to the stigma of another. When one plant's sex cells combine with another plant's sex cells, it 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 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."

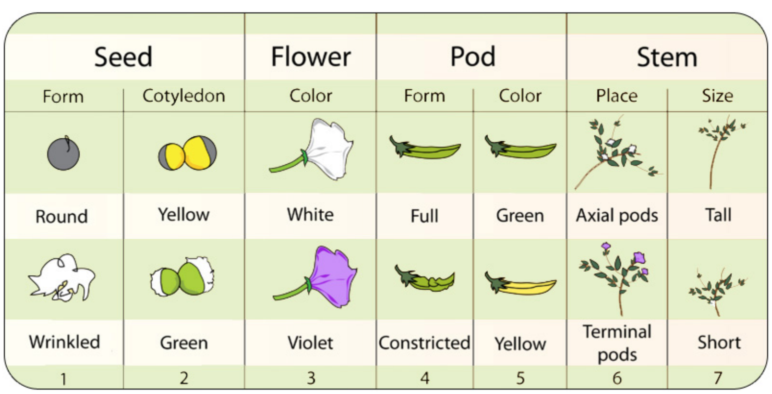



FIGURE 6.2
Characteristics of pea plants.

## 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 (children) 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. There was no blending of traits in any of Mendel's experiments.

An interactive pea plant experiment can be found at http://sonic.net/~nbs/projects/anthro201/exper/ .

## Dominance

Mendel had to come up with a theory of inheritance to explain his results. He developed a theory called "the law of segregation."

He proposed that each pea plant had two hereditary factors for each trait. There were two possibilities for each hereditary factor, such as short or tall. 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.

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. When fertilization occurs, the offspring receive one factor from each gamete, so the offspring have two hereditary factors.

This law explains what Mendel had seen in the F1 generation, because the two heredity factors 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, all the plants appeared tall.

In the F2 generation, produced by the cross of the F1, 25% of the offspring would have two short heredity factors, so they would appear short. 75% would have at least one tall heredity factor and would be tall (see below).

In genetics problems the dominant factor is represented with a capital letter ($T$) 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.

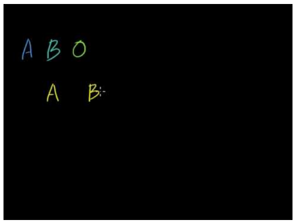
### Tall x Short

The above example crosses 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 are allowed to self-pollinate, each parent will give one factor to the F2 generation. The F2 offspring will be $TT$, $Tt$, $tT$ or $tt$. That is, 75% (3 of 4) tall and 25% (1 of 4) short. A Punnett Square helps determine these possibilities.

## Probability and Punnett Squares

If this is confusing, don't worry. A **Punnett Square** is a special tool used to predict the offspring from a cross, or mating between two parents.

An explanation of Punnett squares can be viewed at http://www.youtube.com/watch?v=D5ymMYcLtv0 (25:16).

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An example of a Punnett square ( **Figure** 6.3) shows the results of a cross between two purple flowers that each have one dominant factor and one recessive factor (*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 color purple is the dominant trait in pea plants.

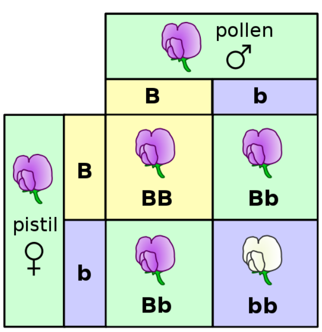



FIGURE 6.3

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

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 the 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** 6.1).

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

Practice more Punnett Squares here:

- http://www.zerobio.com/drag_gr11/mono.htm
- http://www2.edc.org/weblabs/WebLabDirectory1.html

**TABLE 6.1: The Punnett Square of a white flower (bb) crossed with a purple flower (Bb)**

| | b | b |
|---|---|---|
| **B** | Bb | Bb |
| **b** | bb | bb |

## Lesson Summary

- Gregor Mendel is considered the father of genetics, the science of studying inheritance.
- According to Mendel's law of segregation, an organism has two factors for each trait, but each gamete only contains one of these factors.
- A Punnett square is useful for predicting the outcomes of crosses.

## Review Questions

### Recall

1. What is the term for the offspring of a cross, or the first generation?

2. What is the F2 generation?

3. Who is considered the father of genetics?

### Apply Concepts

4. Why did Mendel select peas as a model for studying genetics?

5. What is the difference between a dominant trait and a recessive trait?

6. Why would it be much easier to study genetics in pea plants than in people?

### Think Critically

7. 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?

8. In peas, purple flowers (*P*) are dominant over white flowers (*p*). If a *pp* plant is crossed with a *Pp* plant, what ratio of plants in the offspring would you predict?

9. In guinea pigs, black fur (*B*) is dominant over white fur (*b*). If a *BB* guinea pig is crossed with a *Bb* guinea pig, what ratio of guinea pigs in the offspring would you predict?

10. In guinea pigs, smooth coat (*S*) is dominant over rough coat (*s*). If a *SS* guinea pig is crossed with a *ss* guinea pig, what ratio of guinea pigs in the offspring would you predict?

11. In humans, unattached ear lobes are dominant over attached ear lobes. If two parents have attached earlobes, what is the predicted ratio in the offspring?

## Further Reading / Supplemental Links

- http://www.mendelweb.org/MWtoc.html
- http://www.estrellamountain.edu/faculty/farabee/BIOBK/BioBookgenintro.html
- http://sonic.net/~nbs/projects/anthro201/
- http://anthro.palomar.edu/mendel/mendel_1.htm

## Points to Consider

- Do you think all traits follow this simple pattern where one factor controls the trait?
- Can you think of other examples where Mendel's laws do not seem to fit?

# 6.2 Modern Genetics

## Lesson Objectives

- Compare Mendel's laws with our modern understanding of chromosomes.
- Explain how codominant traits are inherited.
- Distinguish between phenotype and genotype.
- Explain how polygenic traits are inherited.

## Check Your Understanding

- What is a visual representation of a genetic cross?
- What is stated in Mendel's law of segregation?

## Vocabulary

- codominance
- genotype
- heterozygous
- homozygous
- phenotype
- polygenic inheritance

## Mendel and 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 lesson, we will explore the other 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** 6.2). 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).

**TABLE 6.2: Genotypes**

| 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 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** 6.4).

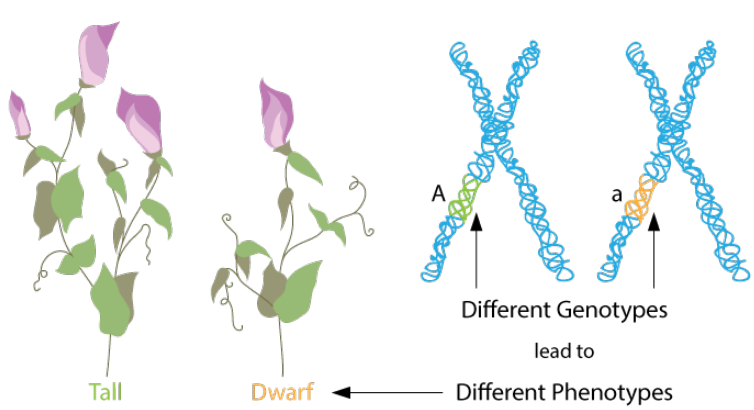



FIGURE 6.4
Different genotypes (AA, Aa, aa or TT, Tt, tt) will lead to different phenotypes, or different appearances of the organism

## Exceptions to Mendel's Laws: Incomplete Dominance and Codominance

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 to 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** 6.5). Neither the red nor the white allele is dominant, so the phenotype of the offspring is a blend of the two parents.

FIGURE 6.5

Pink snapdragons are an example of incomplete dominance.

Another example of incomplete dominance is sickle cell anemia, a disease in which a blood protein called hemoglobin is produced incorrectly, causing the red blood cells to have a sickle shape. 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** 6.6). Both the dominant and recessive alleles are expressed, so the result is a phenotype that is a combination of the recessive and dominant traits.

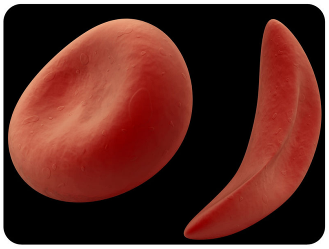


FIGURE 6.6
Sickle cell anemia causes red blood cells to become misshapen and curved (right cell) unlike normal, rounded red blood cells (left cell).

### Codominance

Another exception to Mendel's laws is a 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 3 alleles, instead of 2!

The ABO blood types ( **Figure** 6.7) are named for the protein, or antigen, attached to the outside of the blood cell. An antigen is a substance that provokes an immune response, your body's defenses against disease, which will be discussed further in the *Diseases and the Body's Defenses* chapter.

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*) doesn't 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.

There are two possible genotypes for type A blood, homozygous ($I^AI^A$) and heterozygous ($I^A$i), and two possible genotypes for type B blood, ($I^BI^B$ and $I^B$i). 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 antigens 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.

## Polygenic Traits and Environmental Influences

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. 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** 6.8). 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.

## Lesson Summary

- Variants of genes are called alleles.
- Genotype is the combination of alleles that an individual has for a certain gene, while phenotype is the appearance caused by the expression of the genotype.

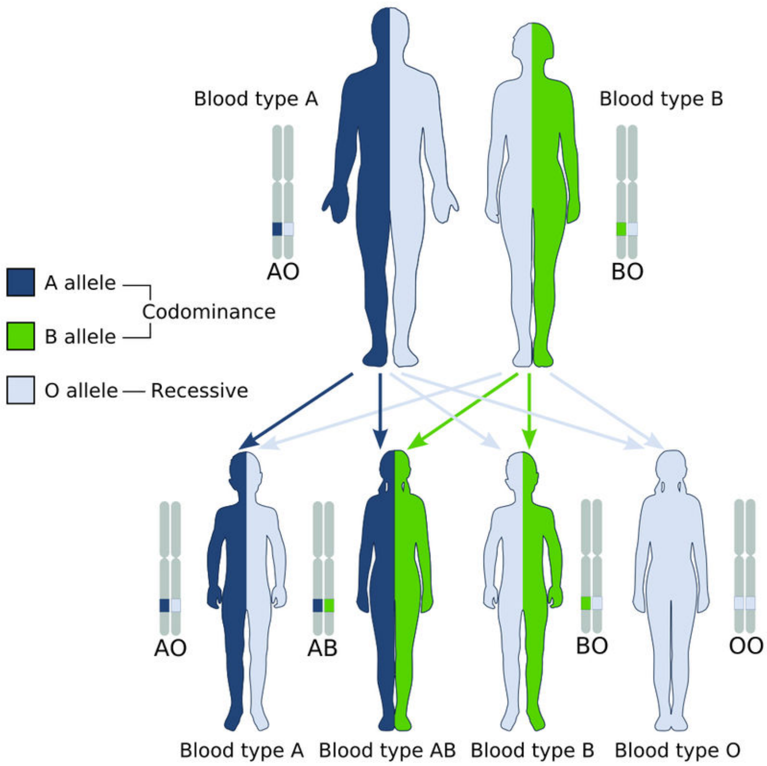



FIGURE 6.7
An example of codominant inheritance is ABO blood types.

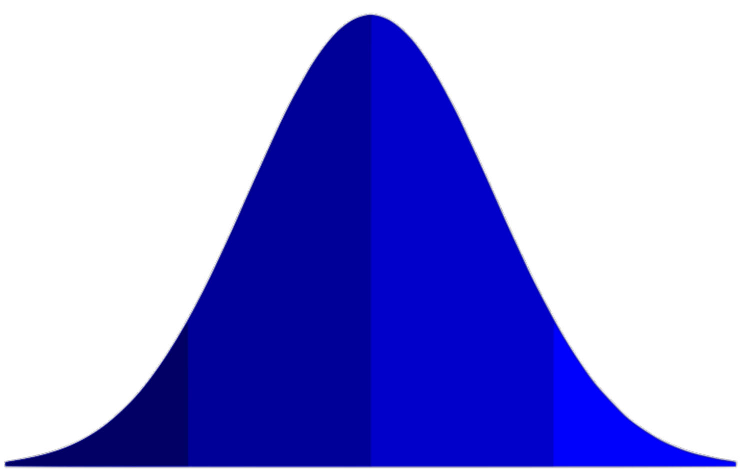


FIGURE 6.8
Polygenic traits tend to result in a distribution that resembles a bell-shaped curve, with few at the extremes and most in the middle. There may be 4 or 6 or more alleles involved in the phenotype. At the left extreme, individuals are completely dominant for all alleles, and at the other extreme, individuals are completely recessive for all alleles. Individuals in the middle have various combinations of recessive and dominant alleles.

- Incomplete dominance and codominance do not fit Mendel's rules because one allele does not entirely mask the other.
- In polygenic inheritance, many genes control a trait. Each dominant allele adds to the next dominant allele.

## Review Questions

### Recall

1. What is a variant of a gene that occurs at the same place on homologous chromosomes?
2. What is the type of allele that only affects the phenotype in the homozygous condition?
3. What type of allele masks the expression of the recessive allele?
4. What is the term for the specific alleles of an individual for a particular trait?
5. What is the term for the appearance of the organism, as determined by the genotype?

### Apply Concepts

6. If two individuals have a certain phenotype, such as tall pea plants, does that mean they must have the same genotype?
7. What is the term for the pattern of inheritance where an individual has an intermediate phenotype between the two parents?
8. What is the inheritance pattern where both alleles are expressed?

### Think Critically

9. IQ in humans varies, with most people having an IQ of around 100, and with a few people at the extremes, such as 50 or 150. What type of inheritance do you think this might describe?
10. 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.

## Further Reading / Supplemental Links

- http://staff.jccc.net/pdecell/evolution/polygen.html
- http://www.estrellamountain.edu/faculty/farabee/BIOBK/BioBookgenintro.html
- http://www.physorg.com/news188148947.html/

## Points to Consider

- Hypothesize about the genetic differences between males and females.
- Can you name any human genetic disorders?
- If a baby inherits an extra chromosome, what might the result be?

# 6.3 Human Genetics

## Lesson Objectives

- List the two types of chromosomes in the human genome.
- Predict patterns of inheritance for traits located on the sex chromosomes.
- Describe how some common human genetic disorders are inherited.
- Explain how changes in chromosomes can cause disorders in humans.

## Check Your Understanding

- How many alleles does an individual have for each gene/trait?
- How do we predict the probability of traits being passed on to the next generation?
- What do we call complexes of DNA wound around proteins that pass on genetic information to the next generation of cells?

## Vocabulary

- autosomes
- pedigree
- sex-linked inheritance
- sex-linked trait

## Special Inheritance Patterns

What gene determines if a baby is male or female? How are humans born with genetic disorders, like cystic fibrosis or Down Syndrome? We can apply Mendel's rules to describe how many human traits and genetic disorders are inherited.

We can now also explain special inheritance patterns that don't fit Mendel's rules.

## 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, 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 from the father and an X from the mother, what will be the child's sex? 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 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 (see **Figure** 6.9 and **Table** 6.3). Boys are much more likely to be colorblind than girls. 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 color-blind? She would have to inherit two genes for colorblindness, which is very unlikely. Many sex-linked traits are inherited in a recessive manner.

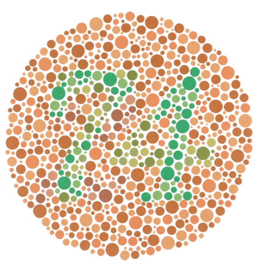


FIGURE 6.9

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

**TABLE 6.3: According to this Punnett square, the son of a woman who carries the colorblindness trait and a normal male has a 50% chance of being colorblind**

| | $X^c$ | X |
|---|---|---|
| **X** | **$X^cX$** (carrier female) | **XX** (normal female) |

**TABLE 6.3:** (continued)

| | $X^c$ | X |
|---|---|---|
| **Y** | **$X^cY$** (colorblind male) | **XY** (normal male) |

## 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 or dominant 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.

What are the possible genotypes of the offspring in **Table** 6.4? What are the possible phenotypes?

**TABLE 6.4: According to this Punnett square, two parents that are carriers of cystic fibrosis of the cystic fibrosis gene have a 25% chance of having a child with cystic fibrosis**

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

### 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 their 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.

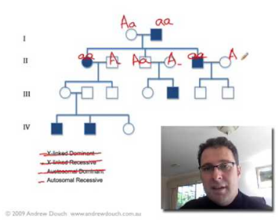
## Pedigree Analysis

A **pedigree** is a chart which 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.

**Figure** 6.10 shows a pedigree displaying recessive inheritance of a disorder through three generations. 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 he trait is inherited in a dominant or recessive fashion, and possibly whether individuals with the trait are heterozygous or homozygous.

Pedigree analysis is discussed in http://www.youtube.com/watch?v=HbIHjsn5cHo (9:13).

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## 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 also cause disorders.

### Extra Chromosomes

One common example of an extra-chromosome disorder is Down syndrome ( **Figure** 6.11). Children with Down syndrome are mentally disabled and also have physical deformities. Down syndrome occurs when a baby receives an extra chromosome 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. Down syndrome is therefore also known as Trisomy 21.

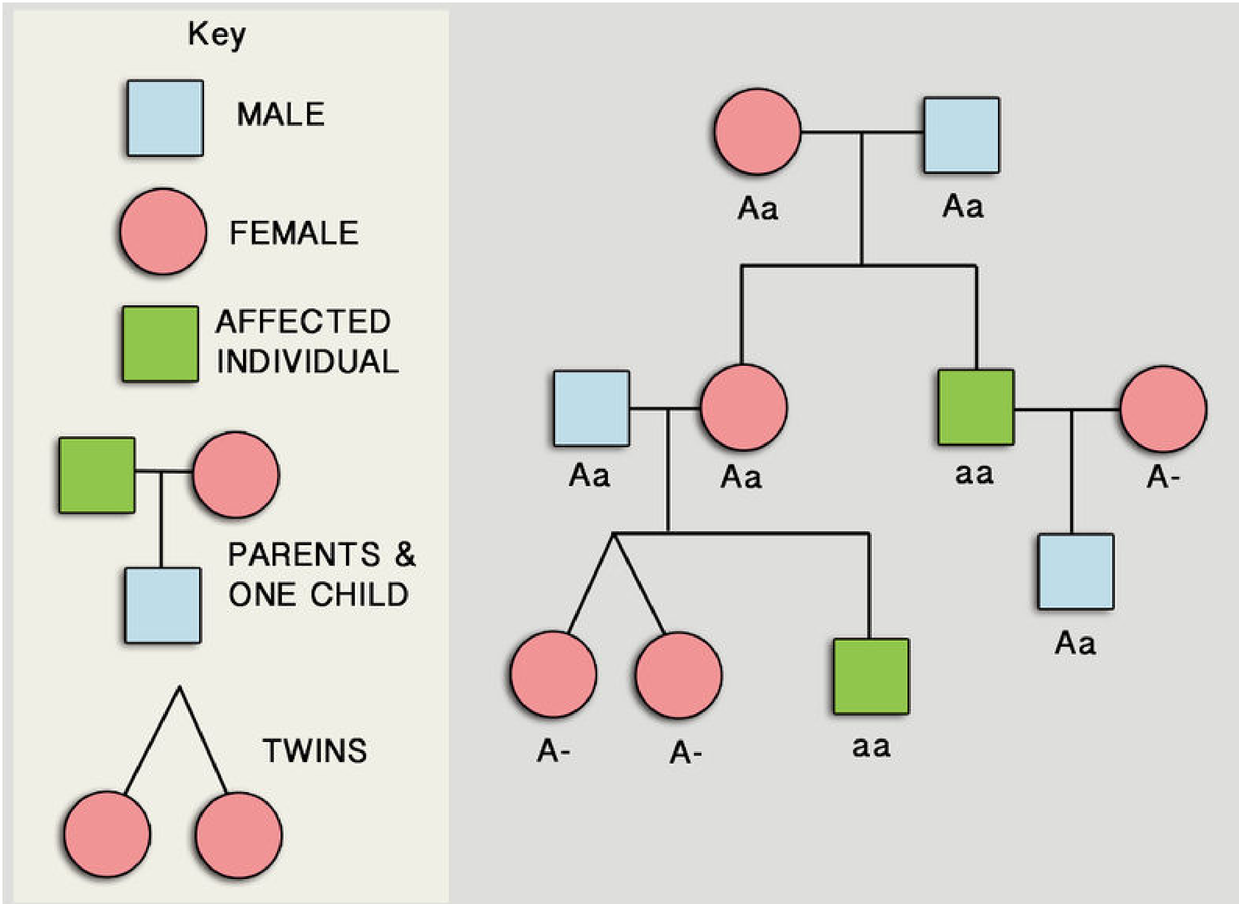


FIGURE 6.10
In a pedigree, squares symbolize males, and circles represent females. A horizontal line joining a male and female indicates that the couple had offspring. Vertical lines indicate offspring which are listed left to right, in order of birth. Shading of the circle or square indicates an individual who has the trait being traced. The inheritance of the recessive trait is being traced. "A" is the dominant allele and "a" is the recessive allele.

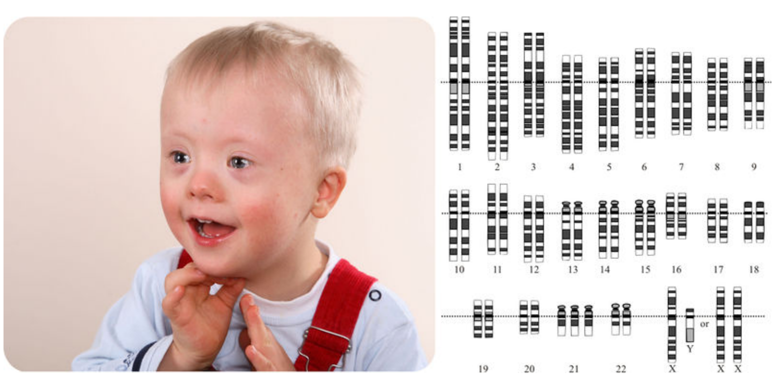

FIGURE 6.11
A child with Down syndrome.

Another example of a chromosomal disorder is Klinefelter syndrome, in which a male inherits an extra "X" chromosome. These individuals have underdeveloped sex organs and elongated limbs, and 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.

## Lesson Summary

- Some human traits are controlled by genes on the sex chromosomes.
- Human genetic disorders can be inherited through recessive or dominant alleles, and they can be located on the sex chromosomes or autosomes (non-sex).
- Changes in chromosome number can lead to disorders like Down syndrome.

## Review Questions

### Recall

1. How many chromosomes do you have in each cell of your body?

### Apply Concepts

2. How is Down's syndrome inherited?

### Think Critically

3. A son cannot inherit colorblindness from his father. Why not?

4. 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?

## Further Reading / Supplemental Links

- http://www.articlesbase.com/health-articles/what-is-haemophilia-412305.html
- http://geneticdisorderinfo.wikispaces.com/
- http://www.hhmi.org/biointeractive/vlabs/cardiology/index.html

## Points to Consider

- Human cloning is illegal in many countries. Do you agree with these restrictions?
- Why would it be helpful to know all the genes that make up human DNA?
- It may be possible in the future to obtain the sequence of all your genes. Would you want to take advantage of this opportunity? Why or why not?

# 6.4 Genetic Advances

## Lesson Objectives

- Explain how clones are made.
- Explain how vectors are made.
- Explain what sequencing a genome tells us.
- Describe how gene therapy works.

## Check Your Understanding

- What part of the cell contains the genetic material?
- What are the base pairing rules for DNA?

## Vocabulary

- cloning
- gene therapy
- Human Genome project
- plasmid
- recombinant DNA
- somatic cell
- transformation
- vector

## Biotechnology and DNA Technology

Since Mendel's time, there have been many changes in the understanding of genetics. As scientists learn more about how DNA works, they can develop technologies that allow us to reveal the genetic secrets encoded in our DNA and even alter an organism's DNA.

Genetic engineering (also known as "biotechnology" or "DNA technology") helps us better understand and predict the inheritance of genetic diseases, treat these diseases, produce new medicines, and even produce new food products.

*Biotechnology: An Introduction* can be viewed at http://www.youtube.com/watch?v=nnSYigHofb0 (1:05).


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## 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, as well as producing 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.

A clone is an exact copy. 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 be used in medicine or in research.

Bacteria have small rings of DNA in the cytoplasm, called **plasmids** ( **Figure** 6.12). When putting foreign DNA into a bacterium, the plasmids are often used as a vector. Viruses can also be used as vectors.

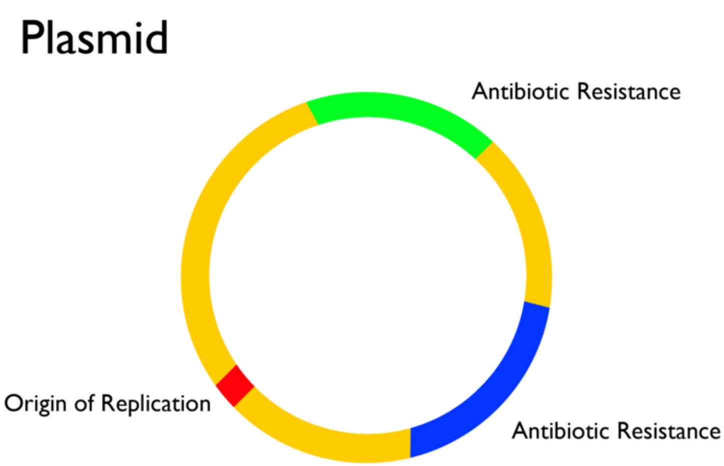



FIGURE 6.12
This image shows a drawing of a plasmid. The plasmid has two large segments and one small segment depicted. The two large segments (green and blue) indicate antibiotic resistances usually used in a screening procedure, and the small segment (red) indicates an origin of replication. The origin of replication is where DNA replication starts, copying the plasmid. The antibiotic resistance segments ensure only bacteria with the plasmid will grow.

## 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. This process is shown in **Figure** 6.13.

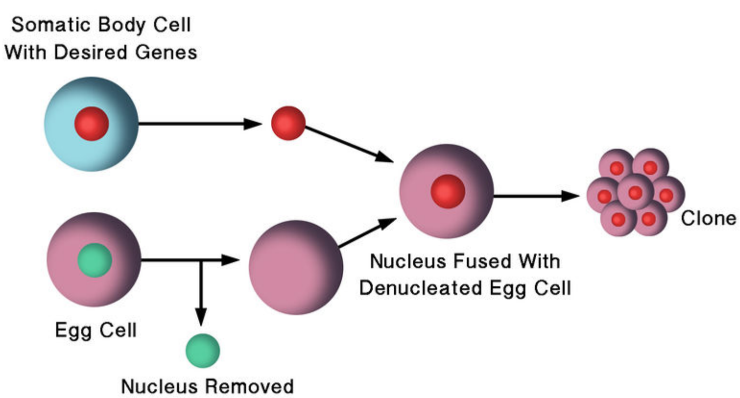



FIGURE 6.13
To clone an animal, a nucleus from the animal's cells are fused with an egg cell (from which the nucleus has been removed) from a donor.

### 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?

## 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** 6.14) 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.

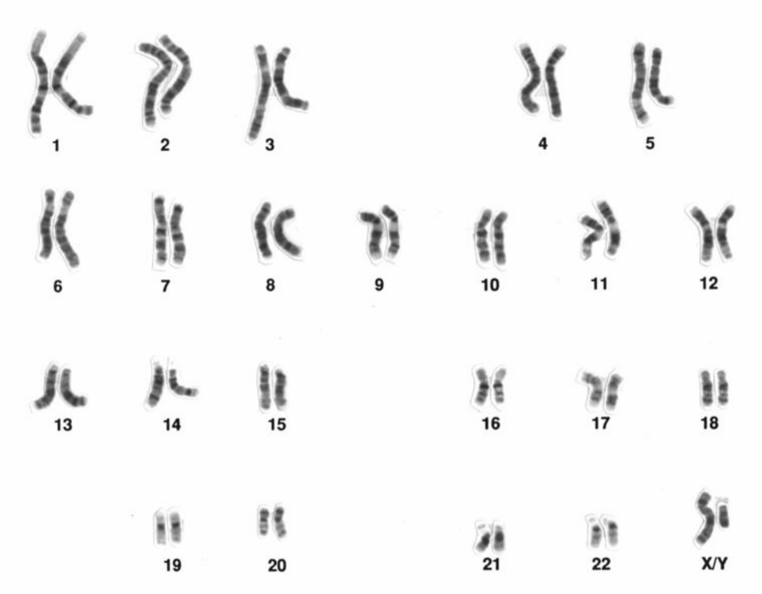


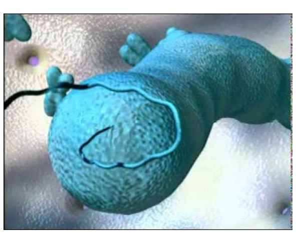

FIGURE 6.14

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, and 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 Human Genome Project. Exploring Our Molecular Selves* can be viewed at http://www.youtube.com/watch?v=VJycRYBNtwY (3:41).



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## Gene Therapy

**Gene therapy** is the insertion of genes into a person's cells to cure a genetic disorder. 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*)

### 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. 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.

### 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 in 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.

## Biotechnology in Agriculture

Biotechnology has also led scientists to develop useful applications in agriculture and food science. These include the development of transgenic crops - the placement of genes into plants to give the crop a beneficial trait. Benefits include:

- Improved yield from crops.
- Reduced vulnerability of crops to environmental stresses.
- Increased nutritional qualities of food crops.
- Improved taste, texture or appearance of food.
- Reduced dependence on fertilizers, pesticides and other chemicals.

Crops are obviously dependent on environmental conditions. Drought can destroy crop yields, as can too much rain or floods. But what if crops could be developed to withstand these harsh conditions?

Biotechnology will allow the development of crops containing genes that will enable them to withstand harsh conditions. For example, drought and salty soil are two significant factors affecting crop productivity. 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, trying 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 phenotypes in those crops.

Thale cress ( **Figure** 6.15), 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 6.15
Thale cress (*Arabidopsis thaliana*).

## Lesson Summary

- Using recombinant DNA technology, a foreign gene can be inserted into an organism's DNA.
- Cloning of mammals is still being perfected, but several cloned animals have been created by implanting the nucleus of a somatic cell into a cell in which the nucleus has been removed.
- The Human Genome Project produced a genetic map of all the human chromosomes and determined the sequence of every base pair in our DNA.
- Gene therapy involves treating an illness caused by a defective gene through the use of a vector to integrate a normal copy of the gene into the patient.

## Review Questions

### Recall

1. What is the term for all the genetic information of the human species?
2. What are the rings of accessory DNA in bacteria that are often used as a vector in genetic engineering?
3. What is the term for producing identical copies of an organism?
4. What is the vehicle used to introduce foreign DNA into an organism?

### Apply Concepts

5. What supplies the cytoplasm of the clone's cells during the cloning of an organism?
6. What is one application of recombinant DNA technology?
7. Can gene therapy cure a disease caused by a virus?

### Critical Thinking

8. What are the benefits of having access to your entire genetic code? What are the possible problems?

9. Should human cloning be legal in the US? Why or why not?

## Further Reading / Supplemental Links

- http://www.ornl.gov/sci/techresources/Human_Genome/home.shtml
- http://history.nih.gov/exhibits/genetics/sect4.htm
- http://learn.genetics.utah.edu/units/disorders/whataregd/ada/
- http://www.lifesitenews.com/ldn/2007/nov/07112003.html
- http://www.le.ac.uk/ge/genie/vgec/sc/genomics.html

## Points to Consider

Next we begin to discuss evolution, the change in species over time.

- Fossils provide evidence of evolution, but what is a fossil?
- If two animals are similar in structure, would you guess they are closely related? Why or why not?

# 6.5 References


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# CHAPTER 7 MS Evolution

## Chapter Outline



Does this frog look a little scary? It looks that way on purpose. This frog is a poisonous dart frog. They live in Central and South America. Why do you think the frog is so brightly colored? Why do you think the frog is poisonous? Why does the frog only live in warmer climates? There are also many different types of poisonous dart frogs. Some are red, some blue, some yellow. So why is there such a great diversity of poisonous dart frogs?

Scientists who study evolution are concerned with these types of questions, but they ask them about all of the species on the planet. Why are there millions of different types of species? Why are some small, some large, some furry, and some covered in feathers? These questions will be explored as we learn about the theory of evolution.

# 7.1 Evolution by Natural Selection

## Lesson Objectives

- Explain how evolution is the change of an inherited trait in a population over many generations.
- Explain how evolution is caused by the process of natural selection.
- Describe how both Darwin and Wallace developed the theory of evolution by natural selection at the same time.

## Check Your Understanding

- What does the word "inherit" mean?
- Why do offspring have some of the same traits as their parents?

## Vocabulary

- acquired trait
- adaptation
- artificial selection
- evolution
- Galápagos Islands
- inherited traits
- natural selection
- trait

## Darwin's Observations and The 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** 7.1) was also fascinated by the diversity of living things 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** is the process that explains why species change over time. Darwin spent over 20 years traveling around the world and making observations before he fully developed his theory.

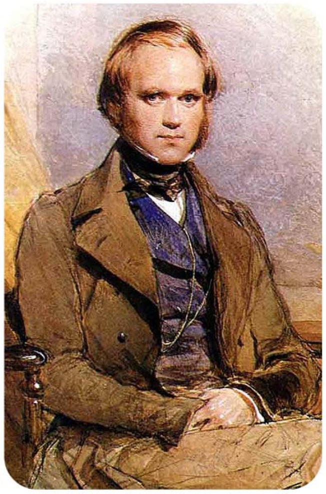

FIGURE 7.1
Charles Darwin was one of the most influential scientists who has ever lived. Darwin introduced the world to the theory of evolution by natural selection, which laid the foundation for how we understand the living world today.

### Voyage of the

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 over 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** 7.2), Darwin made observations about plants and animals around the world. He also collected specimens to study when he returned to England.

Each time the 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.

### 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** 7.3).

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 iguana on the same set of islands that were so different from one another. What do you think? 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** 7.4). 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


FIGURE 7.2
Charles Darwin's famous five year voyage was aboard the HMS Beagle from 1831-1836.


FIGURE 7.3
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.

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 upwards, allowing them to stretch their necks ( **Figure** 7.5). Darwin began to hypothesize that organisms developed traits over time because of differences in their environments.

FIGURE 7.4
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 is a unique animal found only in the Galápagos Islands. There are only about 200 tortoises remaining on these islands.

FIGURE 7.5
This tortoise 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** 7.6). 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.

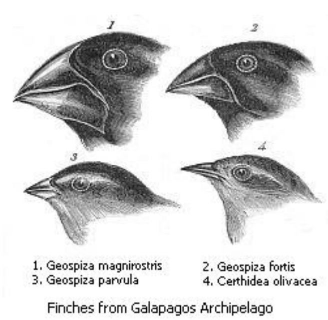


FIGURE 7.6
Four of Darwin's finch species from the Galápagos Islands. The birds came from the same finch ancestor. They evolved as they adapted to different food resources on different islands. The first bird uses its large beak to crack open and eat large seeds. Bird #3 is able to pull small seeds out 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.

For a video of naturalist Sir David Attenborough on Charles Darwin and evolution, see http://www.youtube.com/w atch?v=uz7U4k522Pg (4:27).


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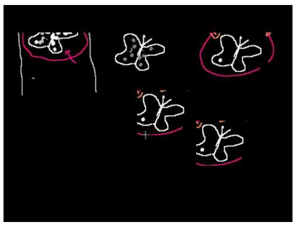
An overview of evolution can be seen at http://www.youtube.com/watch?v=GcjgWov7mTM (17:39).



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Darwin's ideas can be summarized in the *Natural Selection and the Owl Butterfly* video: http://www.youtube.com/watch?v=dR_BFmDMRaI (13:29).


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## Influences on Darwin

When Darwin returned to England five years later, 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, such as:

- All organisms never change and never go extinct.
- The world is 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. Before the voyage of the *Beagle*, Jean-Baptiste Lamarck proposed the idea that evolution occurs. 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. The findings of Charles Lyell, a well-known geologist, also influenced Darwin. Lyell taught Darwin about geology, paleontology and the changing Earth. Lyell's findings suggested the Earth must be much older than 6,000 years.

After the Voyage of the *Beagle*, another naturalist, Alfred Wallace ( **Figure** 7.7), 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 7.7
Alfred Wallace developed a similar theory of evolution by natural selection.

## Natural Selection and Adaptation

The theory of evolution by natural selection means that the inherited traits of a population change over time through a process called natural selection. **Inherited traits** are features that are passed from one generation to the next. For example, your eye color is an inherited trait (you inherited it 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** 7.8).

FIGURE 7.8
Human earlobes may be free or attached. 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. Your summer tan is not passed on to your offspring. Natural selection only operates on traits like earlobe shape that have a genetic basis, not on traits like a summer tan that are acquired.

**Natural selection** explains how organisms in a population develop traits that allow them to survive and reproduce. These traits will most likely be passed on to their offspring. Evolution occurs by natural selection. Take the giant tortoises on the Galápagos 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 bacteria to survive and reproduce in its environments are called **adaptations.**

Natural selection occurs when:

1. There is some variation in the inherited traits of organisms within a species.
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 winter, dark fur makes a rabbit easy for foxes to spot and catch in the snow. Natural selection suggests that 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** 7.9). Over time, dark fur rabbits will become uncommon. Rabbits will adapt to have white fur.

FIGURE 7.9
In winter, the fur of Arctic hares turns white. The camouflage may make it more difficult for fox and other predators to locate hares against the white snow.

### Why so many species?

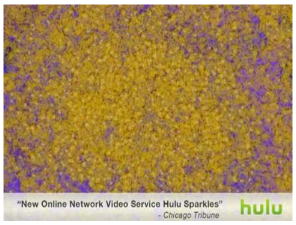
Scientists estimate that there are between 5 million and 100 million species on the planet. But why are there so many? As environments change over time, organisms must constantly adapt to those environments. Diversity of species increases the chance that at least some organisms adapt and survive any 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.

## Lesson Summary

- Evolution is a change in species over multiple generations.

- Natural selection is how evolution occurs when organisms develop traits that allow them to survive, reproduce, and pass on their traits to their offspring.
- Adaptations are the result of natural selection.
- Charles Darwin is credited with developing the theory of evolution by natural selection.

*The Simpsons - Homer Evolution* can be viewed at http://www.youtube.com/watch?v=faRlFsYmkeY (1:30).

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## Review Questions

### Recall

1. Define biological evolution.

2. What was the name of the ship that Darwin traveled on?

3. What is the name of the islands where Darwin studied evolution?

4. Who proposed a theory of evolution by natural selection that was similar to Darwin's theory?

### Apply Concepts

5. How is evolution the result of natural selection?

6. What is an example of an adaptation?

7. What is the difference between an inherited trait and an acquired trait?

8. A giraffe's long neck allows the giraffe to eat leaves from high in the tree. This is an example of an ___________-____.

### Critical Thinking

9. If a species of finch lives on an island with small seeds that fall easily into cracks between rocks, what kind of beak traits will be selected for over time?

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## Points to Consider

- What kind of evidence supports the theory of evolution by natural selection?
- How does genetics provide a basis for Darwin's original observations?

# 7.2 Evidence of Evolution

## Lesson Objectives

- Explain how the scientific theory of biological evolution is based on physical evidence and experiments.
- Discuss the significance of the fossil record as evidence for evolution.
- Compare vestigial structures and embryos as a biological basis for evolution.
- Explain the genetic basis for evolution.

## Check Your Understanding

- Where did Charles Darwin collect evidence of evolution and what kinds of evidence did he find?
- What is natural selection?
- What kinds of traits change through evolution?

## Vocabulary

- embryology
- fossil
- fossil record
- genome
- paleontologist
- radiometric dating
- vestigal structure

## The Fossil Record

**Fossils** are preserved parts 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** 7.10).

Until recently, fossils were the main source of evidence for evolution ( **Figure** 7.11).

- The location of each fossil in layers of rock provides clues to the age of the species and how species evolved in the past.

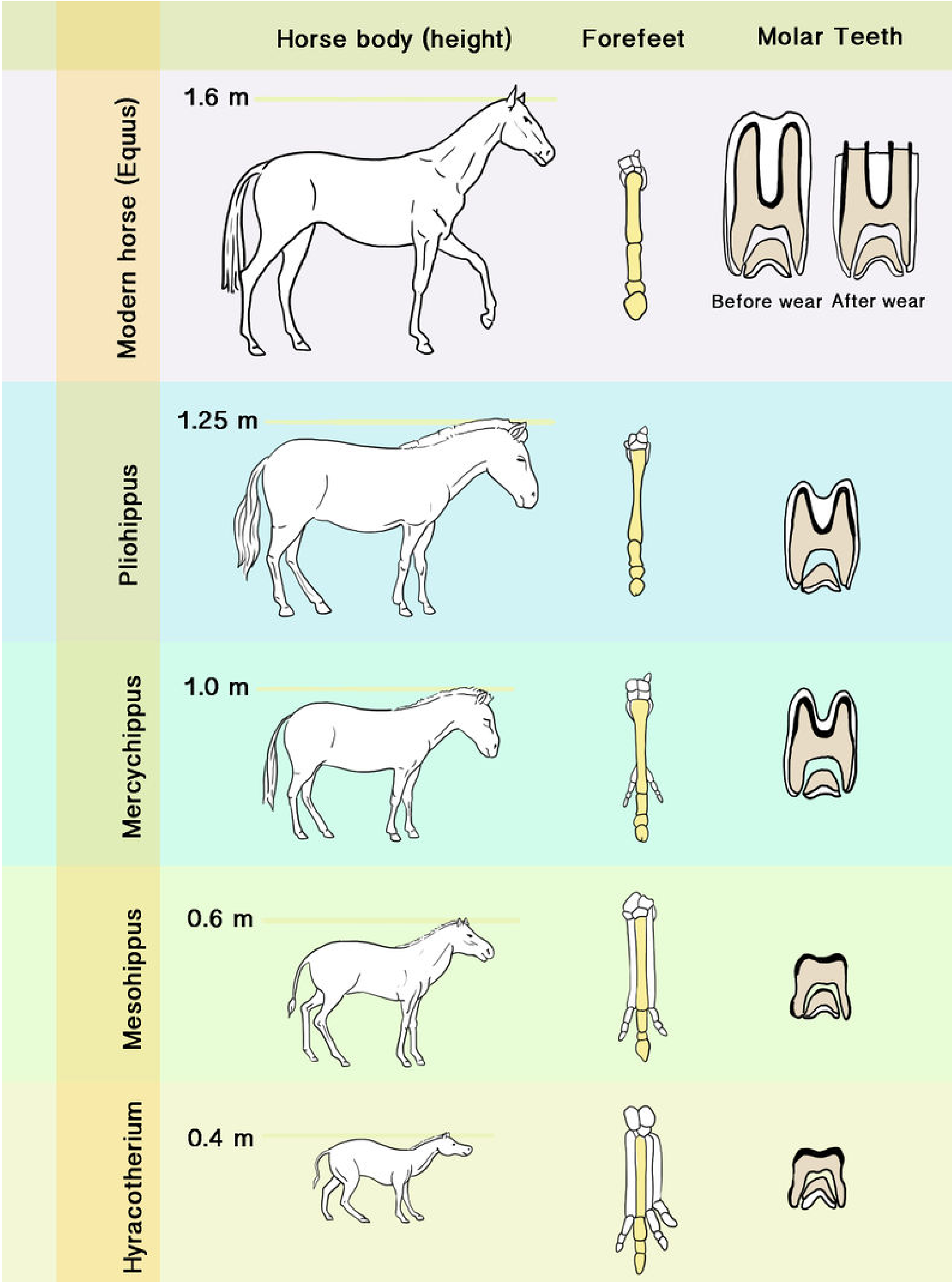


FIGURE 7.10

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.

- In the past, organisms were spread out differently across the planet. Fossils also allow us to understand how earthquakes, volcanoes, shifting seas, and other movements of the continents affect where organisms once lived and how they adapted to their changing environments.

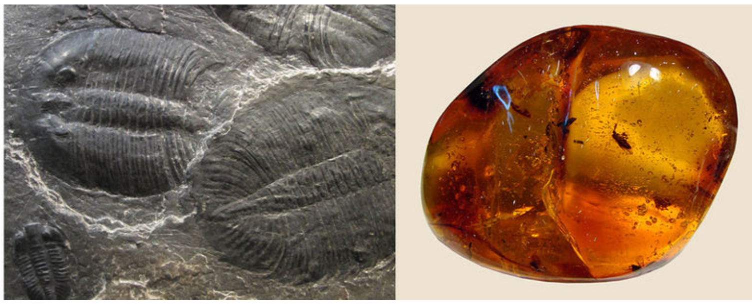

FIGURE 7.11
A fossil is the remains of a plant or animal that existed some time in the distant past. Left: Fossils, such as this one, were found in rocks or soil that formed long ago. Right: About 40 to 60 million years ago these insects were trapped in a gooey substance, called resin, that comes from 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. These layers provide evidence for when organisms lived on Earth, how species evolved, and how some species have gone extinct. The fossils and the order in which fossils appear is called the **fossil record**.

Geologists use a method called **radiometric dating** to determine the age of rocks and fossils in each layer of rock. This technique measures the how fast the radioactive materials in each rock layer are broken down ( **Figure** 7.12).

FIGURE 7.12
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.

## Vestigial Structures

Millions of species of organism are alive today. Even though two different species may not look similar, they may have similar internal structures that suggest they have a "common ancestor," or organism that they both evolved from a long time ago.

Some of the most interesting kinds of evidence for evolution are body parts that have lost their use through evolution ( **Figure** 7.13). 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 do not use their wings to fly in the air; however they do use them to "fly" 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 ( **Figure** 7.14).

FIGURE 7.13
Mole rats live under ground 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, 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.

Many traits of one type of animal appear in the embryo of another type of animal. For example, fish embryos and human embryos both have gill slits. In fish they develop into gills, but in humans they disappear before birth.

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. See http://www.pbs.org/wgbh/evolution/library/04/2/pdf/l_042_03.pdf for additional information and a comparative diagram of human, monkey, pig, chicken and salamander embryos.

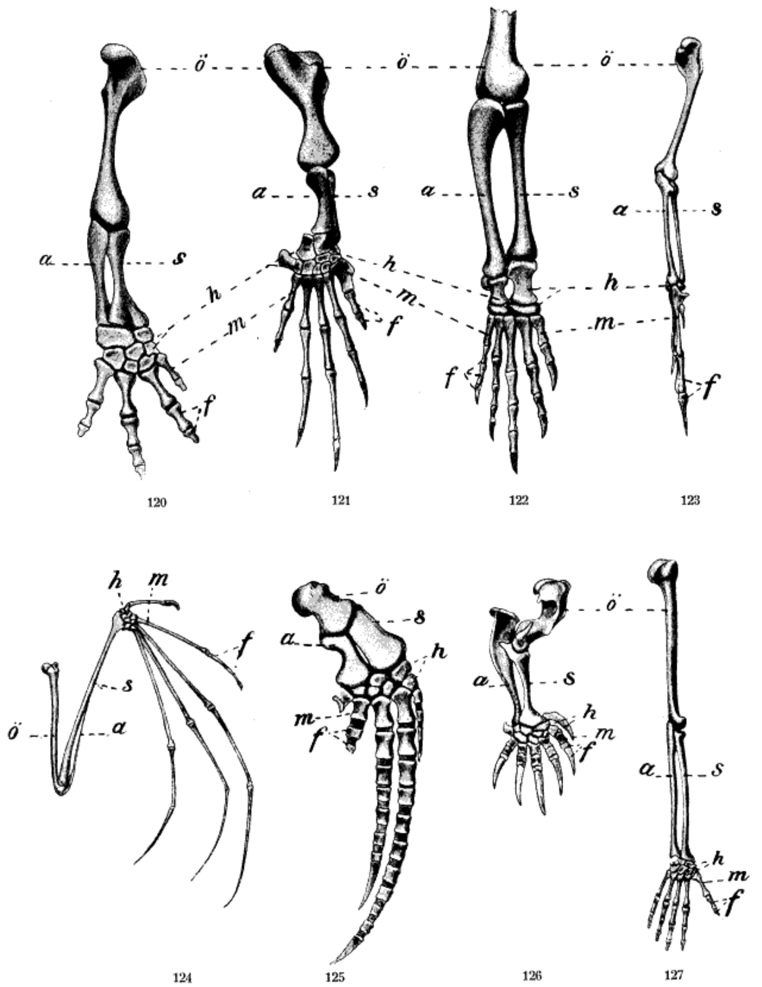

FIGURE 7.14

The bones in your arms and hands have the same bone pattern as those in the wings, legs, and feet of the animals pictured here. The bone structures clockwise from top left are: salamander, turtle, crocodile, bird, human, mole, whale, bat. How have the bones adapted for different uses in each animal?

## Similar Molecules

Arguably, some of the best evidence of evolution comes from examining the molecules and DNA found in all organisms ( **Figure** 7.15).

In the 1940's, scientists studying molecules and DNA 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. For example, a chicken and a gorilla will have more differences between their DNA and amino acid sequences then a gorilla and an orangutan. This provides additional evidence that the gorilla and orangutan are more closely related than the gorilla and the chicken.

### Similar Genetics

The study of genetics has revealed the record of evolution left in the genomes of all organisms ( **Figure** 7.16). It also provides new information about the relationships among species and how evolution occurs.

Genetic evidence for evolution includes:

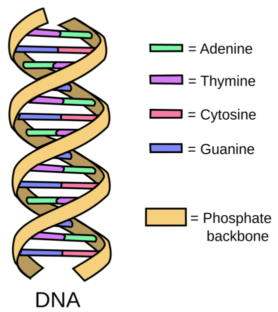


FIGURE 7.15

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.

1. The same biochemical building blocks –such as amino acids and nucleotides - are responsible for life 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 reveal patterns of evolution.

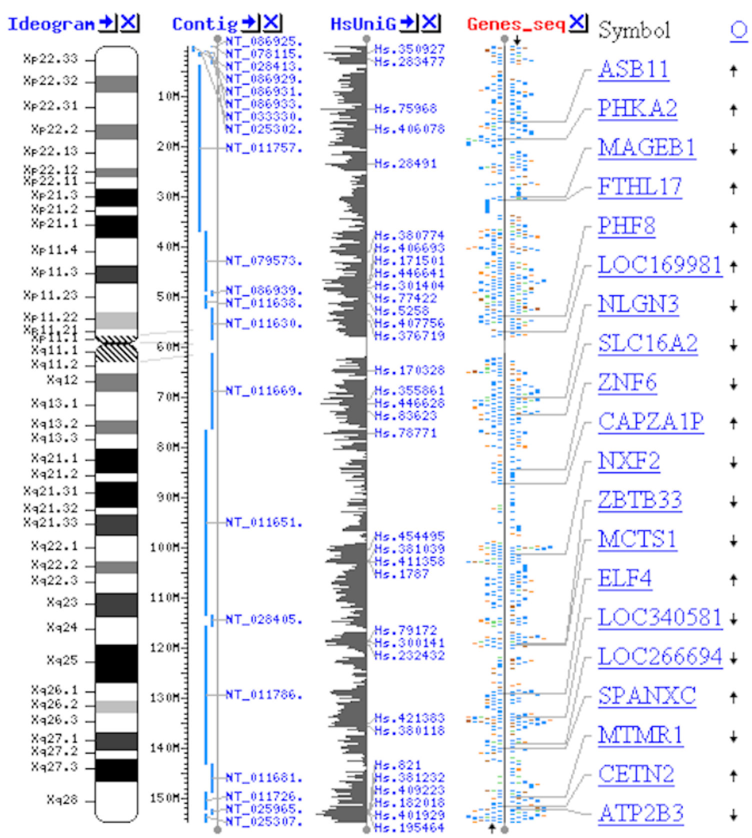


FIGURE 7.16

This is a map of the genes on just one of the 46 human chromosomes. Similarities and differences between the genomes (the genetic makeup) of different organisms reveal the relationships between the species. The human and chimpanzee genomes are almost identical- there is only a difference of 1.2% between the two genomes.

## Lesson Summary

- Fossils provide evidence of how different organisms exist as environmental conditions change over time.

- Radiometric dating has been used to determine that the oldest known rocks on Earth are between 4-5 billion years old. The oldest fossils are between 3-4 billion years old.
- Vestigial structures indicate that two species have a common ancestor.
- The similarities between embryos suggests that animals are related and have common ancestors.
- The same biochemical building blocks –such as amino acids and nucleotides - are responsible for life in all organisms, from bacteria to plants and animals.
- The similarities and differences between the genomes reveal patterns of evolution.

## Review Questions

### Recall

1. What are the different kinds of evidence of evolution? How do geologists determine the age of rocks and fossils?
2. What is a vestigial structure?
3. What is an embryo?
4. What is a molecular clock?

### Apply Concepts

5. What is an example of a vestigial structure?
6. How do the embryos of different species support the theory of evolution?
7. How do similarities between molecules support the theory of evolution?

### Critical Thinking

8. If a type of bird in California is 80% genetically similar to a bird in Nevada, do you think they evolved from a common ancestor? Why or why not?
9. How does one recent scientific advancement support a part of Darwin's Theory of Evolution by Natural Selection?

## Further Reading / Supplemental Links

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## Points to Consider

- How do you think new species evolve?
- How long do you think it takes for a new species to evolve?

# 7.3 Macroevolution

## Lesson Objectives

- Compare and contrast microevolution and macroevolution.
- Define speciation as the formation of new species.
- Explain the ways that speciation can occur.

## Check Your Understanding

- Why can't an individual person evolve? Why can only groups evolve over many generations?
- What causes a species or a population to evolve?

## Vocabulary

- allopatric speciation
- behavioral isolation
- evolutionary tree
- geographic isolation
- macroevolution
- microevolution
- population
- reproductive isolation
- speciation
- sympatric speciation

## Microevolution and Macroevolution

A species is a group of organisms that have similar characteristics and can mate with one another to produce offspring. The offspring of two members of the same species must also be able to reproduce. So, how are new species created? Through the process of evolution.

A **population** is a group of organisms of the same species that live in the same area ( **Figure** 7.17). But does evolution happen as small changes build up in a population of organisms over time and gradually lead to a new species? Or is it possible that drastic environmental changes rapidly give rise to new species? Or can both small and large changes cause evolution to occur?

FIGURE 7.17
This school of fish are considered a species because they are able to mate with one another. But they are 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 organisms 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. As a result, the only remaining mosquitoes are the pesticide-resistant mosquitoes. When these mosquitoes reproduce the next year, they produce more mosquitoes with the pesticide-resistant trait.

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 for 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 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.

### Evolution Acts on the Phenotype

Natural selection acts on the phenotype - the traits or characteristics - of an individual, not on the underlying genotype. 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 choose a homozygous individual over a heterozygous individual. The recessive *a* allele will be maintained in the population through heterozygous *Aa* individuals. Thus, 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.

Tay-Sachs disease is an autosomal recessive genetic disorder. It is caused by the homozygous recessive genotype, *rr*.

Affected individuals usually die from complications of the disease in early childhood. If the parents are each heterozygous (Rr) for the Tay-Sachs, they will not die, but they will be carriers. If you create a Punnett Square, what are the chances of a child inheriting the disorder? 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** 7.18).

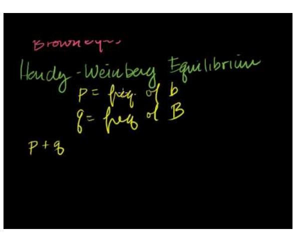
### Hardy-Weinberg Equilibrium

The Hardy-Weinberg model states that a population will remain at **genetic equilibrium**, with no evolution, as long as five conditions are met:

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 of the conditions exists, then evolution can occur. The Hardy-Weinberg model is a mathematical formula used to predict allele frequencies in a population at genetic equilibrium.

A video explanation of the Hardy-Weinberg model can be viewed at http://www.youtube.com/watch?v=4Kbruik_LOo (14:57).

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## 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. Natural selection causes beneficial heritable traits to become more common in a population, and unfavorable heritable traits to become less common. For example, a

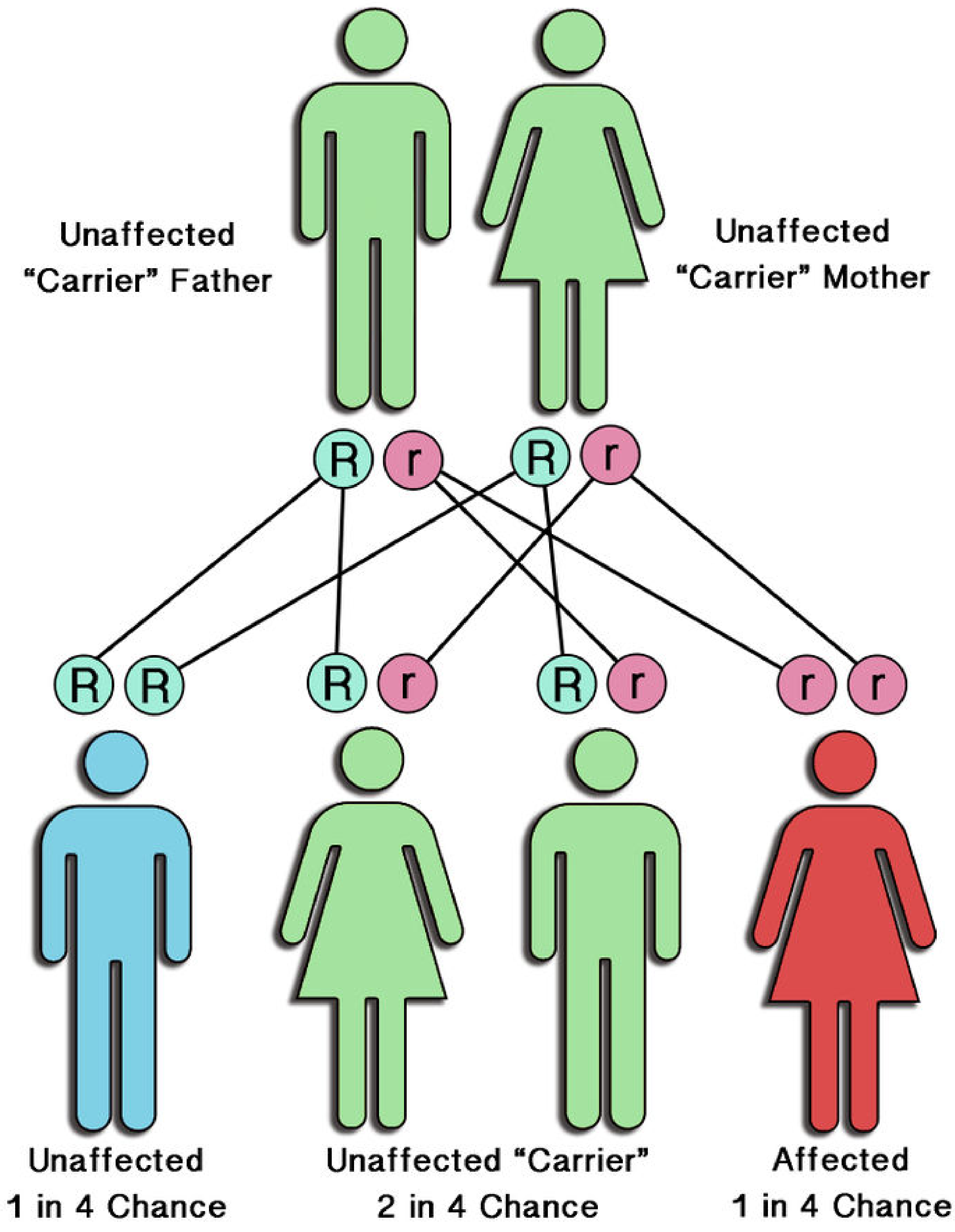


FIGURE 7.18

Tay-Sachs disease is inherited in the autosomal recessive pattern. Each parent is an unaffected carrier of the lethal allele.

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 to pass specific traits on to the next generation. For example, a farmer may choose to breed only cows that produce the best milk and not breed cows that produce less milk . Humans have also artificially bred dogs to create new breeds ( **Figure** 7.19).

FIGURE 7.19
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. Yet there is at least one difference between their genes that determine size.

### Reproductive Isolation

There are two main ways that speciation happens naturally. Both processes create new species by isolating populations of the same species from each other. Organisms can be geographically isolated or isolated by a behavior. Over a long period of time, usually thousands of years, each of the isolated populations evolves in a different direction.

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** happens 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:

- A mountain range.
- A canyon.
- Rivers, streams, or an ocean.
- A desert.

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 separate species.

- When the Grand Canyon in Arizona formed, two populations of one squirrel species were separated by the giant canyon, shown in **Figure** 7.20. 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. 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 7.20
Left: The Abert squirrel is found on the southern rim of the Grand Canyon. Right: The Kaibab squirrel is found on the northern rim of the Grand Canyon.

### Isolation without Physical Separation

**Sympatric speciation** happens when groups from the same species stop mating because of something other than physical separation, such as behavior. 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** 7.21).

- Two groups of Galápagos finch species lived in the same space, but each had their 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.

## Rates of Evolution

How fast is 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.

FIGURE 7.21
Scientists suspect that two types of orca whales live in the same part of the Pacific Ocean for part of the year, but do not mate.

The rate of evolution depends on how much an organism's genotype changes 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. Since bacteria go through many generations in a few days, we can actually trace their evolution as it is happening.

## Evolutionary Trees

Charles Darwin came up with the idea of an evolutionary tree to represent the relationships between different species and their common ancestors ( **Figure** 7.22). The base of the tree represents the ancient ancestors of all life. The separation into large branches shows where these original species evolved into different populations.

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** 7.23).

An interactive Tree of Life can be found at http://www.wellcometreeoflife.org/interactive/ .

## Lesson Summary

- Microevolution results from evolutionary changes that are small and do not lead to the creation of a new species.
- Macroevolution refers to large evolutionary changes that result in new species.
- The creation of a new species is called speciation.
- Allopatric speciation occurs when groups from the same species are geographically isolated physically for long periods.

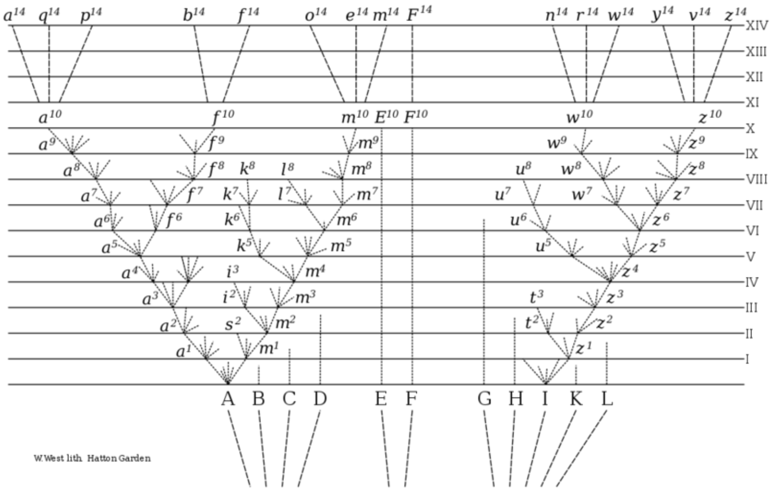


FIGURE 7.22
Darwin drew this version of the "Tree of Life" to represent how species evolve and diverge into separate directions. Each point on the tree where one branch splits off from another represents the common ancestor of the species on the separate branches.

- Sympatric speciation occurs when groups from the same species stop interbreeding, because of something other than physical separation, such as behavior.
- The rate of evolution is a measurement of the speed of evolution.
- Evolutionary trees are used to represent the relationships between different species and their common ancestors.

## Review Questions

### Recall

1. What is the difference between macroevolution and microevolution?
2. What do the branches on the Tree of Life represent?
3. Which organism has a faster rate of evolution: a human or a bacterium?
4. What are two possible reasons why organisms to evolve and adapt?

### Apply Concepts

5. How do you know if two related organisms are members of the same species?
6. Why do the squirrels on opposite side of the Grand Canyon look different?
7. How is artificial selection different from natural selection?
8. What, other than physical isolation, could cause a species to split into two different directions of evolution?

### Critical Thinking

9. "We have no current evidence of evolution occurring." Is the above statement true or false? Why or why not?

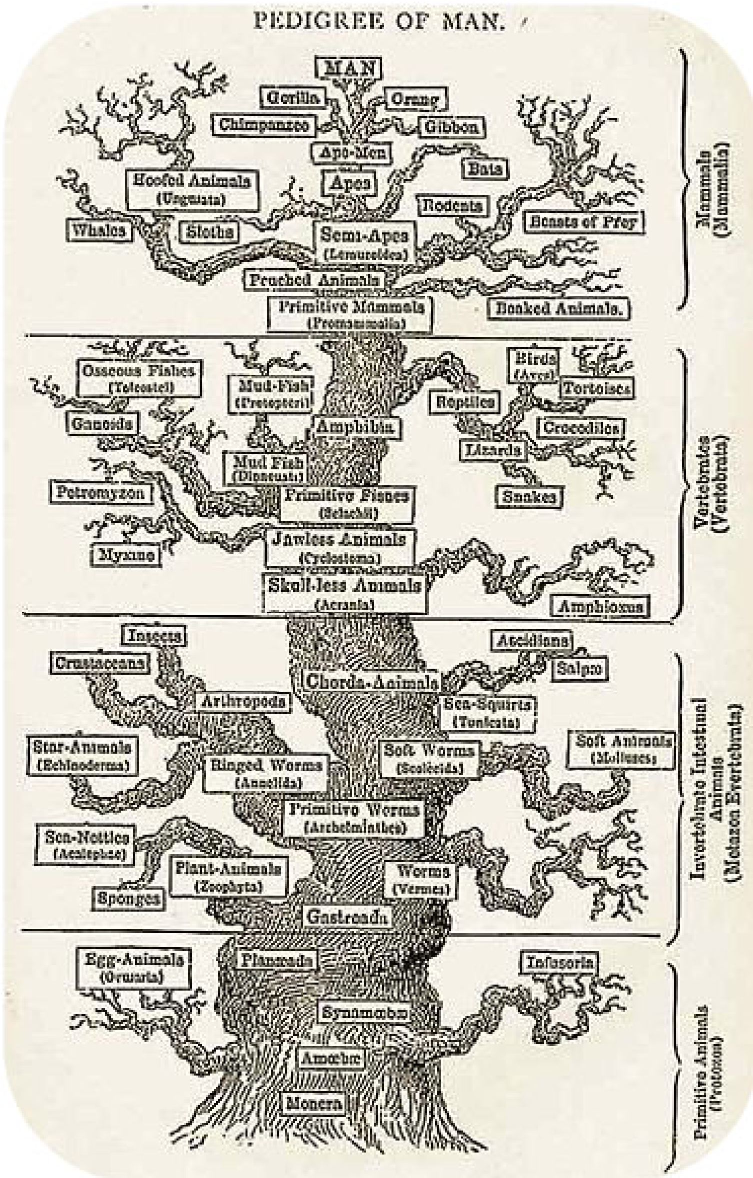


FIGURE 7.23

Scientists have drawn many different versions of the "Tree of Life" to show different features of evolution. This Tree of Life was made by Ernst Haeckel in 1879.

## Further Reading / Supplemental Links


- Yeh, Jennifer, Modern Synthesi, (From Animal Sciences).
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## Points to Consider

- How old is the Earth?
- When did the first life forms develop?
- For how much of Earth's history have humans existed?

# 7.4 History of Life on Earth

## Lesson Objectives

- Explain how geologists and paleontologists use evidence to determine the history of Earth and life on Earth.
- Define the age of the earth as four to five billion years old.
- Explain how scientists need to know what the environment (what chemicals were around, the temperature, etc.) was like on Earth billions of years ago to know how life formed.

## Check Your Understanding

- What are fossils?
- How does the fossil record contribute to the evidence of evolution?

## Vocabulary

- Cambrian explosion
- extinct
- geologic time scale
- mass extinction
- stromolites

## 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.

### Over 4 Billion Years

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.

## Origin of Life on Earth

There is good evidence that life has probably existed on Earth for most of Earth's history. 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** 7.24).

FIGURE 7.24
Some of the oldest fossils on Earth are made of algae and a kind of bacteria found along the coast of Australia.

### Life from Random Reactions

How did evolution begin? It started with the first signs of life. How did life begin 3.5 to 4 billion years ago? 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. 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 random reactions between chemical compounds, which formed molecules. These molecules created proteins and nucleic acids (RNA or DNA), and then cells.

How long did it take to form the first life forms? As much as 1 billion years ( **Figure** 7.25). 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?"

FIGURE 7.25
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.

## 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 in **Figure** 7.26 illustrates the timing of events like:

- Earthquakes
- Volcanic eruptions
- Major erosion
- Meteorites hitting Earth
- The first signs of life forms
- Mass extinctions

## Evolution of Major Life Forms

Life on Earth began about 3.5 to 4 billion years ago. The first life forms were single-cell organisms similar to bacteria. The first multicellular organisms did not appear until about 610 million years ago. Many of the modern types of organisms we know today 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 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.

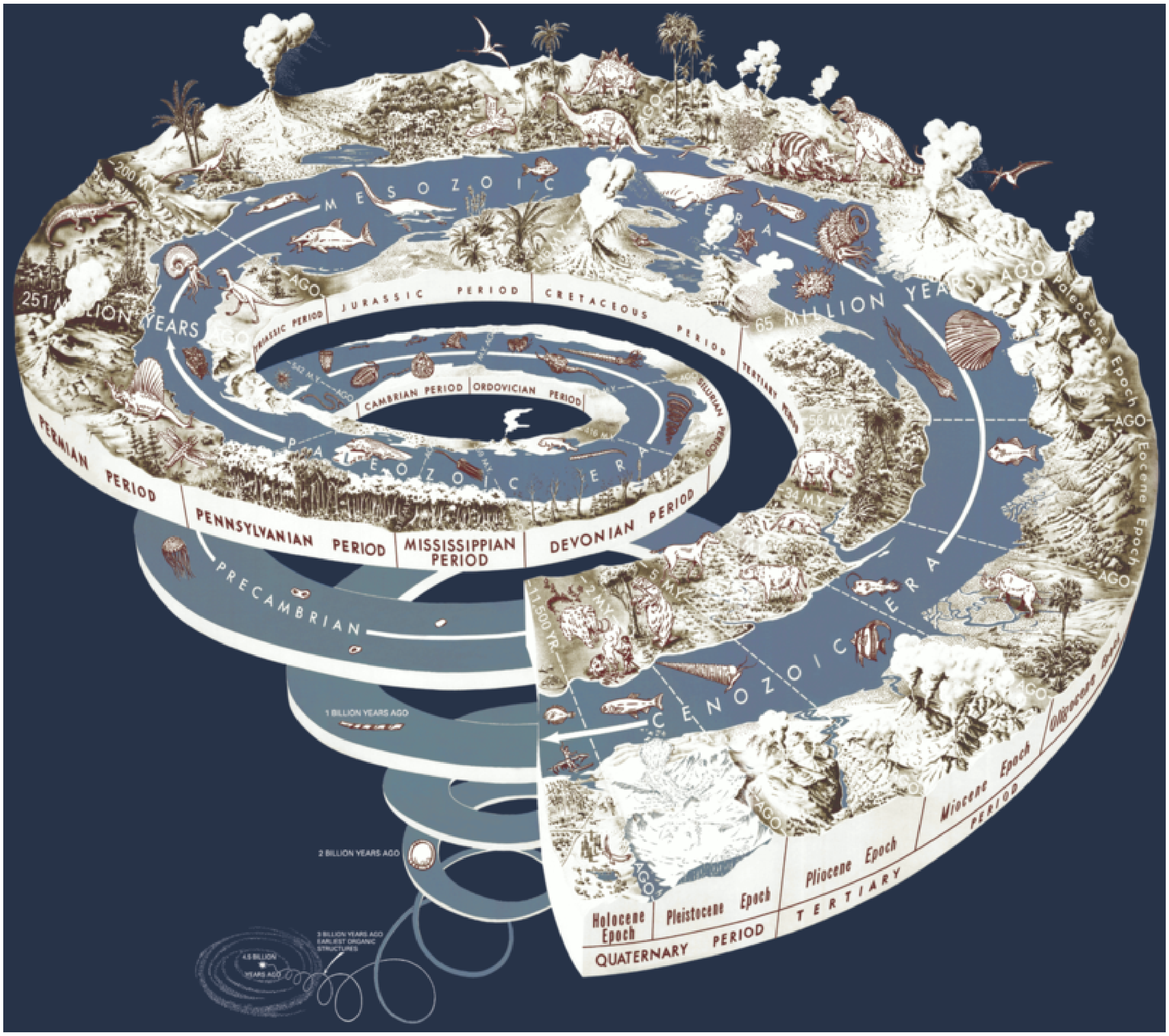


FIGURE 7.26

The geologic time scale of Earth's past is organized according to events which 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.

Even though large life forms have been very successful on Earth, most of the life forms on Earth today are still prokaryotes –small, 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.

## Mass Extinctions

An organism goes **extinct** when all of the members of a species do not exist anymore. 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** 7.27).

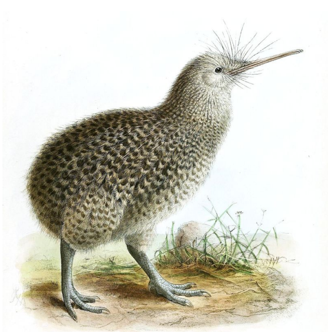

FIGURE 7.27

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 until Europeans arrived and brought cats, fox 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** 7.28).

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 massive 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 Pangea, 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 so much marine life to go extinct ( **Figure** 7.29).

FIGURE 7.28
The fossil of Tarbosaurus, one of the land dinosaurs that went extinct during one of the mass extinctions.


FIGURE 7.29
The supercontinent Pangaea encompassed all of today's continents in a single land mass. This configuration limited shallow coastal areas which harbor marine species, and 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 ( **Figure** 7.30). 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 a 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.

FIGURE 7.30
The fossil record demonstrates the presence of dinosaurs, which went extinct over 65 million years ago.

After each mass extinction, new species develop to fill the habitats where old species lived. This is well documented in the fossil record ( **Figure** 7.31).

## Lesson Summary

- During the 1800s, geologists, paleontologists and naturalists found several forms of physical evidence that confirmed that the earth is over 4 billion years old.
- Geologists and other earth scientists use geologic time scales to describe when events occurred throughout the history of Earth.
- The first life forms were single-celled organisms, prokaryotic organisms, similar to bacteria.
- Mass extinctions, such as the extinction of dinosaurs and many marine mammals, happened after major catastrophes such as volcanic eruptions and major earthquakes changed the environment.

## Review Questions

### Recall

1. How do scientists determine the age of a rock or fossil today?
2. How do we know the maximum and minimum possible age of the Earth?
3. How long ago did life start on Earth?
4. When did mammals first appear on Earth?
5. What kinds of events are recorded on a geological time scale?

### Apply Concepts

6. Why is it difficult to determine how life started on Earth?
7. Why are extinctions a part of natural selection?

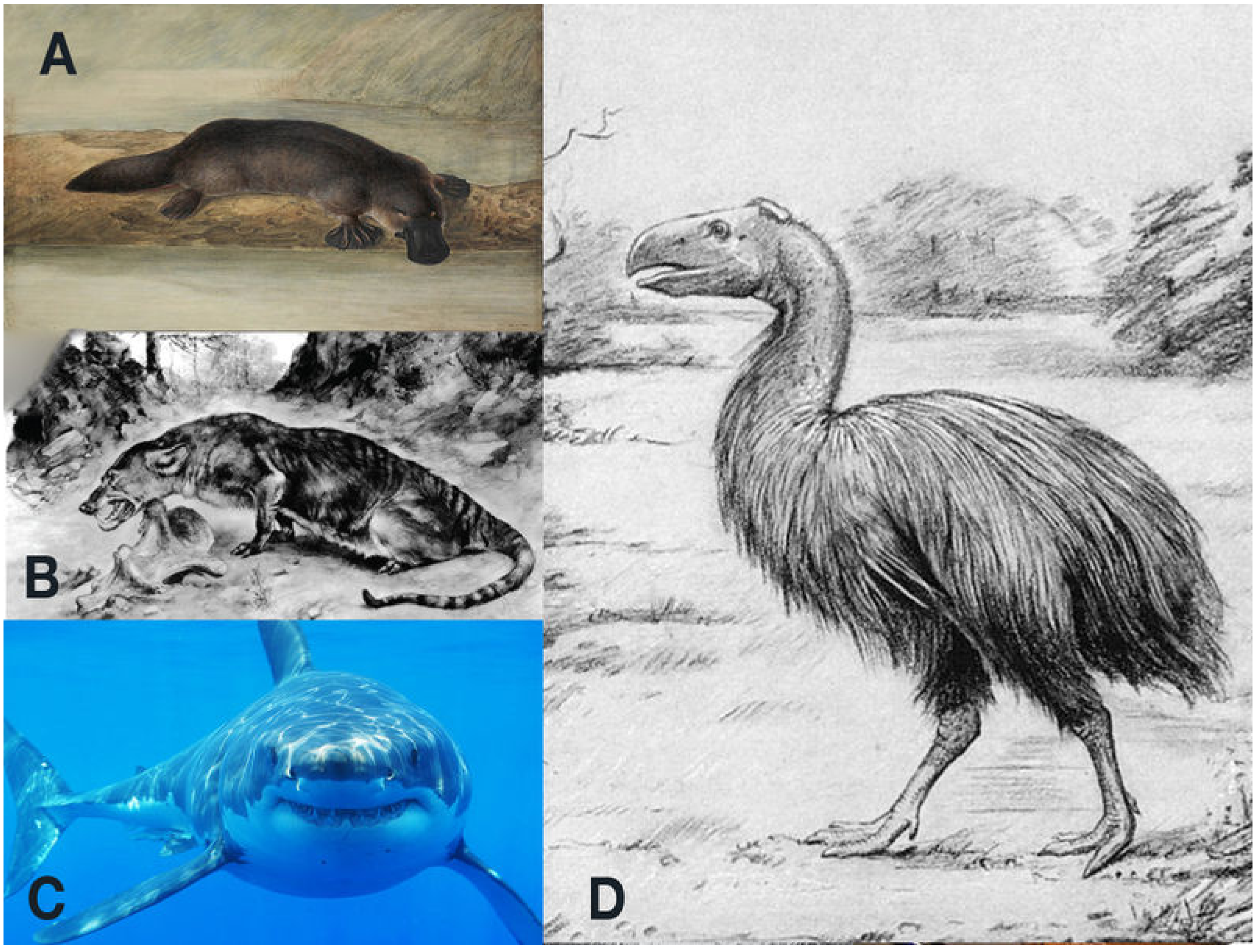


FIGURE 7.31
Mammals and birds quickly invaded ecological niches formerly occupied by the dinosaurs. Mammals included monotremes (A), marsupials, and hoofed placentals (B). Modern sharks (C) patrolled the seas. Birds included the giant, flightless Gastornis (D).

### Think Critically

8. In order to develop the best theory for the extinction of the dinosaurs, what other information might be useful?

9. You are a scientist investigating the origin of life on earth? Ask three questions that will help you complete your investigation.

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## Points to Consider

- What are prokaryotic organisms?
- Compare and contrast prokaryotes and eukaryotes.

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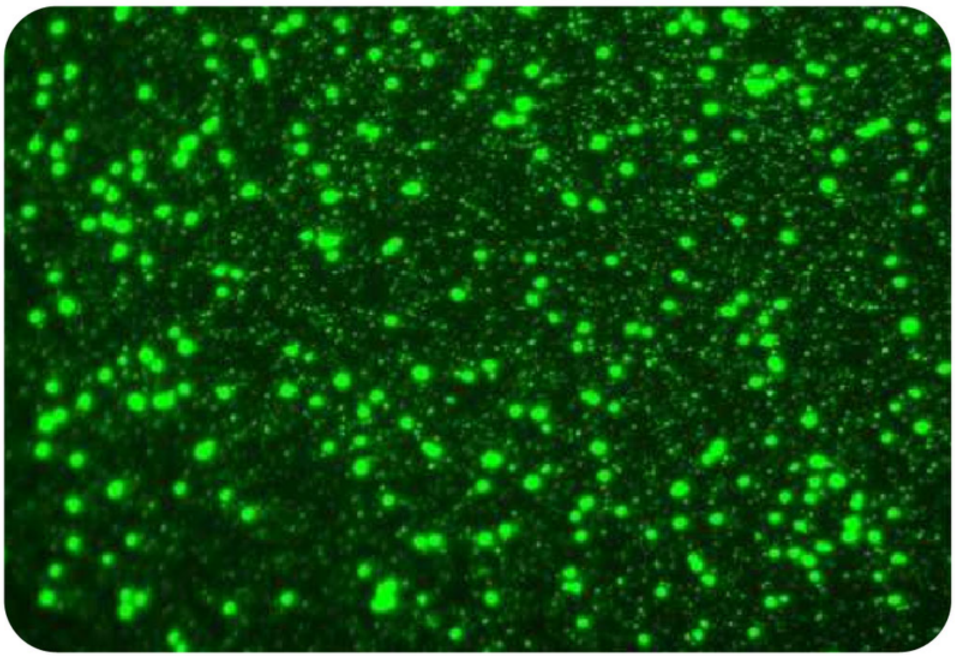
# CHAPTER 8 MS Prokaryotes

## Chapter Outline





The above image shows bacteria dyed with a fluorescent color. They look just like little cells. Well, that's exactly what they are.

Bacteria are prokaryotic organisms. About 3.5 billion years ago, long before the first plants, people, or other animals appeared, prokaryotes were the first life forms on Earth. For at least a billion years, prokaryotes ruled the Earth as the only existing organisms.

What do you think of when you think of bacteria? Germs? Diseases? Bacteria can be harmful, but they can also help you. How do you think bacteria can help humans and other organisms?

Did you know that bacteria are not the only type of prokaryote? There is another type, called archaea, which we will explore in addition to the questions asked above.

*Jed Fuhrman. commons.wikimedia.org/wiki/File:Seawater_small_life.png. CC BY 2.5.*

# 8.1 Bacteria

## Lesson Objectives

- Describe the cellular features of bacteria.
- Explain the ways in which bacteria can obtain energy.
- Explain how bacteria reproduce themselves.
- Identify some ways in which bacteria can be helpful.
- Identify some ways in which bacteria can be harmful.

## Check Your Understanding

- How do prokaryotic and eukaryotic cells differ?
- What are some components of all cells, including bacteria?

## Vocabulary

- bacilli
- chemotroph
- cocci
- conjugation
- cyanobacteria
- decomposer
- flagella
- nucleoid
- peptidoglycan
- spirilli
- transduction

## Characteristics of Bacteria

Even though life is much more diverse on Earth today, bacteria (singular, bacterium) are still the most abundant organisms on Earth. Recall that prokaryotes are single-celled organisms that lack a nucleus, and that the prokaryotes include bacteria and archaea.

### 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** 8.1). Bacteria can be classified by their shape:

1. **Bacilli** are rod-shaped.
2. **Cocci** are sphere-shaped.
3. **Spirilli** are spiral-shaped.

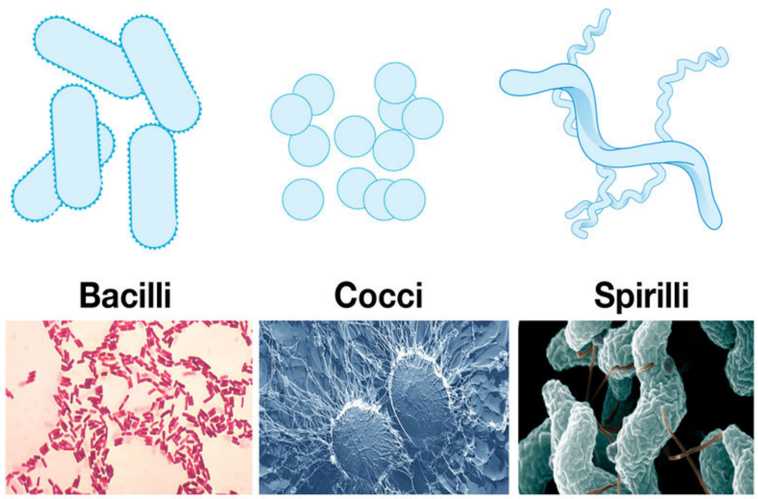



FIGURE 8.1
Bacteria come in many different shapes. Some of the most common shapes are bacilli (rods), cocci (spheres), and spirilli (spirals). Bacteria can be identified and classified by their shape. Bottom left: Escherichia coli is an example of bacteria that are rod-shaped, or bacilli. Bottom center: Staphylococcus aureus is an example of bacteria that are sphere-shaped, or cocci. Bottom right: Campylobacter is an example of bacteria that are spiral, or spirula.

### The Cell Wall

Bacteria are surrounded by a cell wall consisting of **peptidoglycan**, a complex molecule consisting 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.

Another type of bacteria, called parasitic bacteria, depends on a host organism for energy and nutrients. If the host starts attacking the bacteria, the bacteria release a layer of slime that surrounds the cell wall for an extra layer of protection.

### Differences between Eukaryotes and Prokaryotes

Recall that all prokaryotes, including bacteria, lack many of the things that eukaryotes contain, such as membrane-bound organelles (like mitochondria or chloroplasts) or a nucleus ( **Figure** 8.2).

### Similarities to Eukaryotes

Like eukaryotic cells, prokaryotic cells do have:

1. Cytoplasm, the fluid inside the cell.
2. A plasma membrane, which acts as another barrier.
3. Ribosomes, where proteins are assembled.
4. DNA, contained in a large circular strand, forming a single chromosome, that is compacted into a structure called the **nucleoid**. Many bacteria also have additional small rings of DNA known as **plasmids**.

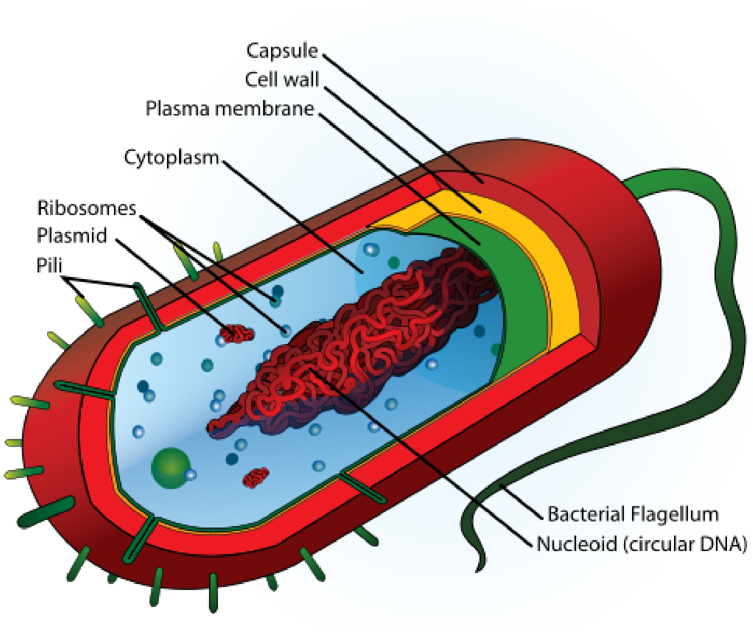



FIGURE 8.2
The structure of a bacterial cell is distinctive from a eukaryotic cell because of features such as an outer cell wall and the circular DNA of the nucleoid, and the lack of membrane-bound organelles.

### Flagella

Some bacteria also have tail-like structures called **flagella** ( **Figure** 8.3). Flagella help bacteria move. As the flagella rotate, they spin the bacteria and propel them forward.

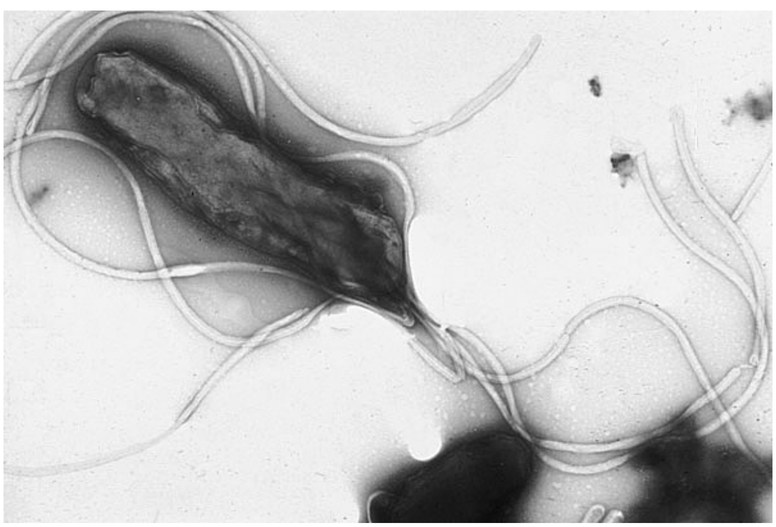


FIGURE 8.3
The flagella facilitate movement in bacteria. Bacteria may have one, two, or many flagella - or none at all.

## Obtaining Food and Energy

Bacteria obtain energy and nutrients in a variety of different ways:

- Bacteria known as decomposers break down wastes and dead organisms into smaller molecules to get the

energy they need to survive.
- Photosynthetic bacteria use the energy of the sun, together with carbon dioxide, to make their own food. Briefly, in the presence of sunlight, carbon dioxide and water is turned into glucose and oxygen. The glucose is then turned into usable energy. Glucose is like the "food" of the bacteria. An example of photosynthetic bacteria is **cyanobacteria**, as seen in **Figure** 8.4.

FIGURE 8.4
Cyanobacteria are photosynthetic bacteria. These bacteria carry out all the reactions of photosynthesis within the cell membrane and in the cytoplasm; they do not need chloroplasts.

- Bacteria can also be chemotrophs. **Chemotrophs** obtain energy by breaking down chemical compounds in their environment, such as nitrogen-containing ammonia. They do not use the energy from the sun. Nitrogen cannot be made by living organisms, so it must be continually recycled. The bacteria help cycle the nitrogen through the environment for other living things to use. Organisms need nitrogen to make organic compounds, such as DNA.
- Some bacteria depend on other organisms for survival. For example, mutualistic bacteria live in nutrient-rich part of the roots of legumes, such as pea plants. The bacteria turn nitrogen-containing molecules into nitrogen that the plant can use. In this relationship, both the bacteria and the plant benefit.
- Other bacteria are parasitic and can cause illness. In a parasitic relationship, the bacteria benefit and the other organism is harmed. Harmful bacteria will be discussed later in the lesson.

## Reproduction in Bacteria

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 ( **Figure** 8.5). Binary fission can happen very rapidly. Some species of bacteria can double their population in less than ten minutes ( **Figure** 8.6)!

Sexual reproduction does not occur in bacteria. But not all new bacteria are clones. This is because bacteria can still combine and exchange DNA. This exchange 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.
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.

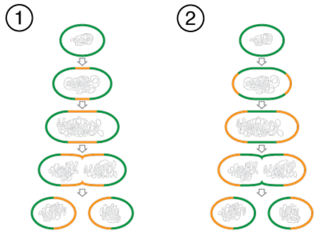



FIGURE 8.5
Bacteria cells reproduce by binary fission, resulting in two daughter cells identical to the parent cell.

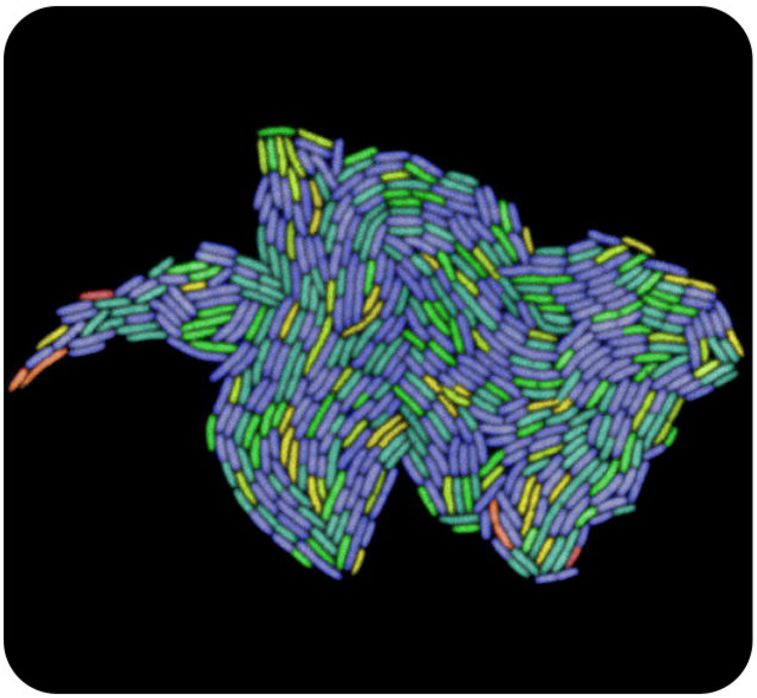


FIGURE 8.6
Bacteria can divide rapidly. This image is of a growing colony of E. coli bacteria. In the right environment the growth and division of two *E. coli* can form a colony of hundreds of bacteria in just a few hours.

## Helpful Bacteria

Bacteria are helpful to humans and to other living things because they can:

1. Recycle essential nutrients in the soil.
2. Aid in animal digestion.
3. Produce food for consumption.
4. Produce chemicals used in medicines.

### Decomposers

Bacteria are important 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.

### Digestion

Bacteria also help you digest your food. Several species of bacteria, such as *E. coli*, are found in your digestive tract. In fact, bacteria cells outnumber your own cells in your gut!

### Food Production

Bacteria are involved in producing some foods. Yogurt is made by using bacteria to ferment milk. Cheese can also be made from milk with the help of bacteria ( **Figure** 8.7). Fermenting cabbage with bacteria produces sauerkraut.

FIGURE 8.7
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.

## Harmful Bacteria

There are also ways that bacteria can be harmful to humans and other animals.

### Diseases

Bacteria are responsible for many types of human illness, including:

- Strep throat.
- Tuberculosis.
- Pneumonia.
- Leprosy.
- Lyme disease.

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 can also lead to outbreaks of food poisoning. Raw eggs and undercooked meats can contain bacteria that can cause digestive problems. Foodborne infection can be prevented by cooking meat thoroughly and washing surfaces that have been in contact with raw meat. Washing of hands before and after handling food also helps stop 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*. Since inhaling the spores of this bacterium can lead to a deadly infection, 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.

## Lesson Summary

- Bacteria contain a cell wall containing peptidoglycan and a single chromosome contained in the nucleoid.
- Bacteria can obtain energy through several means including photosynthesis, decomposition, and parasitism, symbiosis, and chemosynthesis.
- Bacteria reproduce through binary fission.
- Bacteria are important decomposers in the environment and aid in digestion.
- Some bacteria can be harmful when they contribute to disease, food poisoning, or biological warfare.

## Review Questions

### Recall

1. What are prokaryotes?
2. What are the possible shapes that bacteria can have?
3. What is the purpose of the flagella?
4. What is a chemotroph?

### Apply Concepts

5. How is the DNA in prokaryotes different from the DNA in eukaryotes?

6. How do bacteria reproduce without having sex?

7. What are the ways bacteria can go through genetic recombination?

8. How are cyanobacteria similar to plants?

9. How are bacteria important in nature?

10. How can you avoid becoming sick from bacteria that cause food poisoning?

### Think Critically

11. If a species of bacteria lives in the roots of a plant and supplies the plant with nitrogen, is this a parasitic bacteria? Explain why or why not.

12. How might you genetically modify bacteria so that they produce a chemical they do not normally produce?

## Further Reading / Supplemental Links

- http://www.bt.cdc.gov/agent/anthrax
- http://www.cdc.gov/ncidod/dvbid/plague/index.htm
- http://www.cdc.gov/nczved/dfbmd/disease_listing/salmonellosis_gi.html
- http://www.ucmp.berkeley.edu/bacteria/bacteria.html
- http://commtechlab.msu.edu/sites/dlc-me/zoo
- http://www.cellsalive.com/cells/bactcell.htm

## Points to Consider

- In the next section we will discuss the Kingdom Archaea. “Archae” shares the same root word as “archives” and “archaic,” so what do you think it means?
- What do you think the earliest life forms on Earth looked like?
- How do you think these early life forms obtained energy?

# 8.2 Archaea

## Lesson Objectives

- Identify the differences between archaea and bacteria.
- Explain how the archaea can obtain energy.
- Explain how the archaea reproduce.
- Discuss the unique habitats of the archaea.

## Check Your Understanding

- What are the three shapes of bacteria?
- How do bacteria reproduce?
- How can bacteria be harmful?

## Vocabulary

- halophiles
- methanogens
- thermophiles

## What are Archaea?

For many years, archaea were classified as bacteria. However, when scientists compared the DNA of the two prokaryotes, they found that there were 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. In most archaea, the cell wall is assembled from proteins, providing both chemical and physical protection. In contrast to bacteria, most archaea do not have peptidoglycan in their cell walls.
2. The plasma membranes of the archaea also are 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.
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.

## 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.

## Types of Archaea

The first archaea described were unique in that they could survive in extremely harsh environments where no other organisms could survive.

### Halophiles

The **halophiles**, which means "salt-loving," live in environments with high levels of salt ( **Figure** 8.8). 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.

### Thermophiles

The **thermophiles** live in extremely hot environments ( **Figure** 8.9). 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** 8.10). This is an example of a mutualistic relationship. Methanogens are named for their waste product, a gas called methane.

Although archaea are known for living in unusual environments, like 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 and among the plankton in the ocean ( **Figure** 8.11). Therefore, scientists are just beginning to discover some of the important roles that archaea have in the environment.

FIGURE 8.8
Halophiles, like the Halobacterium shown here, require high salt concentrations.

FIGURE 8.9
Thermophiles can thrive in hot springs and geysers, such as this one, the Excelsior Geyser in the Midway Geyser Basin of Yellowstone National Park, Wyoming.

## Lesson Summary

- Archaea are prokaryotes that differ from bacteria somewhat 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.
- Archaea are known for living in extreme environments.

FIGURE 8.10
Cows are able to digest grass with the help of the methanogens in their gut.

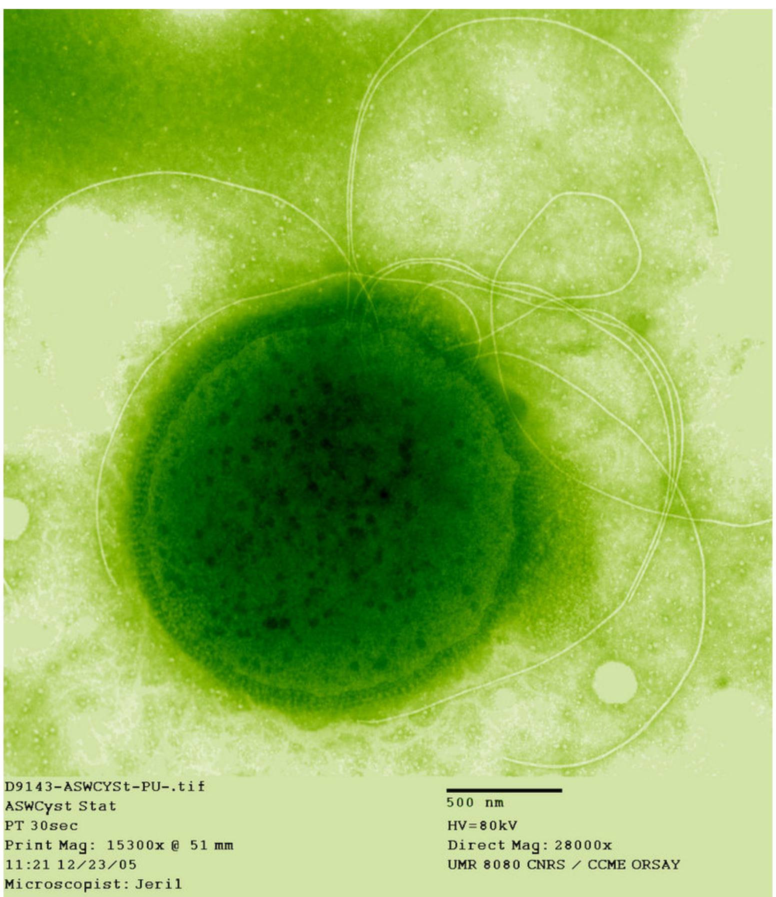



FIGURE 8.11
Thermococcus gammatolerans are another type of archaea.

## Review Questions

### Recall

1. What are the two types of prokaryotes?
2. How are the cell walls of archaea different from those of bacteria?
3. How do archaea obtain energy?
4. How do archaea reproduce?
5. Where do halophiles live?
6. Where do thermophiles live?

### Apply Concepts

7. How could you tell the difference between archaea and bacteria?
8. If an organism is classified as a methanogen, what does this mean?
9. What is an example of a mutualistic relationship between archaea and another organism?

### Think Critically

10. A teacher tells you she wants you to do a project on parasitic archaea. Why will you be unable to complete the project?

11. You find bacteria at the bottom of the Great Salt Lake, and another scientist calls them methanogens. Explain why that scientist is incorrect.

## Further Reading / Supplemental Links

- http://www.ncbi.nlm.nih.gov/pubmed/2112744?dopt=Abstract
- http://www.popsci.com/environment/article/2008-07/they-came-underseas
- http://www.sciencedaily.com/releases/2006/06/060605191500.htm

## Points to Consider

In the next chapter we will move on to the protists and fungi. How do you think they are different from archaea and bacteria?

- Can you think of some ways that fungi can be helpful?
- Can you think of some ways that fungi can be harmful?

# 8.3 References


1. Diagrams: Mariana Ruiz Villarreal (User:LadyofHats/Wikimedia Commons); Bottom left: Courtesy of Dr. William A. Clark/CDC; Bottom center: Courtesy of Eric Erbe and Christopher Pooley/USDA; Bottom right: Courtesy of De Wood and Christopher Pooley/USDA. Diagrams: http://commons.wikimedia.org/wiki/File:Bacteria_morphologic_forms_simplified.svg; Bottom left: http://commons.wikimedia.org/wiki/File:Bacillus_coagulans_01.jpg; Bottom center: http://commons.wikimedia.org/wiki/File:Staphylococcus_aureus,_50,000x,_USDA,_ARS,_EMU.jpg; Bottom right: http://commons.wikimedia.org/wiki/File:Campylobacter.jpg . Public Domain
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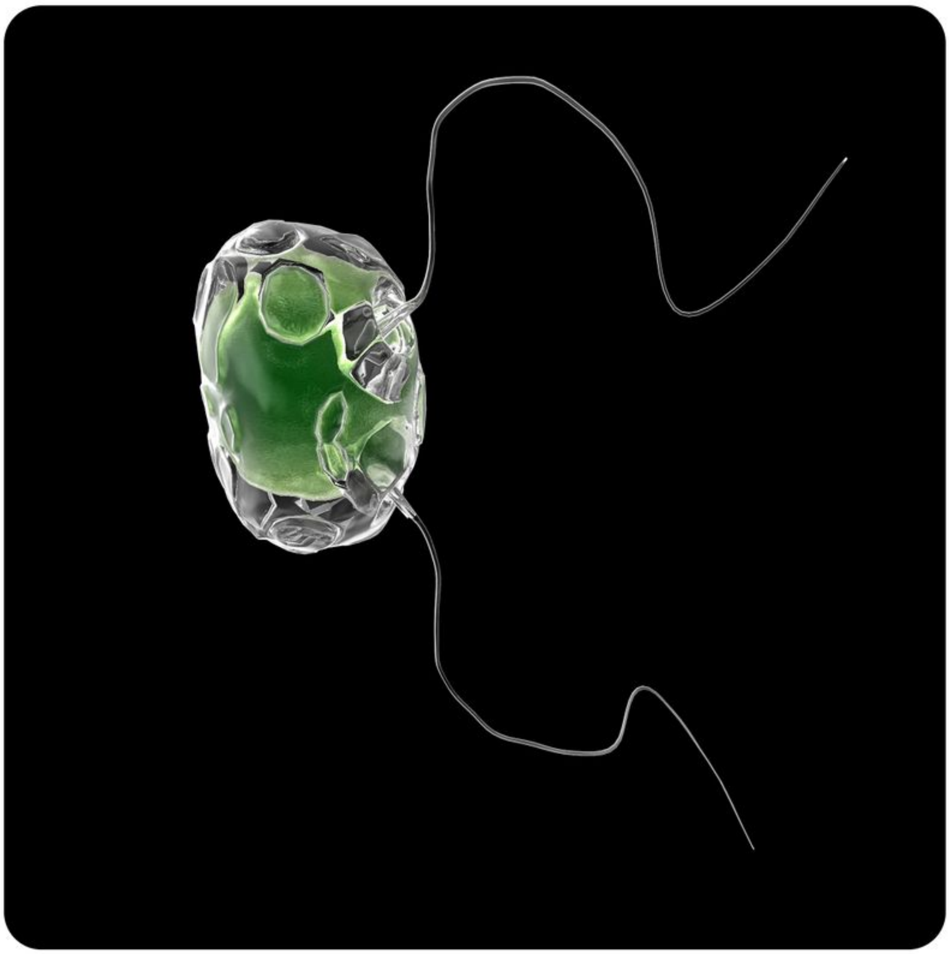
# CHAPTER 9 MS Protists and Fungi

## Chapter Outline





What does the above image look like to you? A bacteria? An animal? A plant? Actually, it is not found in any of those categories. The above organism is called a "protist."

Protists are a unique category of organisms because they are very different when compared to each other, but they can be very similar to plants, animals, and fungi.

What are fungi? They are another kingdom of organisms that are not related to protists, but are equally interesting. There are estimated to be 1.5 million species of fungi, although only 5% of them are classified.

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# 9.1 Protists

## Lesson Objectives

- Explain why protists cannot be classified as plants, animals, or fungi.
- List the similarities that exist between most protists.
- Identify the three subdivisions of the organisms in the kingdom Protista.

## Check Your Understanding

- What are some basic differences between a eukaryotic cell and a prokaryotic cell?
- List some characteristics that all cells have.

## Vocabulary

- autotroph
- cilia
- filter-feeder
- heterotroph
- protist
- protozoa
- pseudopodia

## What are Protists?

**Protists** are eukaryotes, and most are single-celled. You can think about protists as all eukaryotic organisms that are neither animals, nor plants, nor fungi.

Even among themselves, they have very little in common. Although theses organisms were put in the category *Protista* by Ernst Haeckel in 1866, the Kingdom Protista was not an accepted classification in 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." This kingdom contains the eukaryotes that cannot be put into any other kingdom.

### Unicellular or Multicellular?

Most protists, such as the ones shown in **Figure** 9.1, are so small that they can be seen only with a microscope. Protists are mostly unicellular (one-celled) eukaryotes that exist as independent cells. A few protists are multicellular (many-celled) and surprisingly large. These protists do not, however, show cellular specialization or differentiation into tissues. For example, kelp is a multicellular protist and can be over 100-meters long with cells that perform mostly the same jobs.

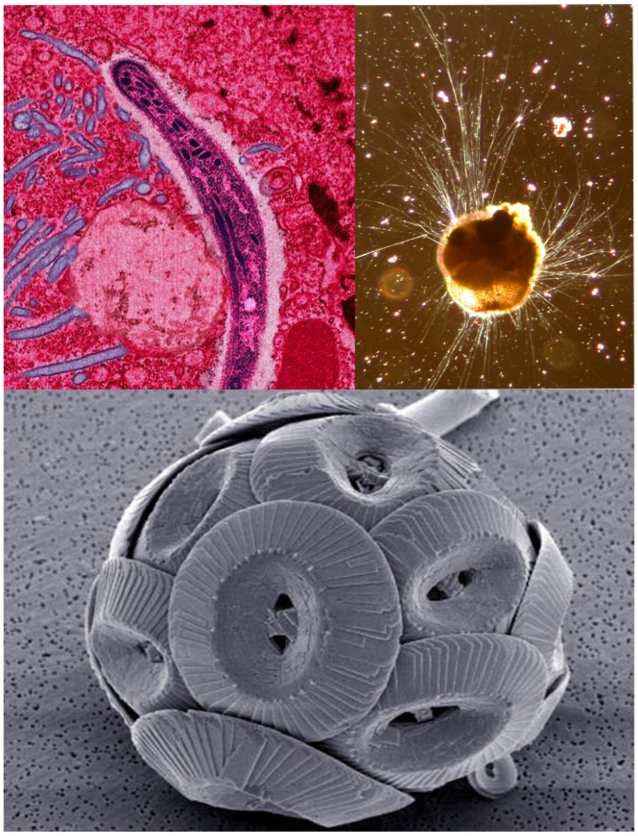

FIGURE 9.1
Protists come in many different shapes.

## 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.

For classification, the protists are divided into three groups:

1. Animal-like protists
2. Plant-like protists
3. Fungi-like protists.

But remember, protists are not animals, nor plants, nor fungi ( **Figure** 9.2).

FIGURE 9.2
This slime mold is a protist. Slime molds had previously been classified as fungi but are now placed in the Kingdom Protista. Slime molds live on decaying plant life and in the soil.

### Classification of Protists

As there are many different types of protists, the classification of protists can be difficult. Recently, scientists confirmed that the protists are related by analyzing their DNA. Protists with more common DNA sequences are more closely related to each other then those with fewer common DNA sequences.

Find information on different types of protists here: http://www.ucmp.berkeley.edu/alllife/eukaryotasy.html .

### How Protists Obtain Food

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.

For such simple organisms, protists get their food in a complicated process. Although there are many photosynthetic protists, such as algae, that get their energy from sunlight, many others 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 its cell wall and cell membrane 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 paralyzed, the food material moves through the vacuole and into the cytoplasm of the protist.

Other protists are parasitic and absorb nutrients meant for their host, harming the host in the process.

## Animal-like Protists

Animal-like, plant-like, and fungi-like protists are different from each other mainly because they have different ways of getting carbon. Carbon is important in the formation of organic compounds like carbohydrates, lipids, proteins, and nucleic acids. You get it from eating, as do other animals.

Animal-like protists are called protozoa. **Protozoa** are single-celled eukaryotes that share certain traits with organisms in the animal kingdom. Like animals, they can move, and they they get their carbon from outside sources. They are **heterotrophs**, which 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 zooflagellates, ciliates, and the sporozoans ( **Figure** 9.3).

Some animal-like protists literally “eat with their tails.” The tail of a protist is a flagellum. These protists are called flagellates. Flagellates are **filter-feeders**. They acquire oxygen and nitrogen by constantly whipping the flagellum

FIGURE 9.3
Euglena are animal-like protists. Over 1000 species of Euglena exist. They are used in industry in the treatment of sewage.

back and forth, a process called filter-feeding. The whipping of the flagellum creates a current that brings food into the protist. Recall that prokaryotes can also have flagella (plural for flagellum).

### Different Kinds of Animal-like Protists

Are there different types of animal-like protists? Yes. They are different because they move in different ways.

- Flagellates have long flagella, or tails. Flagella rotate in a propeller-like fashion. An example of a flagellate is the *Trypanosoma*, which causes African sleeping sickness.
- Other protists have what are called transient **pseudopodia**, which are like temporary feet. The cell surface extends out a membrane, and the force of this membrane moves the cell forward. An example of a protist with a pseudopod is the amoeba.
- Another way protists move is by the movement of 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. The *paramecium* has cilia that propel it.
- A few protists are do not move at all, such as the *toxoplasma*. These protists form spores that become new protists, and are known as sporozoa.

## Plant-like Protists

Plant-like protists are **autotrophs.** This means that they produce their own food. They perform photosynthesis to produce sugar by using carbon dioxide and the energy from sunlight, just like plants. Plant-like protists live in soil, in seawater, on the outer covering of plants, and in ponds and lakes ( **Figure** 9.4). Protists like these can be unicellular or multicellular. Some protists, such as kelp, live in huge colonies in the ocean.

Plant-like protists are essential to the environment because they produce oxygen through photosynthesis, which helps other organisms, like animals, survive.

Plant-like protists are classified into a number of basic groups ( **Table** 9.1).

FIGURE 9.4
Red algae are a very large group of protists making up about 5,000–6,000 species. They are mostly multicellular, live in the ocean. Many red algae are seaweeds and help create coral reefs.

**TABLE 9.1: Plantlike Protists**

| Phylum | Description | Number (approximate) | Example |
|---|---|---|---|
| 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* |

## Fungus-like Protists

Fungus-like protists are heterotrophs that have cell walls and reproduce by forming spores (see Lesson 9.2 for more information about spores). Fungus-like protists usually do not move, but some develop movement at some point in their lives.

There are essentially three types of fungus-like protists (see **Table** 9.2):

1. Water molds.
2. Downy mildews.
3. Slime molds.

Slime molds represent the characteristics of the fungus-like protists. Most slime molds 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. 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 a several centimeters long. *Fuligo*, sometimes called “vomit mold,” is a yellow slime mold found in decaying wood.



**TABLE 9.2: Fungus-like Protists**

**TABLE 9.2:** (continued)

| Protist | Source of Carbon | Environment | Characteristics |
|---|---|---|---|
| Mycetozoa: slime molds ( **Figure** 9.5) | dispose of dead plant material, feed on bacteria | common in soil, on lawns, and in the forest commonly on deciduous logs | Includes the cellular slime mold, which involves numerous individual cells attached to each other, forming one large "supercell," essentially a bag of cytoplasm containing thousands of individual nuclei. The plasmodial slime molds spend most of their lives as individual cells, but when a chemical signal is released, they form a cluster that acts as one organism. |

FIGURE 9.5
An example of a slime mold.

## 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, 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 are used to analyze the chemical signals used 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. Chemicals from other kinds of algae are used to produce many kinds of plastics.

## Lesson Summary

- Protists are highly diverse organisms that belong to the Kingdom Protista.
- Protists are divided into three subgroups: animal-like protists, plant-like protists and fungus-like protists.
- Animal-like protists are unicellular eukaryotes that share certain traits with animals, such as mobility and heterotrophy.
- Plant-like protists are unicellular or multicellular autotrophs that live in soil, in seawater, on the outer covering of plants, and in ponds and lakes.
- Fungus-like protists, such as water molds, downy mildews, and slime molds, are heterotrophs that reproduce by forming spores.

## Review Questions

### Recall

1. List the characteristics that all protists share.

2. List two ways that protists obtain food.

3. Describe the characteristics of an animal-like protist.

4. Describe the characteristics of a plant-like protist.

5. Describe the characteristics of a fungi-like protist.

6. Name three kinds of fungi-like protists.

### Apply Concepts

7. Explain why protists are important to life on Earth.

8. You find a protist that is a heterotroph and lives in the ocean. Is this protist most similar to a plant, animal, or fungus? Why or why not?

### Critical Thinking

9. Imagine that you are a scientist delivering a paper called *Protists: the Junk-Drawer Kingdom*. Explain your reasoning for this title?

## Further Reading / Supplemental Links

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## Points to Consider

- Fungi comprise one of the eukaryotic kingdoms. Think about what might distinguish a fungi-like protist from a true fungus?
- Given the vast differences between the protists discussed in this lesson, think about the possibilities of dividing this kingdom into additional kingdoms. How might that division be accomplished? Is that a good idea or would it just lead to confusion?

# 9.2 Fungi

## Lesson Objectives

- Describe the characteristics of fungi.
- Identify structures that distinguish fungi from plants and animals.
- Explain how fungi can be used in industry.

## Check Your Understanding

- What is a significant difference between a protist and other eukaryotic organisms?
- What are some of the distinguishing characteristics of fungus-like protists?

## Vocabulary

- budding
- chitin
- fruiting body
- hyphae
- mycelial fragmentation
- mycelium
- mycorrhizal symbiosis
- parasite
- spore

## 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** 9.6). Our environment needs fungi. Fungi help decompose matter and make nutritious food for other organisms. Fungi are all around us and are useful in many ways.

If you had to guess, would you say a fungus is a plant or 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

FIGURE 9.6
These many different kinds of organisms that demonstrate the huge diversity within the Kingdom Fungi.

"food" from outside of themselves. In other words, they must "eat" their food like animals and many bacteria do.

Yeasts, molds, and mushrooms are all different kinds of fungi ( **Figure** 9.7). There may be as many as 1.5 million species of fungi. 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.

### Fungi and Symbiotic Relationships

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. This form of helping each other out is called **mycorrhizal symbiosis.** Mycorrhizal means "roots" and symbiosis means "relationship" between organisms ( **Figure** 9.8).

As the plants and fungi form the close relationship, the plant and the fungus "feed" one another. The plant provides glucose and sucrose to the fungus that the plant makes through photosynthesis, which the fungus cannot do. The fungi then provides minerals and water to the roots of the plant.

FIGURE 9.7
The blue in this blue cheese is actually mold.

FIGURE 9.8
This mushroom and tree live in symbiosis with each other.

### 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. Although lichens may not be the prettiest organisms in nature, they are unique. A lichen is really two organisms that live very closely together: a fungus and a bacteria or algae. The cells from the algae or bacteria live inside the fungus. Each organism provides nutrients for the other.

What is it called when two organisms live close together and form a relationship? Symbiosis. A lichen is the result of symbiosis between a fungus and another organism. Because this relationship helps both organisms, it is called a mutualistic relationship.

### 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**.

Examples of parasitic fungi include the following:

- Beginning in 1950, Dutch Elm trees in the United States began to die. Since then much of the species has 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. The tree tried to stop the growth of the fungus by blocking its own ability to gain water. However, without water the tree soon died.
- Some parasitic fungi cause human diseases such as athlete's foot and ringworm. These fungi feed on the outer layer of warm, moist skin.

### Fungi as Predators

Fungi growing on a tree trunk does not seem very dangerous. But some fungi are actually hunters. For example, some fungi trap nematodes. A nematode is a worm that some fungi like to eat. These hungry fungi live deep in the soil where they set traps for unsuspecting nematodes by making a circle with their hyphae. **Hyphae** are like arms and legs. They look like cobwebs and can be sticky. Fungi set out circular rings of hyphae with a lure inside, which brings the nematode inside the fungus ( **Figure** 9.9).

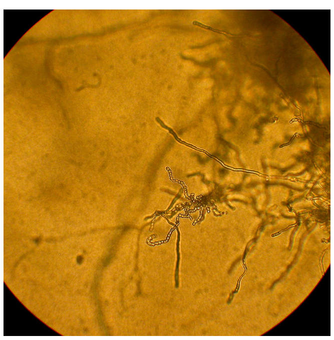

FIGURE 9.9
Hyphae are the cobweb-like arms and legs of fungi.

### 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." 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.

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.

Why do you think a large surface area allows fungi to obtain more nutrients?

### Fungi Body Parts

The most important body parts of a fungi include:

1. Cell wall: A layer around the cell membrane of fungi cells, similar to that found in plant cells.
2. Hyphae: These are thread-like structures which interconnect and bunch up into a **mycelium.** 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.
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** 9.10). Those spores, discussed in the next section, are the basic reproductive units of fungi.

FIGURE 9.10

A mushroom is a fruiting body.

## Fungi Reproduction

Reproduction of fungi is different for different fungi. Many fungi reproduce both sexually or asexually, while some reproduce only sexually and some only asexually. Asexual reproduction takes only one parent and sexual reproduction takes two parents.

### Asexual Reproduction

Fungi reproduce asexually through three methods:

1. **Spores**: Spores are formed by the fungi and released to create new fungi. Have you ever seen a puffball? A puffball is a kind of fungus that has thousands of spores in a giant ball. Eventually the puffball bursts and releases the spores in a huge "puff."
2. **Budding**: The fungus grows part of its body, which eventually breaks off. The broken-off piece becomes a "new" organism.
3. **Mycelial fragmentation**: In this method, a piece of the mycelium splits off of the fungi. A fragmented piece of the mycelium can eventually produce a new colony of fungi.

Asexual reproduction is faster and produces more fungi than sexual reproduction. Some species of fungi can only perform asexual reproduction. This form of reproduction is controlled by many different factors, including environmental conditions such as the amount of sunlight and carbon dioxide the fungus receives, as well as the availability of food.

### Sexual Reproduction

Almost all fungi can reproduce through the process of meiosis. Meiosis is a type of cell division where haploid cells are produced (discussed in chapter titled *Cell Division, Reproduction and DNA*). But meiosis in fungi is really different from sexual reproduction in plants or animals.

In plants and animals, meiosis occurs in diploid cells and is a process that produces haploid cells. Remember, a diploid cell is a cell with two sets of chromosomes, one from each parent. A haploid cell has one set of chromosomes. In meiosis, four haploid cells are produced. Each haploid cell has half the chromosome number of the parent cell.

However, in fungi, meiosis occurs right after two haploid cells fuse, producing four haploid cells. Mitosis then produces a haploid multicellular "adult" organism or haploid unicellular organisms. Mitosis is cell division that creates two genetically identical offspring cells ( **Figure** 9.11).

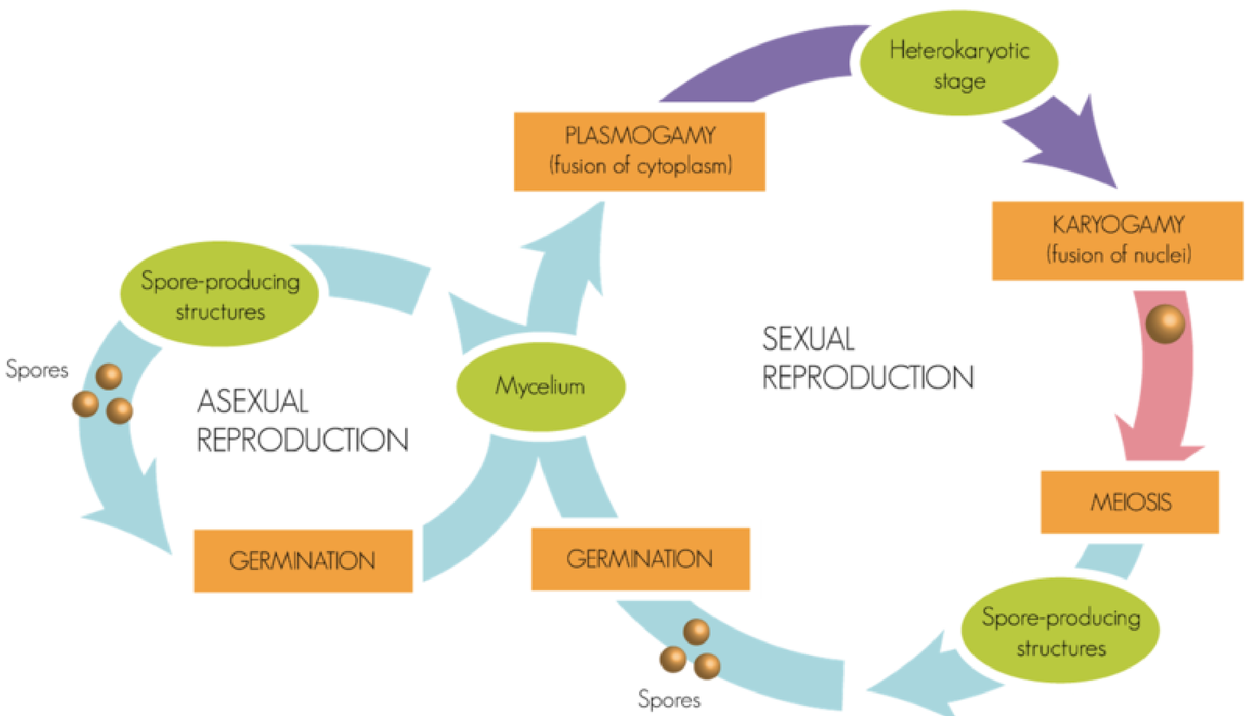


FIGURE 9.11

A diagram of how asexual and sexual reproduction work in fungi.

## Classification of Fungi

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 usually have a leaf or flower that is attached to a stem. Also:

- Fungi and plants have similar structures.
- Plants and fungi live in the same kinds of habitats, such as growing in soil.
- Plants and fungi both have a cell wall, which animals do not have.

### Structure of Fungi

There are a number of characteristics that make fungi different from other eukaryotic organisms:

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 have to obtain their food from outside sources.
2. The cell walls in many species of fungi contain chitin. **Chitin** is a nitrogen-containing material 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 that transfer water and nutrients.
4. One characteristic that is unique to fungi is the presence of hyphae, which combine in groups called mycelia, as described above.

### The Evolution of Fungi

Fungi appeared during the Paleozoic Era, a geologic time period lasting from about 570 million to 248 million years ago. This is also the time when fish, insects, amphibians, reptiles, and land plants appeared. The first fungi most likely lived in water and had flagella that released spores. The first land fungi probably appeared in the Silurian period (443 million years ago to about 416 million years ago), the same time period that land plants also first appeared. See different types of fungi here: http://www.tolweb.org/Fungi .

## Roles of Fungi

Fungi are found all over the globe in many different kinds of habitats. Fungi even thrive in deserts. Most fungi are found on land rather than in the ocean, though some species live only in ocean habitats. Fungi are extremely important to these ecosystems because they are one of the major decomposers of organic material. Scientists have estimated that there are nearly 1.5 million species of fungi.

### Importance of Fungi for Human Use

Humans use fungi for food preparation or preservation and other purposes.

- Yeasts are help ferment beer, wine and bread ( **Figure** 9.12).
- Some fungi are used in the production of soy sauce and tempeh, a source of protein used in Southeast Asia.
- Mushrooms are used in the diet of people all over the globe.
- Fungi can produce antibiotics, such as penicillin.
- The chitin in the cell walls of fungi has been said to have healing properties.

### Edible and Poisonous Fungi

Some of the best known types of fungi are mushrooms, which can be edible or poisonous.

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*, the most commonly eaten

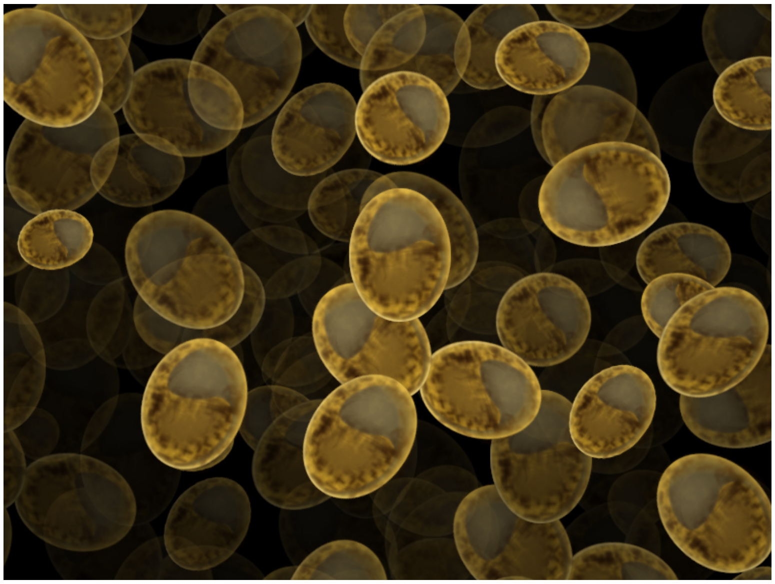

FIGURE 9.12

*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. There are several other species of yeast used in brewing beer. Each can impart a distinctive taste.

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 stomach ache, while others may kill you. Some mushrooms you can eat when they are cooked but are poisonous when raw.

Have you ever eaten blue cheese? Do you know what makes it blue? You guessed it. 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.

### Fungi Control of Pests

Some fungi work as natural pesticides. For example, some fungi may be used to limit or kill harmful organisms like mites, pest insects, certain weeds, worms, and other fungi that harm or kill crops.

## Lesson Summary

- Fungi are classified in their own kingdom based on their structures, ways of obtaining food, and on they reproduce.
- Fungi live with other organisms in symbiotic relationships.
- Fungi reproduce asexually and sexually.
- Fungi appeared during the Paleozoic Era.
- Fungi are widely used in foods, industry, and medicine.

## Review Questions

### Recall

1. What are two characteristics distinguishes fungi from plants?

2. How many species of fungi exist?

3. Name two human diseases caused by fungus.

4. What is a lichen?

### Apply Concepts

5. Explain how mycorrhizal symbiosis works.

6. Describe the relationship between the ambrosia beetle and fungi.

7. If you see mold on your bread, what part of the fungus are you observing?

8. Describe the three methods of asexual reproduction in fungi.

### Critical Thinking

9. "Sexual reproduction in fungi is similar to sexual reproduction in animals." Explain why this statement is true or false.

10. You go back in time to talk with scientists who believe that fungi are a type of plant. What will you tell them?

## Further Reading / Supplemental Links


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- http://www.ucmp.berkeley.edu/fungi/fungi.html
- http://www.perspective.com/nature/fungi

## Points to Consider

- Plants are fascinating, diverse organisms. Although scientists used to think that fungi were plants, we now know that plants and fungi are separate. In this lesson we have discussed fungi. Next we start discussing plants. What do you think sets plants apart from fungi?

# 9.3 References


1. Ute Frevert; false color by Margaret Shear; Scott Fay/UC Berkeley; Richard Lampitt and Jeremy Young/Natural History Museum, London. Protists come in many different shapes. . CC BY 2.5
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5. Courtesy of the NPS. An example of a slime mold . Public Domain
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12. Zappy's. Illustration of the useful fungi Baker's yeast . CC BY-NC 3.0

# CHAPTER 10 MS Plants

## Chapter Outline



How many questions can you ask about flowers? Why are they so brightly colored? Why are there so many different kinds? Do all plants have flowers? What are plants with flowers called? Why did plants evolve to have flowers?

What other structure is included in the above image on the plant? Those are berries, or the fruits of the plant. What is a fruit? Why is the fruit important for a plant? Why did plants evolve to have fruit?

Scientists and naturalists have been asking these questions for centuries. While reading, see if you can answer some of the above questions and ask some more of your own.

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# 10.1 Introduction to Plants

## Lesson Objectives

- Describe the major characteristics that of organisms in Kingdom Plantae.
- Describe plants' major adaptations for life on land.
- Explain plants' reproductive cycle.
- Explain how plants are classified.

## Check Your Understanding

- What are the major differences between a plant cell and an animal cell?
- What is photosynthesis?

## Vocabulary

- alternation of generations
- angiosperms
- cuticle
- gymnosperms
- nonvascular plants
- phloem
- seedless vascular plants
- vascular tissue
- xylem

## What Are Plants?

Plants have adapted to a variety of environments, from the desert to the tropical rain forest to our lakes and oceans. In each environment, plants have become crucial to supporting animal life. From tiny mosses to extremely large trees ( **Figure** 10.1), 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. As discussed in the *Cell Functions* chapter, photosynthesis is the process by which plants capture the energy of sunlight and use carbon dioxide from the air to make their own food. Lastly, plants must be multicellular. Recall that some protists are eukaryotic and photosynthetic, but are not considered plants because they are mostly unicellular.

FIGURE 10.1
There is great diversity in the plant kingdom, from tiny mosses to huge trees.

## Adaptations For Life On Land

Before plants evolved, most photosynthetic organisms lived in the water. So, where did plants come from? Evidence shows that plants evolved from freshwater green algae ( **Figure** 10.2). 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. (For a review of plant cells, see the *Cells and Their Structures* chapter.) So what separates green algae, which are protists, from green plants?

FIGURE 10.2
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** 10.3). 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:
    a. **Xylem**: Responsible for the transport of water and nutrients from the roots to the rest of the plant. Generally (not always), xylem carries water from the roots up to the rest of the plant.
    b. **Phloem**: Carries the sugars made during photosynthesis (in the leaves) to the parts of the plant where they are needed. Generally (not always), phloem carries sugars down to the rest of the plant.

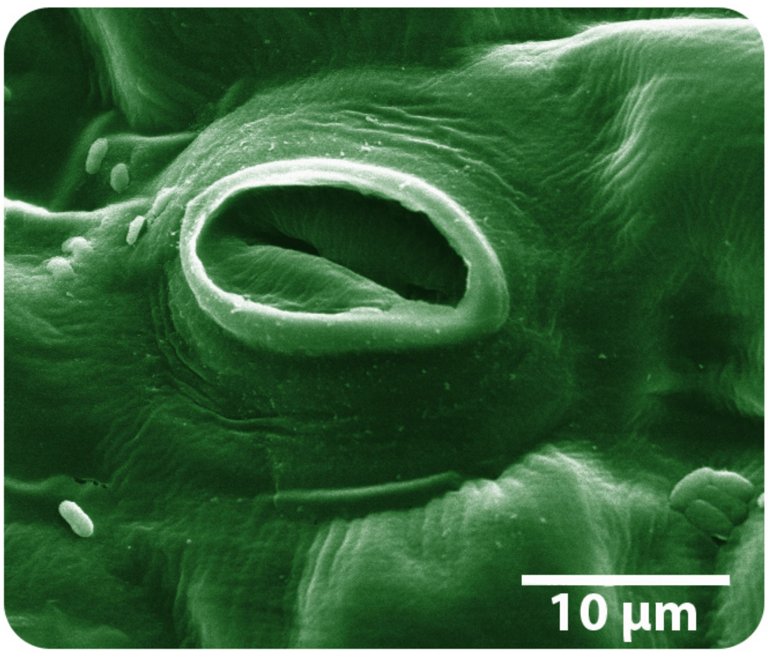


FIGURE 10.3
Stomata are pores in leaves that allow gasses to pass through, but they can be closed to conserve water.

## Plant Reproduction and Life Cycle

The life cycle of a plant is very different from the life cycle of an animal. A human cannot exist unless it is made entirely of diploid cells (cells with two sets of chromosomes). Plants can live, however, when they are made up of diploid cells or haploid cells (cells with one set of chromosomes).

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.

Briefly, alternation of generations can be summarized in the following four steps: follow along in **Figure** 10.4 as you read through the steps.

1. The gametophyte produces the gametes, or sperm and egg, by mitosis. Remember, gametes are haploid.
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 gametophyte.

As we will see in the following lessons, 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.

In flowering plants, the female gametophyte, the ovary, is found within the sporophyte. The male gametophyte is the pollen.

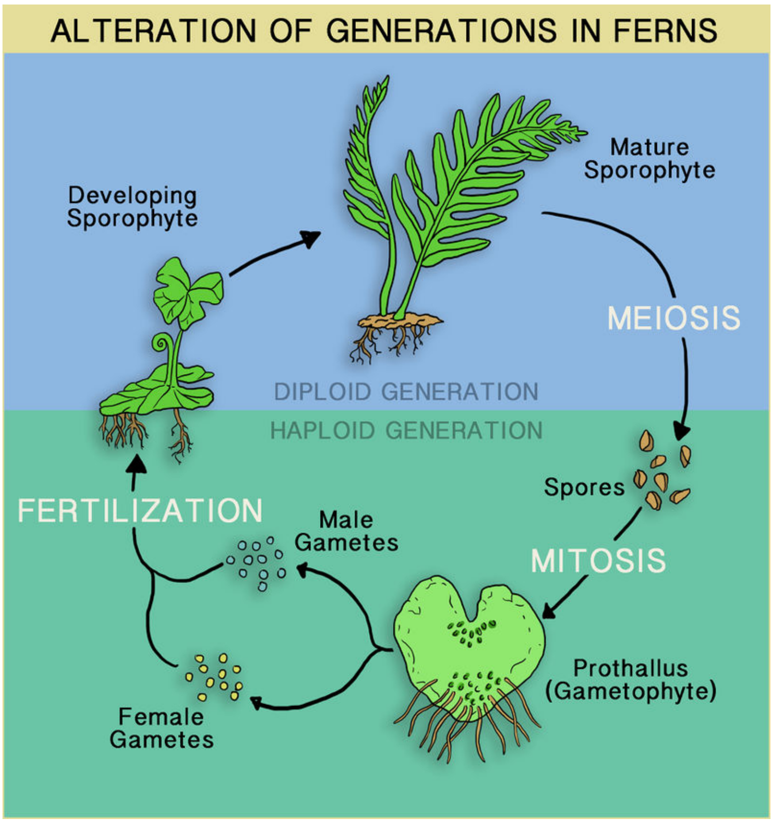


FIGURE 10.4
In ferns, the sporophyte is dominant and produces spores that germinate into a gametophyte. After fertilization the sporophyte is produced. Ferns will be discussed in further detail in the next lesson.

## Classification of Plants

Plants are formally divided into 12 phyla (plural for phylum), and these phyla are gathered into four groups. These four groups are based on the evolutionary history of significant features in plants:

1. **Nonvascular plants** evolved first, and keep the embryo inside of the reproductive structure after fertilization. These plants do not have vascular tissue (xylem and phloem).
2. **Seedless vascular plants** evolved to have vascular tissue after the nonvascular plants, but do not have seeds.
3. Non-flowering plants, or **gymnosperms**, evolved to have seeds, but do not have flowers.
4. Flowering plants, or **angiosperms**, evolved to have vascular tissue, seeds, and flowers.

These four groups are the focus of the next two lessons. **Figure** 10.5 shows some of the rich diversity of the plant kingdom.

FIGURE 10.5
The plant kingdom contains a diversity of organisms. Note that *Volvox* in the upper left is a protist, not a plant.

## Lesson Summary

- Plants are multicellular photosynthetic eukaryotes that evolved from green algae.
- Plants have several adaptive features for living on land, including a cuticle, stomata, and vascular tissue.
- Plants are informally divided into four groups: the nonvascular plants, the seedless vascular plants, the nonflowering plants (gymnosperms) and the flowering plants (angiosperms).

## Review Questions

### Recall

1. What is the purpose of the stomata?
2. What term describes the plant life cycle?
3. What is the diploid stage of the alternation of generations?
4. What is the term for plants that lack vascular tissue?
5. What is the term for plants that have flowers and bear fruit?

### Apply Concepts

6. Plants evolved from green algae. How are they different from green algae?
7. Describe how plants evolved from water-living organisms to organisms that live on land.

### Critical Thinking

8. A scientist mistakes a photosynthetic protist from a plant. However, the protist is not a plant. Explain why.
9. Why do you think plants are necessary for animal life?

## Further Reading / Supplemental Links

- http://www.ucmp.berkeley.edu/plants/plantae.html
- http://www.bioedonline.org/slides/slide01.cfm?q=%22Plantae%22
- http://www.wisc-online.com/objects/index_tj.asp?objID=BIO804
- http://www.perspective.com/nature/plantae
- http://plants.usda.gov

## Points to Consider

Next we discuss seedless plants.

- Can you think of examples of plants that do not have seeds?
- If a plant does not have seeds, how can it reproduce?

# 10.2 Seedless Plants

## Lesson Objectives

- Name examples of nonvascular seedless plants.
- Name examples of vascular seedless plants.
- Explain the reproduction strategies of seedless plants.
- Describe the ways seedless plants impact humankind.

## Check Your Understanding

- What is a plant?
- How are plants classified?

## Vocabulary

- club mosses
- ferns
- hornworts
- horsetails
- liverworts
- mosses
- sporangium
- whisk ferns

## Seedless Plants

What do you think a forest looked like millions of years ago? Or tens of millions of years ago? Or hundreds of millions of years ago? Probably very different than today.

Nonvascular seedless plants and vascular seedless plants have had a great impact on all our lives. More than 300 million years ago, during the Carboniferous period, forests looked very different than they do today. Seedless plants grew as tall as today's trees in large swampy forests ( **Figure** 10.6). The remains of these forests formed the coal that we depend on today. Although most of these giant seedless plants are now extinct, smaller relatives still remain.


FIGURE 10.6
Seedless plants were dominant during the Carboniferous period, as illustrated by this drawing.

## Nonvascular Seedless Plants

Nonvascular seedless plants, as their name implies, lack vascular tissue. Of course, they don't have seeds either. 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 can have stem-like and root-like structures. These plants are very short because they cannot move nutrients and water up a stem.

Nonvascular plants are classified into three phyla:

1. Mosses
2. Hornworts
3. Liverworts

### Mosses

**Mosses** have a scientific name, *Bryophyta*. They 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. The gametophyte produces the gametes that, after fertilization, develop into the diploid sporophyte. The sporophyte forms a capsule, called the **sporangium**, which releases spores ( **Figure** 10.7).

FIGURE 10.7
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 part of the phylum *Anthocerophyta*. 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** 10.8). They usually grow in moist and humid areas.

### Liverworts

**Liverworts** are in the phylum *Hepatophyta*. They 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** 10.9). Liverworts can often be found along stream beds.

## 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

FIGURE 10.8
In hornworts, the "horns" are the sporophytes that rise up from the leaflike gametophyte.

FIGURE 10.9
Liverworts with a flattened, ribbon-like body are called thallose liverworts.

vascular tissue allowed these plants to grow much taller than nonvascular plants, forming the ancient swamp forests mentioned previously. Most of these large vascular seedless plants are now extinct, but their smaller relatives still remain.

Seedless vascular plants include:

1. Club mosses.
2. Ferns.
3. Horsetails.
4. Whisk ferns.

### Clubmosses

**Clubmosses**, in the phylum *Lycophyta*, are so named because they can look similar to mosses ( **Figure** 10.10).

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 10.10
Clubmosses can resemble mosses, but clubmosses have vascular tissue, while mosses do not.

## Ferns

**Ferns**, in the phylum *Pterophyta*, are the most common seedless vascular plants ( **Figure** 10.11). They usually have large divided leaves called fronds. In most ferns, fronds develop from a curled-up formation called a fiddlehead ( **Figure** 10.12). 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.

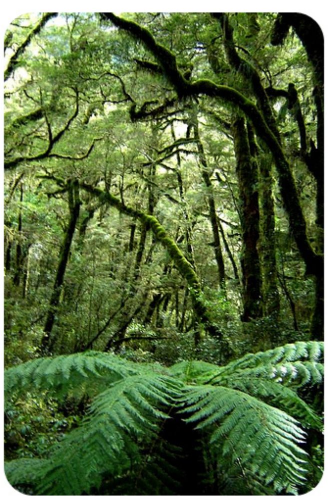

FIGURE 10.11
Ferns are common in the understory of the tropical rainforest.

FIGURE 10.12
The first leaves of most ferns appear curled up into fiddleheads.

### Horsetails

**Horsetails**, in the phylum *Sphenophyta*, have hollow, ribbed stems and are often found in marshes ( **Figure** 10.13). 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 (mostly, photosynthesis 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 10.13
Horsetails are common in marshes.

### Whisk Ferns

**Whisk ferns**, in the phylum *Psilophyta*, have green branching stems with no leaves, so they resemble a whisk broom ( **Figure** 10.14). Another striking feature of the whisk ferns is its spherical yellow sporangia.

FIGURE 10.14
Whisk ferns have no leaves and bear yellow sporangia.

## Reproduction of 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. In the life cycle of the nonvascular seedless plants, the gametophyte stage is the longest part of the cycle. The gametophyte is photosynthetic.

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 (see **Figure** 10.14).

The sporangia of ferns are often on the underside of the fronds ( **Figure** 10.15). 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 10.15
This fern is producing spores underneath its fronds.

## Why Seedless Plants Are Important

### Seedless Plants Became Coal

The greatest influence of 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. 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** 10.16).

Ferns are also found in many gardens as ornaments. The fiddleheads of certain species of ferns are used in gourmet food. Some species of ferns, like the maidenhair fern, are used as medicines.

## Lesson Summary

- Nonvascular seedless plants include mosses, liverworts, and hornworts.
- Vascular seedless plants include clubmosses, ferns, whisk ferns, and horsetails.

FIGURE 10.16
Sphagnum, or peat moss, is commonly added to soil to help absorb water and keep it in the soil.

- Nonvascular seedless plants spend most of their life cycle in the gametophyte stage, while vascular seedless plants spend most of their life as a sporophyte.
- The death of seedless plants millions of years ago produced coal.
- Mosses and ferns are used commonly in gardening.

## Review Questions

### Recall

1. What is vascular tissue?

2. What is an example of a nonvascular seedless plant?

3. What is an example of a vascular seedless plant?

4. Compare and contrast the fern gametophyte and sporophyte.

5. What are some of the distinguishing features of horsetails?

6. What does the sporophyte of the hornwort look like?

### Apply Concepts

7. Your friend finds a whisk fern and insists it is the same as a fern. Explain why it is different.

8. Explain why the following quote is true: "Clubmoss is not a type of moss."

### Critical Thinking

9. "After they died, many seedless plants have been a great benefit to humans." Explain why you agree or disagree with the statement.

10. Explain to a group of gardeners how they may use seedless plants.

## Further Reading / Supplemental Links

- http://www.cavehill.uwi.edu/FPAS/bcs/bl14apl/bryo1.htm
- http://www.microscopy-uk.org.uk/mag/indexmag.html
- http://www.microscopy-uk.org.uk/mag/artjul98/jpmoss.html
- http://www.biologycorner.com/bio2/notes_plants.html
- http://forestencyclopedia.com/p/p1893
- http://www.hiddenforest.co.nz/plants/clubmosses/clubmosses.htm
- http://amerfernsoc.org/

## Points to Consider

Next we discuss plants with seeds.

- Can you think of examples of plants that have seeds?
- Can you think of a plant that has seeds but no flowers or fruits?
- Why do you think having flowers is beneficial to a plant?

# 10.3 Seed Plants

## Lesson Objectives

- Describe the importance of the seed.
- Explain the ways in which seeds are dispersed.
- Define and give examples of gymnosperms.
- Define and give examples of angiosperms.
- Explain some uses of seed plants.

## Check Your Understanding

- What are the two types of seedless plants?
- How do seedless plants reproduce?

## Vocabulary

- anther
- calyx
- carpel
- complete flowers
- conifers
- corolla
- dormant
- ginko
- incomplete flowers
- ovary
- sepals
- stamen
- stigma

## Seeds and Seed Dispersal

### 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. 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 very 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, as shown in **Figure** 10.17.

FIGURE 10.17
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 spread the seed ( **Figure** 10.18).

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.

## Gymnosperms

Plants with "naked" seeds, meaning they are not enclosed by a fruit, are called gymnosperms. Instead, the seeds of gymnosperms are usually found in cones.

There are four phyla of gymnosperms:

1. Conifers.

FIGURE 10.18
Fleshy fruits aid in seed dispersal since animals eat the fruits and carry the seeds to a new location.

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 pines, firs, spruces, cedars, and the coastal redwood trees in California that 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** 10.19). 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 material, is carried by the wind to fertilize the seed cones that contain the female gamete ( **Figure** 10.20).

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** 10.21). 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 10.19
A red pine, which bears seeds in cones, is an example of a conifer.

FIGURE 10.20
The end of a pine tree branch bears the male cones that produce the pollen.

### 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** 10.22). 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.

FIGURE 10.21
Cycads bear their pollen and seeds in cones on separate 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.

### 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** 10.23). Overall, there are about 70 different species in this diverse phylum.

## Angiosperms

Angiosperms, in the phylum *Anthophyta*, are the most successful phylum of plants. This category also contains the largest number of individual plants (see **Figure** 10.24). 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.

### The Parts of a Flower

Even though flowers may look very different from each other, they do have some structures in common. Follow along in **Figure** 10.25 as the structures are explained below:

- The green outside of a flower that often looks like a leaf is called the **sepal** ( **Figure** 10.26). 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** 10.26) 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.
- 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.

FIGURE 10.22
Ginkgo trees are gymnosperms with broad leaves.

- 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.

When flowers have all of these parts, they are known as **complete flowers**. Other flowers may be missing one or more of these parts and are known as **incomplete flowers. Table** 10.1 summarizes the parts of the flower.

**TABLE 10.1: Review the parts of the flower**

| Flower 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 anther that produces pollen. |

TABLE 10.1: (continued)

| Flower part | Definition |
|---|---|
| **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** | Larged bottom part of the carpel where the ovules are contained. |

FIGURE 10.23
One type of gnetophyte is Welwitschia.

FIGURE 10.24
Angiosperms are the flowering plants.

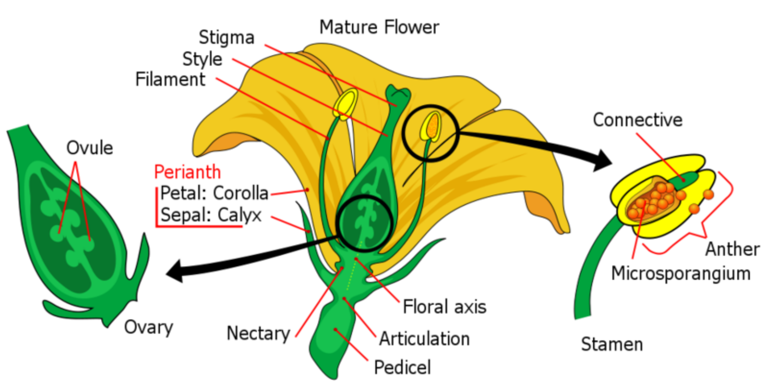


FIGURE 10.25
A complete flower has sepals, petals, stamens, and one or more carpels.

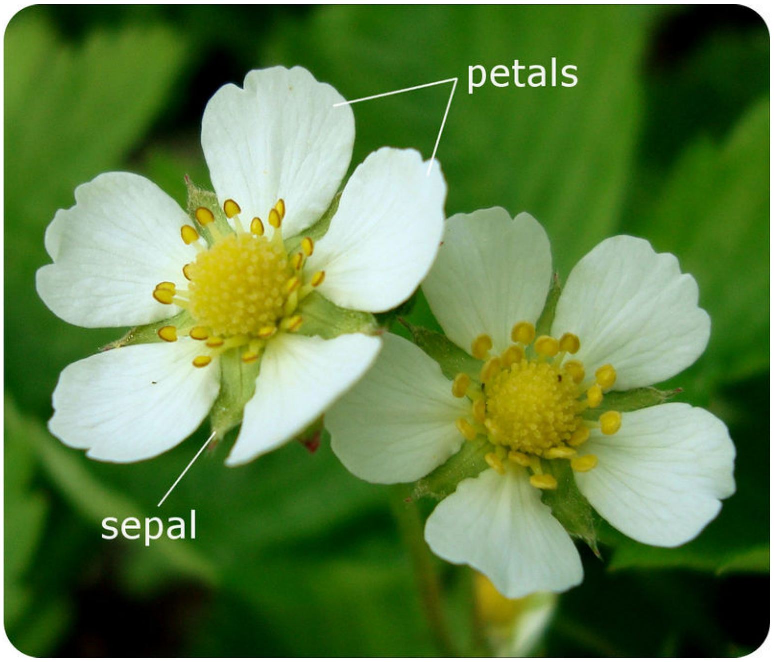


FIGURE 10.26
This image shows the difference between a petal and a sepal.

### 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 to increase seed dispersal and are also nutritious foods.

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.

## Lesson Summary

- Seeds consist of a dormant plant embryo and stored food.
- Seeds can be dispersed by wind or by animals that eat fleshy fruits.
- Gymnosperms, seed plants without flowers, include conifers, cycads, gingkoes, and gnetophytes.
- Angiosperms are flowering plants.
- Seed plants provide many foods and products for humans.

## Review Questions

### Recall

1. How do seeds help plants adapt to their environment?
2. What are two ways that plants disperse their seeds?
3. What are some examples of gymnosperms?
4. Firs, spruces, and pines belong to what group of gymnosperms?
5. Where is the pollen stored in a flower?
6. How are plants pollinated?

### Apply Concepts

7. What is the purpose of a plant developing a fruit?
8. How are gymnosperms and angiosperms different?
9. What are some uses that seed plants have for humans?
10. Why is the ginkgo tree considered a "living fossil"?

### Think Critically

11. Why did angiosperms evolve the ability to produce flowers? Use the terms "adaptation" and "environment" in your explanation.

## Further Reading / Supplemental Links

- http://www.ucmp.berkeley.edu/seedplants/seedplants.html
- http://hcs.osu.edu/hcs300/gymno.htm
- http://biology.clc.uc.edu/Courses/bio106/gymnospr.htm
- http://www.biologie.uni-hamburg.de/b-online/e02/02d.htm
- http://www.emc.maricopa.edu/faculty/farabee/BIOBK/BioBookflowers.html

## Points to Consider

Now that we have discussed the types of plants, we turn to plant responses.

- Do you think plants can respond to their environment? Why or why not?
- How might plants and fruit change colors?
- How do you think trees know when it's time to lose their leaves?

# 10.4 Plant Responses

## Lesson Objectives

- List the major types of plant hormones and the main functions of each.
- Define tropism and explain examples of tropisms.
- Explain how plants sense the changes of seasons.

## Check Your Understanding

- Why do plants need sunlight?

## Vocabulary

- abscisic acid
- apical dominance
- auxin
- cytokinins
- ethylene
- gibberellins
- gravitropism
- hormones
- phototropism
- thigmotropism
- tropism

## 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 towards 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 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. Animal hormones will be discussed in the *Controlling the Body* chapter. In both plants and animals, hormones travel from cell to cell in response to a stimulus and also activate a specific response.

## Types of Plant Hormones

Five different types of plant hormones are involved in the main responses of plants. Their functions are listed in **Table** 10.2.

**TABLE 10.2: Plant Hormone Function**

| Hormone | Function |
|---|---|
| Ethylene | Fruit ripening and abscission |
| Gibberellins | Break the dormancy of seeds and buds; promote growth |
| Cytokinins | Promote cell division; prevent senescence |
| Abscisic Acid | Close the stomata; maintain dormancy |
| Auxins | Involved in tropisms and apical dominance |

### Ethylene

**Ethylene** has two functions. It (1) helps ripen fruit and is (2) 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** 10.27).

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 plastic bag–what do you think will happen to the unripe fruit?

FIGURE 10.27
Left: The hormone ethylene is signaling these tomatoes to ripen. Right: 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** 10.28). 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 (grow) or for a bud to open.

FIGURE 10.28
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 (unnatural) environments ( **Figure** 10.29). Cytokinins prevent senescence, or the process of aging. So florists sometimes apply cytokinins to cut flowers, so they do not get old and die.

## 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 and maintain dormancy (resting). 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 (begin to grow), 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** 10.30).

## 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 (cutting off branches) helps produce a fuller plant with more branches. You actually need to cut off branches off a plant for it to grow more branches! Auxins are also involved in tropisms, which will be discussed in the next section.

FIGURE 10.29
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.

## 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** 10.3). The auxins allow plants to curve its growth specific directions. The auxin moves to one side of the stem, where it starts a chain of events that cause 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.

TABLE 10.3: **Tropisms**

| Type of Tropism | Stimulus |
|---|---|
| Phototropism | light |
| Gravitropism | gravity |
| Thigmotropism | touch |

FIGURE 10.30
A decrease in levels of abscisic acid allows these buds to break dormancy and put out leaves.

### Phototropism

You might have noticed that plants bend towards the light. This is an example of a tropism where light is the stimulus, known as **phototropism** ( **Figure** 10.31). To obtain more light for photosynthesis, leaves and stems grow towards 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.

### Gravitropism

So, how do the roots of seeds know to grow downward? How do the roots know which way is up? **Gravitropism** is a growth towards or away from the pull of gravity ( **Figure** 10.32). Again, the hormone auxin is involved in this response. Auxin builds up on the lower side of the stem, encouraging growth on this side of the stem and causing it to bend upwards over time. Shoots also show a gravitropism, but in the opposite direction. If you place a plant on its side, the stem and new leaves will curve upwards. Shoots are new plant growth. Shoots can include stems, flowering stems with flower buds, and leaves.

FIGURE 10.31
These seedlings bending toward the sun are displaying phototropism.

FIGURE 10.32
This shoot is exhibiting gravitropism because 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 bean 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 in contact with the pole grows slower than the opposite side of the stem. This causes the stem to bend around the pole.

See the following link for an example of thigmotropism: http://biology.kenyon.edu/edwards/project/steffan/b45sv.htm .

## Seasonal Changes

Have you seen the leaves of plants change colors? 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 certain climates ( **Figure** 10.33).

FIGURE 10.33
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 the change of seasons by the change in temperature, this is not the way plants know the seasons are changing. Plants determine the time of year by the length of the day. Because of the tilt of the Earth, during winter days, there are less hours of light than during summer days. That's why during the winter it may start getting dark very early during the evening and even stay 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 may not set until late that night. With their hormones, 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 hormones are stimulated and they send messages telling the leaves to change colors and fall from the plant.

If a plant kept it leaves over the winter, would it be able to perform photosynthesis? Not very much because it would be too dark. So, the plant sheds its leaves during the winter to rest and then regrows the leaves during the spring and summer months to make use of the increase in sunlight.

## Lesson Summary

- Plant hormones are chemical signals that control different processes in plants.
- A plant tropism is growth towards or away from a stimulus such as light or gravity.
- Many plants go through seasonal changes after detecting differences in day length.

## Review Questions

### Recall

1. What is the term for dropping fruits, flowers, or
2. What hormone is involved with fruit ripening?
3. What hormone is involved in tropisms?
4. What is phototropism?

### Apply Concepts

5. Explain how are hormones involved in seed germination.
6. Cells begin to divide in the stem of the plant. What hormones are involved in this process?
7. The tendril of a bean meets the a metal pole. What will happen to the tendril and why?
8. How do plants detect the change in seasons?
9. Explain two seasonal responses in plants.

### Critical Thinking

10. A scientist hypotheses that plants lose their leaves due to a colder temperatures in the winter. Explain why this hypothesis is untrue.

## Further Reading / Supplemental Links

www.plantphysiol.org/cgi/reprint/116/1/329.pdf

- http://plantphys.info/apical/apical.html
- http://www.cals.ncsu.edu/nscort/outreach_exp_gravitrop.html

## Points to Consider

In the next chapter we will turn our attention to animals.

- List some ways you think animals are different from plants.
- What characteristics do you think define an animal?
- Can you think of examples of animals that do not have hard skeletons?

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# CHAPTER 11 MS Introduction to Invertebrates

## Chapter Outline



The above image shows an organism from the phylum Cnidaria. What does that mean? Good question.

You may call the above organism a jellyfish. But a jellyfish is not a fish at all, although it is a part of the animal kingdom. Kingdoms are divided up into phyla, and this organism is classified in the phylum called Cnidaria.

How is the above organism different from you? What is its body shape? Does it have a brain? Does it have a way to digest food? Can it eat like us? Can it breathe? These are the types of questions scientists ask when they classify organisms, or put them into categories.

This chapter will explore how different invertebrates, organisms without a backbone, are classified into different categories. After reading this chapter, see if you can do a better job asking the right questions to put organisms into specific categories.

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# 11.1 Overview of Animals

## Lesson Objectives

- List the characteristics that define the animal kingdom.
- Define and give examples of the invertebrates.

## Check Your Understanding

- What are the main differences between an animal cell and a plant cell?
- How do animals get their energy?

## Vocabulary

- bilateral symmetry
- complete digestive tract
- incomplete digestive tract
- invertebrate
- radial symmetry
- segmentation

## Classification of Animals

How are animals different from other forms of life? Recall that all animals are eukaryotic, meaning that they have cells with true nuclei and membrane-bound organelles. Animals are also multicellular. Remember that protists can be unicellular. Because animals are multicellular, animal cells can be organized into tissues, organs, and organ systems. Finally, animals are heterotrophic, meaning they must eat nutrients (food) that come from outside of their bodies in order to create energy ( **Figure** 11.1).

## How Are Animals Classified?

Recall that each kingdom of life, including the animal kingdom, is divided into smaller groups called phyla (singlular = phylum) based on their shared characteristics. There are 38 animal phyla. For example, the phylum Mollusca largely consists of animals with shells, like snails and clams. Animals were classfied by how they look, and now DNA evidence is used to confirm that organisms in a particular phylum are related.

FIGURE 11.1
Animals are heterotrophs, meaning they must eat to get molecules necessary for their growth and energy.

### What characteristics are used to classify animals?

1. Body Symmetry: One example of a physical characteristic used to classify animals is body symmetry. In organisms that show **radial symmetry**, such as sea stars, the body is organized like a circle ( **Figure** 11.2). Therefore, any cut through the center of the animal creates two identical halves.

Other animals, such as humans and worms, show **bilateral symmetry,** meaning their left and right sides are mirror images.

FIGURE 11.2
Sea stars are radially symmetrical.

2. Animals are also often classified by their body structure. For example, **segmentation**, the repetition of body parts, defines one phylum of worms ( **Figure** 11.3). Animals that have a true body cavity, defined as a fluid-filled space, and internal organs (like humans) are also classified in separate phyla from those animals that do not have a true body cavity.

3. The structure of the digestive system of animals can also be used as a characteristic for classification. Animals

with **incomplete digestive tracts** have only one opening in their digestive tracts, while animals with **complete digestive tract** have two openings, the mouth and anus.

FIGURE 11.3
A segmented body plan defines the phylum that includes the earthworms.

In this chapter we will focus on **invertebrates**, animals that do not have a backbone.

## What Are Invertebrates?

Besides being classified into phyla, animals are also often characterized as being invertebrates or vertebrates. These are terms based on the skeletons of the animals. **Vertebrates** have a backbone made of bone or cartilage, while invertebrates have no backbone. All vertebrate organisms are in the phylum Chordata, while invertebrates make up several diverse phyla, some of which are listed in **Table** 11.1.

**TABLE 11.1: The invertebrates, animals without a backbone, include a variety of organisms**

| Phylum | Examples |
|---|---|
| Porifera | Sponges |
| Cnidaria | Jellyfish, corals |
| Platyhelminthes | Flatworms, tapeworms |
| Nematoda | Nematodes, heartworm |
| Mollusca | Snails, clams |
| Annelida | Earthworms, leeches |
| Arthropoda | Insects, crabs |
| Echinodermata | Sea stars, sea urchins |

Invertebrates include insects, earthworms, jellyfish, sea stars, and a variety of other animals. **Figure** 11.4 shows an example of a familiar invertebrate, the snail.

In the next lessons we will discuss some of phyla within the animal kingdom that contain invertebrates.

## Lesson Summary

- Animals are multicellular, eukaryotic heterotrophs.
- Animals can be classified using physical characteristics, such as symmetry.
- Invertebrates are animals without a backbone.

FIGURE 11.4
Snails are an example of invertebrates, animals without a backbone.

## Review Questions

### Recall

1. What are three main features that define the animal kingdom?
2. What does heterotrophic mean?
3. What defines the invertebrates?
4. What are some examples of invertebrates?

### Apply Concepts

5. What is the difference between animals that show radial and bilateral symmetry?
6. Name two examples of animals, not included in this lesson, which show bilateral symmetry.
7. What are some examples of animals that show radial symmetry that are not included in this lesson?
8. Do humans have a body cavity? What kind of organs are found there?
9. What is the difference between an incomplete and complete digestive system?
10. How is segmentation used to classify animals?

### Critical Thinking

11. While diving in the ocean, you find a circular squishy animal that does not contain bones. How will you describe this animal to a scientist? What kind of symmetry does it show? Is it an invertebrate or vertebrate?

## Further Reading

- http://animaldiversity.ummz.umich.edu/site/index.html
- http://animals.nationalgeographic.com/animals/invertebrates.html

## Points to Consider

The first invertebrates we will look at are the sponges and cnidarians.

- What do you think that jellyfishes and corals have in common?
- Think of some examples of animals that show bilateral symmetry, meaning that the left side is a mirror image of the right?

# 11.2 Sponges and Cnidarians

## Lesson Objectives

- Describe the key features of sponges.
- Describe the key features of cnidarians.
- List examples of cnidarians.

## Check Your Understanding

- How are animals classified?
- What is an invertebrate?

## Vocabulary

- cnidarians
- corals
- gastrovascular cavity
- medusa
- nematocysts
- polyp
- sessile

## Ocean Invertebrates

The ocean is home to many different types of organisms, including phytoplankton, zooplankton, fish. Phytoplankton, tiny photosynthetic organisms that float in the water, make their own food from the energy of the sun. Small water animals, known as zooplankton, and larger animals, such as fish, use phytoplankton as a source of food. These animals can then be eaten by larger water animals, such as larger fish and sharks.

Among the different types of animals that live in the ocean, the **sponges** and **cnidarians** are important invertebrates. The Sponges are believed to be one of the most ancient forms of animal life on earth. The cnidarians, which include the jellyfish, also are among the oldest and most unusual animals on earth.

## Sponges

What do you think of when you think of a sponge? Something to wash the dishes with? Well, you are right. Up until recently, people took sponges out of the ocean and used them to clean their dishes. Now, we make sponges out of unnatural materials. But the organisms still live in the ocean.

Sponges 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 ( **Figure** 11.5). Sponges pump water through their bodies because they are **sessile**, meaning they cannot move, and filter feeders, meaning they must filter the water to separate organisms and nutrients they want to eat from those they do not.

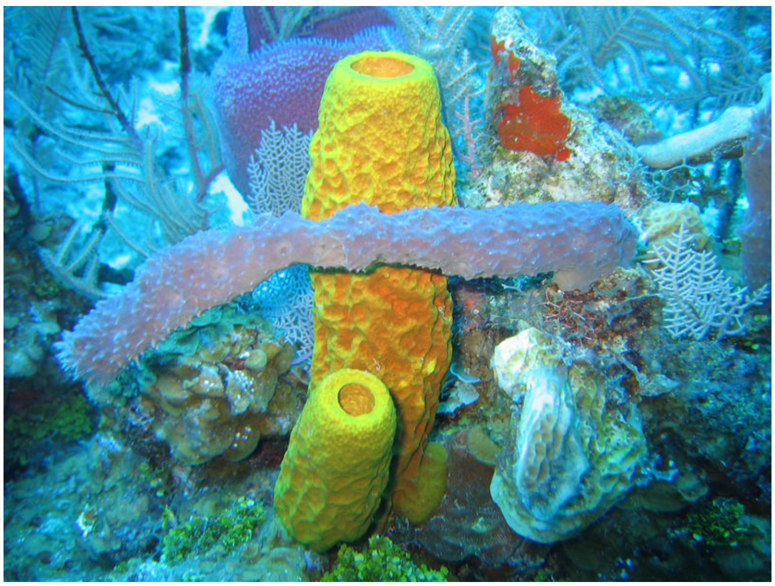

FIGURE 11.5
Sponges have tube-like bodies with many pores.

Sponges evolved earlier than other animals, so they do not have brains, stomachs, or other organs. In fact, sponges do not even have true tissues. Instead, their bodies are made up of specialized cells that do specific jobs. For example, some cells control the flow of water into and out of the sponge by increasing or decreasing the size of the pores.

## Cnidarians

Cnidarians, in the phylum *Cnidaria*, include organisms such as the jellyfish and sea anemones ( **Figure** 11.6) that are found in shallow ocean water. You might recognize that these animals can give you a painful sting if you step on them. That's because cnidarians have stinging cells known as **nematocysts**. When touched, the nematocysts release a thread of poison that can be used to paralyze prey-usually food for the jellyfish.

The body plan of cnidarians is unique because these organisms show radial symmetry, meaning 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.
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 inner tissue 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. Cnidarians do not have true organs, however.

FIGURE 11.6

Left: Jellyfish have bell-shaped bodies with tentacles. Center: Sea anemones can sting and trap fish with their tentacles. Right: One type of sea anemone is home to the clownfish. The clownfish and the sea anemone help each other survive. Clownfish are the only fish that do not get stung by the tentacles of the sea anemone. The clownfish, while being provided with food, cleans away fish and algae leftovers from the anemone.

2. Coral reefs look like big rocks, but they are actually alive. They are built from cnidarians called corals ( **Figure** 11.7). 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.

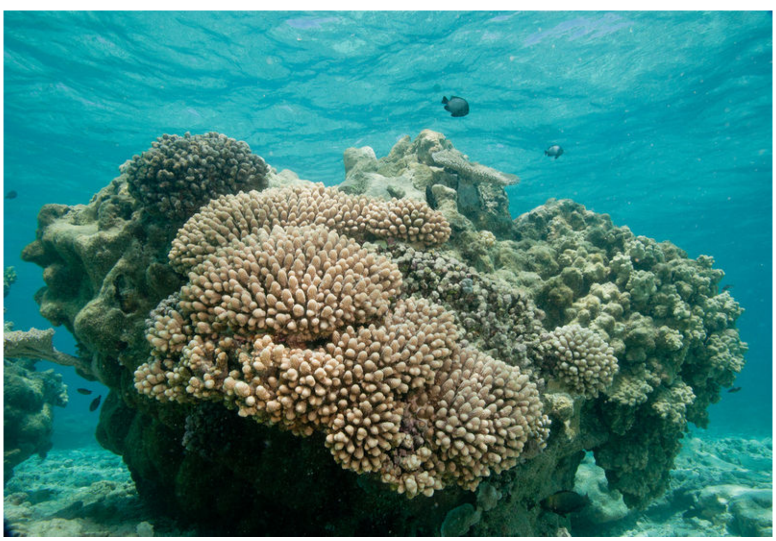

FIGURE 11.7

Corals are colonial cnidarians.

## Lesson Summary

- Sponges are sessile filter feeders without true tissues.
- Cnidarians, such as jellyfish, have radial symmetry and true tissues.

- Some cnidarians form colonies, such as the Portuguese Man o' War and corals.

## Review Questions

### Recall

1. What is the only animal to lack true tissues?
2. In what phylum are the sponges?
3. How do sponges gain nutrition?
4. Where are most cnidarians found?
5. What are some examples of cnidarians?

### Apply Concepts

6. Cnidarians show radial symmetry. What does this mean?
7. How do cnidarians sting their prey?
8. Describe the nervous system of the cnidarians.
9. How is a jellyfish different from a Portuguese Man o' War?
10. How are coral reefs built?

### Critical Thinking

11. Which organisms do you think evolved first–the sponge or the cnidarian? Explain your answer with two pieces of evidence from the lesson.

## Further Reading / Supplemental Links

- http://www.ucmp.berkeley.edu/porifera/porifera.html
- http://animaldiversity.ummz.umich.edu
- http://www.pbs.org/kcet/shapeoflife/animals/cnidaria.html
- http://tolweb.org/tree?group=Cnidaria&contgroup=Animals http://www.ucmp.berkeley.edu/cnidaria/cnidaria.html http://tolweb.org/tree?group=Cnidaria&contgroup=Animals
- http://animaldiversity.ummz.umich.edu/site/accounts/information/Porifera.html

## Points to Consider

Next we discuss worms.

- How do you think that worms are different from sponges and cnidarians?
- How do you think that worms might be similar to sponges and cnidarians?

# 11.3 Worms

## Lesson Objectives

- Describe the major features of the flatworms.
- Describe the major features of the roundworms.
- Describe the major features of the segmented worms.

## Check Your Understanding

- In terms of body structure, what does segmentation refer to?
- What is a body cavity?

## Vocabulary

- cephalization
- hydroskeleton
- tapeworms

## What are Worms?

The word "worm" is not very scientific. But it is a word that informally describes animals that have long bodies with no arms or legs. Worms show bilateral symmetry, meaning that the right side of their bodies is a mirror of the left. Worms live in many different types of environments, including in the ocean, in fresh water, on land, and as parasites of plants and animals.

Three types of worms with different body types will be explored in this lesson:

1. Flatworms, which have ribbon-like bodies with no body cavity.
2. Roundworms, which have a body cavity but no segments.
3. Segmented worms, which have both a body cavity and segmented bodies.

## Flatworms

Worms in the phylum *Platyhelminthes* are called flatworms because they have flattened bodies. Some species of flatworms are free-living organisms that feed on small organisms and rotting matter. These types of flatworms include marine flatworms and fresh-water flatworms such as *Dugesia* and this colorful flatworm ( **Figure** 11.8).

Other types of flatworms are parasitic and 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 that help the worm attach to the intestines of an animal host ( **Figure** 11.9).

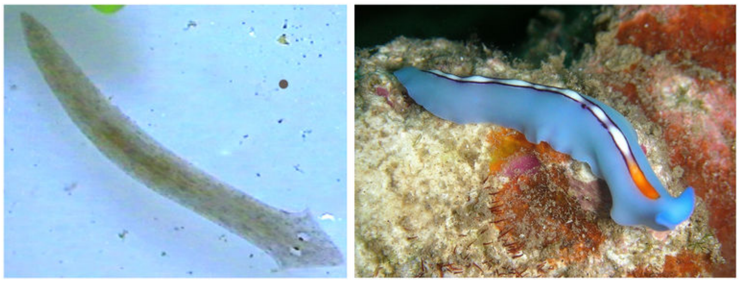

FIGURE 11.8
Left: Dugesia is a type of flatworm with a head region and eyespots. Right: Marine flatworms can be brightly colored.

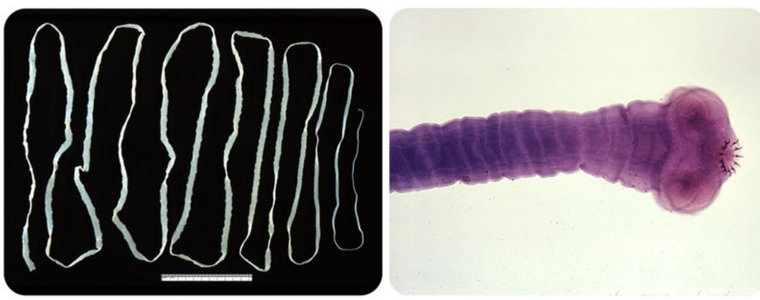

FIGURE 11.9
Tapeworms are parasitic flatworms that live in the intestines of their hosts. Tapeworms attach to the intestinal wall with a head region that has hooks and suckers. They can be very long.

### Characteristics of Flatworms

The main characteristics of flatworms can be summarized as follows:

1. Flatworms have no true body cavity and an incomplete digestive system, meaning that the digestive tract has only one opening.
2. Flatworms do not have a respiratory system, so they have pores that allow oxygen to enter through their body.
3. There are no blood vessels in the flatworms. Their gastrovascular cavity helps them to digest food and to send nutrients throughout the body.
4. The flatworms have a ladder-like nervous system with 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.

## Roundworms

The phylum *Nematoda* includes non-segmented worms known as nematodes or roundworms ( **Figure** 11.10).

### Characteristics of Flatworms

There are specific differences between the flatworms and the 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. They also include a large digestive organ known as the gut.
3. Roundworms also have a simple nervous system with a primitive brain. The nerves are connected from the top to the bottom of the body.

FIGURE 11.10
Nematodes can be parasites of plants and animals.

Roundworms can be free-living organisms, but they are probably best known for their role as significant plant and animal parasites. 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, is caused by infection with a type of roundworm ( **Figure** 11.11).

## Segmented Worms

The phylum *Annelida* includes segmented worms, such as the common earthworm, some marine worms, and leeches ( **Figure** 11.12). These worms are known as the segmented worms because their bodies are segmented, or separated into repeating units. Most segmented worms feed on dead organic matter, while leeches can live in freshwater and suck blood from host organisms.

### Characteristics of Segmented Worms

1. Segmented worms have a well-developed body cavity filled with fluid, which serves as a **hydroskeleton**, a supportive structure that helps move the worm's muscles.

FIGURE 11.11
One roundworm parasite causes elephantiasis, a disease characterized by swelling of the limbs.

2. 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, including an esophagus and intestines. The circulatory system consists of paired hearts and blood vessels, while the nervous system consists of the brain and a ventral nerve cord.

FIGURE 11.12
Both earthworms (left) and parasitic leeches (right) are segmented worms.

**Table** 11.2 compares the three worm phyla.

**TABLE 11.2: Comparison of the three worm phyla**

| Type of Worm | Body Cavity | Segmented | Digestive System | Example |
|---|---|---|---|---|
| Flatworm | No | No | Incomplete | Tapeworm |
| Roundworm | Yes | No | Complete | Heartworm |
| Segmented | Yes | Yes | Complete | Earthworm |

## Lesson Summary

- The flatworms have no true body cavity and include free-living *Dugesia* and parasitic tapeworms.
- The roundworms, which can also be parasitic or free-living, are non-segmented worms with a complete digestive tract and a primitive brain.
- The segmented worms include the common earthworm and leeches.

6. Describe the respiratory system of the flatworms.

7. How does the body plan of the roundworms differ from that of the flatworms?

8. Describe the digestive system of roundworms.

9. What features distinguish Phylum Annelida from the other worms?

10. Describe the skeletal system of a segmented worm.

### Critical Thinking

11. Which phylum includes worms with organs that are most similar to the organs found in humans? Support your answer with three pieces of evidence.

## Further Reading / Supplemental Links

- http://animaldiversity.ummz.umich.edu/site/accounts/information/Annelida.html
- http://animaldiversity.ummz.umich.edu/site/accounts/information/Nematoda.html
- http://animaldiversity.ummz.umich.edu/site/accounts/information/Platyhelminthes.html
- http://www.ucmp.berkeley.edu/platyhelminthes/platyhelminthes.html
- http://www.ucmp.berkeley.edu/phyla/ecdysozoa/nematoda.html
- http://www.ucmp.berkeley.edu/annelida/annelida.html
- http://animaldiversity.ummz.umich.edu

## Points to Consider

Next we further our discussing of the invertebrates.

- Can you think of some invertebrates other than those discussed in this chapter?
- How would these other invertebrates be more advanced compared to worms?

# 11.4 References


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4. Flickr:darkfur93. A snail is an invertebrate . CC BY 2.0
5. Courtesy of the U.S. National Oceanic and Atmospheric Administration. http://commons.wikimedia.org/wiki/File:Sponges_in_Caribbean_Sea,_Cayman_Islands.jpg . Public Domain
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7. USFWS - Pacific Region. Corals are colonial cnidarians. . CC BY 2.0
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9. Courtesy of the Centers for Disease Control and Prevention. Left: http://commons.wikimedia.org/wiki/File:Taenia_saginata_adult_5260_lores.jpg; Right: http://totallyfreeimages.com/118004/Scolex-of-Taenia-solium . Public Domain
10. Courtesy of William Wergin and Richard Sayre, ARS. Nematodes can be parasites of plants and animals . Public Domain
11. Courtesy of the Centers for Disease Control and Prevention. http://commons.wikimedia.org/wiki/File:Elephantiasis.jpg . Public Domain
12. Left: Flickr:Squeezyboy; Right: Greg Schechter. Left: http://www.flickr.com/photos/squeezyboy/82103077/; Right: http://www.flickr.com/photos/gregthebusker/3744971726 . Left: Public Domain; Right: CC BY 2.0

# CHAPTER 12 MS Other Invertebrates

## Chapter Outline



What do spiders, clams, and grasshoppers all have in common? They are all invertebrates. So is the above organism, commonly known as a starfish. As you know, even though all of these organisms are invertebrates, they are very different from each other. They are in four different phyla.

You may know where a spider lives and you may even know some things about how it catches its prey. But where does a starfish live? Does it move? How does it reproduce? How does it eat? If a starfish is an invertebrate, how come it looks so different from other invertebrates? These are all questions that scientists ask when they are classifying an organism.

Scientists and naturalists now classify starfish in a phylum called *Echinodermata*, one of four phyla explored in this chapter.

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# 12.1 Mollusks

## Lesson Objectives

- Discuss what characteristics define mollusks.
- Describe the different types of mollusks.
- Explain why mollusks are important.

## Check Your Understanding

- What is an invertebrate?
- How are animals classified?

## Vocabulary

- mantle
- nacre
- pearl
- radula

## 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, including clams, mussels, scallops, oysters, and snails. Their glossy pearls, mother of pearl, and abalone shells are like pieces of jewelry.

### The Phylum Mollusca

Mollusks belong to the phylum *Mollusca*. The mollusk body is often divided into different parts:

1. A head with eyes or tentacles
2. A muscular foot and a mass housing the organs. In most species, the muscular foot helps the mollusk move.
3. A **mantle**, or fold of the outer skin lining the shell. The mantle also releases calcium carbonate that creates the external shell, just like the ones you find on the beach.
4. The majority of ocean mollusks have a gill or gills to absorb oxygen from the water.
5. All species have a complete digestive tract that begins at the mouth and runs to the anus.

6. Many species have a feeding structure, the **radula**, found only in mollusks. The radula is made mostly of chitin, a tough, semitransparent substance. Radulae range from structures used to scrape algae off rocks to the beaks of squid and octopuses.

### What Are the Mollusks Related to?

Mollusks are most likely related to organisms in the phylum *Annelida*, like the earthworm and leech. Scientists believe they are related because when they are in the early stage of development, they look very similar. Unlike annelids, however, mollusks do not have body segmentation, and their body shape is usually quite different as well.

### How Big Are Mollusks?

The giant squid ( **Figure** 12.1), which until recently had not been observed alive in its adult form, is one of the largest organisms in the phylum *Mollusca*. However, the colossal squid is even larger and can grow up to 46 feet long. The smallest mollusks are snails that are microscopic in size.

FIGURE 12.1
The colossal squid, one of the largest invertebrates, here measures 30 feet in length.

## 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 living classes are listed in **Table** 12.1. Which classes are you most familiar with?

As you can see, the majority of mollusk species live in ocean environments, and many of them are found in the shallow waters. Freshwater species are mostly bivalves and gastropods. Some gastropods, like land snails and slugs, live on land.

**TABLE 12.1: Mollusk Classes**

| Molluscan Class | Number of Species | Habitat | Features of Class/Examples |
|---|---|---|---|

**TABLE 12.1:** (continued)

| Molluscan Class | Number of Species | Habitat | Features of Class/Examples |
|---|---|---|---|
| Caudofoveata | 70 | Deep ocean | Worm-like organisms |
| Aplacophora | 250 | Deep ocean | Worm-like organisms |
| Polyplacophora | 600 | Rocky marine shorelines | Chitons ( **Figure** 12.2) |
| Monoplacophora | 11 | Deep ocean | Limpet (cone shaped)-like organisms |
| Gastropoda | 150,000 (80% of living molluscan diversity) | Marine (some limpets live in deep ocean around hot hydrothermal vents), freshwater, and terrestrial | Abalone, limpets, conch, nudibranchs (sea slugs), sea hares (large sea-slug), sea butterfly, snails, and slugs ( **Figure** 12.3, **Figure** 12.4, and **Figure** 12.5). |
| Cephalopoda | 786 | Marine | Most neurologically advanced of all invertebrates; include squid, octopus, cuttlefish, and nautilus ( **Figure Figure** 12.6). |
| Bivalvia | 8,000 | Marine (some clams live in deep ocean around hot hydrothermal vents) and freshwater. | Most bivalves are filter feeders (matter and food particles are filtered from the water, typically by passing the water over a specialized filtering structure); bivalves include clams, oysters, scallops, and mussels. |
| Scaphopoda | 350 | Marine | Tusk shells |

FIGURE 12.2
A chiton.

## Importance of Mollusks

Mollusks are important in a variety of ways, including as food, for decoration, in jewelry, and in scientific studies. They are even used as roadbed material and in vitamin supplements.

FIGURE 12.3
An example of a gastropod species, the ostrich foot.

FIGURE 12.4
A picture of limpets.

FIGURE 12.5
A sea slug underwater

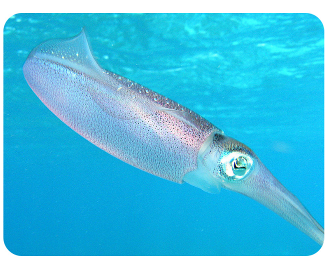

FIGURE 12.6
A Caribbean reef squid, an example of a cephalopod.

### Mollusks as Food

Edible species of mollusks include numerous species of clams, mussels, oysters, scallops, marine and land snails, squid, and octopus. Many species of mollusks, such as oysters, are farmed in order to produce more than could be found in the wild ( **Figure** 12.7).

FIGURE 12.7
An oyster harvest in Ireland.

### Mollusks in Decoration and Jewelry

Two natural products of mollusks used for decorations and jewelry are pearls and nacre, or mother of pearl. A **pearl** is the hard, round object produced within the mantle of a living shelled mollusk. Fine quality 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.

**Nacre** is an iridescent inner shell layer produced by some bivalves, some gastropods, and some cephalopods. It has been used in sheets on floors, walls, countertops, doors, and ceilings. It is also inserted into furniture; it can be found in buttons, watch faces, knives, guns, and jewelry; and is used as decorations on various musical instruments.

### Mollusks in Scientific Studies

Several mollusks are ideal subjects for scientific investigation, especially in the area of neurobiology. 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 also responsible for a variety of learning tasks. Some slug brain studies have even allowed scientists to better understand human brains!

## Lesson Summary

- The mollusk body often has a head with eyes or tentacles, a muscular foot, a mass with organs inside, and a mantle, which creates the external shell.
- Other mollusk structures include a gill or gills for absorbing oxygen, a complete digestive tract, and a radula.
- 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.
- Mollusks are important as food, for decoration, and in scientific studies.

## Review Questions

### Recall

1. What are the main characteristics of mollusks?

2. What are mollusk shells made out of?

### Apply Concepts

3. What evidence shows that mollusks and annelids are related? How are they different?

4. What habitats do marine mollusks live in?

5. What makes the California sea slug ideal for studies of learning and memory?

### Critical Thinking

6. Oysters, one of the bivalve filter feeders, filter up to five liters of water per hour. Oysters filter these pollutants and either eat them or shape them into small packets that are left on the bottom where they are harmless. When there is a high concentration of bacteria in the water from sewage run-off, this can kill the oysters and make them risky to eat. What do you think happens to the pollutants after the bacteria enter the environment?

## Further Reading / Supplemental Links

- http://www.manandmollusc.net/links_educational.html
- http://www.oceanicresearch.org/education/wonders/mollusk.html
- http://www.manandmollusc.net/links_medicine.html

## Points to Consider

- Many mollusks demonstrate bilateral symmetry. How do you think this differs from the radial symmetry evident in echinoderms, in the next lesson?
- As we have seen, some species of mollusks live in the deep ocean around hot hydrothermal vents. In the next lesson we will learn that many echinoderms also live in the deep sea. What adaptations do you think both groups might have for living in such a unique environment?
- Mollusks have an exoskeleton, which is primarily external and composed of calcium carbonate. As a result many of these are preserved in the fossil record. How do you think this compares to the type of skeleton that an echinoderm has and to its fossil record?

# 12.2 Echinoderms

## Lesson Objectives

- Discuss the traits of echinoderms.
- List the types of echinoderms.
- Explain the roles echinoderms play.

## Check Your Understanding

- What is meant by body symmetry?
- What is radial symmetry?
- What is bilateral symmetry?

## Vocabulary

- nerve net
- water vascular system

## What are Echinoderms?

We're all familiar with starfish ( **Figure** 12.8). But sea urchins ( **Figure** 12.9) and sand dollars ( **Figure** 12.10) are in the same phylum. 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 phylum without freshwater or land-living members.

## Characteristics of Echinoderms

As mentioned earlier, echinoderms show radial symmetry. Other key echinoderm features include:

1. Despite the fact that echinoderms have a hard exterior appearance, they do not have an external skeleton. Instead, a thin outermost skin covers an internal endoskeleton made of tiny plates and spines, contained within tissues of the organism. This provides rigid support.
2. Some groups, such as sea urchins, have spines ( **Figure** 12.9) that protect the organism from predators and from colonization by encrusting (covering or coating) organisms. Sea cucumbers also use these spines, or warts, to help them move ( **Figure** 12.11).

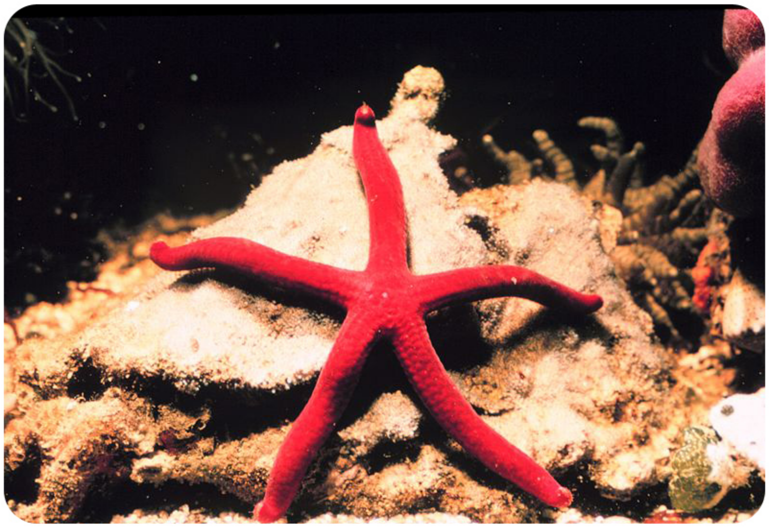

FIGURE 12.8
A starfish, showing the radial symmetry characteristic of the echinoderms.

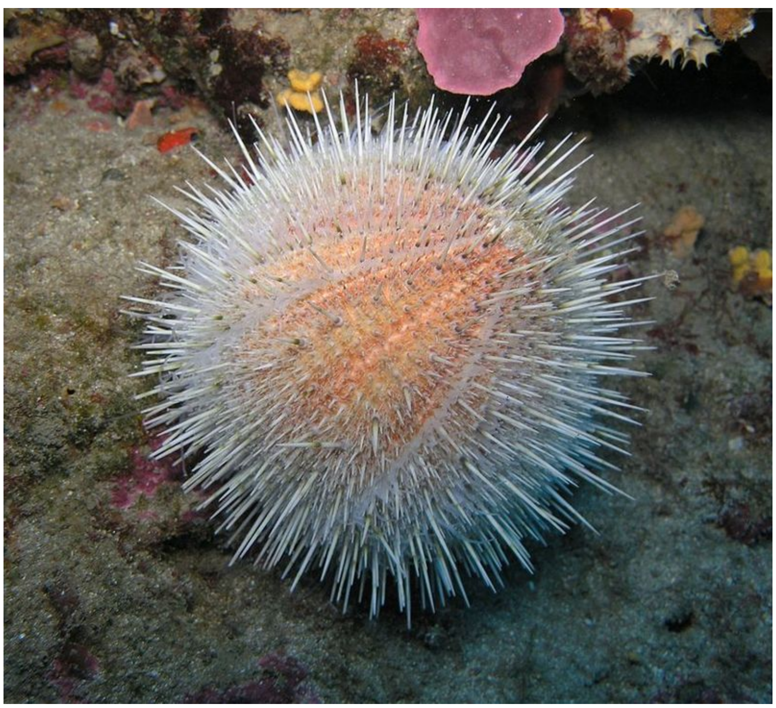

FIGURE 12.9
Another echinoderm, a sea urchin, showing its spines.

3. Echinoderms have a unique **water vascular system**, a network of fluid-filled tubes, that helps the organism absorb oxygen and release carbon dioxide, eat, and move. This system allows them to function without gill slits.

4. Echinoderms have a very simple digestive system, often leading directly from mouth to anus.

5. Echinoderms have an open circulatory system, meaning that fluid moves freely in the body cavity, but no heart.

6. The echinoderm nervous system is a **nerve net**, or interconnected neurons with no central brain.

FIGURE 12.10
An echinoderm, the keyhole sand dollar.

FIGURE 12.11
An echinoderm, the giant California sea cucumber.

### Types of Echinoderms

The echinoderms are subdivided into two major groups:

1. Eleutherozoa, which contains the echinoderms that can move, like starfish and most other echinoderms.
2. Pelmatozoa, including immobile crinoids such as feather stars ( **Figure** 12.12).

**Table** 12.2 lists the four main classes of echinoderms present in the Eleutherozoa Group:

FIGURE 12.12
This feather star is an echinoderm.

**TABLE 12.2: Eleutherozoa Echinoderms**

| Echinoderm Class | Representative Organisms |
|---|---|
| Asteroidea | Starfish and sea daisies |
| Ophiuroidea | Brittle stars ( **Figure** 12.13) |
| Echinoidea | Sea urchins and sand dollars |
| Holothuroidea | Sea cucumbers |

FIGURE 12.13
The giant red brittle star, an ophiuroid echinoderm.

Echinoderms are spread all over the world at almost all depths, latitudes, and environments in the ocean. Most echinoderms are found in reefs, but some, like crinoids, live on shallow shores around the poles. In the deep ocean, sea cucumbers are common, sometimes making up 90% of organisms.

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.



## How Do Echinoderms Reproduce?

2. Grazers, which are organisms that feed on available plants.
3. Deposit feeders, which are organisms that feed on small pieces of organic matter, usually in the top layer of soil.
4. Active hunters, which actively hunt their prey.

### Ecological Role

Echinoderms play numerous ecological roles. Most bare rock is covered in mussels and barnacles, but the echinoderm sea urchin creates a more complex ecosystem when it also lives on the rock. Sand dollars and sea cucumbers that burrow into the sand provides 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, so the coral can have an easier time filter-feeding.

Echinoderms are also the staple diet of many organisms, including the sea otter. Many sea cucumbers provide a habitat for parasites, including crabs, worms, and snails.

Recently, some marine ecosystems have been overrun by seaweed, which caused the destruction of entire reefs. Scientists believe that the extinction of large quantities of echinoderms caused the destruction.

### Echinoderms as Food

In some countries, echinoderms are considered delicacies. Around 50,000 tons of sea urchins are captured each year, and consumed mostly in Japan, Peru, and France. Sea cucumbers are considered a delicacy in some southeastern Asian countries.

### Echinoderms as Medicine

Echinoderms are also used as medicines, 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.

### Echinoderms in Farming

The external covering of echinoderms is used as a source of lime by farmers in some areas where limestone is unavailable. About 4,000 tons of the animals are used each year for this purpose.

## Lesson Summary

- Echinoderms belong to the phylum *Echinodermata*, the largest phylum without freshwater or land-living members.
- Echinoderms show radial symmetry and have an endoskeleton, and a unique water vascular system. Some have spines.
- Fertilization is generally external, and regeneration is fairly common among echinoderms.
- Echinoderms consist of two main subdivisions: the mobile Eleutherozoa and the immobile Pelmatazoa.
- Echinoderms are found all over the world at almost all depths, latitudes, and marine environments.
- Echinoderms play important ecological and economical roles in the community.

## Review Questions

### Recall

1. What are three important characteristics of echinoderms?
2. What three different feeding strategies of echinoderms?
3. What protection do echinoderms have against predators?

### Apply Concepts

4. Chemical elements within their skeletons makes echinoderms stronger. How could this be an advantage in echinoderms that must move to find food?

### Critical Thinking

5. The larvae of many echinoderms, especially starfish and sea urchins, are pelagic, meaning they live in the open ocean. How does being pelagic allow echinoderms to be found throughout the entire world?

## Further Reading / Supplemental Links

- http://dictionary.reference.com
- http://www.oceanicresearch.org/education/wonders/echinoderm.html
- http://www.junglewalk.com/info/echinoderm-information.htm
- http://invertebrates.si.edu/echinoderm/

## Points to Consider

Next we discuss arthropods, which have more advanced tissues and organs.

- Why might there be an advantage to having a heart as part of the circulatory system?

# 12.3 Arthropods

## Lesson Objectives

- Define arthropods.
- Describe the features of crustaceans.
- Describe the characteristics of centipedes and millipedes.
- List the features of arachnids.
- Explain why arthropods are important.

## Check Your Understanding

- What is an invertebrate?
- What do mollusks and echinoderms have in common?

## Vocabulary

- carapace
- cephalothorax
- ganglia
- gastric mill
- molting
- pedipalps
- silk

## What are Arthropods?

Have you ever seen an ant? A spider? A fly? A moth? With over a million described species in the phylum containing arthropods, chances are you encounter one of these organisms every day, even without leaving your house. They may be pests to some people, but arthropods play beneficial roles in ecosystems and economically for humans.

Arthropods belong to the phylum *Arthropoda*, which means "jointed feet," and includes four living subphyla. These are:

- Chelicerata, including spiders ( **Figure** 12.14), mites, scorpions ( **Figure** 12.15) and related organisms.
- Myriapoda, including centipedes ( **Figure** 12.16) and millipedes ( **Figure** 12.17) and their relatives.
- Hexapoda, including insects and three small orders of insect-like animals.
- Crustacea, including lobsters ( **Figure** 12.18), crabs ( **Figure** 12.19), barnacles ( **Figure** 12.20), crayfish ( **Figure** 12.21), and shrimp.

FIGURE 12.14
A species of spider in its web.

FIGURE 12.15
A species of scorpion.

FIGURE 12.16
A centipede, from the subphyla of myriapods.

FIGURE 12.17
A species of millipede found in Hawaii.

## Characteristics of Arthropods

Characteristics of arthropods include:

FIGURE 12.18
The blue American lobster illustrates the segmented body plan of the arthropods.

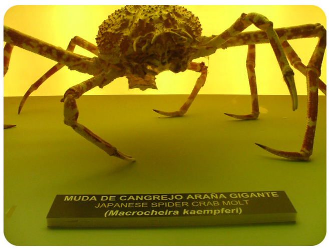


FIGURE 12.19
Giant spider crabs.

FIGURE 12.20
Barnacles.

FIGURE 12.21
A crayfish.

1. A segmented body with appendages on at least one segment.
2. Appendages that are 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 haemolymph, a blood-like fluid. A series of hearts (more than one) move the haemolymph into the body cavity where it comes in direct contact with the tissues.
6. A complete digestive system with a mouth and anus.
7. Both aquatic and land-living arthropods have gas exchange or breathing systems. 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, or 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 that used for breathing underwater, and another used to absorb oxygen from the air.

### How Many Species?

It is the largest phylum in the animal kingdom, with more than a million described species, making up more than 80% of all described living species. Arthropods are found commonly in marine, freshwater, land, and even air environments. They range in size from microscopic plankton (approximately $\frac{1}{4}$ mm) up to the largest living arthropod, the Japanese spider crab, with a leg span up to 12 feet.

## Crustaceans

Crustaceans are a large group of arthropods, consisting of almost 52,000 species. The majority of crustaceans are aquatic, living in either ocean or freshwater habitats. A few groups have adapted to living on land, such as land crabs, hermit crabs, and woodlice ( **Figure** 12.22). Crustaceans are among the most successful animals and are found as much in the oceans as insects are on land.

FIGURE 12.22

A terrestrial arthropod, a species of woodlice.

### Classes of Crustaceans

Six classes of crustaceans are generally recognized. These are listed in **Table** 12.3.

**TABLE 12.3: Classes of Crustaceans**

| | Class | Examples |
|---|---|---|
| 1 | Branchiopoda | Includes brine shrimp |
| 2 | Remipedia | A small class or organisms found in deep caves connected to salt water |
| 3 | Cephalocarida | The horseshoe shrimp |
| 4 | Maxillopoda | Includes barnacles and copepods |
| 5 | Ostracoda | Small animals with bivalve shells |
| 6 | Malacostraca | The largest class, with the largest and most familiar animals: crabs, lobsters, shrimp, krill, and woodlice |

### Can Crustaceans Move?

The majority of crustaceans can move, although a few groups are parasitic and live attached to their hosts. Adult barnacles cannot move, so they attach themselves headfirst to a rock or log.

### 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, close to the antennae and a collection of major ganglia below the gut.
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 other crustaceans, the females keep the eggs until they hatch into free-swimming larvae.

## Centipedes and Millipedes

Centipedes and millipedes belong to the subphylum Myriapoda, which contains 13,000 species, all of which live on land and are divided among four classes, (1) centipedes, (2) millipedes, (3) Symphyla, and (4) Pauropods. They range from having over 750 legs (a species of millipede) to having fewer than ten legs. They have a single pair of antennae and simple eyes.

### The Myriapoda 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. They eat 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** 12.23) are fast, predatory, 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, which may grow larger than 12 inches. Learn more about centipedes at http://www.enchantedlearning.com/subjects/invertebrates/arthropod/Centipede.shtml.

FIGURE 12.23
Centipede

### Millipedes

Most millipedes are slower than centipedes and feed on leaf litter and loose organic material. Around 8,000 species have been described, although there may be as many as 80,000 or more species actually alive.

### Symphyla and Pauropods

The third class, Symphyla, contains 200 species. They resemble centipedes but are smaller and translucent. Many spend their lives in the soil, but some live in trees. The pauropods are typically 0.5-2.0mm long and live in the soil of all continents except Antarctica. Over 700 species have been described, and they are believed to be closely related to millipedes.

## Arachnids

Arachnids are a class of joint-legged invertebrates in the subphylum Chelicerata. They live mainly on land, but are also found in freshwater and in all marine environments, except for the open ocean. There are over 100,000 named species, including spiders, scorpions, daddy-long-legs, ticks, and mites ( **Figure** 12.24). There may be up to 600,000 species in total, including unknown ones.

FIGURE 12.24
Left: A daddy-long-legs with a captured woodlouse. Center: Various diseases are caused by species of bacteria that are spread to humans by "hard" ticks, like the one shown here. Right: A female crab spider sharing its flower with velvet mites.

### 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. Several mites are parasitic and some of those are carriers of disease.
8. 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. **Table** 12.4 shows the four most familiar subgroups, with a description of each.

TABLE 12.4: **Subgroup of Arachnid**

| Subgroup of Arachnid | Representative Organisms | Approximate Number of Species | Description |
| --- | --- | --- | --- |

**TABLE 12.4:** (continued)

| Subgroup of Arachnid | Representative Organisms | Approximate Number of Species | Description |
|---|---|---|---|
| Araneae | Spiders | 40,000 | Found all over the world, ranging from tropics to the Arctic, some in extreme environments; All produce **silk**, used for trapping insects in webs, aiding in climbing, forming smooth walls for burrows, producing egg sacs, and wrapping prey Nearly all spiders inject venom to protect themselves or to kill prey; only about 200 species have bites that can be harmful to humans |
| Opiliones | Daddy-long-legs | 6,300 | Known for extremely long walking legs; no silk nor poison glands Many are omnivores, eating small insects, plant material and fungi; some are scavengers, eating decaying animal and other matter Mostly nocturnal (come out at night), colored in hues of brown; a number of diurnal (come out during the day) species have vivid patterns of yellow, green, and black |

**TABLE 12.4:** (continued)

| Subgroup of Arachnid | Representative Organisms | Approximate Number of Species | Description |
|---|---|---|---|
| Scorpiones | Scorpions | 2,000 | Characterized by a tail with six segments, the last bearing a pair of venom glands and a venom-injecting barb<br>Predators of small arthropods and insects, they use pincers to catch prey, then either crush it or inject it with a fast-acting venom, which is used to kill or paralyze the prey; only a few species are harmful to humans<br>Nocturnal; during the day find shelter in holes or under rocks<br>Unlike the majority of arachnids, scorpions produce live young, which are carried about on the mother's back until they have molted at least once; they reach an age of between four to 25 years |
| Acarina | Mites and ticks | 30,000 | Most are small (no more than 1.0 mm in length), but some ticks and one species of mite may become 10-20 mm in length<br>Live in nearly every habitat, including aquatic and terrestrial<br>Many are parasitic, affecting both invertebrates and vertebrates, and may transit diseases to humans and other mammals; those that feed on plants may damage crops |

## Why Arthropods are Important

### Arthropods as Food

Many species of crustaceans, especially crabs, lobsters, shrimp, prawns, and crayfish, are consumed by humans. 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, and over 80% is produced in Asia, with China producing nearly half the world's total.

### 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.

### Ecological Roles

Mites, ticks, centipedes, and millipedes are decomposers, meaning they break down dead plants and animals and turn them into soil nutrients. This is an extremely important role because it supplies the plants with the minerals and nutrients necessary for life. Plants pass along those minerals and nutrients to animals.

## Lesson Summary

- The phylum Arthropoda includes 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, appendages used for feeding, sensory structures, defense, and locomotion, a dorsal heart, ventral nervous system, and hard exoskeleton.
- Arthropods are the largest phylum in the animal kingdom with more than a million described species; they are found in all environments.
- Crustaceans consist of almost 52,000 species, the majority of which are aquatic.
- Arachnids mainly live on land and comprise over 100,000 named species. Adaptations for life on land include specialized breathing structures and appendages for movement.
- Arthropods are used for food, in pest and weed control, and as decomposers, enriching the soil.

## Review Questions

### Recall

1. What are arthropod appendages used for?

2. What breathing systems do land-living arthropods use?

### Apply Concepts

3. How is the scorpions' method of producing young different from most other arachnids?

4. How are arthropods useful? Pick one example and explain how they are useful to humans or other organisms.

### Critical Thinking

5. Arachnids have several adaptations for living on land. Pick one adaptation and explain how it is beneficial for a land-living existence.

## Further Reading / Supplemental Links

- http://cybersleuth-kids.com/sleuth/Science/Animals/Arthropods/index.htm
- http://www.oceanicresearch.org/education/wonders/arthropods.htm
- http://www.biokids.umich.edu/critters/Crustacea

## Points to Consider

Insects are the focus of the next lesson.

- Arthropods are characterized by the possession of a segmented body with appendages on at least one segment and they are covered by a hard exoskeleton made of chitin. How do you think the general arthropod body plan is specialized in insects?
- Insects are the only group of invertebrates to have developed flight. Compare this mode of locomotion to those discussed in the groups of arthropods already discussed. What advantages might there be to using flight for a method of locomotion?

# 12.4 Insects

## Lesson Objectives

- Describe the characteristics of insects.
- Explain how insects obtain food.
- Describe reproduction and the life cycle of insects.
- Explain how insects are important.
- Describe how insect pests are controlled.

## Check Your Understanding

- What is an arthropod?
- Is a spider an insect? Why or why not?

## Vocabulary

- exocuticle
- homing
- larvae
- metamorphosis
- nymphs
- pheromones
- pupa
- spiracles
- sponging

## 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** 12.25).

### Characteristics of Insects

Characteristics of Insects include:

FIGURE 12.25
A stick insect, showing how well it blends in to its environment.

- Segmented bodies with an exoskeleton. The outer layer of the exoskeleton is called the cuticle. It is made up of two layers, a thin and waxy water-resistant outer layer (the **exocuticle**), and an inner, much thicker layer. The exocuticle is thinner in many soft-bodied insects and especially in caterpillars ( **Figure** 12.26).

FIGURE 12.26
Caterpillar feeding on a host plant.

- The segments of the body are organized into three distinct but joined units: a head, a thorax, and an abdomen (see **Figure** 12.27 and **Table** 12.5).

### TABLE 12.5: Insect Structures

| Head | Thorax | Abdomen |
|---|---|---|
| A pair antennae, a pair of compound eyes (one to three simple eyes) and three sets of appendages that form the mouthparts | Six segmented legs and two or four wings | Has most of the digestive, respiratory, excretory, and reproductive structures |

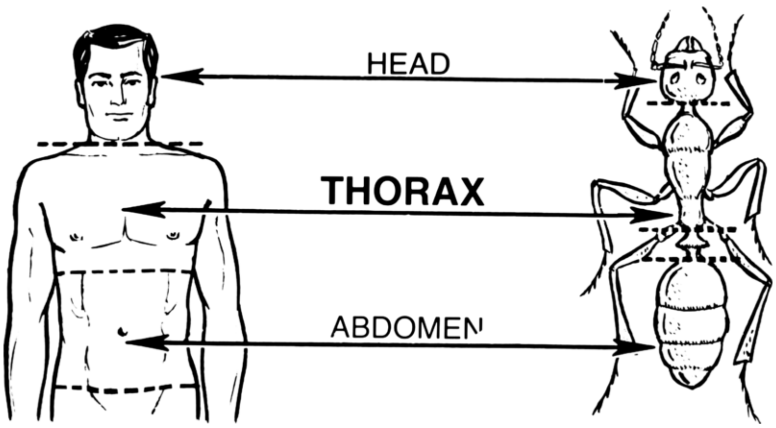


FIGURE 12.27
A diagram of a human and an insect, comparing the three main body parts: head, thorax, and abdomen.

- The nervous system is divided into a brain and a ventral nerve cord.
- Respiration occurs without lungs. Insects do 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.
- The circulatory system is simple and consists of only a single tube with openings. The tube pulses and circulates blood-like fluids inside the body cavity.
- Insect movement includes flight, walking, and swimming. Insects are the only invertebrates to develop the ability to fly and this has played an important role in their success. Insect flight is not very well understood. Primitive insect groups use muscles that act directly to move the wings. More advanced groups have foldable wings and their muscles act on the wall of the thorax and give power to the wings indirectly.
- Many adult insects use six legs for walking and 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, especially water striders ( **Figure** 12.28). A large number of insects 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.

Insects use many different senses for both communicating and receiving information. Many insects have special sensory organs. **Table** 12.6 summarizes five types of communication that are used by various insects.

### TABLE 12.6: Insect Communication

| Types of Communication | Representative Organisms | Description |
|---|---|---|
| **Visual** | | |
| Ultraviolet wavelengths (light most animals cannot see) | Bees | Perceive ultraviolet wavelengths of light (outside of what humans can see) |
| Polarized light (light most animals cannot see) | Bees | Detect polarized light |
| Bioluminescence | Fireflies | Reproduction and Predation: Some species produce flashes to attract mates; other species to attract prey (food). |

**TABLE 12.6:** (continued)

| Types of Communication | Representative Organisms | Description |
|---|---|---|
| **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. |
| Hearing | Some predatory and parasitic insects | Predation: Some nocturnal species can hear the ultrasonic sounds of bats, which help them avoid predators. Can detect sounds made by prey or hosts. |
| **Chemical** | | |
| Wide range of insects have evolved chemical communication; chemicals are used to attract, repel, or provide other kinds of information; use of scents is especially well developed in social insects. | Moths | Antennae of males can detect **pheromones** (chemicals released by animals, especially insects, that influence the behavior of others within the same species) of female moths over distances of many miles ( **Figure** 12.29). |
| Infrared | Blood-sucking insects | Have special sensory structures that can detect infrared light in order to find their hosts. |
| "Dance Language" | Honey bees | Honey bees are the only invertebrates to have evolved this type of communication; length of dance represents distance to be flown. |

FIGURE 12.28
A pair of water striders mating, showing how water surface tension allows for them to stand on the water.

FIGURE 12.29
A yellow-collared scape moth, showing its feathery antennae.

### Insects are Social

Social insects, such as termites ( **Figure** 12.30), ants, and many bees and wasps ( **Figure** 12.31), 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, after a long trip or after a long time.

A few insects migrate, such as the monarch butterfly, which flies from Mexico to North America every winter (

**Figure** 12.32).

FIGURE 12.30
Damage to this nest brings the workers and soldiers of this social insect, the termite, to repair it.

FIGURE 12.31
A wasp building its nest.

## 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. How many winged orders are there?

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,

FIGURE 12.32
Monarch butterflies in an overwintering cluster.

aphids, and cicadas; wasps, bees, and ants; beetles; twisted-winged parasites; snakeflies; alderflies and dobsonflies; lacewings and antlions; Scorpios and hangingflies (including fleas); true flies; caddisflies; and butterflies, moths, and skippers.

## How Insects Obtain Food

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. Insects have a wide range of mouthparts used for feeding. Examples include:

- Insects like mosquitoes and aphids have special mouthparts that help them pierce and suck. Some are herbivorous, like aphids and leafhoppers, while others eat other insects, like assassin bugs and female mosquitoes.
- Examples of chewing insects include dragonflies, grasshoppers, and beetles. Some larvae have chewing mouthparts, as in moths and butterflies ( **Figure** 12.33).
- Some insects use siphoning, as if sucking through a straw, like moths and butterflies. You may have seen a butterfly or moth putting a long mouth-tube into at a flower while it siphons the nectar of the flower.
- 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.

## Reproduction and Life Cycle of Insects

Most insects can reproduce very quickly within a short period of time. With a short generation time, they evolve faster and can adjust to environmental changes faster. Most insects reproduce by sexual reproduction. The female produces eggs, which are fertilized by the male, and then the eggs are usually placed in a precise microhabitat at or near the required food. Most insects are oviviparous, where the young hatch after the eggs have been laid. In some insects, there is asexual reproduction. In the most common type, the offspring are almost identical to the mother. This is most often seen in aphids and scale insects.

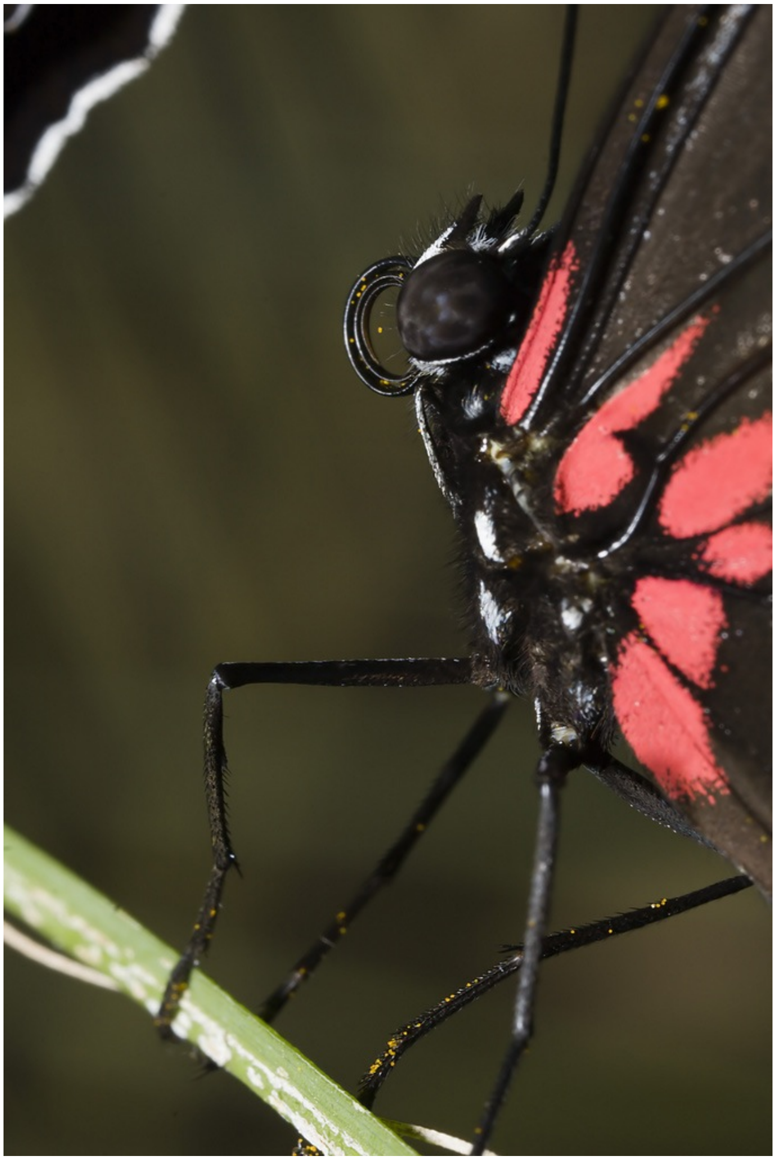

FIGURE 12.33
The mouth of a butterfly up close.

## Three Types of Metamorphosis

An insect can have one of three types of metamorphosis and life cycle ( **Table** 12.7). **Metamorphosis** describes how insects transform from an immature or young insect into an adult insect (in at least two stages).

TABLE 12.7: Type of Metamorphosis

| **Type of Metamorphosis** | None | Incomplete | Complete |
|---|---|---|---|

**TABLE 12.7:** (continued)

| Type of Metamorphosis | None | Incomplete | Complete |
|---|---|---|---|
| **Characteristics** | Only difference between adult and **larvae** (young or non-adult insects) is size | • Young, called **nymphs** ( **Figure** 12.34), usually similar to adult<br>• Wings then appear as buds on nymphs or early forms<br>• When last molt is completed, wings expand to full adult size | • Insects have different forms in immature and adult stages, have different behaviors, and live in different habitats<br>• Immature form is called larvae and remains similar in form but increases in size<br>• Larvae usually have chewing mouthparts even if adult mouthparts are sucking ones<br>• At last larval stage of development, insect forms into pupa ( **Figure** 12.35), and does not eat or move<br>• During **pupa** stage, wing development begins, after which the adult emerges |
| **Example** | Silverfish | Dragonflies | Butterflies and Moths |

## Importance of Insects

Many insects are considered to be pests by humans. At the same time, insects are very important.

### Ecological Importance

In the environment, some insects pollinate flowering plants, as in wasps, bees, butterflies, and ants. Many insects, especially beetles, are scavengers, feeding on dead animals and fallen trees. As decomposers, insects help create top soil, the nutrient-rich layer of soil that helps plants grow.

FIGURE 12.34
Nymphs and egg cases.

### Economic Importance

Insects also produce useful substances, such as honey, wax, lacquer, and silk. Honeybees have been raised by humans for thousands of years for honey. The silkworm has 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 and insect larvae, are also commonly used as fishing bait.

### Insects as Food

In some parts of the world, insects are used for human food. Some 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 ( **Figure** 12.36).

### Insects 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.

## Controlling Insect Pests

Though insects can be important, some are also considered pests. Common insect pests include:

1. Parasitic insects (mosquitoes, lice, bed bugs).
2. Insects that transmit diseases (mosquitoes, flies).

FIGURE 12.35
The chrysalis (pupal stage) of a monarch butterfly.

FIGURE 12.36
Grasshoppers have been added to this taco.

3. Insects that damage structures (termites).
4. Insects that destroy crops (locusts, weevils).

Many scientists who study insects are involved in various forms of pest control, often using insect-killing chemicals, but more and more rely on other methods. Ways to control insect pests are described below.

- Biological control of pests in farming is a method of controlling pests by using other insects. Insect predators, such as lady beetles and lacewings, consume a large number of other insects during their lifetime. If you add ladybugs to your farm or garden, then they will act like a pesticide, or insect-killing chemical.

- Insecticides 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 poisonings, killing of fish, honeybee poisonings, and the contamination of meat and dairy products.

## Lesson Summary

- Insects are the most diverse group of animals on Earth.
- They have segmented bodies with an exoskeleton, and relatively simple nervous, respiratory, and circulatory systems.
- Insects are the only invertebrates to have developed flight.
- Some insects, like termites, ants, and many bees and wasps, are social and live together in large well-organized colonies.
- Insect movement includes flight, walking, and swimming.
- There are two major groups of insects, the wingless and the winged, and these are subdivided into various orders.
- Insects obtain food with the use of specialized appendages for capturing and eating.
- Most insects can rapidly reproduce within a short period of time.
- An insect can have one of three types of metamorphosis and life cycle.
- Insects are beneficial both environmentally and economically.
- Insect pests can be controlled with chemical or biological means.

## Review Questions

### Recall

1. What are the three main parts of the insect body?

2. Why is the insect's circulatory system said to be "simple"?

3. What does metamorphosis mean?

### Apply Concepts

4. Describe the difference between the life cycle of a silverfish and the life cycle of a butterfly.

5. What makes parasitoids especially effective at killing other insect pests?

6. Describe what it means when an insect is said to be "social."

### Critical Thinking

7. Why do you think an exoskeleton allowed insects to better adapt to their environments than some other invertebrates?

## Further Reading / Supplemental Links

- http://homeschooling.gomilpitas.com/explore/bugs.htm
- http://rusinsects.com/links/view.php?id=20
- http://www.kidsolr.com/science/page18.html
- http://pestworldforkids.org/learninggames.html

## Points to Consider

Next we begin the discussion of fishes, amphibians, and reptiles.

- Some of the adaptations that insects have evolved for life on land are also displayed in amphibians and reptiles. What could be some of these? How are they similar and different?
- Insects have some very specialized sensory capabilities. How do you think these compare to those found in fish, amphibians, and reptiles?

# 12.5 References


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4. Cody Long. http://www.flickr.com/photos/shakestercody/2607836717/ . CC BY 2.0
5. Steve Childs. http://commons.wikimedia.org/wiki/File:Chelidonura_varians.jpg . CC BY 2.0
6. Jan Derk. A Caribbean reef squid, an example of a cephalopod . Public Domain
7. Eoin Gardiner. An oyster harvest . CC BY 2.0
8. Courtesy of Dr. James P. McVey, NOAA Sea Grant Program. http://commons.wikimedia.org/wiki/File:Reef0296.jpg . Public Domain
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# Chapter 13 MS Fishes, Amphibians, and Reptiles

## Chapter Outline



Vertebrates have a backbone. But there are many organisms that have backbones, including fish, amphibians, reptiles, birds, and mammals! So, how do we distinguish between them? We put them in categories.

But sometimes it is difficult to put organisms into specific categories. Observe the above image. What kind of organism is it? A snake? A lizard? A newt? It looks like a snake because it does not have legs. But it is also has the head of a lizard. What other information do you need to know before you can classify the above organism? What questions do you need to ask?

You may ask: Does it have ears? What other organisms have similar hearts or lungs? Are the organism's genes more like those of lizards or to those of snakes? Do they live in water, on land, or both?

These are the type of questions scientists ask when they encounter an organism not easily classified. Consider the differences amongst organisms who are closely related as you read about vertebrate creatures. And then see if you can identify the above organism.

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# 13.1 Introduction to Vertebrates

## Lesson Objectives

- Describe the general features of chordates.
- List the three groups of chordates and their characteristics.
- List the general features of vertebrates.
- Describe the classification of vertebrates.

## Check Your Understanding

- What is a invertebrate?
- What is a vertebrate?

## Vocabulary

- cranium
- endostyle
- notochord

## 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. All chordates (phylum *Chordata*) have a **notochord**, a hollow nerve cord along the back.

They also have:

1. Pharyngeal slits, which help to filter out food particles.
2. An **endostyle**, which has small hairs and is used to gather food particles and move them along the digestive tract.
3. A post-anal tail, which is present during the lifetimes of some chordates and during the development of others.

The chordate phylum is broken down into three subphyla:

1. Urochordata (represented by tunicates): Urochordates have a notochord and nerve cord only during the larval stage ( **Figure** 13.1). The urochordates consist of 3,000 species of tunicates, sessile marine animals with sack-like bodies and tubes for water movement.

2. Cephalochordata (represented by lancelets): Cephalochordates have a notochord and nerve cord but no vertebrae, or bones in the backbone ( **Figure** 13.2). Cephalochordates consist of 30 species of lancelets (burrowing marine animals).
3. Vertebrata (the vertebrates): Humans fall in this category. In all vertebrates except for hagfish, the notochord is smaller and surrounded by vertebrae. Vertebrates all have backbones or spinal columns. About 58,000 species have been described, including many familiar groups of large land animals.

The origin of chordates is currently unknown. The first clearly identifiable chordates appear in the Cambrian Period (about 542 - 488 million years ago) as lancelet-like specimens.

FIGURE 13.1

Tunicate colonies of *Botrylloides violaceus* (subphylum Urochordata) have tentacles at openings of tubes that take in food and water and release waste and water.

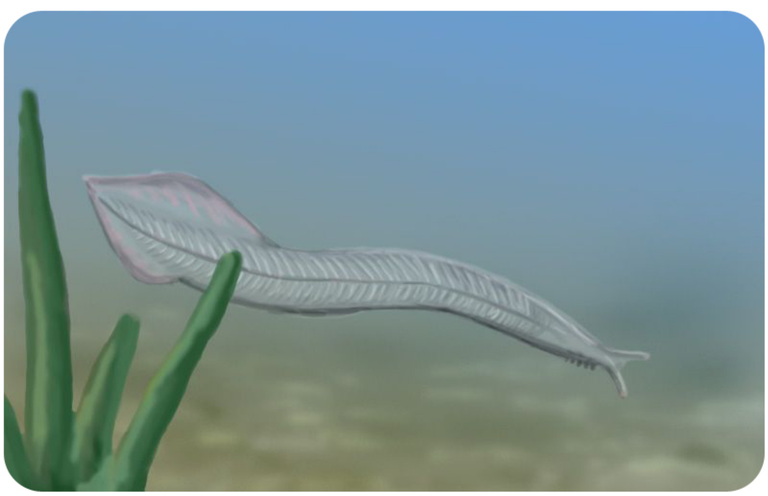

FIGURE 13.2

*Pikaia gracilens* (subphylum Cephalochordates), perhaps the oldest known ancestor of modern vertebrates, resembled a living chordate, known as a lancelet, and perhaps swam much like an eel. What other modern-day organisms does a pikaia look like?

## What are Vertebrates?

Vertebrates, in the subphylum Vertebrata, are chordates with a backbone. Vertebrates have a braincase, or **cranium**, and an internal skeleton (except for lampreys). You can tell the difference between verebrates and other chordates by looking at their head. Vertebrates have cephalization. Cephalization means an organism's nervous tissue is found toward one end of the organism. In other words, this is like having eyes in your head. Why do you think this type of body design is an advantage?

Typical vertebrate traits include:

- A backbone or spinal column.
- Cranium.
- Internal skeleton.
- Defined head with pronounced cephalization.
- Sensory organs, especially eyes.

Living vertebrates range in size from a carp species, as little as 0.3 inches, to the blue whale, as large as 110 feet ( **Figure** 13.3).

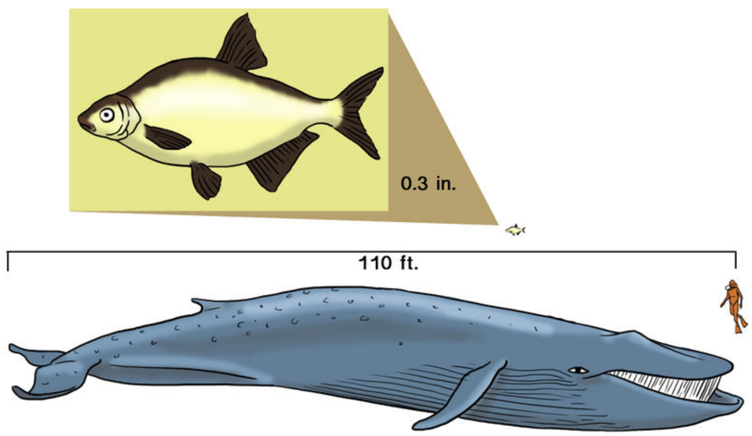


FIGURE 13.3
Vertebrates vary in size.

## Classification of Vertebrates

Vertebrates can be divided into two major groups: those with or without jaws. There are more than 100 species of jawless vertebrate. There are more than 50,000 species of vertebrate with jaws.

The jawed vertebrates include species of fish with cartilage, the strong, flexible tissue found in human ears, bony fish, and four-limbed animals. These animals are known as tetrapods. Some tetrapods include amphibians, reptiles, birds, and mammals ( **Table** 13.1).

**TABLE 13.1: Species of the Main Groups of Tetrapods**

| Type of Tetrapod | Number of Species |
|---|---|
| Amphibians | 6,000 |
| Reptiles | 8,225 |
| Birds | 10,000 |
| Mammal-like Reptiles | 4,500 |
| Mammals | 5,800 |

## Lesson Summary

- Chordates are characterized by a notochord.
- There are three main groups of chordates, including tunicates, lancelets and vertebrates.
- Vertebrates are distinguished by having a backbone or spinal column.
- Vertebrates are classified into two major groups: those without jaws and those with jaws.

## Review Questions

### Recall

1. What is the main feature that characterizes the chordates?

2. What are the main features of vertebrates?

### Apply Concepts

3. Which two structures that all chordates possess sometime during their life cycle (during development or otherwise) are used for food gathering, and how are these structures used?

4. Why do you think cephalization is not necessary in urochordates and cephalochordates? Explain how this is illustrated in tunicates.

### Critical Thinking

5. The first clearly-identifiable chordates are lancelet-like (small, burrowing marine animals with a lancet shape) specimens. Propose one way that these first chordates could have evolved into a swimming-like animal.

## Further Reading / Supplemental Links

- http://www.ucmp.berkeley.edu/chordata/chordata.html
- http://www.ucmp.berkeley.edu/vertebrates/vertintro.html

## Points to Consider

- How do you think a notochord could help fish adapt to swimming?
- How do you think cephalization could be an advantage in movement and feeding in fish?

# 13.2 Fishes

## Lesson Objectives

- List the general traits of fish.
- Describe the features of jawless fish.
- List the general features of the cartilaginous fish.
- Describe the features of bony fish and the significance of this superclass.
- List some of the reasons why fish are important.

## Check Your Understanding

- What are the unique characteristics of vertebrates?
- What are the two main groups of vertebrates?

## Vocabulary

- aquaculture
- barbels
- cartilaginous skeleton
- ectothermic
- pineal eye
- placoid

## 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. Fish are aquatic vertebrates, which became a dominant form of sea life and eventually evolved into land vertebrates.

They have a number of characteristic traits and are classified into two major groups: jawless fish and jawed fish. Jawed fish are further divided into those with bones and those with just cartilage. Fish, in general, are important to humans in many ways. Can you think of some of these ways?

Some characteristics of fish include:

1. They are **ectothermic**, meaning their temperature depends on the temperature of their environment. This is unlike humans, whose temperature is controlled inside of the body.
2. They are covered with scales.
3. They have two sets of paired fins and several unpaired fins.

4. Fish also have a streamlined body that allows them to swim rapidly ( **Figure** 13.4).

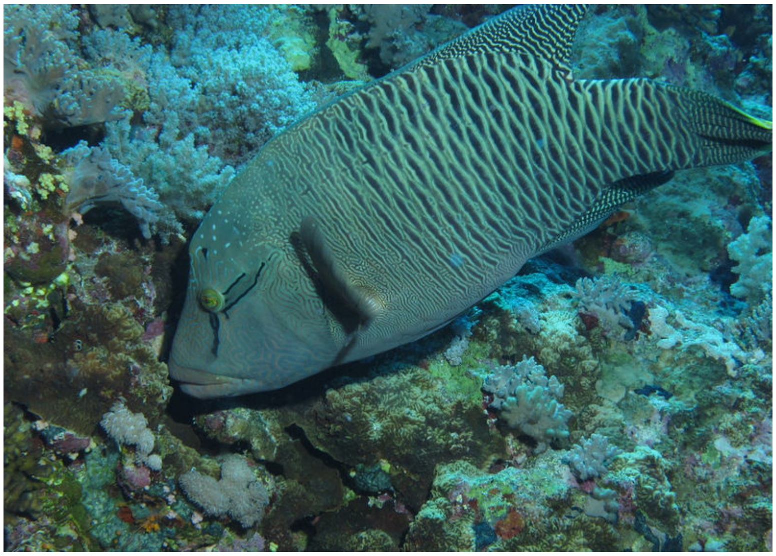

FIGURE 13.4
The humphead or Napoleon wrasse shows some of the general traits of fish, including scales, fins and a streamlined body.

### How do Fish Breathe?

In order to absorb oxygen from the water, fish use gills ( **Figure** 13.5). Gills take dissolved oxygen from water as the water flows over the surface of the gill.

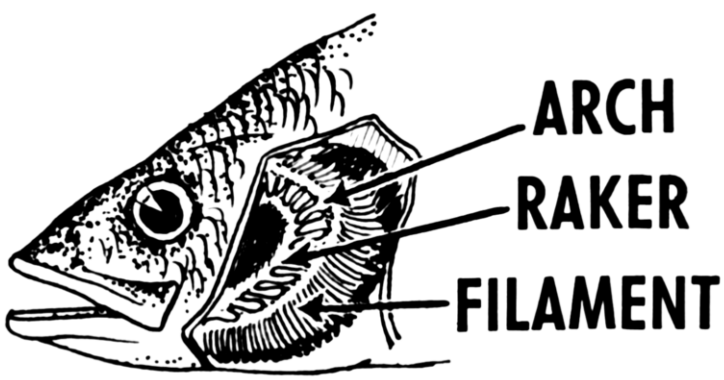


FIGURE 13.5
Gills help a fish breathe.

### How Do Fish Reproduce?

Fish reproduce sexually. They lay eggs that can be fertilized either inside or outside the body. In most fish, the eggs develop outside the mother's body. In the majority of these species, fertilization 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 51-foot whale shark ( **Figure** 13.6) to the stout infantfish, which is about 0.5 inches.

FIGURE 13.6
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** 13.7). 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 13.7
One of the cartilaginous fish, a stingray, shows very flexible pectoral fins connected to the head.

Although most fish live in aquatic habitats, such as ocean, lakes, and rivers, there are some that spend a lot of time out of water. Mudskippers, for example, feed and interact with each other on mudflats for up to several days at a time and only go underwater when digging burrows ( **Figure** 13.8). They breathe by absorbing oxygen across the skin, similar to how frogs breathe.

See http://www.youtube.com/watch?v=ZUsARF-CBcI for further information (5:35).


MEDIA

Click image to the left for more content.

FIGURE 13.8

Mudskippers, shown on the mudflats, spend time feeding and interacting with each other.

## Jawless Fishes

Jawless fish, part of the superclass Agnatha, 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** 13.9). Although hagfish belong to the subphylum Vertebrata, they do not technically have vertebrae.

In addition to the absence of jaws, fish in this class are characterized by the absence of paired fins or an identifiable stomach. Characteristics they do have include:

1. A notochord, both in larvae and adults.
2. Seven or more paired gill pouches.
3. The branchial arches, a series of arches that support the gills of aquatic amphibians and fishes, lie close to the body surface.
4. A light sensitive **pineal eye**, an eye-like structure that develops in some cold-blooded vertebrates.
5. A **cartilaginous skeleton**, or a skeleton made of bone-like material called cartilage.
6. A heart with two chambers.
7. Reproduction using external fertilization.

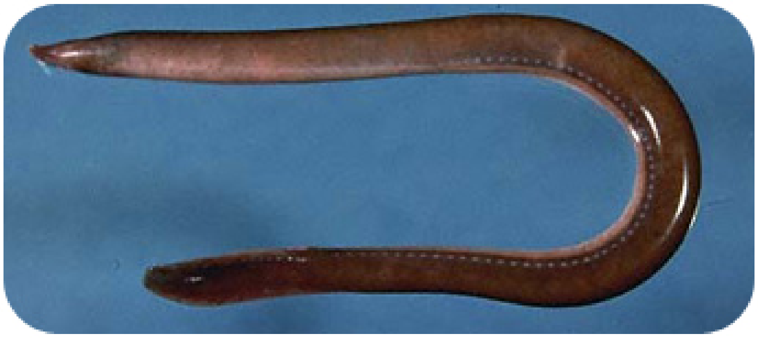

FIGURE 13.9
A hagfish

8. They are ectothermic.

Many jawless fish in the fossil record were armored with heavy bony-spiky plates. The first armored fish in this class evolved before bony fish and tetrapods, including humans.

## Cartilaginous Fishes

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. The cartilaginous fishes are jawed fish with paired fins, paired nostrils, scales, two-chambered hearts, and skeletons made of cartilage rather than bone. Cartilage does not have as much calcium as bones, which makes bones rigid. Cartilage is softer and more flexible than bone.

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 50-foot whale shark shown in **Figure** 13.6.

### 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 gonads, and in an organ called Leydig's Organ, only found in cartilaginous fishes. The tough skin of this group of fish is covered with dermal teeth, or **placoid** scales. In adult chimaera, the placoids are very small, making it feel like sandpaper. The teeth found in the mouth of cartilaginous fish evolved from teeth found on the skin.

### Superorders

The sharks, rays and skates are further broken into two superorders:

1. Rays and skates.
2. Sharks ( **Figure** 13.10).

Sharks are some of the most frequently studied cartilaginous fish. Sharks are distinguished by such features as:

- The number of gill slits.
- The numbers and types of fins.

- The type of teeth.
- 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**, a characteristic of carpet sharks.
- A long snout (or nose-like area), characteristic of groundsharks.
- Large jaws and 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.

FIGURE 13.10

A spotted Wobbegong shark showing skin flaps around the mouth and camouflage coloration.

## Bony Fishes

There are almost 27,000 species of bony fish, which are divided into two classes: ray-finned fish and lobe-finned fish. Most bony fish are ray-finned. There are only eight living species of lobe-finned fish, including lungfish ( **Figure** 13.11) and coelacanths ( **Figure** 13.12).

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, which helps them breathe without having to swim.
5. The ability to see in color, unlike most other fish.

One of the most interesting adaptations of these fish is their ability to produce replacement, bone, by replacing cartilage from within, with bone. They also produce "spongy," bone. This means that the fish have a lightweight, flexible bone on the inside, surrounded by stronger and more rigid bone on the outside. This type of bone allows the fish to move in different ways compared to the cartilaginous fish.

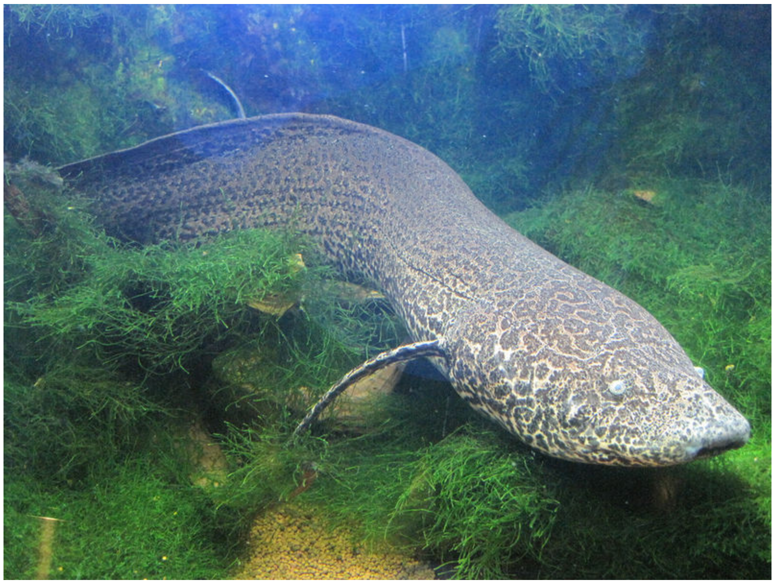

FIGURE 13.11
One of the only eight living species of lobe-finned fish, the lungfish.

FIGURE 13.12
One of the eight living species of lobe finned fish, the coelacanth.

### 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** 13.13). Other very large bony fish include the Atlantic blue marlin, the black marlin, some sturgeon species, the giant grouper and the goliath grouper. In contrast, the dwarf pygmy goby measures only 0.6 inches.

## Why Fish are Important

How are fish important? Of course, they are used as food ( **Figure** 13.14). 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, a type of farming known as **aquaculture**. Fish are also caught for recreation to display in the home and or in public aquaria.

## Lesson Summary

- The general traits of fish help adapt them for living in an aquatic environment, mostly for swimming, and also for absorbing oxygen.
- Fish are ectothermic (cold-blooded), although some show warm-blooded adaptations.

FIGURE 13.13
An ocean sunfish, the most massive bony fish in the world, up to 11 feet long and weighing 5,070 pounds!

FIGURE 13.14
Workers harvest catfish from the Delta Pride Catfish farms in Mississippi.

- Jawless fish do not have bone, but they do have cartilage.
- Fish with jaws consist of both the cartilaginous fish and the bony fish.
- Cartilaginous fishes include sharks, rays, skates and chimaera.
- Bony fish form the largest group of vertebrates in existence today, and have true bone that can regenerate.
- Fish are an important food source for humans.

## Review Questions

### Recall

1. What are three traits that all fish have in common?

2. What is an example of one exception to the general traits of fish?

3. What are three characteristics of jawless fish?

4. List three ways that fish are important.

### Apply Concepts

5. Between the hagfish and a cartilaginous fish, the structure of the jaw evolved? Why do you think this major structure evolved in fish? How does it benefit them?

6. What is the major difference between cartilaginous fish and bony fish? Why do you think the bony fish evolved to be different?

### Critical Thinking

7. Mudskippers are an example of a fish species that must absorb oxygen across the skin, instead of through gills, since they spend most of their time out of water. What kind of environment would pressure fish to evolve to breathe in air instead of breathing in the water?

## Further Reading / Supplemental Links

- http://kids.nationalgeographic.com/Animals
- http://www.fws.gov/educators/students.html
- http://www.pbs.org/emptyoceans/educators/activities/fish-youre-eating.html

## Points to Consider

Amphibians are next.

- How do you think the gills of fish relate to the lungs of other animals?
- Lungfish have paired lungs similar to those of tetrapods. How do you think the breathing systems of lungfish could be similar to and different from tetrapods in the way they breathe?
- What structures are different between fish and amphibians, that allow amphibians to live on land?

# 13.3 Amphibians

## Lesson Objectives

- Describe amphibian traits.
- List the features of salamanders.
- Compare and contrast frogs and toads with other amphibians.
- Describe the roles of amphibians.

## Check Your Understanding

- What are some adaptations that amphibians, like fish, have for living in the water?
- What are the characteristics that amphibians share with all other vertebrates?

## Vocabulary

- convergent adaptation
- ecdysis
- hyoid bone
- tympanum
- valarian respiration

## 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. Their ancestors evolved from living in the sea to living on land. There are approximately 6,000 species of amphibians, of many different body types, physiologies, and habitats, ranging from tropical to subarctic regions. Frogs, toads, salamanders, newts, and caecilians are all types of amphibians ( **Figure** 13.15).

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.

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 using lungs.

FIGURE 13.15
One of the many species of amphibian is this dusky salamander.

### Where do Amphibians Live?

Most amphibians live in fresh water, not salt 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, where 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.

### 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:

- A glandular 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.
- In frogs and toads, the tail disappears in adulthood.

## 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).
3. Sirens.

Salamanders are characterized by slender bodies, short legs, and long tails. They are most closely related to the caecilians, little-known legless amphibians ( **Figure** 13.16). Since they have moist skin, 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. Salamanders are carnivorous, eating only other animals, not plants. They will eat almost any smaller animal. Finally, salamanders have the ability to grow back lost limbs, as well as other body parts. This process is known as **ecdysis**.

FIGURE 13.16

Left: The marbled salamander shows the typical salamander body plan: slender body, short legs, long tail and moist skin. Right: A species of South American caecilian, *Siphonops Annulatuss*, a 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. Species that live on land have lungs that are used in breathing, much like breathing in mammals. Other land-living salamanders do not have lungs or gills. Instead, they "breathe", or exchange gases, through their skin. This is known as **valarian respiration**, and requires blood vessels that exchange gases to be spread throughout the skin.

### How Big Are Salamanders?

Salamanders are found in most moist or arid habitats in the northern hemisphere. They are generally small, but 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** 13.17).

## Frogs and Toads

Frogs and toads ( **Figure** 13.18) are amphibians in the order Anura. In terms of classification, there is actually not a big difference between frogs and toads. Some amphibians that are called "toads" have leathery, brown colored, wart covered skin, but they are still in the same order as frogs.

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 1-foot goliath frog of Cameroon.

FIGURE 13.17
The Pacific giant salamander can reach up to 6 feet in length and weigh up to 66 pounds.

FIGURE 13.18
A toad, showing typical characteristics of leathery and warty skin, and brown coloration.

### Characteristics of Frogs

Adult frogs are characterized by long hind legs, a short body, webbed finger-like parts, and the lack of a tail ( **Figure** 13.19). 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, and 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 10 vertebrae. Frog and toad skin hangs loosely on the body, and skin texture can be smooth, warty, or folded.

In order to live on land and in water, frogs have three eyelid membranes: one is see-through to protect the eyes underwater, and 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 13.19
A tree frog. Notice the powerful muscles in the limbs and the coverings around the eyes.

### "Ribbiting"

Frogs typically lay their eggs in puddles, ponds or lakes. Their larvae, or tadpoles, have gills, and the frogs develop in water. You may hear males "ribbiting," producing a mating call used to attract females to the bodies of water best for mating and breeding. Frogs calls can occur during the day or night.

Listen here http://www.youtube.com/watch?v=mISMwN-0ggE for these distinctive sounds (3:30).

MEDIA
Click image to the left for more content.

### Eating

Adult frogs are meat-eaters and eat mostly arthropods, annelids, and gastropods. Frogs do not have teeth on their lower jaw, so they usually swallow their food whole, using the teeth they do have to hold the prey in place. Other frogs do not have any teeth, so they must swallow their prey whole.

## Roles of Amphibians

### Amphibians as Foods

Frogs are raised as a food source. Frog legs are a delicacy in China, France, the Philippines, northern Greece and the American south, especially Louisiana.

### Amphibians in Research

Amphibians are used in cloning research and other branches of embryology, 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 certain biological phenomena in developmental biology, because it is easy to raise in a lab and has a large and easy to study embryo. Many *Xenopus* genes have been identified and cloned, especially those involved in development.

Many environmental scientists believe that amphibians, including frogs, indicate when an environment is damaged. Since they live on land and water, when species of frogs begin to decline, it often indicates that there is a bigger problem with the ecosystem.

### Amphibians in Popular Culture

Amphibians can be found in folklore, fairy tales and popular culture. Numerous legends have developed over the centuries around the salamander (its name originates from the Persian, for "fire" and "within") , many related to fire. This connection likely originates from the tendency of many salamanders to live inside rotting logs. When placed into the fire, salamanders would escape from the logs, lending to the belief that the salamander was created from flames.

## Lesson Summary

- Amphibians have adaptations for both aquatic (gills), and terrestrial (lungs and moist skin) lifestyles.
- Most amphibians must reproduce in water.
- Development includes a shell-less egg, larval stage, and adult stage.
- Salamanders have some unique features, including the use of the hyoid bone in hunting prey, and the process of ecdysis.
- Adult frogs and toads have features for living in the water (such as webbed finger-like parts) and for living on the land (such as long hind legs for jumping).
- Frogs are well known for their mating calls, which are used to attract females to aquatic breeding grounds.
- Amphibians play a role as a food source, are used in various types of biological research, can serve as indicators of ecosystem health, and are found in folklore and popular culture.

## Review Questions

### Recall

1. Describe three general traits of amphibians.
2. Describe the life cycle of amphibians from egg stage to adult stage.

### Apply Concepts

3. What are two ways that amphibians have adapted to living on land?
4. Why would a scientist want to use a frog for research?
5. Name one way amphibians have evolved to avoid predation.

### Critical Thinking

6. A frog's skin must remain moist at all times in order for oxygen to pass through the skin and into the blood. Why does this fact make frogs susceptible to many toxins in the environment?

## Further Reading / Supplemental Links

- http://kids.nationalgeographic.com/Animals
- http://amphibiaweb.org
- http://helpafrog.org
- http://www.epa.gov/gmpo/education/photo/amphibians.html

## Points to Consider

Future studies of molecular genetics should soon provide further insights to the evolutionary relationships among frog families. These studies will also clarify relationships among families belonging to the rest of vertebrates. We discuss reptiles next.

- Although care of offspring is poorly understood in frogs, it is estimated that up to 20% of amphibian species care for their young, and that there is a great diversity of parental behaviors. As you begin to examine the reproductive system of reptiles in the next lesson, think about what kinds of parental behaviors reptiles might have and how they compare to that of amphibians.

# 13.4 Reptiles

## Lesson Objectives

- List reptile traits.
- Describe the general features of lizards and snakes.
- List the characteristics of alligators and crocodiles.
- Describe the traits of turtles.
- Explain the importance of reptiles.

## Check Your Understanding

- How have amphibians adapted to living on land?
- What features in amphibians are also useful to reptiles who live in water?

## Vocabulary

- amniotes
- nictitating membrane
- poikilothermic

## Traits of Reptiles

What reptiles do you know? Snakes, alligators, and crocodiles are all reptiles. Reptiles are tetrapods and **amniotes**, which means their embryos are surrounded by a thin membrane. Modern reptiles live on every continent except Antarctica. They range in size from the newly-discovered Jaragua Sphaero, 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 include crocodiles, gharials ( **Figure** 13.20), caimans, and alligators.
3. Testudines, which includes turtles and tortoises.
4. Sphenodontia, which includes tuatara ( **Figure** 13.21).

Reptiles are air-breathing, ectothermic vertebrates that have skin covered in scales. Most reptiles have a closed circulatory system with a three-chambered heart. All reptiles breathe using lungs. They also have two small kidneys. Usually their sense organs, like ears, are well developed, though snakes do not have external ears (middle and inner ears are present). All reptiles have advanced eyesight.

FIGURE 13.20
An Indian gharial crocodile.

FIGURE 13.21
A tuatara.

### How do Reptiles Reproduce?

The majority of species are egg-laying, although certain species of squamates can give birth to live young. This is achieved either by oviparity (the egg stays in the female until birth), or viviparity (offspring born without eggs). Many of the viviparous species feed their fetuses by a placenta, similar to those of mammals. Some reptiles provide care for their young.

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 calcium-containing shells. An amnion (the innermost of the embryonic membranes), chorion (the outermost of the membranes surrounding the embryo), and allantois (a vascular embryonic membrane) are present during embryonic life. There are no larval stages of development.

Most reptiles reproduce sexually, although six families of lizards and one snake are capable of asexual reproduction. In some species of squamates, a population of females is able to produce a nonsexual diploid clone of the mother. This asexual reproduction, called parthenogenesis, also occurs in several species of gecko.

## 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 Squamata

Members of the order are distinguished by horny 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, which are able to open their mouths very wide to eat large prey ( **Figure** 13.22).

FIGURE 13.22
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 by chemical signals called pheromones.

Adult lizards range from 1 inch in length, like some Caribbean geckos, to nearly 10 feet ( **Figure** 13.23).

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, although most are so small that insects are their primary prey. A few species are omnivorous or herbivorous, and others have reached sizes where they can prey on other vertebrates, such as birds and mammals.

FIGURE 13.23
A Komodo dragon, the largest of the lizards, attaining a length of 10 feet.

## 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. Many lizards can change color in response to their environments or in times of stress ( **Figure** 13.24). The most familiar example is the chameleon, but more subtle color changes can occur in other lizard species.

FIGURE 13.24
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. 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

All snakes are meat-eaters, and 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 and anacondas that are over 17 feet long ( **Figure** 13.25).

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 13.25
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. The body scales may be smooth, keeled or granular ( **Figure** 13.26). In the shedding of scales, known as molting, the complete outer layer of skin is shed in one layer ( **Figure** 13.27). Molting replaces old and worn skin, allows the snake to grow, and helps it get rid of parasites such as mites and ticks.

Although different snake species reproduce in different ways, all snakes use internal fertilization. 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.

### 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. 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

FIGURE 13.26
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 13.27
A California snake shedding its skin.

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, even when the prey is swallowed whole!

## 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. Think about how organisms with the same ancestors can evolve to be so different.

The basic crocodilian body plan ( **Figure** 13.28) 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.

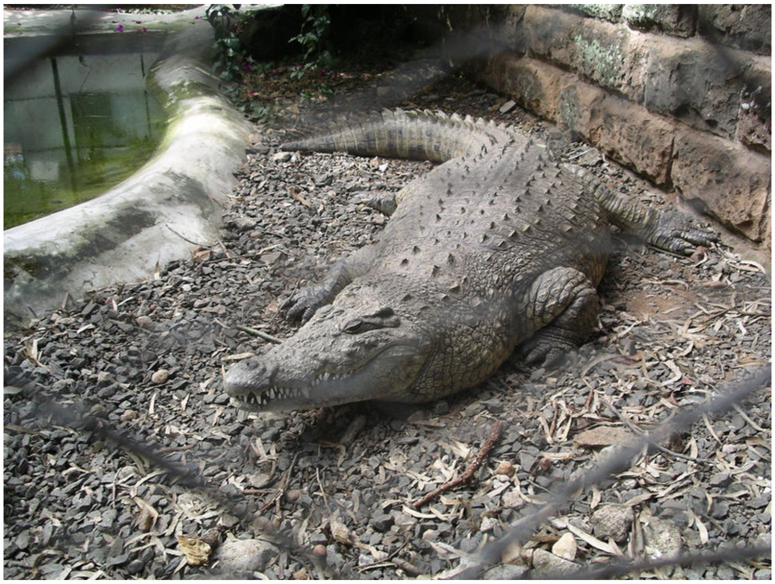

FIGURE 13.28
Nile crocodiles display the basic crocodilian body plan.

### Characteristics of Crocodiles

Crocodilians have a flexible, semi-erect posture. They can walk in 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. Crocodilians also have a secondary bony palate that enables them to breathe when under water, even if the mouth is full of water. Their internal nostrils open in the back of their throat, where a special part of the tongue called the palatal valve closes off their respiratory system when they are underwater, allowing them to breathe.

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, but it may also have a social function.

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!

The sex of developing crocodilians is determined by the temperature of the eggs during incubation (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.

### 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. As in many other aquatic or amphibian tetrapods, the eyes, ears, and nostrils are all located on the same "face" in a line one after the other. They see well during the day and may even have color vision, but they have excellent night vision. A third transparent eyelid, the **nictitating membrane**, protects their eyes underwater.

While birds and most reptiles have a ring of bones around each eye which supports the eyeball, crocodiles lack these bones, just like mammals and snakes. 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, preventing water from entering their external head openings. The middle ear cavity has a complex of bony air-filled passages and a branching tube.

The upper and lower 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, making 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.

## 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 bony or cartilaginous shell developed from their ribs. About 300 species are alive today, and some are highly endangered. Like other reptiles, turtles are **poikilothermic**, meaning their temperature changes in response to their environment.

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.

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 ( **Figure** 13.29).

FIGURE 13.29
Turtle eggs.

Most turtles that spend most of their life 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** 13.30) have glands near their eyes that produce salty tears, which remove excess salt taken in from the water they drink.

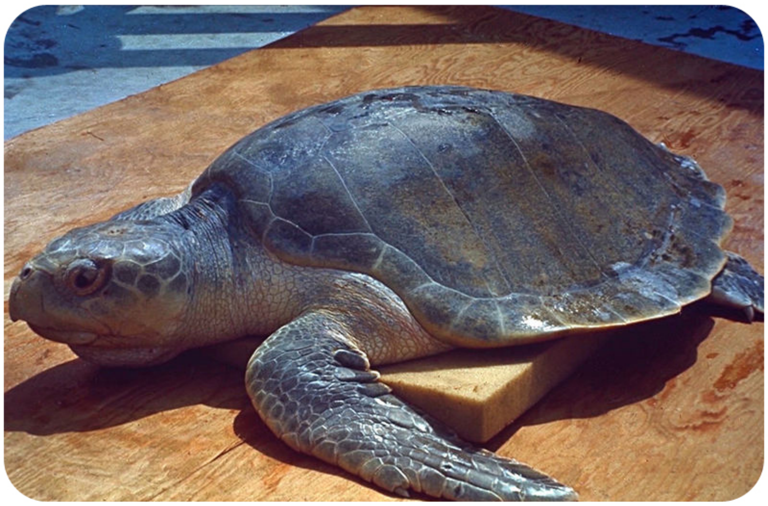

FIGURE 13.30
A species of sea turtle, showing placement of eyes, shell shape, and flippers.

Turtles have exceptional night vision due to the unusually large number of cells that sense light in their eyes. Turtles have color vision.

In some species, temperature determines whether an egg develops into a male or female. Large numbers of eggs are placed by the female 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.

### How do Turtles Eat?

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 turtles usually have knife-sharp ridges for slicing through their prey. 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** 13.31), which can have a shell length of 7 feet and can weigh more than 2,000 pounds. The only surviving giant tortoises are on the Seychelles and Galapagos Islands and can grow to over 4 feet in length and weigh about 670 pounds ( **Figure** 13.32). The smallest turtle is the speckled padloper tortoise of South Africa, measuring no more than 3 inches in length, and weighing about 5 ounces.

## Importance of Reptiles

The chief impact of reptiles on humans is their role as predators of pest species. For example, in many different countries, like India, snakes kill rats that can be pests and carriers of disease. Also, since turtles live for hundreds of

FIGURE 13.31
The leatherback turtle can reach up to 7 feet in length and weigh over 2,000 pounds.

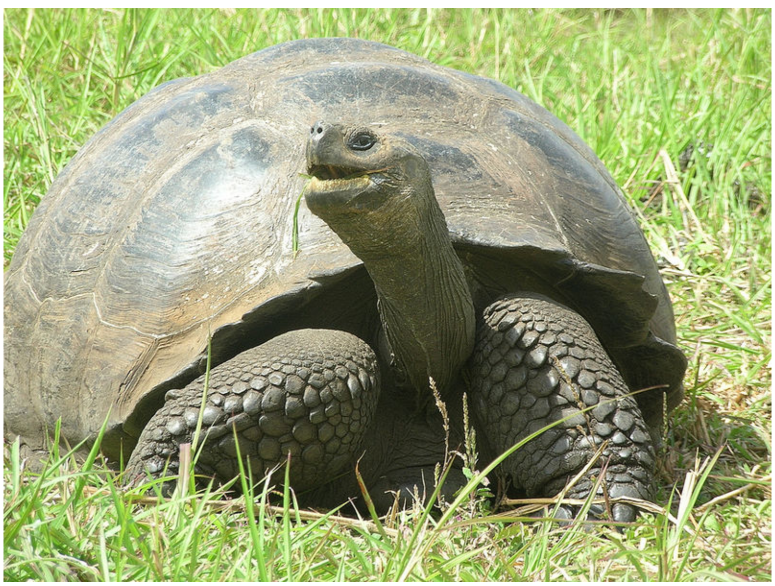

FIGURE 13.32
A Galapagos giant tortoise can grow to over 4 ft in length and weigh about 670 lb.

years, genetic researchers are examining the turtle's DNA for possible genes involved in a long life.

### Reptiles as Food

Reptiles are also important as food sources:

- Green iguanas 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.
- 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.

### 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 snake's shed and then heal again, they are a symbol of healing and medicine, as shown in the Rod of Asclepius ( **Figure** 13.33).

In Egyptian history, the Nile cobra is found on the crown of the pharaoh. This snake was worshipped as one of the gods.

FIGURE 13.33
The Rod of Asclepius, where the snake is a symbol of healing and medicine.

## Lesson Summary

- Reptiles are air-breathing, cold-blooded vertebrates characterized by a scaly skin.
- Reptiles have a variety of reproductive systems, with different strategies for providing nutrition to developing young.
- Lizards and snakes are distinguished by a unique type of scaly skin and movable quadrate bones.
- Lizards have some unique adaptations, including regeneration of lost limbs or tails and changing color.
- Snakes are distinguished by lack of eyelids, limbs, external ears and vestiges of forelimbs.
- Snakes have various adaptations for killing and eating their prey.
- Crocodilia have a flexible semi-erect posture, lifelong replacement of teeth, and a secondary bony palate.
- The sex of developing crocodilians is determined by the incubation temperature of the eggs.
- Other crocodilian traits, such as salt glands, nictitating membranes, ear flaps, and sensory pits, are adaptations for aquatic living.
- Turtles are characterized by a special bony or cartilaginous shell. They have specialized adaptations for aquatic living, such as eye placement and salt glands, and adaptations for terrestrial living as well, like placement of eyes and protection of eggs.
- Reptiles play important roles as predators of pest species, food sources, pets, in medical and scientific research, and in folklore, religion and popular culture.

## Review Questions

### Recall

1. Describe three general traits of reptiles.
2. Describe two different types of reproduction in reptiles.
3. How are snakes different from legless lizards?

### Apply Concepts

4. Name two adaptations of a crocodilian stomach which help it in digestion.
5. Name two organs that a turtle or a snake have that closely resemble organs in humans. Why are they similar?

### Critical Thinking

6. The shape and structure of a turtle's shell can give its inhabitant advantages for avoiding predators, aid in swimming and diving, and for walking on land. Given what you know about a turtle's shell, explain how the structure and shape could help the turtle in the above situations.

## Further Reading / Supplemental Links

- http://kids.nationalgeographic.com/Animals
- http://www.amnh.org/exhibitions/lizards
- http://teacher.scholastic.com/activities/explorations/lizards/index.htm
- http://www.turtles.org
- http://www.gma.org/turtles
- http://www.flmnh.ufl.edu/cnhc/cbd.html

## Points to Consider

Next, we continue our discussions with birds and mammals

- What colorful displays do you think are used to attract mates in birds and mammals?
- How do you think the hearts of fish, amphibians, and reptiles compare to that of birds and mammals?
- How do birds or mammals reproduce? By eggs like fish and amphibians? Or do they have live births?

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# CHAPTER 14 MS Birds and Mammals

## Chapter Outline



Observe the above organism. It has a bill like a duck. Does that make it a bird? It has fur like a dog or beaver, so is it a mammal? But it also has webbed feet. What is this creature? These are the questions scientists asked when they first discovered the duck-billed platypus. It is classified as a mammal, but it also has some bird and even reptile DNA. Surprisingly, it also lays eggs, while almost all other mammals give birth to live young.

The platypus shows how great the diversity of life is on Earth. Organisms are not always easily classifiable, but most warm-blooded vertebrates can be classified as either a bird or a mammal.

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# 14.1 Birds

## Lesson Objectives

- List and describe general traits of birds.
- Explain how birds are adapted for flight.
- List different breeding systems in birds and describe nesting, incubation and parental care.
- Illustrate the diversity of birds with examples of some of the varied groups.
- Explain how birds are important, both economically and ecologically.

## Check Your Understanding

- Birds and reptiles have some traits in common. For example, birds are egg-layers and most reptiles are also oviparous. What do the eggs of both groups have in common?
- What traits do birds have as a result of their being warm-blooded?

## Vocabulary

- aerofoil
- altricial
- monogamous
- polygamous
- precocial

## Characteristics of Birds

How many different types of birds can you think of? Robins, ostriches, hummingbirds, chickens. All of these are birds, but they are also all very different from each other. There is an amazingly wide diversity of birds. Like amphibians, reptiles, mammals, and fish, they are vertebrates. What does that mean? It means they have a backbone. Birds have forelimbs modified as wings, but not all birds can fly.

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 2-inch bee hummingbird to the 9-foot ostrich ( **Figure** 14.1). 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.

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

FIGURE 14.1
The ostrich can reach a height of 9 feet! Pictured here are ostriches with young in Namibia, Africa.

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 most 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** 14.2). 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.

What other traits do you think might be important for flight? Feathers help because they 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, flapping flight at certain times, while at other times they soar, using up less energy ( **Figure** 14.3).

About 60 living bird species are flightless, such as penguins, as were many extinct birds. Flightlessness often evolves when birds live on isolated islands, probably due to limited resources and the absence of land predators. For example, the flightless cormorant can no longer fly, but its wings are now adapted to swim in the sea ( **Figure** 14.4).

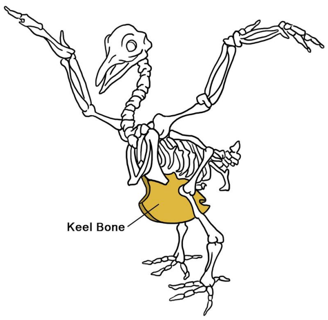


FIGURE 14.2

A bony ridge along the breastbone (blue) allows birds to remain stable as they fly.

FIGURE 14.3

One bird's flight, as seen in a tern species.

FIGURE 14.4

A flightless cormorant can no longer fly, but uses its wings for swimming.

## 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. If successful, it will lead to breeding. Most male birds sing a type of song to attract females. Some displays are very elaborate and may include dancing, aerial flights, or wing or tail drumming.

Listen here http://www.youtube.com/watch?v=rL4Z9d9oObY for singing birds (4:53).

MEDIA

Click image to the left for more content.

Birds reproduce by internal fertilization. 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. 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.

### How Do Birds Protect Their Offspring?

Why do you think eggs come in so many different colors? If an egg is hidden in a hole or burrow, away from predators, then the eggs are most often pale or white.

Birds that make nests in the open have camouflaged eggs ( **Figure** 14.5). 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. Many are elaborate, shaped like cups, domes, plates, mounds or burrows. The albatross, however, makes a nest that is simply a scrape on the ground. Still others, like the common guillemot, do not use nests. Instead, they lay their eggs on bare cliffs. Male 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.

## Young Birds and Parental Care

In birds, 95% of species are **monogamous**, meaning the male and female remain together for breeding for a few years or until one mate dies. 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 length and type of parental care varies widely amongst different species of birds. At one extreme, in a group of birds called the magapodes, 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**. At the other extreme, many seabirds care for their young for extended periods of time, the longest being that of the

FIGURE 14.5
Nest and eggs of the common moorhen, showing camouflaged eggs.

great frigatebird. Their chicks receive 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** 14.6). 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 tasks are shared between parents, like 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.

Some chicks, like those of the ancient murrelet, follow their parents out to sea the night after they hatch, in order to avoid land predators. In most species, however, the young do not leave the nest until they can fly.

FIGURE 14.6
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.

## Diversity of Birds

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.

Birds that live in different environments will encounter different foods and different predators. The feeding habits of birds are related to the beak shape and size, as well as the shape of the feet. Birds can be carnivores, insectivores, or generalists, feeding on a variety of foods. Some, such as hummingbirds, feed on nectar. Can you think of some examples of beak shape and size that are adapted to the type of food a bird eats?

### Beaks

As mentioned above, 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** 14.7). Hummingbirds, on the other hand, have long, thin, pointed bills, which are adapted for getting the nectar out of flowers ( **Figure** 14.8).

FIGURE 14.7
The down-curved, hooked bill of a scarlet macaw, a large colorful parrot.

### Feet

Bird feet can also vary greatly among different birds. Some birds, like gulls and terns, have webbed feet used for swimming or floating ( **Figure** 14.9). Other birds, such as herons, gallinules, and rails, have four long spreading toes, which are adapted for walking delicately in the wetlands ( **Figure** 14.10). Now you can predict how the beaks and feet of birds will look depending on where they live and the type of food they eat.

FIGURE 14.8
A long, thin and pointed bill of the Swallow-tailed Hummingbird.

FIGURE 14.9
The webbed feet of a great black-backed gull.

FIGURE 14.10
The long spreading toes of an American purple gallinule.

## Why Birds are Important

We are probably most familiar with birds as food. Around the world, people consume chicken, turkey, and even more exotic birds, like ostriches. Can you think of other ways that birds are important?

1. In agriculture, humans harvest bird droppings for use as fertilizer.
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, this warns humans that they may also become infected in the near future.
3. 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. Many fruit-eating birds help disperse seeds.
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** 14.11 and **Figure** 14.12). Seabirds add nutrients to soil and to water with their production of guano.
5. Birds have important cultural relationships with humans. Birds are common pets in the Western world. 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.
6. Birds also play prominent and diverse roles in folklore, religion, and popular culture, and have been featured in art since prehistoric times, as in early cave paintings.

## Lesson Summary

- Birds are warm-blooded.
- Adaptations for flight involve features that are lightweight, flexible, strong and that take advantage of air currents.
- Reproduction usually involves a courtship display, nest production, egg laying, incubation and parental care.
- With 10,000 bird species, there is a lot of diversity. Specialized structures are adapted for specific habitats or living requirements.

FIGURE 14.11
The kereru is an important browser species in New Zealand.

FIGURE 14.12
The kokako, another important browser species of New Zealand.

- Birds are important economically, ecologically, and in human culture.

## Review Questions

### Recall

1. List three traits which are important for flight.
2. Give an example of how a bird's breeding system is adapted to avoid predators.

### Apply Concepts

3. Explain how the absence of land predators on islands results in flightlessness in birds.
4. A large bird that nests with other birds has pale eggs even though the environment is brown and the eggs stand out to predators. Why have these birds not evolved camouflaged eggs?

### Critical Thinking

5. You detect the presence of antibodies to the West Nile Virus in young chickens. How did the chickens get the virus? What does this mean about human West Nile infections?

## Further Reading / Supplemental Links

- Department of Health, Florida. Available on the web at: www.doh.state.fl.us.
- Oliver L. Austin, Birds of the World. Western Publishing Company, Inc., New York, 1961.
- http://www.birds.cornell.edu/AllAboutBirds/studying
- http://kids.nationalgeographic.com/Animals
- http://www.ucmp.berkeley.edu/diapsids/birds/birdintro.html
- http://www.fs.fed.us/global/wings/birds.htm

## Points to Consider

Mammals are next.

- Birds and mammals are the only warm-blooded vertebrates. As in birds, mammals exhibit wide diversity and live in varied habitats. Based on what you know about adaptations in birds, how do you think mammalian limbs are adapted for movement in different habitats?
- As in birds, mammals have different foods they eat depending on their environment. Instead of beaks, mammals have different kinds of teeth. In what way(s) do you think teeth in mammals are adapted for different kinds of diets?

# 14.2 Mammals

## Lesson Objectives

- List and describe general traits of mammals.
- Compare reproduction in monotremes, marsupials and placental mammals.
- Describe how mammals can be grouped according to their anatomy and their habitats.
- Explain how non-human mammals can benefit people and how they play an ecological role.

## Check Your Understanding

- Mammals are warm-blooded, like birds. What traits do you think they have in common because of this?
- Describe courtship displays in birds. As you learn about mammals, think about how their courtship is similar to or differs from that seen in birds.

## Vocabulary

- harem
- mammary glands
- marsupial
- monotremes
- neocortex
- placental
- sexual dimorphism

## Characteristics of Mammals

What is a mammal? These animals range from bats, cats and rats to dogs, monkeys 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.

What allows them to live in such diverse environments? They have evolved specialized traits, unlike any other group of animal. There is a tremendous amount of diversity within the group in terms of reproduction, habitat, and adaptation for living in those different habitats. Some of their traits directly benefit people, while also playing important ecological roles.

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.

All mammals, except for one, 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.

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 about 1,200 genera, 153 families and 29 orders.

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** 14.13). Whales have evolved into the largest mammals.

FIGURE 14.13
Dolphins have all adapted to swimming and reproducing in water.

## Reproduction in Mammals

There are similarities between the reproductive habits or mammals and those of reptiles, birds, and amphibians. See if you can spot them.

The egg-laying monotremes, such as echidnas ( **Figure** 14.14) and platypuses ( **Figure** 14.15), use one opening, the cloaca, to urinate, release waste, and reproduce, just as lizards and birds do. They lay leathery eggs, similar to those of lizards, turtles and crocodilians. Monotremes feed their young by "sweating" milk from patches on their bellies, since they lack the nipples present on other mammals.

All other mammals give birth to live young and belong to one of two different categories:

1. **Marsupial**: most female marsupials have an abdominal pouch or skin fold where there are mammary glands and a place for raising the young ( **Figure** 14.16).
2. **Placental**: female placentals have a placenta that feeds the fetus and removes waste products.

FIGURE 14.14
The echidna is a member of the monotremes, the most primitive order of mammals.

FIGURE 14.15
Another monotreme, the platypus, like other mammals in this order, lays eggs and has a single opening for the urinary, genital, and digestive organs.

Some mammals are alone until a female can become pregnant. Others form social groups with big differences between sexes, a trait called **sexual dimorphism**. Dominant males are those that are 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** 14.17). This group of females is called a **harem**.

FIGURE 14.16
A marsupial mammal, this kangaroo has a joey (young kangaroo) in its abdominal pouch.

FIGURE 14.17
A mating system with a harem of many females and one male, as seen in the seal species. Think back to what you learned about courtship displays in birds. How is such conduct in mammals similar or different?

## Groups of Mammals

As is true for most animal groups, mammal groups can be characterized a number of ways: according to their anatomy, the habitats where they live, or their feeding habits.

Most mammals belong to the placental group. Within this group are several subgroups including:

1. Lagomorphs, such as hares and rabbits.
2. Rodents, including rats, mice and other small, gnawing mammals.
3. Carnivores, such as cats, dogs, bears and other meat eaters ( **Figure** 14.18).
4. Insectivores, including moles and shrews ( **Figure** 14.19).
5. Bats and primates.
6. Ungulates, including hoofed animals such deer, sheep, goats, pigs, buffalo and elephants, as well as marine mammals, such as whales and manatees ( **Figure** 14.20).

FIGURE 14.18
A caracal, hunting in the Serengeti.

FIGURE 14.19
One of the subgroups of placental mammals is the insectivores, including moles and shrews. Pictured here is the Northern short-tailed shrew.

Why do you think the above groups of animals are placed together? Can you think of some examples of tooth type that are adapted for a mammal's diet? Or types of limbs that are adapted for living in different types of habitats?

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 in 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** 14.21). Others live in water, such as manatees, whales, dolphins, and seals. Still others are adapted for flight, like bats, or for gliding, like some marsupials and rodents.

FIGURE 14.20
The ungulates (hoofed animals), like the giraffe here, is one of the subgroups belonging to the placental mammals.

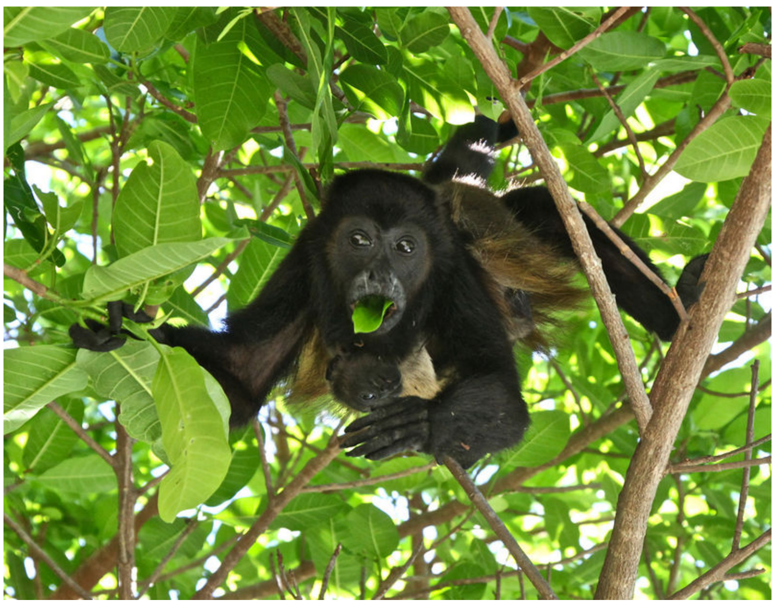

FIGURE 14.21
This howler monkey shows adaptations for an arboreal existence.

## Importance of Mammals

Mammals are significant in the ways they benefit people, the economy, and ecosystems. Ecologically, nectar-feeding and fruit-eating bats ( **Figure** 14.22) play an important role in plant pollination and seed dispersal, respectively.

### Importance to Humans

We see examples of mammals (other than people!) serving our needs everywhere. We have pets that are mammals, most commonly dogs and cats. Mammals are also used for transport (horses, donkeys, mules, and camels), food (cows and goats), and work (dogs, horses, and elephants). See a working dog in **Figure** 14.23.

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 14.22
Bats, like this Egyptian fruit bat, belong to another subgroup of placental mammals. Ecologically, fruit bats play an important role in seed dispersal.

FIGURE 14.23
A Labrador retriever working as an assistance dog.

### 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 stories of a number of Native American tribes.

## Lesson Summary

- Organisms in the class Mammalia are distinguished by the presence of hair, sweat glands, three middle ear bones and a neocortex area in the brain.
- There is a lot of variation in mammalian reproductive systems. Mammals consist of both the egg-laying monotremes and those that are viviparous. The latter group includes marsupial and placental mammals.
- The 5,400 species of mammals can be grouped according to physical features as well as the type of habitat.
- Mammals have specific adaptations for living on land, in trees, in water and for flight.
- Non-primate mammals have an form important relationships with humans and play key ecological roles.

## Review Questions

### Recall

1. What are three main characteristics of mammals?

2. What are two ways that monotremes are different from viviparous mammals?

### Apply Concepts

3. With respect to characteristics of feet, limbs and tails, what features would you expect mammals to have for:

- Jumping?
- Living in trees?

4. Give examples of two different adaptations of limbs in mammals, naming a mammal species, a structure, and how it is adapted.

### Critical Thinking

5. Instead of beaks, as in birds, mammals have different kinds of teeth. Incisors are specialized for cutting and nipping, premolars for shearing and grinding, and canines for piercing. Based on what you know about mammal diets, name two mammal species, the kind of diet they eat, and one type of specialized teeth that would be best adapted for the diet.

## Further Reading / Supplemental Links

- http://kids.nationalgeographic.com/Animals
- http://nationalzoo.si.edu/Animals/SmallMammals/ForKids
- http://www.ucmp.berkeley.edu/mammal/mammal.html
- http://www.americazoo.com/goto/index/mammals/classification.htm

## Points to Consider

Next we turn to primates.

- Think of some significant similarities between the mammals you read about in this lesson with those in the next lesson, particularly human beings.
- What do you think are some of the significant adaptations in the evolution of primates?

# 14.3 Primates and Humans

## Lesson Objectives

- List and describe general traits of primates.
- Summarize mating systems of primates.
- Review the types of habitats primates can be found in.
- Describe the three main groupings of primates.
- List the traits of the hominids, their diet, reproduction and social system.

## Check Your Understanding

- What are general traits of mammals?
- Describe the mating systems in mammals.

## Vocabulary

- hybrid
- omnivorous
- pentadactyl
- quadrupedal

## What are Primates?

If primates are mammals, what makes them seem so different? Primates, including humans, have several unique features only belonging to this group of mammals. 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.

The biological order primates are mostly **omnivorous**, meaning they eat both plant and animal material. The order contains all of the species commonly related to the lemurs, monkeys, and apes ( **Figure** 14.24). The order of primates includes humans.

Key features of primates include:

- Five fingers, known as **pentadactyl**.
- Similar teeth.
- A nonspecialized body plan,
- Certain eye orbit characteristics, such as a **postorbital bar**, or a bone that runs around the eye socket.

FIGURE 14.24

Top left: A ring tailed lemur. Lemurs belong to the prosimian group of primates. Top right: One of the New World monkeys, a squirrel monkey. Bottom left: Chimpanzees, pictured here, 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*, humans, who are part of the great apes. This subspecies lived in Europe and western and central Asia from about 100,000 –40,000 B.C.

An **opposable thumb** is a finger that allows a grip that can hold objects. While this opposable thumb is a characteristic feature of this group, other orders, such as opossums, also have this feature.

### 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 level 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 as seen in **Figure** 14.24 and **Figure** 14.25, 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.

New World species, including tamarins and marmosets ( **Figure** 14.26), 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 significant size difference between the sexes.

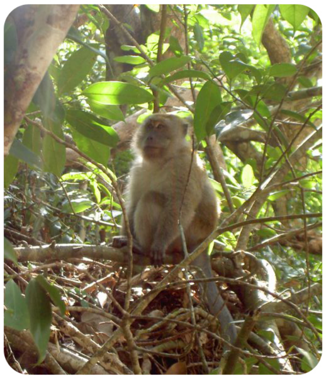

FIGURE 14.25
An Old World monkey, a species of macaque.

FIGURE 14.26
Tamarins (left) and Marmosets (right) are both New World monkeys.

### Where do Non-human Primates Live?

Non-human primates live mostly in Central and South America, Africa and South Asia. Since primates evolved from arboreal (living in trees) animals, many modern species live mostly in trees.

Other species live on land most of the time, such as baboons ( **Figure** 14.27) and the Patas monkey. Only a few species live on land all of the time, for example, the gelada and humans.

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 **brachiation**, or the ability to move by swinging their arms from one branch to another ( **Figure** 14.28). Another feature for climbing are expanded finger-like parts, such as those in tarsiers, which improve grasping ( **Figure** 14.29).

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.

## Primate Classification

The primate order is divided informally into three main groupings:

1. **Prosimians**: The prosimians constitute species whose bodies most closely resemble that of the early proto-primates, the earliest examples of primates ( **Figure** 14.30). Prosimians include the lemurs.
2. New World monkeys: The New World monkeys include the capuchin, howler and squirrel monkeys, who live exclusively in the Americas.

FIGURE 14.27
Baboons are partially terrestrial. Pictured here is a mother baboon and her young in Tanzania.

FIGURE 14.28
A gibbon shows how its limbs are modified for hanging from trees.

3. Old World monkeys and apes: The Old World monkeys and the apes (all except for humans, who inhabit the entire earth) inhabit Africa and southern and central Asia.

## The Human Family

The great apes are the members of the biological family Hominidae, which includes four living genus: chimpanzees, gorillas, humans, and orangutans.

### Characteristics

Hominids 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** 14.31). In all species, the males are, on average, larger and stronger than the females.

FIGURE 14.29
A species of tarsier, with expanded digits used for grasping branches.

FIGURE 14.30
One of the prosimians, a greater bush baby.

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 es ( **Figure** 14.32). Chimpanzees sharpen sticks to use as spears in hunting; they also use sticks to gather food and to "fish" for termit.

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.

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 their 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

FIGURE 14.31
A gorilla mother and baby, members of the great apes. The gorilla is the largest of the hominids, weighing up to 309-397 lbs.

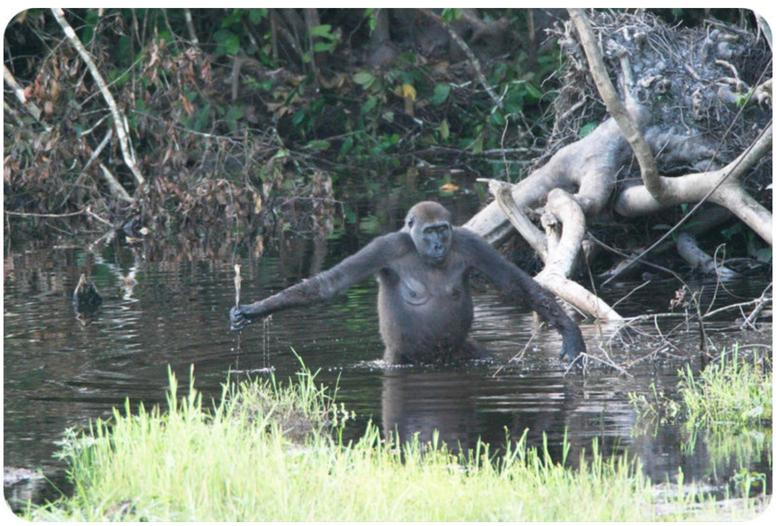

FIGURE 14.32
Tool using in a primate. This gorilla uses a stick to determine the water's depth.

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 are classified together in the subfamily, the Hominidae, because they have more than 97% of their DNA in common!

All organisms in the Hominidae also communicate with some kind of language or create simple cultures beyond the family or band (a group of animals functioning together).

Can you think of human characteristics that are unique to humans? Some say that only humans have the capacity for empathy, or the ability to understand and share the feelings of others. Do you think there are other characteristics that only humans have?

## Lesson Summary

- Primates are characterized by pentadactyly, similar teeth and certain eye orbit features. Primates also have opposable thumbs and a large cerebrum relative to the rest of the brain.
- Old World species tend to have significant sexual dimorphism, whereas New World species generally do not show significant sexual differences.
- Many primates live in a variety of forested habitats, whereas others are partially terrestrial, and some, like the gelada and humans, are fully terrestrial. A few species are adapted for living in aquatic habitats.
- There are three subgroups within the primates order: prosimians, including the lemurs; New World monkeys, and the Old World monkeys and the apes.
- The great apes, consisting of seven species, are large, tailless primates, with sexual dimorphism. Most species are quadrupedal, but all are able to use their hands.
- Most great apes are omnivorous, but fruit is the preferred food among all species but humans.
- The great apes have unique reproductive and parental care features, especially when compared with most other mammals.
- Gorillas, chimpanzees and humans share some common characteristics.

## Review Questions

### Recall

1. Name three characteristics of Primates?

2. What theory might explain why human teeth and jaws are smaller for our size than those of other apes?

### Apply Concepts

3. All primates have opposable thumbs. List two ways in which non-human primates might use opposable thumbs.

4. Primates are thought to have developed several of their traits and habits while living in trees. What primate features might be an advantage in an arboreal (tree) habitat?

### Critical Thinking

5. Gorillas and chimpanzees live in family groups of around five to 10 individuals. What might be two of their possible strategies for feeding, when fruit is hard to find?

## Further Reading / Supplemental Links

- http://kids.nationalgeographic.com/Animals
- http://nationalzoo.si.edu/Animals/Primates
- http://www.ucmp.berkeley.edu/mammal/eutheria/primates.html
- http://pslc.ws/macrog/paul/lemurs.htm

## Points to Consider

The behavior of animals is next.

- What do you think the "behavior" of animals refers to? Give some examples.

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# Chapter 15 MS Behavior of Animals

## Chapter Outline



You have probably seen a spider web before. You may even know that spiders create webs to catch their prey. But have you thought about how the spider learns to spin a web? Are young spiders taught by older spiders? Or do spiders just "know" how to spin a web when they are born?

Animals have different behaviors for different reasons. Some they learn. Some they are born knowing how to do. In the case of spiders, they know from birth how to spin a web. No one teaches them.

Is this different from humans? Are there things you just know how to do? Or do you have to learn every new behavior? Find the answers to these questions as you read.

# 15.1 Understanding Animal Behavior

## Lesson Objectives

- Give examples of animal behavior.
- Explain why animal behavior is important.
- Describe innate behavior and how it evolves.
- List ways that behavior can be learned.

## Check Your Understanding

- What is an animal?
- What are some examples of animals that behave very differently from each other?

## Vocabulary

- animal behavior
- conditioning
- habituation
- innate behavior
- insight learning
- instinct
- learned behavior
- observational learning
- reflex behaviors

## Examples of Animal Behavior

Barking, purring, and playing are just some of the ways that dogs and cats behave. These are examples of animal behavior.

**Animal behavior** is any way that animals act, either alone or with other animals. Can you think of other examples of animal behavior? What about insects and birds? How do they behave? The pictures in **Figure** 15.1 show just some of the ways that these and other animals act. Look at the pictures and read about the behaviors. Think about why the animal is behaving that way.

FIGURE 15.1
Top row, left to right: The cat is stalking a mouse. It is a hunter by nature. The bird is using its beak to add more grass to its nest. What will the bird use its nest for? The spider is busy spinning a web. If you have ever walked into a spider web, you know how sticky a spider web can be. Why do spiders spin webs? The wasp is starting to build a nest. Have you seen nests like this on buildings where you live? Why do wasps build nests? Bottom row, left to right: The mother dog is nursing her puppies. In what other ways do mother dogs care for their puppies? The lizard is perched on a rock in the sun. Lizards like to lie on rocks and "sun" themselves. Do you know why? The rabbit is running away from a fox. Did you ever see a rabbit run? Do you think you could run that fast?

## 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 spider spins its sticky web to trap insects. 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. 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, as well as 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 survive themselves. Behaviors that help animals or their young survive increase the animals' fitness. You read about fitness in the *Evolution* chapter. Animals with higher fitness have a better chance of passing their genes to the next generation. If genes control behaviors that increase fitness, the behaviors become more common in the species. This is called evolution by natural selection.

## Innate Behavior

All of the behaviors shown in the images above 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 in **Figure** 15.1, 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 in **Figure** 15.2 has found a source of food. When the bee returns to its hive, it will do a dance, 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 15.2
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. A mother gull and two of her chicks are shown in **Figure** 15.3. 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. This is what the baby birds in **Figure** 15.4 are doing. This innate behavior, called gaping, causes the mother to feed them.

Another example of innate behavior in birds is egg rolling. It happens in some species of water birds, like the graylag goose shown in **Figure** 15.5. 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 15.3

This mother gull will feed her chick after it pecks at a red spot on her beak. Both pecking and feeding behaviors are innate.

FIGURE 15.4

When these baby birds open their mouths wide, the mother instinctively feeds them. This innate behavior is called gaping.

FIGURE 15.5

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 mother 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. This behavior is shown in **Figure** 15.6. 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 15.6
One of the few innate behaviors in human beings is the grasp reflex. It occurs only in babies.

## Learned Behavior

Just about all other 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/ for additional information.

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 awhile, you may no longer have noticed it. If so, you had become habituated to the sound.

Another example of habituation is shown in **Figure** 15.7. 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 gotten 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 15.7
This scarecrow is no longer scary to these crows. They have 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 how 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. 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.

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Click image to the left for more content.

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 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 way they learn skills 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 in **Figure** 15.8 are playing and practicing their hunting skills at the same time. The dogs in **Figure** 15.9 are playing tug-of-war with a toy. 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.

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 child in **Figure** 15.10 is playing in the sand. He is learning about the world through play. What do you think he might be learning?

### 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

FIGURE 15.8
These two lion cubs are playing. They are not only having fun. They are also learning how to be better hunters.

FIGURE 15.9
They are really playing. This play fighting can help them learn how to be better predators.

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.

FIGURE 15.10
Playing in a sandbox is fun for young children. It can also help them learn about the world. For example, this child may be learning that sand is soft.

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 in **Figure** 15.11. 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 15.11
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.

## Lesson Summary

- Animal behavior is any way that animals act. This behavior may be either alone or with other animals.
- Behaviors that increase fitness can evolve over time. This process occurs by natural selection.
- Innate behavior is behavior that occurs naturally. This behavior occurs in all members of a species.
- Learned behavior is behavior that is learned. It occurs only through experience or practice.

## Review Questions

### Recall

1. Give two examples of animal behavior.
2. Define innate behavior.
3. State three ways that behavior can be learned.

### Apply Concepts

4. Identify one drawback of innate behavior.
5. What is the difference between learned behavior and innate behavior?
6. Why is play important for baby animals?
7. Explain how you could use conditioning to teach a dog to sit.

### Critical Thinking

8. Explain how egg rolling by graylag geese is likely to have evolved.
9. Describe how the grasp reflex might help a baby survive.
10. A crow was seen dropping nuts on a rock to crack the shells and then eating the nut meats. No other crows in the flock were ever observed cracking nuts in this way. What type of learning could explain the behavior of this crow?

## Further Reading / Supplemental Links

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- http://www.unmc.edu/Physiology/Mann/mann19.html

*Pavlov's Dogs Get Conditioned* can be viewed at http://www.youtube.com/watch?v=CpoLxEN54ho (3:10).

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## Points to Consider

Next, we discuss the types of animal behaviors.

- Did you ever watch a long line of ants marching away from their ant hill? What were they doing? How were they able to work together? What do you think explains group behaviors such as this?

# 15.2 Types of Animal Behavior

## Lesson Objectives

- List ways that animals communicate.
- Describe social behavior in animals.
- Explain the purpose of mating behavior.
- Describe how animals defend their territory.
- Identify animal behaviors that occur in cycles.

## Check Your Understanding

- What is an animal?
- Give examples of a wide variety of animals.
- List some behaviors that animals, such as spiders and rabbits, have in common.

## Vocabulary

- biological clock
- circadian rhythms
- communication
- cooperation
- courtship behaviors
- display behavior
- hibernation
- language
- mating
- migration
- social animals

## 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 that human beings communicate. Most other animals also communicate. **Communication** is any way that 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.

## Ways That Animals Communicate

### 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 in **Figure** 15.12 may look like he is smiling, but he is really showing fear. He is communicating to other chimpanzees that he will not challenge them.

FIGURE 15.12
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 in **Figure** 15.13. 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 15.13
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 all 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 were marking 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 that 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 that humans communicate is with facial expressions. Look at the faces of the young child in **Figure** 15.14. Can you tell from her face what 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 that humans share information without using words.

FIGURE 15.14
What does this girl's face say about how she is feeling?

## 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, like those in **Figure** 15.15, live together in large groups called colonies. 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.

Honeybees and bumblebees also live in colonies. A colony of honeybees is shown in **Figure** 15.16. 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.

## 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 in **Figure** 15.17. They show clearly why cooperation is important. A single ant would not be able to carry this large

FIGURE 15.15
The ants in this picture belong to the same colony. They have left the colony's nest to search for food.

FIGURE 15.16
All the honeybees in this colony work together. Each bee has a certain job to perform. The bees are gathered together to fly to a new home. How do you think they knew it was time to gather together?

insect back to the nest to feed the other ants. With cooperation, the job is easy.

FIGURE 15.17
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 insect with other ants that do not leave the nest.

Animals in many other species cooperate. For example, lions live in groups called prides. A lion pride is shown in **Figure** 15.18. 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 15.18
Members of this lion pride work together. Males cooperate by defending the pride. Females cooperate by hunting and sharing the food.

## Mating Behavior

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. Remember the peacock raising his tail feathers in **Figure** 15.13? This is an example of courtship behavior. The peacock is trying to impress females of his species with his beautiful feathers.

Another example of courtship behavior in birds is shown in **Figure** 15.19. This bird is called a 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 a video of a blue-footed booby doing his courtship dance at: http://www.travelpod.com/travel-photo/harryandnorah/the_other_way/1199840760/blue-footed-booby-courting-dance.avi/tpod.html.

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.

FIGURE 15.19
This blue-footed booby is a species of sea bird. The male pictured here is doing a courtship "dance." He is trying to attract a female for mating.

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 to protect 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 is injured. This is what the killdeer in **Figure** 15.20 is doing. The predator thinks she is injured and will be easy prey. The mother leads the predator away from the nest and then flies away.

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.

FIGURE 15.20
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?

## 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 in **Figure** 15.21 is also using display behavior to defend his territory. He is displaying his red breast to warn other robins to stay away.

FIGURE 15.21
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.

## 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 shown in **Figure** 15.22.

FIGURE 15.22

These geese are flying south for the winter. Flocks of geese migrate in V-shaped formations.

Some animals migrate very long distances. The map in **Figure** 15.23 shows the migration route of a species of hawk called Swainson's hawk. 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.

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.

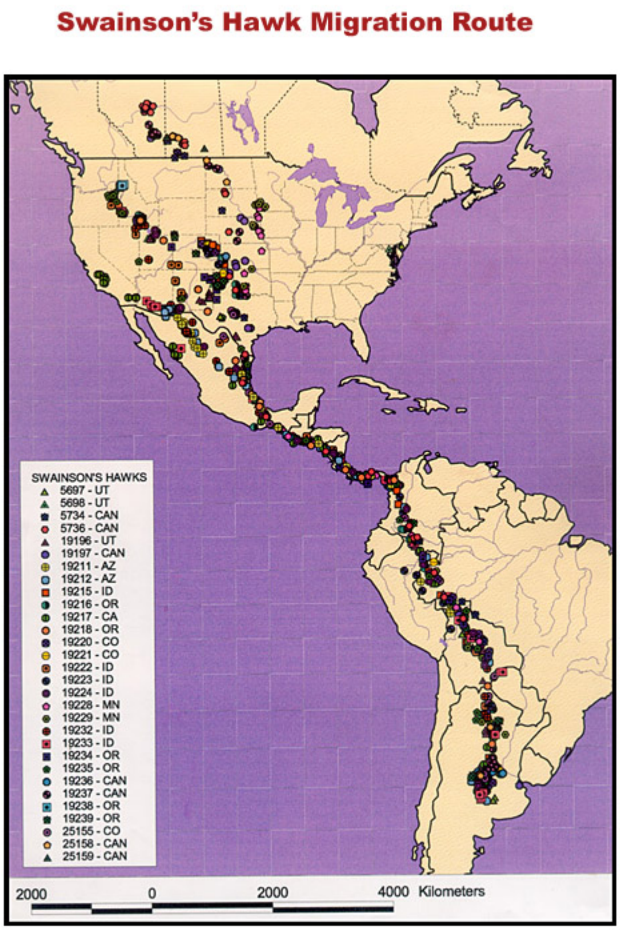


FIGURE 15.23

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.

### 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.

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 controls the biological clock. That's why the clock causes changes that repeat every 24 hours.

## Lesson Summary

- Communication is any way that animals share information.

- Social animals live together in groups. These animals need to cooperate with one another.
- Some of the most important animal behaviors involve attracting mates. Others involve caring for offspring.
- Some animals defend the area where they live from other animals.
- Many animal behaviors occur in cycles that repeat daily or yearly.

## Review Questions

### Recall

1. List two ways that animals communicate.
2. Describe how ants in a colony cooperate.
3. What is courtship behavior?

### Apply Concepts

4. Why do male dogs urinate on fire hydrants and other objects?
5. Give an example of a circadian rhythm.
6. How do ants use chemicals to communicate?
7. What is the advantage of animals using display behavior instead of fighting to defend their territory?
8. What is migration, and why do animals migrate?

### Critical Thinking

9. Explain how courtship behaviors could evolve.
10. How do adult animals increase their own fitness by teaching skills to their young?

## Further Reading / Supplemental Links


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## Points to Consider

Next we start discussing the human body.

- The biological clock located just below the human brain controls behaviors such as the sleep-wake cycle. The brain is part of the nervous system. Can you name some other body systems found in humans?
- Which body system includes the bones? Which system includes the muscles? What do bones and muscles do?

# 15.3 References


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# CHAPTER 16 MS Skin, Bones, and Muscles

## Chapter Outline



What are human skeletons made out of? Bone. What is connected to the bone? Muscle. What layer rests on top of muscle to protect your body? Skin. Bones, muscle, and skin form the foundation of your body.

The person in the above figure is moving. How do his bones help him to move? How are his muscles working with his bones? What would happen if the he did not have skin? What would happen if his bones were removed? Human bodies cannot work without a collection of different tissues and organs. If you remove one, the others will not operate in the same way.

While reading this chapter, think about the individual functions of bones, muscles, and skin. But also remember to consider how they work together to form a whole human.

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# 16.1 Organization of Your Body

## Lesson Objectives

- List the levels of organization in the human body.
- Identify the four types of tissues that make up the body.
- Identify 12 organ systems.
- Describe how organs and organ systems work together to maintain homeostasis.

## Check Your Understanding

- What is a cell?
- What are some of the differences between a prokaryotic cell and an eukaryotic cell?
- What are some of the basic functions of animal cells?

## Vocabulary

- cardiovascular system
- connective tissue
- epithelial tissue
- feedback regulation
- muscular tissue
- negative feedback loop
- nervous tissue
- positive feedback loop

## Cells, Tissues, Organs

### Homeostasis

The people in **Figure** 16.1 just jumped into freezing icy water. They are having fun, but imagine how cold they must feel! What happens to their bodies when one moment they are warm and the next they are freezing? If their bodies are working right, they will begin to shiver. Shivering helps the body return to a stable temperature.

The ability of the body to maintain a stable internal environment in response to change is called homeostasis. Homeostasis allows your body to adapt to change. Change might be from jumping into cold water or running in hot weather. Or it might be from not getting enough food when you are hungry. Homeostasis is a very important characteristic of living things.

FIGURE 16.1

The bodies of these swimmers are working hard to maintain homeostasis while they are in the icy pool water. Otherwise, their life processes would stop working as soon as they got into the water.

### Homeostasis and Cells

Cells are the most basic units of life in your body. They must do many jobs to maintain homeostasis, but each cell does not have to do every job. Cells have specific jobs to maintain homeostasis. For example, nerve cells move electrical messages around the body, and white blood cells patrol the body and attack invading bacteria.

There are many additional different types of cells. Other cells include red blood cells, skin cells, cells that line the inside of your stomach, and muscle cells.

### Groups of Cells Form Tissues

Cells are grouped together to carry out specific functions. A group of cells that work together is called 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 shown in **Figure** 16.2.

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 structure and support 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 bodies to move. There are three types of muscle tissue: smooth muscle, skeletal muscle, and cardiac muscle.
4. **Nervous tissue** is made up of the nerve cells that together form the nervous system. 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, shown in **Figure** 16.3, is made up of the four types of tissues.


FIGURE 16.2
Your body has four main types of tissue: nervous tissue, epithelial tissue, connective tissue, and muscle tissue. They are found throughout your body.

## 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?

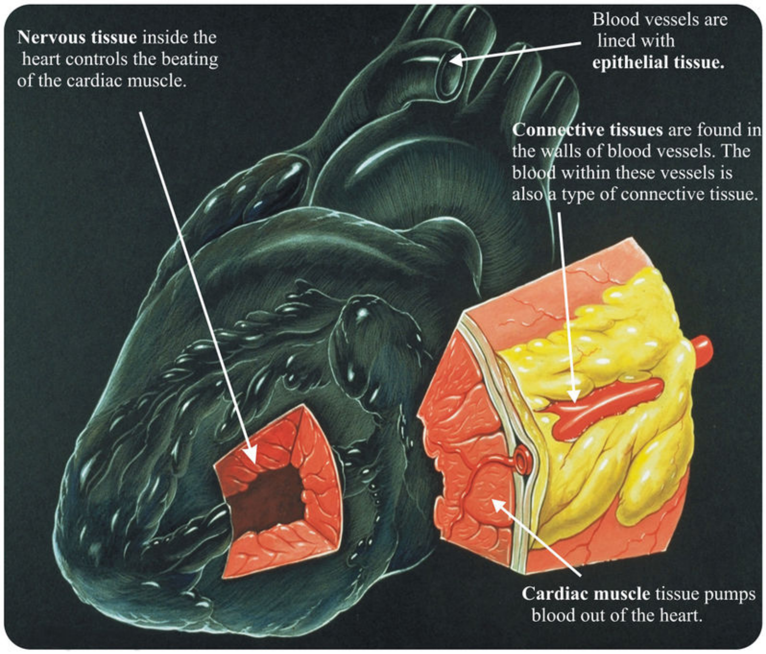



FIGURE 16.3
The four different tissue types work together in the heart as they do in the other organs.

### Organ Systems Work Together

Your body's 12 organ systems are shown in **Table** 16.1. Your organ systems do not work alone in your body. They must all be able to work together to maintain homeostasis.

**TABLE 16.1: Major Organ Systems of the Human Body**

| Organ System | Major Tissues and Organs | Function |
|---|---|---|
| Cardiovascular | Heart; blood vessels; blood | Transports oxygen, hormones and nutrients to the body cells. Moves wastes and carbon dioxide away from cells |
| Lymphatic | Lymph nodes; lymph vessels | Defense against infection and disease, moves lymph between tissues and the blood stream |
| Digestive | Esophagus; stomach; small intestine; large intestine | Digests foods and absorbs nutrients, minerals, vitamins, and water |
| Endocrine | Pituitary gland, hypothalamus; adrenal glands; Islets of Langerhans; ovaries; testes | Hormones communicate between cells to maintain homeostasis |
| Integumentary | Skin, hair, nails | Protection from injury and water loss; physical defense against infection by microorganisms; temperature control |
| Muscular | Cardiac (heart) muscle; skeletal muscle; smooth muscle; tendons | Movement, support, heat production |
| Nervous | Brain, spinal cord; nerves | Collects, transfers and processes information |

**TABLE 16.1:** (continued)

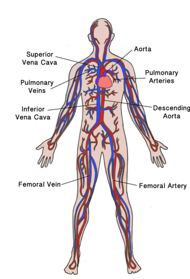
| Organ System | Major Tissues and Organs | Function |
|---|---|---|
| Reproductive | Female: uterus; vagina; fallopian tubes; ovaries Male: penis; testes; seminal vesicles | Production of gametes (sex cells) and sex hormones; production of offspring |
| Respiratory | Trachea, larynx, pharynx, lungs | Brings air to sites where gas exchange can occur between the blood and cells (around body) or blood and air (lungs) |
| Skeletal | Bones, cartilage; ligaments | Supports and protects soft tissues of body; movement at joints; produces blood cells; stores minerals |
| Urinary | Kidneys; urinary bladder | Removes extra water, salts, and waste products from blood and body; control of pH; controls water and salt balance |
| Immune | Skin; bone marrow; spleen; white blood cells | Defense against diseases |

For example, when the people in **Figure** 16.1 jumped into the cold water, their integumentary system (skin), cardiovascular system, muscular system, and nervous system worked quickly together to ensure the icy water did not cause harm to their bodies.

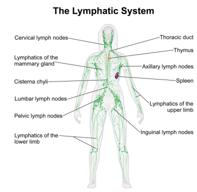
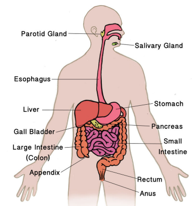
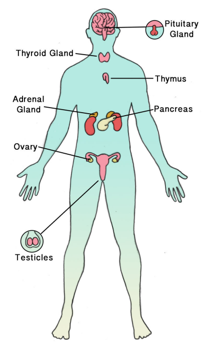
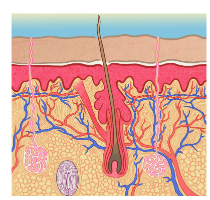
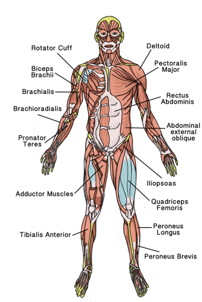
For example, the nervous system sent nerve messages from the skin to tell the cardiovascular system to reduce the blood flow to the skin. Blood flow is then increased to the internal organs and large muscles to help keep them warm and supply them with oxygen. The nervous system also sent messages to the respiratory system to breathe faster. This allows for more oxygen to be delivered by the blood to the muscular system.

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.

**TABLE 16.2: Major Organ Systems of the Human Body**

| Organ System | Example |
|---|---|
| Cardiovascular |   |

### TABLE 16.2: (continued)

| Organ System | Example |
| --- | --- |
| Lymphatic |   |
| Digestive |   |
| Endocrine |   |
| Integumentary |  |
| Muscular |   |

## TABLE 16.2: (continued)

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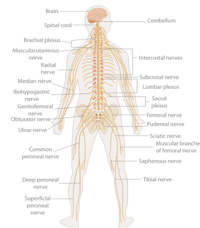
<tr><td>Nervous</td><td>
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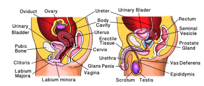
<tr><td>Reproductive</td><td>
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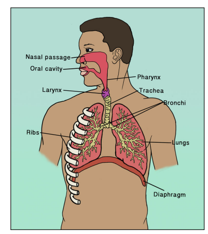
<tr><td>Respiratory</td><td>
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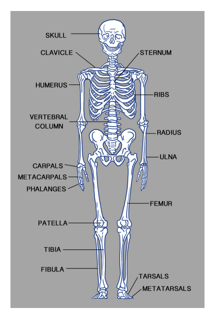
<tr><td>Skeletal</td><td>
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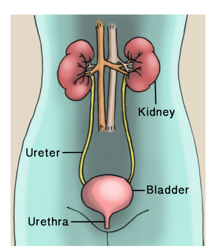
<tr><td>Urinary</td><td>
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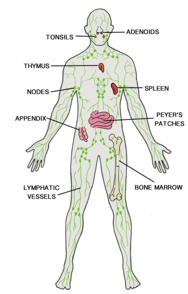
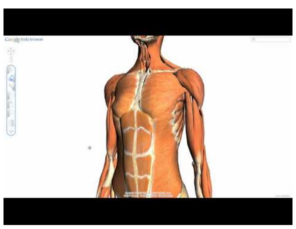
**TABLE 16.2:** (continued)

| Organ System | Example |
| --- | --- |
| Immune |  |



You can watch overviews of the human organ systems at the link below.

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



MEDIA

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## Homeostasis and Feedback Regulation

As described above, homeostasis is an organism's ability to keep a constant internal environment. Keeping a stable internal environment requires constant adjustments as conditions change inside and outside of cells.

The endocrine system plays an important role in homeostasis because hormones, which are the messengers of the endocrine system, regulate the activity of body cells. The release of hormones into the blood is controlled by a stimulus, or signal. For example, the stimulus either causes an increase or a decrease in the amount of hormone released. Then, the response to the signal changes the internal conditions and may itself become a new stimulus. This kind of control is called feedback regulation or a feedback loop.

**Feedback regulation** occurs when the response to a stimulus has an effect of some kind on the original stimulus. The type of response determines what the feedback is called. Take the men jumping in the water as an example. When the nervous system reduced blood flow to the skin, this was caused by a feedback loop sensing the change in environment. Feedback loops return body systems back to "normal."

A **negative feedback loop** is one in which the response to a stimulus decreases the effect of the original stimulus. A **positive feedback loop** is one in which the response to a stimulus increases the original stimulus. These are explained in more detail below.

### Thermoregulation: A Negative Feedback Loop

Negative feedback is the most common feedback loop in the body. Negative feedback decreases the effect of a stimulus on the body ( **Figure** 16.4). For instance, if you get stuck in a smoky environment during a fire, the amount of carbon dioxide in your body will increase. In the negative feedback loop, your lungs will be signaled to increase your breathing rate and exhale more carbon dioxide. The effect is to reduce the amount of carbon dioxide in your body. You can remember that this is a negative feedback loop because you are decreasing the effect of the stimulus.

Thermoregulation is another example of negative feedback. 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 causes a response —the skin makes sweat and blood vessels near the skin surface dilate. This response helps decrease body temperature.

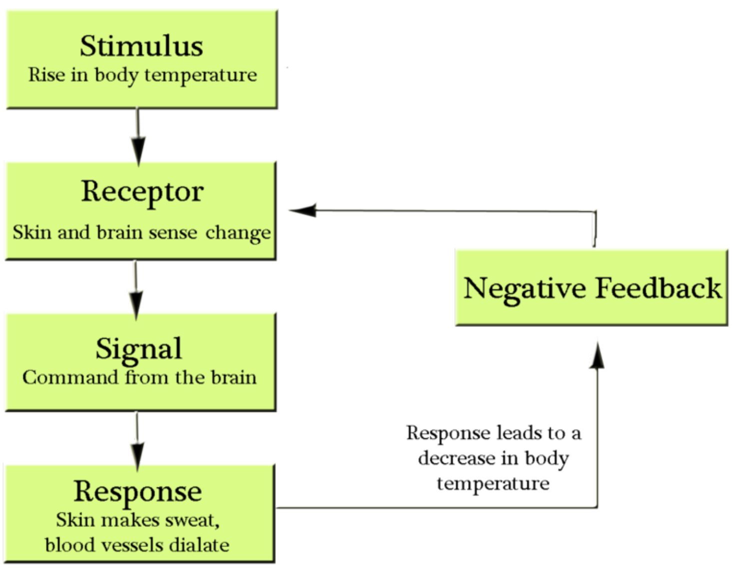


FIGURE 16.4
Feedback Regulation.

Positive feedback is less common than negative feedback. Positive feedback acts to increase the effect of a stimulus. An example of positive feedback is milk production. As the baby drinks its mother's milk, nerve messages from the mammary glands cause a hormone, prolactin, to be released. The more the baby suckles, the more prolactin is released, which causes more milk to be produced.

## Lesson Summary

- The levels of organization in the human body include: cells, tissues, organs, and organ systems.
- A tissue is a group of cells that work together.
- An organ is made of two or more tissues that work together.
- Organs that work together make up organ systems.
- There are four tissue types in the body: epithelial tissue, connective tissue, muscle tissue, and nervous tissue.
- There are 12 major organ systems in the body.
- Organs and organ systems work together to maintain homeostasis.

# Review Questions

## Recall

1. What is homeostasis?
2. What are the four levels of organization in an organism?
3. List the four types of tissues that make up the human body.

## Apply Concepts

4. What is the difference between a tissue and an organ?
5. Identify the organ system to which the following organs belong: skin, stomach, brain, lungs, and heart.
6. Give an example of how two organ systems work together to maintain homeostasis.

## Critical Thinking

7. A classmate says that all four tissue types are never found together in an organ. Do you agree with your classmate? Explain your answer.
8. Why do you think an organ is able to do many more jobs than a single tissue?

# Further Reading / Supplemental Links

- http://en.wikipedia.org/wiki/Tissue_%28biology%29

# Points to Consider

The first system we will discuss is the integumentary system.

- What organs do you think makes up the integumentary system?
- What other body systems might the integumentary system work with to maintain homeostasis?

# 16.2 The Integumentary System

## Lesson Objectives

- List the functions of skin.
- Describe the structure of skin.
- Describe the structure of hair and nails.
- Identify two types of skin problems.
- Describe two ways to take care of your skin.

## Check Your Understanding

- What is homeostasis?
- What is epithelial tissue?

## Vocabulary

- dermis
- epidermis
- integumentary system
- keratin
- melanin
- oil gland
- sunburn
- sweat gland

## Your Skin and Homeostasis

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 or uncover it to cool off. In fact, you see it so often it is easy to forget the important role your skin plays in keeping you healthy.

Your skin is part of your **integumentary system** ( **Figure** 16.5), which is the outer covering of your body. The integumentary system is made up of your skin, hair, and nails. Your integumentary system has many roles in homeostasis, including protection, the sense of touch, and controlling body temperature.

FIGURE 16.5
Skin acts as a barrier that stops water and other things, like soap and dirt, from getting into your body.

## Functions of Skin

Your skin covers the entire outside of your body. Your skin is your body's largest organ, yet it is only about 2 millimeters thick. It has many important functions. The skin:

- Provides a barrier. It keeps organisms that could harm the body out. It stops water from leaving the body, and stops water from getting into the body.
- Controls body temperature. It does this by making sweat, 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 chemical called melanin is made by certain skin cells when they are exposed to sunlight. Melanin blocks sun light 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? The dead cells are filled with a tough, waterproof protein called **keratin**. As the dead cells are shed or removed from the upper layer, they are replaced by the skin cells below them.

As you can see in **Figure** 16.6, two different layers make up the skin —the epidermis and the dermis. A fatty layer, called subcutaneous tissue, lies under the dermis, but it is not part of your skin.

The color, thickness and texture of skin vary over the body. There are two general types of skin:

1. Thin and hairy, which is the most common type on the body.
2. Thick and hairless, which is found on parts of the body that experience a lot of contact with the environment, such as the palms of the hands or the soles of the feet.

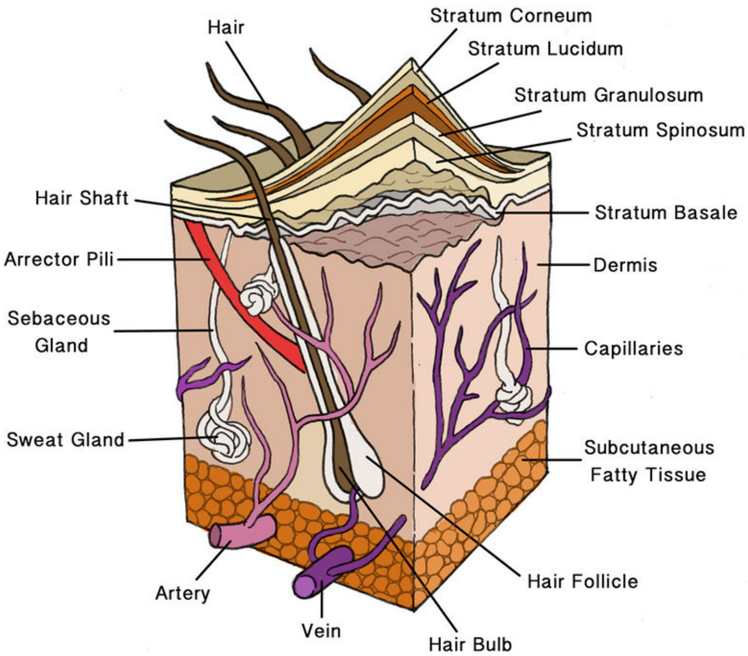


FIGURE 16.6

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. The epidermis is divided into several layers of epithelial cells. The epithelial cells are formed by mitosis in the lowest layer. These cells move up through the layers of the epidermis to the top. 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 that contains the protein collagen. Collagen is a long, fiber-like protein that is very strong. The dermis is tightly connected to the epidermis by a thin wall of collagen fibers.

As you can see in **Figure** 16.6, the dermis contains hair follicles, sweat glands, oil glands, and blood vessels. 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," shown in **Figure** 16.7.

FIGURE 16.7
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 follicles open out into the epidermis, but they start in the dermis. **Oil glands** release, or secrete, an oily substance, called sebum, into the hair follicle. An oil gland is shown in **Figure** 16.6. 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** 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. This is why sweat can help maintain homeostasis. The skin also releases excess water, salts, and other wastes in sweat. A sweat gland is shown in **Figure** 16.6.

## Nails and Hair

Nails and hair are made of the same types of cells that make up skin. Hair and nails contain the tough protein keratin.

### Nails

Fingernails and toenails both grow from nail beds. A nailbed is thickened to form a lunula, or little moon, which you can see in **Figure** 16.8. Cells forming the nail bed are linked together to form the nail. 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, which is a good thing, 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, which allow you to receive more information about objects you touch. Nails are made up of many different parts, as shown in **Figure** 16.8.

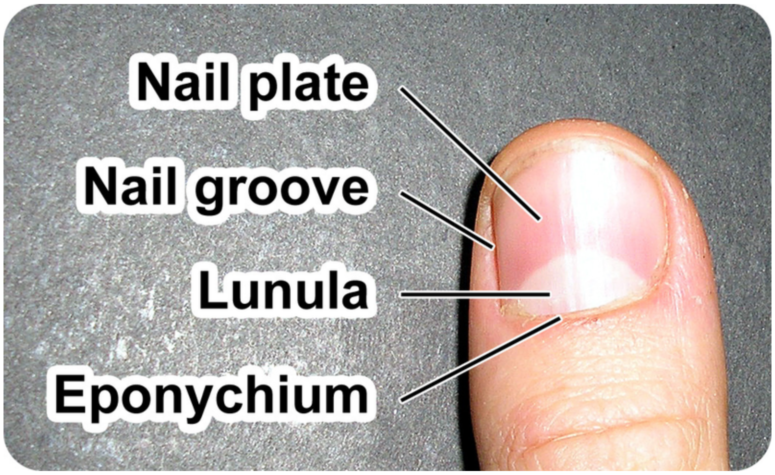


FIGURE 16.8
The structure of fingernails is similar to toenails. The free edge is the part of the nail that extends past the finger, beyond the nail plate. The nail plate is what we think of when we say "nail," the hard portion made of the tough protein keratin. The lunula is the crescent shaped whitish area of the nail bed. The cuticle is the fold of skin at the end of the nail.

### Hair

Hair sticks out from the epidermis, but it grows from the dermis, as shown in **Figure** 16.9. Hair is also made of keratin, the same protein that makes up skin and nails. 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. Similar to nails and skin, the cells that make up the hair strand are dead and filled with keratin.

Hair color is caused by different types of melanin in the hair cells. In general, the more melanin in the cells, the darker the hair color; the less melanin, the lighter the hair color.

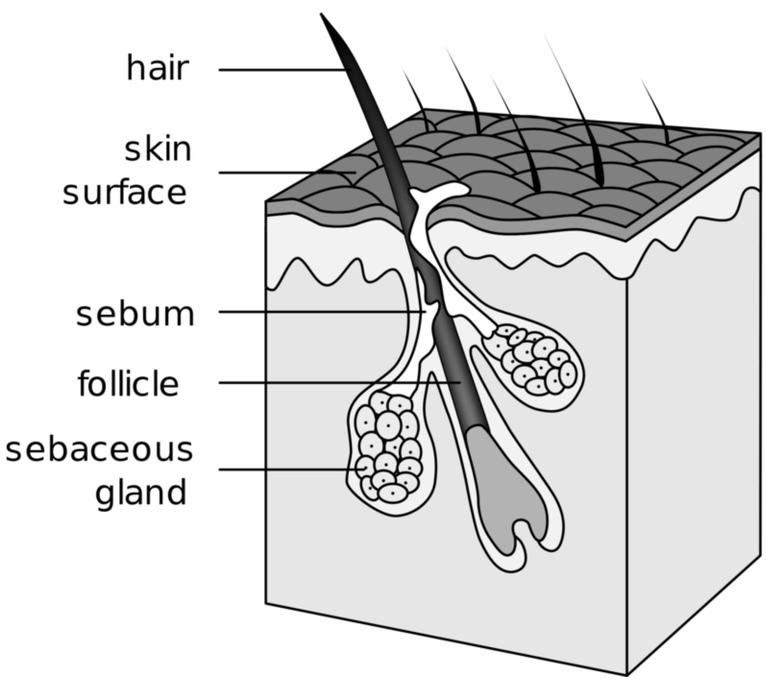


FIGURE 16.9
Hair, hair follicle, and oil glands. The oil, called sebum, helps to prevent water loss from the skin.

Hair helps to keep the body warm. When you feel cold, your skin gets a little bumpy. These bumps are caused by tiny muscles that pull on the hair, causing the hair to stick out. The erect hairs help to trap a thin layer of air that is warmed by body heat. In mammals that have much more hair than humans, the hair traps a layer of warm air near the skin and acts like warm blanket. Hair also protects the skin from ultraviolet (UV) radiation from the sun.

Hair also acts 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.

## Keeping Skin Healthy

Some sunlight is good for 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 girl in **Figure** 16.10, get sunburned more quickly than people with darker skin. This is because melanin in the skin acts as a natural sunblock that helps to protect the body from UV radiation. When exposed to UV radiation, certain skin cells make melanin, which causes skin to tan. Children and teens who have gotten 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 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. As people age, their skin gets wrinkled. Wrinkles are caused mainly by UV radiation and by the loosening of the connective tissue in the dermis due to age.

FIGURE 16.10
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.

## Bathing and Skin Hygiene

During the day, your skin can collect many different things. Sweat, oil, dirt, dust, and dead skin cells can build up on the skin surface. If not washed away, the mix of sweat, oil, dirt, and dead skin cells can encourage the excess growth of bacteria. These bacteria feed on these substances and cause a smell that is commonly called body odor.

Dirty skin is also more prone to infection. Bathing every day helps to remove dirt, sweat and extra skin cells, and helps to keep your skin clean and healthy.

## Injury

Your skin can heal itself even after a large cut. Cells that are damaged or cut away are replaced by cells that grow in the bottom layer of the epidermis and the dermis. When an injury cuts through the epidermis into the dermis, bleeding occurs. A blood clot and scab soon forms. After the scab is formed, cells at the bottom of the epidermis begin to divide by mitosis and move to the edges of the scab. A few days after the injury, the edges of the wound are pulled together.

If the cut is large enough, the production of new skin cells will not be able to heal the wound. Stitching the edges of the injured skin together can help the skin to repair itself. The person in **Figure** 16.11 had a large cut that needed to be stitched together. When the damaged cells and tissues have been replaced, the stitches can be removed.

FIGURE 16.11

Sewing the edges of a large cut together allows the body to repair the damaged cells and tissues, and heal the tear in the skin.

## Lesson Summary

- Skin acts as a barrier that keeps particles and water out of the body.
- The skin helps to cool the body in hot temperatures, and keep the body warm in cool temperatures.
- Skin is made up of two layers, the epidermis and the dermis.
- Pimples occur when the skin produces too much sebum.
- Hair and nails are made of keratin, the same protein as skin.
- Nails grow from nail beds and hairs grow from hair follicles in the skin.
- Skin cancer can be caused by excess exposure to ultraviolet light from the sun or tanning beds.
- Frequent bathing helps keep the skin clean and healthy.
- Wearing sun block and a hat when outdoors can help prevent skin cancer.

## Review Questions

### Recall

1. Identify two functions of skin.
2. How does the integumentary system help maintain homeostasis?
3. What are the two layers of the skin?
4. Identify the layer of skin from which hair grows.
5. Name two functions of nails.
6. Name two functions of hair.

### Apply Concepts

7. In what way are hair and nails similar to skin?
8. The skin makes too much sebum, what type of skin problem might this cause?
9. How does washing your skin help to keep you healthy?
10. Why are stitches sometimes needed if a person gets a deep or long cut in their skin?

### Critical Thinking

11. The World Health Organization recommends that no person younger than 18 years old use a tanning bed. Why do you think using a tanning bed is not recommended?

## Further Reading / Supplemental Links

- http://www.cdc.gov/mmwr/preview/mmwrhtml/mm5540a9.htm
- http://www.cdc.gov/Features/SkinCancer

## Points to Consider

Next we turn to the skeletal system.

- How might what you eat affect your bones?
- What do you think is the most important function of your skeletal system?

# 16.3 The Skeletal System

## Lesson Objectives

- Identify the main tissues and organs of the skeletal system.
- List four functions of the skeletal system.
- Describe three movable joints.
- Identify two nutrients that are important for a healthy skeletal system.
- Describe two skeletal system injuries.

## Check Your Understanding

- What is an organ system?
- What is connective tissue?

## Vocabulary

- ball and socket joint
- bone marrow
- cartilage
- fracture
- gliding joint
- hinge joint
- joint
- ligament
- movable joint
- pivot joint
- skeletal system
- skeleton
- sprain

## 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.

Your skeleton is important for many different things. Bones are the main organs of the skeletal system. They are made up of living tissue. Humans are vertebrates, which are animals that have a backbone. The sturdy set of bones and cartilage that is found inside vertebrates is called a **skeleton**.

The adult human skeleton has 206 bones, some of which are named in **Figure** 16.12. Strangely, even though they are smaller, the skeletons of babies and children have many more bones and more cartilage than adults have. As a child grows, these "extra" bones grow into each other, and cartilage slowly hardens to become bone tissue.

Living bones are full of life. They contain many different types of tissues. **Cartilage** is found at the end of bones and is made of tough protein fibers called collagen. 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**.

## Functions of Bones

Your skeletal system gives shape and form to your body, but it is also important in maintaining homeostasis. 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 are organs. Recall that organs are made up of two or more types of tissues. Bones come in many different shapes and sizes, but they are all made of the same materials.

The two main types of bone tissue are compact bone and spongy bone.

- Compact bone makes up the dense outer layer of bones.
- Spongy bone is found at the center of the bone, and is lighter and less dense 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**. There are two types of bone marrow - red marrow and yellow marrow.

- Red marrow makes red blood cells, platelets, and most of the white blood cells for the body (discussed in the *Diseases and the Body's Defenses* chapter).
- Yellow marrow makes white blood cells.

The bones of newborn babies contain only red marrow. As children get older, some of their red marrow is replaced by yellow marrow. In adults, red marrow is found mostly in the bones of the skull, the ribs, and pelvic bones.

Bones come in four main shapes. They can be long, short, flat, or irregular. Identifying a bone as long, short, flat, or irregular is based on the shape of the bone, not the size of the bone. For example, both small and large bones can be classified as long bones. The small bones in your fingers and the largest bone in your body, the femur, are all long bones. The structure of a long bone is shown in **Figure** 16.13.

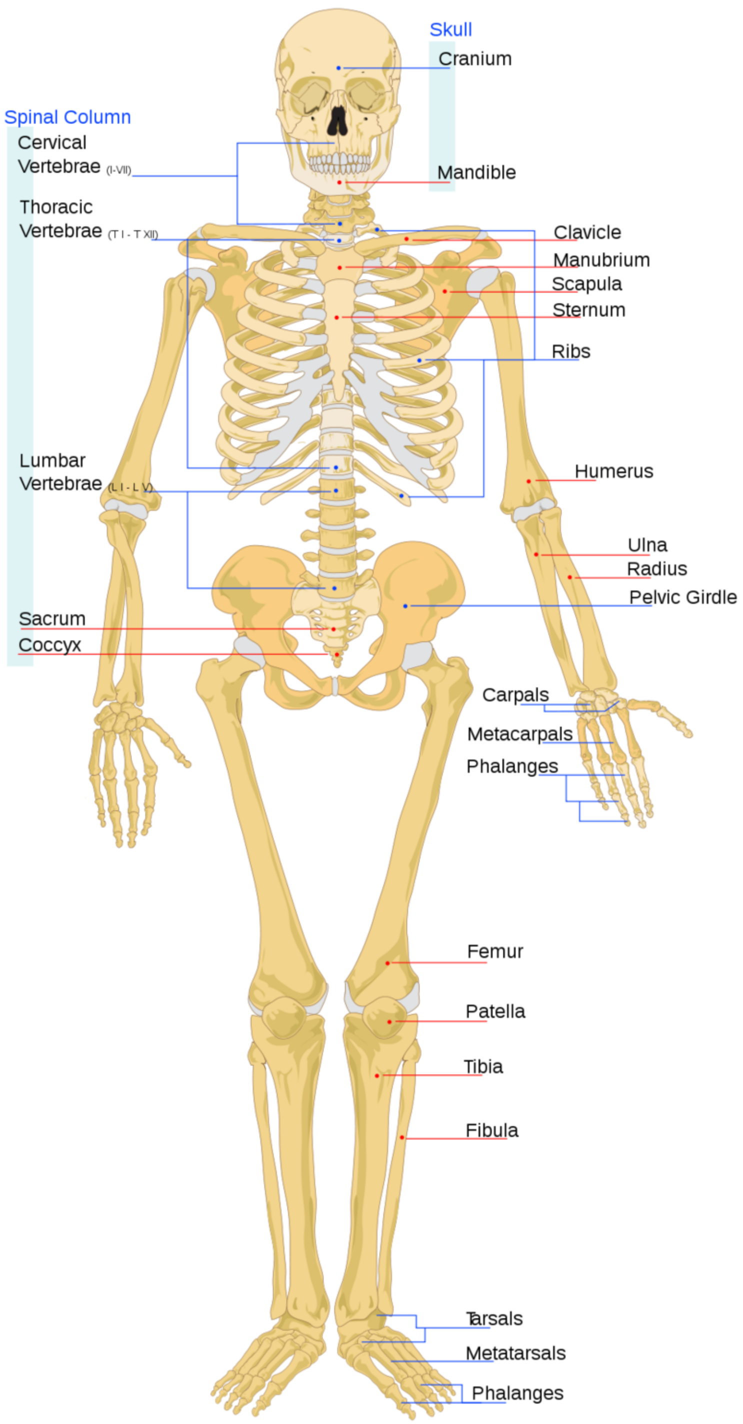


FIGURE 16.12
The skeletal system is made up of bones, cartilage, and ligaments. The skeletal system has many important functions in your body.

## Bone Growth

Your skeleton begins growing very early in development. After only eight weeks of growth from a fertilized egg, your skeleton has been formed by cartilage and other connective tissues.

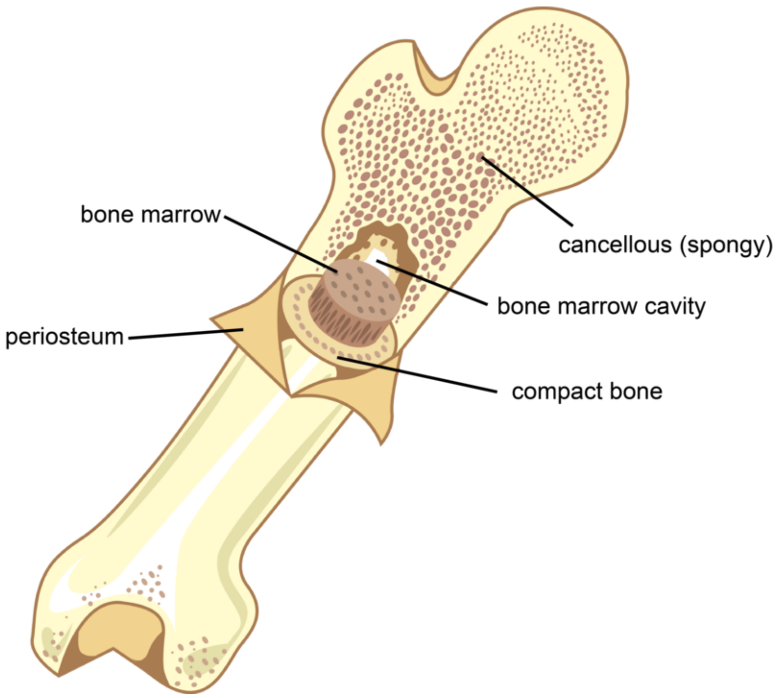


FIGURE 16.13
Bones are made up of different types of tissues.

At this point your skeleton is very flexible. After a few more weeks of growth, the cells that form hard bone begin growing in the cartilage, and your 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 plate, 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.

## Joints and How They Move

A **joint** is a point at which two or more bones meet. There are three 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** 16.14).
2. Partly movable joints allow only a little movement. Your backbone has partly movable joints between the vertebrae ( **Figure** 16.15).
3. **Movable joints** allow movement.

Joints are a type of lever, which is a rigid object that is used to increase the amount of force put onto another object. Can openers and scissors are examples of levers. Joints reduce the amount of energy that is spent moving the body around. Just imagine how difficult it would be to walk about if you did not have knees!

FIGURE 16.14
The skull has fixed joints. Fixed joints do not allow any movement of the bones, which protects the brain from injury.

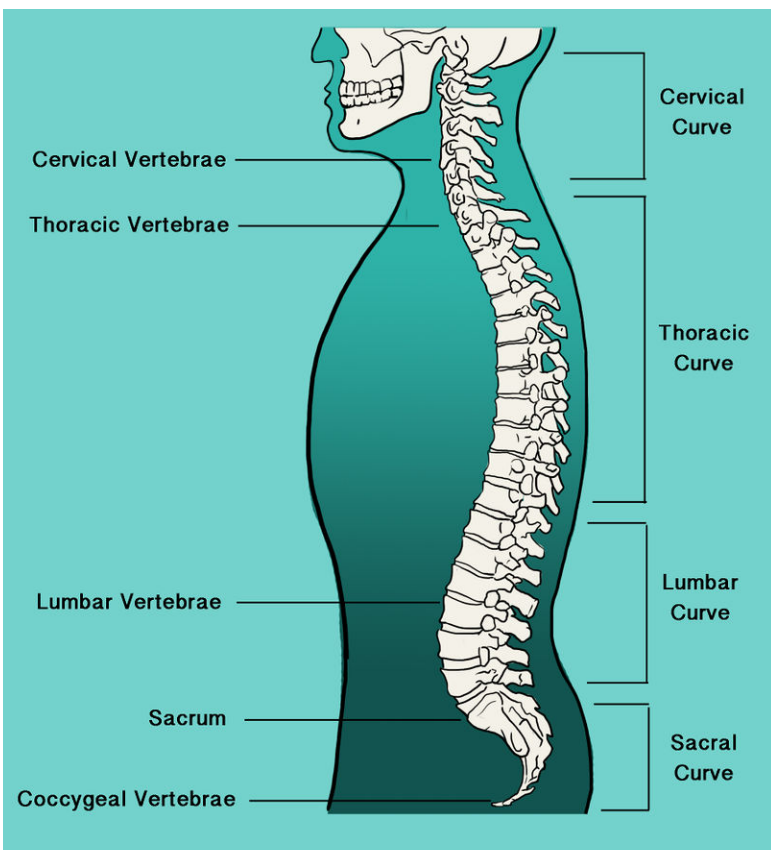


FIGURE 16.15
The joints between your vertebrae are partially movable.

## Movable Joints

Movable joints are the most mobile joints of all. They are also the most common type of joint in your body. Your fingers, toes, hips, elbows, and knees all provide examples movable joints. The surfaces of bones at movable joints are covered with a smooth layer of cartilage. The space between the bones in a movable joint is filled with a liquid called synovial fluid. Synovial fluid is a thick, stringy fluid that looks like egg white. The fluid gives the bone a smooth cushion when they move at the joint. Four types of movable joints are shown below.

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, shown in **Figure** 16.16, and the shoulder.

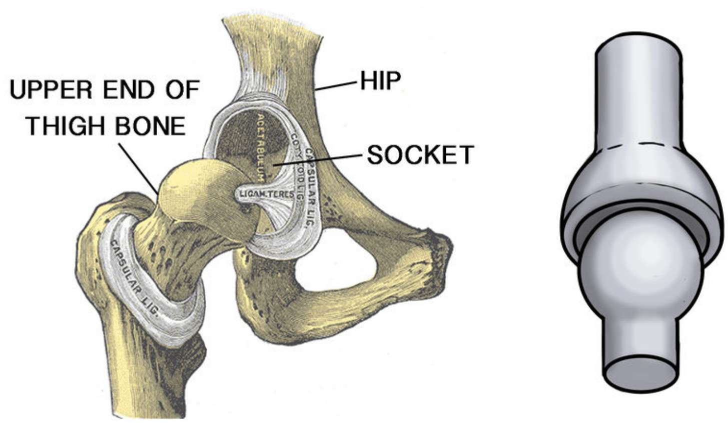


FIGURE 16.16
Ball and Socket Joint. Your hip joint is a ball and socket joint. The "ball" end of one bone fits into the "socket" of another bone. These joints can move in many different directions.

2. In a **hinge joint**, the ends of the bones are shaped in a way that allows motion only in two directions, forward and backward. Examples of hinge joints are the knees and elbows. A knee joint is shown in **Figure** 16.17.

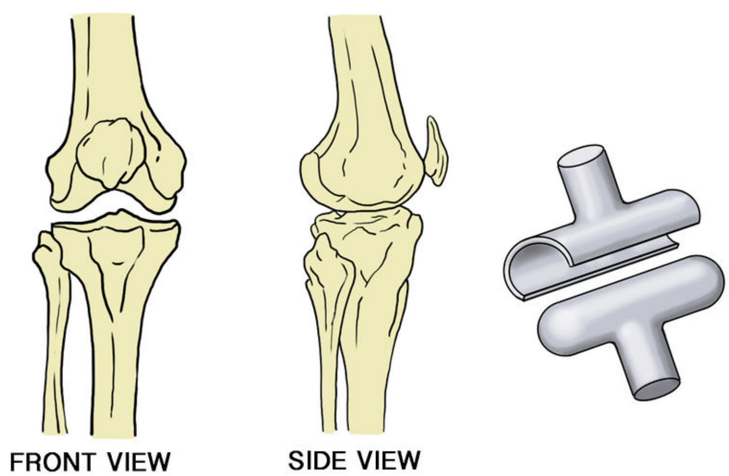


FIGURE 16.17
Hinge Joint. The knee joint is a hinge joint. Like a door hinge, a hinge joint allows backward and forward movement.

3. The **pivot joint** is formed by a process that rotates within a ring, the ring being formed partly of bone and partly of ligament. 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. A pivot joint is shown in **Figure** 16.18.

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.

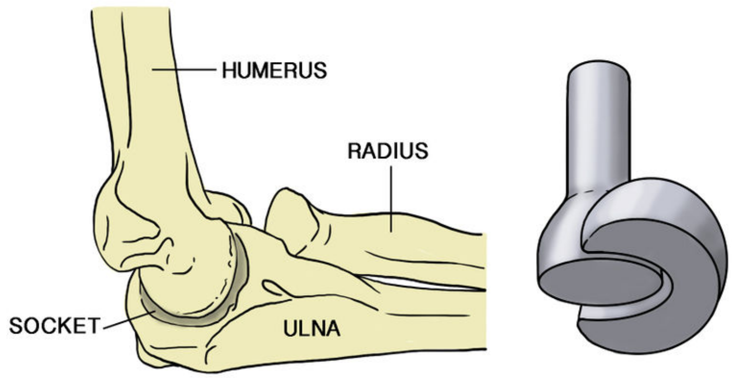


FIGURE 16.18
Pivot Joint. The joint at which the radius and ulna meet is a pivot joint. Movement at this joint allows you to flip your palm over without moving your elbow joint.

## Keeping Bones and Joints Healthy

Your body depends on you to take care of it, just like you may take care of a plant or a dog. 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 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 become lighter and more porous than they should be. Light and porous bones are more likely to break, which can cause pain and prevent a person from walking. 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 of milk provides about 300 mg of calcium, or about 30% of the daily requirement. Other sources of calcium are shown in **Figure** 16.19.

Your skin makes vitamin D when exposed to sunlight. The pigment melanin in the skin acts 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.

Fish is naturally rich in vitamin D. 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 $3\frac{1}{2}$-ounce portion of cooked salmon provides 360 IU of vitamin D.

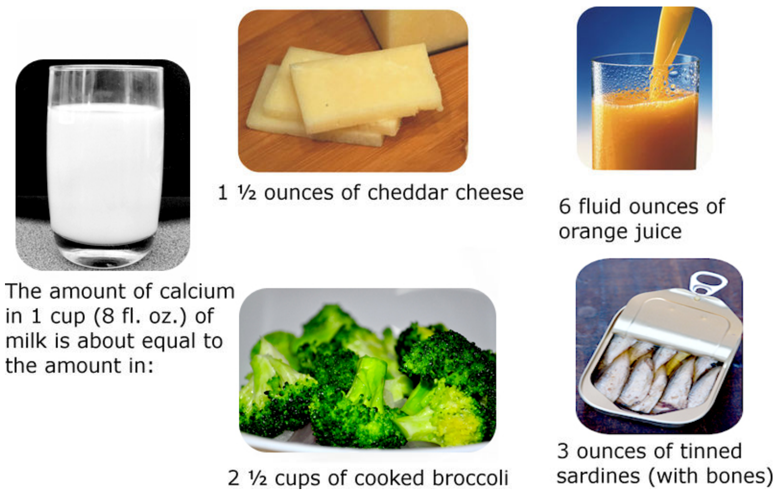


FIGURE 16.19
There are many different sources of calcium. Getting enough calcium in your daily diet is important for good bone health. How many ounces of cheddar cheese would provide your recommended daily intake of calcium?

### 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. A broken ulna has been repaired with pins in **Figure** 16.20.

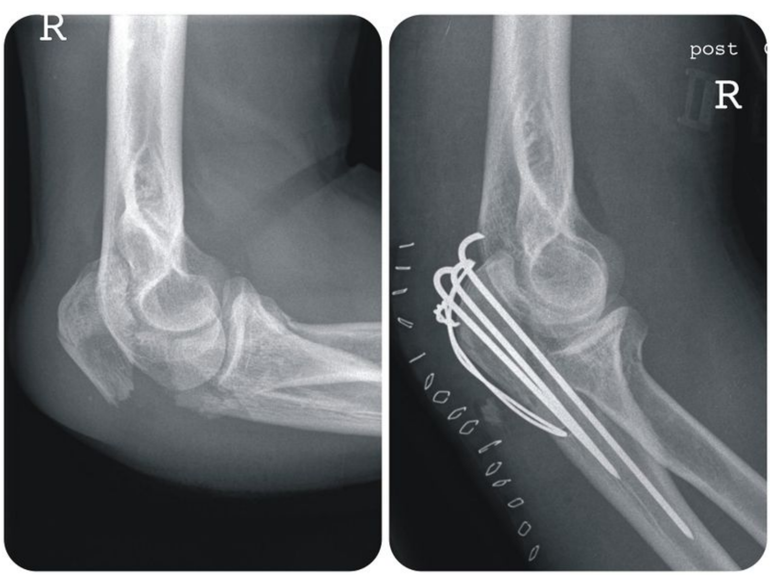


FIGURE 16.20
The upper part of the ulna, just above the elbow joint, is broken, as you can see in the X-ray at left. The X-ray at right was taken after a surgeon inserted a system of pins and wires across the fracture to bring the two pieces of the ulna into close proximity.

### 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 looser. Osteoarthritis is the most common form of arthritis. It has many causes, 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. A sprain of the anterior cruciform ligament (ACL), a small ligament in the knee, is a common injury among athletes. Ligament injuries can take a long time to heal. Treatment of the injury includes rest and special exercises that are developed by a physical therapist.

### 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. Stretching can improve your posture, and helps prevent some aches and pains associated with tight muscles.

## Lesson Summary

- Bones, cartilage, and ligaments make up the skeletal system.
- The skeleton supports the body against the pull of gravity.
- The skeleton provides a framework that supports and protects the soft organs of the body.
- Bones work together with muscles to move the body.
- Blood cells are mostly made inside the bone marrow.
- There are three types of joints in the body: fixed, partly movable, and movable.
- Calcium and vitamin D are two of the most important nutrients for a healthy skeletal system.
- The break down of the cartilage leads to pain and stiffness in the joint.
- A sprain is an injury to a ligament.
- A fracture is a break or crack in a bone.

## Review Questions

### Recall

1. What are the main organs of the skeletal system?

2. Name one tissue of the skeletal system.

3. List four functions of the skeletal system.

4. Name three types of movable joints.

5. Name two things you can do to keep your skeletal system healthy.

### Apply Concepts

6. "All joints in the body are movable." Do you agree with this statement? Explain why or why not.

7. How are the joints in your body similar to levers?

8. Why is calcium important for a healthy skeletal system?

9. The recommended daily amount of calcium for teenagers is 1300 mg. If a person gets only 1000 mg a day, what percentage of the recommended daily amount are they getting?

10. What part of the skeletal system does osteoarthritis affect?

11. Why might a doctor need to insert pins into a broken bone?

### Critical Thinking

12. You are a doctor. An athlete comes to you with a torn ACL and asks you to give him a cast. Tell him why that is not the correct treatment for his injury.

## Further Reading / Supplemental Links

- http://www.girlshealth.gov/bones
- http://www.cdc.gov/nccdphp/dnpa/nutrition/nutrition_for_everyone/basics/calcium.htm

## Points to Consider

Next we discuss the muscular system.

- How do you think your skeletal system interacts with your muscular system?
- How could a broken bone affect the functioning of the muscular system?

# 16.4 The Muscular System

## Lesson Objectives

- Identify the three muscle types in the body.
- Describe how skeletal muscles and bones work together to move the body.
- Describe how exercise affects the muscular system.
- Identify two types of injuries to the muscular system.

## Check Your Understanding

- What is muscle tissue?
- What is the function of the muscular system?

## Vocabulary

- aerobic exercises
- anaerobic exercises
- cardiac muscle
- contraction
- extensor
- flexor
- involuntary muscle
- muscle fibers
- muscular system
- physical fitness
- skeletal muscle
- smooth muscle
- strain
- tendon
- voluntary muscle

## Types of Muscles

The **muscular system** is the body system that allows us to move. You depend on many muscles to keep you alive. Your heart, which is mostly muscle, pumps blood around your body. Muscles are always moving in 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**.

Nearly all movement in the body is the result of muscle contraction.

Certain muscle movements happen without you thinking about them, while you can control other muscle movements. Muscles that you can control are called **voluntary muscles**. Muscles that you cannot control are called **involuntary muscles**.

There are three different types of muscles in the body ( **Figure** 16.21):

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.
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. Unlike skeletal muscle, smooth muscle can never be under your control.
3. **Cardiac muscle** is also an involuntary muscle, found only in the heart.

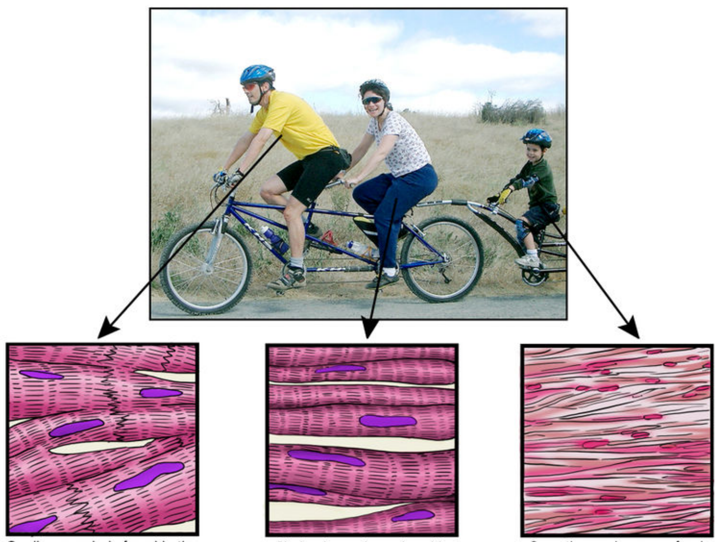


FIGURE 16.21
There are three types of muscles in the body: cardiac, skeletal, and smooth. Everyone has the same three types of muscle tissue, no matter their age.

## Muscles, Bones, and Movement

Skeletal muscles are attached to the skeleton by 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. When they relax, they get longer. By contracting and relaxing, muscles pull on bones and allow the body to move. Muscles work together in pairs. 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**.

For example, the biceps and triceps muscles work together to allow you to bend and straighten your elbow. Your biceps muscle, shown in **Figure** 16.22, contracts, and at the same time the triceps muscle relaxes. The biceps is the flexor and the triceps is the extensor of your elbow joint. In this way the joints of your body act like levers. This lever action of your joints decreases the amount of energy you have to spend to make large body movements.

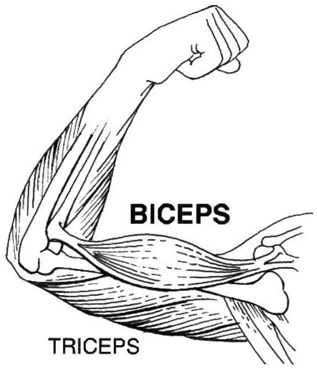


FIGURE 16.22

The biceps and triceps act against one another to bend and straighten the elbow joint. To bend the elbow, the biceps contract and the triceps relax. To straighten the elbow, the triceps contract and the biceps relax.

## Muscles and the Nervous System

Muscles are controlled by the nervous system (see the *Controlling the Body* chapter). Nerves send messages to the muscular system from the brain. Nerves also send messages to the brain from the muscles. For example, when you want to move your foot, electrical messages called impulses move along nerve cells from your brain to the muscles of your foot. At the point at which the nerve cell and muscle cells meet, the electrical message is converted to a chemical message. The muscle cells receive the chemical message, which causes tiny protein fibers inside the muscle cells to get shorter. The muscles contract, pulling on the bones, and your foot moves.

## Muscles and Exercise

Your muscles are important for carrying out everyday activities. The ability of your body to carry out your daily activities without getting out of breath, sore, or overly tired is called **physical fitness**. Physical exercise is any activity that maintains or improves physical fitness and overall health. Regular physical exercise is important in preventing lifestyle diseases such as heart disease, cardiovascular disease, Type 2 diabetes, and obesity. Regular exercise 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.
- **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 avoid activity-related injuries.

### Anaerobic Exercise and Muscular Strength

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, as shown in **Figure** 16.23. After many muscle contractions, muscle fibers build up larger energy stores and the muscle tissue gets bigger. The larger a muscle is, the greater the force it can apply to lift a weight or move a body joint. The muscles of weightlifters are large and strong.

FIGURE 16.23
Anaerobic exercises involve the muscles working against resistance. In this case the resistance is the person's own body weight.

### Aerobic Exercise and Muscular Endurance

Aerobic exercises are exercises that cause your heart to beat faster and allow your muscles to use oxygen to contract. Aerobic exercise causes many different changes in skeletal muscle. Muscle energy stores are increased and the ability to use oxygen improves. If you exercise aerobically, overtime, your muscles will not get easily tired and you will use oxygen and food more efficiently. Aerobic exercise also helps improve cardiac muscle. Overtime, the heart muscles will increase in size and be able to pump a larger volume of blood to your cells. Examples of an aerobic exercise are shown in **Figure** 16.24.

FIGURE 16.24
When done regularly, aerobic activities such as cycling, make the heart stronger.

### 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, as shown in **Figure** 16.25.

A **strain** happens when muscle fibers tear because the muscle contracts too much or contracts before the muscle is warmed up. Strains are also known as "pulled muscles." Some injuries are caused by overuse. An overuse injury happens if the muscle or joint is not rested enough between activities. Overuse injuries often involve tendons. Overuse of tendons can cause tiny tears within the protein fibers of the tendon. These tiny tears lead to swelling, pain, and stiffness, a condition called tendinitis. Tendinitis can affect any tendon that is overused. Strains and tendinitis are usually treated with rest, cold compresses, and stretching exercises that a physical therapist designs for each patient.

FIGURE 16.25

Warming up before the game helps the players avoid injuries. Some warm-ups may include stretching exercises. Some researchers believe stretching before activities may help prevent injury.

Proper rest and recovery are also as important to health as exercise is. If you do not get enough rest, your body will become injured and will not improve or react well to exercise. You can also rest by doing a different activity. For example, if you run, you can rest your running muscles and joints by swimming. This type of rest is called "active rest."

## Steroids

Anabolic steroids are hormones that cause the body to build up more protein in its cells. Muscle cells, which contain a lot of protein, get bigger when exposed to anabolic steroids. Your body naturally makes small amounts of anabolic steroids. They help your body repair from injury, and help to build bones and muscles. Anabolic steroids are used as medicines to treat people that have illnesses that affect muscle and bone growth. But some athletes who do not need steroids take them to increase their muscle size. When taken in this way, anabolic steroids can have long-term affects other body systems. They can damage the person’s kidneys, heart, liver, and reproductive system. If taken by adolescents, anabolic steroids can cause bones to stop growing, resulting in stunted growth.

## Lesson Summary

- The body has three types of muscle tissue: skeletal, smooth, and cardiac.
- Muscles move the body by contracting against the skeleton.
- Muscles are controlled by the nervous system.
- Regular exercise improves the health of the muscular system and makes muscles bigger and stronger.
- Muscular strength is the ability of a muscle to exert force during a contraction.
- Muscular endurance is the ability of a muscle to continue to contract over a long time without getting tired.
- A strain is an injury to a muscle in which the muscle fibers tear because the muscle contracts too much or contracts before the muscle is warmed up.
- Tiny tears and swelling in a tendon results in tendinitis.

## Review Questions

### Recall

1. Name the three types of muscle tissue in the body.
2. Which of the three types of muscles in the body is voluntary?
3. What is a tendon?
4. What is a muscle strain?

### Apply Concepts

5. Describe how skeletal muscles and bones work together to move the body.
6. How does aerobic exercise affect the heart?
7. How does aerobic exercise affect skeletal muscle?
8. How does anaerobic exercise affect skeletal muscle?
9. Why is warming up before exercise a good idea?

### Critical Thinking

10. A friend of yours says that taking steroids is not bad for their health because humans produce steroids in their body anyway. Can you explain to them why taking anabolic steroids is dangerous?

## Further Reading / Supplemental Links

- http://www.cdc.gov/nccdphp/dnpa/physical/everyone/index.htm

## Points to Consider

Next we move on to the digestive system.

- How does your muscular system depend on your digestive system?
- How does what you choose to eat affect your muscular system and your skeletal system?

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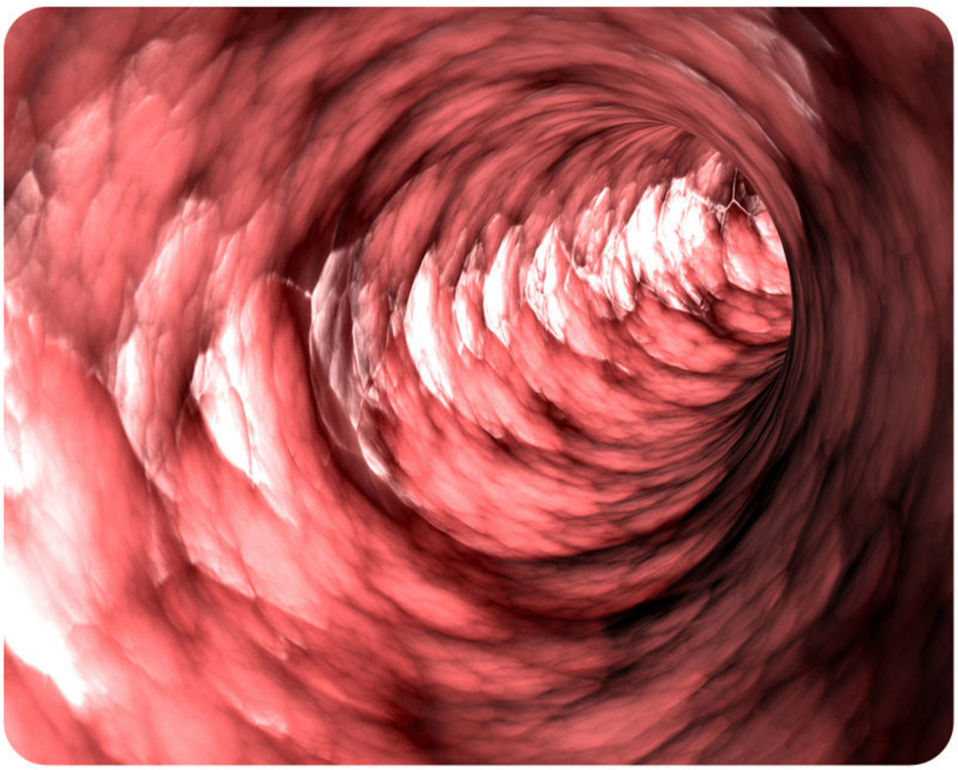
# CHAPTER 17 MS Food and the Digestive System

## Chapter Outline





The above image shows a close-up of the inside of a "fleshy" tunnel. Could it be an intestine? It could. Or it could be something else. But what is an intestine? It is an organ in the digestive system. The digestive system does what you think it does - it digests your food.

But does the inside of your intestine really look like a tunnel? Some would say an intestine looks more like a mountain range, with peaks and valleys. Why? The peaks and valleys would represent the villi that are inside of the intestines. They increase the surface area of the intestine so they can absorb as many nutrients as possible.

So what is another function of the digestive system? Absorption. What happens when you get sick? Does the digestive system work properly? What nutrients and vitamins do you need in order to make sure that your digestive system and your whole body works properly? What do the villi in the intestines have to do with these processes? As you read, think about the organs that help you digest and absorb the nutrients in your foods. Also, consider how healthy eating leads to healthy organ systems.

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# 17.1 Food and Nutrients

## Lesson Objectives

- Explain why the body needs food.
- Identify the roles of carbohydrates, proteins, and lipids.
- Give examples of vitamins and minerals, and state their functions.
- Explain why water is a nutrient.

## Check Your Understanding

- What are the four types of organic compounds?
- What do all cells need in order to function?
- What are muscles made of?

## Vocabulary

- calorie
- essential amino acid
- minerals
- nutrients
- starch
- trans fat
- vitamins

## 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. The girl shown in **Figure** 17.1 is eating fresh vegetables as part of a healthy meal. Why do you need foods like these for good health? What role does food play in the body?

Your body needs food for three reasons:

1. Food gives your body energy. You need energy for everything you do.
2. Food provides building materials for your body. Your body needs building materials so it can grow and repair itself.
3. Food contains substances that help control body processes. Your body processes must be kept in balance for good health.

FIGURE 17.1
This girl is eating a salad of vegetables and leafy green vegetables. Fresh vegetables such as these are excellent food choices 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 six types of nutrients:

1. Carbohydrates.
2. Proteins.
3. Lipids.
4. Vitamins.
5. Minerals.
6. Water.

Carbohydrates, proteins, and lipids give your body energy. Proteins provide building materials. Proteins, vitamins, and minerals help control body processes.

## Nutrients that Provide Energy

Molecules of 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. The energy in food is measured in units called **calories.**

### Carbohydrates

Carbohydrates are nutrients that include sugars, starches, and fiber. How many grams of carbohydrates you need each day are shown in **Figure** 17.2. It also shows some foods that are good sources of carbohydrates.

There are two types of carbohydrates: simple and complex.

### 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, the simplest sugar of all. Glucose is used by cells for energy.

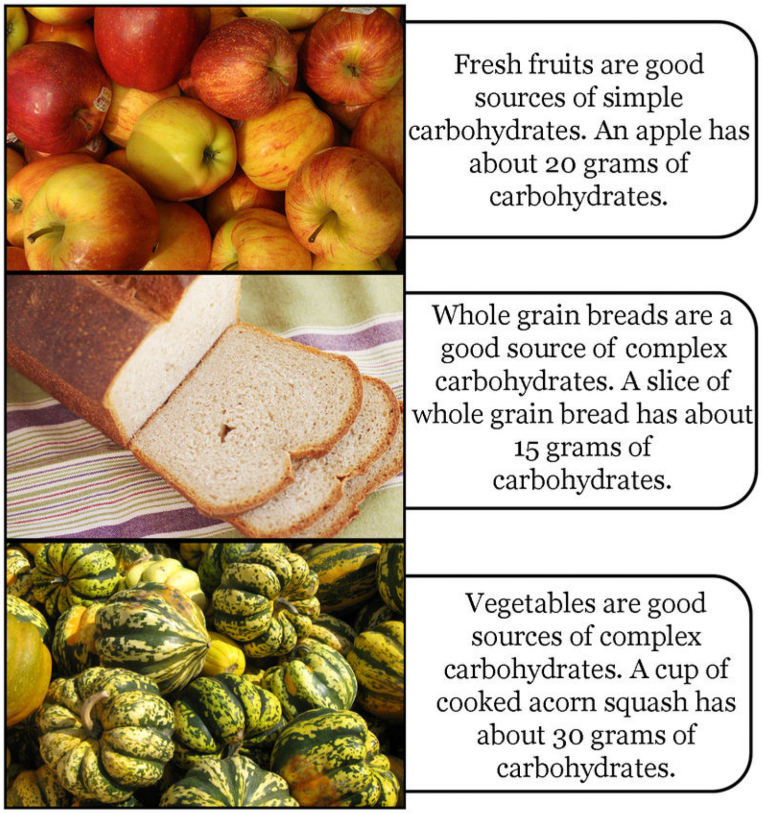


FIGURE 17.2

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. What other foods do you think are good sources of complex carbohydrates?

Remember the discussion of cellular respiration in the *Cell Functions* chapter? Cellular respiration turns glucose into the usable form of chemical energy, ATP. One gram of sugar provides your body with four Calories of energy.

Some people cannot digest lactose, the sugar in milk. This condition is called lactose intolerance. If people with this condition drink milk, they may have cramping, bloating, and gas. To avoid these symptoms, they should not drink milk, or else they should drink special, lactose-free milk.

### Complex Carbohydrates

**Starch** is a large, complex carbohydrate. Starches are found in foods such as vegetables and grains. Starches are broken down by the body into sugars that provide energy. Like sugar, one gram of starch provides your body with four calories of energy.

Fiber is another type of large, complex carbohydrate. Unlike sugars and starches, fiber does not provide energy. However, it has other important roles in the body. There are two types of fiber found in food: soluble fiber and insoluble fiber. Each type has a different role. Soluble fiber dissolves in water. It helps keep sugar and fat at normal levels in the blood. Insoluble fiber does not dissolve in water. As it moves through the large intestine, it absorbs water. This helps keep food waste moist so it can pass easily out of the body.

Eating foods high in fiber helps fill you up without providing too many calories. Most fruits and vegetables are high in fiber. Some examples are shown in **Figure** 17.3.

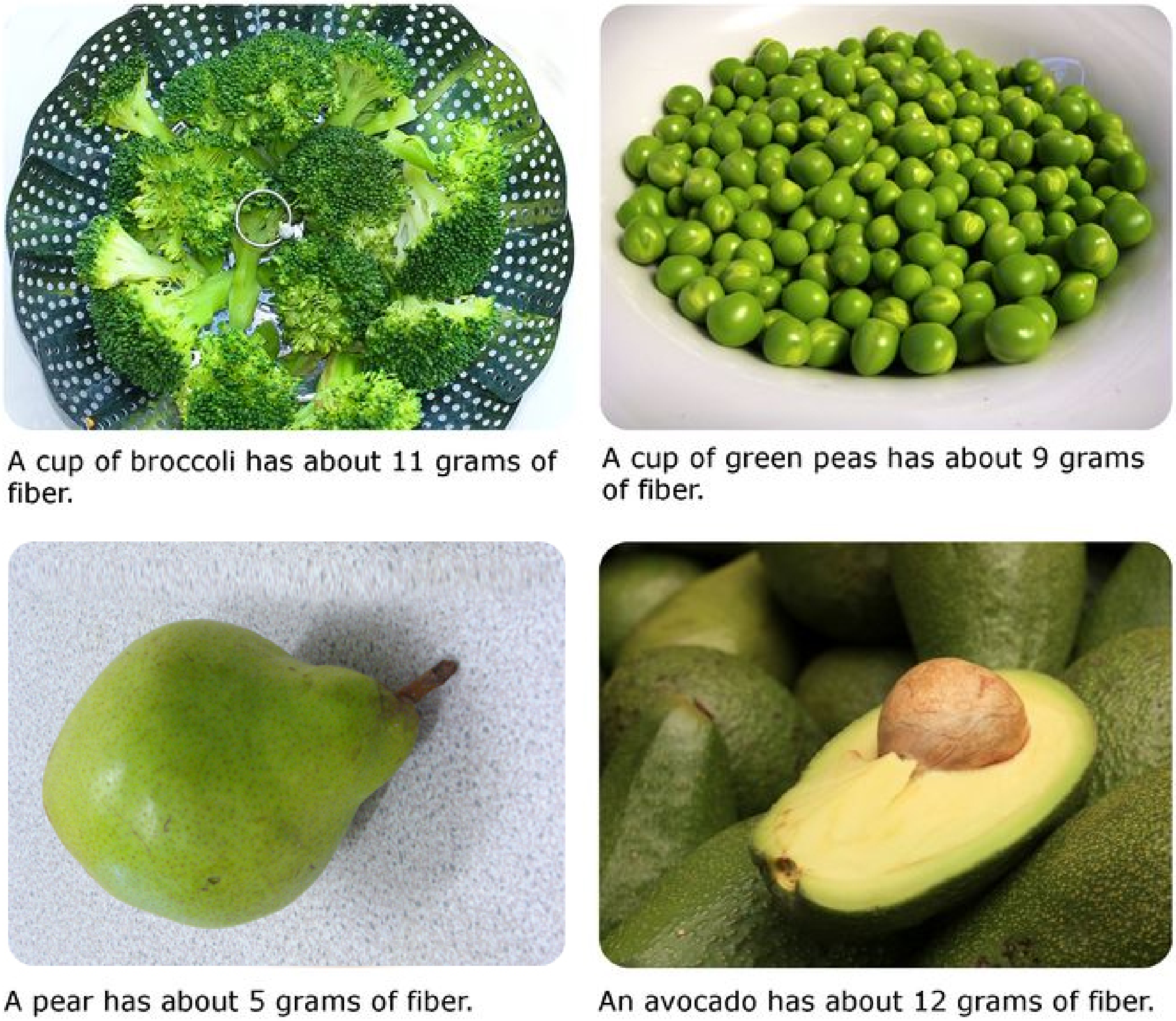


FIGURE 17.3

Between the ages of 9 and 13 years, girls need about 26 grams of fiber a day, and boys need about 31 grams of fiber a day. Do you know other foods that are high in fiber?

### Proteins

Proteins are nutrients made up of smaller molecules called amino acids. As discussed in the *Introduction to Living Things* chapter, the amino acids are arranged like "beads on a string." These amino acid chains then fold up into a three-dimensional molecule. Proteins have several important roles in the body. For example, proteins:

- Make up muscles.
- Help control body processes.
- Help the body fight off bacteria and other “foreign invaders.”
- Carry substances in the blood.

If you eat more proteins than you need for these purposes, the extra proteins are used for energy. One gram of protein provides four calories of energy. This is the same amount as one gram of sugar or starch. How many grams of proteins you need each day are shown in **Figure** 17.4. It also shows some foods that are good sources of proteins.


FIGURE 17.4
Between the ages of 9 and 13 years, you need about 34 grams of proteins a day. What other foods do you think are good sources of proteins?

There are many different amino acids, the building blocks of proteins, but your body needs only 20 of them. Your body can make ten of these amino acids from simpler substances. The other ten amino acids must come from the proteins in foods. These ten are called **essential amino acids**. Only animal foods, such as milk and meat, contain all ten essential amino acids in a single food. Plant foods are missing one or more essential amino acids. However, by eating a combination of plant foods, such as beans and rice, you can get all ten essential amino acids.

### Lipids

Lipids are nutrients such as fats that store energy. The heart and skeletal muscles rely mainly on lipids for energy. One gram of lipids provides nine calories of energy. This is more than twice the amount provided by carbohydrates or proteins. Lipids have several other roles in the body. For example, lipids:

- Protect nerves.
- Help control blood pressure.
- Help blood to clot.
- 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.

Fats and other lipids are necessary for life. However, they can be harmful if you eat too much of them, or the wrong type of fats. Fats can build up in the blood and damage blood vessels. This increases the risk of heart disease.

There are two types of lipids, saturated and unsaturated.

1. Saturated lipids can be unhealthy, even in very small amounts. They are found mainly in animal foods, such as meats, whole milk, and eggs. Saturated lipids increase cholesterol levels in the blood. Cholesterol is a fatty substance that is found naturally in the body. Too much cholesterol in the blood can lead to heart disease. It is best to limit the amount of saturated lipids in your diet.

1. Unsaturated lipids 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 because your body cannot make them. 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. You should do your best to eat fewer foods that contain it.

Beginning in 2010, California banned trans fats from restaurant products, and, beginning in 2011, from all retail baked goods.

## Vitamins and Minerals

Vitamins and minerals are also nutrients. They do not provide energy, but they are needed for good health.

### Vitamins

**Vitamins** are substances that the body needs in small amounts to function properly. Humans need 13 different vitamins. Some of them are listed in **Table** 17.1. The table also shows how much of each vitamin you need each 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.

**TABLE 17.1: Vitamins Needed For Good Health**

| Vitamin | One Reason You Need It | Some Foods that Have It | How Much of It You Need Each Day (at ages 9–13 years) |
|---|---|---|---|
| Vitamin A | Needed for good vision | Carrots, spinach, milk, eggs | 600 $\mu g$ (1 $\mu g = 1 \times 10^{-6}$ g) |
| Vitamin $B_1$ | Needed for healthy nerves | Whole wheat, peas, meat, beans, fish, peanuts | 0.9 mg (1 mg = $1 \times 10^{-3}$ g) |
| Vitamin $B_3$ | Needed for healthy skin and nerves | Beets, liver, pork, turkey, fish, peanuts | 12 mg |
| Vitamin $B_9$ | Needed to make red blood cells | Liver, peas, dried beans, green leafy vegetables | 300 $\mu g$ |
| Vitamin $B_{12}$ | Needed for healthy nerves | Meat, liver, milk, shellfish, eggs | 1.8 $\mu g$ |
| Vitamin C | Needed for growth and repair of tissues | Oranges, grapefruits, red peppers, broccoli | 45 mg |
| Vitamin D | Needed for healthy bones and teeth | Milk, salmon, tuna, eggs | 5 $\mu g$ |
| Vitamin K | Needed for blood to clot | Spinach, Brussels sprouts, milk, eggs | 60 $\mu g$ |

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 are listed in **Table** 17.1. They include whole grains, vegetables, fruits, and milk.

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. Getting too much of some vitamins can also cause health problems. The vitamins to watch out for are vitamins A, D, E, and K. These vitamins are stored by the body, so they can build up to high levels. Very high levels of these vitamins can even cause death, although this is very rare.

### Minerals

**Minerals** are chemical elements that are needed for body processes. Minerals are different from vitamins because they do not contain the element carbon. Minerals that you need in relatively large amounts are listed in **Table** 17.2. 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.

TABLE 17.2: **Minerals Needed For Good Health**

| Mineral | One Reason You Need It | Some Foods that Have It | How Much of It You Need Each Day (at ages 9–13 years) |
|---|---|---|---|
| Calcium | Needed for strong bones and teeth | Milk, soy milk, green leafy vegetables | 1,300 mg |
| Chloride | Needed for proper balance of water and salts in body | Table salt, most packaged foods | 2.3 g |
| Magnesium | Needed for strong bones | Whole grains, green leafy vegetables, nuts | 240 mg |
| Phosphorus | Needed for strong bones and teeth | Meat, poultry, whole grains | 1,250 mg |
| Potassium | Needed for muscles and nerves to work normally | Meats, grains, bananas, orange juice | 4.5 g |
| Sodium | Needed for muscles and nerves to work normally | Table salt, most packaged foods | 1.5 g |

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 are listed in **Table** 17.2. They include milk, green leafy vegetables, and whole grains.

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.

## Water

Did you know that water is also a nutrient? By weight, your cells are about two-thirds water, so you cannot live without it. In fact, you can survive for only a few days without water.

You lose water in each breath you exhale. You also lose water in sweat and urine. If you do not take in enough water to replace the water that you lose, you may develop dehydration. Symptoms of dehydration include dry mouth, headaches, and feeling dizzy. Dehydration can be very serious. Severe dehydration can even cause death.

When you exercise, especially on a hot day, you lose more water in sweat than you usually do. You need to drink extra water before, during, and after exercise. The child in **Figure** 17.5 is drinking water while playing outside on a warm day. He needs to drink water to avoid dehydration.

FIGURE 17.5
When you are active outside on a warm day, it's important to drink plenty of water. You need to replace the water you lose in sweat.

Getting too much water can also be dangerous. Excessive water may cause a condition called hyponatremia. In this condition, water collects in the brain and causes it to swell. Hyponatremia can cause death. It requires emergency medical care.

## Lesson Summary

- The body needs food for energy, building materials, and substances that help control body processes.
- Carbohydrates, proteins, and lipids provide energy and have other important roles in the body.
- Vitamins and minerals do not provide energy but are needed in small amounts for the body to function properly.
- The body must have water to survive.

## Review Questions

### Recall

1. What are three reasons that your body needs food?

2. Which nutrients can be used for energy?

3. What are some foods that are good sources of vitamin C?

4. What are two minerals that are needed for strong bones and teeth?

### Apply Concepts

5. Name two types of fiber and state the role of each type of fiber in the body.

6. Your body needs 20 different amino acids. Why do you need to get only ten of these amino acids from food? Name foods you can eat to get these ten amino acids.

7. Compare and contrast saturated and unsaturated lipids.

8. Identify three vitamins that are produced in the body. How are they produced?

9. Why do you need to drink extra water when you exercise on a hot day? What might happen if you did not drink extra water?

### Critical Thinking

10. List some of the functions of proteins in the body. Based on your list, predict health problems people might have if they do not get enough proteins in foods.

## Further Reading / Supplemental Links

- Alexandra Powe Allred. *Nutrition.* Perfection Learning, 2005.
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- DK Publishing. *Food.* DK Children, 2005.
- Donna Shryer. *Body Fuel: A Guide to Good Nutrition.* Marshall Cavendish Children's Books, 2007.
- http://www.nlm.nih.gov/medlineplus/ency/article/002404.htm
- http://www.textbookofbacteriology.net/normalflora.html
- http://www.alexandrapoweallred.com/

## Points to Consider

Think about how you can be sure you are getting enough nutrients.

- Do you think knowing the nutrients in the foods you eat are important?
- Do you have to keep track of all the nutrients you eat, or is there an easier way to choose foods that provide the nutrients you need?

# 17.2 Choosing Healthy Foods

## Lesson Objectives

- State how to use MyPyramid to get the proper balance of nutrients.
- Describe how to read food labels to choose foods wisely.
- Explain how to balance food with exercise.

## Check Your Understanding

- What is a nutrient?
- Why do you need extra energy when you exercise?

## Vocabulary

- ingredient
- main ingredient
- MyPlate
- MyPyramid
- nutrition facts label
- obesity
- serving size

## Introduction

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? Two tools can help you choose foods wisely: MyPyramid and food labels.

## MyPyramid

**MyPyramid** 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 sex, and your level of activity. MyPyramid is shown in **Figure** 17.6. 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.

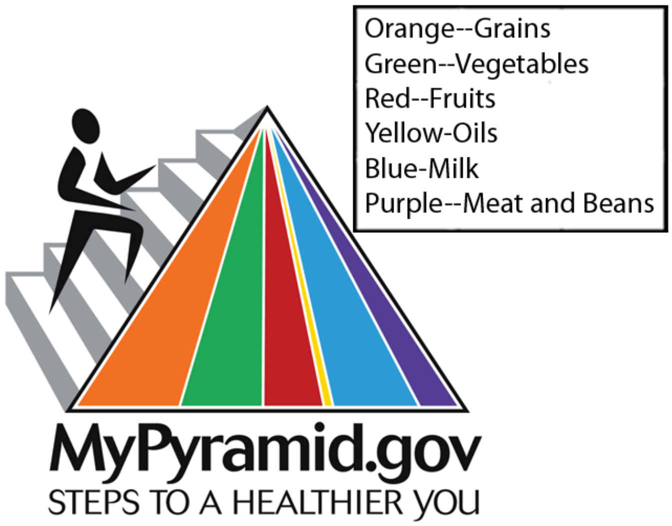


FIGURE 17.6
MyPyramid can help you choose foods wisely for good health. Each colored band represents a different food group. The key shows which food group each color represents. Which colored band of MyPyramid is widest? Which food group does it represent?

### Using MyPyramid

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?

### Healthy Eating Guidelines

Did you ever hear the saying, “variety is the spice of life”? Variety is also the basis of a healthy eating plan. When you choose foods based on MyPyramid, you should choose a variety of different foods. Follow these guidelines to make the wisest food choices for good health. Keep in mind that nutritional rules may change as you get older. As food provides energy and nutrients for growth and development, nutritional requirements may vary with body weight, age, sex, activity, and body functioning.

- 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, go for 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.

### What about Ice Cream, Cookies, and Potato Chips?

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.

## 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. See http://www.choosemyplate.gov/ for further information.

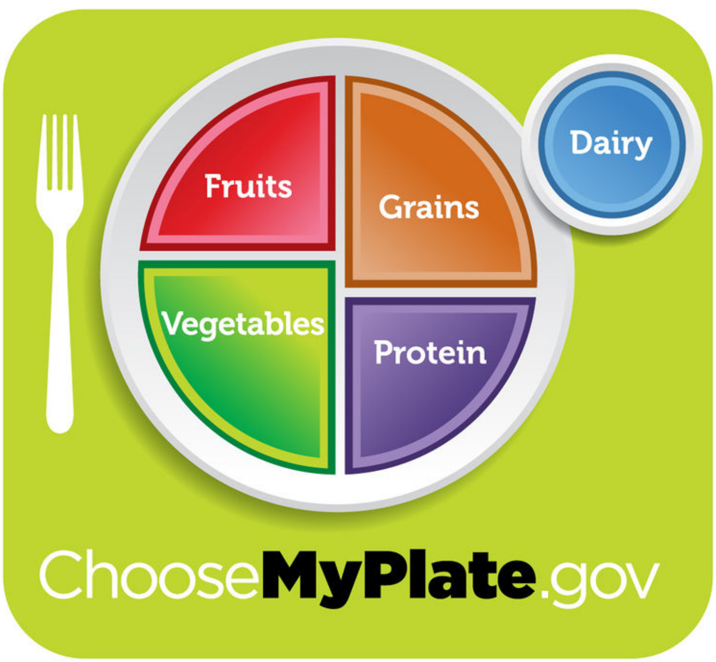


FIGURE 17.7
MyPlate is a visual guideline for balanced eating, replacing MyPyramid in 2011.

The following guidelines accompany MyPlate:

1. Balancing Calories

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

2. Foods to Increase

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

3. Foods to Reduce

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

## Food Labels

In the United States, packaged foods are required by law to have nutrition facts labels. A **nutrition facts label** shows the nutrients in a food. Packaged foods are also required to list their ingredients. An **ingredient** is a specific item that a food contains.

### Using Nutrition Facts Labels

An example of a nutrition facts label is shown in **Figure** 17.8. 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 in **Figure** 17.8 is a serving. The calories in one serving are listed next. In this food, there are 250 calories per serving.

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 in **Figure** 17.8. 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.

### Using Ingredients Lists

The food label in **Figure** 17.9 includes the list of ingredients in a different food. The ingredients on food labels are always listed from the highest amount to the lowest amount. This means that the main ingredient is listed first. The **main ingredient** is the ingredient that is present in the food in the greatest amount. As you go down the list, the ingredients are present in smaller and smaller amounts.

Reading the ingredients lists on food labels can help you choose the healthiest foods. At the top of the list, look for ingredients such as whole grains, vegetables, milk, and fruits. These are the ingredients you need in the greatest amounts for balanced eating. Avoid foods that list fats, oils, sugar, or salt at the top of the list. For good health, you should avoid getting too much of these ingredients. Be aware that ingredients such as corn syrup are sugars.

You should also use moderation when eating foods that contain ingredients such as white flour or white rice. These ingredients have been processed, and processing removes nutrients. The word "enriched" is a clue that an ingredient

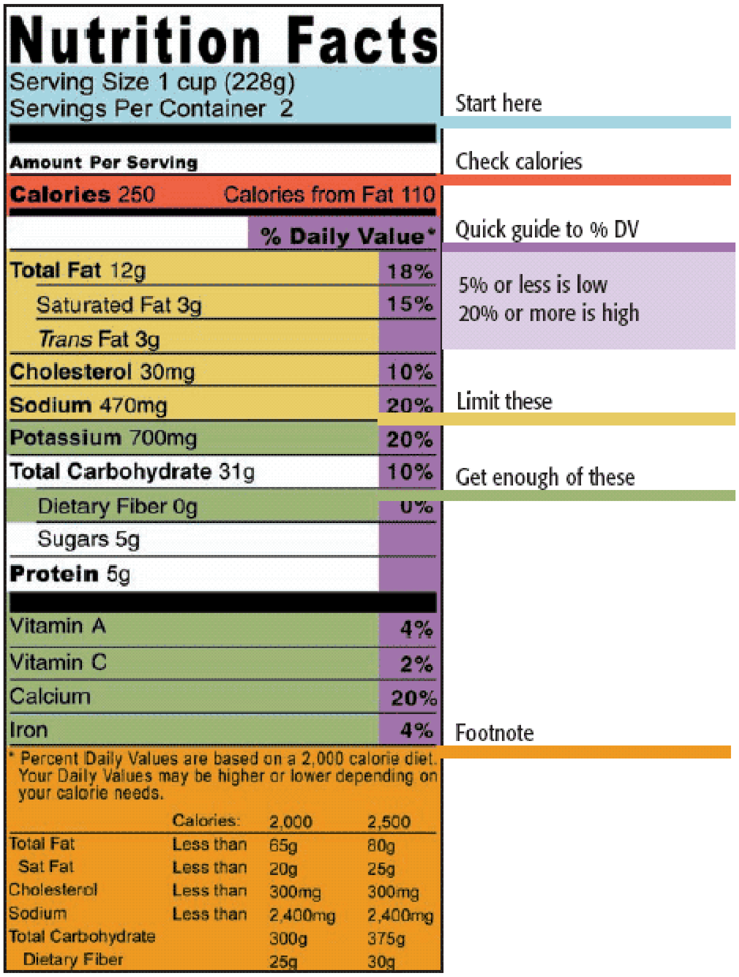


FIGURE 17.8

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?

has been processed. Ingredients are enriched with added nutrients to replace those lost during processing. However, enriched ingredients are still likely to have fewer nutrients than unprocessed ingredients.

## Balancing Food with Exercise

Look at MyPyramid in **Figure** 17.6. 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. **Figure** 17.10 shows some activities that can help you use extra energy.

### How Does Fat Form?

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

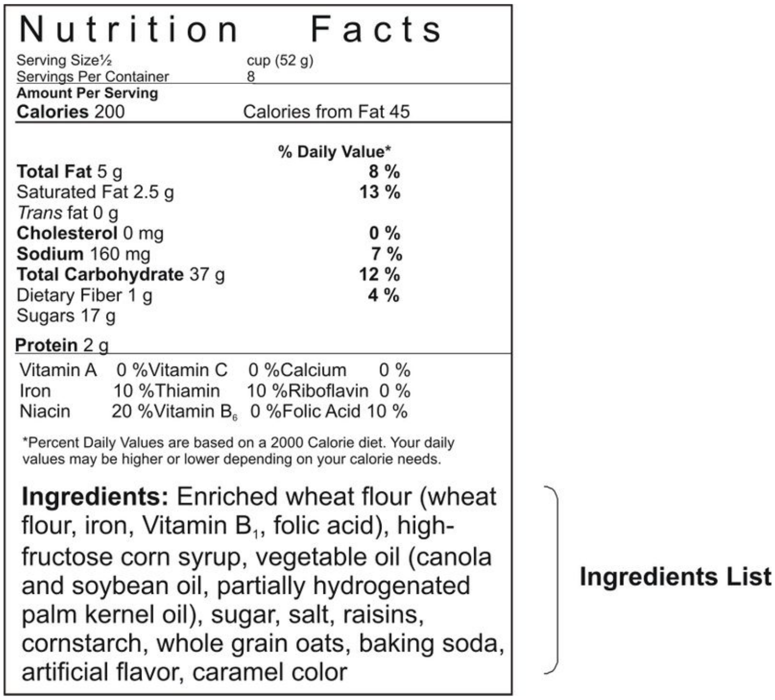


FIGURE 17.9
This food label includes the list of ingredients in the food. The main ingredient is enriched wheat flour, followed by high-fructose corn syrup. Why should you avoid foods with ingredients such as these at the top of the ingredients list?

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 that remain obese during their entire adulthood usually do not live as long as people that 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.

## Lesson Summary

- MyPyramid shows how much you should eat each day of foods from six different food groups.
- Reading food labels can help you choose the healthiest foods.
- Regular exercise helps you use extra energy and avoid unhealthy weight gain.

## Review Questions

### Recall

1. List the six food groups represented by MyPyramid.

2. Which food group contains soybeans, kidney beans, and fish?

3. What guideline should you follow in choosing foods from the grains food group?


FIGURE 17.10

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?

4. Which ingredient is always listed first on a food label?
5. What happens if you take in more energy than you use, day after day?

### Apply Concepts

6. Explain how you can use MyPyramid to choose foods that provide the proper balance of nutrients.
7. Why should you limit foods like ice cream and potato chips in a healthy eating plan?
8. Explain how you can use food labels to choose foods that are high in fiber.
9. Why should you try to avoid foods with processed ingredients? What are some examples of processed ingredients?

### Critical Thinking

10. You are trying to convince your friends that it is worth it to eat healthy and do physical activity. What will you tell them? Give examples from the chapter.

## Further Reading / Supplemental Links

- Eric Schlosser and Charles Wilson. *Chew on This: Everything You Don't Want to Know about Fast Food.* Houghton Mifflin, 2006.
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CK–12. High School *Biology*. Chapter 38, Lesson 1.

- http://www.cfsan.fda.gov/~acrobat/nutfacts.pdf
- http://www.cfsan.fda.gov/~dms/foodlab.html
- http://www.health.gov/dietaryguidelines/dga2005/document/pdf/DGA2005.pdf
- http://www.mypyramid.gov
- http://www.newswise.com/articles/view/537296
- http://www.nlm.nih.gov/medlineplus/ency/article/002459.htm
- http://www.nlm.nih.gov/medlineplus/exerciseforchildren.html
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- http://www.sciencemag.org/cgi/content/summary/307/5716/1716

## Points to Consider

Next we discuss the digestive system.

- Discuss how you think foods may be broken down into nutrients that your body can use? For example, how do you think an apple becomes simple sugars that your body can use for energy? Or how might a piece of cheese become proteins that your body can use for building materials?

# 17.3 The Digestive System

## Lesson Objectives

- List the functions of the digestive system.
- Explain the role of enzymes in digestion.
- Describe the digestive organs and their functions.
- Explain the roles of helpful bacteria in the digestive system.
- List ways to help keep your digestive system healthy.

## Check Your Understanding

- What is a chemical reaction?
- What is an enzyme?
- What are bacteria?

## Vocabulary

- absorption
- chemical digestion
- digestion
- digestive system
- duodenum
- esophagus
- food allergies
- ileum
- jejunum
- large intestine
- mechanical digestion
- small intestine
- stomach
- villi

## What Does the Digestive System Do?

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 main organs of the digestive system are shown in **Figure** 17.11.

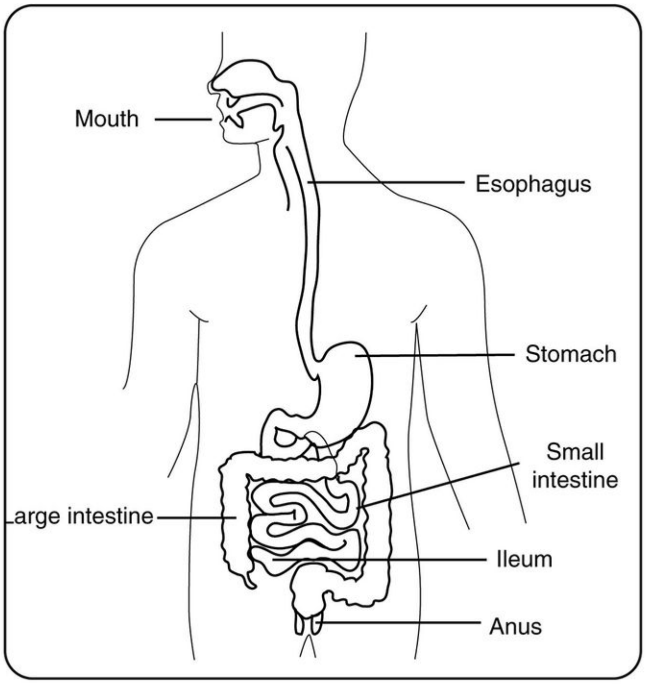


FIGURE 17.11
This drawing shows the major organs of the digestive system. Trace the path of food through the organs of the digestive system as you read about them in this lesson.

**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. This is a physical process. In **chemical digestion**, large food molecules are broken down into small nutrient molecules. This is a chemical process.

**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.

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.

## The Role of Enzymes in Digestion

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. Examples of digestive enzymes are:

- Amylase, produced in the mouth. It helps break down large starches 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. Bile acids also help to remove cholesterol from the body.

### Hormones and Digestion

If you are a typical teenager, you like to eat. For your body to break down, absorb and spread the nutrients 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 like chemical messengers.

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.

## Digestive Organs and Their Roles

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. From **Figure** 17.11 you can see that the digestive organs form a long tube. 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.

The organs of the digestive system are lined with muscles. The muscles contract, or tighten, to push food through the system. This is shown in **Figure** 17.12. 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.

The liver, gall bladder, and pancreas are also organs of the digestive system. They are shown in **Figure** 17.13. 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.

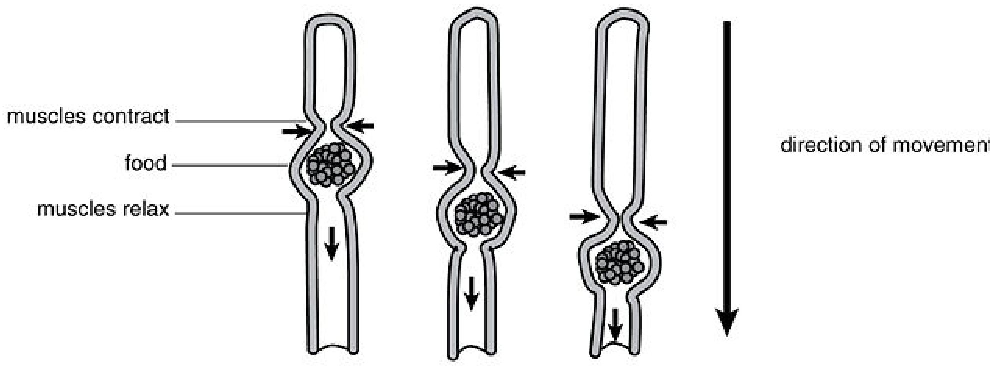


FIGURE 17.12
This diagram shows how muscles push food through the digestive system. Muscle contractions travel through the system in waves, pushing the food ahead of them. This is called peristalsis.

### 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 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 upside down! You could choke if you try to swallow when you are not upright.

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

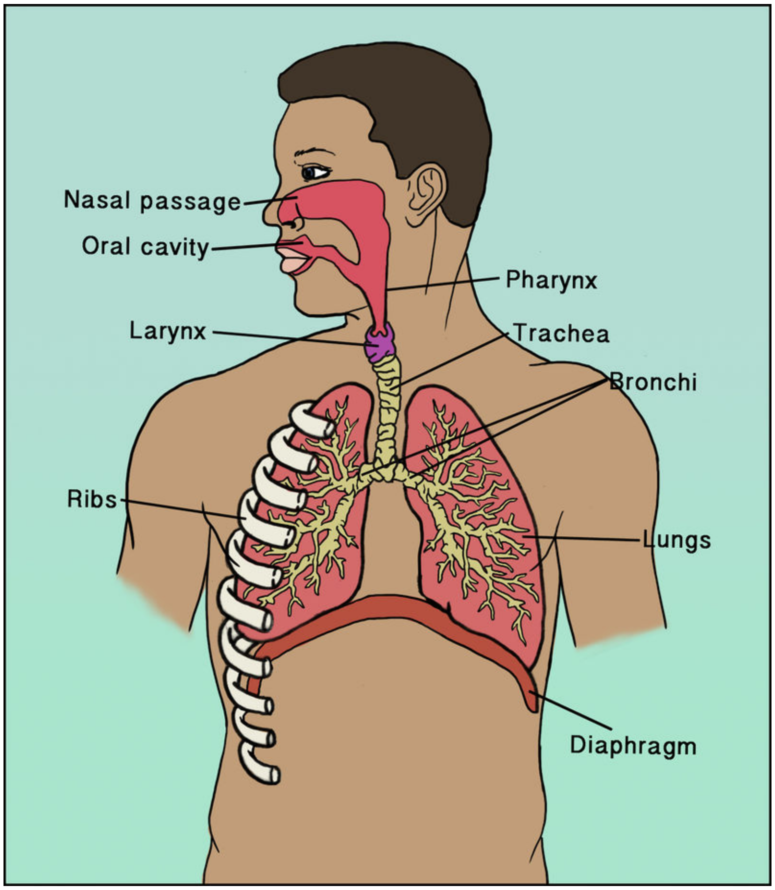


FIGURE 17.13
This drawing shows the liver, gall bladder, and pancreas. These organs are part of the digestive system. Food does not pass through them, but they secrete substances needed for chemical digestion.

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** is narrow tube that starts at the stomach and ends at the large intestine (see **Figure** 17.11). In adults, the small intestine is about 23 feet long. It is made up of three parts, the duodenum, the jejunum and the ileum.

1. The **duodenum** is the first part of the small intestine. This is where most chemical digestion takes place. Many enzymes and other chemicals are secreted here.
2. The **jejunum** is the second part of the small intestine. This is where most nutrients are absorbed into the blood. The jejunum is lined with tiny "fingers" called **villi**. A magnified picture of villi is shown in **Figure** 17.14. 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!
3. The **ileum** is the third part of the small intestine. Like the jejunum, the ileum is covered with villi. A few remaining nutrients are absorbed in the ileum. From the ileum, any remaining food waste passes into the large intestine.

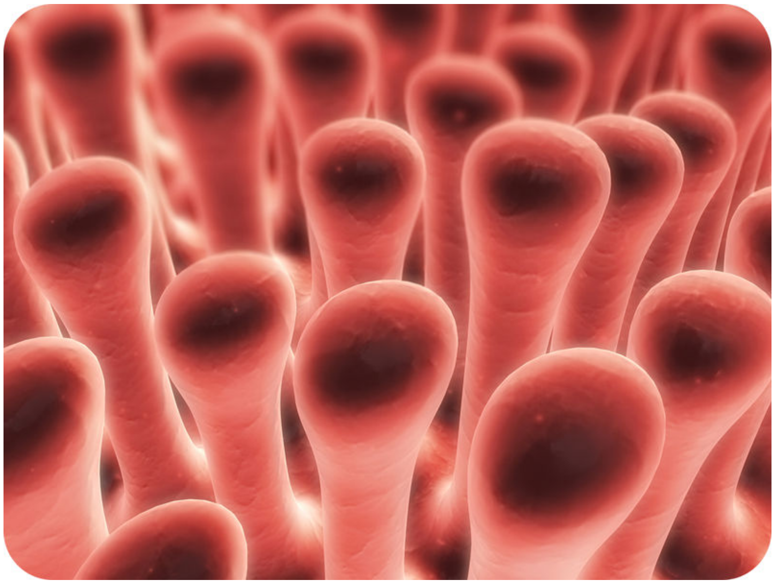

FIGURE 17.14
This is what the villi lining the small intestine look like when magnified. Each one is actually only about 1 millimeter long. Villi are just barely visible with the unaided eye.

The small intestine is much longer than the large intestine. So why is it called "small"? If you compare the small and large intestines in **Figure** 17.11, you will see why. 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 5 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.

### Liver

The liver has a wide range of functions, a few of which are:

- Removing toxins from the blood.
- Keeping glucose levels stable.
- Creating proteins.
- Producing biochemicals for digestion.

The liver is necessary for survival. You cannot live without a liver. The liver is one of the most important organs in the body when it comes to getting rid of toxins, especially from the gut. The liver filters blood from the intestine. This filtering process can remove microorganisms such as bacteria, fungi, viruses and parasites from the blood. Almost 2 quarts of blood pass through the liver every minute. Since the liver also ensures that glucose levels remain stable, people with liver problems are at risk for diabetes.

## 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. But don't worry. Most of these bacteria are helpful. They have several roles in the body. For example, intestinal bacteria:

- Produce vitamins $B_{12}$ and 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.

## Keeping Your Digestive System Healthy

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 awhile. 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.

### Foodborne Illness

Harmful bacteria can enter your digestive system in food and make you sick. This is called foodborne illness. The bacteria, or the toxins they produce, may cause vomiting or cramping, in addition to the symptoms mentioned above. 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.
- 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.

### Food Allergies

**Food allergies** are like other allergies. They occur when the immune system reacts to harmless substances as though they were harmful. Almost 10 percent of children have food allergies. Some of the foods most likely to cause allergies are shown in **Figure** 17.15.

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.

If you think you may have food allergies, a doctor can test you to find out for sure. The tests will identify which foods you are allergic to. Then you can avoid eating these foods. This is the best way to prevent the symptoms of food allergies. To avoid the foods you are allergic to, you may have to read food labels carefully. This is especially likely if you are allergic to common food ingredients, such as soybeans, wheat, or peanuts.

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


FIGURE 17.15
Some of the foods that commonly cause allergies are shown here. They include nuts, eggs, fish, milk, and shellfish. Are you allergic to any of these foods?

intolerance. A person who is lactose intolerant does not make enough lactase, the enzyme that breaks down the milk sugar lactose. About 75 percent of the world's population is lactose intolerant.

## Lesson Summary

- The digestive system breaks down food, absorbs nutrients, and gets rid of food wastes.
- Digestive enzymes speed up the reactions of chemical digestion.
- The main organs of the digestive system are the mouth, esophagus, stomach, small intestine, and large intestine.
- Bacteria in the large intestine produce vitamins and have other roles in the body.

## Review Questions

### Recall

1. What are three functions of the digestive system?
2. Identify two roles of helpful bacteria in the large intestine.
3. List two rules that can help prevent foodborne illness.

### Apply Concepts

4. Describe the roles of the mouth in digestion.
5. In which organs of the digestive system does absorption of nutrients take place?
6. Explain the role of enzymes in digestion. Give examples to illustrate your answer.
7. Describe peristalsis, and explain why it is necessary for digestion.
8. How can the inner surface area of the small intestine be as big as a basketball court? How does this help the small intestine absorb nutrients?

### Critical Thinking

9. Assume a person has an illness that prevents the large intestine from doing its normal job. Why might the person have diarrhea?
10. Explain why eating high-fiber foods can help prevent constipation.

## Further Reading / Supplemental Links

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## Points to Consider

- After nutrients are absorbed into the blood, think about how the blood could carry them to all the cells of the body. How does the blood travel? What keeps the blood moving?

# 17.4 References


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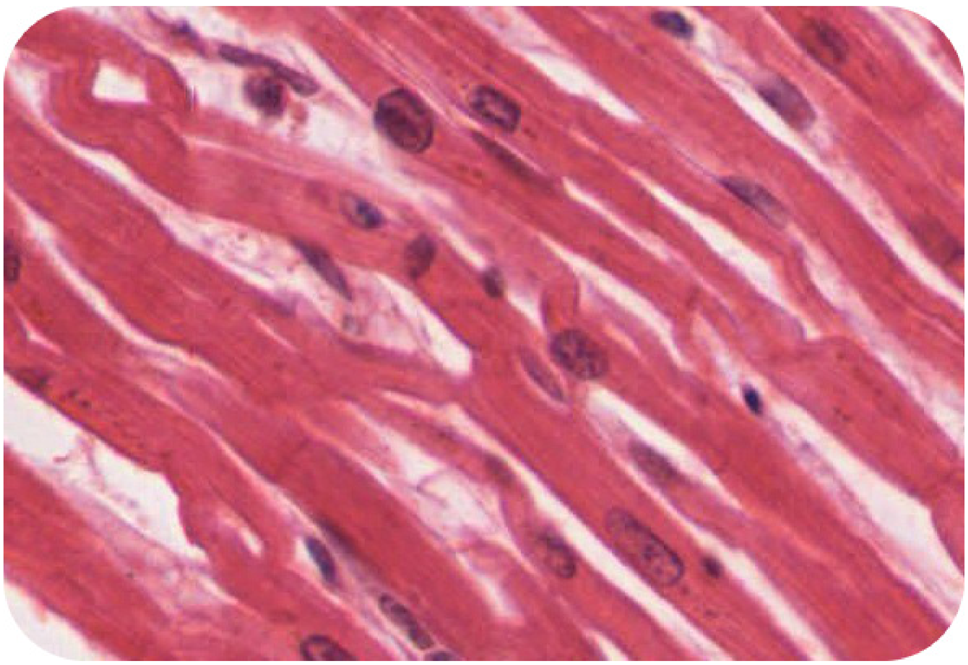
# CHAPTER 18 MS Cardiovascular System

## Chapter Outline





What does the above image show? It could be any of a number of things. A bowl of melted strawberry ice cream. Some chewed bubble gum. But the above image is actually a close-up of cardiac muscle, the muscle that makes up your heart. If you recall, cardiac muscle is one of three muscle types in the human body. Is cardiac muscle found anywhere else in the body? No. Cardiac muscle is only found in the heart!

Why is cardiac muscle only found in the heart? Why does the heart need its own special muscle? What does blood do, anyway? If a heart pumps blood, how does the heart get the blood it needs to keep pumping? What happens if the heart does not get enough blood?

You may have heard of a heart attack - but what is actually happening in the heart when that happens?

Consider these questions about the heart and cardiac muscle as you read about one of the most important and intriguing systems in the body, the cardiovascular system.

# 18.1 Introduction to the Cardiovascular System

## Lesson Objectives

- Identify the main structures of the cardiovascular system.
- Identify three types of blood vessels.
- Describe the differences between the pulmonary and the systemic circulations.
- Identify the main structures of the lymphatic system.
- Outline how the cardiovascular and the lymphatic systems work together.

## Check Your Understanding

- What is an organ system?
- What are the three types of muscles found in the human body?

## Vocabulary

- arteries
- blood
- capillaries
- lymphatic system
- plasma
- pulmonary circulation
- systemic circulation
- veins

## Functions of the Cardiovascular System

Your cardiovascular system has many jobs. It acts as a message delivery service, a pump, a heating system, and a protector of the body against diseases. Every cell in your body depends on your cardiovascular system. In this chapter, you will learn how your cardiovascular system works and how it helps to maintain homeostasis.

The cardiovascular system shown in **Figure** 18.1 is the organ system that is made up of the heart, the blood vessels, and the blood. It moves nutrients, hormones, gases (such as oxygen) and wastes (such as carbon dioxide) to and from your cells. It also helps to keep you warm by moving warm blood around your body. To do these tasks, your cardiovascular system works with other organ systems, such as the respiratory, endocrine, and nervous systems.

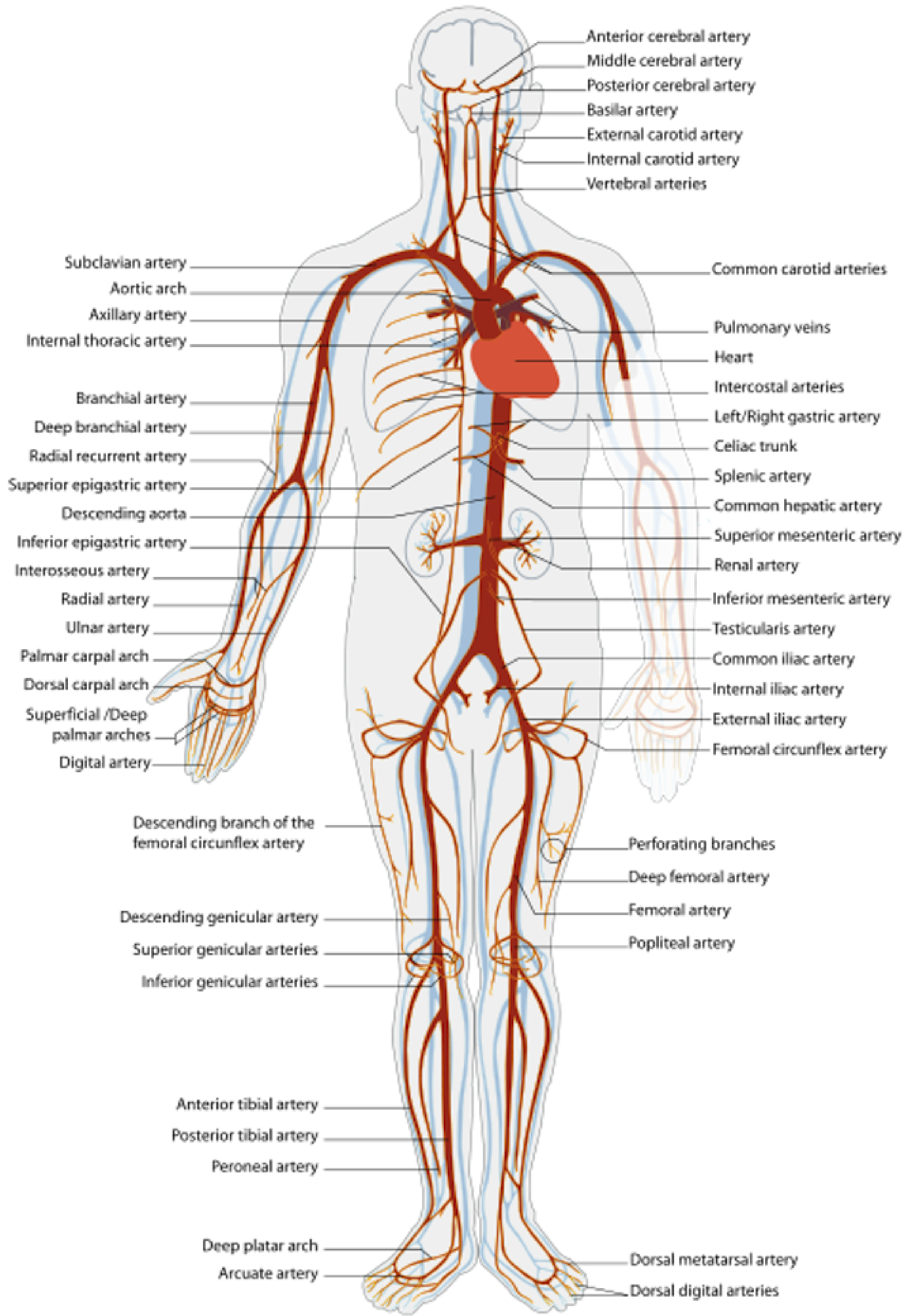



FIGURE 18.1

The cardiovascular system moves nutrients and other substances throughout the body.

### The Movement of Gases

The movement of gases, especially oxygen and carbon dioxide, is one of the most important jobs of the cardiovascular system. But the cardiovascular system cannot do this alone. It must work with other organ systems, especially the respiratory system, to move these gases throughout your body.

Oxygen is needed by every cell in your body. You breathe in oxygen and breathe out carbon dioxide through your respiratory system. Once oxygen enters your lungs, it must enter your blood stream in order to move around your body. Oxygen is moved in your blood by attaching to a protein called **hemoglobin**. The oxygen moves from the blood into the tissues, while carbon dioxide travels in the opposite direction. Carbon dioxide is transported back to the lungs, where it moves out of the blood and into your lungs for release from your body.

## Parts of the Cardiovascular System

Your heart pushes the blood around your body through the blood vessels. The heart, shown in **Figure** 18.2, is made of cardiac muscle. The heart is connected to many blood vessels that bring blood all around the body. The cardiac muscle contracts and pumps blood through the blood vessels.

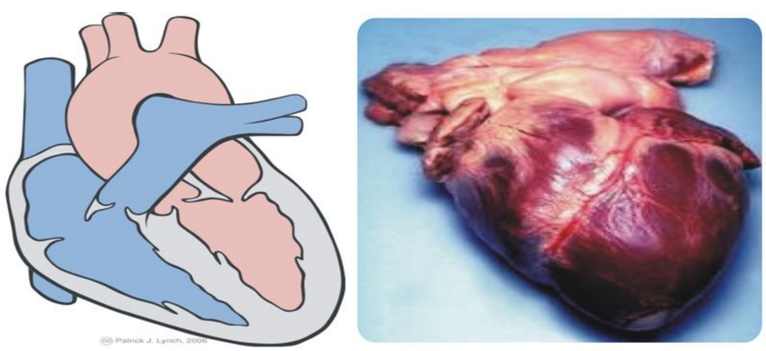


FIGURE 18.2
Blood is collected in the heart and pumped out to the lungs, where it releases carbon dioxide and picks up oxygen before it is pumped to the rest of the body.

### Blood Vessels

The job of the blood vessels is to move the blood around the body. There are three main types of blood vessels in the body.

1. **Arteries** are blood vessels that carry blood *away* from the heart. Arteries have thick walls that have a layer of smooth muscle, as shown in **Figure** 18.3. Arteries usually carry oxygen-rich blood around the body. The blood that is in arteries is under pressure. The contractions of the heart muscle causes blood to push against the walls of the arteries. This "push" is referred to as **blood pressure**. Blood pressure is highest in the arteries and decreases as the blood moves into smaller blood vessels. Thick walls help prevent arteries from bursting under the pressure of blood.

2. **Veins** are blood vessels that carry blood back *to* the heart. Veins have thinner walls than arteries do, as you can see in **Figure** 18.4. The blood in veins is not under pressure. Veins have valves that stop blood from moving backward. Blood is moved forward in veins when the skeletal muscles squeeze the veins. Blood that is carried by veins is usually low in oxygen. The only veins that carry oxygen-rich blood are called the pulmonary veins, which carry blood to the heart from the lungs.

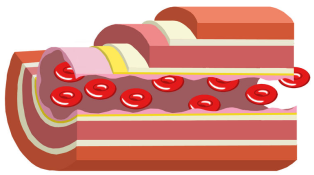


FIGURE 18.3
Arteries are thick-walled vessels with many layers, including a layer of smooth muscle.

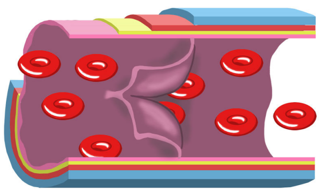


FIGURE 18.4
The walls of veins are not as thick as artery walls; veins have valves that stop blood from flowing backward.

3. **Capillaries** these are the tiniest blood vessels in the body. Every cell in the body needs oxygen, but arteries are too large to bring oxygen and nutrients to single cells. Further from the heart, arteries form capillaries. The walls of capillaries are only as thick as a single layer of cells. Capillaries connect arteries and veins together, as shown in **Figure** 18.5. Capillaries also send water, oxygen and other substances to body cells, while they collect carbon dioxide and other wastes from cells and tissues. Capillaries are so narrow that blood cells must move in single file through them. A capillary bed is the network of capillaries that supply an organ with blood. The more active a tissue or organ is, the more capillaries it needs to get nutrients and oxygen.

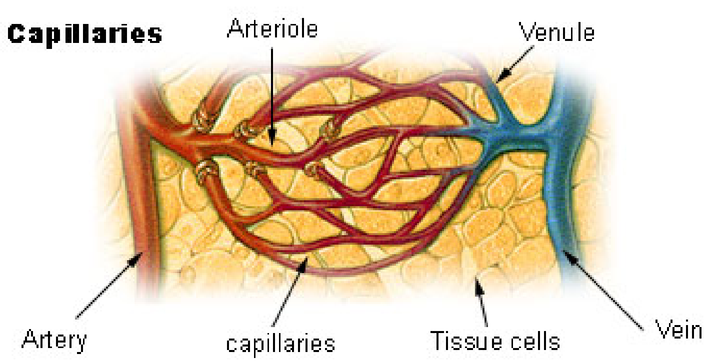



FIGURE 18.5
Capillaries connect arteries and veins.

## Blood

**Blood** is a body fluid that is a type of connective tissue. Blood is made of blood cells, and a liquid called **plasma**. The main types of cells found in blood are red blood cells and white blood cells.

- **Red blood cells** carry oxygen. Oxygen-rich blood is bright red and oxygen-poor blood is dark red.
- **White blood cells** fight against infection and disease.

The cardiovascular system of humans is "closed." That means the blood never leaves the blood vessels inside of the body Other organisms have blood vessels that interact with the environment.

## Two Blood Circulation Systems

The blood is pumped around in two large "loops" within the body. One loop moves blood around the body - to the head, limbs, and internal organs. The other loop moves blood to and from the lungs where carbon dioxide is released and oxygen is picked up by the blood. A simple version of these two "loops" is shown in **Figure** 18.6.

**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. **Pulmonary circulation** is the part of the cardiovascular system that carries oxygen-poor blood away from the heart to the lungs, and returns oxygen-rich blood back to the heart.

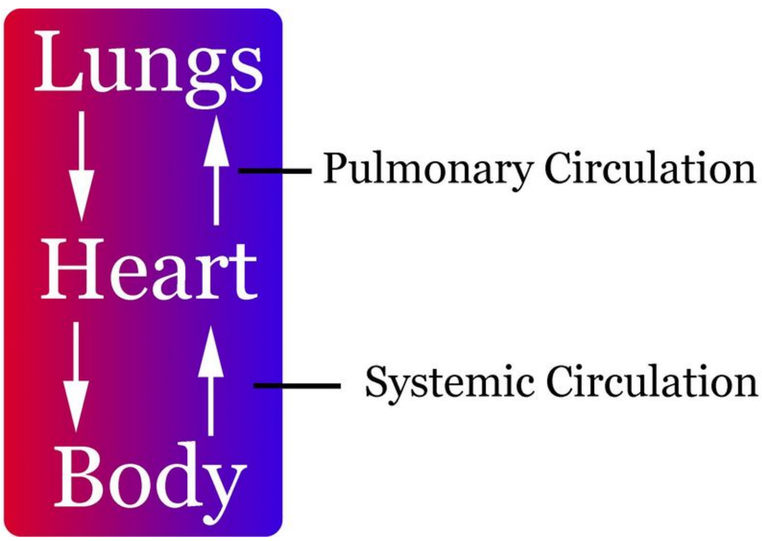



FIGURE 18.6
The double circulatory system. Trace the systemic circulation. Where is the path of pulmonary circulation?

## The Lymphatic System

The **lymphatic system** is a network of vessels and tissues that carry a clear fluid called lymph. The lymphatic system, shown in **Figure** 18.7 spreads all around the body. **Lymph vessels** are tube-shaped, just like blood vessels. 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."

### Role of the Lymphatic System in Circulation

You may think that your blood vessels have thick walls without any leaks, but it'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, which are shown in **Figure** 18.8. The fluid that collects in the lymph vessels is called **lymph**. The lymphatic

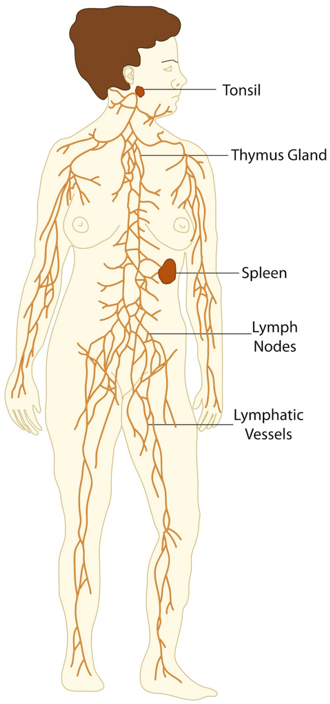



FIGURE 18.7
The lymphatic system helps return fluid that leaks from the blood vessels back to the cardiovascular system.

system then returns the lymph to the cardiovascular system. Unlike the cardiovascular system, the lymphatic system is not closed 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.

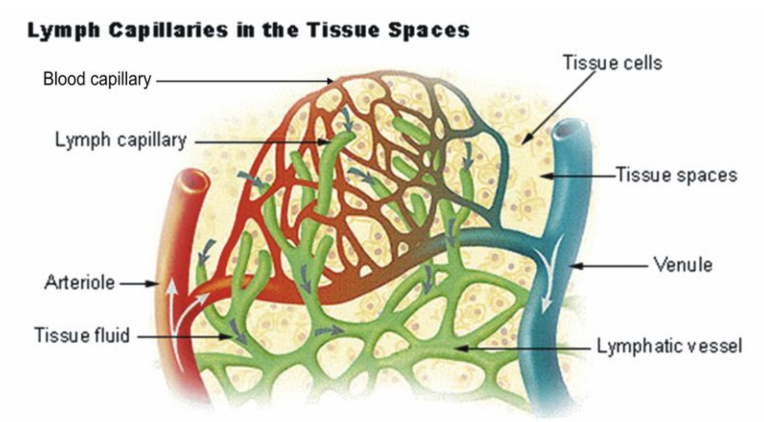



FIGURE 18.8
Lymph capillaries collect fluid that leaks out from blood capillaries.

## Role of the Lymphatic System in the Body's Defenses

The lymphatic system also plays an important role in the immune system. The lymphatic system makes white blood cells that protect the body from diseases.

## Organs of the Lymphatic System

Along with the lymph vessels, lymph ducts, and lymph nodes, the lymphatic system also includes many organs. The tonsils, thymus, and spleen, which are shown in **Figure** 18.7, also help prevent diseases. Many of these organs are also part of the immune system.

### Tonsils

If you open your mouth and look at your throat in a mirror, you may see some lumps in the back of your throat. These are your tonsils. **Tonsils** are areas of lymphatic tissue on either side of the throat **Figure** 18.9. There are also tonsils in the nasal cavity and behind the tongue. Like other organs of the lymphatic system, the tonsils are also part of the immune system. The immune system helps protect the body against infection. The tonsils are believed to help fight off nose and throat, and other upper respiratory tract infections such as colds. Tonsillitis is an infection of the tonsils that can cause a sore throat and fever.

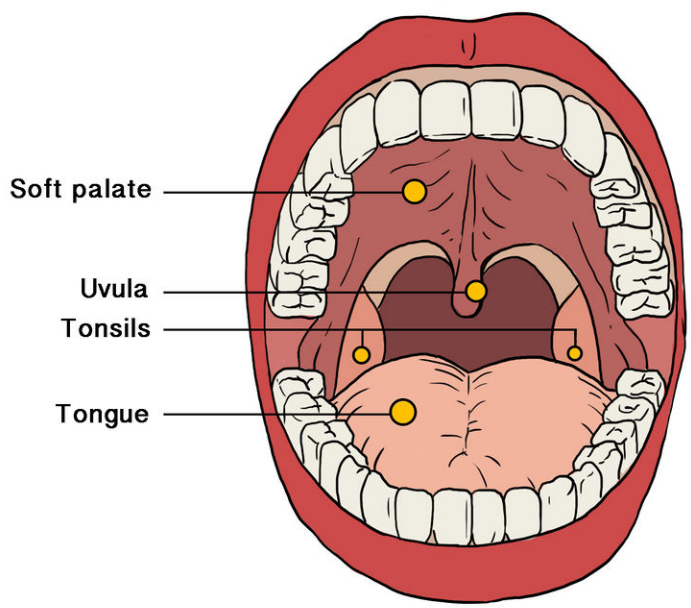



FIGURE 18.9
This illustration shows the tonsils in the back of the throat, but there are also tonsils in the nasal cavity and behind the tongue.

### Bone Marrow

**Bone marrow** is the tissue found in the middle of bones. The marrow in the large bones of adults makes new blood cells, like white blood cells, called T-cells. Other white blood cells, called B-cells, are also created in the bone marrow.

### Thymus

The **thymus** is found in the upper chest. Chemicals made by the thymus help produce cells that fight infection. White blood cells called **lymphocytes** move from the bone marrow to the thymus to finish growing. The thymus grows to its largest size near puberty, and gets smaller as a person ages. If a person's thymus is surgically removed or damaged by disease while they are young, the person will be more prone to infection.

### Spleen

The spleen is in the abdomen, as shown in **Figure** 18.10. In an area of the spleen called **red pulp**, materials are filtered from the blood, including old and dead red blood cells. The spleen also makes red blood cells. Areas called **white pulp** help fight infections by making white blood cells. If a person's spleen is surgically removed, or does not work properly, the person is at risk for certain infections. You can learn more about the roles of the lymphatic system and white blood cells in the *Diseases and the Body's Defenses* chapter.

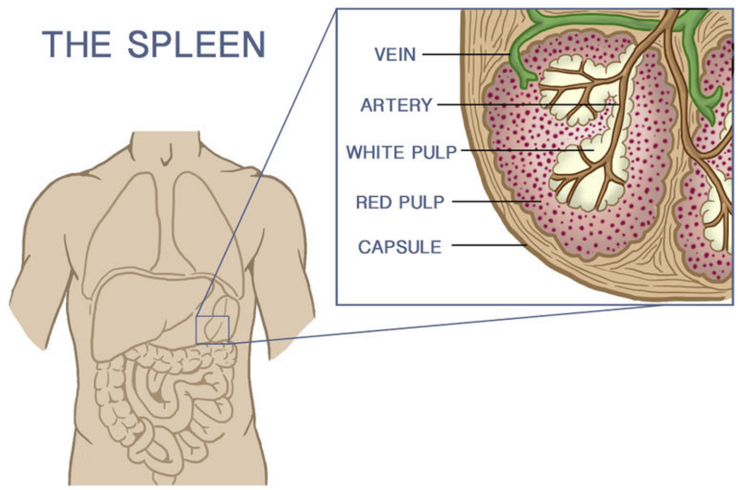



FIGURE 18.10
In the spleen, the white pulp makes white blood cells, while the red pulp acts like a filter and removes dead and dying cells from the blood.

## Lesson Summary

- **Table** 18.1 summarizes the structures and functions of the cardiovascular and lymphatic systems.

**TABLE 18.1: Structures and Functions of the Cardiovascular and Lymphatic Systems**

| System | Structure (organs and tissues) | Function |
|---|---|---|
| **Lymphatic** | Lymph vessels | Transport fluid (lymph) from between body cells back to blood |
| | Lymph nodes | Trap invading diseases and cells with cancer |
| | Spleen, tonsils, and adenoids | Trap invading diseases |
| | Thymus | where white blood cell (lymphocytes) grow larger |
| **Cardiovascular** | Blood vessels | Transport blood around the body |
| | Blood | Moves oxygen and nutrients; also carries white blood cells to sites of infection and inflammation |
| | Heart | Pumps blood around the body |

- The cardiovascular system includes the heart, the blood vessels, and the blood.

- There are three main types of blood vessels in the body: arteries, veins, and capillaries.
- 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.
- Pulmonary circulation is the part of the cardiovascular system that carries oxygen-poor blood away from the heart to the lungs, and returns oxygen-rich blood back to the heart.
- Organs of the lymphatic system include the tonsils, thymus, and spleen.
- The lymphatic system works with the cardiovascular system to return body fluids to the blood.

## Review Questions

### Recall

1. Identify the three main parts of the cardiovascular system.
2. Identify three types of blood vessels found in the body.
3. Which blood vessels move blood away from the heart?
4. What are the smallest blood vessels in the body called?
5. Which blood vessels bring blood back to the heart?
6. Identify three main organs of the lymphatic system.
7. Name one function of tonsils.

### Apply Concepts

8. Where does blood in the pulmonary system go after it leaves the heart?
9. Where does blood in systemic circulation go after it leaves the heart?
10. What does blood that leaves the heart in systemic circulation have that body cells need?
11. How do the cardiovascular and lymphatic systems work together?
12. What is lymph, and where does it come from?
13. What might happen if a person did not have a spleen?

### Critical Thinking

14. Explain how there are actually two circulatory systems in the body.

## Further Reading / Supplemental Links

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

## Points to Consider

Next we look further at the heart and blood vessels.

- How can the heart pump blood to the entire body?
- How do you think a hole in the heart muscle affect blood flow?

# 18.2 Heart and Blood Vessels

## Lesson Objectives

- Describe the structure of the heart.
- Outline how blood moves through the heart.
- Describe the importance of valves in the heart.
- Describe the coronary circulation.

## Check Your Understanding

- What is the role of the cardiovascular system?
- What is the main function of the heart?

## Vocabulary

- atrioventricular (AV) valves
- atrium
- semilunar (SL) valves
- valves
- ventricles

## The Heart

What is the heart? How does it pump blood? The heart is divided into four chambers, 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." The four chambers of the heart are shown in **Figure** 18.11.

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.
- 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.

### Where is the Heart?

The heart is closer to the center of the body than you may think. It is usually found in the left to middle of the chest, with the largest part of the heart slightly to the left. It always feels like the heart is on the left side of the body because the left ventricle is bigger and stronger than the right ventricle. The heart is also surrounded by the lungs.

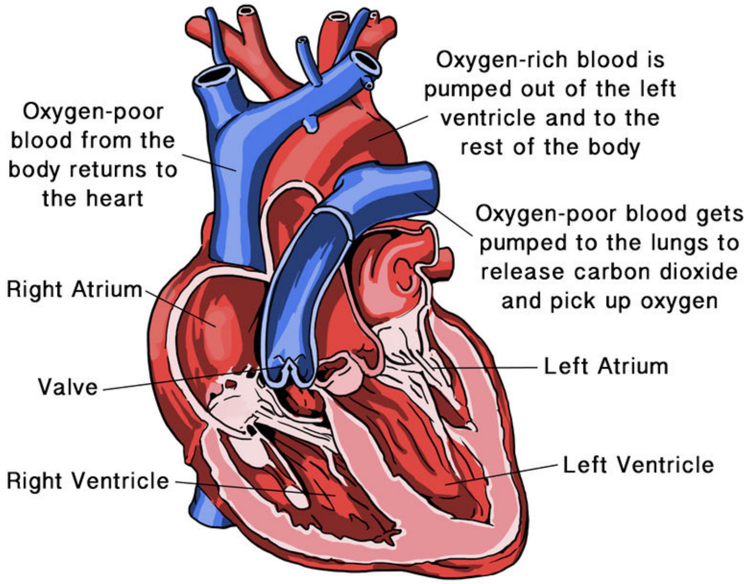



FIGURE 18.11
The atria receive blood and the ventricles pump blood out of the heart.

## 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 Heartbeat

To move blood through the heart, the cardiac muscle needs to contract in an organized way. Blood first enters the atria, as shown in **Figure** 18.12. 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. So how is the blood kept from flowing back on itself?

**Valves** in the heart keep the blood flowing in one direction. You can see some of the valves in **Figure** 18.12. 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 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.

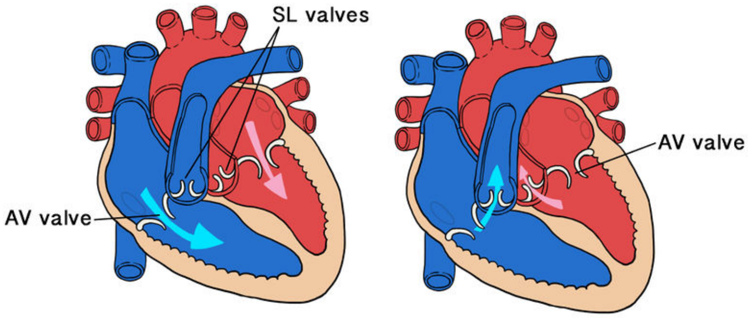



FIGURE 18.12
Blood flows in only one direction in the heart. Blood enters the atria, which contract and push blood into the ventricles. The atria relax and the ventricles fill with blood. Finally, the ventricles contract and push blood around the body.

### Control of the Heartbeat

The heart is a made up of cardiac muscle cells. Cardiac cells are able to contract by themselves. They do not need help from the nervous system. This is different from skeletal muscle, which needs messages from nerves to contract. The number of times a heart contracts over a certain amount of time is called the **heart rate**. Exercising or getting scared can make the heart rate increase. After the exercise is over, or the fear has passed, the heart rate returns to normal.

## Blood Circulation and Blood Vessels

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. The main arteries and veins of the heart are shown in **Figure** 18.13.

### 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.

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

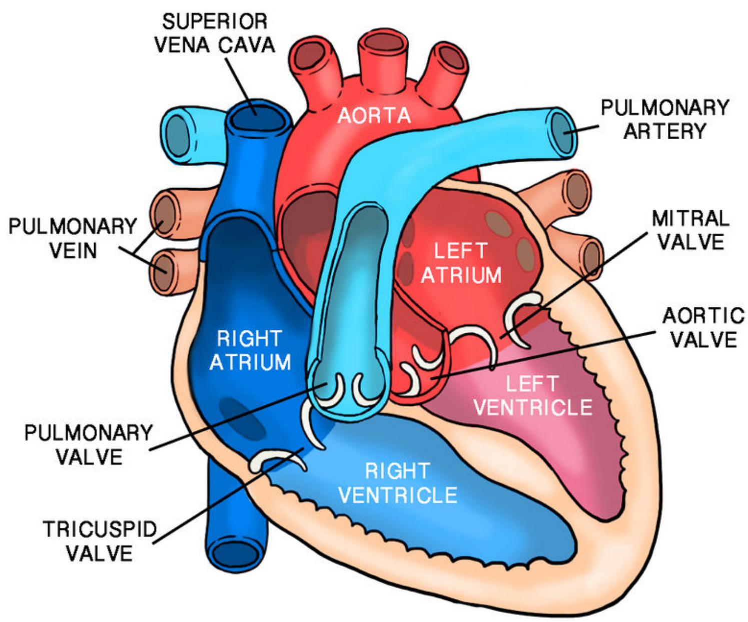



FIGURE 18.13

The right side of the heart pumps deoxygenated blood into pulmonary circulation, while the left side pumps oxygenated blood into systemic circulation.

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.

## Lesson Summary

- The heart is divided into four chambers, the left and right atria and the left and right ventricles.
- 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-poor blood back from the lungs into the left side of the heart, which then pumps the oxygen-poor blood to the rest of the body.
- The valves in the heart prevent blood from flowing backward into the heart.

## Further Reading / Supplemental Links

- http://thevirtualheart.org/anatomyindex.html

## Review Questions

### Recall

1. Name the four chambers of the heart.
2. Where does oxygen-poor blood first enter the heart?
3. Do ventricles pump blood out of the heart, or do they pump blood into the atria?
4. Do the inferior vena cava and superior vena cava carry oxygen-poor or oxygen-rich blood?
5. To what organ or organs does systemic circulation bring blood?
6. To what organ or organs does pulmonary circulation bring blood?

### Apply Concepts

7. Why can the heart be considered to be two separate pumps?
8. What is the purpose of the valves in the heart?

### Critical Thinking

9. How might a hole in the heart wall between the two ventricles affect the circulation of blood?

## Points to Consider

A more in-depth look at blood is next.

- How do different parts of the blood impact the cardiovascular system?
- How can diet affect how blood carries oxygen?

# 18.3 Blood

## Lesson Objectives

- List the main parts of blood.
- Identify three functions of blood.
- Name the oxygen-carrying protein found in red blood cells.
- Identify the main function of white blood cells.
- Describe the importance of the ABO blood system.
- Identify three blood disorders or diseases.

## Check Your Understanding

- What is the main function of the blood?
- What is the role of oxygen in aerobic (cellular) respiration?

## Vocabulary

- ABO blood type system
- antibody
- blood clotting
- fibrin
- hemoglobin
- hemophilia
- leukemia
- lymphoma
- platelets
- red blood cells
- sickle cell disease
- universal donor
- universal recipient
- white blood cells

## 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 shown in **Figure** 18.14. The different parts of blood have different roles.

Some of the roles of blood include:

- The defense of the body against diseases.
- The movement of chemical messages, such as hormones and hormone-like substances.
- The control of body temperature.
- The repair of damage to body tissues.

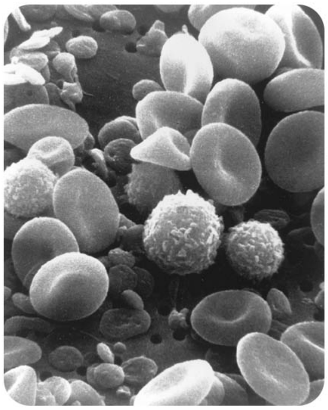


FIGURE 18.14
A scanning electron microscope (SEM) image of human blood cells. Red blood cells are the flat, bowl-shaped cells, the tiny disc-shaped pieces are platelets and white blood cells are the round cells shown in the center.

### Plasma

If you were to filter out all the cells in blood, plasma is what would be left over. Plasma is the golden-yellow liquid part of the blood. Plasma is about 90 percent water and about 10 percent 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 RBCs their red color.

Red blood cells are made in the red marrow of long bones, ribs, 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. Red blood cells are shown in **Figure** 18.15. Mature RBCs do not have a nucleus or other organelles.

FIGURE 18.15
The flattened shape of RBCs helps them to carry more oxygen than if they were rounded.

### White Blood Cells

**White blood cells** (WBCs) are usually larger than red blood cells. They have a nucleus but do not have hemoglobin. 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. WBCs defend the body against infection by bacteria, viruses, and other diseases. There are different WBCs with different jobs.

- Neutrophils can squeeze through capillary walls and swallow particles such as bacteria and parasites.
- Macrophages can also swallow and destroy old and dying cells, bacteria, or viruses. In **Figure** 18.16 a macrophage is attacking and swallowing two particles, possibly diseases. Macrophages also release chemical messages that cause the number of WBCs to increase.
- Lymphocytes fight infections caused by viruses and bacteria. Some lymphocytes attack and kill cancer cells. Lymphocytes called B-cells make antibodies. An **antibody** is a protein that finds harmful antigens and destroys them. To learn more about the role of WBCs in protecting the body from infection, see the *Diseases and the Body's Defenses* chapter.

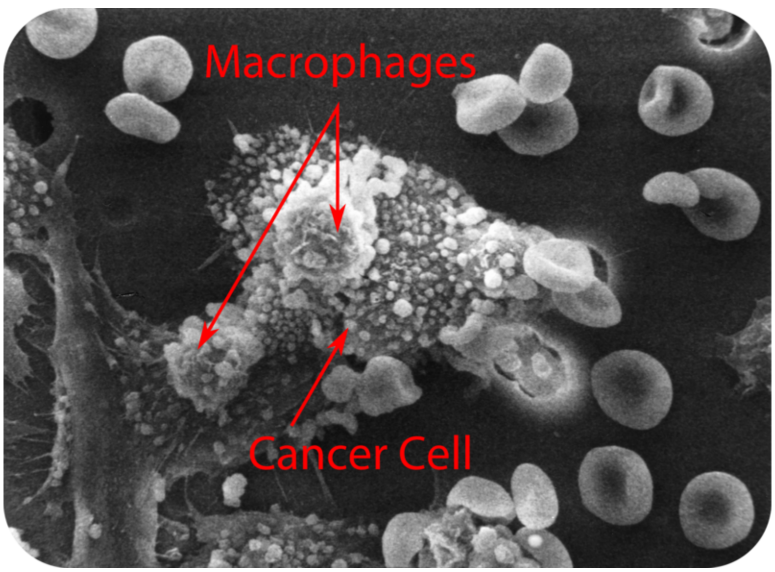



FIGURE 18.16
A type of WBC, called a macrophage, is attacking a cancer cell

### Platelets

**Platelets** 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. A platelet sits between a RBC and a WBC in **Figure** 18.17. 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 RBCs 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 10 days before they are removed by the liver and spleen.

## Transport of Chemical Messages

The blood also acts as a messenge delivery service, like a post office. Chemical messengers called hormones are carried and brought to cells by the blood.

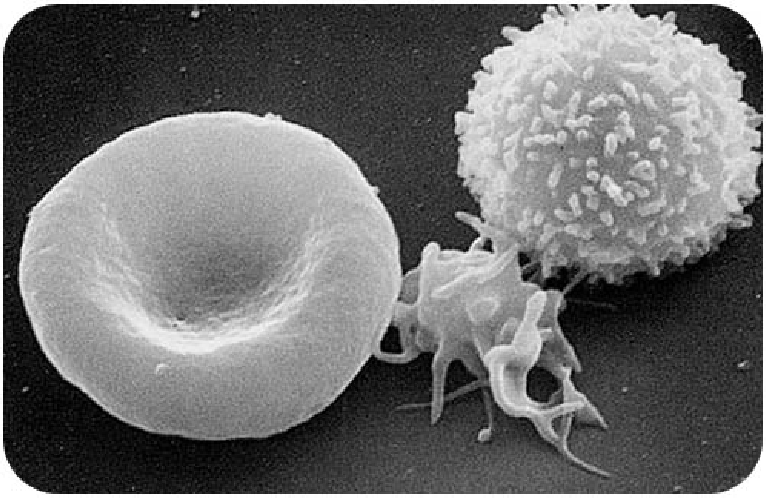


FIGURE 18.17
A platelet lies between a RBC, at left, and a WBC at right. Platelets are little pieces of larger cells that are found in the bone marrow.

## Control of Body Temperature

How do your blood vessels control your body temperature? Your blood also moves heat around your body. 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 surface. The heat is then released from the skin. What do you think your blood vessels do when your body temperature is decreasing?

## Blood Clotting

**Blood clotting** is a complex process by which blood forms solid clots. As discussed above, clotting is important to stop bleeding and begin the repair of damaged blood vessels. Blood clotting disorders can lead to an increased risk of bleeding or clotting inside a blood vessel. Platelets are important for the proper clotting of blood.

Clotting is started almost immediately when an injury damages the inside lining of a blood vessel. The steps involved in clotting are described below:

1. Platelets clump together, forming a clot at the injury site.
2. Proteins in the plasma cause a chemical reaction that brings a protein called **fibrin** to the site.
3. The fibrin forms a web across the platelet clot, trapping red blood cells.
4. This mass of platelets, fibrin, and red blood cells forms a clot that turns into a scab.

Certain nutrients are needed for the clotting system to work properly. Two of these are calcium and vitamin K. Bacteria that live in your intestines make enough vitamin K, so you do not need to eat extra vitamin K in your food.

## Blood Types

Do you know what your blood type is? Maybe you have heard someone say that they some 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 any 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. Blood also has different types of antibodies, or proteins released by the blood cells that attack other strange substances or diseases in the body. Different blood types have different antibodies (see **Table** 18.2). What type of antibodies do people with Type O blood produce? Anti-A and anti-B antibodies. This means that 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, as shown in **Figure** 18.18. 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.

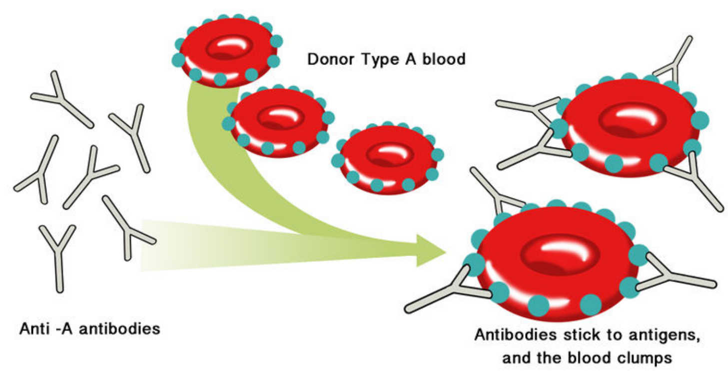



FIGURE 18.18

A person with type O blood has A and B antibodies in their plasma; if the person was to get type A blood instead of type O, Their A antibodies would attach to the antigens on the RBCs and cause them to clump together.

### The Rhesus System

The second most important blood group system in human blood is the Rhesus (Rh) system. 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 positive blood are called **universal recipients** because they can receive any blood type. The antigens and antibodies that define blood type are listed in **Table** 18.2.

TABLE 18.2: **Blood Types, Antigens, and Antibodies**

| Blood type | Antigen type | Plasma antibodies | Can receive blood from types | Can donate blood to types |
|---|---|---|---|---|

**TABLE 18.2:** (continued)

| 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 |

## 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.

### Sickle-Cell Disease

**Sickle-cell disease** is a blood disease that is caused by abnormally-shaped blood protein hemoglobin. Many of the RBCs of a person with sickle cell disease are long and curved (sickle-shaped), as shown in **Figure** 18.19. The long, sickle-shaped RBCs can have damaged cell membranes, which can cause them to burst. The long 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 disease are most often well, but can occasionally have painful attacks. The disease is not curable, but can be treated with medicines.

There is an advantage, however, to sickle-cell disease. People who are carriers for the sickle cell gene, or who are heterozygous, are resistant to severe malaria. See the *Genetics* chapter for further information.

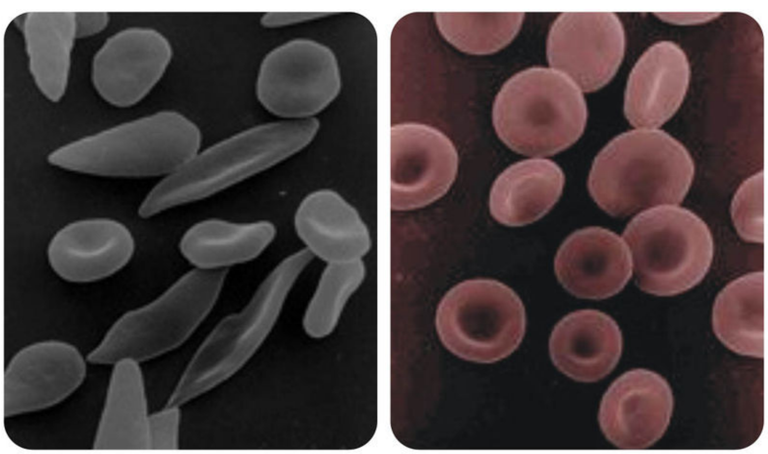


FIGURE 18.19
The RBCs of a person with sickle-cell disease (left) are long and pointed, rather than straight, like normal cells (right). The abnormal cells cannot carry oxygen properly and can get stuck in capillaries.

### Anemia

Anemia is a disease that occurs when there is not enough hemoglobin in the blood to carry oxygen to body cells. Hemoglobin 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 RBCs.
- A lack of RBC 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 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 contains iron, cannot be made.

In the United States, 20 percent of all women of childbearing age have iron deficiency anemia, compared with only 2 percent 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 in **Table** 18.3. Eating vitamin C along with iron-containing food increases the amount of iron that the body can absorb.

**TABLE 18.3: Sources of Iron**

| 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, $\frac{1}{2}$ cup | 3.3 |
| Cooked fresh spinach, $\frac{1}{2}$ cup | 3.2 |
| Cooked ground beef, 3 oz | 2.2 |
| Cooked sirloin beef, 3 oz | 2.0 |

### Leukemia

**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 type of cancer in white blood cells called *lymphocytes.* There are many types of lymphoma.

### Hemophilia

**Hemophilia** is the name of a group of sex-linked hereditary diseases that affect the body's ability to control blood clotting. Hemophilia is caused by a lack of clotting factors in the blood. 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.

## Lesson Summary

- Blood is a fluid connective tissue that contains red blood cells, white blood cells, platelets, and plasma.

- The red blood cells give blood its red color.
- Blood carries oxygen and nutrients to body cells and carries wastes away. It also helps to maintain body temperature and to carry chemical messengers called hormones around the body.
- Hemoglobin is the oxygen-carrying protein that is found in red blood cells.
- White blood cells defend the body against infection by bacteria, viruses and other pathogens.
- Blood type is determined by the presence or absence of certain molecules, called antigens, on the surface of red blood cells (RBCs).
- There are four blood types; A, B, AB, and O.
- If a person receives the wrong blood type, antibodies in the recipient's blood will attack the antigens on the RBCs in the donor blood.
- Sickle-cell disease is a blood disease that is caused by abnormally-shaped hemoglobin, and important blood protein.
- Anemia is a disorder caused by a lack of hemoglobin in the blood.

## Review Questions

### Recall

1. What types of cells are found in blood?
2. What is the liquid part of blood called?
3. What is the function of platelets?
4. Identify one other function of blood other than bringing oxygen to body cells.
5. What is the oxygen-carrying protein found in red blood cells?
6. Identify two ways that white blood cells defend the body from infection.
7. Identify three blood disorders or diseases.
8. Identify two good sources of iron in the diet.

### Apply Concepts

9. How are the red blood cells of the different blood groups different?
10. Why are people with type O blood called "universal donors?"
11. Why are people with type AB blood called "universal recipients?"
12. What is a common cause of anemia in young people?

### Critical Thinking

13. How can the shape of the hemoglobin protein in a person with sickle-cell disease affect other body systems?

## Further Reading / Supplemental Links

- http://www.nhlbi.nih.gov/health/dci/Diseases/Sca/SCA_WhatIs.html
- http://www.leukemia-lymphoma.org/all_page?item_id=7026

## Points to Consider

The health of the cardiovascular system is next.

- Why do you think the blood in veins not under pressure?
- How might your diet affect your cardiovascular system?

# 18.4 Health of the Cardiovascular System

## Lesson Objectives

- Outline the cause of blood pressure in arteries.
- Identify the healthy range for blood pressure.
- Describe three types of cardiovascular disease.
- Identify things you can do to avoid cardiovascular disease.

## Check Your Understanding

- What is the role of the cardiovascular system?

## Vocabulary

- angina
- atherosclerosis
- blood pressure
- cardiovascular disease (CVD)
- coronary heart disease
- heart attack
- hypertension
- plaque
- stroke

## Blood Vessels and Blood Pressure

The health of your whole body depends on the good health of your cardiovascular system. **Blood pressure** occurs when circulating blood puts pressure on the walls of blood vessels. The pressure causes the walls of the arteries to move in a rhythmic fashion.

Blood in arteries is under the greatest amount of pressure. A person's pulse is the throbbing of their arteries that results from the heart beat. 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 pressure.

The **systolic** pressure is the highest pressure in the arteries. The **diastolic** pressure is the lowest pressure. Pressure in arteries is most commonly measured by an instrument called a **sphygmomanometer**, shown in **Figure** 18.20. The height of the column of mercury shows the pressure of the circulating blood. Many modern blood pressure devices no longer use mercury, but values are still reported in millimeters of mercury (mm Hg).


FIGURE 18.20

A digital sphygmomanometer is made of an inflatable cuff and a pressure meter to measure blood pressure.

### Healthy Blood Pressure Ranges

Healthy ranges for blood pressure are:

- Systolic: less than 120 mm Hg
- Diastolic: less than 80 mm Hg

Blood pressure is usually written as systolic/diastolic mm Hg. For example, a reading of 120/80 mm Hg is said as "one twenty over eighty." These measures of blood pressure can change with each heartbeat and over the course of the day. Age, gender and race also influence blood pressure values. Pressure also varies with exercise, emotions, sleep, stress, nutrition, drugs, or disease.

Studies have shown that people whose systolic pressure is around 115 mm Hg rather than 120 mm Hg 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.

**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 mm Hg or higher, and/or their diastolic blood pressure is always 90 mm Hg or higher. Having hypertension increases a person's chance for developing heart disease, having a stroke, and other serious cardiovascular diseases. Hypertension often does not have any symptoms, so a person may not know they have high blood pressure. For this reason, hypertension is often called the silent killer. Treatments for hypertension include diet changes, exercise, and medication.

## Atherosclerosis and Other 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** 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, shown in **Figure** 18.21.

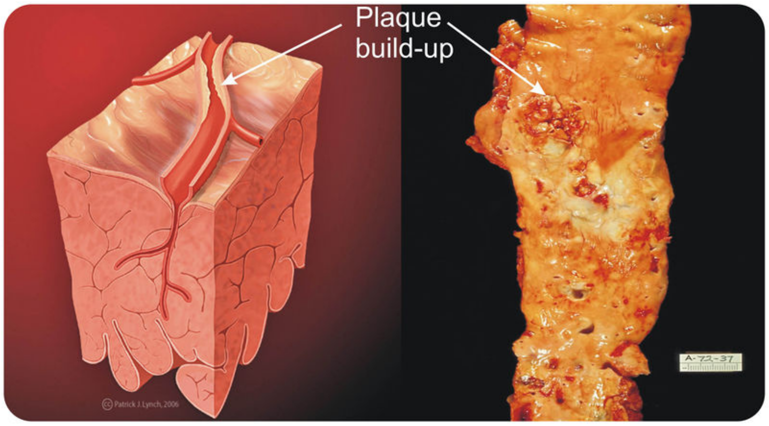



FIGURE 18.21

Atherosclerosis is sometimes referred to as hardening of the arteries; plaque build-up decreases the blood flow through the artery.

### Atherosclerosis

Atherosclerosis normally begins in later childhood, and is usually 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. According to the American Heart Association, atherosclerosis is a leading cause of CVD.

### Coronary Heart Disease

Hearts have arteries that require oxygen, too. Muscle cells in the heart are given oxygen by **coronary arteries**. Blocked flow in a coronary artery can result in a lack of oxygen and the death of heart muscle. **Coronary heart disease** is the end result of the buildup of plaques 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, called **angina** 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 about 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. How a blocked coronary artery can cause a heart attack, and cause part of the heart muscle to die, is shown in **Figure** 18.22. If part of the cardiac muscle becomes injured, the heart will not work as well as it used to.

### 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. It can be caused by a blood clot, an object that gets caught in a blood vessel, or by a bleeding blood vessel. 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. Many other risk factors, however, such as avoiding or quitting smoking are also important.

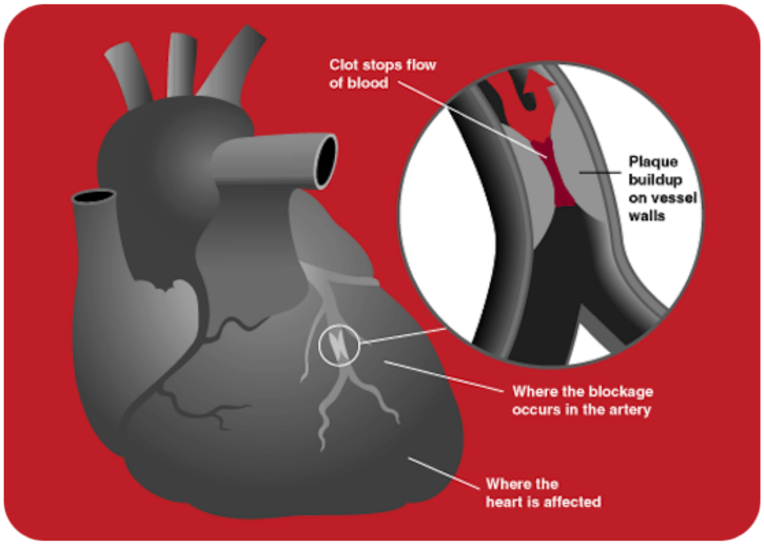



FIGURE 18.22
A blockage in a coronary artery stops oxygen getting to part of the heart muscle, so areas of the heart that depend on the blood flow from the blocked artery are starved of oxygen.

## Keeping Your Cardiovascular System Healthy

There are many risk factors that can cause a person to develop CVD. A **risk factor** is anything that is linked to an increased chance of developing a disease or an infection. Some of the risk factors for CVD 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:

- **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 CVD.
- **High cholesterol levels**: high amounts of low-density lipids in the blood, also called "bad cholesterol," increase the risk of CVD.
- **Obesity**: being obese, especially if the fat is mostly found in the upper body, rather than the hips and thighs, increases risk significantly.
- **High blood pressure**: hypertension can cause atherosclerosis.
- **Lack of physical activity**: aerobic activities, such as the one shown in **Figure** 18.23, 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 CVD ( **Figure** 18.24).

FIGURE 18.23
Sixty minutes a day of vigorous aerobic activity, such as basketball, is enough to help keep your cardiovascular system healthy.

FIGURE 18.24
The USDA's MyPyramid recommends that you limit the amount of such foods in your diet to occasional treats.

## Lesson Summary

- Blood pressure is the force put on the walls of blood vessels by circulating blood.
- The force put on the walls of arteries is called blood pressure.
- Blood pressure is measured by an instrument called a sphygmomanometer.
- In the United States, the healthy ranges for systolic pressure is less than 120 mm Hg and a diastolic pressure of less than 80 mm Hg.
- Hypertension occurs when a person's blood pressure is always high.
- A cardiovascular disease (CVD) is any disease that affects the cardiovascular system. Atherosclerosis, coronary heart disease, and stroke are examples of CVDs.
- Cardiovascular diseases are lifestyle diseases. Having a poor diet and not getting enough exercise are two major causes of CVD.

## Review Questions

### Recall

1. What is the cause of blood pressure?
2. What is the healthy range for blood pressure?
3. When is a person considered to have hypertension?
4. What is atherosclerosis?
5. What are three risks factor for cardiovascular disease?

### Apply Concepts

6. How is the pulse related to blood pressure?
7. Is the blood in veins under pressure? Explain your answer.
8. Why is hypertension called a silent killer?
9. A stroke could be thought of as a "brain attack," in a similar way to a heart attack. How are strokes and heart attacks similar?
10. What is the difference between a controllable risk factor and an uncontrollable risk factor?
11. Why are cardiovascular diseases called lifestyle diseases?

### Critical Thinking

12. One of your friends says, "Heart disease is genetic and people have it in my family, so there is nothing I can do about it." Explain to your friend how cardiovascular disease can be a lifestyle choice. Also, give your friend three recommendations on things he/she can do to prevent cardiovascular disease.

## Further Reading / Supplemental Links

- http://bio-alive.com/animations/cardiovascular.htm
- http://www.cdc.gov/nccdphp/dnpa/physical/everyone/recommendations/index.htm
- http://en.wikipedia.org/wiki/Aerobic_exercise
- http://www.cdc.gov/bloodpressure

## Points to Consider

Next we take a look at the respiratory system.

- Do you think there is a relationship between the cardiovascular system and the respiratory system? What could it be?
- Do you think hypertension affects the ability of the blood to release carbon dioxide and pick up oxygen in the lungs? Why?

# 18.5 References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2. Left: Patrick Lynch, C. Carl Jaffe, M.D.; Right: User:alexanderpiavas134/Wikipedia. Left: http://commons.wikimedia.org/wiki/File:Heart_circulation_diagram.svg; Right: http://commons.wikimedia.org/wiki/File:Humhrt2.jpg . Left: CC BY 2.5; Right: Public Domain
3. Laura Guerin. CK-12 Foundation . CC BY-NC 3.0
4. Laura Guerin. CK-12 Foundation . CC BY-NC 3.0
5. Courtesy of the National Cancer Institute. Capillaries connect arteries and veins . Public Domain
6. Sam McCabe. CK-12 Foundation . CC BY-NC 3.0
7. User:The Emirr/Wikimedia Commons. http://commons.wikimedia.org/wiki/File:TE-Lymphatic_system_diagram.svg . CC BY 3.0
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17. Courtesy of the Electron Microscopy Facility at The National Cancer Institute at Frederick. http://commons.wikimedia.org/wiki/File:Red_White_Blood_cells.jpg . Public Domain
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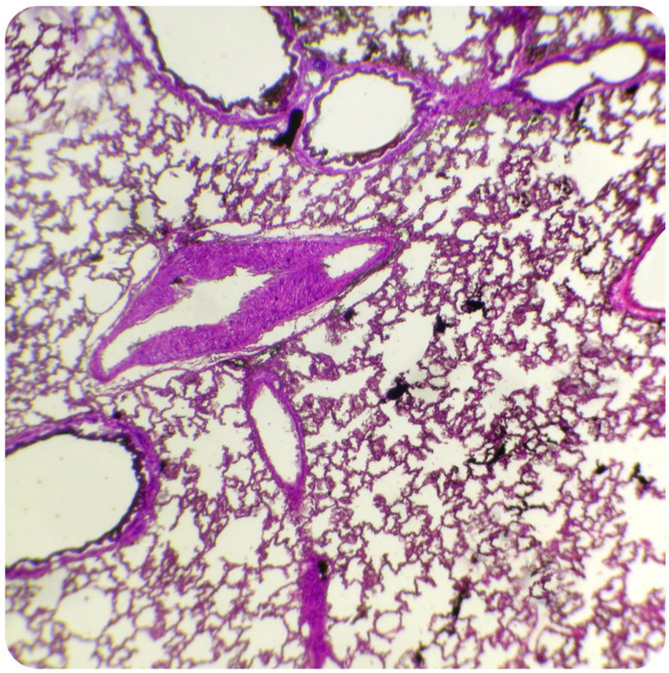
20. User:Julo/Wikimedia Commons. http://commons.wikimedia.org/wiki/File:BloodPressure.jpg . Public Domain
21. Left: Patrick J. Lynch, C. Carl Jaffe, M.D.; Right: Courtesy of the CDC/Dr. Edwin P. Ewing, Jr. Left: http://commons.wikimedia.org/wiki/File:Heart_coronary_artery_lesion.jpg; Right: http://commons.wikimedia.org/wiki/File:Atherosclerosis,_aorta,_gross_pathology_PHIL_846_lores.jpg . Left: CC BY 2.5; Right: Public Domain
22. Courtesy of the FDA. http://commons.wikimedia.org/wiki/File:Heart_attack_diagram.png . Public Domain
23. Kenneth Lu. http://www.flickr.com/photos/toasty/2577398394 . CC BY 2.0
24. Clara. http://commons.wikimedia.org/wiki/File:Christmas_Cookies.jpg . CC BY 2.0

# CHAPTER 19 MS Respiratory and Excretory Systems

## Chapter Outline





The above image shows the tissue found inside of the lungs. The lungs contain alveoli. Alveoli absorb oxygen and send it to the blood vessels. They also move carbon dioxide from the blood vessels back to the lungs to be exhaled.

Alveoli look like clumps of grapes. Why do you think it is important that your body have many alveoli? What would happen if your alveoli lost their ability to function? Why do you think alveoli are shaped like spheres?

The respiratory system is important because it brings oxygen to cells in your body. But it also removes a waste, carbon dioxide. Another system in your body, the excretory system, also removes wastes. The excretory system moves waste from your digestive system and from your blood out of your body.

How do the respiratory system and excretory system work together? How does damage in one system affect the other? Consider these questions about respiration and waste removal as you read the following chapter.

# 19.1 The Respiratory System

## Lesson Objectives

- Identify the parts of the respiratory system.
- Identify the main function of the respiratory system.
- Describe how breathing works.
- Outline how the respiratory system and the cardiovascular system work together.
- Identify how breathing and cellular respiration are connected.

## Check Your Understanding

- What is an organ system?
- What is the role of the circulatory system?
- How does your blood get oxygen?

## Vocabulary

- alveoli
- diaphragm
- epiglottis
- exhalation
- external respiration
- gas exchange
- inhalation
- internal respiration
- larynx
- pharynx
- respiration
- respiratory system
- trachea

## Roles of the Respiratory System

You breathe mostly without thinking about it. Remember how uncomfortable you felt the last time you had a cold or a cough? You usually do not think about your respiratory system or how it works until there is a problem with it. Every cell in your body depends on your respiratory system.

Your **respiratory system** is made up of the tissues and organs that allow oxygen to enter the 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 in **Figure** 19.1.

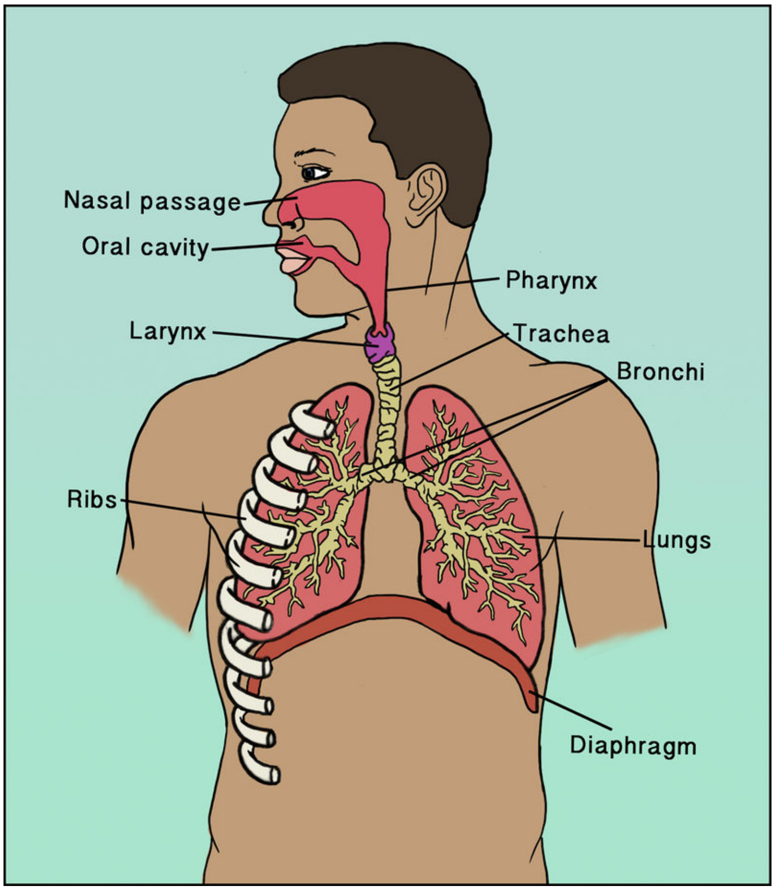



FIGURE 19.1
The respiratory system. Air moves in through the nose and mouth and down the trachea, which is a long, straight tube in the chest.

## Parts of the Respiratory System

**Figure** 19.1 shows many of the structures of the respiratory system. Each of the parts has a specific job. The parts of the respiratory system include the following:

- 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.

- The nose and nasal cavity filter, warm, and moisten the air you breathe. The nose hairs and mucus produced by the cells in the nose catch particles in the air and keep them from entering the lungs. When particles in the air do reach the lungs, what do you think happens?
- 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.
- Since food goes down the pharynx, how is it stopped from entering the trachea? A flap of tissue called the *epiglottis* closes over the trachea when food is swallowed to prevent choking or inhaling food.
- The bronchioles lead to the alveoli. **Alveoli** are the little sacs at the end of the bronchioles. They look like little bunches of grapes, as shown in **Figure** 19.2. Oxygen is exchanged for carbon dioxide in the alveoli. **Gas exchange** is the name we give to the process that allows oxygen to enter the blood and carbon dioxide to move out of the blood - the two gases are "exchanged."

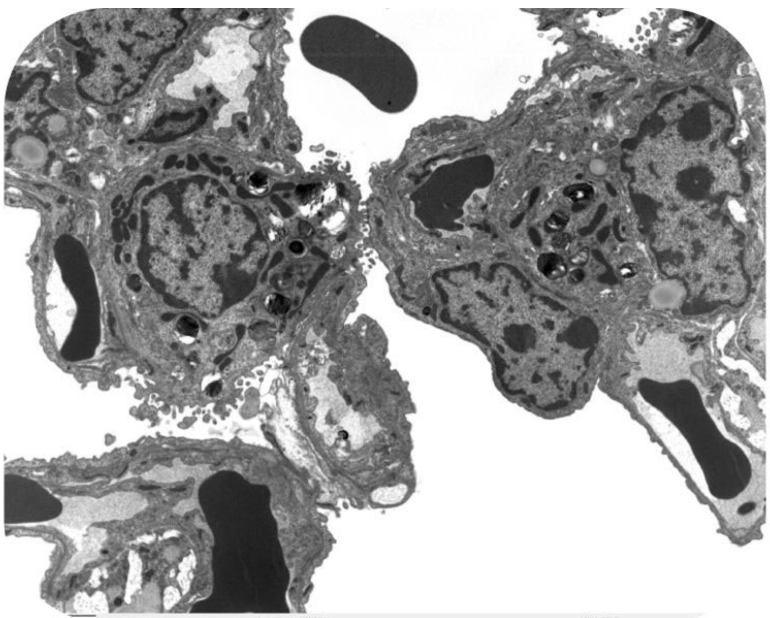


FIGURE 19.2

The alveoli are the tiny grape-like structures in the lungs and the sites of gas exchange.

## 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 also control your breathing. 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 man in **Figure** 19.3 is exhaling before he surfaces from the pool water.

How do lungs allow air in? As mentioned above, air moves into and out of the lungs by the movement of muscles. 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

FIGURE 19.3
Being able to control breathing is important for many activities, such as swimming. The man in the photograph is exhaling before he surfaces from the water.

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.

The walls of the alveoli are very thin and allow gases to enter into them. The alveoli are lined with capillaries. These capillaries are shown in **Figure** 19.4. 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.

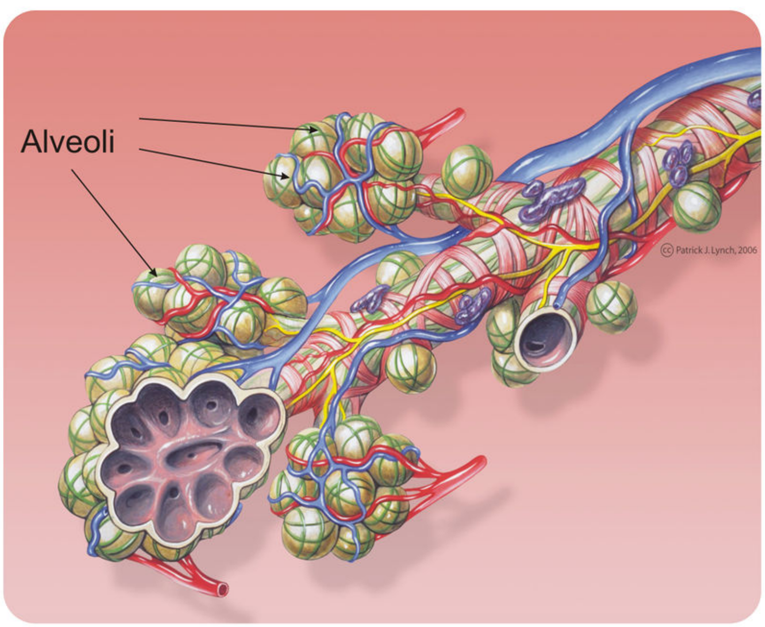



FIGURE 19.4
The bronchi and alveoli. During respiration, oxygen gets pulled into the lungs and enters the blood by passing across the thin alveoli membranes and into the capillaries.

### Breathing and Respiration

When you breath in, oxygen is drawn in through the mouth and down into the lungs. The oxygen then passes across the thin lining of the capillaries and into the blood. The oxygen molecules are carried to the body cells by the blood. Carbon dioxide from the body cells is carried by the blood to the lungs where it is released into the air. 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. There are actually two parts to respiration, external respiration and internal respiration. **External respiration** is the movement of oxygen into the body and carbon dioxide out of the body. **Internal respiration** is the exchange of oxygen and carbon dioxide between the blood and the cells of the body ( **Figure** 19.5).

## 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 blood stream from the alveoli. Then, the oxygen-rich blood returns to the heart.
2. Oxygen-rich blood is then pumped through the aorta.
3. From the aorta, oxygen-rich blood travels to the smaller arteries and finally to the capillaries.
4. The oxygen molecules move out of the capillaries and into the body cells.
5. While oxygen moves from the capillaries and into body cells, carbon dioxide moves from the cells into the capillaries.

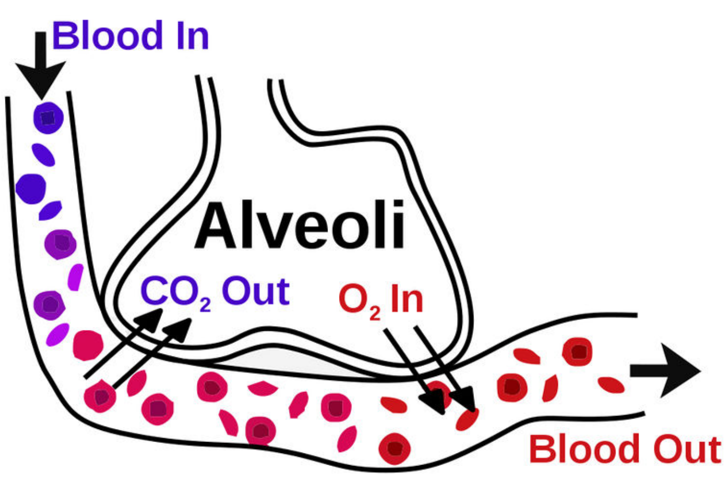



FIGURE 19.5

Gas exchange is the movement of oxygen into the blood and carbon dioxide out of the blood.

## Breathing and Cellular Respiration

The oxygen that arrives at the cells from the lungs is used by the cells to help release the energy stored in molecules of sugar. Cellular respiration is the process of breaking down glucose to release energy (see the *Cell Functions* chapter). The waste products of cellular respiration include carbon dioxide and water. The carbon dioxide molecules move out of the cells and into the capillaries that surround the cells. As explained above, the carbon dioxide is removed from the body by the lungs.

## Lesson Summary

- Your respiratory system is made up of the tissues and organs that allow oxygen to enter and carbon dioxide to leave your body.
- Respiratory system organs include your nose, mouth, larynx, pharynx, lungs, and diaphragm.
- During inhalation, the diaphragm contracts and moves downward, and brings air into the lungs.

During exhalation, the diaphragm and rib muscles relax and air is pushed out of the lungs.

- 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, a waste gas, moves into the blood capillaries and is brought to the lungs to be released into the air during exhalation.
- The oxygen that arrives from the lungs is used by the cells during cellular respiration to release the energy stored in molecules of sugar.

## Review Questions

### Recall

1. Name the five main organs in the respiratory system.
2. What is the main function of the respiratory system?
3. In what part of the lung does gas exchange occur?
4. What is the important gas that is carried into the lungs during inhalation?

### Apply Concepts

5. A classmate says that lung muscles cause the lungs to move during breathing. Do you agree with your classmate?
6. How do the respiratory system and the cardiovascular system work together?
7. Breathing is an involuntary action. Does this mean that you cannot control your breathing?
8. What is the difference between breathing and respiration?
9. What is the name of the waste gas that is released during exhalation?

### Critical Thinking

10. If a disease caused the alveoli to collapse, how might this affect a person's health?

## Points to Consider

- How do you think the health of your respiratory system might affect the health of other body systems?

# 19.2 Health of the Respiratory System

## Lesson Objectives

- Identify the organs affected by a respiratory disease.
- Identify how a respiratory disease can affect the rest of the body.
- Describe how asthma affects breathing.
- Outline how smoking affects the respiratory system.
- Identify what you can do to keep your respiratory system healthy.

## Check Your Understanding

- What is the role of the respiratory system?
- What are some of the organs in the respiratory system?

## Vocabulary

- allergen
- asthma
- bronchitis
- chronic disease
- chronic obstructive pulmonary disease (COPD)
- emphysema
- environmental tobacco smoke (ETS)
- lifestyle disease
- lung cancer
- pathogen
- pneumonia
- respiratory disease
- tuberculosis (TB)

## Respiratory System Disease

Most of the time your respiratory system works well. But your respiratory system can sometimes be knocked out of homeostasis. Recall that homeostasis is the balancing act your body performs that keeps everything inside of your body stable. Anything that stops the respiratory system from doing its job disrupts homeostasis. When homeostasis is thrown out of balance, your respiratory system can get diseases. There are many causes of respiratory diseases, and many ways to treat such diseases.

In general, diseases that last a short time are called acute diseases. Other diseases can last for a long time, perhaps years. Diseases that last for a long time are called **chronic diseases**. Both acute and chronic diseases affect the respiratory system. **Respiratory diseases** are diseases of the lungs, bronchial tubes, trachea, nose, and throat ( **Figure** 19.6). These diseases can range from a mild cold to a severe case of pneumonia. Respiratory diseases are common and may cause 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 can be genetic.

FIGURE 19.6

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, which means they 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.

Chronic bronchitis may not be caused by a bacterium or a virus. Chronic bronchitis occurs when a cough produces phlegm, for at least three months in a two-year period. Tobacco smoking is the most common cause of chronic bronchitis, but it can be caused by environmental pollution, such as smog and dust. It is generally part of a disease called chronic obstructive pulmonary disease (COPD). Treatments for bronchitis include antibiotics and steroid drugs used to reduce inflammation.

### Asthma

**Asthma** is a chronic illness in which the bronchioles are inflamed and become narrow, as shown in **Figure** 19.7. The muscles around the bronchioles contract which narrows the airways. Large amounts of mucus are also made by the cells in the lungs. A person with asthma has difficulty breathing. Their chest feels tight and they wheeze. Asthma can be caused by different things, such as allergies. An **allergen** is any antigen that is not actually a disease, but your body responds to it as if it were a disease. Allergens can cause allergic reactions. Common allergens that cause asthma are mold, dust, or pet hair.

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. The symptoms of asthma can usually be controlled with medicine. Bronchodilators are drugs that reduce inflammation of the bronchioles and are often used to treat asthma. An inhaler is usually a bronchodilator.

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.

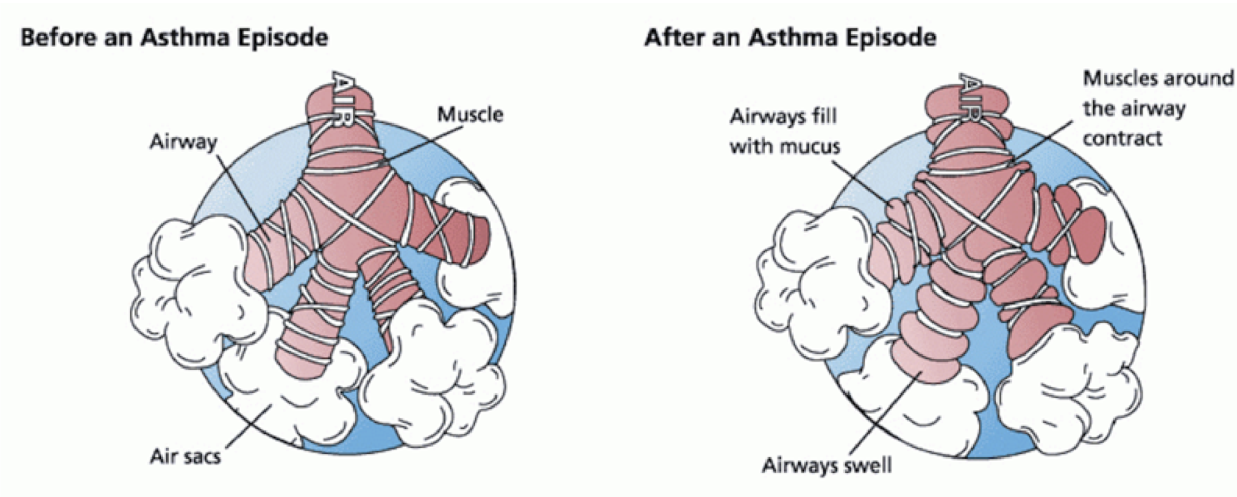



FIGURE 19.7
Asthma occurs when the bronchioles swell and the muscles around the bronchioles contract.

### Pneumonia

**Pneumonia** is an illness that occurs when the alveoli become inflamed and filled with some kind of fluid. When a person has pneumonia, gas exchange cannot happen 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. Sometimes people take vaccines to prevent certain types of pneumonia.

### Tuberculosis

**Tuberculosis (TB)** is a common and often deadly disease caused by a genus of bacterium called *Mycobacterium*. When a disease like TB can passed from person to person, it is called "infectious." 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.

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 in **Figure** 19.8, remind people how to stop the spread of the disease.


FIGURE 19.8
A public health notice from the early 20th century reminded people that TB could be spread very easily.

### Cancer

**Lung cancer** is a disease where 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, which is the most common cause of cancer-related death in men and the second most common in women, is responsible for 1.3 million deaths worldwide every year ( **Figure** 19.9). 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 19.9
The inside of lung showing cancerous tissue.

### Emphysema

**Emphysema** is a chronic lung disease caused by the breakdown of the lung tissue. The surfaces of healthy alveoli are springy and flexible. They stretch out a little when full of air and relax when air leaves them. But the breakdown of the tissues that support the alveoli and the capillaries that feed the alveoli cause the alveoli to become hard and stiff. Eventually, the walls of the alveoli break down and the alveoli become larger. When alveoli become larger, oxygen cannot enter the blood as it did before. Symptoms of emphysema include shortness of breath during exercise. Damage to the alveoli, which can be seen in **Figure** 19.10, is not curable. Smoking is the leading cause of emphysema.


FIGURE 19.10
The lung of a smoker who had emphysema (left). The black areas are enlarged alveoli, and 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

### Pathogens

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 shown in **Figure** 19.11. 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.

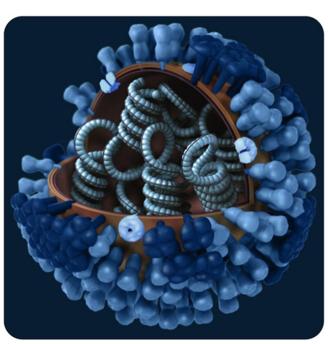


FIGURE 19.11
This is the influenza virus that causes the swine flu, or H1N1. The Center for Disease Control and Prevention recommends that children between the ages of 6 months and 19 years get a flu vaccination each year.

### Pollution

The quality of the air 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 can be either outdoor pollution or indoor pollution. Outdoor air pollution can be caused by car exhaust fumes, smoke from factories and forest fires, volcanoes, and animal feces. These pollutants contain tiny particles that can get "stuck" in the tissues of the respiratory system and irritate the lungs. Indoor air pollution can be caused by tobacco smoke, dust, mold, insects, rodents, and cleaning chemicals.

### Lifestyle Choices

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 U.S. 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."

## Dangers of Smoking

Tobacco use, particularly cigarette smoking, is a preventable cause of death in the United States. This means that people would not die if they stopped smoking. Cigarette smoking alone is directly responsible for approximately 30 percent of all yearly cancer deaths in the United States. The main health risks of using tobacco are linked to diseases of the cardiovascular system and respiratory system. Cardiovascular diseases caused by smoking include heart disease and stroke.

Diseases of the respiratory system that are caused by exposure to tobacco smoke include:

- Emphysema.
- Lung cancer.
- Cancers of the larynx and mouth.

Cigarette smoking causes 87 percent of lung cancer deaths. Smoking and using tobacco is also linked to the risk of developing other types of cancer, such as pancreatic and stomach cancer.

### Indoor Air Pollution

Cigarettes, like the ones shown in **Figure** 19.12, are a major source of indoor air pollution. Cigarette smoke contains about 4,000 substances, including over 60 cancer-causing chemicals. Many of these substances, such as carbon monoxide, tar, arsenic, and lead, are toxic to the body. Non-smokers can also be affected by tobacco smoke. Exposure to secondhand smoke, also known as **environmental tobacco smoke (ETS)**, greatly increases the risk of lung cancer and heart disease in nonsmokers.

### Chronic Obstructive Pulmonary Disease

**Chronic obstructive pulmonary disease (COPD)** is a disease of the lungs that occurs when the airways narrow and air cannot enter the lungs as well as it did before. This leads to shortness of breath. The lack of air entering the lungs usually gets worse over time. COPD is most commonly caused by smoking. Gases and particles in tobacco smoke trigger an inflammatory response in the lung. The inflammatory response in the larger airways is known as chronic bronchitis. In the alveoli, the inflammatory response causes the breakdown of the tissues in the lungs, leading to emphysema.

FIGURE 19.12
Tobacco use, particularly cigarette smoking, is the single most preventable cause of death in the United States.

## Keeping Your Respiratory System Healthy

Many of the diseases related to smoking are called **lifestyle diseases**, diseases that are caused by choices that people make in their daily lives. For example, the choice to smoke can lead to cancer in later life. But there are many things you can do to help keep your respiratory system healthy.

### Avoid Smoking

Never smoking or quitting now are the most effective ways to reduce your risk of developing chronic respiratory diseases, such as cancer.

### Eat Well, Exercise Regularly, and Get Rest

Eating a healthful diet, getting enough sleep, and being active every day can help keep your immune system strong.

### Wash Your Hands

Washing your hands often, and 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.

Some viruses and bacteria can live from 20 minutes up to 2 hours or more on surfaces like cafeteria tables, doorknobs, and desks.

### 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 and getting sicker, if you catch something else.

### Visit Your Doctor

Getting the recommended vaccinations can help prevent diseases such as whooping cough and flu. Seeking medical help for diseases such as asthma can help stop the disease from getting worse.

## Lesson Summary

- Respiratory diseases are diseases that affect the lungs, bronchial tubes, trachea, nose, and throat.
- Respiratory diseases can reduce the amount of oxygen that gets into the blood.
- Asthma is an illness that occurs when the bronchioles are inflamed and become narrow.
- Difficulty breathing happens because of the inflammation, contraction of the muscles, and the production of mucus by the cells that line the bronchioles.
- Diseases of the respiratory system that are caused by exposure to tobacco smoke include emphysema, lung cancer and cancers of the larynx and mouth.
- Cigarette smoking causes 87 percent of lung cancer deaths.
- Avoid smoking, get enough exercise, and wash your hands in order to protect your respiratory system from illness.

## Review Questions

### Recall

1. Identify two organs that can be affected by respiratory diseases.
2. What lifestyle activity has the largest health impact on the respiratory system?
3. Identify three diseases caused by smoking.
4. Identify three things besides smoking that can cause a respiratory disease.
5. What are two things you can do to keep your respiratory system healthy?

### Apply Concepts

6. How might a respiratory disease affect the rest of the body?
7. How does asthma affects the bronchioles?
8. Explain how washing your hands can help prevent you from catching a cold.

### Critical Thinking

9. Pneumonia is a disease that causes the alveoli to fill up with fluid. How might this affect the lungs' ability to absorb oxygen?
10. A person who has never smoked before gets lung cancer. How might they have contracted the disease?

## Further Reading / Supplemental Links

- http://www.cdc.gov/vaccines/vpd-vac/pertussis/default.htm
- http://www.cdc.gov//HealthyLiving/
- http://en.wikipedia.org/wiki/Cigarette_smoking
- http://www.cancer.gov/cancertopics/factsheet/Tobacco/cancer
- http://www.cancer.gov/cancertopics/factsheet/Tobacco/cancer
- http://www.cdc.gov/flu/protect/covercough.htm

## Points to Consider

Next, we move on to the excretory system.

- The excretory system gets rids of a certain type of waste. What type of waste do you think is removed by this system?

# 19.3 The Excretory System

## Lesson Objectives

- Identify the functions of the excretory system.
- List the organs of the excretory system.
- Describe the parts of urinary system.
- Outline how the kidneys filter blood.
- Identify three disorders of the urinary system.

## Check Your Understanding

- What are some "wastes" that must be removed from your body?
- Do your circulatory and respiratory systems remove "waste?"

## Vocabulary

- excretion
- excretory system
- kidney
- kidney dialysis
- kidney failure
- nephron
- urinary bladder
- urinary system
- urinary tract infection (UTI)
- urination
- urine

## The Excretory System

One of the most important ways your body maintains homeostasis is by keeping the right amount of water and salts inside your body. If you have too much water in your body, your cells can swell and burst. If you have too little water in your body, your cells can shrivel up like an old apple. Either extreme can cause illness and death of cells, tissues, and organs. The organs of your **excretory system** help to keep the correct balance of water and salts within your body.

Your body also needs to remove the wastes that build up from cell activity and from digestion. These wastes include carbon dioxide, urea, and certain plant materials. If these wastes are not removed, your cells can stop working and you can get very sick. The excretory system can also help to release wastes from the body. **Excretion** is the process of removing 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 in **Table** 19.1.

**TABLE 19.1: Organs of the Excretory System**

| Organ(s) | Function | Other Organ System of which it is Part |
|---|---|---|
| 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 |

### Functions of the Excretory System

The excretory system controls the levels of water and salts in your body by removing wastes. This means the excretory system has an important role in maintaining homeostasis. Your body takes nutrients from food and uses them for energy, growth, and repair. After your body has taken what it needs from the food, waste products are left behind in the blood and in the large intestine. These waste products need to be removed from the body. The kidneys work with the lungs, skin, and intestines to keep the correct balance of nutrients, salts and water in your body.

## The Urinary System

Sometimes, the urinary system is called the excretory system. But the urinary system is only one part of the excretory system. Recall that the excretory system is 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. It includes:

- Two kidneys.
- Two ureters.
- One bladder.
- One urethra.

The urinary system is shown in **Figure** 19.13.

## Organs of the Urinary System

1. As you can see from **Figure** 19.13, 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 rib cage.
2. Ureters are tube-shaped and bring urine from the kidneys to the urinary bladder.

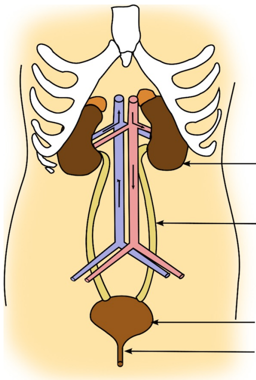



FIGURE 19.13
The kidneys filter the blood that passes through them and the urinary bladder stores the urine until it is released from the body.

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 also contains salts and nitrogen-containing molecules. The amount of urine released from the body depends on many things. Some of these include the amounts 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.

## How the Kidneys Filter Wastes

The kidneys are important organs in maintaining homeostasis. 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.

There are many blood vessels in the kidneys, as you can see in **Figure** 19.14. The kidneys remove urea from the blood through tiny filtering units called nephrons. **Nephrons** are tiny, tube-shaped structures found inside each kidney. A nephron is shown in **Figure** 19.15. Each kidney has up to a million nephrons. Each nephron collects a small amount of fluid and waste from a small group of capillaries.

If the body is in need of more water, water is removed from the fluid inside the nephron and is returned to the blood. The fluid within nephrons is carried out into a larger tube in the kidney called a ureter, which you can see in **Figure** 19.15. Urea, together with water and other wastes, forms the urine as it passes through the nephrons and the kidney.

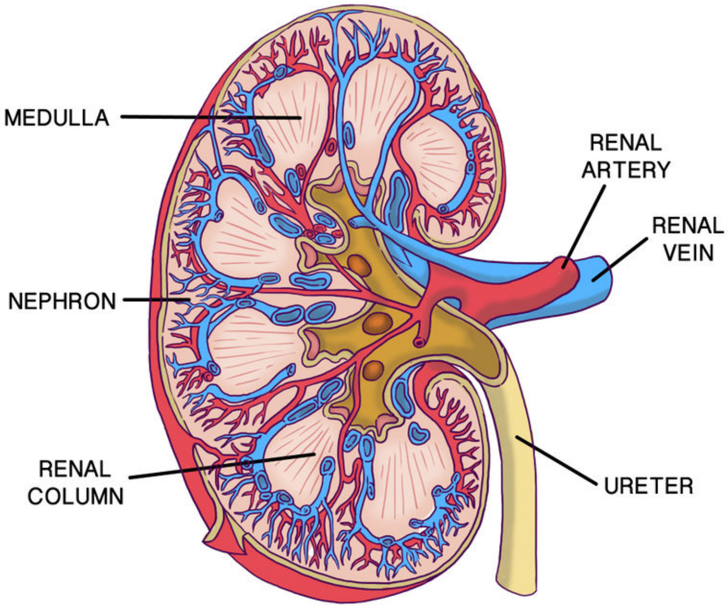



FIGURE 19.14
Structures of the kidney; fluid leaks from the capillaries and into the nephrons where the fluid forms urine then moves to the ureter and on to the bladder.

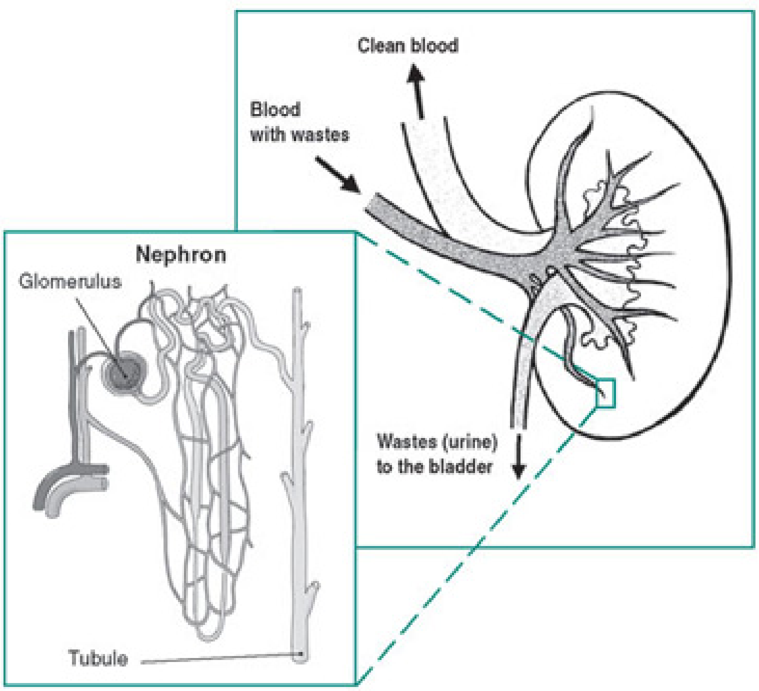



FIGURE 19.15
The location of nephrons in the kidney. The fluid collects in the nephron tubules, and moves to the bladder through the ureter.

## Formation of Urine

The process of urine formation is as follows:

1. Blood flows into the kidney through the renal artery, shown in **Figure** 19.15. 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 $\frac{1}{4}$ 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 $1\frac{1}{2}$ to $2\frac{1}{2}$ 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

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.

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, as shown in **Figure** 19.16. The pituitary gland is also part of the endocrine system. The pituitary gland releases hormones, which 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 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?

## Excretory System Problems

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, like the one shown in **Figure** 19.17. Stones form in the kidneys and may be found anywhere in the urinary system. They vary in size. Some stones cause great pain, while others cause very little pain. Some stones may need to be removed by surgery or ultrasound treatments.

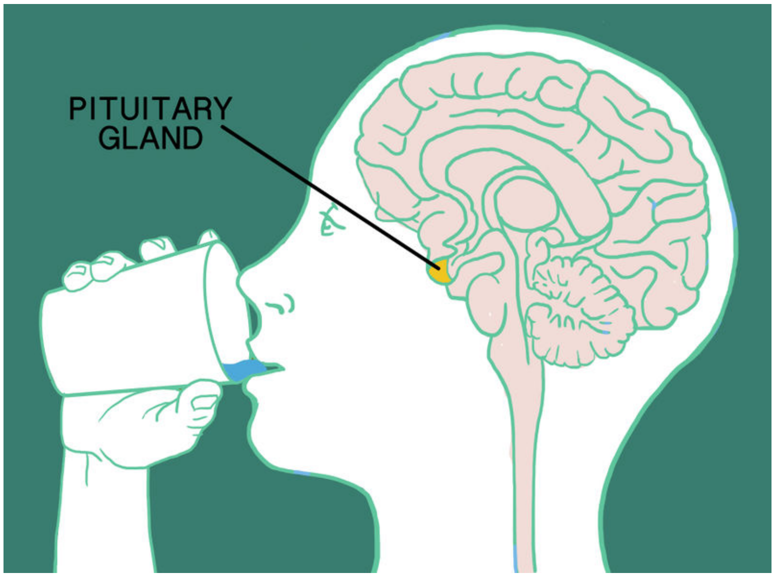



FIGURE 19.16

The pituitary gland is found directly below the brain and releases hormones that control how urine is produced.

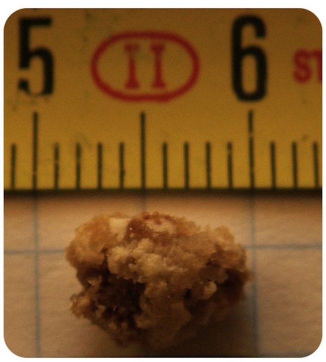


FIGURE 19.17

A kidney stone. The stones can form anywhere in the urinary system.

### 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. Homeostasis is disrupted because the fluids in the body are out of balance. 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 (also called a hemodialyzer) filters the blood of waste by pumping it through a fake kidney. The filtered blood is then returned to the patient's body. A dialysis machine is shown in **Figure** 19.18.

### 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

FIGURE 19.18
During dialysis, a patient's blood is sent through a filter that removes waste products. The clean blood is returned to the body.

bladder infection. Women get UTIs more often than men. UTIs are often treated with antibiotics.

## Lesson Summary

- The excretory system controls the chemical make-up of liquids found in the body.
- The organs of the excretory system remove wastes. They also maintain the proper levels of water, salts, and nutrients in the body.
- The lungs, skin, kidneys, and large intestine are all organs in the excretory system.
- The urinary system is made up of the kidneys, the ureters, the bladder, and the urethra.
- The filtering parts of the kidneys are the nephrons.
- Water and waste molecules move out of the blood capillaries and into the nephrons. Most of the water returns to the blood.
- Urine collects in the nephron and moves to the urinary bladder through the ureters.
- The filtering action of the kidneys is controlled by the pituitary gland.
- ADH is the hormone released by the pituitary gland and controls the how water is reabsorbed by the blood from the kidneys.
- Disorders of the urinary system include kidney stones, kidney disease, and urinary tract infections.

## Review Questions

### Recall

1. What is the main function of the excretory system?
2. List the organs that make up the excretory system.
3. What is urine made of?
4. What is the purpose of the urinary bladder?
5. What connects the kidneys to the urinary bladder?

### Apply Concepts

6. What is the difference between the urinary system and the excretory system?

7. How do the kidneys filter the blood?

8. The walls of the urinary bladder are stretchy. What do you think is the advantage of having these stretchy walls?

9. What does antidiuretic hormone (ADH) do?

10. What is a urinary tract infection?

11. Why is kidney failure such a serious health problem?

### Critical Thinking

12. If a person's urine is dark brown, what are two organs in the body that might not be functioning properly? Explain what might be wrong with the two organs.

## Further Reading / Supplemental Links

- http://kidney.niddk.nih.gov/kudiseases/pubs/yourkidneys

## Points to Consider

Next we turn our attention to the nervous system.

- What do you think the nervous system is? What do you think it does?

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9. Courtesy of the National Cancer Institute. http://visualsonline.cancer.gov/details.cfm?imageid=2348 . Public Domain
10. Left: Courtesy of Dr. Edwin P. Ewing, Jr./CDC; Right: Courtesy of the National Institutes of Health. Left : http://commons.wikimedia.org/wiki/File:Centrilobular_emphysema_865_lores.jpg; Right: http://commons.wikimedia.org/wiki/File:Copd_versus_healthy_lung.jpg . Public Domain
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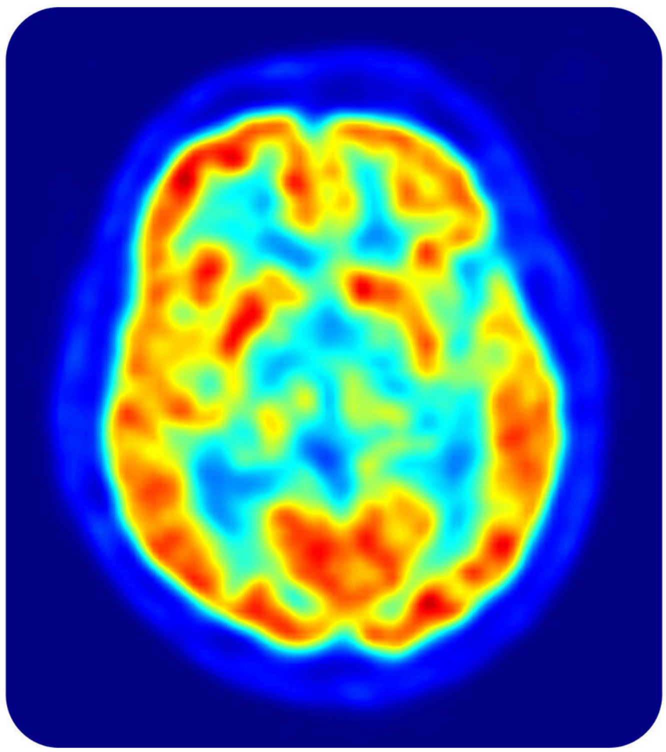
# Chapter 20 MS Controlling the Body

## Chapter Outline





The above image shows a PET scan of a human brain. A PET scan is a recently created technological tool that allows scientists to see activity in the brain. The red and yellow spots are the most active parts of the brain.

But if one part of the brain is more active than another, what does that mean? Are there different parts of the brain? Do they have different jobs? The brain controls all body functions, including ones you cannot control, like digestion, and ones you can control, like texting on a cellphone. But how does it control every function when it sits in your skull on top of your body?

Does the brain send messages to other parts of your body? What does a "message" in your body look like?

Additionally, what would it mean if there were few active parts in the above brain scan? Would a person's brain be functioning properly? What kind of diseases can cause brain damage?

Consider these questions about the brain as you read about the system that controls all other body systems, the nervous system.

*Jens Langner. commons.wikimedia.org/wiki/File:PET−image.jpg. Public Domain.*

# 20.1 The Nervous System

## Lesson Objectives

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

## Check Your Understanding

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

## Vocabulary

- autonomic nervous system
- axon
- brain
- brain stem
- cell body
- central nervous system
- cerebellum
- cerebrum
- dendrite
- motor division
- motor neuron
- nerve
- nerve impulse
- nervous system
- neuron
- neurotransmitter
- parasympathetic division
- peripheral nervous system
- sensory division
- sensory neuron
- somatic nervous system
- spinal cord
- sympathetic division
- synapse

## What Does the Nervous System Do?

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

Michelle was riding her scooter when she hit a hole in the road 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** 20.1).

FIGURE 20.1

Staying balanced when riding a scooter requires control over the body's muscles. The nervous system controls the muscles and maintains balance.

The **nervous system** controls all of the systems of the body. Controlling muscles and maintaining balance are just two of its roles. 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.
- Think, learn, remember, and use language.

The nervous system works by sending and receiving electrical signals. The signals are carried by nerves in the body, similar to the wires that carry electricity all over a house. 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 to muscles in her body. Some muscles tightened while others relaxed. As a result, Michelle's body became balanced again. How did her nervous system do all that in a split second? To answer this question, you need to know how the nervous system carries messages.

## Neurons and Nerve Impulses

The nervous system is made up of nerves. A **nerve** is a bundle of nerve cells. A nerve cell that carries messages is called a **neuron** ( **Figure** 20.2). 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.

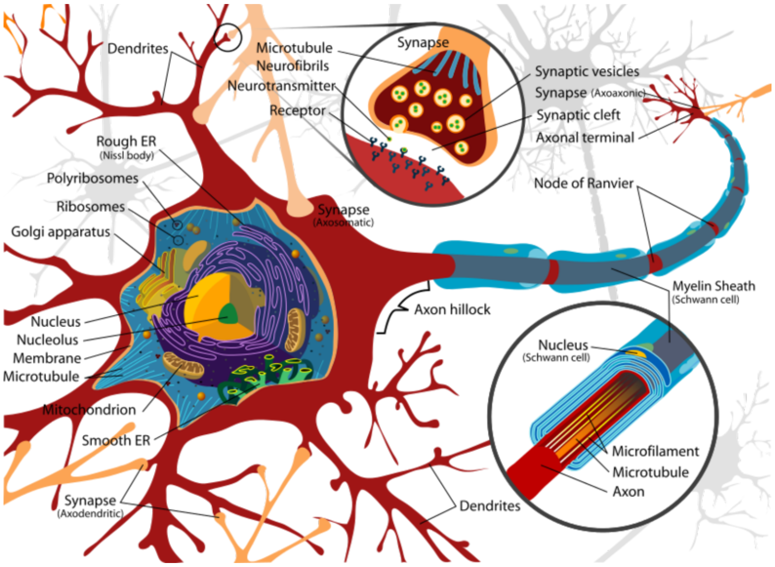



FIGURE 20.2
The axons of many neurons, like the one shown here, are covered with a fatty layer called myelin sheath. The sheath covers the axon, like the plastic covering on an electrical wire, and allows nerve impulses to travel faster along the axon.

### What Does a Neuron Look Like?

A neuron has a special shape that lets it pass signals from one cell to another. As shown in **Figure** 20.2, a neuron has three main parts:

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.

### 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 type 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 synapse, as shown in **Figure** 20.3.

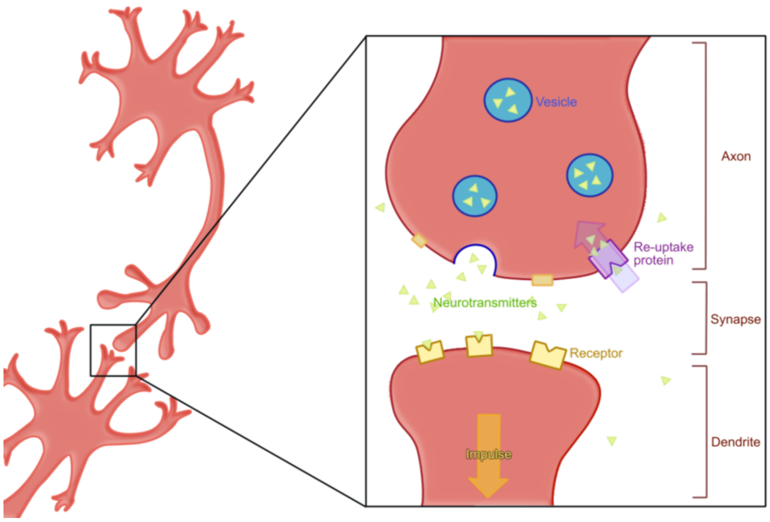



FIGURE 20.3

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.

## The Central Nervous System

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

### The Brain

What weighs about 3 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

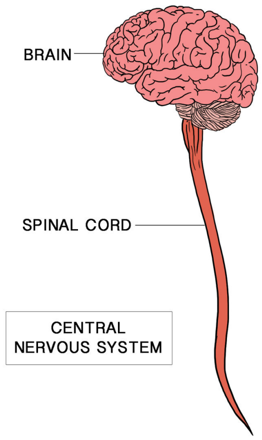



FIGURE 20.4
The brain and spinal cord make up the central nervous system.

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 learn, think, remember, and use language. The brain controls the organs in our body and our movements as well. As shown in **Figure** 20.5, the brain consists of three main parts, the cerebrum, the cerebellum and the brain stem.

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 20.5
Side and bird's eye views of the brain. Can you find the locations of the three major parts of the brain?

The cerebrum is divided into a right and left half, as shown in **Figure** 20.5. Each half of the cerebrum is called a hemisphere. The two hemispheres are connected by a thick bundle of axons called the corpus callosum. It lies deep inside the brain and carries messages back and forth between the two hemispheres.

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.

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

Each hemisphere of the cerebrum is divided into four parts, called lobes. The four lobes are the:

1. Frontal.
2. Parietal.
3. Temporal.
4. Occipital.

Each lobe has different jobs. Some of the functions are listed in **Table** 20.1.

**TABLE 20.1: Cerebrum Lobe Functions**

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

### The Spinal Cord

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

## 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)** contains all the nerves in the body that are found outside of the central nervous system. The network of nerves that make up the peripheral system is shown in **Figure** 20.6. They include nerves of the hands, arms, feet, legs, and trunk. They also include nerves of the scalp, neck, and face. Nerves that send and receive messages to the internal organs are also part of the peripheral nervous system.

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

### 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? Eyes. For hearing? Ears.

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

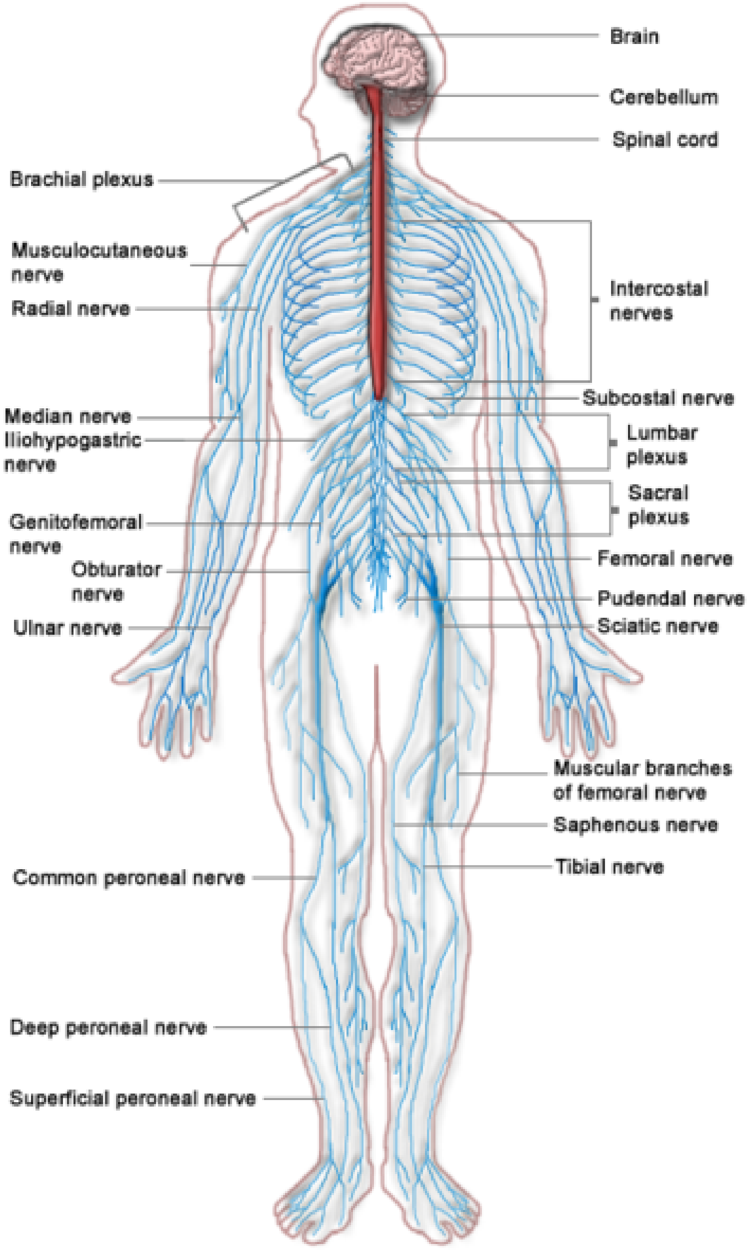



FIGURE 20.6
The blue lines in this drawing represent nerves of the peripheral nervous system. Every peripheral nerve is connected directly or indirectly to the spinal cord.

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** 20.8). 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.

### The Motor Division

The **motor division** of the peripheral system carries messages from the central nervous system to internal organs and muscles. **Figure** 20.7 shows that the motor division is also divided into two parts, the somatic nervous system

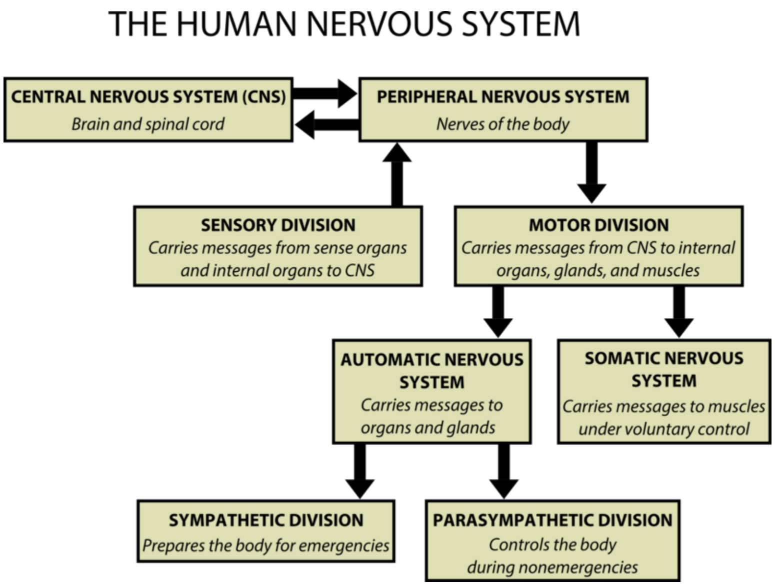



FIGURE 20.7
The central nervous system interprets messages from sense organs and internal organs and the motor division sends messages to internal organs, glands, and muscles.

FIGURE 20.8
Which lobes of the cerebrum interpret messages from each of the senses? Which senses would be stimulated by these raspberries?

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 women in **Figure** 20.9 are using their somatic nervous systems to control the muscles needed to play the violin. The brain sends messages to motor neurons that move their hands so they can play. Without the messages from the brain, they would not be able to move their hands and play the violin.

FIGURE 20.9
These women's central nervous systems are controlling the movements of their hands and arms as they play the violin. The brain sends commands to the somatic nervous system, which controls the muscles of the 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** 20.10). 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 20.10
The woman pictured here is just pretending to be frightened, but assuming that she really was scared, think of which division of the autonomic nervous system would prepare her body for an emergency.

Remember Michelle on her scooter at the start of this lesson? Why was her heart pounding after she got her balance back? The answer is her autonomic nervous system. The sympathetic division prepared her to deal with the emergency by increasing her heart rate. The fact that this happened in the blink of an eye shows how amazing the nervous system is.

## Lesson Summary

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

## Review Questions

### Recall

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

### Apply Concepts

6. Explain how one neuron transmits a nerve impulse to another neuron.

7. Compare and contrast the three main parts of the brain.

8. Why is the spinal cord like a two-way highway?

### Critical Thinking

9. A baby girl sees a toy and reaches out to grab it. Describe the path of messages through the baby's nervous system, from her eyes to her hand.

10. Assume you are so startled by a sudden loud noise that your heart starts pounding fast. Explain what controls your reaction to the loud sound.

## Further Reading / Supplemental Links

- Body Atlas. *Nerves, Brain and Senses.* Ticktock Media Ltd., 2004.
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- http://www.pbs.org/wgbh/nova/magnetic/animals.html
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## Points to Consider

- The sensory division of the peripheral nervous system carries messages from sense organs to the central nervous system. What are some examples of sense organs?
- Do you know how sense organs work? For example, do you know how your eyes sense light?

# 20.2 Eyes and Vision

## Lesson Objectives

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

## Check Your Understanding

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

## Vocabulary

- cornea
- iris
- lens
- myopia
- pupil
- retina
- visible light
- vision
- wavelength

## 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 may look at the clock to see what time it is. Then, they might look out the window to see what the weather is like. They probably look in a mirror to comb their hair. In school, they use their eyes to read the board, their textbooks, and the expressions on their friend's faces. After school, they may keep their eye on the ball while playing basketball ( **Figure** 20.11). Then, they might read their homework assignment and text messages from their friends.

You may use your sight just as much as the students described above. In fact, you may depend on your sight so much that you have a hard time thinking of anything you do without it, except sleep. Why is sight so important?

FIGURE 20.11
All eyes are on the ball in this basketball game. Think about how we use the sense of sight in other games.

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

### Seeing in Three Dimensions

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

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 apples on the tree **Figure** 20.13. In this picture, they appear in color, the way you would normally see them. In **Figure** 20.14, they appear without color, in shades of gray.

FIGURE 20.12

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

## 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** 20.15). They also had to be able to judge which fruits were ripe and which were still green. Ripe fruits are usually red, orange, yellow, or purple. Being able to see in color was important for finding food. It was an adaptation that would help fruit-eating primates survive.

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

FIGURE 20.13
Humans with color vision see the apples on this tree; the bright red color of the apples stands out clearly from the green background of leaves.

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

## How the Eye Works

The job of the eye is to focus light. The parts of the eye, shown in **Figure** 20.16, help it to carry out its job. Follow the path of light through the eye as you read about it below.

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

FIGURE 20.15
With color vision, you can tell which cherries in this picture are ripe, because cherries turn red as they ripen.

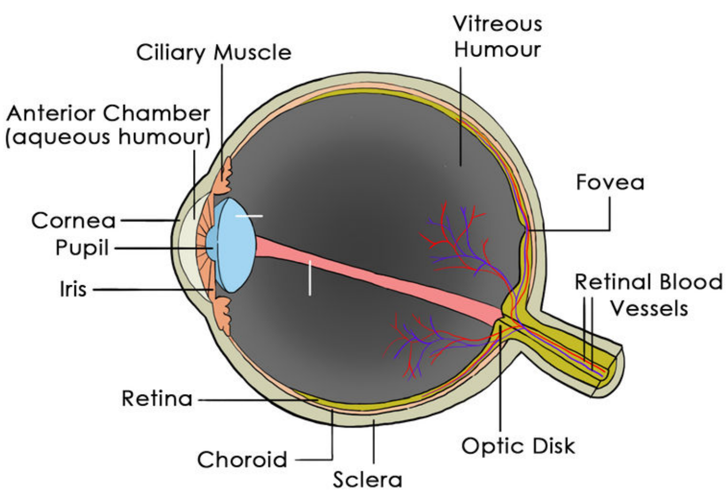


FIGURE 20.16
The human eye is a complex structure that senses light; the light passes through the cornea, pupil, and lens, and is focused on the retina.

the eye.

2. Next, light passes through the pupil. The **pupil** is a black opening in the eye that lets light enter the eye. Surrounding the pupil is the **iris,** most commonly brown, blue, gray, or green.
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 shown in **Figure** 20.17.
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 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.

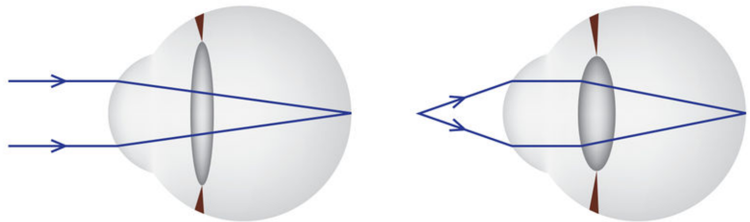

FIGURE 20.17
Light from objects at different distances is focused by the lens of the eye. Muscles in the eye control the shape of the lens so the light is focused on the back of the eye no matter how far the object is from the lens.

### The Nature of Light

Now you know that eyes sense light. But do know what light is? You need to understand light to fully understand vision.

**Visible light** is a type of electromagnetic (EM) radiation. EM Radiation describes how waves move through space. Other types of EM Radiation include microwaves. But visible light is the only type of EM radiation that can be sensed by the human eye. To be visible to humans, EM radiation has to travel in waves of certain wavelengths. **Wavelength** is the distance from any point on one wave to the same point on the next wave. The different types of electromagnetic radiation are shown in **Figure** 20.18. Just a small part of the full range of EM radiation is visible to the human eye.

### Colors of Light

Visible light from the sun does not have color. But if you bend visible light by passing it through a prism, it produces a "rainbow" of light of different colors ( **Figure** 20.19). Why does this happen? Different colors of visible light have slightly different wavelengths. Light of different wavelengths bends by different degrees when it passes through a prism. This separates visible light into all of its colors.

### Light and Vision

Except for objects that give off their own light, we don't see things just because light strikes them. We see things because light strikes them and then reflects, or bounces back, from their surface. What we see is the reflected light. Some things reflect all the light that strikes them. These things appear white. Some things do not reflect any light. Instead, they absorb all the light that strikes them. These things appear black. Other things, like the beads in **Figure** 20.20, reflect just one wavelength of light. Whatever wavelength they reflect is the color we see. For example, beads that reflect only red light look red to us.

## Lenses and Vision Correction

You probably know people that need eyeglasses or contact lenses to see clearly. Maybe you need them yourself. Lenses are used to correct vision problems. Two of the most common 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. How a person with myopia might see two boys that are a few

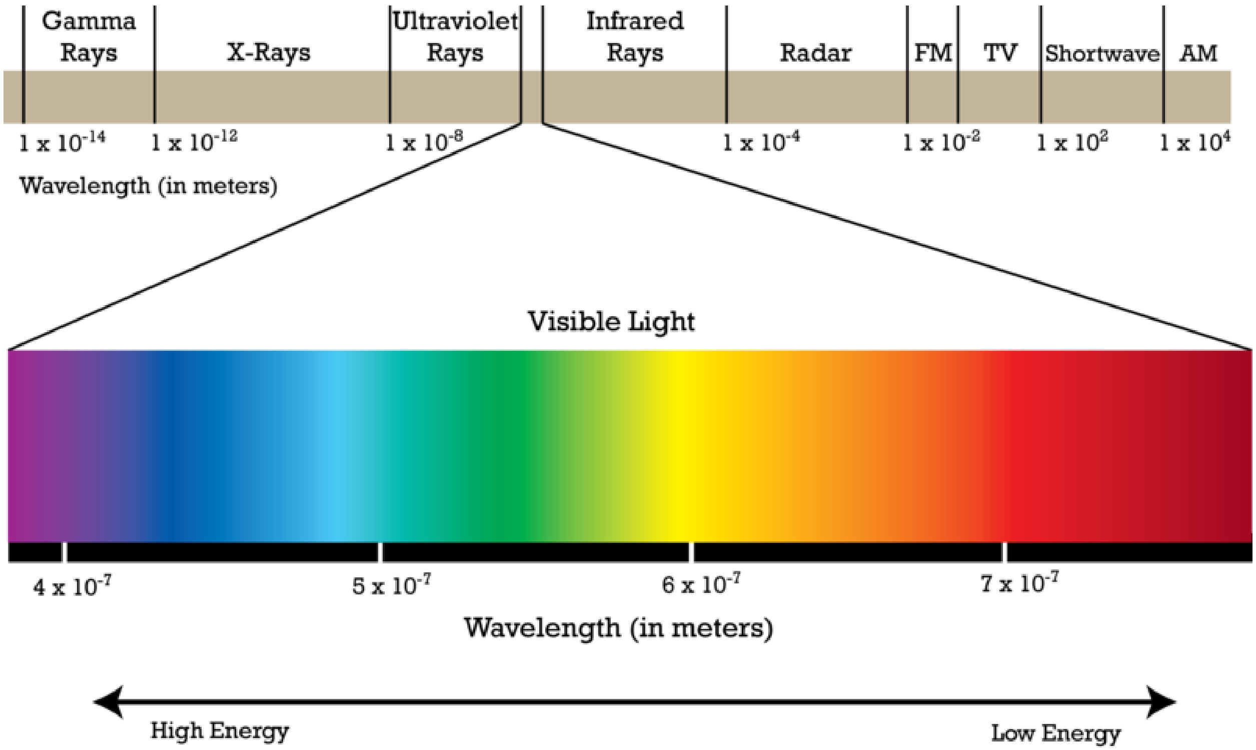


FIGURE 20.18
This diagram shows the wavelengths of electromagnetic radiation, from shortest (extreme left) to longest (extreme right); the human eye can sense only visible light, which falls in a narrow range of wavelengths, but the eyes of some animals can detect radiation of different wavelengths;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

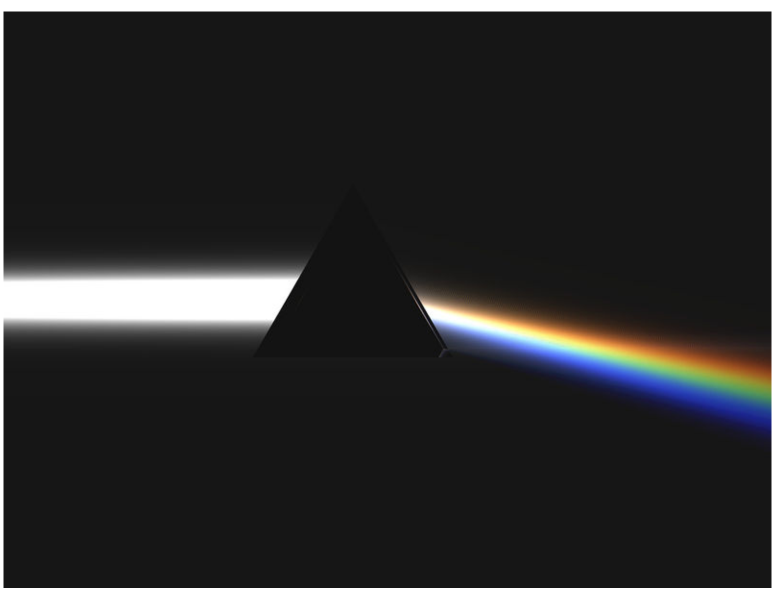

FIGURE 20.19
A prism bends white light to create a "rainbow" of red, orange, yellow, green, blue, indigo, and violet light.

FIGURE 20.20
These plastic beads reflect light of different wavelengths, so they appear to be different colors.

meters away is shown in **Figure** 20.21.

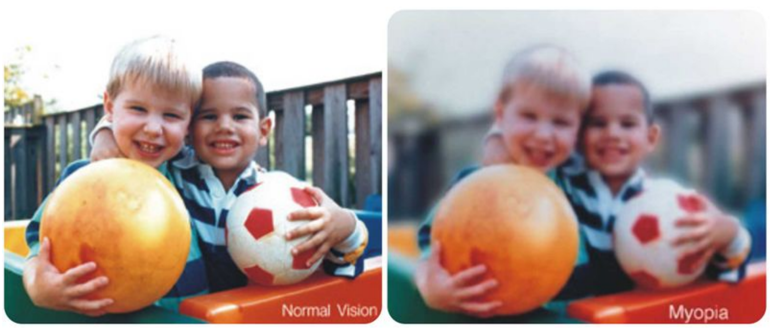


FIGURE 20.21
On the left, you can see how a person with normal vision sees two boys. The right image shows how a person with myopia sees the boys.

In myopia, the eye is too long. In **Figure** 20.22, you can see how images are focused on the retina of someone with myopia. 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.

### 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. As shown in **Figure** 20.22, this results in images being focused in back of the retina. Hyperopia is corrected with a convex lens, which curves outward like the outside of a bowl. The lens changes the focus so images fall on the retina as they should.

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

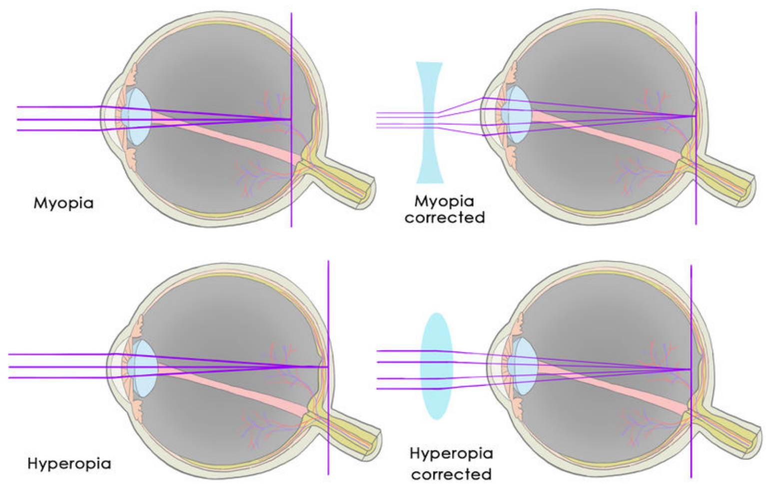


FIGURE 20.22
The eye of a person with myopia is longer than normal. As a result, images are focused in front of the retina (top left), A concave lens is used to correct myopia to help focus images on the retina (bottom left). Farsightedness occurs when objects are focused in back of the retina (top right). It is corrected with a convex lens (bottom right).

## Lesson Summary

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

## Further Reading / Supplemental Links

- Body Atlas. *Nerves, Brain and Senses.* Ticktock Media Ltd., 2004.
- Donald B. Light. *The Senses.* Chelsea House Publications, 2004.
- Christopher Sloan. *The Human Story: Our Evolution from Prehistoric Ancestors to Today.* National Geographic Children's Books, 2004.

## Review Questions

### Recall

1. What is vision?
2. Describe the lens of the eye and what it does.
3. What is hyperopia?

### Apply Concepts

4. What happens when light is focused on the retina of the eye?
5. Black is sometimes defined as the absence of light. Why?
6. Assume you see a bright red apple. Why does the apple look red?
7. What causes myopia, and what type of lens corrects it?

### Critical Thinking

8. Explain how humans can see in three dimensions.
9. Why were depth perception and color vision important for early primates?

## Points to Consider

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

# 20.3 Other Senses

## Lesson Objectives

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

## Check Your Understanding

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

## Vocabulary

- anvil
- cochlea
- ear
- ear canal
- eardrum
- hammer
- hearing
- oval window
- pinna
- reflex arc
- semicircular canals
- stirrup
- taste buds
- touch

## Hearing and Balance

Imagine walking through the fruit market shown in **Figure** 20.23. What do you sense with your eyes? All of the brightly colored fruits. You would also hear the noisy bustle of the market. As you checked to see if a piece of fruit was firm, you would feel its smooth skin. If you tried a sample of the fruit, you would taste its juicy sweetness. Clearly, a market like this is a feast for all of the senses. In this lesson, you will read how your nervous system senses the sound, feel, taste, and smell of a market like this —and of everything else around you.

FIGURE 20.23
This outdoor fruit market stimulates all the senses —sight, sound, smell, taste, and touch.

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

### Hearing

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

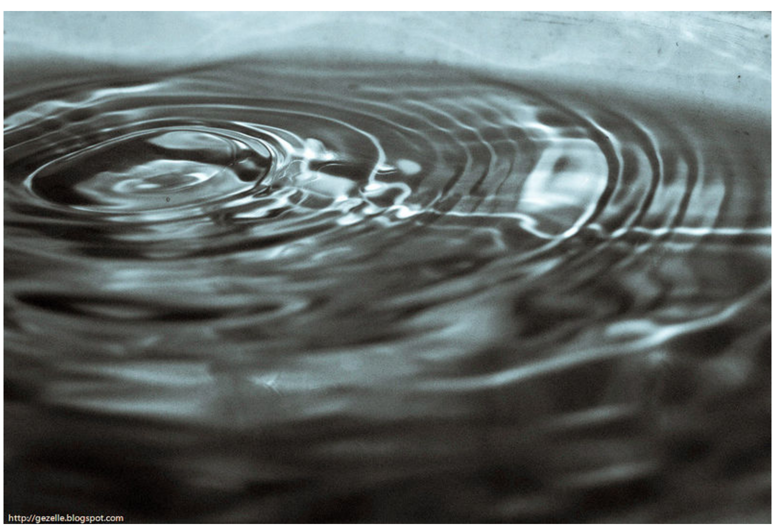


FIGURE 20.24
Sound waves travel through the air in all directions away from a sound like waves traveling through water away from where a pebble was dropped.

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

Assume a car horn blows in the distance. Sound waves spread through the air from the horn. Some of the sound waves reach your ear. The steps below show what happens next. They explain how your ears sense the sound.

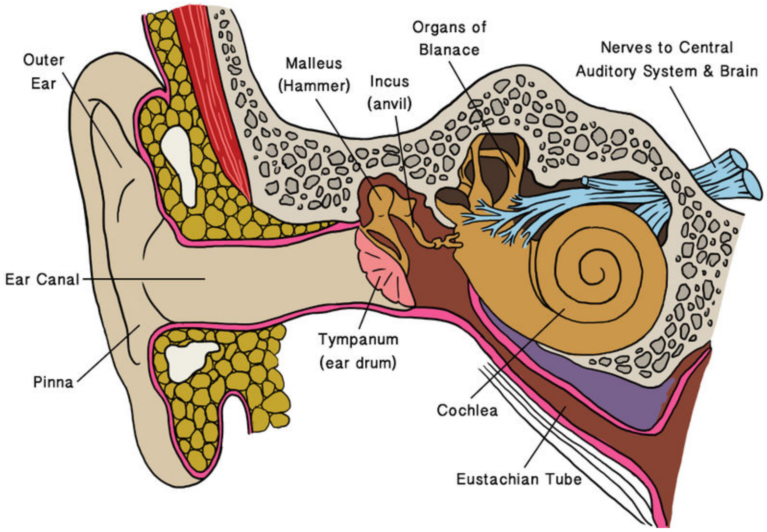


FIGURE 20.25
Read the names of the parts of the ear in the text, then find each of the parts in the diagram.

1. The sound waves enter the **pinna**, or outer ear. This is the part of the ear you can see.
2. The sound waves travel to the **ear canal**. This is a tube-shaped opening in the ear.
3. At the end of the ear canal, the sound waves hit the **eardrum**. This is a thin membrane that vibrates like the head of a drum when sound waves hit it.
4. The vibrations pass from the eardrum to the **hammer**. This is the first of three tiny bones that pass vibrations through the ear.
5. The hammer passes the vibrations to the **anvil**, the second tiny bone that passes vibrations through the ear.
6. The anvil passes the vibrations to the **stirrup**, the third tiny bone that passes vibrations.
7. From the stirrup, the vibrations pass to the **oval window**. This is another membrane like the eardrum.
8. The oval window passes the vibrations to the **cochlea**. The cochlea is filled with liquid that moves when the vibrations pass through, like the waves in water when you drop a pebble into a pond. Tiny hair cells line the cochlea and bend when the liquid moves. When the hair cells bend, they release neurotransmitters.
9. The neurotransmitters trigger nerve impulses that travel to the brain through the auditory nerve. The brain 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 in **Figure** 20.26 may not realize it, but her ears —along with her cerebellum —are mostly responsible for her ability to perform on the balance beam.

The parts of the ears involved in balance are the **semicircular canals**. In **Figure** 20.25, the semicircular canals are the parts numbered 10. The canals contain liquid, and are like the bottle of water in **Figure** 20.27. When the bottle

FIGURE 20.26
This gymnast is using the semicircular canals in her ears, along with the cerebellum in her brain, to help keep her balance on the balance beam.

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. In response, the cerebellum sends commands to muscles to contract or relax so the body stays balanced.

FIGURE 20.27
This bottle of water models the semicircular canals in your ears. When you tip the bottle, the water moves up or down the sides of the bottle; when you tip your head, the liquid inside the semicircular canals moves up and down the sides of the canals. Tiny hair cells lining the canals sense the movement of liquid and send messages to the brain.

## Touch

When you look at the prickly cactus in **Figure** 20.28, 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 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 20.28
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. When messages avoid the brain in this way, it forms a **reflex arc**, like the one shown in **Figure** 20.29.

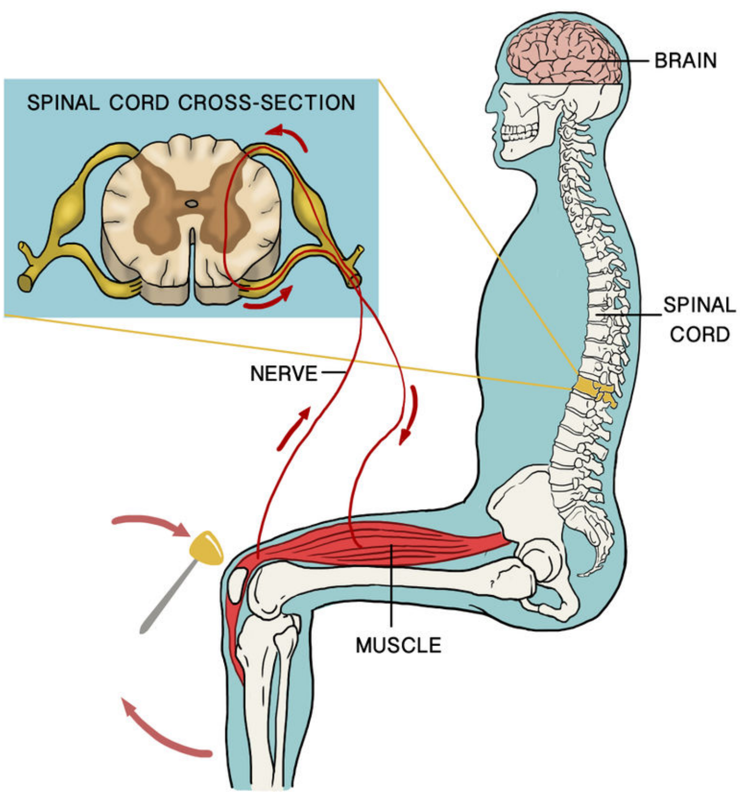


FIGURE 20.29
Reflex Arc: When a reflex hammer taps your knee, you may immediately kick your leg—without even thinking about it. The nerve impulse from your knee travels to the spinal cord, and the spinal cord sends a message to your muscles to kick your leg.

## Taste and Smell

Your sense of taste is controlled by sensory neurons on your tongue that sense the chemicals in food. The neurons are grouped in bundles within **taste buds** ( **Figure** 20.30). There are five different types of taste neurons on the tongue. Each type detects a different taste. The tastes are

1. Sweet.
2. Salty.
3. Sour.
4. Bitter.
5. Umami, which is a meaty taste.

When taste neurons sense chemicals, they send messages to the brain about them. The brain then decides what tastes you are sensing.

FIGURE 20.30
Tiny bumps that cover the tongue contain taste buds, bundles of sensory neurons that allow you to detect different types of tastes, such as sweet and salty tastes.

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. You experience the taste and smell at the same time. Being able to smell as well as taste food greatly increases the number of different tastes you are able to sense. For example, you can use your sense of taste alone to learn that a food is sweet, but you have to use your sense of smell as well to learn that the food tastes like strawberry cheesecake.

## Lesson Summary

- The ears detect sound waves and help maintain balance. The skin senses pain, pressure, and temperature.
- Sensory cells on the tongue and in the nose detect tastes and smells.
- The senses of hearing, balance, touch, taste, and smell give us information about our life and help keep us safe.

## Further Reading / Supplemental Links

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

- Donald B. Light. *The Senses.* Chelsea House Publications, 2004.
- Elaine Landau. *The Sense of Touch.* Children's Press, 2008.

## Review Questions

### Recall

1. What are the two main functions of the ears?
2. Which structure in the ear changes sound waves in the air into vibrations?
3. What happens after the oval window in the ear passes vibrations to the cochlea?
4. Which parts of the ear sense changes in the body's position?
5. What are the five tastes sensed by neurons on the tongue?

### Apply Concepts

6. Why does death of hair cells in the cochlea cause hearing loss?
7. How and why do reflex arcs occur?
8. Why is your sense of taste affected when you have a stuffy nose?
9. How could the ability to feel pain help prevent serious injury? Give an example.

### Critical Thinking

10. Explain the statement, "You listen with your ears, but you hear with your brain."

## Points to Consider

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

# 20.4 Health of the Nervous System

## Lesson Objectives

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

## Check Your Understanding

- What is the role of the nervous system?
- What are some of the main parts of the nervous system?

## Vocabulary

- concussion
- drug
- drug abuse
- drug addiction
- drug overdose
- hallucinogenic drug
- paralysis
- physical dependence
- stimulant drug
- tolerance
- tumor
- withdrawal

## Nervous System Diseases

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

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

### Central Nervous System Infections

When you think of infections, you probably think of an ear infection or strep throat. You probably don't think of a brain or spinal cord infection. But bacteria and viruses can infect these organs as well as other parts of the body. At the same time, 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** 20.31). 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.

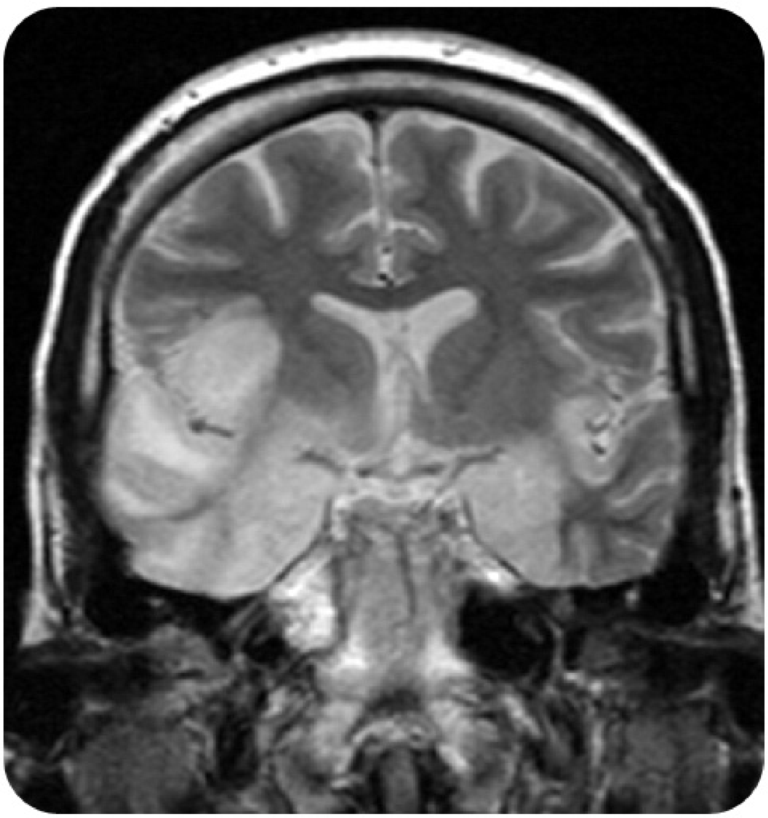

FIGURE 20.31
This scan shows a person with encephalitis.

### 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 headache. Another telltale symptom is a stiff neck. Meningitis can be caused by viruses or bacteria. Viral meningitis often clears up on its own after a few days. Bacterial meningitis is much more serious ( **Figure** 20.32). It may cause brain damage and death. People with bacterial meningitis need emergency medical treatment. They are usually given antibiotics to kill the bacteria.

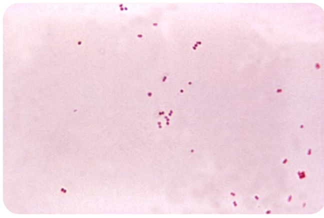

FIGURE 20.32
These bacteria —shown at more than 1,000 times their actual size - are the cause of bacterial meningitis. Despite their tiny size, they can cause very serious illness.

A vaccine to prevent meningitis recently became available. It can be given to children as young as 2 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** 20.33).

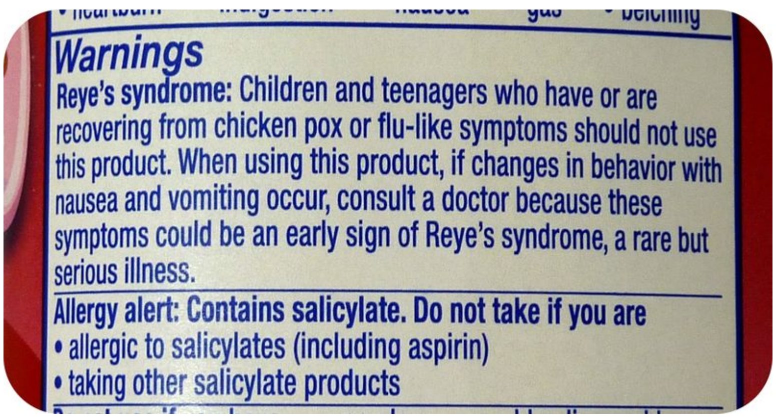


FIGURE 20.33
Since 1988, the U.S. Food and Drug Administration has required that all aspirin and aspirin-containing products carry this warning label.

### Other Nervous System Diseases

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

Cerebral palsy is a disease caused by injury to the developing brain. The injury occurs before, during, or shortly after birth. Cerebral palsy is more common in babies that have a low weight at birth. 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, brain injury, or tumor. The seizures of epilepsy can often be controlled with medicine. There is no known cure for the disease, but children with epilepsy may outgrow it by adulthood.

A headache is a very common nervous system problem. Headaches may be a symptom of serious diseases, 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 ( **Figure** 20.34). Mild pain relievers such as ibuprofen may also help.

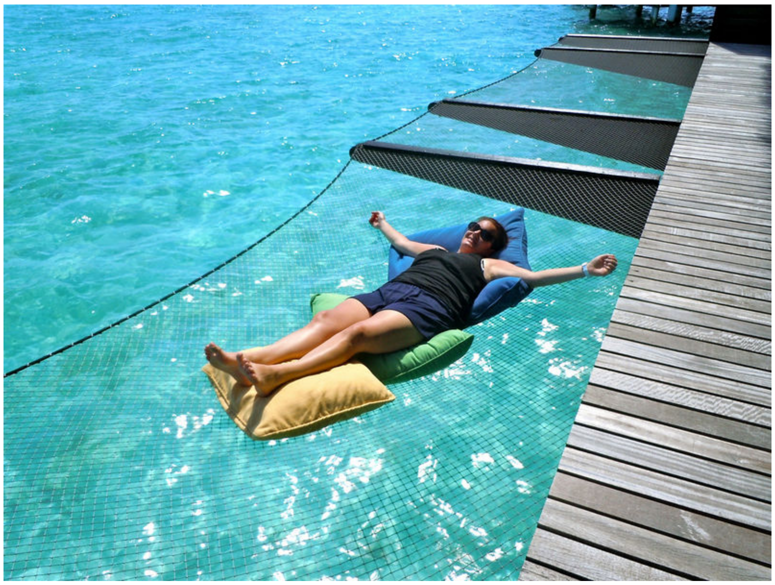

FIGURE 20.34

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 in **Table** 20.2. The diseases have no known cure, but medicines may help control their symptoms.

**TABLE 20.2: Incurable Nervous System Diseases**

| 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 |

## Injuries to the Central Nervous System

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

### Brain Injuries

The mildest and most common type of brain injury is a **concussion**. This is a bruise on the surface of the brain. It may cause temporary problems such as headache, drowsiness, and confusion. Most concussions in young people occur when they are playing sports, especially contact sports like football. A concussion normally heals on its own in a few days.

A single concussion is unlikely to cause permanent damage. But repeated concussions may lead to lasting problems. People that have had two or more concussions may have life-long difficulties with memory, learning, speech, or balance. You can see an animation of a how a concussion occurs by visiting http://www.pennmedicine.org/encyclopedia/em_DisplayAnimation.aspx?gcid=000034&ptid=17 .

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

### Spinal Cord Injuries

Spinal cord injuries 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.

Some people recover from spinal cord injuries. But many people are paralyzed for life. Thanks to the work of Christopher Reeve ( **Figure** 20.35), 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.

## Dangers of Alcohol and Other Drugs

A **drug** is any chemical substance that affects the body or brain. Some drugs are medicines ( **Figure** 20.36). Although these drugs are helpful when used properly, they can be misused like any other drugs. Drugs that aren't medicines include both legal and illegal drugs. Examples of legal drugs are alcohol and caffeine. Although these drugs can be used legally by adults, they can still do harm. Examples of illegal drugs include marijuana and cocaine.

### Types of Psychoactive Drugs

Drugs like alcohol, marijuana, and cocaine affect the brain. Drugs that affect the brain are called psychoactive drugs. They influence how a person feels, thinks, or acts.

FIGURE 20.35
Former *Superman* star Christopher Reeve was paralyzed from the neck down in a fall from a horse. The injury crushed his spinal cord so his brain could no longer communicate with his body.

FIGURE 20.36
Drugs that are prescribed by a doctor can be misused just like illegal drugs.

If you think you have never used a psychoactive drug, think again. Do you drink soft drinks, such as colas? Most of them contain caffeine, which is a psychoactive drug. Caffeine is also found in coffee and chocolate ( **Figure** 20.37).

FIGURE 20.37
All three of these popular products contain the stimulant drug caffeine.

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

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

Examples of depressant drugs include alcohol and morphine.

- A **hallucinogenic drug** is a psychoactive drug that can cause strange sensations, perceptions, and thoughts. Examples of hallucinogenic drugs include marijuana and LSD.

### Drug Abuse

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

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

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

## Keeping the Nervous System Healthy

There are many choices you can make to keep your nervous system healthy. One obvious choice is to avoid using alcohol or other drugs. Not only will you avoid the injury that drugs themselves can cause. You will also be less likely to get involved in other risky behaviors that could harm your nervous system. Another way to keep the nervous system healthy is to eat a variety of healthy foods. The minerals calcium and potassium and vitamins $B_1$ and $B_{12}$ are important for a healthy nervous system. Some foods that are good sources for these minerals and vitamins are shown **Figure** 20.38.

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** 20.39).
- Wear a safety belt every time you ride in a motor vehicle.
- Avoid unnecessary risks, such as performing dangerous stunts on your bike.
- Never dive into water that is not approved for diving. If the water is too shallow, you could seriously injure your brain or spinal cord. A few minutes of fun could turn into a lifetime in a wheelchair.


FIGURE 20.38
These foods are sources of nutrients needed for a healthy nervous system.

## Lesson Summary

- The nervous system can be affected by infections, tumors, and other diseases.
- Brain or spinal cord injuries may cause permanent disability or even death.
- The use of psychoactive drugs can lead to drug abuse or addiction.
- You can make choices that will help keep your nervous system healthy and safe.

## Review Questions

### Recall

1. What is encephalitis?

FIGURE 20.39
Bicycle helmets help protect from head injuries. Making healthy choices like this can help prevent nervous system injuries that could cause lifelong disability.

2. List symptoms of a concussion.
3. Define "psychoactive drug" and name two examples.

### Apply Concepts

4. List three choices you can make to keep your nervous system healthy.
5. What causes muscle weakness in cerebral palsy?
6. Compare and contrast tension headaches and migraine headaches.
7. Explain what causes paralysis.
8. Which type of psychoactive drug is caffeine? How does caffeine affect the nervous system?

### Critical Thinking

9. Explain why young people should not take aspirin when they have the flu, which is caused by viruses.
10. How is drug tolerance related to drug overdose?

## Further Reading / Supplemental Links

- CK12 High School *Biology,* Chapter 35.
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- Terry Trueman. *Stuck in Neutral.* HarperTeen, 2001.
- http://kidshealth.org/kid/htbw/brain.html
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- http://www.mayoclinic.com/health/migraine-headache/DS00120/DSECTION=causes

## Points to Consider

Next we look more at diseases.

- Give examples of pathogens.
- How do you think pathogens can cause disease?

# 20.5 References


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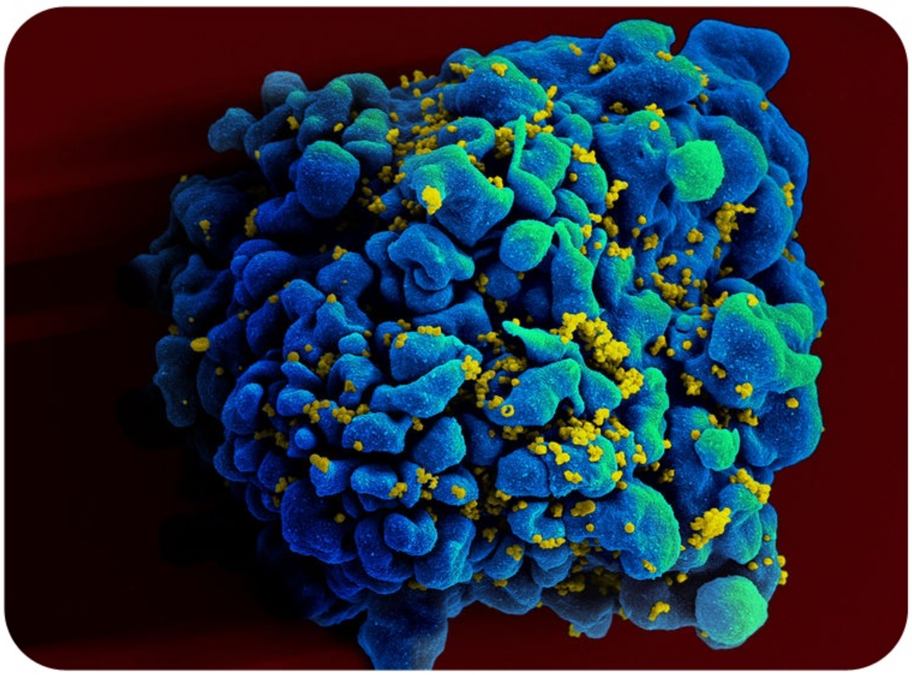
# Chapter 21 MS Diseases and the Body's Defenses

## Chapter Outline





What does the above image look like to you? It is actually a scanning electromicrograph of an HIV-infected H9 T cell. HIV is a deadly virus that is difficult for most humans to remove from their bodies.

You have an immune system that is supposed to stop viruses from infecting your body. So how do HIV and other diseases outsmart the body's immune system? What can we do to prevent HIV and other diseases from infecting our bodies? Why can't medicines cure HIV, but they can cure other illnesses?

Just because human immune systems cannot get rid of HIV, they still help people clear viruses and bacteria every moment of every day. How does the immune system remove dangerous diseases from our bodies? How can we improve our immune system's response to disease?

Your immune system is one of the most complex and interesting systems in your body. Consider the above questions as you read about the amazing ways that immune systems respond to diseases and also how they are limited by dangerous diseases, like HIV.

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# 21.1 Infectious Diseases

## Lesson Objectives

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

## Check Your Understanding

- What are bacteria?
- What is blood made out of?

## Vocabulary

- AIDS
- HIV
- infectious disease

## Causes of Infectious Diseases

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 in **Figure** 21.1. Some types of pneumonia and many cases of illnesses from food are also caused by bacteria.

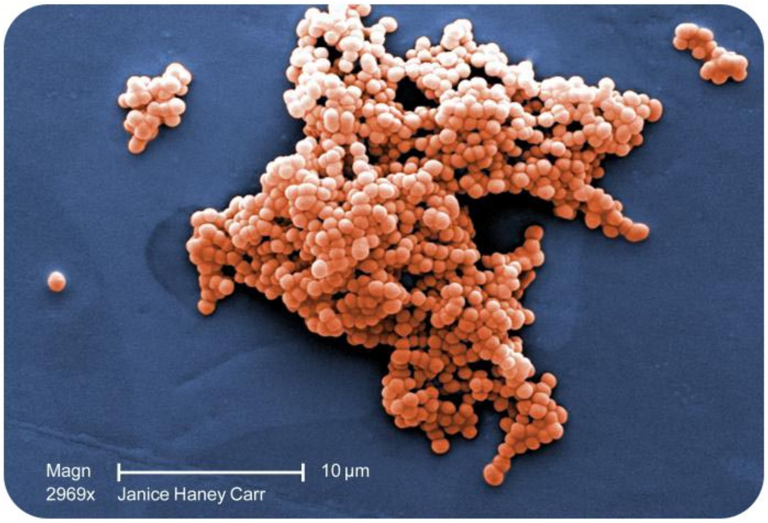


FIGURE 21.1
The structures that look like strings of beads are bacteria. They belong to the genus *Streptococcus*. Bacteria of this genus cause diseases such as strep throat and pneumonia. They are shown here 900 times bigger than their actual size.

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

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

Protozoa are one-celled eukaryotes. 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*, which is shown in **Figure** 21.3.

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*. This virus is shown in **Figure** 21.4. Antibiotics do not affect viruses, because antibiotics only kill bacteria. But medicines called antiviral drugs can treat many diseases caused by viruses.

## How Pathogens Spread

Different pathogens spread in different ways. Some pathogens spread through food. They cause food borne illnesses. These illnesses were discussed in the *Food and Digestive System* chapter. Some pathogens spread through water. *Giardia lamblia* is one example.

FIGURE 21.3
This picture shows a one-celled organism called *Giardia lamblia*. It is a protozoan that causes diarrhea.

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

Water can be boiled to kill *Giardia* and most other pathogens. Several pathogens spread through sexual contact. HIV is one example. It is a virus you will read about below. Other pathogens that spread through sexual contact are discussed in the *Reproductive Systems and Life Stages* chapter.

Many pathogens that cause respiratory diseases spread by droplets in the air. Droplets are released when a person sneezes or coughs. Thousands of tiny droplets are released when a person sneezes, as shown in **Figure** 21.5. 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 21.5
As this picture shows, thousands of tiny droplets are released into the air when a person sneezes. Each droplet may carry thousands of pathogens. You can't normally see the droplets from a sneeze because they are so small. However, you can breathe them in, along with any pathogens they carry. This is how many diseases of the respiratory system are spread.

### 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 an infected person has worn. You can also pick up this fungus from the floor of a public shower. After acne, athlete's foot is the most common skin disease in the United States. Therefore, the chance of coming in contact with the fungus in one of these ways is fairly high.

Bacteria that cause the skin disease impetigo can spread when people share towels or clothes. The bacteria can also spread through direct skin contact in sports like wrestling.

### 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, like the one in **Figure** 21.6, carry West Nile virus. Both pathogens cause fever, headache, and tiredness. If the diseases are not treated, more serious symptoms may develop.

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

## 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.

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

### 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.

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 and the Immune System

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

You will read more about the immune system later in this chapter. HIV invades helper T cells and uses them to reproduce. This is shown in **Figure** 21.7. Then, the virus kills the helper T cells. As the number of viruses in the blood rises, the number of helper T cells falls. Without helper T cells, the immune system is unable to protect the body. 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.

### AIDS

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

The first known cases of AIDS occurred in 1981. Since then, AIDS has led to the deaths of more than 25 million

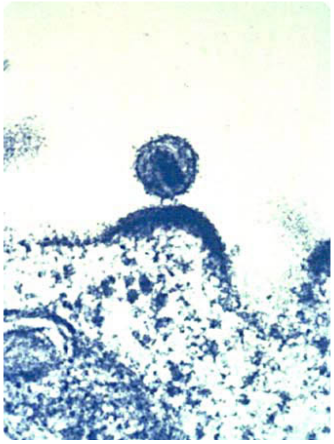

FIGURE 21.7
In this picture, the large structure on the left is a helper T cell. It is infected with HIV. The many small circles on the right are new HIV viruses being shed by the T cell.

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.

## Preventing Infectious Diseases

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

You can also take steps to avoid pathogens in the first place. The 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 wash your hands after being around sick people. The correct way to wash your hands is demonstrated in **Figure** 21.8. If soap and water aren't available, use a hand sanitizer. A hand sanitizer that contains at least 60 percent alcohol will kill most germs on your hands.

The best way to prevent diseases spread by vectors is to avoid contact with the vectors. For example, you can wear long sleeves and long pants to avoid tick and mosquito bites. Using insect repellent can also reduce your risk of insect bites. Many infectious diseases can be prevented with vaccinations. You will read more about vaccinations later in this chapter. 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.

## Lesson Summary

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


FIGURE 21.8

This picture shows the proper way to wash your hands. Frequent hand washing helps prevent the spread of pathogens.

## Review Questions

### Recall

1. Name two examples of infectious diseases.
2. What is a pathogen?
3. List three ways that pathogens can spread.
4. What is HIV?
5. What is the single most important way to avoid pathogens?

### Apply Concepts

6. Why do antibiotics not cure the common cold?
7. Explain why covering your mouth when you cough helps prevent the spread of germs.
8. What role do vectors play in the spread of infectious diseases?
9. How does an HIV infection develop into AIDS?

### Critical Thinking

10. Explain to a friend why using insect repellent reduces your risk of developing Lyme disease.
11. Explain why HIV does not kill people, but causes other illnesses to kill people infected with HIV.

## Further Reading / Supplemental Links

- Jenna Bush. *Ana's Story: A Journey of Hope*. Harper Collins, 2007.
- Scientific American. *Germ Wars: Battling Killer Bacteria and Microbes*. Rosen Publishing Group, 2008.
- http://www.cdc.gov/ncidod/dvbid/westnile/index.htm
- http://www.mayoclinic.com/health/germs/ID00002
- http://www.mayoclinic.com/health/infectious-disease/ID00004
- http://www.nlm.nih.gov/medlineplus/infectiousdiseases.html
- http://www.who.int/mediacentre/factsheets/fs094/en/index.html
- http://www.nlm.nih.gov/medlineplus/infectiousdiseases.html
- http://www.who.int/mediacentre/factsheets/fs094/en/index.html

## Points to Consider

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

# 21.2 Noninfectious Diseases

## Lesson Objectives

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

## Check Your Understanding

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

## Vocabulary

- allergy
- autoimmune disease
- diabetes
- noninfectious disease
- type 1 diabetes
- type 2 diabetes

## Causes of Noninfectious Diseases

Not all diseases spread from person to person. A disease that does not spread from person to person is called a **noninfectious disease**. An examples is cancer. Certain cancers may or may not be caused by pathogens.

Most noninfectious diseases have more than one cause. The causes may include genes and an unhealthy lifestyle. Having a specific gene may increase the chances that people will have certain diseases. But other factors, like lifestyle, may determine if the diseases actually develop. For example, what people eat or whether they smoke may also play a role in whether or not a person gets cancer.

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

## Cancer

Cancer is a disease 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.

### What Causes Cancer?

Cancer is usually caused by mutations. From the *Cell Division, Reproduction, and DNA* chapter, you know that mutations are random errors in genes. Mutations that lead to cancer usually 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. **Figure** 21.9, **Figure** 21.10, and **Figure** 21.11 give examples of carcinogens.

### Pathogens

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

### Chemicals

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

### Radiation

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

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.

### Common Types of Cancer

Cancer is usually found in adults, especially in adults over age 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.

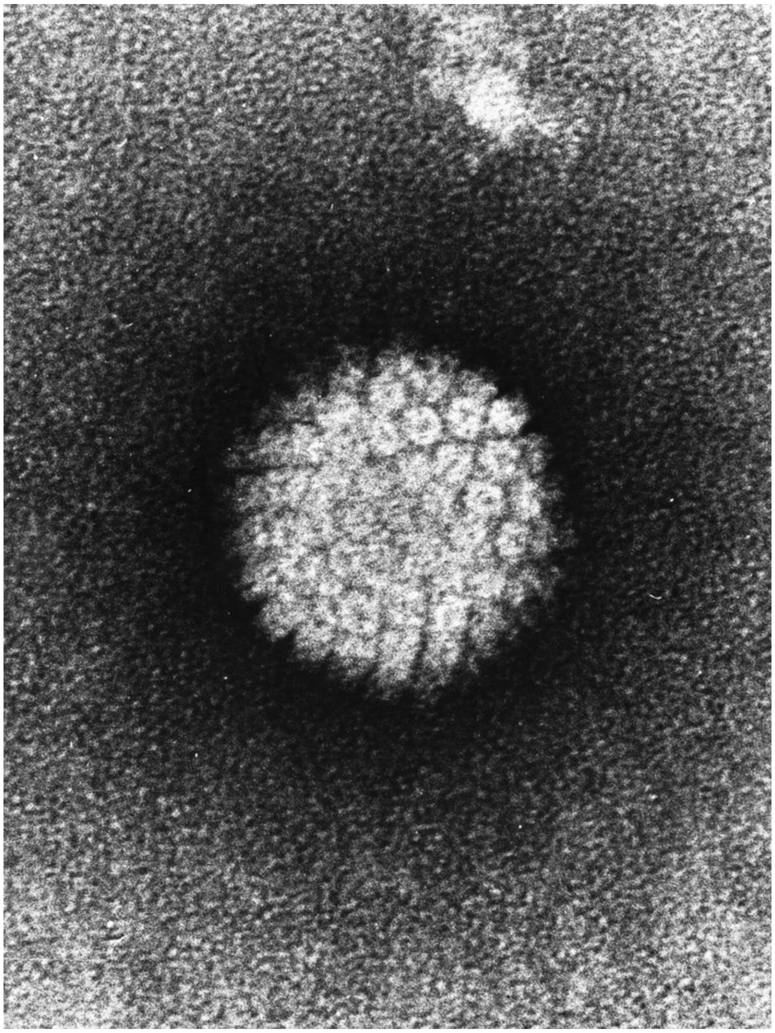

FIGURE 21.9

The mutations that cause cancer may occur when people are exposed to pathogens, such as the human papilloma virus (HPV), which is shown here.

FIGURE 21.10

The mutations that cause cancer may occur when people are exposed to chemical carcinogens, such as those in cigarettes.

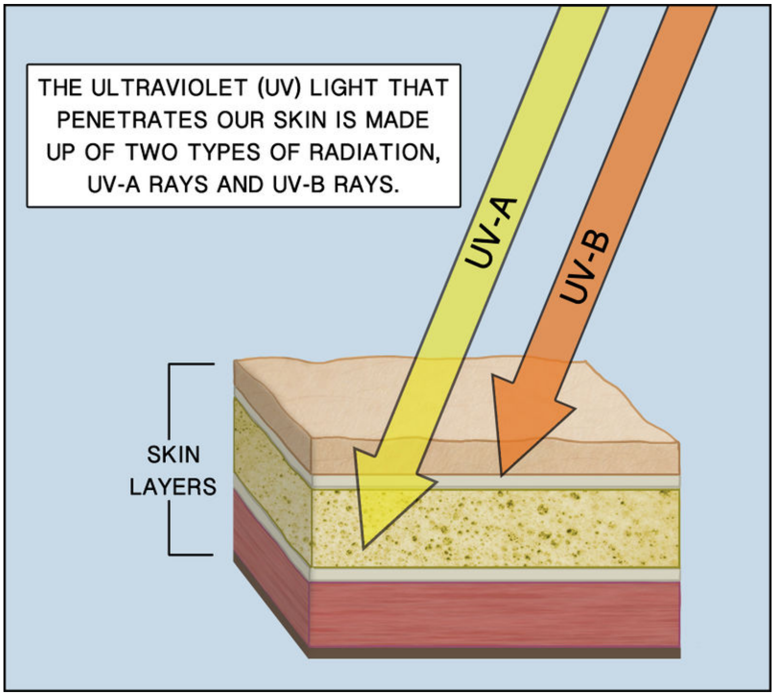


FIGURE 21.11
The mutations that cause cancer may occur when people are exposed to radiation, including the radiation from sunlight.

### Treating Cancer

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

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

## Diabetes

Another noninfectious disease is diabetes. **Diabetes** happens when the pancreas cannot make enough 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 to 10 percent of all cases of diabetes in the United States. Type 2 diabetes accounts for most of the other cases. Both types of diabetes are more likely in people that have certain genes. 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** happens when the immune system attacks normal cells of the pancreas. Since the cells in the pancreas are damaged, the pancreas cannot make insulin. Something in the environment causes the immune system to attack the pancreas, but it is unknown. Scientists think that the cause may be a virus. Type 1 diabetes usually develops in childhood or adolescence.

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


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

### Type 2 Diabetes

**Type 2 diabetes** happens when body cells can no longer use insulin. The pancreas may still make insulin, but the cells of the body cannot use it. 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. Like people with type 1 diabetes, people with type 2 diabetes must frequently check their blood sugar.

## Diseases of the Immune System

The immune system usually protects you from pathogens and other causes of disease. Later in this chapter, you will read more about how the immune system works. 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.

In the last lesson you read about AIDS. AIDS is an infectious disease of the immune system caused by a virus. Some diseases of the immune system are noninfectious. They include autoimmune diseases and allergies.

### 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.

### Allergies

An **allergy** is 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. A ragweed plant is shown in **Figure** 21.13.

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

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

- Drugs such as penicillin.
- Mold.
- Dust.
- The dead skin cells, called dander, of dogs and cats.

FIGURE 21.13
Ragweed is a common roadside weed found throughout the United States. Many people are allergic to its pollen.

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

- Stings of wasps and bees.

To learn more about allergies and their causes, go to http://topics.healthvideo.com/m/21404533/seasonal-and-chronic-allergies.htm#q=OR+Allergy+OR+Allergies . You can watch a video about allergies at this Web site.

Most allergies can be treated with medicines. Medicines used to treat allergies include antihistamines and corticosteroids. These medicines help control the immune system when it attacks an allergen.

Sometimes, allergies cause severe symptoms. For example, they may cause the throat to swell so it is hard to breathe. Severe allergies may be life threatening. They require emergency medical care.

## Preventing Noninfectious Diseases

Most allergies can be prevented by avoiding the substances that cause them. For example, you can avoid pollens by staying indoors as much as possible. You can learn to recognize plants like poison ivy and not touch them. A good way to remember how to avoid poison ivy is "leaves of three, let it be."

Some people receive allergy shots to help prevent allergic reactions. The shots contain tiny amounts of allergens. After many months or years of shots, the immune system gets used to the allergens and no longer responds to them.

Type 1 diabetes and other autoimmune diseases cannot be prevented. 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 that 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. For example, you can reduce your risk of lung cancer by not smoking. You can reduce your risk of skin cancer by using sunscreen. How to choose a sunscreen that offers the most protection is explained in **Figure** 21.15. Some people think that tanning beds are a safe way to get a tan. This is a myth. Tanning beds expose the skin to UV radiation. Any exposure to UV radiation increases in the risk of skin cancer. It doesn't matter whether the radiation comes from tanning lamps or the sun.


FIGURE 21.15

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

## Lesson Summary

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

## Review Questions

### Recall

1. What is a noninfectious disease?
2. List three carcinogens.
3. What other health problems are more likely in people with diabetes?
4. What causes rheumatoid arthritis?
5. How can you reduce your risk of developing skin cancer?

### Apply Concepts

6. Explain how mutations can lead to cancer.
7. Why are frequent urination and excessive thirst symptoms of diabetes?
8. Compare and contrast type 1 and type 2 diabetes.

### Critical Thinking

9. Some allergies affect people during certain seasons, while affect people year-round. Give examples of allergens that you would expect to cause each type of allergy.

10. Why is maintaining a healthy weight especially important for people that have family members with type 2 diabetes?

## Further Reading / Supplemental Links

- Amy M. Mareck. *Fighting for My Life: Growing up with Cancer*. Fairview Press, 2005.
- Jillian Powell. *Allergies*. Cherrytree Books, 2008.
- Marlene Targ Birll. *Diabetes*. Twenty-First Century Books, 2007.
- http://www.cancerindex.org/ccw/guide2c.htm
- http://www.mayoclinic.com/health/allergy/AA99999

## Points to Consider

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

# 21.3 First Two Lines of Defense

## Lesson Objectives

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

## Check Your Understanding

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

## Vocabulary

- fever
- inflammation
- mucus
- phagocytes
- phagocytosis

## First Line of Defense

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

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

### Skin and Mucous Membranes

The skin is a very important barrier to pathogens. The skin is the body's largest organ. In adults, it covers an area of about 16 to 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. As shown in **Figure** 21.16, the skin has several layers. The outer layer is tough and waterproof. It is very difficult for pathogens to get through this layer of skin.

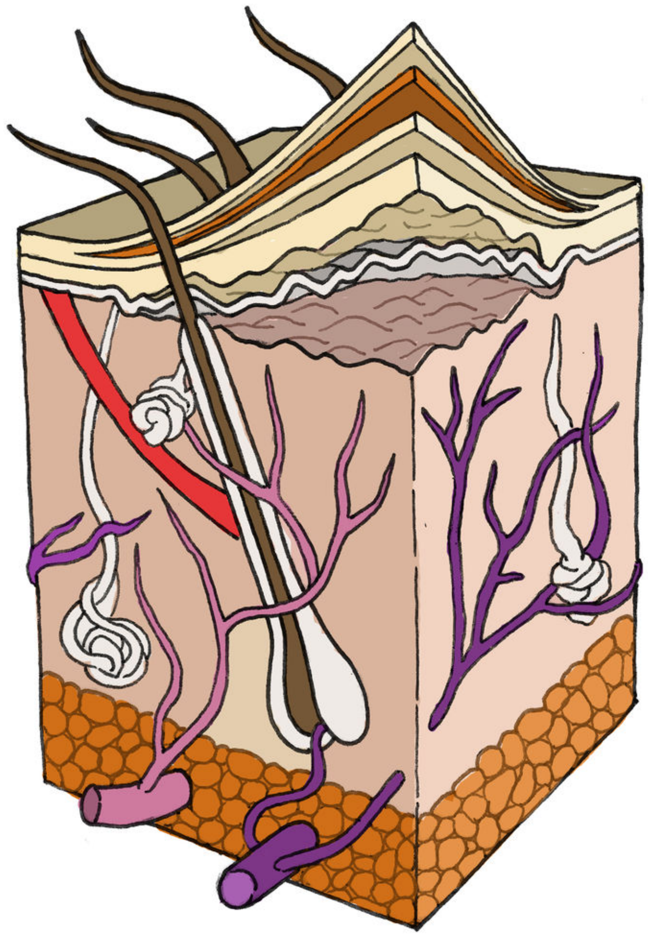

FIGURE 21.16
This drawing shows that the skin has many layers. The outer layer is so tough that it keeps out most pathogens.

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 shown in **Figure** 21.17. Cilia are like 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.

### Chemicals

Most body fluids that you release from your body contain chemicals that kill pathogens. For example, mucus, sweat, tears, and saliva contain enzymes that kill pathogens. The enzymes are called lysozymes. They break down the cell walls of bacteria 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.

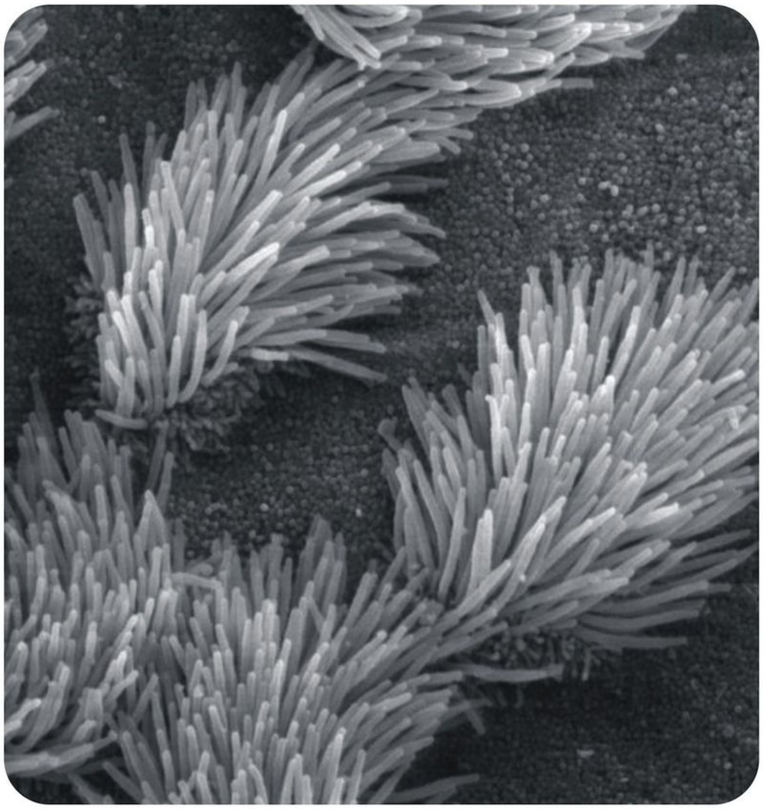

FIGURE 21.17
This is what the cilia lining the lungs look like when they are magnified. Their movements constantly sweep mucus and pathogens out of the lungs. Do they remind you of brushes?

### Helpful Bacteria

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

## Second Line of Defense

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

### Inflammation

If bacteria enter the skin through a scrape, the area may become red, warm, and painful. These are signs of inflammation. **Inflammation** is one way the body reacts to infections or injuries. Inflammation is 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. The chemicals also attract white blood cells to the wound and cause them to leak out of blood vessels into the damaged tissue. You can watch a video animation of this process at http://biology-animations.blogspot.com/search/label/inflammation .

FIGURE 21.18
This child just got a scraped leg. It doesn't seem to hurt, but the break in their skin could let pathogens enter their body. That's why scrapes should be kept clean and protected until they heal.

### White Blood Cells

After white blood cells leave a blood vessel at the site of inflammation, they start "eating" pathogens. From the *Cardiovascular System* chapter, you know that white blood cells are one type of cell that makes up the blood.

The main role of white blood cells is to fight pathogens in the body. There are actually several different kinds of white blood cells. Some white blood cells have very specific functions. They attack only certain pathogens. You will read about these white blood cells later in this chapter.

Other white blood cells attack any pathogens they find. These white blood cells travel to areas of the body that are inflamed. They are called **phagocytes**, which means "eating cells." In addition to pathogens, phagocytes "eat" dead cells. They surround the pathogens and destroy them. This process is called **phagocytosis**. You can watch a video of a phagocyte gobbling up and destroying a pathogen at http://sciencevideos.wordpress.com/2007/09/26/defense-against-infectious-disease/ .

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.

## Lesson Summary

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

## Review Questions

### Recall

1. How does your skin protect you from pathogens?
2. What is mucus?
3. Define inflammation.
4. What are phagocytes?
5. What is a fever?

### Apply Concepts

6. Explain how cilia help rid your body of pathogens.
7. How do helpful bacteria defend your body?
8. How does inflammation help fight pathogens?

### Critical Thinking

9. Why is phagocytosis called a *general* body defense?
10. A fever is a sign of infection. Why might it be considered a good sign?

## Further Reading / Supplemental Links

- Rebecca L. Johnson and Jack Desrocher. *Daring Cell Defenders*. Millbrook Press, 2007.
- Susan Heinrichs Gray. *The Skin*. Child's World, 2005.
- http://hypertextbook.com/facts/2001/IgorFridman.shtml
- http://www.biocarta.com/pathfiles/h_inflamPathway.asp
- http://www.nlm.nih.gov/medlineplus/ency/article/003090.htm

## Points to Consider

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

# 21.4 Immune System Defenses

## Lesson Objectives

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

## Check Your Understanding

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

## Vocabulary

- antigen
- immune response
- immune system
- immunity
- lymph
- lymph nodes
- lymphocytes
- vaccination

## What Is the Immune System?

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**. The immune system has a special response for each type of pathogen.

The **immune system** is also part of the lymphatic system - named for **lymphocytes**, which are the type of white blood cells involved in an immune response. You can see the parts of the immune system in **Figure** 21.19. They include several lymph organs, lymph vessels, lymph, and lymph nodes.

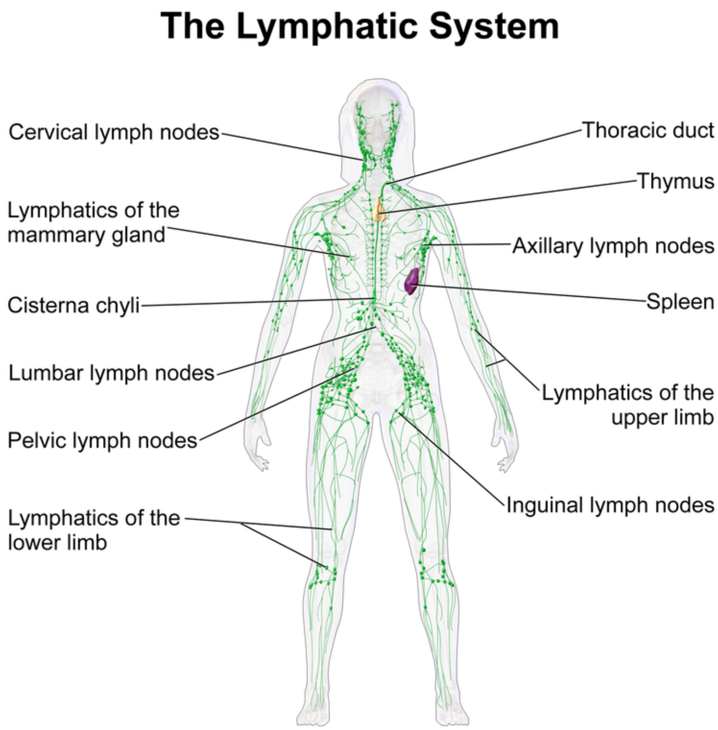


FIGURE 21.19
This diagram shows the parts of the immune system. The immune system includes several organs and a system of vessels that carry lymph. Lymph nodes are located along the lymph vessels.

## Lymph Organs

The lymph organs are the red bone marrow, thymus gland, spleen, and tonsils. Each organ has a different job in the immune system. They are described in **Figure** 21.20, **Figure** 21.21, **Figure** 21.22, and **Figure** 21.23.

## Lymph and Lymph Vessels

Lymph vessels make up a circulatory system that is similar to the cardiovascular system, which you read about in the *Cardiovascular System* chapter. Lymph vessels are like blood vessels, except they 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.

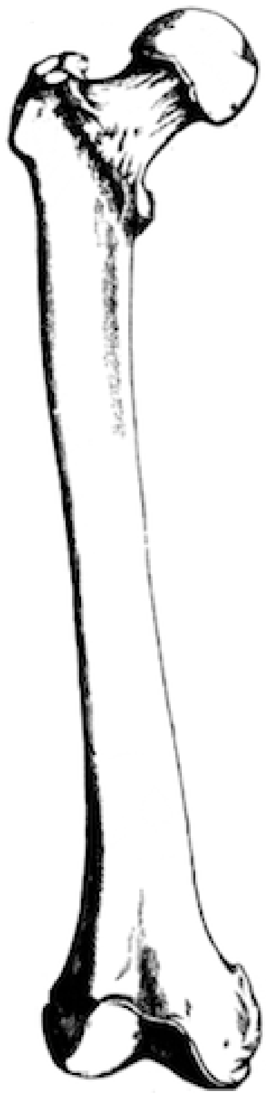

FIGURE 21.20

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

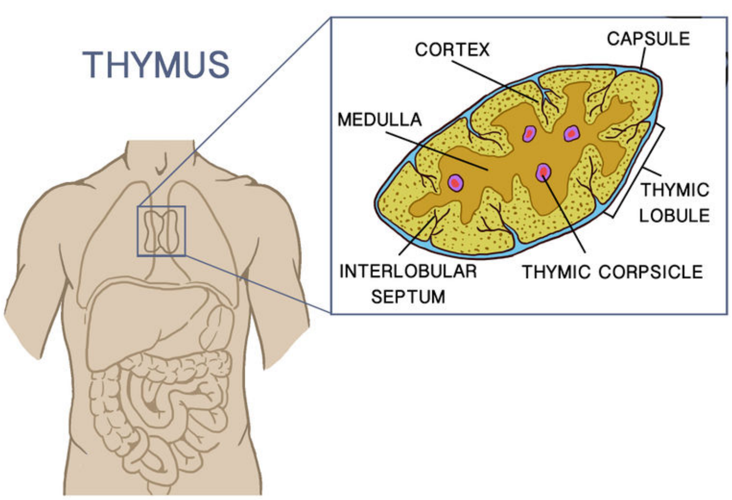


FIGURE 21.21

The thymus gland is in the chest behind the breast bone. It stores lymphocytes while they grow older.

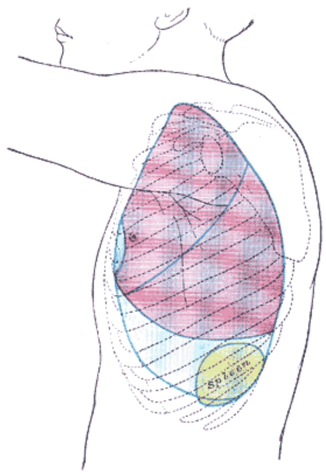


FIGURE 21.22
The spleen is in the abdomen below the lungs. Its job is to filter the toxins out of the blood. Any pathogens that are filtered out of the blood are destroyed by lymphocytes in the spleen.

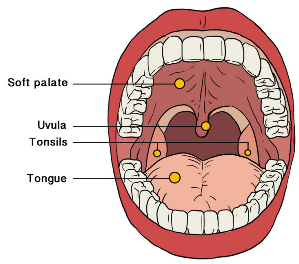


FIGURE 21.23
The tonsils are in the throat. They trap pathogens that enter the body through the mouth or nose. Lymphocytes in the tonsils destroy the trapped pathogens.

## Lymphocytes

Lymphocytes (white blood cells) are the key cells of an immune response. A photograph of a lymphocyte is shown in **Figure** 21.24. There are trillions of lymphocytes in the human body. They make up about one quarter of all white blood cells. Usually, fewer than half of the body's lymphocytes are in the blood. The rest are in the lymph, lymph nodes, and lymph organs.

There are two main types of lymphocytes:

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. They are also found on other cells, like allergens, that enter the body and on cancer cells.

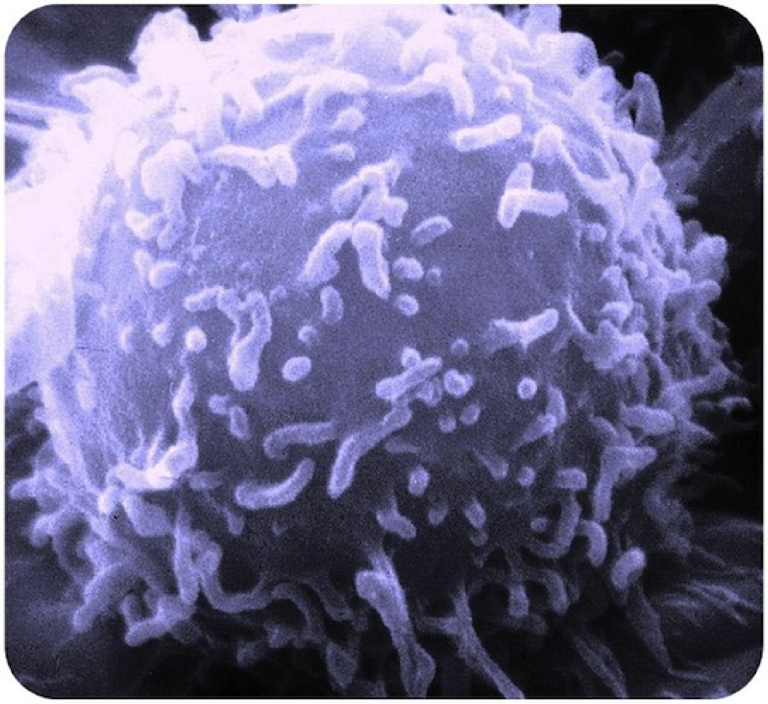

FIGURE 21.24
This image of a lymphocyte was made with an electron microscope. The lymphocyte is shown 10,000 times its actual size.

## Immune Responses

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

## B Cell Response

B cells respond to pathogens and other 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. Each antibody can bind with just one specific type of antigen. They fit together like a lock and key. Once an antigen and antibody bind together, they signal for a phagocyte to destroy them. A diagram of an antibody binding with an antigen is shown in **Figure** 21.25.

## T Cell Response

There are different types of T cells, including killer T cells and helper T cells. Killer T cells destroy infected, damaged, or cancerous body cells. How a killer T cell destroys an infected cell is shown in **Figure** 21.26. When the killer T cell comes into contact with the infected cell, it releases poisons. The poisons make tiny holes in the cell membrane of the infected cell. This causes the cell to burst open. Both the infected cell and the viruses inside it are destroyed.

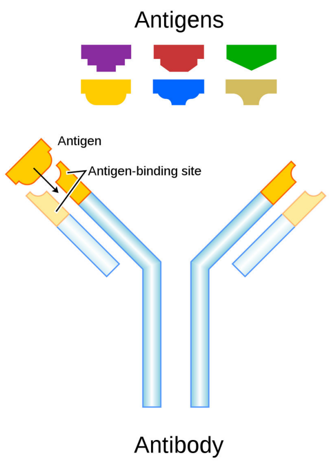


FIGURE 21.25

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.

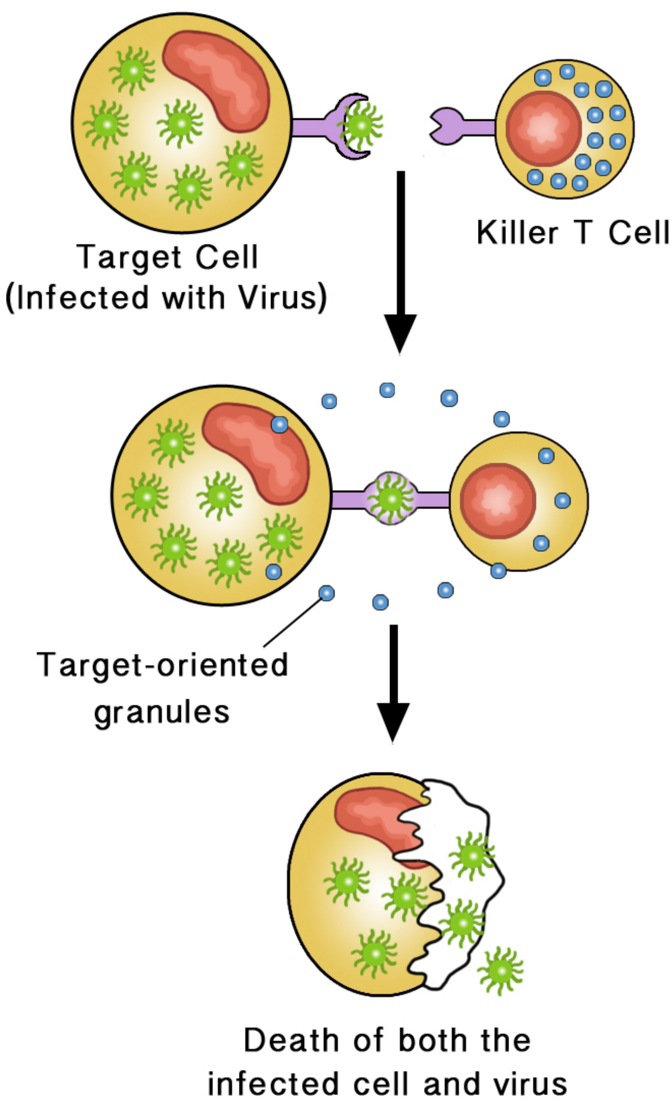


FIGURE 21.26

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.

## Immunity and Vaccination

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 on the disease.

They will quickly produce a new army of B or T cells to fight the pathogen. They will begin a faster, stronger attack than the first time the pathogen invaded the body. As a result, the immune system will be able to destroy the pathogen before it can cause an infection. Being able to 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, the 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 causes an immune response without causing the actual illness. Diseases you have probably been vaccinated against include measles, mumps, and chicken pox.

## Lesson Summary

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

## Review Questions

### Recall

1. What are lymphocytes?
2. What is lymph?
3. What is an antigen?
4. What organ produces B cells and T cells?
5. Define immunity.

### Apply Concepts

6. How are an antigen and antibody like a lock and key?

7. Explain how killer T cells fight pathogens.

8. Helper T cells do not produce antibodies or destroy infected cells. Why are they necessary for immune responses?

9. If you have been vaccinated against measles, you are unlikely to ever have the disease, even if you are exposed to the measles virus. Why?

### Critical Thinking

10. Some children with frequent sore throats have an operation to remove their tonsils. Why might removing the tonsils lead to fewer sore throats?

## Further Reading / Supplemental Links

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- Lorrie Klosterman. *Immune System* (The Amazing Human Body). Benchmark Books, 2008.
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- http://www.niaid.nih.gov/publications/immune/the_immune_system.pdf

## Points to Consider

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

# 21.5 References


1. Courtesy of Janice Haney Carr/Centers for Disease Control and Prevention. http://phil.cdc.gov/phil/details.asp?pid=10591 . Public Domain
2. Courtesy of the CDC/Dr. Lucille K. Georg. http://commons.wikimedia.org/wiki/File:Ringworm_on_the_arm,_or_tinea_corporis_due_to_Trichophyton_mentagrophytes_PHIL_2938_lores.jpg . Public Domain
3. Courtesy of the CDC/Janice Carr. http://commons.wikimedia.org/wiki/File:Giardia_lamblia_SEM_8698_lores.jpg . Public Domain
4. Image copyright MichaelTaylor, 2013. http://www.shutterstock.com . Used under license from Shutterstock.com
5. Courtesy of James Gathany/CDC. http://commons.wikimedia.org/wiki/File:Sneeze.JPG . Public Domain
6. Courtesy of Jim Gathany/CDC. http://commons.wikimedia.org/wiki/File:CulexNil.jpg . Public Domain
7. Courtesy of the NIH. http://commons.wikimedia.org/wiki/File:Hiv_budding.jpg . Public Domain
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9. Courtesy of the National Cancer Institute. http://commons.wikimedia.org/wiki/File:Papilloma_Virus_%28HPV%29_EM.jpg . Public Domain
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19. User:BruceBlause/Wikimedia Commons. http://commons.wikimedia.org/wiki/File:Blausen_0623_LymphaticSystem_Female.png . CC BY 3.0
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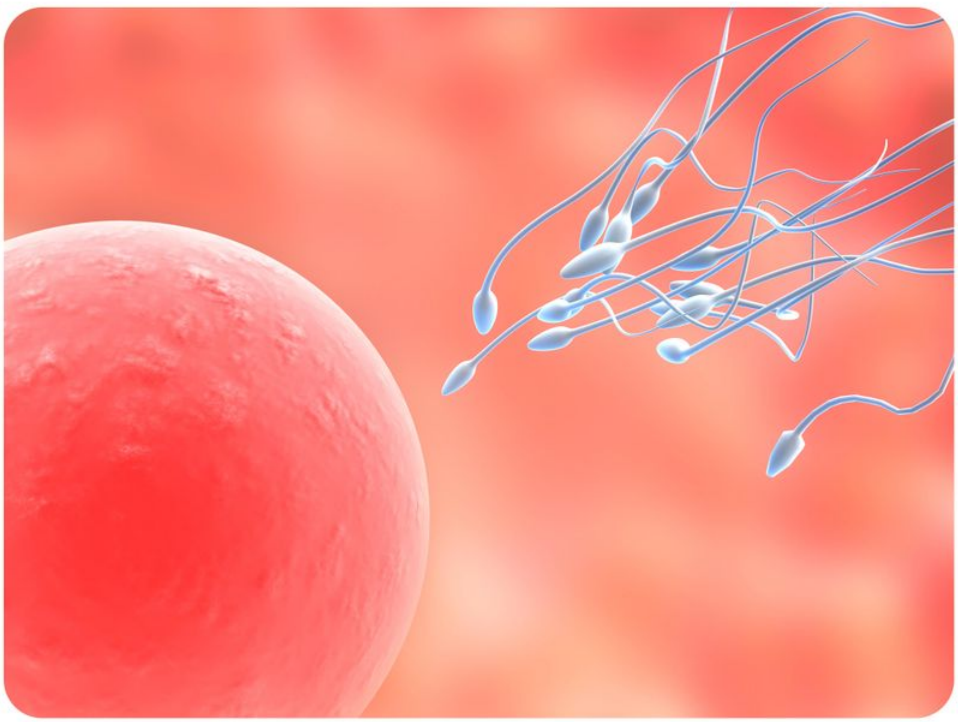
# CHAPTER 22 MS Reproductive Systems and Life Stages

## Chapter Outline





The above image shows sperm trying to get inside of an egg. When a sperm and an egg come together, it is called "fertilization."

What do you notice about the differences between the sperm and the egg? Which one is bigger? Which one is smaller? What does the shape of the sperm remind you of? How about the egg? Does it look like a chicken egg or something else? How are the male and female body systems so different from each other that one creates sperm and the other creates eggs? Think about these questions as you read about the male and female reproductive systems as well as how to keep the systems healthy.

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# 22.1 Male Reproductive System

## Lesson Objectives

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

## Check Your Understanding

- What is the difference between sexual reproduction and asexual reproduction?
- What happens during meiosis?
- What are gametes?

## Vocabulary

- epididymis
- semen
- sperm
- testosterone

## Functions of the Male Reproductive System

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

The male reproductive system has two main functions:

1. Producing sperm.
2. Releasing testosterone into the body.

**Sperm** are male gametes. Gametes were introduced in the *Cell Division, Reproduction, and DNA* chapter. 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. When they grow older, males produce millions of sperm each day.

**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.
- 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 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.

## Male Reproductive Organs

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

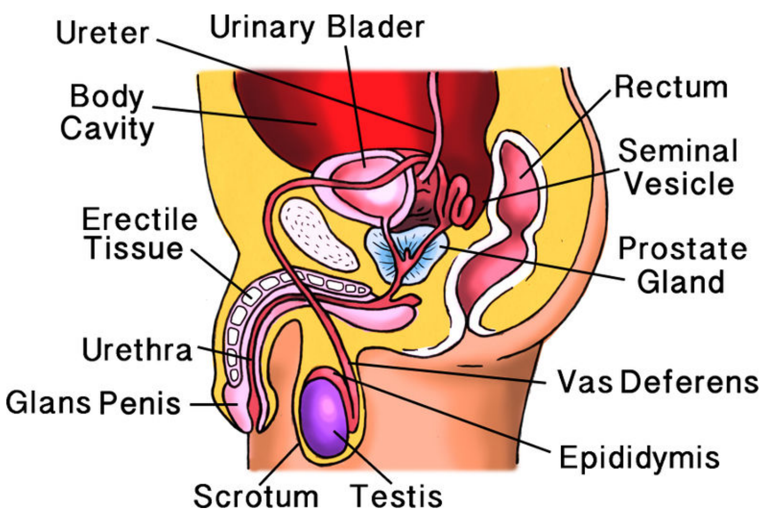


FIGURE 22.1

This drawing shows the organs of the male reproductive system. It shows the organs from the side. Find each organ in the drawing as you read about it in the text.

- 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. As you can see from **Figure** 22.1, the scrotum is a sac that hangs down outside the body. The scrotum also contains the epididymis.

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

Other parts of the male reproductive system include the vas deferens and prostate gland. Both of these structures are shown in **Figure** 22.1.

- The vas deferens is a tube that carries sperm from the epididymis to the urethra.

- The prostate gland secretes a fluid that mixes with sperm to help form semen. **Semen** is a "milky" liquid that carries sperm through the urethra and out of the body.

## Sperm and Sperm Production

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

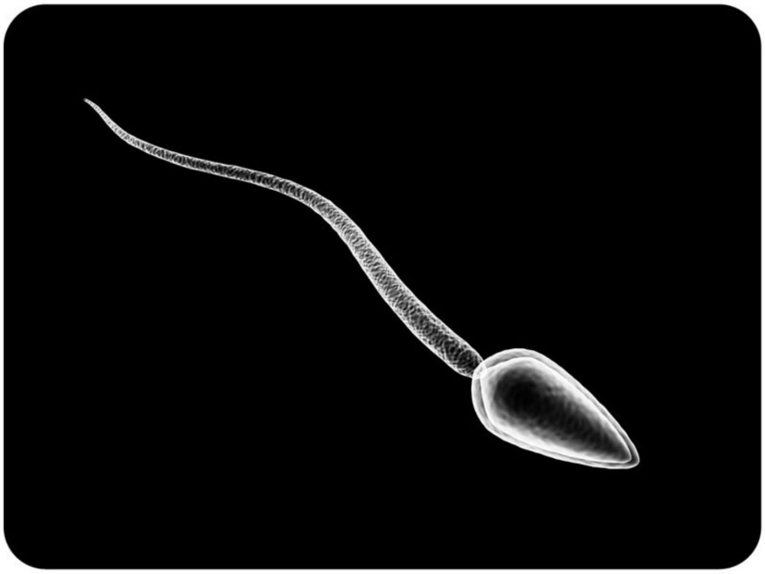

FIGURE 22.2
This drawing of a sperm shows its main parts. What is the role of each part? How do you think the shape of the sperm might help it to swim?

### Sperm

A sperm has three main parts:

1. The head of the sperm contains the nucleus. The nucleus holds the chromosomes. Remember, in humans, the nucleus of the sperm cell contains 23 chromosomes. The head also contains enzymes that help the sperm break through the cell membrane of an egg. You will read more about this process later in this chapter.
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 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 move from the testes to the epididymis.
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 ( **Figure** 22.1). 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!

## Lesson Summary

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

## Review Questions

### Recall

1. What are sperm?
2. What is the main sex hormone in males?
3. Which organs produce sperm and secrete testosterone?
4. What is the function of the tail of a sperm?

### Apply Concepts

5. Arrange the following structures in the order that sperm pass through them: urethra, epididymis, vas deferens.
6. Explain the jobs of testosterone in males.
7. Contrast the roles of the testes and penis in reproduction.
8. How do sperm differ from semen? How are the two related?
9. Why is the epididymis needed for reproduction in males?

### Critical Thinking

10. Explain why sperm production is not completed when spermatids have been produced.

## Further Reading / Supplemental Links

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- http://www3.interscience.wiley.com/journal/118662957/abstract?CRETRY=1&SRETRY=0
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- Alex Firth. *What's Happening to Me?: Boys Edition*. Usborne Books, 2007.
- Frank C. Hawkins and Greta Laube. *The Boy's Body Guide: A Health and Hygiene Book for Boys 8 and Older*. Boys Guide Books, 2007.
- Kate G. Pfeifer. *American Medical Association's Boy's Guide to Becoming a Teen*. Jossey-Bass, 2006.

## Points to Consider

- Do you know which organs in females produce eggs? Do you know how eggs are produced?
- Besides producing eggs, what do you think might be other jobs of the female reproductive system?

# 22.2 Female Reproductive System

## Lesson Objectives

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

## Check Your Understanding

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

## Vocabulary

- cervix
- eggs
- estrogen
- fallopian tubes
- follicle
- menstrual cycle
- menstruation
- ovulation
- uterus

## Functions of the Female Reproductive System

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.
2. Secretes a major sex hormone, estrogen.

One function of the female reproductive system is to produce eggs. **Eggs** 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. This will be discussed later in this lesson.

Another job 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.

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

## Female Reproductive Organs

The female reproductive organs include the vagina, uterus, Fallopian tubes, and ovaries. These organs are shown in **Figure** 22.3.

The breasts are not shown in this figure. They are not considered reproductive organs, 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.

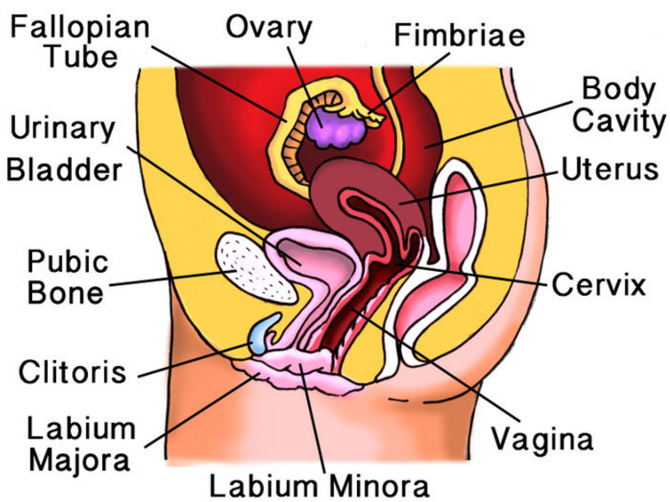


FIGURE 22.3
This drawing shows the organs of the female reproductive system. It shows the organs from the front. Find each organ in the drawing as you read about it in the text.

- 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 (see below). During sexual intercourse, sperm may be released into the vagina. The sperm move through the vagina and into the uterus. During birth, a baby passes from the uterus and 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. The eggs do not fully develop until a female has gone through puberty. About once a month, an egg is released by the ovary. The ovaries also secrete estrogen.

- 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. Notice in **Figure** 22.3 that the end of each Fallopian tube by the ovary has "fingers." They sweep an egg into the Fallopian tube. Then the egg passes through the Fallopian tube to the uterus.

## Eggs and Egg Production

When a baby girl is born, her ovaries contain all 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.

### 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, 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).
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 in **Figure** 22.4 shows how this happens.

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**. The moving fingers of the nearby Fallopian tube sweep the egg into the tube.

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 (see **Figure** 22.5).

## The Monthly Cycle

Egg production in the ovary is part of the menstrual cycle. The **menstrual cycle** is a series of changes in the reproductive system of mature females that repeats every month.

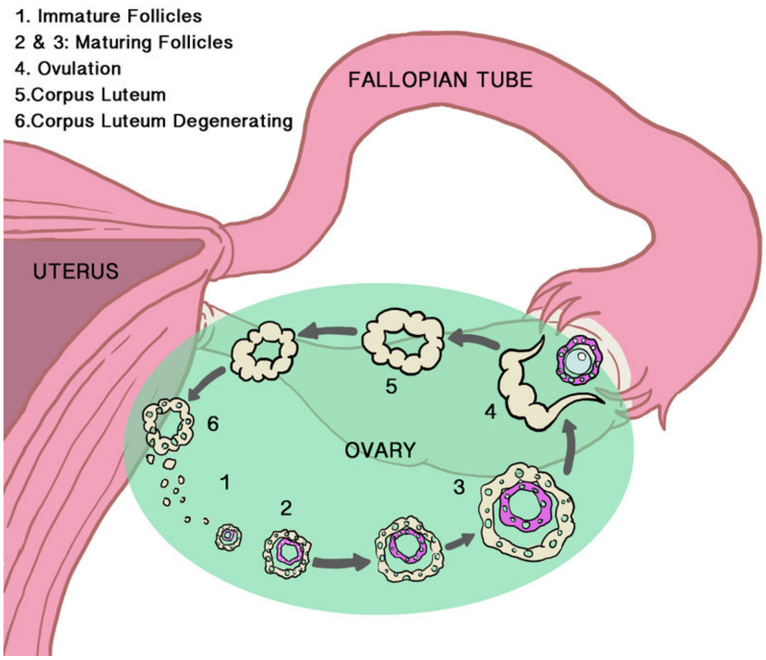


FIGURE 22.4

This diagram shows how an egg and its follicle develop in an ovary. After it develops, the egg leaves the ovary and enters the Fallopian tube. The empty follicle becomes a structure called a corpus luteum. (1) Undeveloped eggs, (2) Egg and follicle developing, (3) Egg and follicle developing, (4) Ovulation.

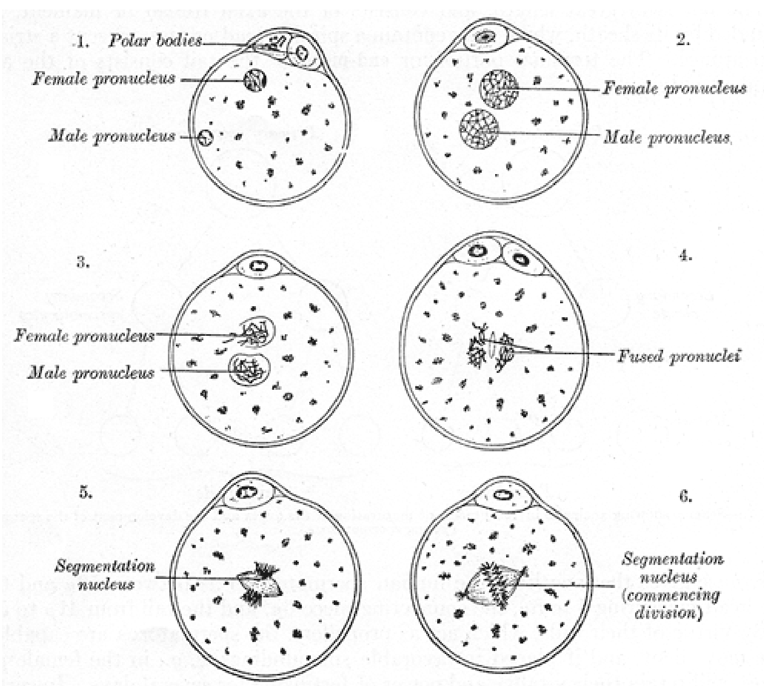


FIGURE 22.5

This image shows the process of fertilization described above.

## Menstruation

While the egg and follicle are developing in the ovary, tissues are building up inside the uterus. 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.

If a sperm *does not* enter an egg in the Fallopian tube, 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 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.

## Lesson Summary

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

## Review Questions

### Recall

1. What are eggs?
2. What is the main sex hormone in females?
3. List the two major roles of estrogen in females.
4. What are the functions of the uterus in female reproduction?

### Apply Concepts

5. Describe what happens during ovulation.
6. Compare and contrast eggs and sperm.
7. Explain how an egg develops in an ovary of a mature female.
8. Explain why menstruation occurs if a sperm does not enter an egg that is released by an ovary.

### Critical Thinking

9. What do you think the extra tissue and blood vessels provide for an egg that is fertilized by a sperm?

## Further Reading / Supplemental Links

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## Points to Consider

The next lesson discussion reproduction.

- After an egg is released, what must occur in order for reproduction to proceed?
- What is the name of the first cell of the new organism?
- Do you know where fertilization occurs?

# 22.3 Reproduction and Life Stages

## Lesson Objectives

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

## Check Your Understanding

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

## Vocabulary

- adolescence
- amniotic sac
- childbirth
- childhood
- fertilization
- fetus
- infancy
- placenta
- puberty
- umbilical cord

## Fertilization and Implantation

The sperm and egg pictured in **Figure** 22.5 don't look anything like a human baby. After these two gametes 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 shown in **Figure** 22.6. If the sperm breaks through the egg's membrane, it will cause changes in the egg that keep other sperm out. It will also cause the egg to go through meiosis. Recall that meiosis begins long before an egg is released from an ovary.

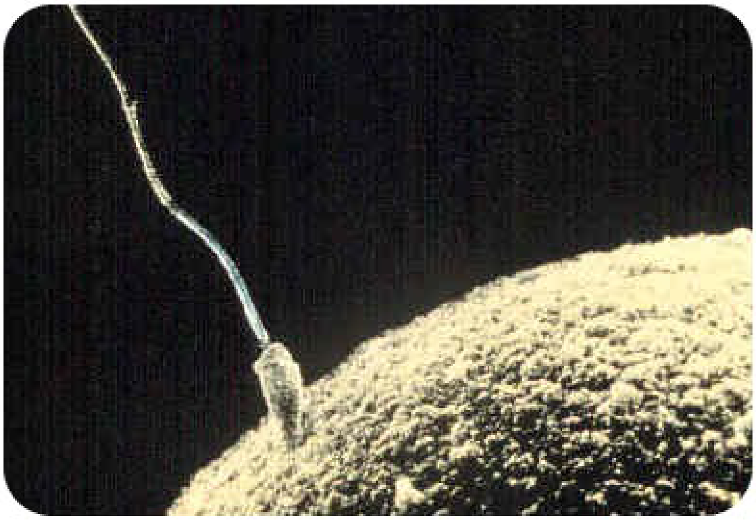

FIGURE 22.6
This sperm is ready to penetrate the membrane of this egg. Notice the difference in size of the sperm and egg. What will happen if the sperm manages to break through the egg's membrane?

The sperm and egg each have only half the number of chromosomes as other cells in the body. 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 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.

## Pregnancy and Childbirth

Once the ball of cells travels to the uterus, it is called an embryo. The embryo stage lasts until the end of the $8^{th}$ week after fertilization. After that point until birth, the developing baby is called a **fetus**.

### Growth and Development of the Embryo

During the embryo stage, the baby grows in size.

$3^{rd}$ 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.

$4^{th}$ week after fertilization: Body organs begin to form.

$8^{th}$ week: All the major organs have started to develop.

**Figure** 22.7 shows some of the changes that take place during the $4^{th}$ and $8^{th}$ weeks. Look closely at the two embryos in the figure. Do you think that the older embryo looks more human? Notice that it has arms and legs and lacks a tail. The face has also started to form and it is much bigger.

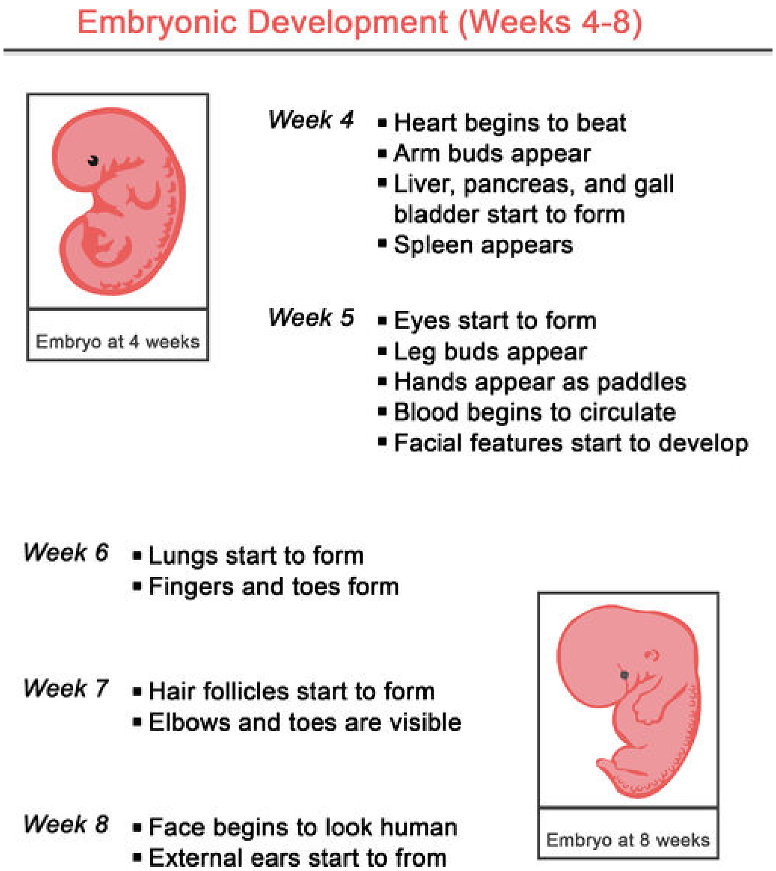


FIGURE 22.7

Embryonic Development (Weeks 4–8). Most organs develop in the embryo during weeks 4 through 8. If the embryo is exposed to toxins during this period, the effects are likely to be very damaging. Can you explain why? (Note: the drawings of the embryos are not to scale.)

### Growth and Development of the Fetus

There are also many changes that take place after the embryo becomes a fetus. Compare the $18^{th}$-week fetus with the $8^{th}$-week embryo.

Some of the differences between them are obvious. For example, the fetus has ears and eyelids. Its fingers and toes are also fully formed. The fetus even has fingernails and toenails. In addition, the reproductive organs have developed 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.

Compare the fetus at 28 weeks and 38 weeks. Do you see how much chubbier the older fetus looks? 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. They are shown in **Figure** 22.8.

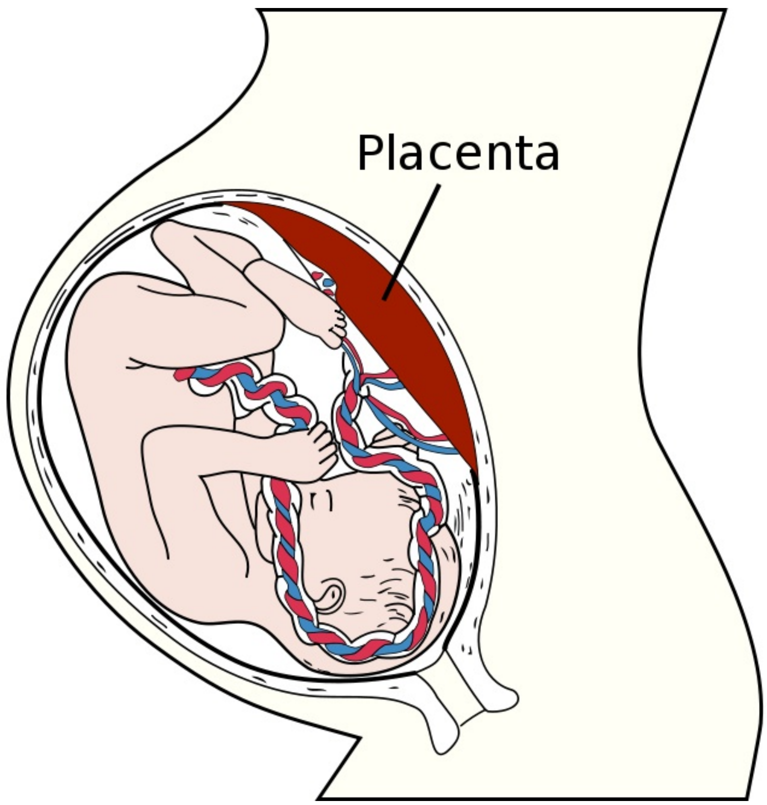


FIGURE 22.8
This fetus is 38 weeks old and ready to be born. Surrounding the fetus is the fluid-filled amniotic sac. The placenta and umbilical cord are also shown here. They provide a connection between the mother's and fetus's blood for the transfer of nutrients and gases.

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

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

It is important for the mother to eat plenty of nutritious 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.

## 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 teeth start to come in, usually at about six months of age ( **Figure** 22.9).
- The baby starts smiling, paying attention to other people, and grabbing toys.
- The baby begins making babbling sounds. By the end of the first year, the baby is starting to say a few words, such as "Mama" and "Dada."
- The baby learns to sit, crawl, and stand. By the end of the first year, the baby may be starting to walk.

FIGURE 22.9

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

**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** 22.10). By age six, children start losing their baby teeth. Their permanent teeth begin coming in to replace them. They also start school and learn how to read and write. They develop friendships and become less dependent on their parents.

FIGURE 22.10
Children develop better motor skills as they get older. What motor skills is this child demonstrating by kicking the ball?

## Puberty and Adolescence

The reproductive organs are found on the body at birth. But they grow very little during childhood. They do not start really working until puberty.

### Puberty

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

The age when puberty begins 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 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 causes the ovaries to secrete estrogen. Estrogen causes the following to happen:

1. The uterus and ovaries to grow.
2. The ovaries start releasing eggs.
3. The menstrual cycle begins.
4. The 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 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:

- Teens develop new thinking abilities. For example, they can think about abstract ideas, such as freedom. They are also better at thinking logically. They are usually better at solving problems as well.
- Teens try to establish a sense of who they are as individuals. They may try to become more independent from their parents. Most teens also have emotional ups and downs. This is partly due to changing hormone levels.
- Teens usually spend much more time with peers than family members ( **Figure** 22.11).


FIGURE 22.11
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?

## 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 also 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 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.

Exercising the body and brain help prevent physical and mental effects. The stages of adulthood are pictured in **Figure** 22.12.

FIGURE 22.12

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

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

## Lesson Summary

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

## Review Questions

### Recall

1. What is fertilization?
2. At about how many weeks after fertilization is a fetus usually ready to be born?
3. What is the difference between an embryo and fetus?
4. Describe an embryo at the end of the $8^{th}$ week after fertilization.

### Apply Concepts

5. How does a fetus change during the last two months before birth?
6. Explain the role of the amniotic sac and placenta during fetal development.
7. Compare and contrast puberty and adolescence.
8. Why is it difficult to say when adulthood begins?

### Critical Thinking

9. Why doesn't a doctor wait for a newborn baby to breathe on its own before cutting the umbilical cord?
10. Explain how pituitary gland controls puberty in boys and girls.

## Further Reading / Supplemental Links


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- http://www.merck.com/mmhe/sec22/ch260/ch260b.html
- http://www.merck.com/mmhe/sec22/ch260/ch260c.html
- http://www.pregnancy.org/pregnancy/fetaldevelopment1.php
- http://www.pregnancy.org/pregnancy/fetaldevelopment2.php


## Points to Consider

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

# 22.4 Reproductive System Health

## Lesson Objectives

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

## Check Your Understanding

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

## Vocabulary

- breast cancer
- chlamydia
- genital herpes
- gonorrhea
- hepatitis B
- sexually transmitted disease (STD)
- syphilis

## Sexually Transmitted Diseases

A healthy reproductive system is important for two reasons:

1. For overall good health.
2. For reproduction.

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

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

STDs are more common in teens and young adults than in older people. One reason is that young people are more likely to take risks. They also may not know how STDs spread. They are likely to believe myths about STDs, like the myths in **Table** 22.1.

**TABLE 22.1: Sexually Transmitted Diseases**

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

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

## Bacterial STDs

In the U.S., **chlamydia** is the most common STD caused by bacteria. Females are more likely than males to develop the disease. Rates of chlamydia among U.S. females in 2006 is given in **Figure** 22.13. 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.

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

## Viral STDs

Genital warts are an STD caused by human papilloma virus, or HPV. They are one of the most common STDs in teens. HPV infections cannot be cured. 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.

**Genital herpes** is an STD caused by a virus called herpes. It is another very common STD. A related herpes virus causes cold sores on the lips ( **Figure** 22.14). 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

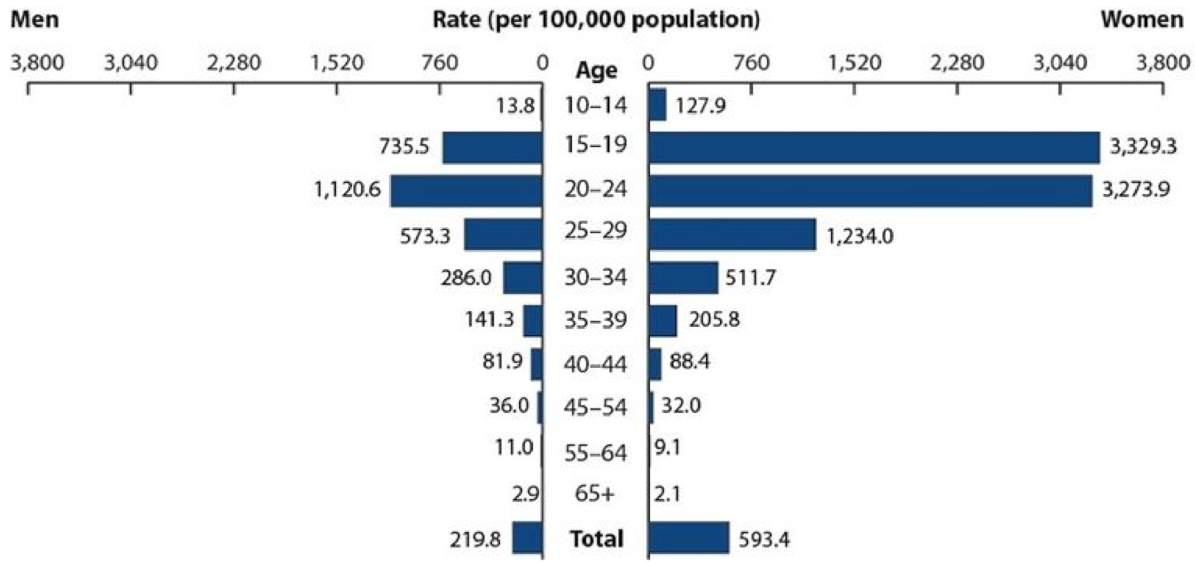


FIGURE 22.13
This graph shows data on the number of cases of chlamydia in U.S. males and females in 2009. Which two age groups had the highest rates of chlamydia? Why do you think rates were highest in these age groups?

genital herpes.

FIGURE 22.14
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 the *Diseases and the Body's Defenses* chapter. HIV can spread through sexual contact. It can also spread through body fluids such as blood. There is no cure for HIV infection, and AIDS can cause death, although AIDS can be delayed for several years with medication. Researchers are trying to find a vaccine to prevent HIV infection.

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

## Other Reproductive System Disorders

Many disorders of the reproductive system are not STDs. They are not caused by pathogens, so they don't spread from person to person. They develop for other reasons. The disorders 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 teens, injuries to the testes most often occur while playing sports. An injury such as a strike or kick to the testes can be very painful. It may also cause bruising and swelling. 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.

A common disorder of the ovaries is an ovarian cyst. A cyst is a sac filled with fluid or other material ( **Figure** 22.15). 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 may 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.

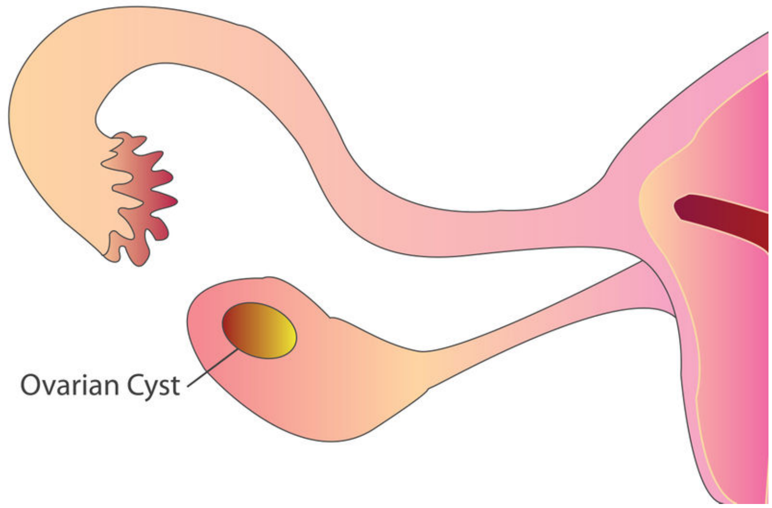


FIGURE 22.15
Ovarian cysts, like this one, are common. They generally do not need to be treated unless they cause symptoms. Most go away without treatment.

## Keeping the Reproductive System Healthy

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

- Eat a balanced diet that is high in fiber and low in fat.
- Drink plenty of water.
- Get regular exercise.
- Maintain a healthy weight.
- Get enough sleep.
- Avoid using tobacco, alcohol, or other drugs.
- Manage stress in healthy ways.

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

If you are a boy, you should always wear a protective cup when you play contact sports. Contact sports include football, soccer, and hockey. Wearing a cup will help protect the testes from injury. You should also do a monthly self-exam to check for cancer of the testes ( **Figure** 22.16).

See also http://kidshealth.org/teen/sexual_health/guys/tse.html

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

If you are a girl and use tampons, be sure to change them every 4 to 6 hours. Leaving tampons in too long can put you at risk of toxic shock syndrome. This is a serious condition.

You should also get in the habit of doing a monthly self-exam to check for breast cancer. Although breast cancer is rare in teens, it's a good idea to start doing the exam when you are young. It will help you get to know what is normal for you. Ask a health care provider if you have any questions.

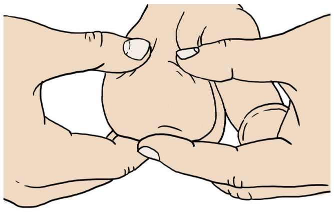

FIGURE 22.16
Teen boys should learn how to examine their testes for lumps that could be a sign of cancer.

## Lesson Summary

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

## Review Questions

### Recall

1. What is a sexually transmitted disease?

2. In the U.S., what is the most common STD caused by bacteria?

3. What is a varicocele?

### Apply Concepts

4. Which of the following STDs can be prevented with a vaccine: genital warts, chlamydia, gonorrhea, or hepatitis B?

5. What is the best way to prevent STDs?

6. Explain how girls can reduce their risk of developing toxic shock syndrome.

7. Why should males start doing self-exams of the testes by age 15?

### Critical Thinking

8. Explain why bacterial STDs are treated differently than viral STDs.

9. It is especially important for females to be protected from HPV infections. Why is this the case?

10. How could a person become infected with an STD without ever being sexually active?

## Further Reading / Supplemental Links

CK–12.org, High School Biology, Chapter 40, Lesson 4

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- http://www.cdc.gov/STD/stats04/trends2004.htm
- http://www.ehow.com/how_2076825_care-female-reproductive-system.html
- http://www.faqs.org/health/Body-by-Design-V2/The-Reproductive-System.html
- http://www.nlm.nih.gov/medlineplus/malereproductivesystem.html
- http://www.nlm.nih.gov/medlineplus/malereproductivesystem.html

## Points to Consider

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

# 22.5 References


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# CHAPTER 23 MS From Populations to the Biosphere

## Chapter Outline



Observe the cheetah hunting its prey. What is it called when one organism hunts another organism? Predation. Predation may not be good for the survival of an individual organism, but it is a very important part of life. This is because every interaction between an organism affects other organisms in an ecosystem.

What other things do you notice about the image? Where is the cheetah hunting? How do you think the cheetah has adapted to live in that particular environment? What do you think the weather is like? Does it rain a lot? Are there bigger trees? Or just small grasses?

All of the living and non-living things and how they interact with each other make up an ecosystem. The study of these interactions is called ecology. Ecologists ask questions like, "What would happen if the cheetahs' prey goes extinct?" and, "What would happen if a fire wiped out the grasslands where cheetahs live?"

Think about other interactions between organisms you have observed. Maybe you have seen a bee sucking the nectar out of a flower, or a cow grazing on grass. What habitats do these organisms live in? How do humans affect their habitats?

All of these questions are ecological questions. Think about them as you read the following chapter.

# 23.1 Introduction to Ecology

## Lesson Objectives

- Define ecology.
- Describe how organisms can interact with their environments.
- Describe levels of organization in ecology.

## Check Your Understanding

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

## Vocabulary

- abiotic
- biome
- biosphere
- biotic
- community
- ecology
- ecosystem

## What is Ecology?

Life Science can be studied at many different levels. You can study small things like molecules or cells. Or you can study big things like whole organisms or groups of organisms. The largest level that you can study is the level of ecology. **Ecology** is the study of how living organisms interact with each other and with their environment.

Because it is such a large field, 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.

A **biome** is a large community of plants and animals that live in the same place. Ecologists can also study biomes. For example, ecologists can study the Arctic, the tropics, or the desert ( **Figure** 23.1). Can you think of different species or biomes that ecologists could study?

Ecologists do two types of research:

1. Field studies.

FIGURE 23.1
An example of a biome, the Atacama Desert, in Chile.

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 rain forest and count all of the insects that live in a certain area. Laboratory studies involve working inside, not in the natural world. Sometimes, ecologists collect data from the field, and then analyze it in the lab. Also, they use computer programs to predict what will happen to organisms in who 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.

An organism's environment includes two types of factors:

1. **Abiotic** factors are the parts of the environment that have never been alive, 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, like organisms, interact with abiotic factors. For example, all animals (biotic factors) breathe in oxygen (abiotic factor). All plants (biotic factor) absorb carbon dioxide (abiotic factor).

Can you think of another way that abiotic and biotic factors interact with each other?

## Levels of Organization in Ecology

Ecology can be studied at small levels or at large levels. Levels of organization are described below from the largest to the smallest:

- The **biosphere** is the part of the planet that has living things on it ( **Figure** 23.2 and **Table** 23.1). This is most of Earth.
- An **ecosystem** is the living things in an area interacting with all of the abiotic parts of the environment ( **Figure** 23.3).
- A **community** are all of the populations of different species that live in the same area and interact with one another.
- A population is a group of organisms belonging to the same species that live in the same area and interact with one another.

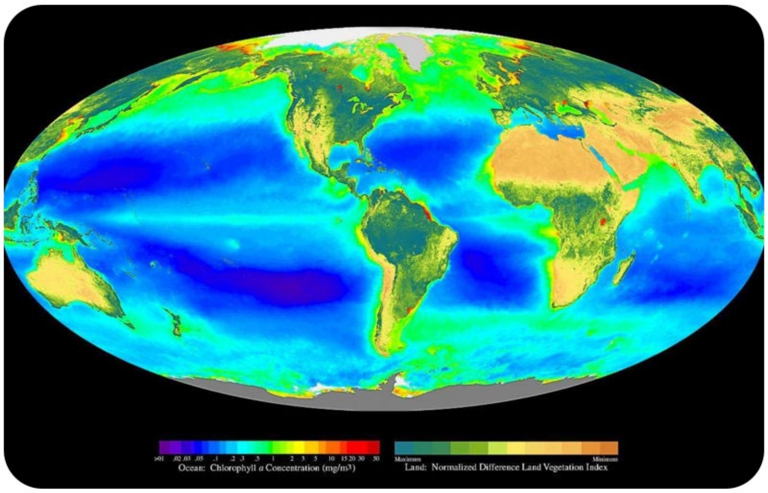


FIGURE 23.2
The global biosphere, which includes all areas that contain life, from the sea to the atmosphere.

### TABLE 23.1: Ecological Range

| Level | Definition |
|---|---|
| population | organisms belonging to the same species that live in the same area and interact with one another |
| community | populations of different species that live in the same area and interact with one another |
| ecosystem | a natural unit composed of all the living forms in an area, interacting with all the abiotic components of the environment |
| biosphere | the part of the planet that has living things |

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

### TABLE 23.2: Ecological Ecosystems

| Level | Question |
|---|---|
| Individual | How do zebras keep water in their bodies? |
| Population | What causes the growth of a zebra populations? |
| Community | How does a disturbance, like a fire or predator, affect the number of mammal species in African grasslands? |
| Ecosystem | How does fire affect the amount of food available in grassland ecosystems? |

**TABLE 23.2:** (continued)

| Level | Question |
| --- | --- |
| Biosphere | How does carbon dioxide in the air affect global temperature? |

FIGURE 23.3
Satellite image of Australia's Great Barrier Reef, an example of a marine ecosystem

## Lesson Summary

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

## Review Questions

### Recall

1. Name three fields you can study when you study ecology.

2. Define ecosystem.

3. Define organism.

4. What are the four main levels of organization in ecology?

### Apply Concepts

5. What is the difference between field studies and laboratory studies?

6. What is the difference between a population and a community?

7. Explain why almost the entire planet is a biosphere.

### Critical Thinking

8. Give an example of how an abiotic factor can interact with the environment.

9. A question that an ecologist could ask at the population level is, "What factors control zebra populations?" Think of two examples of how other species may affect the zebra population.

## Further Reading / Supplemental Links

- http://www.ecokids.ca/pub/index.cfm
- http://www.eco-pros.com/ecologykids.htm
- http://www.kidsolr.com/science/page12.html
- http://www.southplainfield.lib.nj.us/homeworklinks/Ecology.htm
- http://www.surfnetkids.com/ecology.htm;

## Points to Consider

- What do you think causes populations to grow?
- What causes populations to decrease?

# 23.2 Populations

## Lesson Objectives

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

## Check Your Understanding

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

## Vocabulary

- birth rate
- carrying capacity
- death rate
- dispersion
- emigration
- immigration
- limiting factor
- population growth rate

## 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 figure out how healthy or stable the populations are. They also look at how the populations interact with the environment.

First, ecologists will measure the size of the population. The population density is the number of individuals of the same species in a particular area. Ecologists also look at how individuals in a population are spread across an environment. How individuals are spaced within a population is called **dispersion**. Some species may be clumped or clustered ( **Figure** 23.4) in an area. Others may be evenly spaced ( **Figure** 23.5). Still others may be spaced randomly within an area.

FIGURE 23.4
Individuals within this population of purple loosestrife plants are clumped because of the soil quality.

FIGURE 23.5
A population of cacti in the Sonoran Desert generally shows even dispersion due to competition for water.

Ecologists also study age and sex. The **birth rate** is the number of births per individual within 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, it means that the population is growing.

A population with equal birth and death rates will have equal numbers of individuals at each age level. A population with more individuals at or above an age when they can reproduce means that the number of individuals is decreasing in the population. This is because the organisms in this population cannot reproduce any more, so more children cannot be born, and then the population cannot grow.

## Births, Deaths, and Migration

Births, deaths and migration all affect population growth. The **population growth rate** tells you if the number of individuals in a population is increasing or decreasing. Population growth rate depends on birth rate and on death rate. You can predict the growth rate by using the simple equation below:

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 will go down. If the birth and death rates are equal, then the population will stay the same.

Factors that affect reproduction are:

1. Age at first reproduction.
2. How often an organisms reproduces.
3. The number of offspring.
4. Parental care.
5. How long an organisms is able to reproduce.
6. Death rate of offspring.

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 ( **Figure** 23.6), while precocial organisms can take care of themselves at birth and do not require help from their parents ( **Figure** 23.7). In order to reproduce as much as possible, they use very different strategies.

FIGURE 23.6
A hummingbird nest with young illustrates an altricial reproductive strategy, with a few small eggs, helpless and naked young, and intensive parental care.

### 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 growth rate.
2. **Emigration** is the movement of individuals out of a population. This decreases the population growth rate.

The earlier growth rate equation now looks like this:

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 is warmer. In the spring, they return to their homes. ( **Figure** 23.8).

FIGURE 23.7
The Canada goose shows a precocial reproductive strategy. It lays a large number of large eggs, producing well-developed young.

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 23.8
A flock of barnacle geese fly in formation during the autumn migration in Finland.

## Population Growth

If a population is given unlimited amounts of food, moisture, and oxygen, and other environmental factors, it will show a type of growth called exponential growth. Exponential growth means that as a population grows larger, the growth rate increases. This is shown as the J-shaped curve in **Figure** 23.9. You can see that the population grows slowly at first, but as time passes, growth occurs more and more rapidly.

In nature, organisms do not usually have ideal environments with unlimited food. In nature, there are limits. Sometimes, there will be a lot 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?

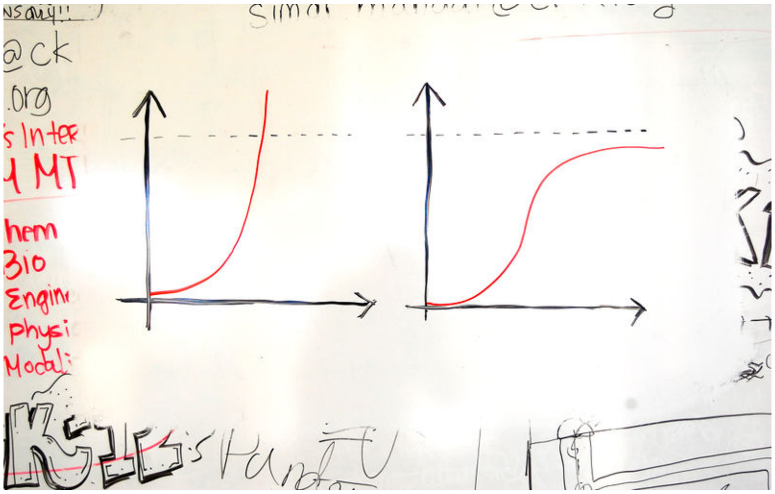

FIGURE 23.9
Growth of populations according to exponential (or J-curve) growth model (left) and logistic (or S-curve) growth model (right)

Usually, populations first grow exponentially. But as populations increase, rates of growth slow down and slowly level off. This is shown as an S-shaped curve in **Figure** 23.9, and is called logistic growth. Why do you think occurs?

## Limiting Factors

**Limiting factors** are things 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 type of growth (S-curve). Competition for resources like food and space cause the growth rate to stop increasing, so the population levels off. This flat line in growth is known as the carrying capacity. The **carrying capacity** is the maximum population size that can be supported in a particular area without destroying the habitat. Limiting factors determine what the carrying capacity is.

### 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.

In nature, when the population size is small, there is plenty of food for each individual. When there is plenty of food, organisms can reproduce, so the birth rate is high. As the population increases, the food supply decreases. When food decreases, organisms cannot reproduce as well, so the birth rates goes down. This will cause the population growth rate to decrease.

When the population decreases to a certain level where every individual can get enough food to eat, and the birth and death rates are stable, the population has reached 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 is also a limiting factor. For example, an individual *Agave americana* actually likes to grow when it is dry. Rainfall limits reproduction, 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.

What kind of growth rate do you think humans follow? Are they growing exponentially (J-curve) or logistically (S-curve)?

## Growth of the Human Population

There are two different beliefs about what type of growth the human population undergoes:

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.

Which do you think is correct?

Does human growth looks like the exponential (J-shaped) graph or the logistic (S-shaped) graph? We don't know all the answers yet, but history gives us some clues. For example, if we look at worldwide human population growth from 10,000 BCE through today, our growth looks like exponential growth. It increases very slowly at first, but later grows at a faster rate. It also does not approach a carrying capacity ( **Figure** 23.10). So maybe humans show exponential growth.

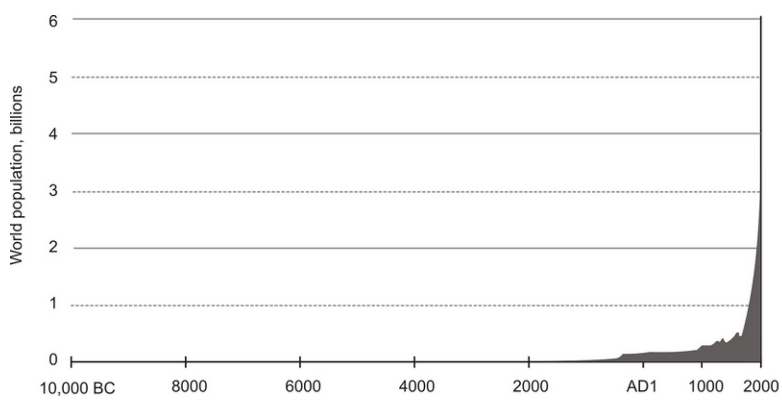


FIGURE 23.10
Worldwide human population growth from 10,000 BCE through today

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** 23.3.

**TABLE 23.3: Stage of Human Population Growth**

| Stage of Human Population Growth | Description |
|---|---|
| Stage 1 | Birth and death rates are high and population growth is stable. This occurred in early human history. |

**TABLE 23.3:** (continued)

| Stage of Human Population Growth | Description |
|---|---|
| Stage 2 | Significant drop in death rate, resulting in exponential growth. This occurred in 18th and 19th century Europe. |
| Stage 3 | Population size continues to grow. |
| Stage 4 | Birth rates equal death rates and populations become stable. |
| Stage 5 | Total population size may level off. |

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.

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 reach a carrying capacity. But many scientists and other Neo-Malthusians believe that humans have already gone over the Earth's carrying capacity for resources and habitat. If this is true, then human overpopulation will lead to a lack of food, disease, or war. These things will cause the population of humans to crash, or cause humans to go extinct.

For additional information, see this 2010 video: http://whoknew.news.yahoo.com/?vid=21435088 .

Which of the above theories makes sense to you? Why?

## Lesson Summary

- A population is made of organisms belonging to the same species, all living in the same area and interacting with each other
- One measure of a population's health is the dispersion of individuals within a population
- The population growth rate shows how the population size changes per population member per unit of time.
- Birth rate, death rate, and migration affect population growth rate.
- In an ideal environment, populations show exponential growth. In nature, limiting factors cause logistic growth.
- There are two major beliefs about human population growth. Neo-Malthusians believe that human population growth is limited, and that overpopulation could have serious consequences. Cornucopians believe that human population growth can continue because of natural resources and technology.

## Review Questions

### Recall

1. Name two ways ecologists know that a population is healthy.

2. Define Birth Rate.

3. Define Death Rate.

4. What is the equation that calculates growth rate in a population, include information on migration?

5. What are three factors that affect reproduction within a population?

### Apply Concepts

6. How does a limiting factor such as food supply limit population size?

7. Give two examples of environmental crises that support the idea that our human population has already grown beyond the carrying capacity resulting in environmental degradation.

8. What is the difference between Neo-Malthusian beliefs and Cornucopian beliefs about human population growth?

### Critical Thinking

9. In the altricial reproductive strategy used by robins and hummingbirds, the birds hatch helpless and naked. Parents spend little energy in just a few small eggs. It is important these offspring survive because there are not very many of them. What strategies might parents use to make sure their young survive?

10. In human history, major advances in technology caused our population to increase rapidly. What do you think these major advances were?

## Further Reading / Supplemental Links

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

## Points to Consider

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

# 23.3 Communities

## Lesson Objectives

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

## Check Your Understanding

- What is a population?
- How do limited resources encourage competition?

## Vocabulary

- camouflage
- character displacement
- commensalism
- competition
- competitive exclusion principle
- keystone species
- mutualism
- parasitism
- predation
- symbiosis

## What is a Community?

From populations, we are moving to the next level of ecology: the community level. In a community, different species that live in the same area interact with each other. The term "community" can be used in different ways. You can study populations in different areas of during different time periods. For example, you may study the fish community in Lake Ontario. But you could also study fish in a lake during a particular time period, like after 1990.

## Community Interactions

Community interactions can be either:

1. Intraspecific: Interactions between members of the same species.
2. Interspecific: Interactions between members of different species.

There are a number of different types of interactions, but we will look at three different types:

1. Competition.
2. Predation.
3. Symbiosis.

## Competition

**Competition** occurs when organisms compete for limited resources, and the "fitness" of one individual is lowered by competing with another individual. The interaction can be between organisms of the same species (intraspecific) or different species (interspecific).

Intraspecific competition happens when members of the same species compete for the same resources. They can compete for food, nutrients, space, or light. 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. The organism that is better adapted to that environment gets to survive. In this case, it is the taller tree.

Interspecific competition happens when individuals of different species share a limited resource in the same area. One species will have lowered reproductive success, growth, or survival. 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. This is similar to what happens within a species. Evolutionary theory says that competition for resources within and between species plays an important role in natural selection ( **Table** 23.4).

In order for two species within the same area to adapt, they may develop different specializations in order to coexist. This is known as **character displacement**. 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** 23.11).

**TABLE 23.4: Main Features of Competition**

| Type of Competition | Description of Competition |
|---|---|
| Intraspecific Competition | Occurs when members of the same species compete for the same resources, like food, nutrients, space, or light |
| Interspecific Competition | Occurs when individuals of different species share a limiting resource in the same area |

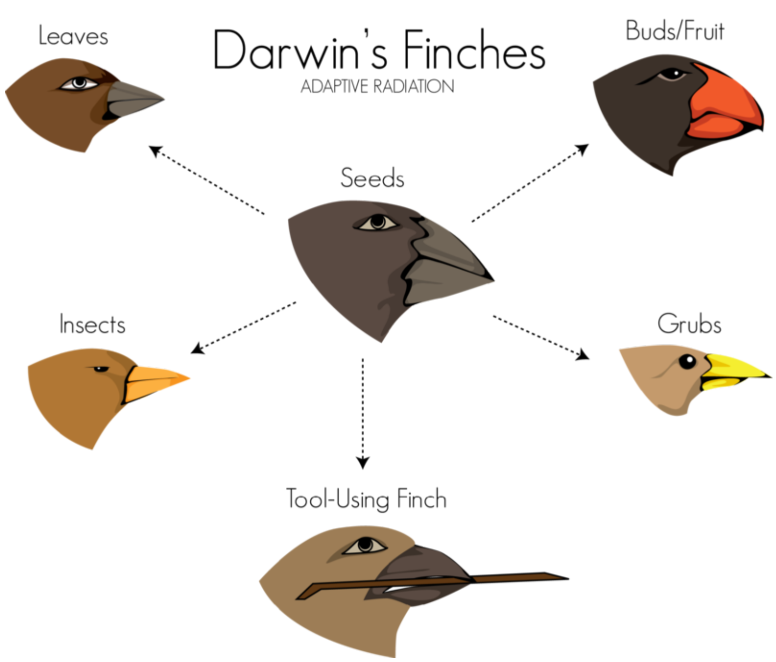


FIGURE 23.11

An example of character displacement, showing different types of bill for eating different types of foods, in Darwin's or Galapagos Finches.

## Predation

**Predation** happens 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.

There are different types of predation, including:

- True predation.
- Grazing.
- Parasitism.

*True predation* happens when a predator kills and eats its prey. Some predators of this type, such as lions ( **Figure** 23.12), 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 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.

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. Starfish can regenerate lost arms when they are eaten.

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 affect 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 may increase. If there are too many deer, then they may decrease the amount of plants or grasses in the ecosystem.

The act of predation can be broken down into four stages:

1. Predator senses the prey.
2. Predator attacks the prey.

FIGURE 23.12
This example of a true predator shows a lioness actively hunting.

3. Predator captures the prey.
4. Predator eats the prey.

At each stage, predators have adaptations for getting the prey. Prey also have adaptations for avoiding predators. ( **Table** 23.5).

Prey sometimes avoid detection by using camouflage ( **Figure** 23.13). **Camouflage** means that species have an appearance (color, shape or pattern) that helps them blend into the background. Mimicry is a related adaptation where a species uses appearance to copy 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** 23.14).

**TABLE 23.5: Main Features of Predation**

| Type of Predation | Description of Predation |
|---|---|
| True Predation | Predator kills and eats its prey |
| Grazing | Predator eats part of the prey, but rarely kills it |

FIGURE 23.13
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 23.14

## Symbiosis

**Symbiosis** describes a close and long-term interaction between different species. At least one species will benefit in a symbiotic relationship. There are three types of symbiotic relationships:

1. **Mutualism**: Both species benefit.
2. **Commensalism**: One species benefits while the other is not affected.
3. **Parasitism**: 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 while they also help the herbivore to digest food. Both species benefit, so it is a mutualistic relationship.

The *Ocellaris* clownfish and the *Ritteri* 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** 23.15).

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.

An example of a parasite is a hookworms. Hookworms live inside of humans and cause them pain, but the hookworms must live inside of a host in order to survive. Parasites may even kill the host they live on. Parasites are found in animals, plants, and fungi.

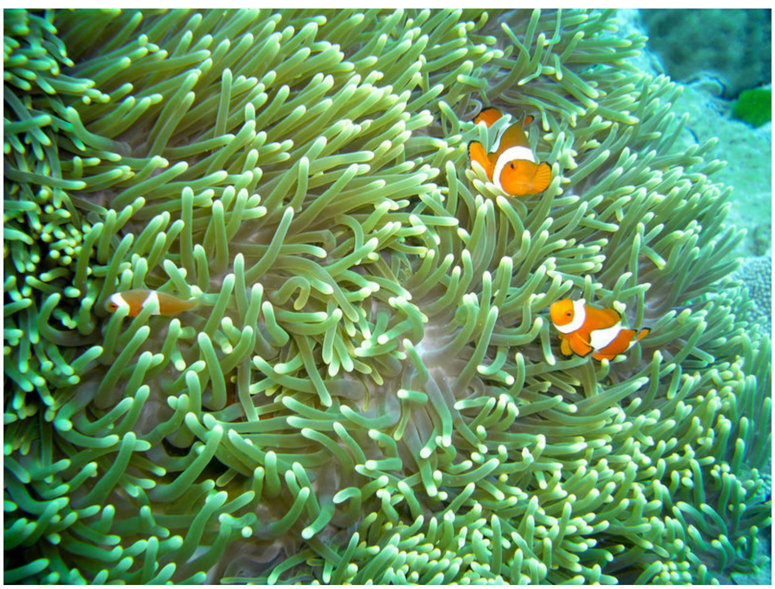

FIGURE 23.15
A mutualistic relationship between the Ocellaris clownfish and the Ritteri sea anemone. Myako Island, Japan. The fish protects the anemone from anemone-eating fish, while the anemone protects the clownfish from its predators, with its stinging tentacles. The clownfish has a special mucus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

## Lesson Summary

- A community is a collection of populations of different species interacting with one another in the same area.
- Community interactions include competition, predation, and symbiosis.
- Intraspecific and interspecific competition occur when individuals share a limiting resource in the same area.

- The competitive exclusion principle plays an important role in natural selection.
- Types of predation include true predation, grazing, and parasitism.
- Prey use different adaptations to avoid detection, attack and capture by predators.
- Symbiosis includes mutualism, commensalism, and parasitism.

## Review Questions

### Recall

1. Define competition.

2. What is the difference between intraspecific and interspecific competition?

3. Name three different types of predation.

4. In the mutualistic relationship between the *Ocellaris* clownfish and the *Ritteri* sea anemones, what benefit does the fish get?

### Apply Concepts

5. If two similar species do not live in the same area, would you expect the two species to compete? Why or why not?

6. How might a predator lower a prey's fitness?

7. In most types of grazing, does the predator lower a prey's fitness? Why or why not?

8. A drone fly looks a lot like a bee, yet it is completely harmless, as it cannot sting at all. What anti-predator mechanism is the drone fly using? Would you expect predators to always avoid drone flies?

### Critical Thinking

9. Choose one of the symbiotic relationships: mutualism, parasitism, or commensalism. Think of an example of that type of symbiosis. Explain why it is that type.

## Further Reading / Supplemental Links

en.wikipedia.org/wiki/Symbiosis

- http://www.nclark.net/CommunitiesBiomes
- http://www.ecokidsonline.com/pub/index.cfm

## Points to Consider

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

# 23.4 Ecosystems

## Lesson Objectives

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

## Check Your Understanding

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

## Vocabulary

- habitat
- niche

## What is an Ecosystem?

The next level after community is an ecosystem. An ecosystem consists of all the biotic factors (plants, animals and micro-organisms) interacting with all of the abiotic factors (water, soil, and air, for instance) in the same area.

You can find an ecosystem in a large body of freshwater or in a small piece of dead wood. Other examples of ecosystems include the coral reef, the Greater Yellowstone ecosystem, the rainforest, the savanna, the tundra, the desert and the urban ecosystem ( **Figure** 23.16).

Ecosystems need energy. They mostly get their energy in the form of sunlight. Matter is also recycled in ecosystems. Recycling of nutrients is important so they can always be available. Elements like carbon, nitrogen, and water are used over and over again by organisms. Human ecosystems could be a household, neighborhood, college, or even a nation. Human ecosystems interact with each other. Since humans live virtually all over the planet today, nearly all ecosystems could be considered human ecosystems.

In 2005, the largest assessment ever conducted of the earth's ecosystems was done by a research team of over 1,000 scientists. The study concluded that in the past 50 years, humans have altered the earth's ecosystems more than any other time in our history.

FIGURE 23.16
An example of a desert ecosystem in Baja California, showing Saguaro cacti.

## Biotic and Abiotic Factors

Biotic factors of an ecosystem include all living parts. Examples of biotic factors include bacteria, fungi, unicellular and multicellular plants, and unicellular and multicellular animals.

Abiotic factors are non-living chemical and physical factors in the environment. The six major abiotic factors are water, sunlight, oxygen, temperature, soil and climate (such as humidity, atmosphere, and wind). Other factors include carbon dioxide, geography, and geology.

Abiotic and biotic factors interact within ecosystems and also between ecosystems. For example, water may be recycled between ecosystems, by the means of a river or ocean current. Some species, such as salmon or freshwater eels, move between marine and freshwater ecosystems.

## Niche

Each organisms plays a particular role, or niche, in its ecosystem. A **niche** is the role a species or population plays in the ecosystem. In other words, a niche is how an organism "makes a living." A niche will include the food of an organism and how it obtains its food and space. Different species can hold similar niches in different locations. The same species may occupy different niches in different locations. Species of the Australian grasslands have the same niche. Once a niche is left vacant, other organisms can fill that position. When the tarpan, a small, wild horse found mainly in southern Russia, became extinct in the early 1900s, the niche was filled by a small horse breed, the konik ( **Figure** 23.17).

When plants and animals are introduced, either intentionally or by accident, into a new environment, they can occupy new niches or the existing niches of native organisms. Sometimes new species out-compete native species. They can even 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** 23.18).

FIGURE 23.17
The konik horse, which filled the niche left by the tarpan, a horse that became extinct in the early 1900s in southern Russia.

FIGURE 23.18
Kudzu, a Japanese vine, introduced intentionally to the southeastern United States, has out-competed the native vegetation.

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

## Habitat

The **habitat** is the environmental area where a particular species lives ( **Figure** 23.19). Abiotic 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 factors will affect the kind of traits an organism must have in order to survive there ( **Figure** 23.20 and **Figure** 23.21).

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

FIGURE 23.20
Another example of a type of habitat, showing a meadow and representative vegetation.

Habitat destruction means what it sounds like - a species' habitat is destroyed. Habitat destruction can cause a species' 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. The *Environmental Problems* chapter

FIGURE 23.21
This image shows wetland reeds, another type of habitat.

will discuss habitat destruction in further detail.

Habitats can also be examined from a human point of view. The environments where we live, work, and reproduce are our habitats.

## Lesson Summary

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

## Review Questions

### Recall

1. Give three examples of ecosystems.

2. List the six most common abiotic factors.

3. What is a niche?

4. Give an example of an organism filling a vacant niche.

5. What is a habitat?

### Apply Concepts

6. Why might a newly introduced species become a pest?

7. Name three abiotic factors that can be used to describe a habitat.

8. Give one example of an organism and its niche that is not included in the chapter.

### Critical Thinking

9. Species that travel distances between important areas for their survival, like migrating birds, may be particularly vulnerable to habitat destruction. How might the creation of multiple national parks or nature reserves help such species?

## Further Reading / Supplemental Links

- http://www.kidsgeo.com/geography-for-kids/0164-ecosystems.php

## Points to Consider

- Now that you understand what makes up an ecosystem, what additional factors do you think might be added to get to the next level, the biome?
- How do you think what you have learned about abiotic and biotic factors might be applied to the classification of different biomes?
- The biosphere is considered to be a global ecological system. Given all you now know about ecology, what do you think the biosphere consists of?

# 23.5 Biomes and the Biosphere

## Lesson Objectives

- Explain what biomes are.
- Describe terrestrial biomes.
- Describe aquatic biomes.
- Describe the features of the biosphere and list specific systems.

## Check Your Understanding

- What is an ecosystem?
- How do ecosystems relate to humans?

## Vocabulary

- aquatic biomes
- elevation
- GAIA hypothesis
- humidity
- latitude
- terrestrial biomes

## What are Biomes?

The biome is the highest level of organization in ecology. Biomes include populations, communities, and ecosystems. A biome is an area with similar geography and climate that includes similar communities of plants and animals.

There are into two major groups of biomes:

1. Terrestrial biomes (land).
2. Aquatic biomes (water).

Different biomes are habitats for different organisms. For example, one may find algae only in the part of the ocean where there is light, while conifers may be mostly found in mountains.

The diversity of animals and plants that can live in a specific biome is determined by the abiotic factors. For example, where there is more land, there are more species. Near the equator, there is also more biodiversity, probably because there is more water caused by high humidity levels.

Biomes are classified in terms of two factors:

1. Latitude.
2. Humidity.

Using these two factors, the World Wildlife Fund (WWF) identified fourteen biomes. They then divided those 14 biomes into 825 terrestrial ecoregions.

Biomes are often given local names. For example, a "temperate grassland" biome is known as "steppe" in central Asia, "prairie" in North America, and "pampas" in South America.

## Terrestrial Biomes

Different **terrestrial biomes** are defined in terms of their plant structures (such as trees, shrubs, and grasses), leaf types (such as broadleaf and needleleaf), and plant spacing (forest, woodland, savanna). Climate also affects what type of terrestrial biomes will exist in a specific area. The following factors affect biome type:

- **Latitude** means how far a biome is from the equator. Moving from the poles to the equator, you will find Arctic, boreal, temperate, subtropical, 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. Higher elevations have a similar affect on biomes as increasing latitude.

This is summarized in **Table** 23.6.

Terrestrial biomes ( **Figure** 23.22) lying within the Arctic and Antarctic Circles do not have very much plant or animal life. Biomes with the highest amount of diversity are near the equator ( **Figure** 23.23).

FIGURE 23.22

One of the terrestrial biomes, taiga, is a coniferous evergreen forest of the subarctic, covering extensive areas of northern North America and Eurasia. This taiga is along the Denali Highway in Alaska. The Alaska Range is in the background.

FIGURE 23.23
Another terrestrial biome is tropical rainforest. The one pictured here is located in the Amazon, Brazil.

**TABLE 23.6: Characteristics of Terrestrial Biome**

| Characteristics of Terrestrial Biome | Description of Characteristics |
|---|---|
| Plant structures | Trees, shrubs, grasses |
| Leaf types | Broadleaf, needleleaf |
| Plant spacing | Forest, woodland, savanna |
| Latitude from poles towards the equator | Arctic, boreal, temperate, subtropical, tropical |
| Humidity | Humid, semi-humid, semi-arid, arid |
| Elevation | Increasing elevation causes habitat types similar to that of increasing latitude |

## Aquatic Biomes

**Aquatic biomes** can be defined according to:

- Size.
- Depth.
- Vegetation, such as a kelp forest.
- Animal communities.

According to the WWF scheme, freshwater biomes can be classified as the following:

- Large lakes ( **Figure** 23.24).
- Large river deltas.
- Polar freshwaters.
- Montane freshwaters (in mountain areas).
- Temperate coastal rivers.
- Temperate floodplain rivers and wetlands.
- Temperate upland rivers.
- Tropical and subtropical coastal rivers.
- Tropical and subtropical floodplain rivers and wetlands.
- Tropical and subtropical upland rivers.
- Xeric (dry habitat) freshwaters and endorheic (interior drainage) basins.
- Oceanic islands.

FIGURE 23.24
Lake Tahoe in Northern California is a freshwater biome.

- Pack ice ( **Figure** 23.26).
- Hydrothermal vents.
- Cold seeps.
- Benthic zone.
- Pelagic zone.
- Neritic zone.

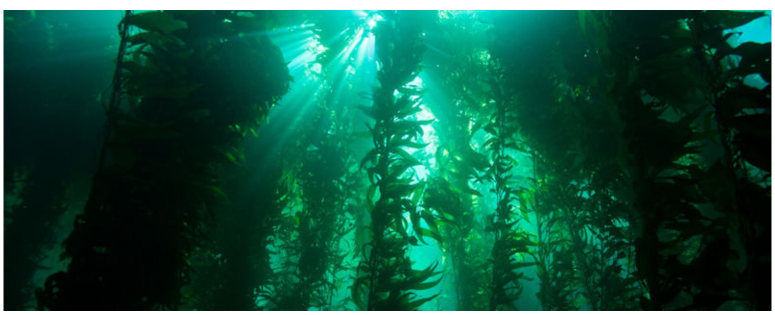

FIGURE 23.25
An example of an aquatic marine biome, a kelp forest.

## The Biosphere

The highest level of ecology is the biosphere. It is the part of the Earth, including the air, land, surface rocks, and water, where you can find life.

The biosphere interacts with the:

- Lithosphere: sphere of soils and rocks.
- Hydrosphere: water.
- Atmosphere: air.

FIGURE 23.26
An example of an aquatic marine biome, pack ice.

The biosphere includes an area between 11,000 meters below sea level to 15,000 meters above sea level. It overlaps with the above three spheres.

The **GAIA hypothesis** states that the biosphere is its own living organism. The hypothesis explains how biotic and abiotic factors interact in the biosphere.

The atmosphere, hydrosphere and lithosphere are cooperating systems that produce a biosphere full of life.

Lynn Margulis, a microbiologist, added to the hypothesis, specifically noting the ties between the biosphere and other Earth systems. For example, when carbon dioxide levels increase in the atmosphere, plants grow more quickly. As their growth continues, they remove more carbon dioxide from the atmosphere.

For a better understanding of how the biosphere works and various dysfunctions related to human activity, scientists have simulated the biosphere in small-scale models. Biosphere 2 ( **Figure** 23.27) is a laboratory in Arizona that contains 3.15 acres of closed ecosystem. BIOS-3 was a closed ecosystem in Siberia, and Biosphere J is located in Japan.

Direct human interactions with ecosystems, including agriculture, city development and other land uses, affect the health of the biosphere and their ecosystems. In terms of the human impact on biomes and ecosystems, the study of ecology is now more important than ever. Scientists that study ecology will move us toward an understanding of how best to live in and manage our biosphere.

## Lesson Summary

- A biome is an area with similar geography and climate that contains ecologically similar communities of plants and animals.
- Biomes are classified in different ways, sometimes according to differences in the physical environment, and sometimes according to latitude and humidity.
- Biodiversity of each biome is determined by abiotic factors, such as water and temperature.
- Terrestrial biomes are classified based on various plant factors and on climate.
- Aquatic biomes are classified based on various factors and divided into freshwater and marine biomes.
- The biosphere is a global ecological system.
- The biosphere is itself a living organism, as explained by the GAIA hypothesis.
- Humans have changed global patterns of biodiversity and ecosystem processes.

FIGURE 23.27
Biosphere 2, in Arizona, contains 3.15 acres of closed ecosystem and is a small-scale model of the biosphere.

## Review Questions

### Recall

1. Define biome.
2. What is the difference between a terrestrial and an aquatic biome?
3. Name a type of biome based on the physical environment.
4. Name the aquatic biomes classified according to depth.
5. What is the GAIA hypothesis?

### Apply Concepts

6. Where would you expect to find more biodiversity, in a rainforest on the equator, or in a desert? Explain why.
7. As you climb a mountain, you will see the vegetation a habitat type change as you gain elevation. What kind of change will result in a similar change in habitat?
8. Name one way that human activity has affected the biosphere (maybe you have heard something on the news?)

### Critical Thinking

9. Water is recycled between the hydrosphere, lithosphere, atmosphere, and biosphere in regular cycles. Why do you think oceans are important for this type of water recycling?

## Further Reading / Supplemental Links

- http://library.thinkquest.org/11353/ecosystems.htm
- http://earthobservatory.nasa.gov/Laboratory/Biome
- http://www.worldbiomes.com/biomes_map.htm
- http://www.mbgnet.net/sets/index.htm
- http://www.mbgnet.net/fresh/index.htm
- http://www.mbgnet.net/salt/index.htm
- http://www.kidsgeo.com/geography-for-kids/0153-biosphere.php
- http://www.geography4kids.com/files/land_intro.html

## Points to Consider

You now have a general idea of what a biome is and how the diversity of a biome is related to other factors. The next chapter, on ecosystem dynamics, will give you a greater understanding of how energy flow, cycling of matter, and succession vary from one biome to another.

- One of the aquatic biomes, the hydrothermal vents, is not dependent on sunlight but on bacteria, which utilize the chemistry of the hot volcanic vents. Can guess where these bacteria fit into the flow of energy in such an ecosystem?

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# Chapter 24 MS Ecosystem Dynamics

## Chapter Outline



This marine iguana eats algae. The algae give the iguana the energy it needs to live. But where does the algae get their energy? The algae get energy from the sun.

You may also notice that the algae are growing on rocks. How can algae grow without soil? What would happen to the iguana population if the algae could not grow on the rocks?

Marine iguanas live on the Galapagos Islands. These islands used to be covered with hot lava, but are now covered with volcanic rock. The Galapagos Islands are also are home to many different plants and animals. How can an island that used to be covered in lava now be home to new plants and animals?

This chapter discusses how energy flows in an ecosystem and also how new ecosystems form. Think about all these questions as you read this chapter.

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# 24.1 Flow of Energy

## Lesson Objectives

- Explain where all the energy in an ecosystem comes from.
- Classify organisms on the basis of how they obtain energy and describe examples of each.
- Be able to draw and interpret a food web.
- Explain the flow of energy through an ecosystem using an energy pyramid.

## Check Your Understanding

- What is photosynthesis?
- What are some examples of organisms that can photosynthesize?
- What is a community?

## Vocabulary

- carnivore
- consumer
- food chain
- food web
- herbivore
- omnivore
- producer
- trophic level

## Energy and Producers

Energy is the ability to do work. In organisms, this work can be physical work, like walking or jumping. It can also be the work used to carry out the chemical processes in their bodies. All organisms need a supply of energy to stay alive.

Some organisms can get the energy from the sun. Other organisms get 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.

### Producers

The energy of the sun is first captured by **producers** ( **Figure** 24.1), organisms that can make their own food. Many producers make their own food through the process of photosynthesis. The "food" the producers make is glucose. Producers make, or produce, food for the rest of the ecosystem.

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 can produce glucose ($C_6H_{12}O_6$) and other complex organic compounds.

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. Algae called phytoplankton are the most common producers in the oceans.

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.

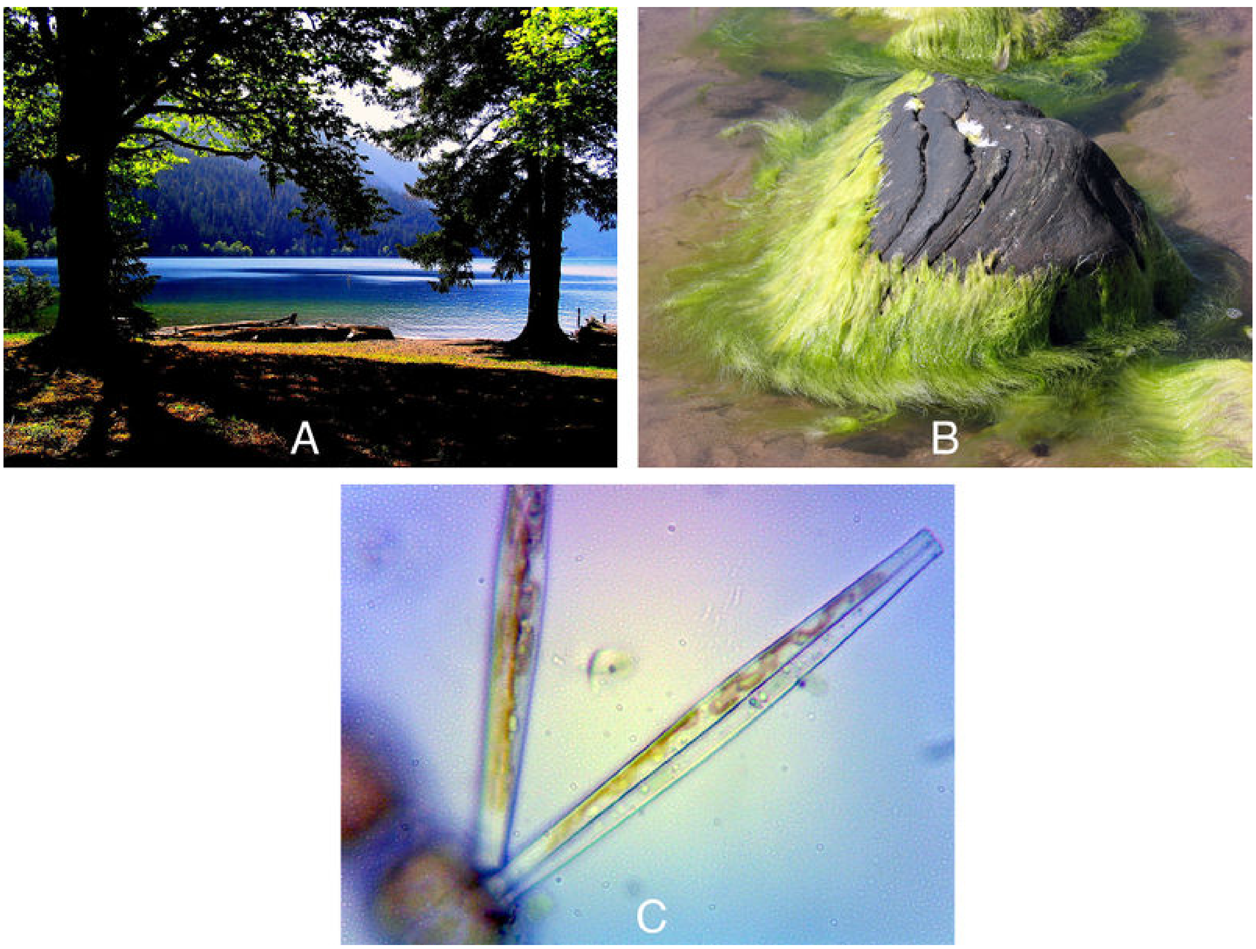


FIGURE 24.1
Producers include plants (a), algae (b), and diatoms, which are one-celled algae (c).

## Consumers and Decomposers

Many organisms are not producers and cannot make their own food from sunlight. The organisms that must consume other organisms to get food for energy are called **consumers**. All animals are consumers.

The consumers can be placed into different groups:

- **Herbivores** are animals that eat producers to get energy. For example, rabbits and deer are herbivores that eat plants. The caterpillar in **Figure** 24.2 is an 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.
- **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.

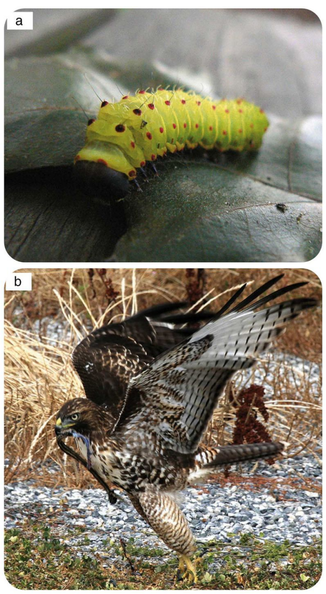


FIGURE 24.2
Examples of consumers are caterpillars (herbivores) and hawks (carnivore).

- Decomposers ( **Figure** 24.3) get nutrients and energy by breaking down dead organisms and animal wastes. Through this process, decomposers release nutrients, such as carbon and nitrogen. These nutrients are recycled back into the ecosystem so that the producers can use them.

The stability of an ecosystem also 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 never be released back into the ecosystem.

## Food Chains and Food Webs

**Food chains** ( **Figure** 24.4) 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

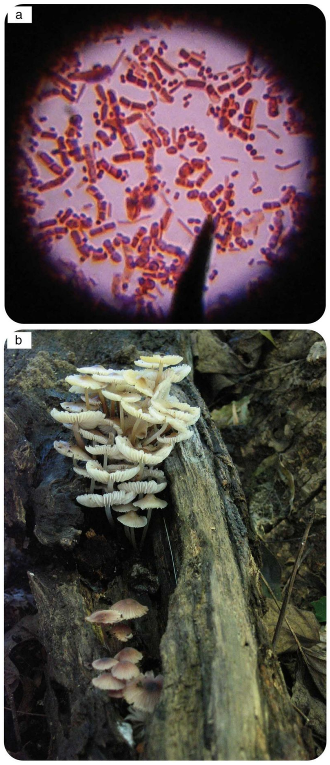


FIGURE 24.3
Examples of decomposers are bacteria (a) and fungi (b).

organism being eaten to the organism that eats it. For example, an arrow from leaves to a grasshopper shows that the grasshopper eats the leaves. Energy and nutrients are moving from the leaves to the grasshopper. Next, a bird might prey on the grasshopper, a snake may eat the bird, and then a hawk might eat the snake.

In an ocean ecosystem, one possible food chain might look like this: phytoplankton $\rightarrow$ krill $\rightarrow$ fish $\rightarrow$ shark.

The producers are always at the beginning of the food chain. The herbivores come next, then the carnivores. 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.

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. 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** 24.5) 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.

## Energy Pyramids

When an herbivore eats a plant, the energy in the plant tissues is used by the herbivore. The herbivore uses this energy 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

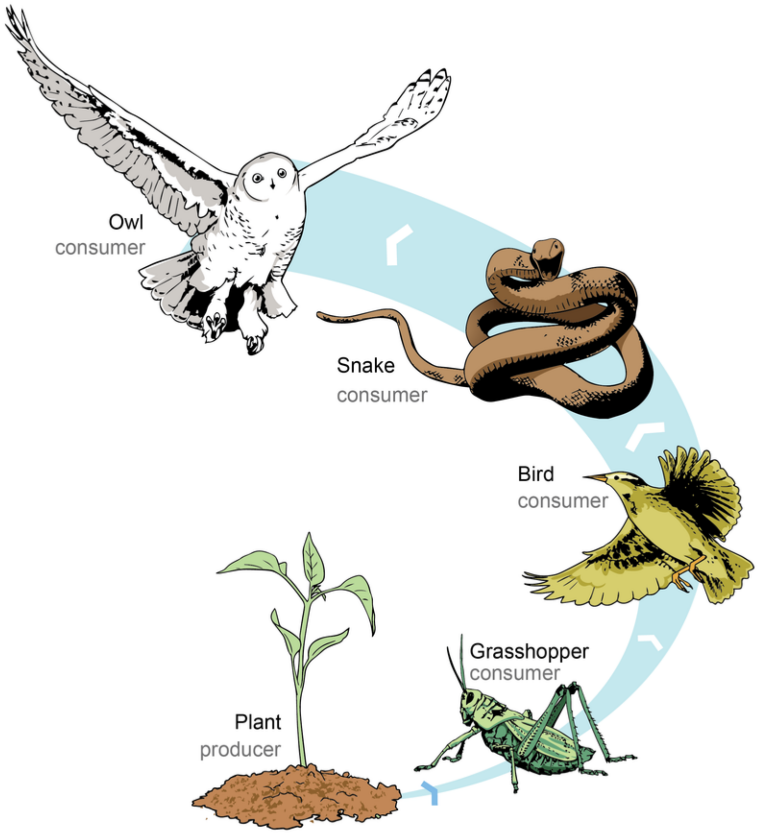


FIGURE 24.4

Food chain. This figure shows, for example, that the snake gets its energy from the bird, and the bird gets its energy from the insect.

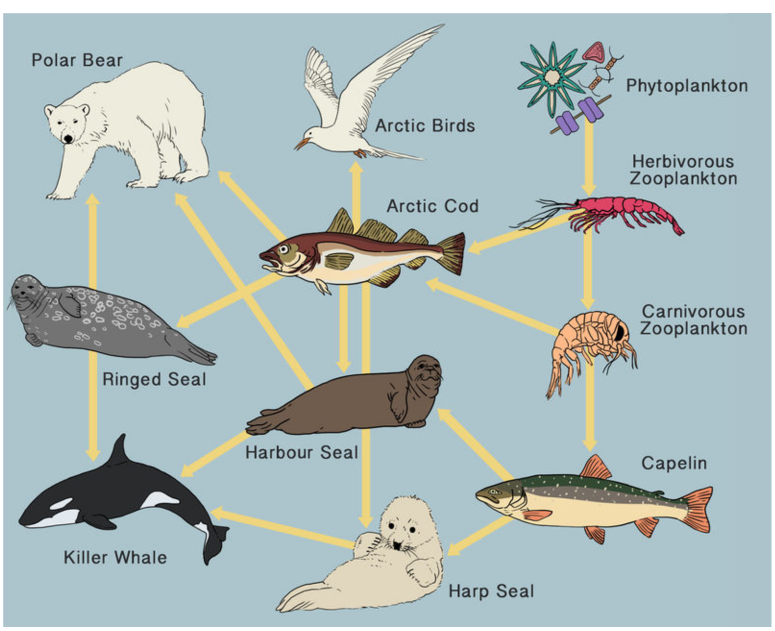


FIGURE 24.5

Food web in the Arctic Ocean.

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 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 shown in **Figure** 24.6. Since there is energy loss in food chains, 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 are found on the first trophic level, at the bottom of the pyramid. The next level will be the herbivores, then the carnivores that eat the herbivores. The energy pyramid in **Figure** 24.6 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.

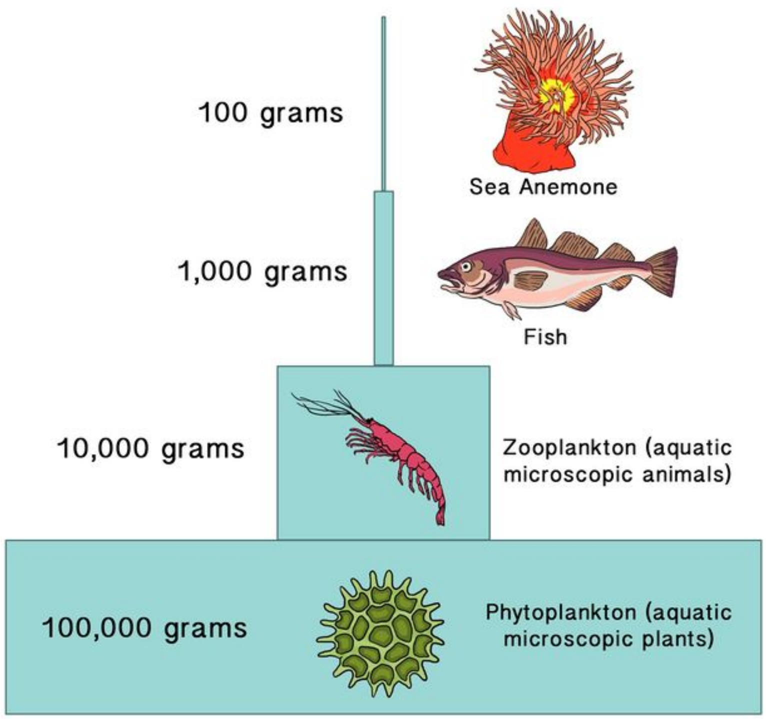


FIGURE 24.6
As illustrated by this ecological pyramid, it takes a lot of phytoplankton to support the carnivores of the oceans.

## Lesson Summary

- Producers, such as plants and algae, can make their own food from the sun and other simple sources.
- Consumers must obtain their nutrients and energy by eating other organisms.
- Decomposers break down animal remains and wastes to get energy.
- Food chains and food webs show the feeding patterns in an ecosystem.
- As energy is transferred along a food chain, energy is lost as heat.

## Review Questions

### Recall

1. How do producers get energy?
2. How do decomposers obtain energy?
3. What shows the complex feeding interactions in a community?
4. What's the term for a consumer that eats both plants and animals?

### Apply Concepts

5. What happens to 90% of the energy that passes from one step in the food chain to the next step?

For questions 6 - 8, Analyze the following food chain: **algae** → **fish** → **herons**

6. What is the producer in the food chain?
7. What is the herbivore in the food chain?
8. What is the carnivore in the food chain?

### Critical Thinking

9. In a forest community, caterpillars eat leaves, and birds eat caterpillars. Draw a food chain using this information.

## Further Reading / Supplemental Links

- http://science-class.net/Ecology/energy_transfer.htm
- http://science-class.net/Ecology/energy_transfer.htm

*Venus fly trap - The Private Life of Plants* can be viewed at http://www.youtube.com/watch?v=ktIGVtKdgwo (3:29).

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Click image to the left for more content.

## Points to Consider

- Animals are made partly of the element carbon. When animals decompose, what happens to the carbon?
- We need nitrogen to make our DNA. Where does it come from? Where does it go? What would happen to nitrogen released from decaying organisms?

- Water is necessary for photosynthesis. Water moves through both the living and non-living parts of an ecosystem. How does water move through the living parts of an ecosystem?

# 24.2 Cycles of Matter

## Lesson Objectives

- Describe the key features of the water cycle.
- Describe the key features of the nitrogen cycle.
- Describe the key features of the carbon cycle.

## Check Your Understanding

- What types of organisms break down animal remains and wastes to release nutrients?
- What are the main chemical elements that are essential for life?

## Vocabulary

- biogeochemical cycles
- fossil fuels
- global warming
- groundwater
- nitrogen fixation
- precipitation
- runoff
- transpiration

## The Water Cycle

Chemicals and nutrients are recycled in an ecosystem in **biogeochemical cycles**. This recycling process involves both the biotic factors and the abiotic factors of the ecosystem. Through biogeochemical cycles, nutrients are constantly being passed through living organisms to non-living matter and back again, over and over. These recycled nutrients contain the elements carbon and nitrogen.

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 is cycled through the biotic and abiotic factors of an ecosystem, moving between living things and non-living things, such as clouds, rivers, and oceans ( **Figure** 24.7).

The water cycle does not have a real starting or ending point, since it is an endless recycling process, but we will start with the oceans. Here are the steps in the water cycle:

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 moves 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.

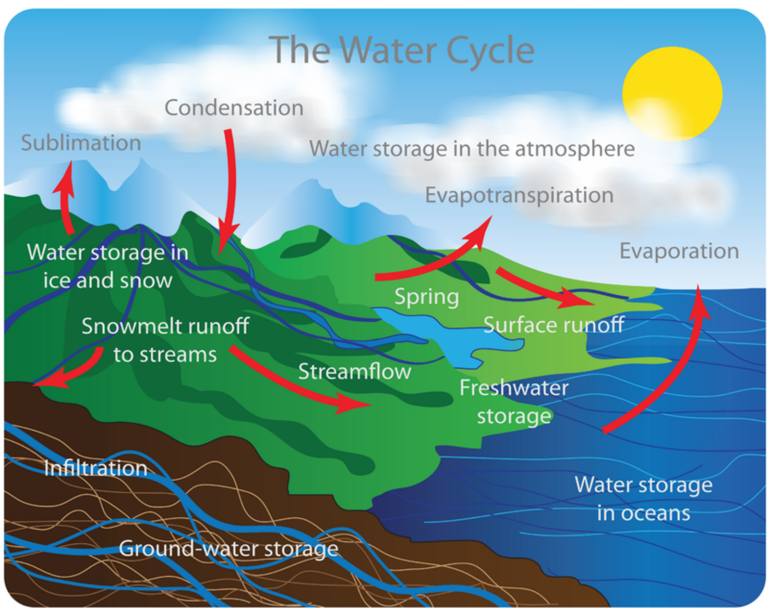
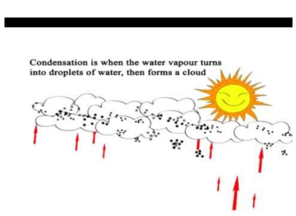



FIGURE 24.7
The water cycle.

See http://www.youtube.com/watch?v=4Cb3SIMRCIE for an animation of the water cycle (3:14).

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## The Carbon Cycle

Carbon is one of the most common elements found in living organisms. Chains of carbon molecules form the backbones of many molecules, such as carbohydrates, proteins, and lipids. Carbon is constantly cycling between living things and the atmosphere ( **Figure** 24.8).

In the atmosphere, there is carbon dioxide. Producers capture the carbon dioxide and convert it to glucose through the process of photosynthesis. As consumers eat producers or other consumers, they gain the carbon from those organisms. Some of this carbon is lost, however, through the process of cellular respiration. That means when our cells burn food for energy, carbon dioxide is released. We, like all animals, exhale this carbon dioxide and return it back to the atmosphere. Also, carbon dioxide is released to the atmosphere as an organism dies and decomposes.

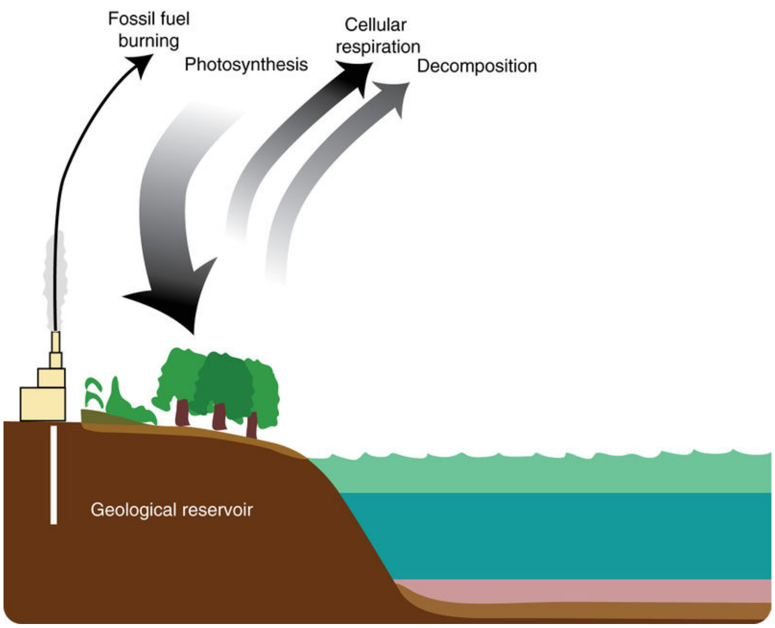



FIGURE 24.8
The carbon cycle.

### 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. These plants and animals are organic matter, with lots of 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** 24.9). 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** (see the *Environmental Problems* chapter for additional information).

FIGURE 24.9

Human activities like burning gasoline in cars are contributing to a global change in our climate.

## The Nitrogen Cycle

Nitrogen is also one of the most common elements in living organisms. It is important for creating both proteins and nucleic acids, like DNA. Nitrogen gas ($N_2$) is in the majority of the air we breathe, but unfortunately, animals and plants cannot use it 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.

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** 24.10).

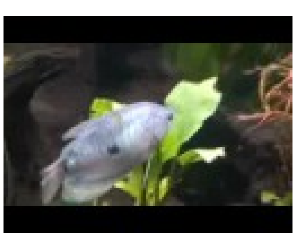
- Lightning: Nitrogen gas can be transformed into nitrate ($NO_3^-$) that plants can use when lightning strikes.
- **Nitrogen fixation**: Special nitrogen-fixing bacteria can also transform nitrogen gas into useful forms. These bacteria live in the roots of plants in the pea family. In water environments, bacteria in the water can fix nitrogen gas into ammonium ($NH_4^+$). 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, it can be used by plants through a process called assimilation.

### Sending Nitrogen back to the Atmosphere

Turning nitrate back into nitrogen gas happens through the work of denitrifying bacteria. These bacteria often live in swamps and lakes. They take in the nitrate and release it 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.

The nitrogen cycle is described at http://www.youtube.com/watch?v=pdY4I-EaqJA (5:08).



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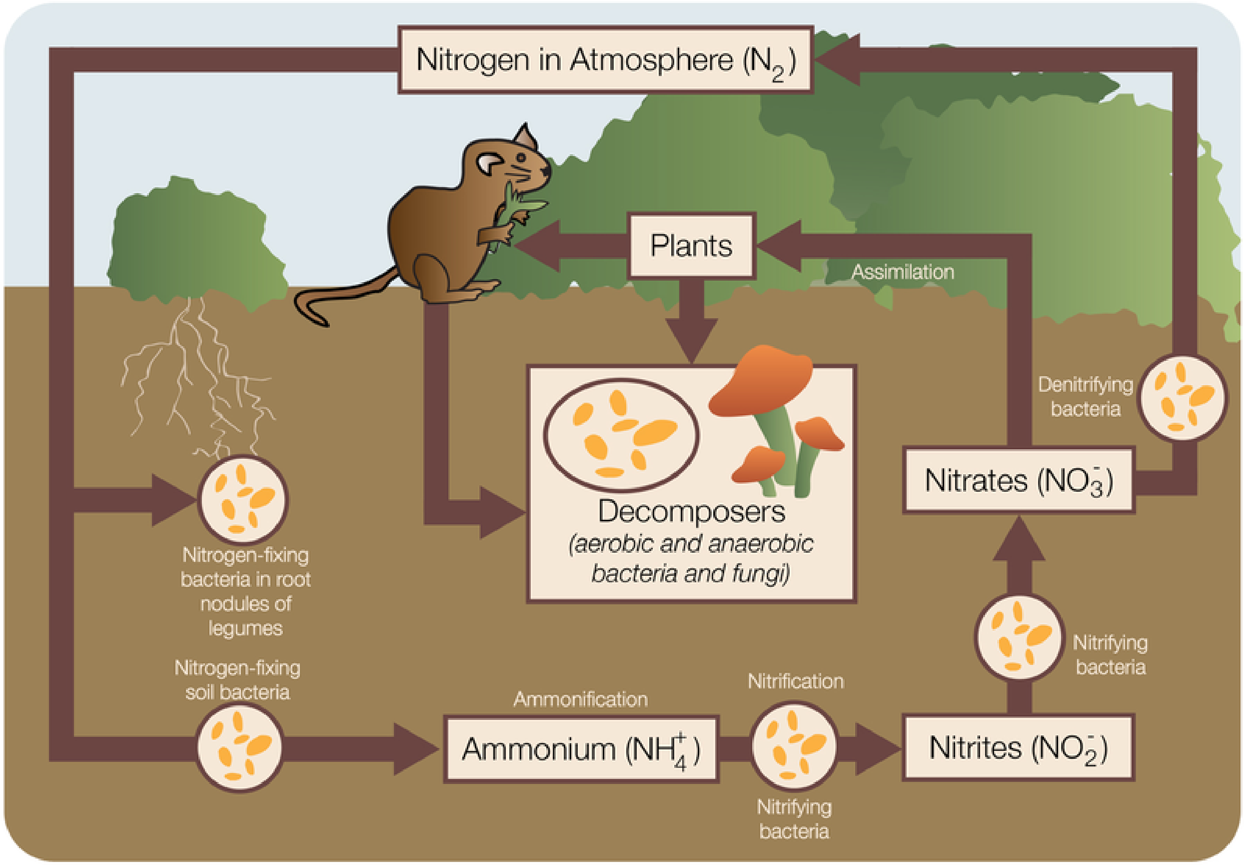


FIGURE 24.10
The nitrogen cycle includes assimilation, when plants absorb nitrogen; nitrogen-fixing bacteria that make the nitrogen available to plants in the form of nitrates; decomposers that transform nitrogen in dead organisms into ammonium; nitrifying bacteria that turn ammonium into nitrates; and denitrifying bacteria that turn nitrates into gaseous nitrogen.

## Lesson Summary

- During the water cycle, water enters the atmosphere by evaporation, and water returns to land by precipitation.
- During the carbon cycle, animals add carbon dioxide to the atmosphere through respiration, and plants remove carbon dioxide through photosynthesis.
- During the nitrogen cycle, gaseous nitrogen is converted into water-soluble forms that can be used by plants, while denitrifying bacteria turn nitrate back into gaseous nitrogen.

## Review Questions

### Recall

1. What is the term for the remains of organisms that are burned for energy?
2. How does water in the atmosphere return to the ground?
3. What are some examples of fossil fuels?
4. What biological process "fixes" carbon, removing it from the atmosphere?

### Apply Concepts

5. What human activities have thrown the carbon cycle off balance?
6. What is the significance of nitrogen-fixing bacteria?
7. What biological process releases carbon back into the atmosphere?
8. What must happen for plants to use nitrogen in the atmosphere?
9. What is the significance of denitrifying bacteria?

### Critical Thinking

10. Why is carbon dioxide referred to as a "greenhouse gas"? Explain the effects of greenhouse gasses on the planet.

## Further Reading / Supplemental Links

- http://earthobservatory.nasa.gov/Library/CarbonCycle
- http://www.cosee-ne.net/resources/documents/OceanLiteracyWorkshopIReport.pdf
- http://www.estrellamountain.edu/faculty/farabee/biobk/BioBookcycles.html
- http://earthobservatory.nasa.gov/Library/CarbonCycle
- http://earthguide.ucsd.edu/earthguide/diagrams/watercycle/index.html

## Points to Consider

- Do ecosystems change over time? Why or why not?
- Can you think of an example of a ecosystem changing over time?

# 24.3 Ecosystem Change

## Lesson Objectives

- Explain the process of ecological succession.
- Distinguish between secondary and primary succession.
- Describe a climax community.

## Check Your Understanding

- What is a biome?
- What is the most abundant element in living things?
- How do humans obtain nitrogen?

## Vocabulary

- climax community
- ecological succession
- pioneer species
- primary succession
- secondary succession

## Ecosystems Change

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. 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.

## Primary Succession

**Primary succession** is the type of ecological succession that happens on lands without plants or animal life. It can take place after a lava flow or a glacier. Since the land that results from these processes is often completely new land, soil must be produced.

Primary succession always starts with a **pioneer species**. This is the species that first lives in the disturbed area.

If life wants to begin on rocks without life, the pioneer species could be a lichen ( **Figure** 24.11). A lichen is actually not one species, but two. There is a symbiotic relationship between a fungus and an algae or cyanobacteria. The fungus is able to absorb minerals and nutrients from the rock, while algae supplies the fungus with sugars. 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 24.11
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 communities. Mosses and grasses will be able to grow in the newly created soil. During early succession, plant species like grasses that grow and reproduce quickly will 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 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 happens where there are already soil and organisms.

**Secondary succession** is the type of succession that happens after something destroys the community. Abandoning a field that was once used for agriculture can lead to secondary succession ( **Figure** 24.12). In this case, the pioneer species would be the grasses that first appear. Slowly, the field would return to the natural state and look like it used to look before the humans used it for agriculture.

Another event that results in secondary succession is a forest fire ( **Figure** 24.13 and **Figure** 24.14). 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,

FIGURE 24.12
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 and trees begin to grow.

then shrubs, and finally bigger trees.

FIGURE 24.13
The early stages of succession after a forest fire are shown in these pictures. Taken two 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.

## Climax Communities

**Climax communities** ( **Figure** 24.15) are the end result of ecological succession. They are a stable balance of all organisms in an ecosystem. The climax community 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.

FIGURE 24.14
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.

FIGURE 24.15
These ancient redwood trees are part of a climax community, the end result of a series of community replacements during succession.

## Lesson Summary

- Ecological succession is the continual replacement of one community by another that happens after big changes in the ecosystem.
- Primary succession happens in disturbed areas that have little or no soil.
- Secondary succession happens in disturbed areas that previously supported life.
- Climax communities develop as the last stage of succession, when the ecosystem is again stable.

## Review Questions

### Recall

1. What is the term for a continuous replacement of one community by another following a disturbance?

2. What type of succession occurs in areas where there is no soil?

3. What type of succession occurs in areas where soil is present?

4. What is the term for the final stage of succession, when the community becomes stable?

### Apply Concepts

5. Imagine a forest fire destroyed a forest. The forest will slowly re-establish itself, which is an example of what kind of succession?

6. A glacier slowly melts, leaving bare rock behind it. As life starts establishing itself on the newly available land, what kind of succession is this?

7. Does the climax community look the same in all parts of the world?

### Critical Thinking

8. An area covered with lava is going through primary succession. Explain in detail all of the stages of succession up until the climax community. Also, describe the complex community.

## Further Reading / Supplemental Links

- http://www.scribd.com/doc/529104/Ecological-Succession
- http://www.biologycorner.com/worksheets/succession.html
- http://ecolibrary.cs.brandeis.edu/general_search.php?id=CS_Succession@Secondary%20succession&page=links

## Points to Consider

- Think about what would happen if dangerous toxins were illegally dumped near a river.
- Discuss why it is important to seek alternative energy sources.
- Do we have an infinite supply of fossil fuels, or will we run out some day?

# 24.4 References


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15. Tony. http://www.flickr.com/photos/humboldthead/420575250/ . CC BY 2.0

# CHAPTER 25 MS Environmental Problems

## Chapter Outline



The image shows smoke pouring into the sky from a factory. This smoke is polluting the air. But what does pollution mean? Is it polluting the air just above the factory? Does the pollution spread? What kind of effects does that kind of smoke have on the environment? What kind of effect does that pollution have on human health?

What about factories that pollute waterways, like rivers, lakes, and oceans? How does that kind of pollution affect the environment and human health? More importantly, what do you think you can do to decrease the amount of pollution in the air and waterways? Are there things you can in your daily life? Think about these questions as you read about the environmental consequences of human activities.

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# 25.1 Air Pollution

## Lesson Objectives

- Discuss the types of outdoor pollution and what causes them.
- Describe the effects of outdoor pollution on the environment.
- Discuss where indoor air pollutants come from and what they are.
- Describe the health hazards of both indoor and outdoor pollutants.
- Discuss how you can protect yourself from air pollution.

## Check your Understanding

- What is pollution?
- What is global warming?

## Vocabulary

- acid rain
- greenhouse gases
- outdoor air pollution
- primary pollutants
- secondary pollutants

## Pollution of Outdoor Air

Air is all around us. Air is essential for life. Sometimes, humans can pollute the air. For example, releasing smoke and dust from factories or cars can cause air pollution. This pollution affects entire ecosystems around the world. Pollution can also cause many human health problems and sometimes death.

You may be familiar with outdoor air pollution, but air pollution can also be found indoors. Air in its unpolluted state cannot be seen, smelled or tasted. Yet the gases in air are very important for life. For example:

- Nitrogen helps build proteins and nucleic acids.
- Oxygen helps to power life.
- Carbon dioxide provides the carbon to build bodies.
- Water supports most forms of life.

**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 are direct pollutants. Particles released from the fire directly enter the air and cause pollution ( **Figure** 25.1). Burning of fossil fuels also directly pollutes the air ( **Figure** 25.2).

FIGURE 25.1
Wildfires, either natural or human-caused, release particles into the air, one of the many causes of air pollution.

FIGURE 25.2
A major source of air pollution is the burning of fossil fuels from factories, power plants, and motor vehicles.

**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 (see below). Both types can hurt the environment or human health.

Most air pollutants can be traced to the burning of fossil fuels. Fossil fuels are burned during the following processes:

- In power plants to create electricity.
- To make machinery run.
- To power stoves and furnaces for heating.
- In transportation, such as cars, trains, and planes.
- In waste facilities.

Another word for "human-caused" is anthropogenic. Anthropogenic air pollution can be caused by agriculture, such as cattle ranching. The use of fertilizers and pesticides can also cause air pollution. Other sources of air pollution include:

- Production of plastics, refrigerants, and aerosols.

- Nuclear power and defense.
- Landfills.
- Mining.
- Biological warfare.

## Environmental Effects of Outdoor Air Pollution

Many outdoor air pollutants may hurt the health of plants and animals, including humans. There are many specific problems caused by the burning of fossil fuels. These include acid rain and global warming.

### Acid Rain

Sulfur oxides are chemicals that are released from coal-fired power plants. Nitrogen oxides are released from motor vehicle exhaust. Sulfur oxides and nitrogen oxides can both cause **acid rain** ( **Figure** 25.3). Acid rain has a very low pH. When the rain hits forests, freshwater habitats, or soils, it can kill insects and aquatic life.

FIGURE 25.3

A forest shows effects caused by acid rain. What do you observe?

### 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 is caused by deforestation, or cutting down trees ( **Figure** 25.4). Trees absorb carbon dioxide, so when trees are cut down, they cannot remove carbon dioxide from the air.

This increase in global temperature will cause the sea level to rise. It is also expected to cause an increase in extreme weather events. It may also change the amount of precipitation. Global warming may also cause food shortages and species extinction.

FIGURE 25.4
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.

## Pollution of Indoor Air

Lack of indoor air movement causes air pollution to stay in places where people often spend a majority of their time. Some indoor pollutants include:

- Radon gas, released from the Earth in certain locations and then trapped inside buildings.
- Formaldehyde gas, emitted from building materials, such as carpeting and plywood.
- Volatile organic compounds (VOCs), given off by paint and solvents as they dry.

Other air pollutants include air fresheners, incense, and other scented items. Wood fires in stoves and fireplaces can produce significant amounts of smoke particles in the air. Use of pesticides and other chemical sprays indoors can be another source of indoor pollution.

Other sources of air pollution include the following:

- Carbon monoxide (CO) is often released by faulty vents and chimneys or by the burning of charcoal indoors.
- Problems with plumbing can release of sewer gas and hydrogen sulfide.
- Dry cleaning fluids, such as tetrachloroethylene, can be released from clothing days after dry cleaning.
- The use of asbestos in factories and in homes in the past has left a very dangerous material in many buildings ( **Figure** 25.5). Asbestos can cause cancer and other lung diseases.

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 can incubate certain bacteria and mold.
- Pollen, dust, and mold from houseplants, soil, and surrounding gardens.

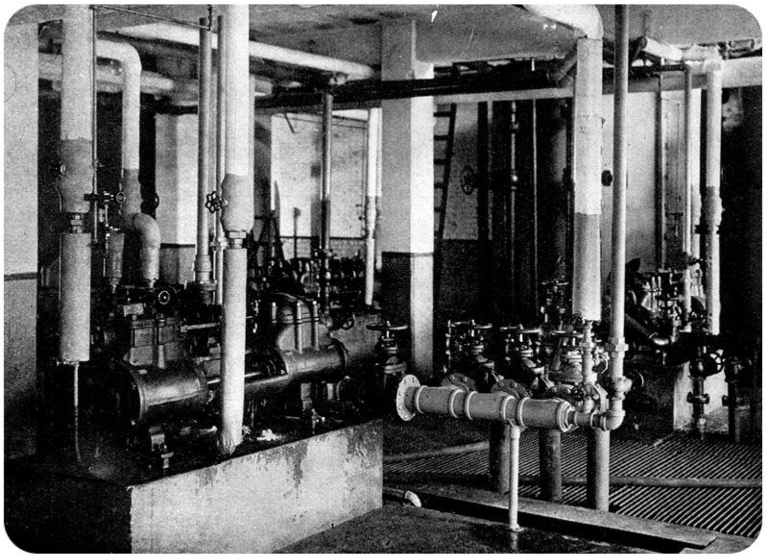

FIGURE 25.5
The use of asbestos in industry and domestic environments in the past, as in the asbestos-covered pipes in the oil-refining plant pictured here, has left a potentially very dangerous material in many businesses.

## 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. 1.5 million of these deaths are caused by indoor sources. Worldwide, there are more deaths linked to air pollution per year than to car accidents. Research by WHO also shows that the worst air quality is in countries with high poverty and population rates, such as Egypt, Sudan, Mongolia, and Indonesia.

Direct causes of air-pollution related deaths include:

- Asthma.
- Bronchitis.
- Emphysema.
- Lung and heart diseases.
- Respiratory allergies.

Certain respiratory conditions can be made worse in people who live closer to or in large cites. Some studies have shown that patients in urban areas suffer lower levels of lung function and more chronic bronchitis and emphysema. Air pollution can also cause an increase in cancer, eye problems, and other conditions. For example, use of certain agricultural herbicides and pesticides, such as DDT and PCBs, can all cause cancer.

### Effects of Smog on Health

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. Smog is caused by coal burning, and by ozone produced by motor vehicle exhaust. Smog can cause eye irritation and respiratory problems. Carbon monoxide from motor vehicle exhaust and from charcoal burning indoors can also cause poisoning and deaths.

### Protecting Yourself from Air Pollution

After reading the above sections, you may be confused as to where the air is healthier, outdoors or indoors. 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 ( **Figure** 25.6) 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:

- Make sure that vents and chimneys are working properly, and never burn charcoal indoors.
- Carbon monoxide detectors can be placed in the home.
- Keep your home as clean as possible from pet dander, dust, dust mites, and mold.
- Make sure air conditioning systems are working properly

Are there any other ways you can think of to protect yourself from air pollution?

FIGURE 25.6
Many people take to wearing masks in public to help maintain their health.

## Lesson Summary

- Outdoor air pollution can change the natural characteristics of the atmosphere and cause unwanted changes to the environment and to human health.
- There are two kinds of pollutants: primary and secondary pollutants.
- There are many sources of human-caused air pollution, the most common being the burning of fossil fuels.
- Outdoor air pollutants cause many environmental effects, among them global warming, global dimming, and ozone depletion.
- Indoor air pollutants are either chemical or biological in nature.
- Both outdoor and indoor pollutants cause many health problems, ranging from respiratory and cardiac to cancer, eye problems, and poisoning.
- While it is not always possible to protect yourself from poor air quality outdoors, there are a number of measures you can take to protect yourself from poor indoor air quality.

## Review Questions

### Recall

1. Define outdoor air pollution.
2. What is the difference between primary and secondary pollutants?
3. Give three examples of indoor air pollutants.

### Apply Concepts

4. Most air pollutants can be traced to the burning of fossil fuels. What are the sources of some of these pollutants?
5. Why does deforestation increase the effects of global warming?
6. Explain why one of the environmental effects of global dimming may result in less food at all trophic levels.
7. Name two environmental effects of ozone depletion.
8. Give an example of air pollutant and explain why is it bad for human health.

### Critical Thinking

9. Even though we have a hole in the ozone layer of the atmosphere, why is it ozone still considered a pollutant?

## Further Reading / Supplemental Links

- http://www.epa.gov/acidrain/education/site_students/
- http://www.koshlandscience.org/exhibitgcc/index.jsp

## Points to Consider

- One of the effects of outdoor air pollution is to cause global warming. How do the effects of global warming affect water pollution?
- How do outdoor air pollutants cause acid rain?

# 25.2 Water Pollution and Waste

## Lesson Objectives

- Describe water pollution sources.
- Explain how water pollution affects living organisms.
- Discuss how to prevent water pollution.
- Discuss ways you can save water

## Check your Understanding

- What are water resources?
- What is the demand for water?
- What are the sources of fresh water?

## Vocabulary

- algal bloom
- ocean acidification
- waterborne diseases
- water pollution

## Sources of Water Pollution

While water may seem limitless and everywhere, it is actually a limited resource. A limited resource is one that we use faster than we can remake it. Unpolluted water is even harder to find ( **Figure** 25.7).

**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.

Natural events, like storms, algal blooms, volcanoes, 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 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.

FIGURE 25.7
Water pollution can cause harmful effects to ecology and human health.

- 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 farms into groundwater or streams.

Specific contaminants causing water pollution include different types of chemicals and pathogens. A small amount of any chemical may not be toxic, but large amount of chemicals in a waterway can cause a lot of damage.

## Effects of Water Pollution on Living Things

Water pollutants can have an effect on both the ecology of ecosystems and on human health.

### Pollution Problem: Eutrophication

Eutrophication is an increase in chemical nutrients, specifically compounds containing nitrogen or phosphorus, in an ecosystem. It occurs when run-off from lawn or farm fertilizers gets into natural waters, such as rivers or coastal waters.

Since there are such high levels of plant nutrients in the water, algae will grow, forming **algal blooms**. The algae grows so large and so fast that when it dies, it sucks the oxygen out of the water. Without oxygen, fish and shellfish cannot live ( **Figure** 25.8).

As a result, humans cannot use the waterway for recreation, fishing or hunting. Drinking water can be affected if the toxic water enters the groundwater. Toxins created during the algal bloom can enter shellfish. If humans eat these shellfish, then they can get shellfish poisoning. This can cause neurological problems in humans.

### Pollution Problem: Ocean Acidification

**Ocean acidification** occurs when carbon dioxide released by human factories into the atmosphere causes the oceans to become acidic. Burning fossil fuels leads to an increase in carbon dioxide into the atmosphere. This carbon dioxide is then absorbed by the oceans.

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 may be fewer marine organisms that humans consume.

FIGURE 25.8
Lake Valencia, Venezuela, showing green algal blooms. How did the algal bloom form? What will it do to the lake over time?

### Pollution Problem: Aquatic Debris

Aquatic debris is trash that gets into fresh and saltwater waterways. It comes from shipping accidents, landfill erosion, or the dumping of trash.

Debris can be very dangerous to aquatic wildlife. Some may swallow plastic bags, while other organisms can be strangled by plastic six-pack rings. Wildlife can also get tangled in nets ( **Figure** 25.9). This may decreases the amount of fish available for human consumption.

FIGURE 25.9
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?

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 cases of diarrheal disease are caused by unsafe water supply. Such **waterborne diseases** can be caused by protozoa, viruses, bacteria, and intestinal parasites. Protozoal infections can be caused by sewage, non-treated drinking water, animal manure, poor disinfection, and groundwater contamination.

## Preventing Water Pollution

In the U.S., concern over water pollution resulted in the enactment of state anti-pollution laws in the latter half of the 1800s, and federal legislation in 1899. The laws prohibit the disposal of any waste into the nation's rivers, lakes, streams, and other bodies of water, unless a person first had a permit. In 1948, the Water Pollution Control Act was passed and gave power to the Surgeon General to reduce water pollution. Growing public awareness and concern for controlling water pollutants led to enactment of the Federal Water Pollution Control Act Amendments of 1972, also known as the Clean Water Act. 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** 25.10).

FIGURE 25.10

A water purification system where contaminants are removed to make clean water.

## Ways to Save Water

Saving water can help make sure we have clean water for future use. Preventing water pollution is one way of saving precious water resources. One way to make sure that water is kept clean and conserved is the use of wastewater reuse or cycling systems. This means that wastewater can be purified at a water treatment plant ( **Figure** 25.11). When wastewater is recycled, waterborne diseases caused by sewage and non-treated drinking water can be prevented.

There are various means of removing contaminants from water. Atmospheric water generation is one technology that can provide high quality drinking water. It involves extracting water from the air by cooling the air and turning it back into a liquid.

Both developed and developing countries can increase protection of ecosystems, especially wetlands, in order to save clean water.

What are some ways you can save water in your own house or community in order to increase the resource of clean water, to be made available to everyone?

FIGURE 25.11
Sand processing mill. Water is used to wash mined sand, then is drained into tanks, filtered, and recycled.

## Lesson Summary

- There are two primary sources of water pollution, point sources and nonpoint sources.
- Specific contaminants causing water pollution include chemicals and pathogens.
- Water pollution can affect both ecology and human health.
- One effect of water pollution is eutrophication, which can harm aquatic ecosystems as well as on human life, including health.
- Water pollution also causes ocean acidification.
- Contaminated groundwater can lead to poisoned drinking water and various health problems, including cancer.
- A variety of water pollutants can cause waterborne diseases.
- Various legislation has regulated contaminants entering into water resources.
- Different ways of saving water can also have an impact on our clean water supply.

## Review Questions

### Recall

1. When is water considered polluted?
2. What is point source pollution?
3. Name some sources of nonpoint source pollution.
4. Name some sources of pollutants that can cause waterborne diseases.

### Apply Concepts

5. Why are nonpoint sources of pollution so difficult to regulate?

6. Why might floating plastic debris be a problem for marine life?

7. What can you do to save clean water?

### Critical Thinking

8. Lakes often become polluted when sewage plants release phosphorous into the water. By what process would the release of phosphorus affect a lake's plant growth? How could this affect water quality and fish and shellfish populations?

## Further Reading / Supplemental Links

- http://www.cdli.ca/CITE/water.htm

## Points to Consider

- Even though water is a renewable resource, there is not always availability of clean water. Control of water pollution, such as removal of phosphorus or creating buffer zones near farms, helps to preserve this renewable resource for the future.
- Methods such as wastewater reuse, atmospheric water generation, reclaiming water, catchment management, and protection of aquatic systems can all contribute towards the dual goals of keeping water clean and also available for future generations.

# 25.3 Natural Resources

## Lesson Objectives

- Define natural resource.
- Describe renewable resources.
- Define nonrenewable resource.
- Discuss the use of fossil fuels as an energy source.
- List alternative uses to fossil fuels.
- Discuss how reducing, reusing, and recycling can help conserve resources.

## Check your Understanding

- What are our natural resources?
- What is the difference between a renewable and nonrenewable resource?

## Vocabulary

- erosion
- hydropower
- natural resources
- nonrenewable resource
- nuclear power
- recycling
- reducing
- renewable resources
- solar power
- wind power

## What are Natural Resources?

A **natural resource** is a naturally occurring substance that is necessary for the support of life. What resources do you use on a daily basis? You may think of air and water. What else is absolutely necessary to your survival? The food you eat. Can you survive with just air, water, and food? Are other resources, like the land you live on, the house you live in, the gasoline your parents put in the car and the tools you use at home or at school resources, too? Yes.

## Renewable Resources

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** 25.12 and **Figure** 25.13). Tides are another example of a resource in unlimited supply.

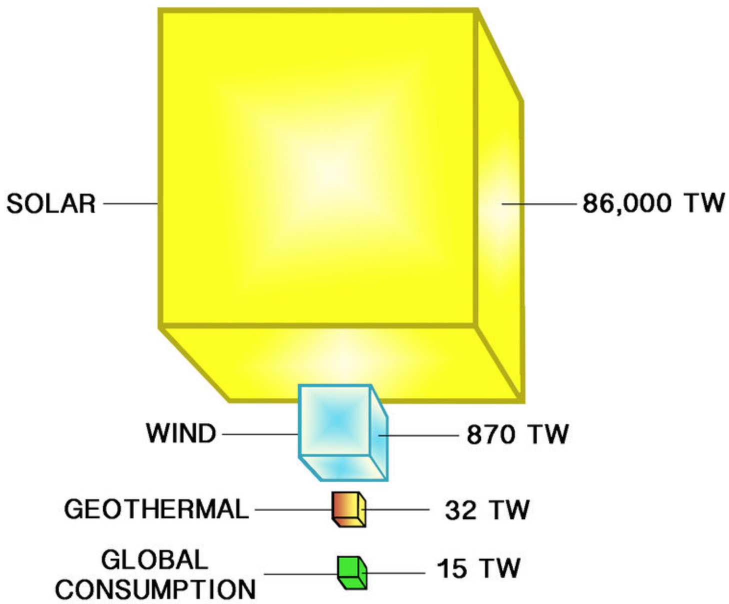


FIGURE 25.12
The figure shows the maxiimum potential of each energy source used worldwide. TW stands for terrawatt, which is a very large unit for measuring energy. Solar radiation and wind energy are considered renewable resources because both can be created just as fast as we use them.

FIGURE 25.13
Wind power, another renewable resource, shown here in a modern wind energy plant.

Based on what you learned in the last two lessons, would you say air and water are renewable resources? Your knowledge about air and water pollution would tell you that clean air and water are not always available.

Soils are often considered renewable, but **erosion** sometimes makes it nonrenewable. Erosion occurs when the nutrient-rich top levels of soil are removed because of wind or bad farming techniques ( **Figure** 25.14).

Living things, like forests and fish, are considered renewable because they can reproduce to replace individuals lost to human consumption. But over-using these resources can lead to species extinction.

Also, metals and other minerals are sometimes considered renewable because they can be recycled.

FIGURE 25.14
Soil as a resource, showing a mixture of eroded rock, minerals, ions, water, air, roots, fungi, animals, and microorganisms, formed over thousands or possibly millions of years.

If something can be renewed, but at great cost economically or ecologically, should that resource still be considered renewable?

For example, energy resources from living things, such as ethanol, plant oils, and methane, are called renewable. But these can have harmful effects on the environment. For example, too much methane in the atmosphere can increase global warming.

*Sustainable* means that a resource 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 can suck all of the nutrients out of a soil.

## 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! It has been estimated that 20 metric tons of phytoplankton produce one liter of gasoline. Humans save been consuming fossil fuels for less than 200 years, yet remaining reserves of oil can supply our needs for only 45 years. Gas can only supply us for another 72 years. Coal can only supply us for 252 years.

- **Nuclear power** is power developed from atoms in certain elements, such as uranium. Currently, there are limited uranium fuel supplies, which will last about 70 years at current rates of use. New technologies could make some uranium fuel reserves more useful.

Population growth, especially in developing countries, should make us think about how fast we are consuming resources. Developing nations will also increase demands on natural resources as they build more factories ( **Figure** 25.15).

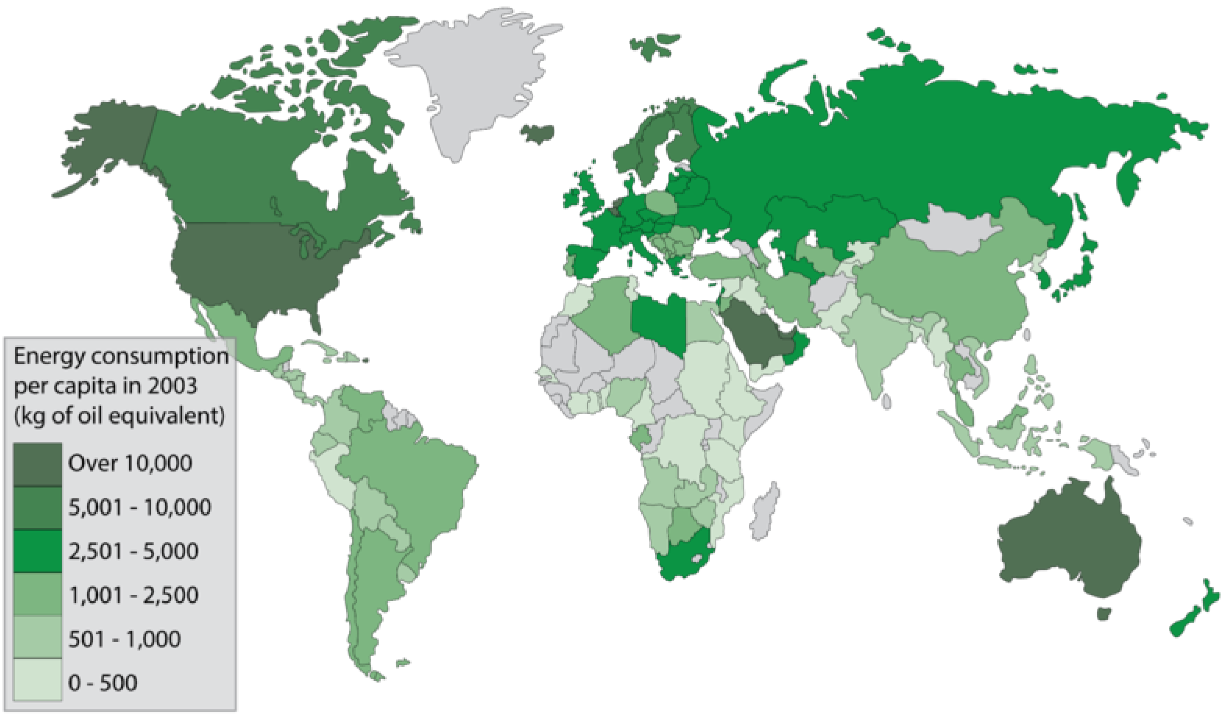


FIGURE 25.15
Per capita energy consumption (2003) shows the unequal distribution of wealth, technology, and energy use.

Improvements in technology, conservation of resources, and controls in population growth could all help to decrease the demand on natural resources.

## Fossil Fuels and Alternative Energy Sources

As you learned in the section on nonrenewable resources, fossil fuels are non-renewable resources. They take millions of years to form naturally, and cannot be replaced as fast as they are consumed.

It was estimated in 2005 that 86% of energy produced in the world came from burning fossil fuels. Wars have been fought over fossil fuels like oil. Producing and burning fossil fuels also harms the environment.

Alternative energy resources are being developed so we do not need to be dependent on fossil fuels anymore. Below are examples of sustainable alternative energy resources:

- **Solar power** uses solar cells to turn sunlight into electricity ( **Figure** 25.16). The electricity can be used to power anything that uses normal coal-generated electricity.

FIGURE 25.16
An example of solar power, using solar cells to convert sunlight into electricity.

- **Wind power** 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** 25.17) 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 25.17
Hydropower plant.

Other alternative energy sources to the burning of fossil fuels include geothermal power, biomass biofuels, tidal power, nuclear energy, and fusion power. Let's examine these briefly to see how they compare with the sources of energy we've already discussed.

- Geothermal power 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 production involves using garbage or other renewable resources, like corn, to create electricity. When garbage decomposes, the methane produced is captured in pipes and burned to produce electricity. Wastes from agriculture could also be recycled. 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** 25.18).
- Nuclear power plants use nuclear energy (fission) to create energy inside of a nuclear reactor. The nuclear reactor releases heat. The released heat, heats water to create steam, which spins a turbine. Again, the spinning turbine creates electricity ( **Figure** 25.19).

FIGURE 25.18
Dam of the tidal power plant in the Rance River, Bretagne, France.

What type of alternative energy source do you think is the most interesting? Which type should we use instead of fossil fuels?

## Reduce, Reuse, and Recycle

You may have heard people say "Reduce, Reuse, Recycle." But what do each one of those words mean?

**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:

FIGURE 25.19
Aerial photo of the Bruce Nuclear Generating Station near Kincardine, Ontario .

- When you go shopping for items, buy quantities you know you will use without waste.
- Turn lights off when not using them.
- Replace burned out bulbs with ones that are more energy-efficient.
- Reduce water use by turning off faucets when not using water.
- Use low-flow shower heads, which save on water and use less energy.
- 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.
- n 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.
- Walk or bicycle instead of using an automobile, in order to save on fuel costs and to cut down on pollution.
- When buying a new vehicle, check into hybrid and semi-hybrid brands to cut down on gas mileage and pollution.

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 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.
- Catching rain or runoff in rain barrels next to buildings.

What are some other ways to reuse resources?

Now we move on to **recycling.** Sometimes it may be difficult to understand the differences between reusing and recycling.

Recycling 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:

- Concrete.
- Batteries.
- Biodegradable waste.
- Electronics.
- Iron and steel.
- Aluminum ( **Figure** 25.20).
- Glass.
- Paper.
- Plastic.
- Textiles, such as clothing.
- Timber.
- Old ships.
- Tires.

FIGURE 25.20
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 out your plastics, glass, and paper if you need to.
- See if your school recycles. If not, you and some friends could start a recycling club, or organize efforts to better recycling goals

The amount that an individual wastes is small in proportion to all the waste produced by society. Yet all small contributions, when added up, make a difference. But that also means that laws need to be created to make sure people and companies reduce, reuse, and recycle. Individuals can vote for leaders who stand for sustainable and 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.

## Lesson Summary

- A natural resource is a naturally occurring substance that is necessary for the support of life.
- Resources are either renewable or nonrenewable.
- Examples of renewable resources include sunlight and wind tides.
- Nonrenewable resources include fossil fuels and nuclear power.
- Burning of fossil fuels causes harmful effects in the environment and can lead to war.
- There are a number of renewable energy sources which offer alternatives to the burning of fossil fuels. They include solar radiation, wind energy, and hydropower.
- Reducing waste, as well as reusing and recycling resources, can help save natural resources.
- There are many things you can do in your household and community to reduce, reuse, and recycle.
- Consumers can influence companies to become more environmentally friendly.
- Individuals can tell their leaders to make wise use of natural resources, and to vote for those leaders who stand for sound ecological practices.

## Review Questions

### Recall

1. Define renewable resource.

2. Give two examples of nonrenewable resources.

3. Why is nuclear power considered a nonrenewable resource?

### Apply Concepts

4. Why must some natural renewable resources, such as geothermal power, fresh water, timber, and biomass be used carefully?

5. What human activities put increasing pressure on how fast we consume such resources?

6. What are the main disadvantages to the burning of fossil fuels as an energy source?

7. What two advantages do solar power, wind power, and hydropower all have in common?

### Critical Thinking

8. Pick one renewable or alternative energy resource. Explain to your mayor why you think it would be good for your community to invest in this natural resource.

## Further Reading / Supplemental Links

- http://dnr.state.il.us/lands/education/index.htm
- http://www.nrcs.usda.gov/feature/education/squirm/skworm.html
- http://fossil.energy.gov/education/energylessons/index.html

## Points to Consider

- Why do you think it is important to protect natural habitats?
- Discuss how the protection of natural resources may be important for biodiversity.

# 25.4 Habitat Destruction and Extinction

## Lesson Objectives

- Discuss what causes destruction of habitats.
- Explain why habitat destruction threatens species.
- Describe causes of extinction other than habitat destruction.
- Explain why biodiversity is important.
- Explain why habitat protection is important, including for maintaining biodiversity.

## Check your Understanding

- What is a habitat?
- What is habitat destruction?
- What is the effect of habitat destruction?
- What is biodiversity?

## Vocabulary

- biodiversity
- desertification
- extinction
- invasive species
- slash-and-burn agriculture

## The Importance of Biodiversity

Some of the importance of biodiversity is shown in the following three figures ( **Figure** 25.21, **Figure** 25.22, and **Figure** 25.23). In this lesson you will read about habitat destruction and the impact of this destruction on biodiversity. **Biodiversity** is a measurement of the amount of variation of the species in a given area.

## Causes of Habitat Destruction

From a human point of view, a habitat is the environment where you live, go to school, go to have fun, and regularly visit. A habitat is the natural home or environment of an organism. Humans often cause habitat destruction for other organisms. Humans cause habitat destruction by land clearing ( **Figure** 25.24) and by the introduction of non-native

FIGURE 25.21
A sampling of some of the wide diversity of animal species on earth.

FIGURE 25.22
Coral reefs are one of the biomes with the highest biodiversity on earth.

FIGURE 25.23
This tropical rain forest shows another biome having one of the greatest biodiversities on earth.

species of plants and animals. Habitat destruction can cause the extinction of species ( **Figure** 25.25). **Extinction** is the complete disappearance of a species. Once a species is extinct, it can never recover.

FIGURE 25.24
Slash-and-burn agriculture, shown here in southern Mexico, clears land for agriculture.

### Land Loss

Clearing habitats of plants for agriculture and development is a major cause of destruction. Within the past 100 years, the amount of total land used for agriculture has almost doubled. Land for the grazing of cattle has more than doubled.

Agriculture alone has cost the United States half of its wetlands ( **Figure** 25.26) and almost all of its tallgrass prairies

FIGURE 25.25

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** 25.27). 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** 25.28).

FIGURE 25.26

Wetlands such as this one in Cape May, New Jersey, filter water and protect coastal lands from storms and floods.

### Slash-and-Burn Agriculture

Other habitats that are being rapidly destroyed are forests, especially tropical rainforests. The rainforest is one of the two major ecosystems with the greatest biodiversity on earth. The largest cause of deforestation today is **slash-and-burn agriculture** ( **Figure** 25.24). This means that when people want to turn a forest into a farm, they cut down all of the trees and then burn them. This technique is used by over 200 million people in tropical forests throughout the world.

These people use the soil very quickly, so nutrients are lost. This often results in people abandoning the forest within a few years. The abandonment can cause erosion and lead to desertification. **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 2090.

FIGURE 25.27
Big bluestem grasses as tall as a human were one of the species of the tallgrass prairie, largely destroyed by agricultural use.

FIGURE 25.28
Herds of bison also made up part of the tallgrass prairie community.

### 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**. Invasive species out-compete the native species for resources. Sometimes native species are so successful at living in a certain habitat that the native species go extinct.

Recently, cargo ships have transported zebra mussels, spiny waterfleas, and ruffe (a freshwater fish) into the Great Lakes ( **Figure** 25.29). 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.

Other causes of habitat destruction include poor fire management, overfishing, mining ( **Figure** 25.30), pollution, and storm damage.

FIGURE 25.29
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.

FIGURE 25.30
Strip coal mining, pictured here, has destroyed the entire ecosystem.

## Examples of Habitat Destruction

### Wetlands

A habitat that is quickly being destroyed is the wetland. By the 1980s, over 80% of all wetlands in seven states 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. Over half of the Portlethen moss in Aberdeenshire, for example, has been lost. A number of species, such as the great crested newt, have gone extinct.

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.

## Other Causes of Extinction

### Global Warming

Another major cause of extinction is global climate change. As we have already seen earlier in this chapter, our increasing need for coal and oil is changing the earth's climate. Any change in the climate can destroy the habitat of a species. For example, if the seas increase in temperature, it may be too warm for certain types of fish to reproduce.

### Overpopulation

Human populations are on the rise. The highest population growth rates are often in developing tropical countries. These countries are also where biodiversity is highest. Development by humans can cause habitats to be destroyed. This destruction can force species to go extinct, or move somewhere else.

### 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 destroyed the habitat of the peregrine falcon. The pesticide collected in organisms low on the food chain. When organisms high on the food chain started to consume the organisms that contained the chemical, they started to die. This caused the disappearance of the peregrine falcon from this area. DDT was then banned in the U.S.

Water pollution threatens vital freshwater and marine resources throughout the world ( **Figure** 25.31). Specifically, industrial and agricultural chemicals, waste, acid rain, and global warming threaten water. As water is essential for all ecosystems, water pollution can result in extinction.

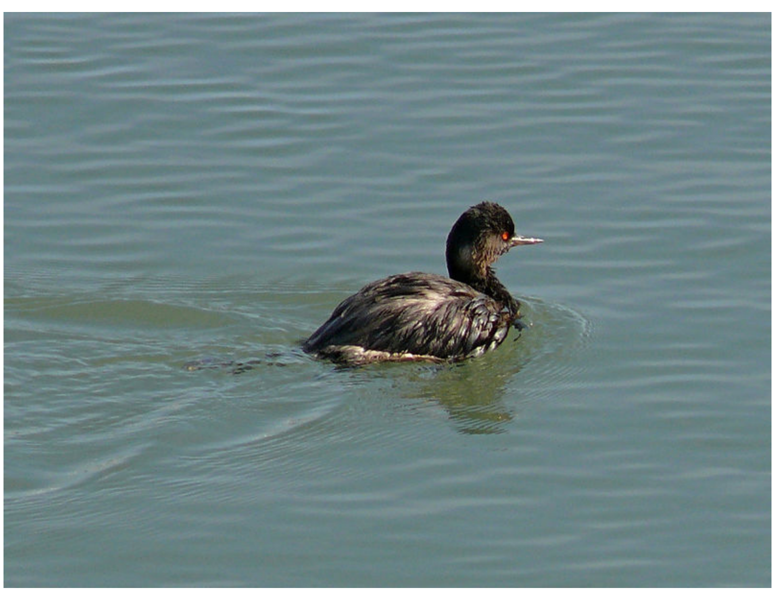

FIGURE 25.31

An oiled bird from 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** 25.32), salts from irrigation, and pesticides from agriculture. These all degrade the soil as well. As soil is the foundation of terrestrial ecosystems and their biodiversity, this can result in extinction.

FIGURE 25.32
Soil contamination.

## Importance of Biodiversity

Does it matter if we are losing thousands of species each year? The answer is yes. It matters even if we consider only direct benefits to humans. But there are many benefits to ecosystems.

### Economic Importance

Economically, there are many direct benefits of biodiversity. In our food supply, when we grow one type of crop on large areas of farmland, it is called a monoculture. Unfortunately, when a certain type of crop is grown year after year, it becomes more likely to develop disease. Agriculture benefits from biodiversity. In 1970, a disease almost wiped out 80% of corn grown in the U.S. ( **Figure** 25.33). This would not have happened if there was a diversity of corn being grown. Certain species of corn would have contracted the disease, while others would not have contracted it.

As many as 40,000 species of fungi, plants, and animals provide us with many varied types of clothing, shelter, and other products. These include poisons, timber, fibers, fragrances, papers, silks, dyes, adhesives, rubber, resins, skins, furs, and more. According to one survey, 57% of the most important prescription drugs come from nature. Specifically, they come from bacteria, fungi, plants, and animals. 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.

Bionics, also known as biomimetics or biomimicry, uses organisms to inspire technology or engineering projects. For example, rattlesnake heat-sensing pits helped inspire the development of infrared sensors. Zimbabwe's Eastgate Centre ( **Figure** 25.34) was inspired by the air-conditioning efficiency of a termite mound ( **Figure** 25.35).

FIGURE 25.33

In order to increase the genetic diversity of corn, these unusually colored and shaped Latin American maize are bred with domestic corn lines. Such hybrids may have increased resistance to local diseases.

FIGURE 25.34

Design of the Eastgate Centre, in Zimbabwe, which requires just 10% of the energy needed for a conventional building of the same size, was inspired by a biological design.

FIGURE 25.35
The air-conditioning efficiency of this termite mound was the inspiration for the Eastgate Centre.

### Ecological Importance

At an ecological level, biodiversity has many benefits. Biodiversity makes ecosystems more stable. Biodiversity helps keep the nutrients in the soil. For example, a diversity of organisms in the soil allows nitrogen fixation and nutrient recycling to happen. Biodiversity allows plants to be pollinated by different types of insects. Also, 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.

Biodiversity is critically important for us and for the earth. What can you do to help protect habitats?

## Protecting Habitats

There are lots of things we can do to protect biodiversity:

- Reduce, reuse, and recycle all resources.
- Do not introduce invasive species.
- Practice sustainable development of land.
- Learn more about biodiversity and its importance.
- Vote for lawmakers who make sure biodiversity is protected.

You can also support areas that protect habitats, like national parks, nature reserves, state parks, and even community and town parks.

Think about sustainable management even at the level of your own backyard. What does your household do with organic waste? Do you have a compost pile, or would you or your family consider starting one? What kinds of trees and shrubs are planted in your yard? Are they native or invasive species? Are they drought-tolerant?

Research some of the vegetation you can plant that will attract native bird, mammal, and other species. Put out bird feeders, especially in the winter in areas where birds may have trouble finding food.

Remember that in addition to all the actions you can take, learning about biodiversity and ecology is an important part of valuing and protecting the diversity of life. Pass on what you learn to others.

## Lesson Summary

- There are a number of causes of habitat destruction, including clearing of land, introduction of invasive species, overfishing, mining, pollution, and storm damage.
- Some habitats affected by destruction include tropical rainforests, wetlands, and coral reefs.
- Biodiversity is important because it directly benefits humans and ecosystems.
- Because of the importance of biodiversity and habitats, it is important that we do what we can as citizens to protect habitats.

## Review Questions

### Recall

1. What are two major causes of habitat destruction?
2. What is the largest cause of deforestation today?

### Apply Concepts

3. How can habitat destruction through pollution kill a species over a long period of time?
4. Why do introduced exotic species have unexpected and negative effects in the new ecosystems?
5. Why is it important to grow different species of the same type of plant?
6. What are some of the things you can do to have a sustainably managed backyard?

### Critical Thinking

7. Explain how biological magnification played a role in the disappearance of the peregrine falcon from the eastern U.S.
8. Pick an environment near where you live that is a natural ecosystem (like a wetland or other area). Explain to a law-maker why it is important to maintain biodiversity in that particular environment.

## Further Reading / Supplemental Links

- http://www.epa.gov/owow/oceans/kids.html
- http://ology.amnh.org/biodiversity
- http://www.biodiversity911.org

## Points to Consider

- Global warming and climate change are frequently in the news these days, with reports of glaciers melting, and possible effects on species, such as the polar bear. Keep aware of these news trends and learn what you can about what species are becoming threatened.

- Our purchasing decisions may affect biodiversity: be more aware of the natural resources used to make and transport any product you buy; Buy recycled products whenever possible; when you buy fish for food, check to be sure that commercial species are not from overharvested areas.

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# CHAPTER 26 MS Life Science Glossary

## Chapter Outline

# 26.1 A

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

**ABO blood type system**
Blood group system that is determined by the presence or absence of certain molecules, called antigens, on the surface of red blood cells (RBCs); there are four blood types in the ABO system: A, B, AB, and O.

**abscisic acid**
Plant hormone involved in maintaining dormancy and closing the stomata.

**absorption**
Process in which substances are taken up by the blood; after food is broken down into small nutrient molecules, the molecules are absorbed by the blood.

**acid rain**
Precipitation or deposits with a low (acidic) pH.

**acquired trait**
A feature that an organism gets during its lifetime in response to the environment (not from genes); not passed on to future generations through gene

**active transport**
The movement of a molecule from an area of lower concentration to an area of higher concentration; requires a carrier protein and energy.

**adaptation**
A beneficial trait that helps an organism survive in its environment.

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

**aerobic exercises**
Types of exercises that cause the heart to beat faster and allow the muscles to obtain energy to contract by using oxygen.

**aerobic respiration**
Cellular respiration in the presence of oxygen.

**aerofoil**
A surface which is designed to aid in lifting or controlling by making use of the air currents through which it moves.

**AIDS**
Acquired immune deficiency syndrome, which is a fatal condition caused by the human immunodeficiency virus (HIV).

**alcoholic fermentation**
Fermentation in the absence of oxygen; produces ethyl alcohol (drinking alcohol) and carbon dioxide; occurs in yeasts.

**algal bloom**
Excessive growth of aquatic vegetation or phytoplankton as a result of eutrophication.

**allele**
An alternative form of a gene.

**allergen**
A substance that triggers an allergy.

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

**allopatric speciation**
Speciation that occurs when groups from the same species are geographically isolated physically for long periods.

**alternation of generations**
A lifecycle that alternates between a haploid gametophyte and a diploid sporophyte; characteristic of plants.

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

**alveoli**
Little *sacs* at the end of the bronchioles where most of the gas exchange occurs.

**amino acid**
The units that combine to make proteins.

**amniotes**
Vertebrates whose embryos are surrounded by an amniotic membrane.

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

**anaerobic exercise**
Types of exercises that involve short bursts of high-intensity activity; forces the muscles to obtain energy to contract without using oxygen.

**anaerobic respiration**
Cellular respiration in the absence of oxygen; fermentation.

**anaphase**
Third phase of mitosis and meiosis (anaphase I and anaphase II) where sister chromatids separate and move to opposite sides of the cell.

**angina**
Chest pain caused by the lack of oxygen to the heart muscle; can happen during times of stress or physical activity.

**angiosperms**
Plants with vascular tissue, seeds, and flowers.

**animal behavior**
Any way that animals act, either alone or with other animals.

**anther**
The pollen-containing structure in a flower.

**antibody**
Protein that identifies pathogens or other substances as being harmful; can destroy pathogens by attaching to the cell membrane of the pathogen.

**antidiuretic hormone (ADH)**
Hormone that controls the absorption of water back into blood.

**antigen**
Any protein that triggers an immune response; usually a foreign protein, unlike any protein that the body makes.

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

**apical dominance**
Suppressing the growth of the side branches of a plant.

**applied science**
The application of science to practical problems.

**aquaculture**
The raising of aquatic plants and animals, especially seaweed, shellfish and other fish.

**aquatic biomes**
Biomes divided into freshwater and marine biomes and defined according to different physical and ecological factors.

**Archaea**
Microscopic one-celled organisms with no nucleus that tend to live in extreme environments.

**arteries**
Blood vessels that carry blood away from the heart.

**artificial selection**
Occurs when humans select which plants or animals to breed to pass specific traits on to the next generation.

**asexual reproduction**
A form of reproduction in which a new individual is created by only one parent.

**asthma**
A chronic illness in which the bronchioles are inflamed and become narrow.

**atherosclerosis**
A chronic inflammation of the walls of arteries that causes swelling and a buildup of material called plaque.

**atom**
The simplest and smallest particle of matter that still retains the physical and chemical properties of the element; the building block of all matter.

**atomic number**
The number of protons in an element.

**ATP**
A usable form of energy inside the cell; adenosine triphosphate.

**atrioventricular (AV) valves**
Valves that stop blood from moving from the ventricles back into the atria.

**atrium**
One of the two small, thin-walled chambers on the top of the heart that blood first enters.

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

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

**autosomes**
The chromosomes other than the sex chromosomes.

**autotroph**
Organism that produces complex organic compounds from simple inorganic molecules using a source of energy such as sunlight.

**auxin**
Plant hormone involved in tropisms and apical dominance.

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

# 26.2 B

**bacilli**
Rod-shaped bacteria or archaea.

**bacteria**
Microscopic one-celled prokaryotic organisms (without a nucleus).

**ball and socket joint**
Joint structure in which the ball-shaped surface of one bone fits into the cuplike depression in another bone; examples include the shoulder and hip joints.

**barbel**
A thin fleshy structure on the external part of the head, such as the jaw, mouth or nostrils, of certain fishes.

**basic science**
Research whose goal is just to find out how the world works, not to solve an urgent problem. Basic research is the source of most new scientific information and nearly all new theories.

**behavioral isolation**
The separation of a population from the rest of its species due to some behavioral barrier, such as having different mating seasons.

**bilateral symmetry**
Body plan in which the left and right side are mirror images.

**binary fission**
An asexual form of reproduction where a cell splits into two daughter cells.

**binomial nomenclature**
The system for naming species in which the first word is the genus and the second word is the species.

**biodiversity**
The number of different species or organisms in an ecological unit (i.e. biome or ecosystem).

**biogeochemical cycles**
The pathway of elements like carbon and nitrogen through the non-living and living parts of the ecosystem.

**biohazard**
Any biological material, such as infectious material that poses a potential to human health, animal health, or the environment.

**biological clock**
Tiny structure in the brain that controls circadian rhythms.

**biome**
A large community of plants and animals that live in the same place.

**biosphere**
The part of the planet and atmosphere with living organisms.

**biotic**
Biological (living) properties of an environment, i.e., the living organisms in a habitat.

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

**blood**
A body fluid that is a type of connective tissue; moves oxygen and other compounds throughout the body.

**blood clotting**
The complex process by which blood forms solid clots.

**blood pressure**
The force exerted by circulating blood on the walls of blood vessels.

**bone marrow**
Soft connective tissue found inside many bones; site of blood cell formation.

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

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

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

**bronchitis**
An inflammation of the bronchi.

**budding**
Asexual reproduction in which part of the body of a fungus, for example, grows and breaks off, eventually becoming a new organism.

# 26.3 C

**calorie**
Unit used to measure the energy in food.

**calyx**
The sepals collectively; outermost layer of the flower.

**Cambrian explosion**
A sudden burst of evolution that may have been triggered by an environmental change(s); made the environment more suitable for a wider variety of life forms; occurred during the Cambrian Period.

**camouflage**
An appearance which helps a species blend into the background.

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

**capillaries**
The smallest and narrowest blood vessels in the body.

**carapace**
The thick dorsal shield seen in many crustaceans; often forms a protective chamber for the gills.

**carbohydrate**
Nutrient that include sugars, starches, and fiber; give your body energy; class of organic compound.

**carcinogen**
Anything that can cause cancer.

**cardiac muscle**
An involuntary and specialized kind of muscle found only in the heart.

**cardiovascular disease (CVD)**
Any disease that affects the cardiovascular system, although the term is usually used to describe diseases that are linked to atherosclerosis.

**cardiovascular system**
The organ system that is made up of the heart, the blood vessels, and the blood.

**carnivore**
An organism that eats other animals.

**carpel**
*Female* portion of the flower; consists of stigma, style, and ovary.

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

**cartilage**
Smooth covering found at the end of bones; made of tough collagen protein fibers; creates smooth surfaces for the easy movement of bones against each other.

**cartilaginous skeleton**
A skeleton made of bone-like material called cartilage.

**cell**
The smallest living unit of life; the smallest unit of structure and function of living organisms.

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

**cell cycle**
Phases in the "life" of eukaryotic cells that leads to cell division.

**cell theory**
All organisms are composed of cells; cells are the basic units of structure and function in an organism; cells only come from preexisting cells.

**cellular respiration**
The process in which the energy in food is converted into energy that can be used by the body's cells; in other words, glucose is converted into ATP.

**cell wall**
Provides strength and protection for the cell; found around plant, fungal, and bacterial cells.

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

**central vacuole**
Large organelle containing water, nutrients, and wastes; can take up to 90% of a plant cell's volume.

**cephalization**
Having a head region with a concentration of sensory organs and central nervous system.

**cephalothorax**
The anterior part of the arachnid body, derived from the fusion of the head and thorax.

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

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

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

**character displacement**
Occurs when two or more species within the same area develop different specializations in order to coexist.

**chemical digestion**
Digestion in which large food molecules are broken down into small nutrient molecules.

**chemical reaction**
A process that breaks or forms the bonds between atoms.

**chemotroph**
Organism that obtains energy by oxidizing compounds in their environment.

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

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

**chitin**
A nitrogen-containing material found in the cell wall of fungi; also found in the shells of animals such as beetles and lobsters.

**chlamydia**
Most common bacteria causing sexually transmitted disease (STD) in the United States.

**chlorophyll**
Green pigment in leaves; helps to capture solar energy.

**chloroplast**
The organelle in which photosynthesis takes place.

**chromatin**
Complex of DNA and proteins; visible when a cell is not dividing.

**chromosome**
DNA wound around proteins; forms during prophase of mitosis and meiosis (prophase I).

**chronic disease**
A disease that lasts for a long time, perhaps a few years or longer.

**chronic obstructive pulmonary disease (COPD)**
A disease of the lungs in which the airways become narrowed; leads to a limitation of the flow of air to and from the lungs causing shortness of breath.

**cilia**
Finger-like projects from the cells; can be found from the cells of mucous membranes.

**circadian rhythms**
An organism's daily cycles of behavior.

**classify**
To organize into groups or categories; scientists classify organisms by their physical features and how closely related they are.

**climax community**
A stable community that is the end product of succession.

**cloning**
Creating an identical copy of a gene, or an an individual with the same genes.

**club mosses**
Seedless vascular plants that resemble mosses.

**cnidarians**
Invertebrates that have radial symmetry; includes the jellyfish.

**cocci**
Sphere-shaped bacteria or archaea.

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

**codominance**
A pattern of inheritance where both alleles are equally expressed.

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

**communication**
Any way that animals share information.

**community**
Populations of different species that occupy the same area and interact with each other.

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

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

**complete digestive tract**
A digestive tract with two openings, a mouth and anus.

**complete flowers**
Flowers that contain all four structures: sepals, petals, stamens, and one or more carpels.

**compound**
Any combination of two or more elements.

**concentration**
The amount of a substance in relation to the volume.

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

**conditioning**
Way of learning that involves a reward or punishment.

**conifers**
Group of gymnosperms that bear cones; includes spruces, pine, and fir trees.

**conjugation**
The transfer of genetic material between two bacteria.

**connective tissue**
Tissue that is made up of different types of cells that are involved in structure and support of the body; includes blood, bone, tendons, ligaments, and cartilage.

**consumer**
An organism that must eat other organisms to obtain energy and nutrients.

**contraction**
Shortening of muscle fibers.

**convergent adaptation**
The appearance of similar traits in groups of animals that are evolutionarily unrelated to each other.

**cooperation**
Working together with others for the common good.

**corals**
Cnidarians that live on ocean reefs in colonies.

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

**corolla**
The petals of a flower collectively are known as the corolla.

**coronary heart disease**
The end result of the buildup of plaques within the walls of the coronary arteries.

**courtship behaviors**
Special behaviors that help attract a mate.

**cranium**
a braincase

**crossing-over**
Exchange of DNA segments between homologous chromosomes; occurs during prophase I of meiosis.

**cross-pollination**
Sexual reproduction in plants where sperm from the pollen of one flower is received by the ovary of another flower.

**cuticle**
Waxy layer that aids water retention in plants.

**cyanobacteria**
Photosynthetic bacteria.

**cytokinesis**
Division of the cytoplasm after mitosis or meiosis.

**cytokinins**
Plant hormone involved in cell division.

**cytoplasm**
All the contents of the cell besides the nucleus, including the cytosol and the organelles.

**cytoskeleton**
The internal scaffolding of the cell; maintains the cell shape and aids in moving the parts of the cell.

**cytosol**
A fluid-like substance inside the cell; organelles are embedded in the cytosol.

# 26.4 D

**daughter cell**
Cells that divide from the parent cell after mitosis or meiosis.

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

**decomposer**
Organism that break down wastes and dead organisms and recycle their nutrients back into the environment.

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

**dermis**
The layer of skin directly under the epidermis; made of a tough connective tissue that contains the protein collagen.

**desertification**
A process leading to production of a desert of formerly productive land.

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

**diaphragm**
A sheet of muscle that extends across the bottom of the rib cage.

**digestion**
Process of breaking down food into nutrients.

**digestive system**
Body system that breaks down food, absorbs nutrients, and gets rid of solid food waste.

**diffusion**
Movement of molecules from an area of high concentration to an area of low concentration; does not require energy.

**diploid**
When a cell has two sets of chromosomes.

**dispersion**
The spacing of individuals within a population.

**display behavior**
Fixed set of actions that carries a specific message.

**DNA**
Deoxyribonucleic acid; a nucleic acid that is the genetic material of all organisms.

**DNA replication**
The synthesis of new DNA; occurs during the S phase of the cell cycle.

**domain**
The least specific category of classification.

**dominant**
Masks the expression of the recessive trait.

**dormant**
Halting growth and development temporarily.

**double helix**
The shape of DNA; a double spiral, similar to a spiral staircase.

**drug**
Any chemical substance that affects the body or brain.

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

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

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

**duodenum**
The first part of the small intestine; where most chemical digestion takes place.

# 26.5 E

**ear**
Sense organ that detects sound.

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

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

**ecdysis**
The ability to regenerate lost limbs, as well as other body parts.

**ecological succession**
The continual replacement of one community by another; occurs after some disturbance of the ecosystem.

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

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

**ectothermic**
cold-blooded; temperature depends on the temperature of their environment.

**eggs**
female gametes or sex cells

**electron**
A negatively charged particle in the atom, found outside of the nucleus.

**electron microscope**
Microscope used to create high magnification (magnified many times) and high resolution (very clear) images.

**element**
A substance that cannot break down into a simpler substance with different properties.

**elevation**
Measures how high land is above sea level.

**embryo**
An animal or plant in its earliest stages of development, before it is born or hatched.

**embryology**
The study of how organisms develop.

**emigration**
Movement of individuals out of a population.

**emphysema**
A chronic lung disease caused by loss of elasticity of the lung tissue.

**endoplasmic reticulum (ER)**
A folded membrane organelle; rough ER modifies proteins and smooth ER makes lipids.

**endostyle**
Used to gather food particles and move them along the digestive tract.

**environmental tobacco smoke (ETS)**
Secondhand smoke, which greatly increases the risk of lung cancer and heart disease in nonsmokers.

**enzyme**
A substance, usually a protein, that speeds up a biochemical reaction.

**epidermis**
The outermost layer of the skin; forms the waterproof, protective wrap over the body's surface; made up of many layers of epithelial cells.

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

**epiglottis**
A flap of connective tissue that closes over the trachea when food is swallowed; prevents choking or inhaling food.

**epithelial tissue**
A tissue that is composed 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.

**erosion**
Process by which the surface of the Earth is worn away by the action of winds, water, waves, glaciers, etc.

**esophagus**
The narrow tube that carries food from the throat to the stomach.

**essential amino acids**
Amino acids that must come from the proteins in foods; you cannot make these amino acids.

**estrogen**
The main sex hormone in females.

**ethylene**
Plant hormone involved in fruit ripening and abscission.

**Eukarya**
Domain in which cells have a nucleus; includes plants, animals, fungi, and protists.

**eukaryote**
Cell belonging to the domain Eukarya (fungi, animals, protists, and plants); has membrane-enclosed nucleus and organelles.

**evidence**
Something that gives us grounds for knowing of the existence or presence of something else.

**evolution**
The process in which something passes to a different stage, such as a living organism turning into a more advanced or mature organism; the change of the inherited traits of a group of organisms over many generations.

**evolutionary tree**
Diagram used to represent the relationships between different species and their common ancestors.

**excretion**
The process of removing wastes from the body.

**excretory system**
The organ system that maintains homeostasis by keeping the correct balance of water and salts in your body; also helps to release wastes from the body.

**exhalation**
Pushing air out of the body through the nose or mouth.

**exocuticle**
The thin and waxy water resistant outer layer of the cuticle.

**experiment**
A test to see if a hypothesis is right or wrong; a test to obtain new data.

**extensor**
The muscle that contracts to cause a joint to straighten.

**external fertilization**
Reproduction where the eggs are fertilized outside the body.

**external respiration**
The movement of oxygen into the body and carbon dioxide out of the body.

**extinct**
Something that does not exist anymore; a group of organisms that has died out without leaving any living representatives.

**extinction**
The cessation of existence of a species or group of taxa.

# 26.6 F

**F1 generation**
The first filial generation; offspring of the P or parental generation.

**F2 generation**
The second filial generation; offspring from the self-pollination of the F1 generation.

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

**feedback regulation**
Control of a biological process based on the effect of a stimulus.

**fermentation**
Anaerobic respiration in which $NAD^+$ is recycled so that is can be reused in the glycolysis (the breakdown of glucose) process.

**ferns**
Seedless vascular plants that have large, divided fronds.

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

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

**fever**
Higher than normal body temperature.

**fibrin**
A tough protein that forms strands during the blood clotting process.

**field scientist**
Scientists who work outdoors.

**filter-feeder**
An organism that feeds by filtering organic matter out of water.

**flagellum (plural flagella)**
A tail-like structure that projects from the cell body of certain prokaryotic and eukaryotic cells, and it usually functions in helping the cell move.

**flexor**
The muscle that contracts to cause a joint to bend.

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

**food allergies**
A condition in which the immune system reacts to harmless substances in food as though they were harmful.

**food chain**
A visual representation of the flow of energy from producers to consumers in a community.

**food web**
A visual representation of the complex eating relationships in a community; a cross-linking of food chains.

**fossil**
The preserved remains or traces of animals, plants, and other organisms from the distant past; examples include bones, teeth, impressions, and leaves.

**fossil fuels**
Fuels made from partially decomposed organic matter that has been compressed underground for millions of years; examples are: coal, natural gas, and oil.

**fossil record**
Fossils and the order in which fossils appear; provides important records of how species have evolved, divided and gone extinct.

**fracture**
Bone injury, often called a *break*; usually caused by excess bending stress on bone.

**fruiting body**
Specialized structure used in sexual reproduction; part of the fungus that produces the spores.

# 26.7 G

**GAIA hypothesis**
The concept that the biosphere is itself a living organism.

**Galápagos Islands**
A group of islands in the Pacific Ocean off South America; known for unusual animal life. Many scientists, including Charles Darwin, made many discoveries that led to and support the theory of evolution by natural selection, while studying the plants and animals on these islands.

**gamete**
Haploid sex cell; egg or sperm.

**ganglia**
A compact group of nerve cells having a specific function.

**gas exchange**
The movement of oxygen across a membrane and into the blood and the movement of carbon dioxide out of the blood.

**gastric mill**
A gizzard-like structure for grinding food.

**gastrovascular cavity**
A large cavity having both digestive and circulatory functions.

**gene**
The inherited unit of DNA that encodes for one protein (or one polypeptide).

**gene therapy**
The insertion of genes into a person's cells to cure a genetic disorder.

**genetics**
The study of inheritance.

**genital herpes**
Common sexually transmitted disease (STD) that is caused by the herpes virus.

**genome**
All of the genes in an organism.

**genotype**
The genetic makeup of a cell or organism, defined by certain alleles for a particular trait.

**genus**
The first word in the two word name given to every organism.

**geographic isolation**
The separation of a population from the rest of its species due to some physical barrier, such as a mountain range, an ocean, or great distance.

**geologic time scale**
A time scale used to describe when events happened in the history of Earth.

**gibberellins**
Plant hormone involved in seed germination and stem elongation.

**ginkgo**
Tree known as the *living fossil* because it is the only species left in the phylum Ginkgophyta.

**gliding joint**
Joint structure that allows one bone to slide over the other; examples includes the joints in the wrists and ankles.

**global warming**
Global increase in the Earth's temperature due to human activities that release greenhouse gasses into the atmosphere.

**golgi apparatus**
The organelle where proteins are modified, labeled, packaged into vesicles, and shipped.

**gonad**
Organ that produces gametes, such as the ovaries and testes.

**gonorrhea**
Common sexually transmitted disease (STD); caused by bacteria.

**gravitropism**
Plant growth towards or away from the pull of gravity.

**greenhouse gases**
The cause of global warming by certain gases via the greenhouse effect.

**groundwater**
Underground water reserves.

**gymnosperms**
Seed plant where seeds are not enclosed by a fruit.

## 26.8 H

**habitat**
Ecological or environmental area where a particular species live.

**habituation**
Learning to get used to something that is not dangerous, after being exposed to it for awhile.

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

**halophiles**
Organisms that live and thrive in very salty environments.

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

**haploid**
When a cell has only one set of chromosomes, typical of a gamete.

**harem**
A group of females followed or accompanied by a fertile male; this male excludes other males access to the group.

**hearing**
The ability to sense sound.

**heart attack**
Event that occurs when the blood supply to a part of the heart is blocked.

**hemoglobin**
Protein that moves oxygen throughout the blood.

**hemophilia**
A group of hereditary diseases that affect the body's ability to control blood clotting.

**hepatitis B**
Sexually transmitted disease (STD) that damages the liver and is caused by a virus called hepatitis B.

**herbivore**
A consumer of producers in a community; often organisms that eat plants.

**heterozygous**
Having two different alleles for a particular trait.

**heterotroph**
Organism which obtains carbon from outside sources.

**hibernation**
State in which an animal's body processes are slower than usual.

**hinge joint**
Joint structure in which the ends of bones are shaped in a way that allows motion in two directions only (forward and backward); examples include the knees and elbows.

**HIV**
The human immunodeficiency virus, which causes AIDS.

**homeostasis**
Maintaining a stable internal environment despite changes in the environment.

**homing**
The ability of an insect to return to a single hole among many other apparently identical holes, after a long trip or after a long time

**homozygous**
Having identical alleles for a particular trait.

**hormones**
Chemical messengers that signal responses to stimuli.

**hornworts**
Seedless nonvascular plants with hornlike sporophytes.

**horsetails**
Seedless vascular plants with hollow, rigid stems.

**Human Genome Project**
International effort to sequence all the base pairs in human DNA; completed in 2003.

**humidity**
The amount of water in the air.

**hybrid**
The offspring of different species, genera, varieties or breeds.

**hydropower**
Use of power from falling water or other water movement to generate and distribute electricity; also known as hydroelectric power.

**hydroskeleton**
Fluid-filled body cavity that provides support for muscle contraction.

**hyoid bone**
A U-shaped bone at the root of the tongue; in salamanders it is used to help catch prey.

**hypertension**
Also called high blood pressure; a condition in which a person's blood pressure is always high; the systolic blood pressure is always 140 mm Hg or higher, and/or their diastolic blood pressure is always 90 mm Hg or higher.

**hypertonic solution**
Having a higher solute concentration than the cell; cell will lose water by osmosis.

**hyphae**
Thread-like structures which interconnect and bunch up into mycelium; helps bring food, such as a worm, inside the fungus.

**hypothesis**
A proposed explanation for something that is testable.

**hypotonic solution**
Having a lower solute concentration than the cell; cell will gain water by osmosis.

# 26.9 I

**ileum**
The third part of the small intestine; covered with villi; the few remaining nutrients are absorbed in the ileum.

**immigration**
Movement of individuals into a population from other areas.

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

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

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

**incomplete digestive tract**
A digestive tract with only one opening.

**incomplete dominance**
A pattern of inheritance where the offspring has a phenotype that is halfway between the two parents' phenotypes.

**incomplete flowers**
Flowers that are missing one or more structures: sepals, petals, stamens, or carpels.

**infancy**
The first year of life after birth.

**infectious disease**
A disease that spreads from person to person.

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

**ingredient**
A specific item that a food contains.

**inhalation**
Taking air into the body through the nose and mouth.

**inherited traits**
Features that are passed from one generation to the next.

**innate behavior**
Any behavior that occurs naturally in all animals of a given species.

**insight learning**
Learning from past experiences and reasoning.

**instinct**
Any behavior that occurs naturally in all animals of a given species; another term for an innate behavior.

**integumentary system**
The outer covering of the body; made up of the skin, hair, and nails.

**internal fertilization**
Reproduction that occurs through the internal deposit of gametes.

**internal respiration**
The exchange of gases between the blood and the cells of the body.

**interphase**
Stage of the cell cycle when DNA is synthesized and the cell grows; composed of the first three phases of the cell cycle.

**invasive species**
Exotic species, introduced into habitats, which then eliminate or expel the native species.

**invertebrate**
Animal without a backbone.

**involuntary muscle**
A muscle that a person cannot consciously control; cardiac muscle and smooth muscle are involuntary.

**iris**
Colored structure at the front of the eye.

**isotonic solution**
A solution in which the amount of dissolved material is equal both inside and outside the cell; no net gain or loss of water.

# 26.10 J

**jejunum**
The second part of the small intestine; where most nutrients are absorbed into the blood; lined with tiny "fingers" called villi.

**joint**
Point at which two or more bones meet.

# 26.11 K

**keratin**
Tough, waterproof protein that is found in epidermal skin cells, nail, and hair.

**keystone species**
A predator species that plays an important role in the community by controlling the prey population.

**kidney**
Organ that filters and cleans the blood and forms urine; also maintains the volume of body fluids, maintains the balance of salt ions in body fluids, and excretes harmful metabolic by-products such as urea, ammonia, and uric acid.

**kidney dialysis**
The process of artificially filtering the blood of wastes; a patient's blood is sent through a filter that removes waste products and the clean blood is returned to the body.

**kidney failure**
When the kidneys are not able to regulate water and chemicals in the body or remove waste products from the blood.

# 26.12 L

**lactic acid fermentation**
Anaerobic respiration that recycles $NAD^+$ for glycolysis (the breakdown of glucose); occurs in animals and some bacteria and fungi.

**language**
Use of symbols or sounds to communicate.

**large intestine**
The relatively wide tube between the small intestine and anus where excess water is absorbed from food waste.

**larvae**
Young or non-adult insects.

**larynx**
Found just below the point at which the pharynx splits into the trachea and the esophagus. Your voice comes from your larynx; air from the lungs passes across thin membranes in the larynx and produces sound; also called the voicebox.

**latitude**
How far a biome is from the equator.

**learned behavior**
Behavior that occurs only after experience or practice.

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

**leukemia**
Cancer of the blood or bone marrow; characterized by an abnormal production of blood cells, usually white blood cells.

**life science**
The study of living organisms, and how they interact with each other and their environment.

**lifestyle disease**
A disease that is caused by choices that people make in their daily lives.

**ligament**
Fibrous tissue that connects bones to other bones; made of tough collagen fibers.

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

**lipid**
Class of organic compound that includes fats, oils, waxes and phospholipids; nutrients, such as fats, that are rich in energy.

**liverworts**
Seedless nonvascular plants that can have flattened bodies resembling a liver.

**lung cancer**
A disease where the cells that line the lungs grow out of control; the growing mass of cells pushes into nearby tissues and can affect how these tissues work.

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

**lymphatic system**
A network of vessels and tissues that carry a clear fluid called lymph; includes lymph nodes, lymph ducts, and lymph vessels.

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

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

**lymphoma**
Cancer of white blood cells called lymphocytes.

**lysosome**
Organelle which contains degradative enzymes; breaks down unneeded materials.

# 26.13 M

**macroevolution**
Big evolutionary changes that result in new species.

**macromolecule**
Very large molecules that make living organisms; includes carbohydrates, lipids, proteins, and nucleic acids.

**main ingredient**
The ingredient that is present in the food in the greatest amount.

**mammary glands**
Specialized sweat glands that produce milk.

**mantle**
A fold of outer skin lining the shell of mollusks; releases calcium carbonate that is used to create the external shell.

**marsupial**
A type of mammal where the female has an abdominal pouch or skin fold within which are mammary glands and a place for raising the young.

**mass extinction**
An extinction when many species go extinct during a relatively short period of time.

**mating**
Pairing of an adult male and female to produce young.

**matter**
Anything that takes up space and has mass.

**mechanical digestion**
Digestion in which large chunks of food are broken down into small pieces.

**medusa**
Cnidarian with a bell-shaped body, with the mouth and tentacles facing downward, such as a jellyfish.

**meiosis**
Nuclear division that results in haploid gametes.

**melanin**
The brownish pigment that gives skin and hair their color.

**menstrual cycle**
The monthly cycle of changes that occur in the uterus and ovaries.

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

**metamorphosis**
The process by which insects transform from an immature or young insect into an adult insect.

**metaphase**
Second phase of mitosis and meiosis (metaphase I and metaphase II) where the chromosomes are aligned in the center of the cell.

**methanogens**
Organisms that live in swamps or in the guts of cows and termites and release methane gas.

**microevolution**
Small changes in inherited traits; does not lead to the creation of a new species.

**microscope**
A set of lenses used to look at things too small to be seen by the unaided eye.

**microscopy**
All the methods for studying things using microscopes.

**migration**
Movement of animals from one place to another; often seasonal.

**minerals**
Chemical elements that are needed for body processes.

**mitochondria**
Organelle where cellular respiration occurs; known as the "powerhouse" of the cell because this is the organelle where the ATP that powers the cell is produced.

**mitosis**
Sequence of steps in which a nucleus is divided into two daughter nuclei, each with an identical set of chromosomes.

**molecule**
Any combination of two or more atoms.

**molting**
The process by which arthropods shed their hard exoskeleton in order to grow.

**monogamous**
A mating system where the couple pair for the duration of the breeding season, or sometimes for a few years or until one mate dies.

**monotremes**
A group of mammals that lays eggs and feeds their young by “sweating” milk from patches on their bellies.

**mosses**
Seedless nonvascular plants with tiny stem-like and stem-like structures.

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

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

**movable joint**
Most mobile type of joint; the most common type of joint in the body.

**mucus**
Sticky, moist substance that coats mucous membranes.

**muscle fibers**
Long, thin cells that can contract; also called muscle cells.

**muscular system**
The body system that allows movement.

**muscular tissue**
Tissue that is composed of cells that have filaments that move past each other and change the size of the cell. There are three types of muscle tissue: smooth muscle, skeletal muscle, and cardiac muscle.

**mutagen**
A chemical or physical agent that can cause changes to accumulate in DNA.

**mutation**
A change in the nucleotide sequence of DNA.

**mutualism**
A type of symbiosis in which both species benefit.

**mycelial fragmentation**
Asexual reproduction involving splitting off of the mycelia; a fragmented piece of mycelia can eventually produce a new colony of fungi.

**mycelium**
Help the fungi absorb nutrients from living hosts; composed of hyphae.

**mycorrhizal symbiosis**
A relationship between fungi and the roots of plants where both benefit; the plant provides sugar to the fungus; the fungi provides minerals and water to the roots of the plant.

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

**MyPlate**
Visual representation of the relative daily portions of various food groups; replaced MyPyramid in 2011.

**MyPyramid**
Diagram that shows how much you should eat each day of foods from six different food groups.

# 26.14 N

**nacre**
The iridescent inner shell layer produced by some bivalves, some gastropods, and some cephalopods; also known as mother of pearl.

**natural resources**
Naturally occurring substances necessary for the support of life.

**natural selection**
Causes beneficial heritable traits to become more common in a population, and unfavorable heritable traits become less common.

**negative feedback loop**
When the response to a stimulus decreases the effect of the original stimulus.

**nematocysts**
Specialized cells in cnidarians that can release a small thread-like structure and toxins to capture prey.

**neocortex**
Site of the cerebral cortex where most of higher brain functions occur.

**nephron**
Tiny, tube-shaped filtering unit found inside each kidney.

**nerve**
Bundle of individual nerve cells.

**nerve impulse**
Electrical signal that is transmitted by neurons.

**nerve net**
Interconnected neurons that send signals in all directions.

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

**nervous tissue**
Tissue composed of nerve cells (neurons) and related cells.

**neuron**
Nerve cell that carries electrical messages.

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

**neutron**
The non-charged particle of the atom; located in nucleus of the atom.

**niche**
A specific role that an organism occupies within an ecosystem.

**nictitating membrane**
A third transparent eyelid.

**nitrogen fixation**
Process by which gaseous nitrogen is converted into chemical forms that can be used by plants.

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

**nonrenewable resource**
A natural resource that exists in fixed amounts and can be consumed or used up faster than it can be made by nature.

**nonvascular plants**
Plants that do not have vascular tissue to conduct food and water.

**notochord**
A hollow nerve cord along the back.

**nuclear envelope**
A double membrane that surrounds the nucleus; helps regulate the passage of molecules in and out of the nucleus.

**nuclear power**
A nonrenewable resource, where nuclear fission is used to generate energy.

**nucleic acid**
Class of organic compound that includes DNA and RNA.

**nucleoid**
The prokaryotic DNA consisting of a condensed single chromosome.

**nucleotide**
The units (monomers) that make up DNA; consists of a 5-carbon sugar, a phosphate group, and a nitrogen-containing base.

**nucleus**
Membrane enclosed organelle in eukaryotic cells that contains the DNA; primary distinguishing feature between a eukaryotic and prokaryotic cell; the information center, containing instructions for making all the proteins in a cell, as well as how much of each one.

**nutrients**
Chemicals in food that your body needs.

**nutrition facts label**
The label on packaged food that shows the nutrients in the food.

**nymphs**
A developmental stage of insects, where the young is usually similar to the adult.

# 26.15 O

**obesity**
Having a very high percentage of body fat; obese people are at least 20 percent heavier than their healthy weight range.

**observational learning**
Learning by watching and copying the behavior of someone else.

**ocean acidification**
Process whereby the oceans' uptake of anthropogenic carbon dioxide from the atmosphere causes an ongoing decrease in ocean pH.

**oil gland**
Skin organ that secretes an oily substance, called sebum, into the hair follicle.

**omnivore**
A consumer in a community that eat both producers and consumers; usually eaters of both plants and animals.

**omnivorous**
Eating both plant and animal material.

**optical (light) microscope**
A microscope that focuses light, usually through a glass lens; used by biologists to visualize small details of biological specimens.

**organ**
A group of tissues that work together to perform a common function.

**organelle**
Small structure found in cells; has specialized functions; many are membrane-bound, such as mitochondria, plastids, and vacuoles. Membrane-bound organelles are found only in eukaryotic cells.

**organic compound**
Compounds made up of a carbon backbone and associated with living things.

**organism**
A living thing.

**organ system**
A group of organs that work together to perform a common function.

**osmosis**
Diffusion of water across a membrane.

**outdoor air pollution**
Chemical, physical, or biological agents that modify the natural characteristics of the atmosphere, and cause unwanted changes to the environment and to human health.

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

**ovaries**
Female reproductive organs that produce eggs and secrete estrogen.

**ovary**
Enlarged part of the carpel where the ovules are contained.

**ovulation**
Release of an egg by an ovary.

# 26.16 P

**paleontologists**
Scientists who study fossils to learn about life in the past.

**paralysis**
Inability to feel or move parts of the body.

**parasite**
The organism that benefits in a relationship between two organisms in which one is harmed.

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

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

**parent cell**
Cell that divides into daughter cells after mitosis or meiosis.

**parthenogenesis**
Reproduction where an unfertilized egg develops into a new individual.

**passive transport**
Movement of molecules from an area of higher concentration to an area of lower concentration; does not require energy.

**pathogen**
A disease causing agent.

**pearl**
The hard, round object produced within the mantle of a living shelled mollusk.

**pedigree**
A chart which shows the inheritance of a trait over several generations.

**pedipalps**
The second pair of arachnid appendages used for feeding, locomotion, and/or reproductive functions.

**pentadactyl**
Having five fingers or toes.

**peptidoglycan**
Complex molecule consisting of sugars and amino acids that makes up the bacterial cell wall.

**Periodic Table**
Table that organizes elements according to their unique characteristics, like atomic number, density, boiling point, and other values.

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

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

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

**pharynx**
A long tube that is shared with the digestive system; both food and air pass through the pharynx.

**phenotype**
The physical appearance that is a result of the genotype.

**pheromones**
Chemicals secreted by animals, especially insects, that influence the behavior or development of others within the same species.

**phloem**
Vascular tissue that carries the sugars made during photosynthesis (in the leaves) to other parts of the plant.

**phospholipid**
A lipid molecule with a hydrophilic head and two hydrophobic tails; makes up the cell membrane.

**photosynthesis**
The process by which specific organisms (including all plants) use the sun's energy to make their own *food* from carbon dioxide and water; process that converts the energy of the sun, or solar energy, into carbohydrates, a type of chemical energy.

**phototropism**
Plant growth towards or away from light.

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

**physical fitness**
The ability of your body to carry out your daily activities without getting out of breath, sore, or overly tired.

**pineal eye**
An eye-like structure that develops in some cold-blooded vertebrates.

**pinna**
Outer part of the ear that gathers sound waves.

**pioneer species**
The species that first inhabit a disturbed area.

**pivot joint**
Joint structure in which the end on one bone rotates within a ring-type structure which can be made partly of bone and partly of ligament.

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

**placental**
A type of mammal that has a placenta that nourishes the fetus and removes waste products.

**placoid**
Plate-like, as in the scales of sharks.

**plaque**
Cell pieces made up of fatty substances, calcium, and connective tissue that build up around the area of inflammation; builds up on the lining of blood vessels.

**plasma**
The straw-colored fluid in blood; about 90 percent water and about 10 percent dissolved proteins, glucose, ions, hormones, and gases.

**plasma membrane**
Surrounds the cell; made of a double layer of specialized lipids, known as phospholipids, with embedded proteins; regulates the movement of substances into and out of the cell; also called the cell membrane.

**plasmid**
Small circular piece of DNA; found in prokaryotic cells.

**platelets**
Fragments of larger cells that are important in blood clotting.

**pneumonia**
An illness in which the alveoli become inflamed and flooded with fluid.

**poikilothermic**
Cold-blooded; without the ability to independently warm the blood.

**polygamous**
A mating system in which where there is more than one mate.

**polygenic inheritance**
A pattern of inheritance where the trait is controlled by many genes and each dominant allele has an additive effect.

**polyp**
Cnidarian with a cup-shaped body directed upward.

**population**
A group of organisms belonging to the same species, that live in the same area, and interact with one another.

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

**positive feedback loop**
When the response to a stimulus increases the original stimulus.

**precipitation**
Water that falls to the earth in the form of rain, snow, sleet, hail.

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

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

**primary pollutants**
Substances released directly into the atmosphere by processes such as fire or combustion of fossil fuels.

**primary succession**
Ecological succession that occurs in disturbed areas that have no or little soil, i.e. after a glacier retreats.

**producer**
An organism that can absorb the energy of the sun and convert it into food through the process of photosynthesis; i.e. plants and algae.

**product**
The end result of a reaction.

**prokaryote**
A microscopic single-celled organism, including bacteria and cyanobacteria; does not have a nucleus with a membrane or other specialized organelles.

**prophase**
Initial phase of mitosis and meiosis (prophase I and prophase II) where chromosomes condense, the nuclear envelope dissolves and the spindle begins to form.

**protein**
Organic compound made up of smaller molecules called amino acids; performs many functions in the cell.

**protist**
Eukaryotic organism that belongs to the kingdom Protista; not a plant, animal or fungi.

**proton**
The positively charged particle of the atom; located in nucleus of the atom.

**protozoa**
Animal-like protists.

**pseudopodia**
A moving fake foot; the cell surface extends out a membrane and the force of this membrane propels the cell forward.

**puberty**
Stage of life when a child becomes sexually mature.

**pulmonary circulation**
The part of the cardiovascular system which carries oxygen-poor blood away from the heart to the lungs, and returns oxygen-rich blood back to the heart.

**Punnett square**
Visual representation of a genetic cross that helps predict the expected ratios in the offspring, first described by Reginald C. Punnett in the early $20^{th}$ century.

**pupa**
Insect metamorphosis stage in which wing development begins.

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

# 26.17 Q

**quadrupedal**
four-footed

## 26.18 R

**radial symmetry**
A body plan in which any cut through the center results in two identical halves.

**radiometric dating**
A method to determine the age of rocks and fossils in each layer of rock; measures the decay rate of radioactive materials in each rock layer.

**radula**
A molluscan feeding structure, composed mostly of chitin.

**reactant**
The raw ingredients in a chemical reaction.

**recessive**
Expression is masked by the dominant factor (allele); only expressed if both factors are recessive.

**recombinant DNA**
DNA formed by the combination of DNA from two different sources, such as placing a human gene into a bacterial plasmid.

**recycling**
The breaking down of an item into raw materials to make new items.

**red blood cells**
Flattened disk-shaped cells that carry oxygen, the most common blood cell in the blood. Mature red blood cells do not have a nucleus.

**reducing**
Minimizing the use of resources.

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

**reflex behaviors**
The only truly innate behaviors in humans, occurring mainly in babies.

**renewable resources**
Resources that are replenished by natural processes at about the same rate at which they are used.

**reproductive isolation**
Allopatric and sympatric speciation; isolation due to geography or behavior, resulting in the inability to reproduce.

**respiration**
The process of getting oxygen into the body and releasing carbon dioxide.

**respiratory disease**
A disease of the lungs, bronchial tubes, trachea, nose, and/or throat.

**respiratory system**
The organ system that allows oxygen to enter the body and carbon dioxide to leave your body.

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

**ribosome**
The cell structure on which proteins are made; not surrounded by a membrane; found in both prokaryotic and eukaryotic cells.

**RNA**
The nucleic acid that carries the information stored in DNA to the ribosome.

**rough endoplasmic reticulum**
The part of the ER with ribosomes attached; proteins can be modified in the rough ER before they are packed into vesicles for transport to the golgi apparatus.

**runoff**
Water that is not absorbed by the soil that eventually returns to streams and rivers.

# 26.19 S

**scanning acoustic microscope**
A microscope that focuses sound waves instead of light.

**scanning electron microscope (SEM)**
A microscope that scans the surfaces of objects with a beam of electrons to produce detailed images of the surfaces of tiny things.

**scientific method**
A careful way of asking and answering questions to learn about the physical world that is based on reason and observable evidence.

**scientific theory**
A well-established set of explanations that explain a large amount of scientific information.

**secondary pollutants**
Substances formed when primary pollutants interact with sunlight, air, or each other.

**secondary succession**
Ecological succession that occurs in disturbed areas that have soil to begin with, i.e. after a forest fire.

**seedless vascular plants**
Plants with vascular tissue but no seeds.

**segmentation**
A body plan that has repeated units or segments.

**selectively permeable**
Semipermeable; property of allowing only certain molecules to pass through the cell membrane.

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

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

**semiconservative replication**
Describes how the replication of DNA results in two molecules of DNA, each with one original strand and one new strand.

**semilunar (SL) valves**
Found in the arteries leaving the heart; prevents blood flowing back from the arteries into the ventricles.

**semipermeable**
Allowing only certain materials to pass through; characteristic of the cell membrane.

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

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

**sepals**
Outermost layer of the flower that is usually leaf-like and green.

**serving size**
Tells you how much of the food you should eat to get the nutrients listed on the label.

**sessile**
Permanently attached and not freely moving.

**sex-linked inheritance**
The inheritance of traits that are located on genes on the sex chromosomes.

**sex-linked trait**
A trait that is due to a gene located on a sex chromosome, usually the X-chromosome.

**sexual dimorphism**
Extreme difference between the sexes.

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

**sexual reproduction**
Reproduction where gametes from two parents combine to make an individual with an unique set of genes.

**sickle cell disease**
A blood disease that is caused by abnormally-shaped blood protein hemoglobin.

**silk**
A thin, strong, protein strand extruded from the spinnerets; most commonly found on the end of the abdomen of spiders.

**sister chromatids**
The two identical molecules of DNA in a chromosome after the DNA is replicated.

**skeletal muscle**
The muscle that is usually attached to the skeleton.

**skeletal system**
Body system that is made up of bones, cartilage, and ligaments.

**skeleton**
Sturdy scaffolding of bones and cartilage that is found inside vertebrates.

**slash-and-burn agriculture**
A method of agriculture in the tropics in which the forest vegetation is cut down and burned, then crops are grown for a few years, and then the forest is allowed to grow back.

**small intestine**
The narrow tube between the stomach and large intestine where most chemical digestion and absorption of nutrients take place.

**smooth endoplasmic reticulum**
Part of the ER that does not have ribosomes attached; where lipids are synthesized.

**smooth muscle**
Involuntary muscle found within the walls of organs and structures such as the esophagus, stomach, intestines, and blood vessels.

**social animals**
Animals that live in groups with other members of their species.

**solar power**
The use of solar cells to convert sunlight into electricity.

**somatic cell**
A body cell; not a gamete.

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

**speciation**
The creation of a new species; either by natural or artificial selection.

**species**
A group of individuals that are genetically related and can breed to produce fertile young; the second word in the two word name given to every organism is the species name.

**sperm**
male gametes or sex cells

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

**spindle**
Fibers that move chromosomes during mitosis and meiosis.

**spiracles**
Openings on the sides of the insect abdomen, through which air is taken in.

**spirilli**
Spiral-shaped bacteria or archaea.

**sponging**
The ability of an insect mouthpart to absorb liquid food.

**sporangium**
Capsule, formed by the sporophyte, which releases spores.

**spore**
The basic reproductive unit of fungi.

**sprain**
A ligament injury; usually caused by the sudden overstretching of a joint which causes tearing.

**stamen**
The part of the flower consisting of a filament and an anther that produces pollen.

**starch**
Large, complex carbohydrate; found in foods such as vegetables and grains; broken down by the body into sugars that provide energy.

**stigma**
The knoblike section of the carpel where the pollen must land for fertilization to occur.

**stimulant drug**
Psychoactive drug that speeds up the nervous system.

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

**stomach**
The sac-like organ at the end of the esophagus where proteins are digested.

**stomata**
Special pores in leaves; carbon dioxide enters the leaf and oxygen exits the leaf through these pores.

**strain**
An injury to a muscle in which the muscle fibers tear because the muscle contracts too much or contracts before the muscle is warmed up.

**stroke**
A loss of brain function due to a blockage of the blood supply to the brain.

**stroma**
Fluid in the chloroplast interior space; surrounds the thylakoids.

**stromolites**
Fossils made of algae and a kind of bacteria; some of the oldest fossils on Earth.

**sunburn**
A burn to the skin that is caused by overexposure to UV radiation from the sun's rays or tanning beds.

**sweat gland**
Gland that opens to the skin surface through skin pores; found all over the body; secretes sweat.

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

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

**sympatric speciation**
Speciation that occurs when groups from the same species stop interbreeding, because of something other than physical separation, such as behavior.

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

**syphilis**
Very serious STD that is caused by bacteria.

**systemic circulation**
The portion of the cardiovascular system which carries oxygen-rich blood away from the heart to the body, and returns oxygen-poor blood back to the heart.

# 26.20 T

**tapeworms**
Intestinal parasites in the phylum Platyhelminthes.

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

**taxonomy**
The science of naming and classifying organisms.

**telophase**
Final phase of mitosis and meiosis (telophase I and telophase II) where a nuclear envelop forms around each of the two sets of chromosomes.

**tendon**
A tough band of connective tissue that connects a muscle to a bone.

**teratogen**
A chemical that causes deformities.

**terrestrial biomes**
Biomes defined based on plant and climatic factors.

**testes**
Male reproductive organs that produce sperm and secrete testosterone.

**testosterone**
The main sex hormone in males.

**theory of evolution**
Theory developed by Charles Darwin that explains how populations of organisms can change over time.

**thermophiles**
Organisms that live in very hot environments, such as near volcanoes and in geysers.

**thigmotropism**
Differential plant growth in response to contact with an object.

**thylakoid**
Flattened sacs within the chloroplast; formed by the inner membranes.

**tissue**
A group of specialized cells that function together.

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

**touch**
The sense of pain, pressure, or temperature.

**trachea**
A long tube that leads down to the chest where it divides into the right and left bronchi in the lungs; also called the windpipe.

**trait**
A feature or characteristic of an organism; for example, your height, hair color, and eye shape are physical traits.

**transcription**
The synthesis of a RNA that carries the information encoded in the DNA.

**transduction**
Transfer of DNA between two bacteria; occurs with the aid of a virus (bacteriophage).

**trans fat**
Manufactured fat that is added to certain foods to keep them fresher for longer.

**transformation**
The process by which bacteria pick up foreign DNA and incorporate it in their genome.

**translation**
The synthesis of proteins as the ribosome reads each codon in RNA, which code for a specific amino acid.

**transmission electron microscope (TEM)**
A microscope that focuses a beam of electrons through an object and can make an image up to two million times bigger, with a very clear image ("high resolution").

**transpiration**
Process by which water leaves a plant by evaporating from the leaves.

**trophic level**
A level of the food chain reflected in the ecological pyramid.

**tropism**
Plant growth response towards or away from a stimulus.

**tuberculosis (TB)**
A common and often deadly infectious disease caused by a type of bacterium called mycobacterium.

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

**tympanum**
Equivalent to the middle ear; used in hearing.

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

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

# 26.21 U

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

**universal donor**
A person with type O positive blood; type O red blood cells do not have any antigens on their membranes and so would not cause an immune reaction in the body of a recipient.

**universal recipient**
A person with type AB positive blood; 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.

**urinary bladder**
Organ that collects the urine which comes from the kidneys.

**urinary system**
The organ system that makes, stores, and gets rid of urine.

**urinary tract infection (UTI)**
Bacterial infections of any part of the urinary tract.

**urination**
The process of releasing urine from the body.

**urine**
A liquid that is formed by the kidneys when they filter wastes from the blood; contains mostly water and also dissolved salts and nitrogen-containing molecules.

**uterus**
Female reproductive organ where a baby develops until birth.

# 26.22 V

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

**valarian respiration**
Respiration in which the capillary beds are spread throughout the epidermis, so that gases can be exchanged through the skin.

**valves**
In the heart; keep the blood flowing in one direction.

**vascular tissue**
Tissues that conduct food, water, and nutrients in plants.

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

**veins**
Blood vessels that carry blood back to the heart.

**ventricle**
One of the two muscular V-shaped chambers that pump blood out of the heart.

**vesicle**
Small membrane-enclosed sac; transports proteins around a cell or out of a cell.

**vestigial structure**
Body part that, through evolution, has lost its use, such as a whale's pelvic bones.

**villi**
Contain microscopic blood vessels; nutrients are absorbed into the blood through these tiny vessels; located on the jejunum and the ileum.

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

**vision**
The ability to see light.

**vitamins**
Substances that the body needs in small amounts to function properly.

**vivipary**
A reproductive system in most mammals and some reptiles and fish, in which living young are produced rather than eggs laid.

**voluntary muscle**
A muscle that a person can consciously control; skeletal muscle is voluntary.

# 26.23 W

**waterborne diseases**
Diseases caused by organisms transmitted via contaminated water.

**water pollution**
The contamination of water bodies by substances, mostly anthropogenic, which cause a harmful effect on living organisms.

**water vascular system**
A network of fluid-filled canals; functions in gas exchange, feeding, and also in locomotion.

**wavelength**
The distance from any point on one wave to the same point on the next wave.

**whisk ferns**
Seedless nonvascular plants with tiny stem-like and stem-like structures.

**white blood cells**
Nucleated blood cells that are usually larger than red blood cells; defend the body against infection by bacteria, viruses, and other pathogens.

**wind power**
The conversion of wind energy into electricity via wind turbines.

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

# 26.24 X

**xylem**

Vascular tissue responsible for the transport of water and nutrients from the roots to the rest of the plant.

# 26.25 Y

## 26.26 Z

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