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# Perry Heights Middle School FlexBook 7th Grade by Ms. Lori Young

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# Contents

# CHAPTER 1 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 Is Life Science?

## 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:**

| 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 |

**TABLE 1.2:** (continued)

| Life Science | What it Examines | Life Science | What it Examines |
|---|---|---|---|
| **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 | 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 | | |

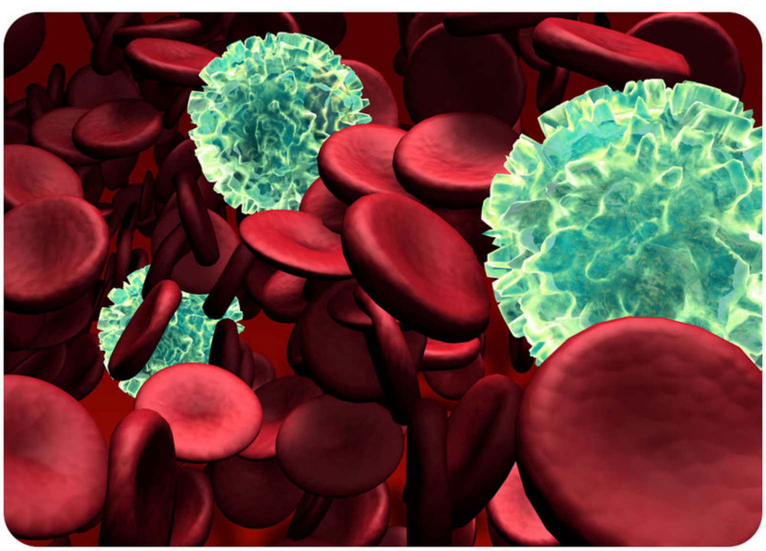


FIGURE 1.2
This drawing shows red blood cells and viruses. Virology is the study of viruses. Cell biology is the study of cells. Though virology can be considered a Life Science, are viruses in fact living?

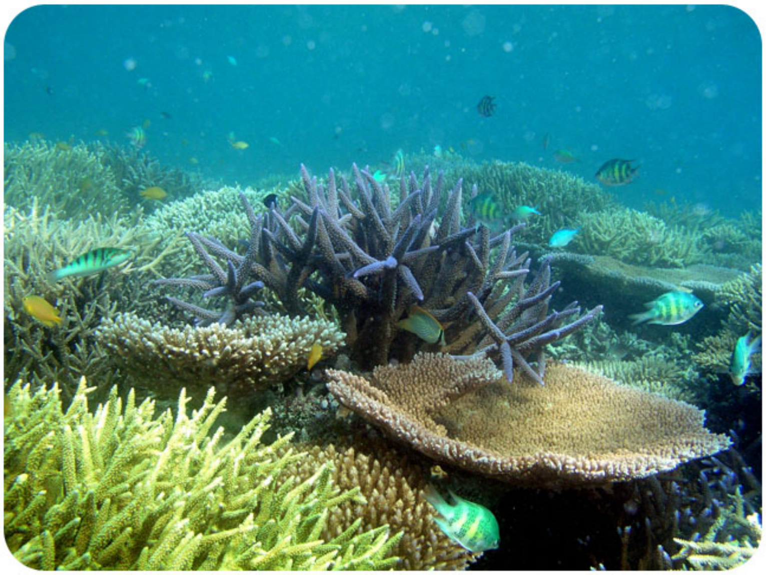


FIGURE 1.3
Biogeography looks at the variation of life forms within a given ecosystem, biome, or for the entire Earth. In other words, it tries to explain where organisms live and at what abundance.

## 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.

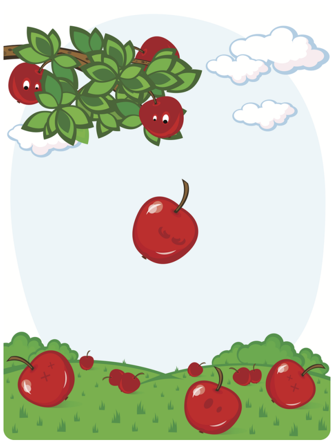


FIGURE 1.4
An apple falls from a tree to the ground, instead of floating in space. This is evidence for the theory of gravity.

**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).

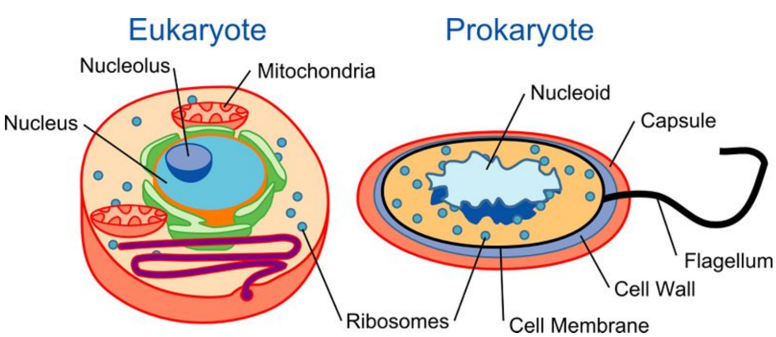



FIGURE 1.5
The two types of cells, eukaryotic (left) and prokaryotic (right).

### 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/user/khanacademy#p/c/7A9646BC5110CF64/0/GcjgWov7mTM .

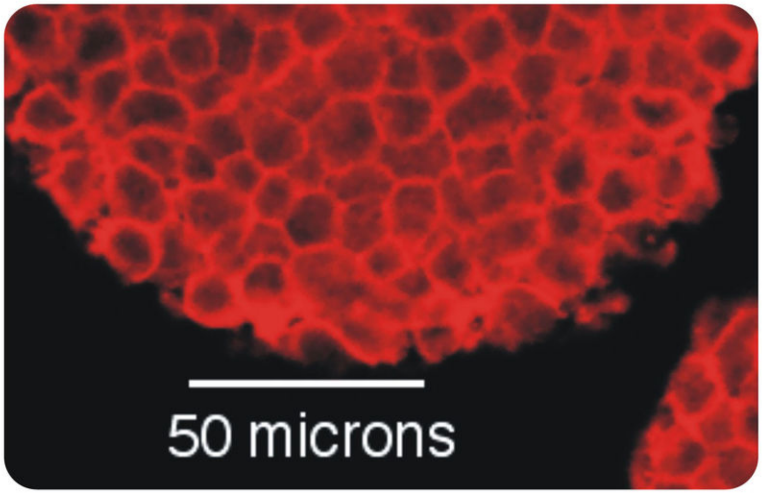



FIGURE 1.6
A mouse cell viewed through a microscope.

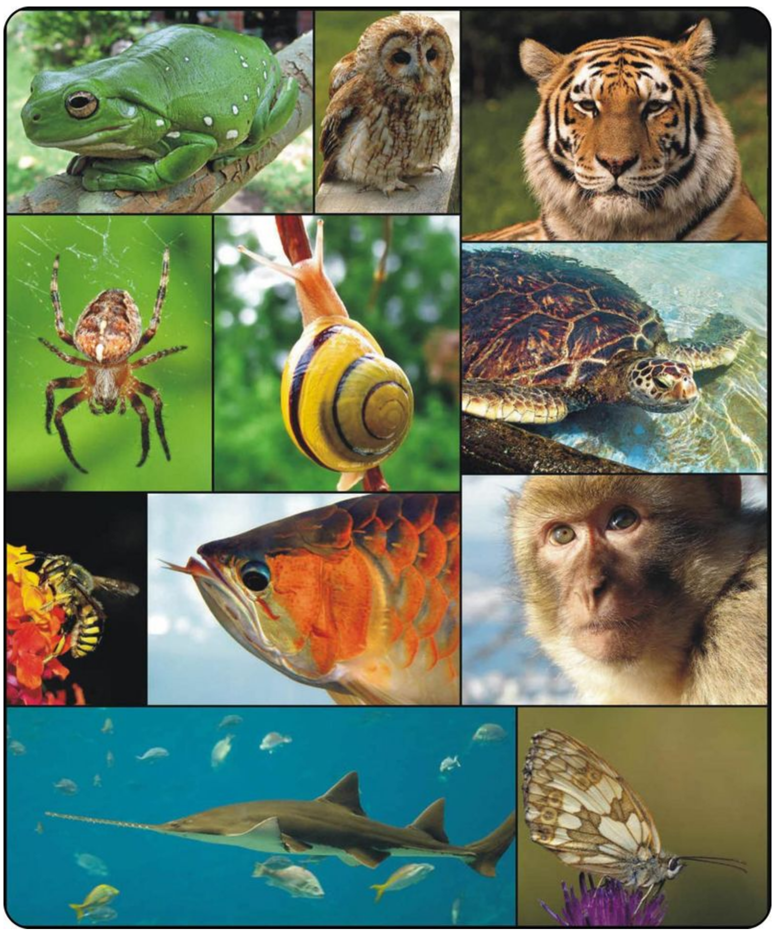
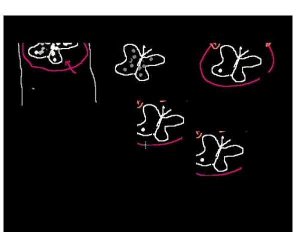


FIGURE 1.7
Evolution explains the millions of varieties of organisms on Earth.



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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

- Moore, John, A., Science as a Way of Knowing: The Foundations of Modern Biology. Harvard University Press, 1993.
- Trefil, James, The Nature of Science, An A-Z Guide to the Laws and Principles Guiding the Universe. Houghton Mifflin, Boston, 2003.
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- American Association for the Advancement of Science. Science for All Americans. 1993.

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- Hedrick, Philip, W., Genetics of Populations (Biological Science (Jones and Bartlett)) Jones and Brothers Publishers, 2005.
- Charles Darwin: And the Evolution Revolution (Oxford Portraits in Science) by Rebecca Stefoff. Oxford Press. New York, 1996.
- Fleisher, Paul, Evolution (Great Ideas of Science). TwentyFirst Century Books, 2006..


## 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

**Check the Resources Tab for Ch 1 for Activities on 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. 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)

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 |

|+ **Deformed Frog Data**

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 The Microscope

## 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 ( **Figure** 1.12) taught himself to make one of the first microscopes ( **Figure** 1.13). 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** 1.14 and **Figure** 1.15). 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.

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

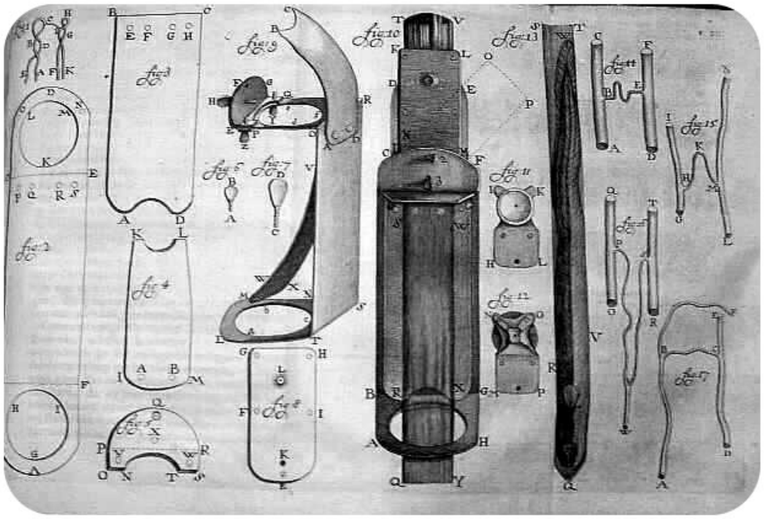

FIGURE 1.13
Drawing of microscopes owned by Antoine van Leeuwenhoek. Bacteria were discovered in 1683 when Antoine Van Leeuwenhoek used a microscope he built to look at the plaque on his own teeth.

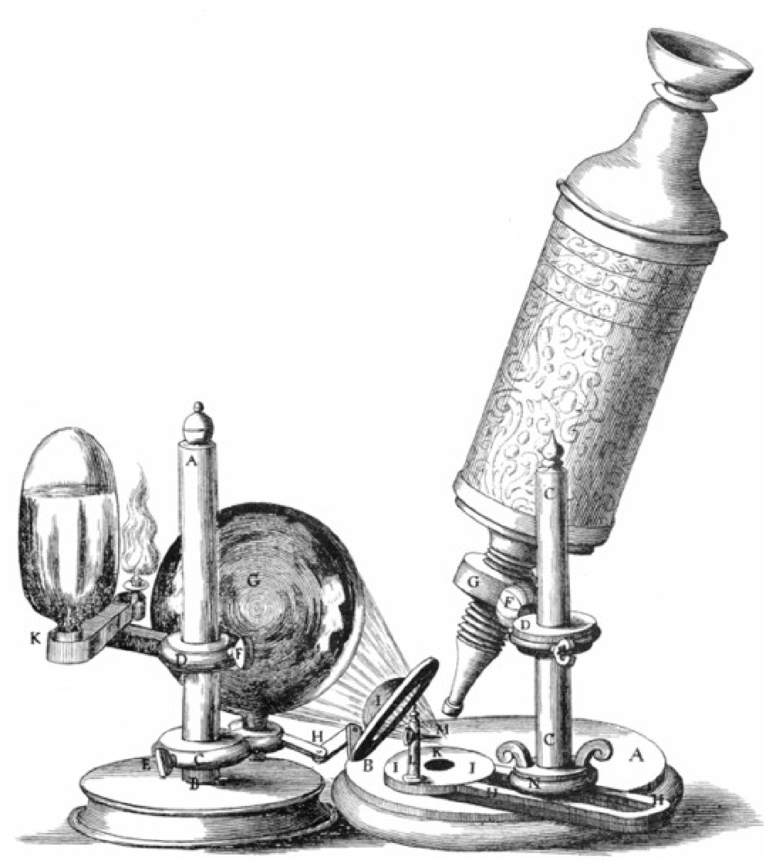

FIGURE 1.14
Robert Hooke's early microscope.

image up to two million times bigger, with a very clear image ("high resolution").

3. **Scanning electron microscopes (SEM)** ( **Figure** 1.16 and **Figure** 1.17) 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

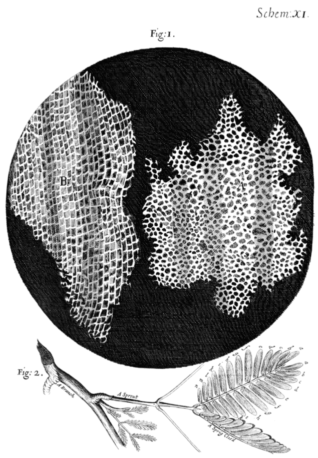


FIGURE 1.15
Cell structure of cork by Hooke.

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.

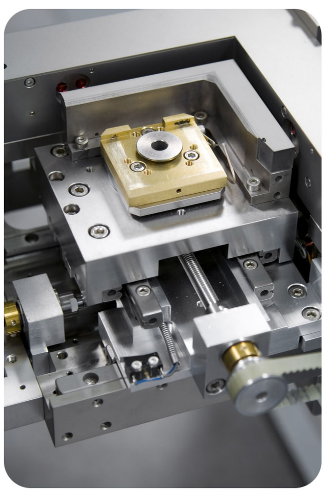

FIGURE 1.16
A scanning electron microscope.

## 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 radiotelemetry device ( **Figure** 1.18), a thermocycler ( **Figure** 1.19) and inoculation (sterile) hoods ( **Figure** 1.20) are all biological equipment.

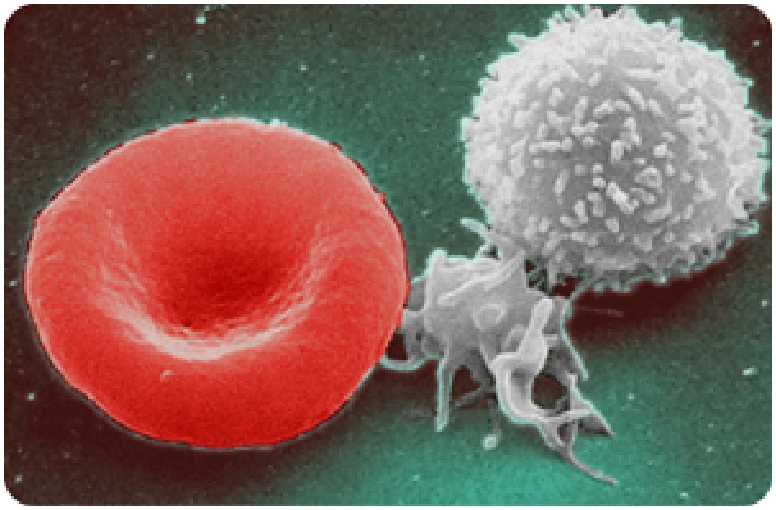

FIGURE 1.17
A scanning electron microscope image of blood cells.

FIGURE 1.18
A radiotelemetry device used to track the movement of seals in the wild.

## 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** 1.21).

Some models are used to show the relationship between different parts of an experiment, or variables. For example,


FIGURE 1.19
A thermocycler used for molecular biological and genetic studies.

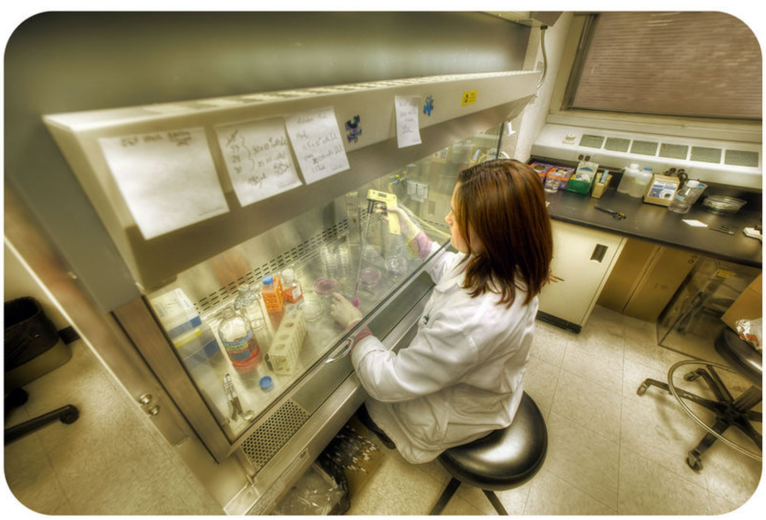

FIGURE 1.20
A sterile laboratory chamber. This laboratory inoculation hood allows researchers to conduct experiments in sterile environments.

the model in **Figure** 1.22 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.

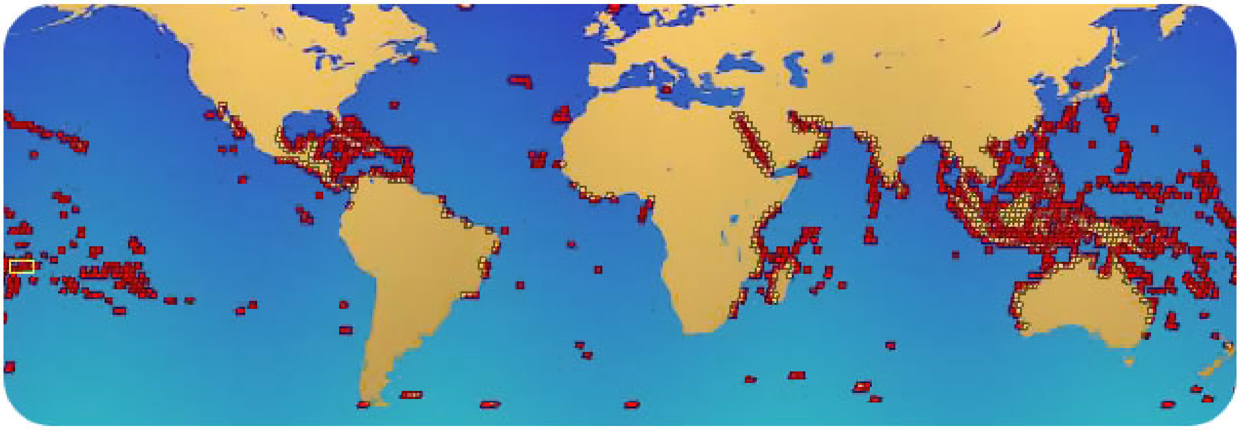

FIGURE 1.21
The above map shows where you can find coral reefs around the world. Coral reefs are shown in red.

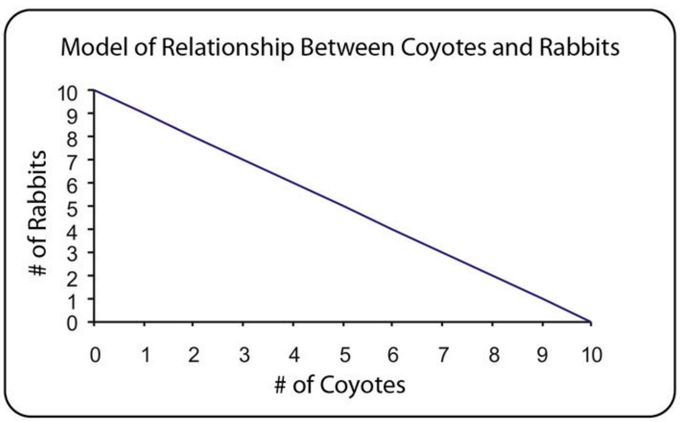


FIGURE 1.22
This graph shows a model of a relationship between a population of coyotes (the predators) and a population of rabbits, which the coyotes eat (the prey).

## 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** 1.22. 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 Life Science 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** 1.23 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 1.23
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** 1.24.

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.

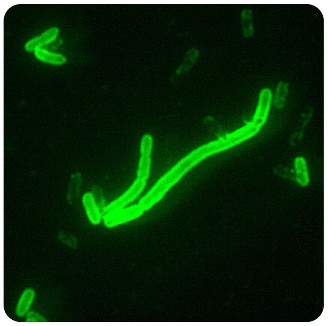

FIGURE 1.24
Scientists studying dangerous organisms such as *Yersinia pestis*, the cause of bubonic plague, use special equipment that helps keep the organism from escaping the lab.

## 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** 1.25) migrations between the United States and Mexico must follow regulations in both countries.

FIGURE 1.25
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

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7. Justin. Evolution explains the millions of varieties of organisms on Earth. . CC-BY-SA 3.0
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25. Derek Ramsey. A Monarch Butterfly . GNU-FDL

# Chapter 2 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.

# 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
Bracket fungi and lichens on a rotting log in Cranberry Glades Park near Marlinton, West VIrginia. 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.

*The Inner Life of the Cell* can be viewed at http://www.youtube.com/watch?v=Mszlckmc4Hw (5:28).

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URL: http://www.ck12.org/flx/render/embeddedobject/4698

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.

### 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.

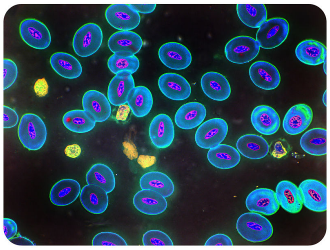

FIGURE 2.2
Reptilian blood cell showing the characteristic nucleus. A few smaller white blood cells are visible. This image has been magnified 1000 times its real size.

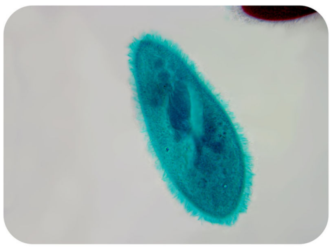

FIGURE 2.3
This paramecium is a single-celled organism.

### Living Things 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.

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

- All organisms are made of cells.
- All living things need energy and resources to survive.

## 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

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

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

FIGURE 2.6
A healthy diet includes protein, fat, and carbohydrate, providing us with organic molecules.

|+ **The Four Main Classes of 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&feature=fvw (6:09).

### Carbohydrates

**Carbohydrates** are sugars or long chains of sugars. An important role of carbohydrates is to store energy. Glucose ( **Figure** 2.7) 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.

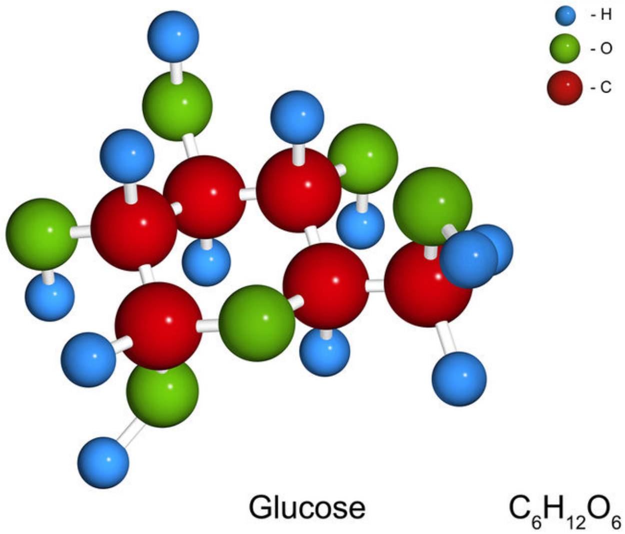


FIGURE 2.7
A molecule of glucose (a carbohydrate).

### 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** 2.8 and **Figure** below). 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.


FIGURE 2.8
Amino Acids connect together like beads on a necklace.

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** below).

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** 2.9).

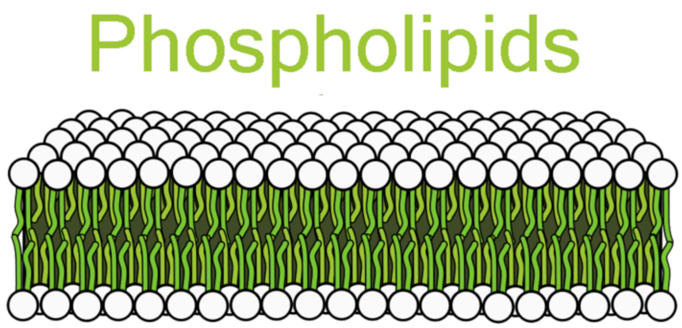


FIGURE 2.9
Phospholipids in a membrane.

### 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** below). 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/user/khanacademy#p/c/7A9646BC5110CF64/4/_-vZ_g7K6P0 .

### 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.

### Points to Consider

- 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 Chemistry 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** 2.10) 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.

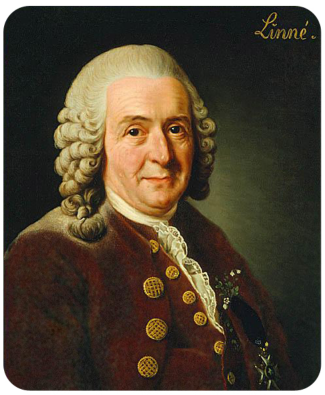


FIGURE 2.10
In the $18^{th}$ century, Carl Linnaeus invented the two-name system of naming organisms (genus and species) and introduced the most complete classification system then known.

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** 2.11, **Figure** 2.12, and **Figure** 2.13). 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.

## 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** 2.14). See http://www.pbs.org/wgbh/nova/orchid/classifying.html for further information.

### TABLE 2.1:

| | |
|---|---|
| Least Specific | Domain<br>Kingdom<br>Phylum<br>Class<br>Order<br>Family |

**TABLE 2.1:** (continued)

| | |
|---|---|
| Least Specific | Domain |
| | Genus |
| Most Specific | Species |

FIGURE 2.11

These leaves are from one of two different species of trees in the Acer, or maple, genus.

FIGURE 2.12

These leaves are from one of two different species of trees in the Acer, or maple, genus.

FIGURE 2.13

One of the characteristics of the maple genus is winged seeds.

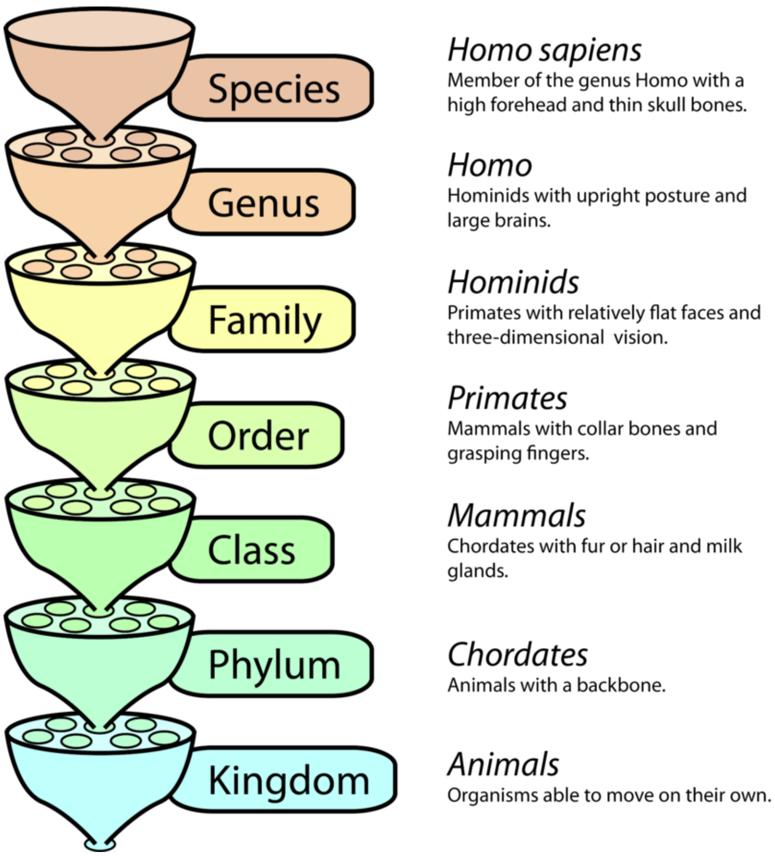


FIGURE 2.14
This diagram illustrates the classification categories for organisms, with the broadest category (Kingdom) at the bottom, and the most specific category (Species) at the top.

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

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URL: http://www.ck12.org/flx/render/embeddedobject/4700

## 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** 2.15).

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 2.15
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** 2.16 and **Figure** 2.17) 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.

### 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:

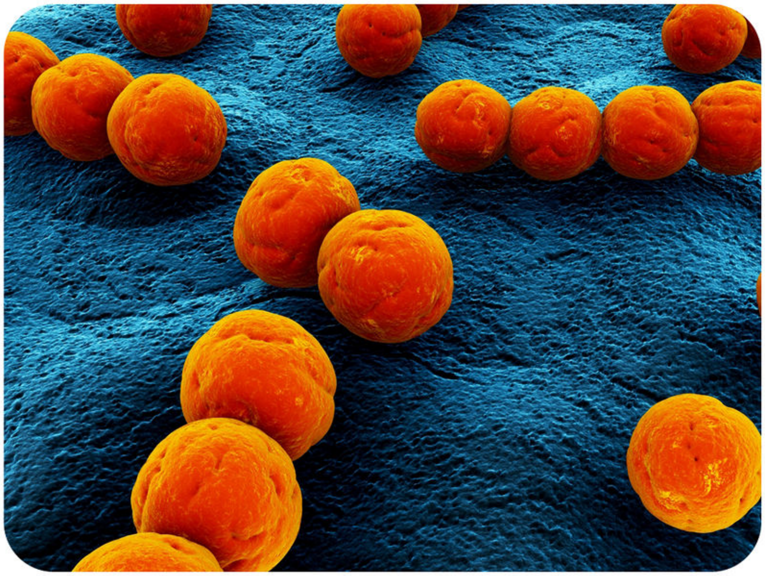

FIGURE 2.16
The Group D Streptococcus organism is in the domain Bacteria, one of the three domains of life.

FIGURE 2.17
The Halobacterium is in the domain Archaea, one of the three domains of life.

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** 2.18).
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** 2.19).

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.

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

| | Archaea | Bacteria | Eukarya |
|---|---|---|---|
| Multicelluar | No | No | Yes |

**TABLE 2.2:** (continued)

| | **Archaea** | **Bacteria** | **Eukarya** |
|---|---|---|---|
| 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 |

FIGURE 2.18
The Western Gray Squirrel is in the domain Eukarya, one of the three domains of life.

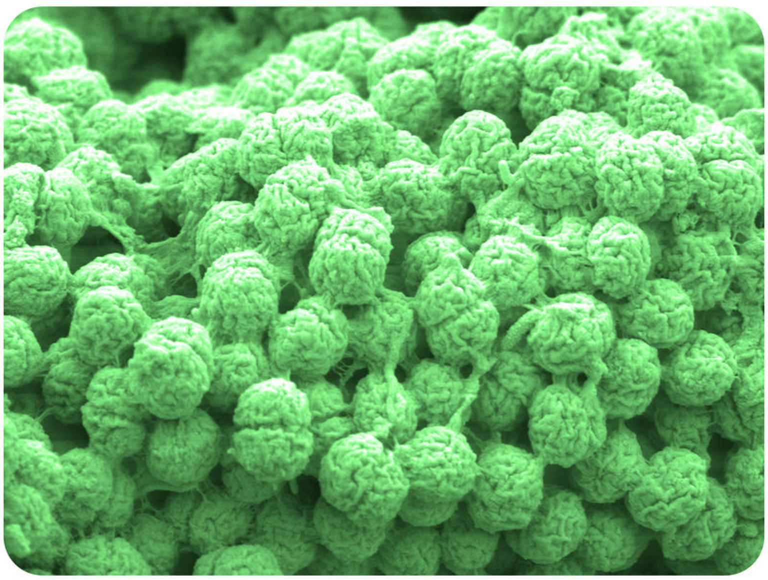

FIGURE 2.19
This microscopic alga is a protist in the domain Eukarya.

|+ **Three domains of life: Bacteria, Archaea, and Eukarya**

## 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** 2.20). 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.

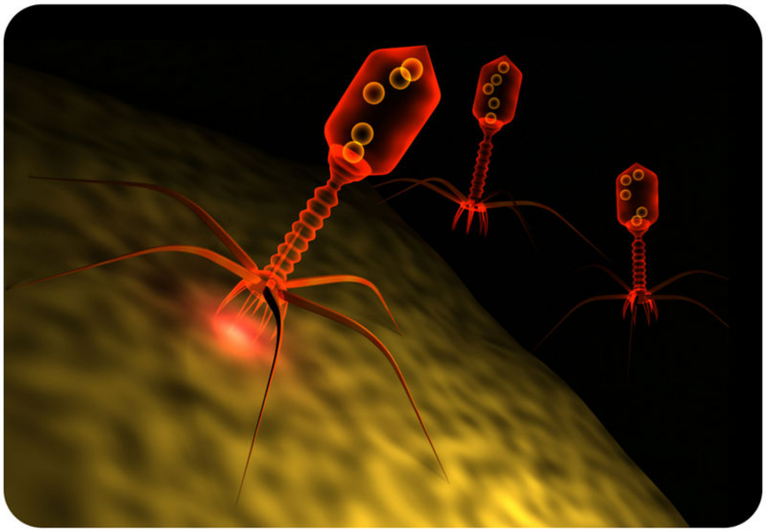

FIGURE 2.20

These "moon lander" shaped viruses infects *Escherichia coli* bacteria.

## Lesson Summary

- Scientists have defined several major categories for classifying organisms: domain, kingdom, phylum, class, order, family, genus, and species.
- The scientific name of an organism consists of its genus and species.
- 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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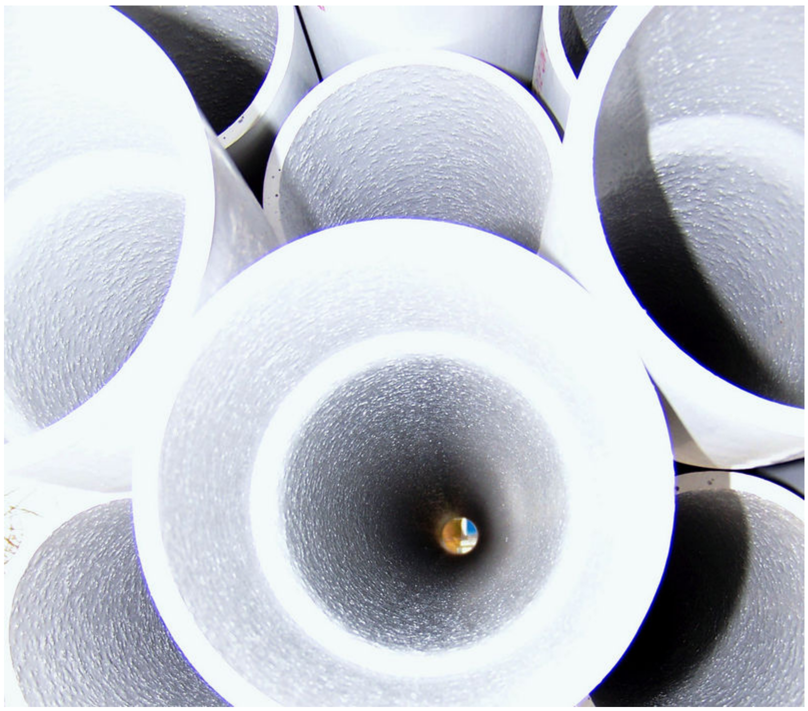
# CHAPTER 3 Cellular Structure and Function

## Chapter Outline

# 3.1 Cytoplasm and Cytoskeletons

- Define cytoplasm.
- Describe the functions of the cytoplasm.
- Describe the components of the cytoskeleton.
- Identify the roles of the cytoskeleton.



**Does a cell have, or even need, a "skeleton"?**

What do you get if you take some tubing, and make the tubes smaller and smaller and smaller? You get very small tubes, or microtubes. Very small tubes, or microtubules, together with microfilaments, form the basis of the "skeleton" inside the cell.

## The Cytoplasm and Cytoskeleton

The **cytoplasm** consists of everything inside the plasma membrane of the cell, excluding the nucleus in an eukaryotic cell. It includes the watery, gel-like material called **cytosol**, as well as various structures. The water in the cytoplasm makes up about two thirds of the cell's weight and gives the cell many of its properties.

### Functions of the Cytoplasm

The cytoplasm has several important functions, including:

1. suspending cell organelles.
2. pushing against the plasma membrane to help the cell keep its shape.
3. providing a site for many of the biochemical reactions of the cell.

### The Cytoskeleton

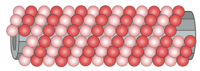
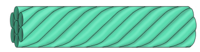
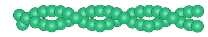
The **cytoskeleton** is a cellular "scaffolding" or "skeleton" that crisscrosses the cytoplasm. All eukaryotic cells have a cytoskeleton, and recent research has shown that prokaryotic cells also have a cytoskeleton. The eukaryotic cytoskeleton is made up of a network of long, thin protein fibers and has many functions. It helps to maintain cell shape. It holds organelles in place, and for some cells, it enables cell movement. The cytoskeleton also plays important roles in both the intracellular movement of substances and in cell division. Certain proteins act like a path that vesicles and organelles move along within the cell. The threadlike proteins that make up the cytoskeleton continually rebuild to adapt to the cell's constantly changing needs. Three main kinds of cytoskeleton fibers are microtubules, intermediate filaments, and microfilaments.

- **Microtubules**, shown in **Figure** 3.1 **(a)**, are hollow cylinders and are the thickest of the cytoskeleton structures. They are most commonly made of filaments which are polymers of alpha and beta tubulin, and radiate outwards from an area near the nucleus called the centrosome. **Tubulin** is the protein that forms microtubules. Two forms of tubulin, alpha and beta, form dimers (pairs) which come together to form the hollow cylinders. The cylinders are twisted around each other to form the microtubules. Microtubules help the cell keep its shape. They hold organelles in place and allow them to move around the cell, and they form the mitotic spindle during cell division. Microtubules also make up parts of cilia and flagella, the organelles that help a cell move.
- **Microfilaments**, shown in **Figure** 3.1 **(b)**, are made of two thin **actin** chains that are twisted around one another. Microfilaments are mostly concentrated just beneath the cell membrane, where they support the cell and help the cell keep its shape. Microfilaments form cytoplasmatic extentions, such as pseudopodia and microvilli, which allow certain cells to move. The actin of the microfilaments interacts with the protein myosin to cause contraction in muscle cells. Microfilaments are found in almost every cell, and are numerous in muscle cells and in cells that move by changing shape, such as phagocytes (white blood cells that search the body for bacteria and other invaders).
- **Intermediate filaments** differ in make-up from one cell type to another. Intermediate filaments organize the inside structure of the cell by holding organelles and providing strength. They are also structural components of the nuclear envelope. Intermediate filaments made of the protein keratin are found in skin, hair, and nails cells.

**TABLE 3.1: Cytoskeleton Structure**

| | Microtubules | Intermediate Filaments | Microfilaments |
|---|---|---|---|
| **Fiber Diameter** | About 25 nm | 8 to 11 nm | Around 7 nm |
| **Protein Composition** | Tubulin, with two subunits, alpha and beta tubulin | One of different types of proteins such as lamin, vimentin, and keratin | Actin |
| **Shape** | Hollow cylinders made of two protein chains twisted around each other | Protein fiber coils twisted into each other | Two actin chains twisted around one another |
| **Main Functions** | Organelle and vesicle movement; form mitotic spindles during cell reproduction; cell motility (in cilia and flagella) | Organize cell shape; positions organelles in cytoplasm structural support of the nuclear envelope and sarcomeres; involved in cell-to-cell and cell-to-matrix junctions | Keep cellular shape; allows movement of certain cells by forming cytoplasmatic extensions or contraction of actin fibers; involved in some cell-to-cell or cell-to-matrix junctions |

**TABLE 3.1:** (continued)

| | Microtubules | Intermediate Filaments | Microfilaments |
|---|---|---|---|
| **Representation** |  |  |  |

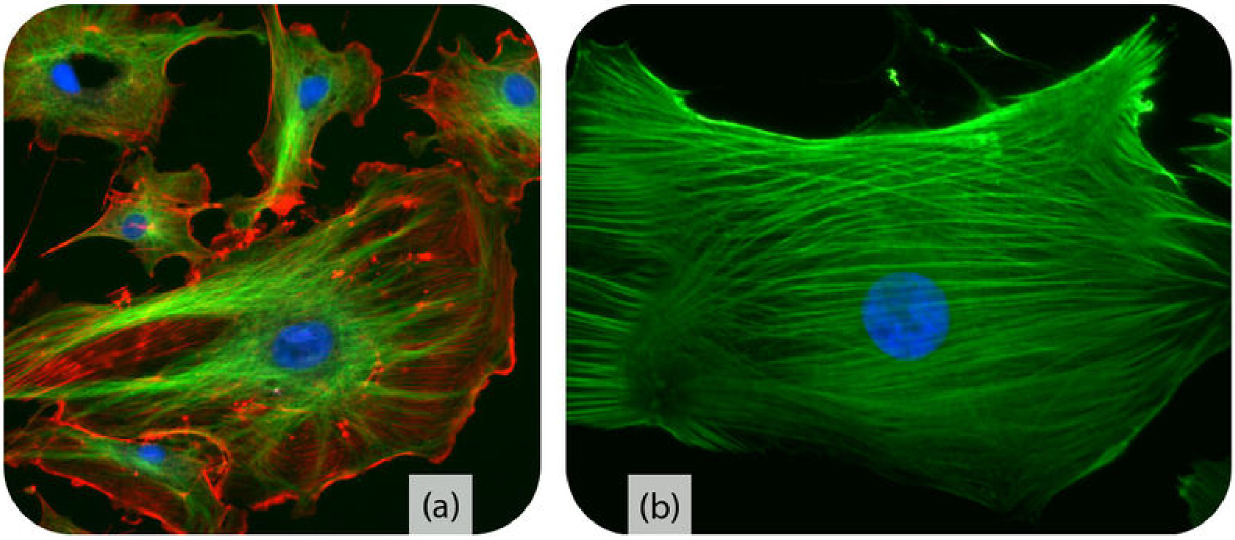
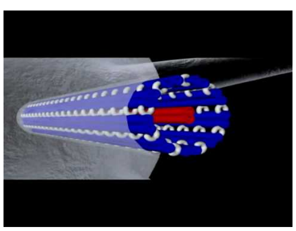



FIGURE 3.1
**(a)** The eukaryotic cytoskeleton. Microfilaments are shown in red, microtubules in green, and the nuclei are in blue. By linking regions of the cell together, the cytoskeleton helps support the shape of the cell. **(b)** Microscopy of microfilaments (actin filaments), shown in green, inside cells. The nucleus is shown in blue.

The cytoskeleton is discussed in the following video: http://www.youtube.com/watch?v=5rqbmLiSkpk (4:50).



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## Summary

- The cytoplasm consists of everything inside the plasma membrane of the cell.
- The cytoskeleton is a cellular "skeleton" that crisscrosses the cytoplasm. Three main cytoskeleton fibers are microtubules, intermediate filaments, and microfilaments.
- Microtubules are the thickest of the cytoskeleton structures and are most commonly made of filaments which are polymers of alpha and beta tubulin.
- Microfilament are the thinnest of the cytoskeleton structures and are made of two thin actin chains that are twisted around one another.

## Practice

Use this resource to answer the questions that follow.

- http://www.hippocampus.org/Biology → Biology for AP* → Search: **Cell Structure and Movement**

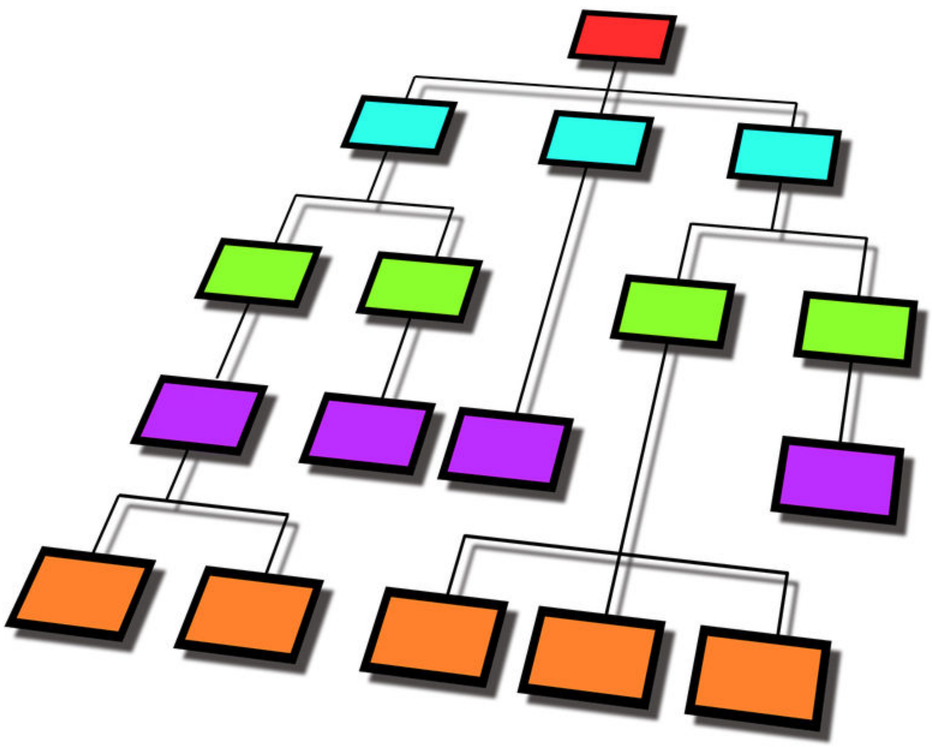
1. Identify the roles of the cytoskeleton.
2. Describe the structure and functions of microtubules.
3. What is a centrosome?
4. What are the subunits that make up microfilaments?
5. What is the nuclear lamina?
6. What is the primary component of cilia and flagella?
7. What is the goal of cytoplasmic streaming?

## Review

1. What is the difference between cytoplasm and cytosol?
2. List two roles of the cytoplasm.
3. Name the three main types of cytoskeleton fibers.
4. List two functions of the eukaryotic cytoskeleton.

# 3.2 Organization of Cells

- Explain how cells are organized in living things.
- Explain the significance of colonial organisms.
- Describe the origin of multicellular organisms.
- Distinguish a tissue from an organ from an organ system.



**Why be organized?**

It can be said organization leads to efficiency. And in you, cells are organized into tissues, which are organized into organs, which are organized into organ systems, which form you. And it can be said that the human body is a very organized and efficient system.

## Organization of Cells

Biological organization exists at all levels in organisms. It can be seen at the smallest level, in the molecules that made up such things as DNA and proteins, to the largest level, in an organism such as a blue whale, the largest mammal on Earth. Similarly, single celled prokaryotes and eukaryotes show order in the way their cells are arranged. Single-celled organisms such as an amoeba are free-floating and independent-living. Their single-celled "bodies" are able to carry out all the processes of life, such as metabolism and respiration, without help from other cells. Some single-celled organisms, such as bacteria, can group together and form a biofilm. A **biofilm** is a large grouping of many bacteria that sticks to a surface and makes a protective coating over itself. Biofilms can show similarities to multicellular organisms. Division of labor is the process in which one group of cells does one job (such as making the "glue" that sticks the biofilm to the surface), while another group of cells does another job (such as taking in nutrients). Multicellular organisms carry out their life processes through division of labor. They have specialized cells that do specific jobs. However, biofilms are not considered multicellular organisms and are instead called colonial organisms. The difference between a multicellular organism and a colonial organism is that individual organisms from a colony or biofilm can, if separated, survive on their own, while cells from a multicellular organism (e.g., liver cells) cannot.

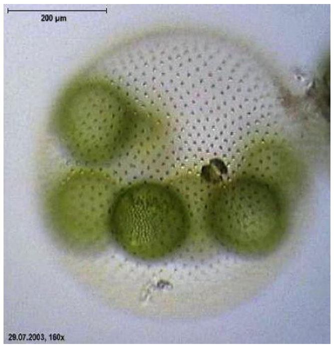



FIGURE 3.2
Colonial algae of the genus *Volvox*.

### Colonial Organisms

**Colonial organisms** were probably one of the first evolutionary steps towards multicellular organisms. Algae of the genus *Volvox* are an example of the border between colonial organisms and multicellular organisms.

Each *Volvox*, shown in **Figure** 3.2, is a colonial organism. It is made up of between 1,000 to 3,000 photosynthetic algae that are grouped together into a hollow sphere. The sphere has a distinct front and back end. The cells have eyespots, which are more developed in the cells near the front. This enables the colony to swim towards light.

### Origin of Multicellularity

The oldest known multicellular organism is a red algae *Bangiomorpha pubescens*, fossils of which were found in 1.2 billion-year-old rock. As the first organisms were single-celled, these organisms had to evolve into multicellular organisms.

Scientists think that multicellularity arose from cooperation between many organisms of the same species. The **Colonial Theory** proposes that this cooperation led to the development of a multicellular organism. Many examples of cooperation between organisms in nature have been observed. For example, a certain species of amoeba (a single-celled protist) groups together during times of food shortage and forms a colony that moves as one to a new location. Some of these amoebas then become slightly differentiated from each other. *Volvox*, shown in **Figure** 3.2, is another example of a colonial organism. Most scientists accept that the Colonial Theory explains how multicellular organisms evolved.

**Multicellular organisms** are organisms that are made up of more than one type of cell and have specialized cells that are grouped together to carry out specialized functions. Most life that you can see without a microscope is multicellular. As discussed earlier, the cells of a multicellular organism would not survive as independent cells. The body of a multicellular organism, such as a tree or a cat, exhibits organization at several levels: tissues, organs, and organ systems. Similar cells are grouped into tissues, groups of tissues make up organs, and organs with a similar function are grouped into an organ system.

### Levels of Organization in Multicellular Organisms

The simplest living multicellular organisms, sponges, are made of many specialized types of cells that work together for a common goal. Such cell types include digestive cells, tubular pore cells, and epidermal cells. Though the different cell types create a large, organized, multicellular structure —the visible sponge —they are not organized into true interconnected tissues. If a sponge is broken up by passing it through a sieve, the sponge will reform on the other side. However, if the sponge's cells are separated from each other, the individual cell types cannot survive alone. Simpler colonial organisms, such as members of the genus *Volvox*, as shown in **Figure** 3.2, differ in that their individual cells are free-living and can survive on their own if separated from the colony.

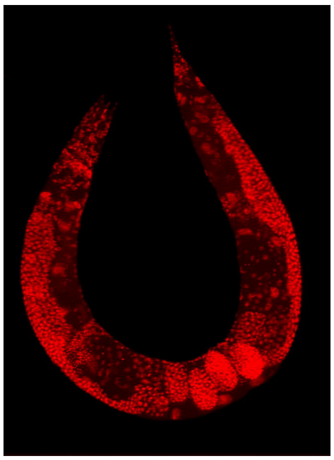


FIGURE 3.3
This roundworm, a multicellular organism, was stained to highlight the nuclei of all the cells in its body (red dots).

A **tissue** is a group of connected cells that have a similar function within an organism. More complex organisms such as jellyfish, coral, and sea anemones have a tissue level of organization. For example, jellyfish have tissues that have separate protective, digestive, and sensory functions.

Even more complex organisms, such as the roundworm shown in **Figure** 3.3, while also having differentiated cells and tissues, have an organ level of development. An **organ** is a group of tissues that has a specific function or group of functions. Organs can be as primitive as the brain of a flatworm (a group of nerve cells), as large as the stem of a sequoia (up to 90 meters, or 300 feet, in height), or as complex as a human liver.

The most complex organisms (such as mammals, trees, and flowers) have organ systems. An **organ system** is a group of organs that act together to carry out complex related functions, with each organ focusing on a part of the task. An example is the human digestive system, in which the mouth ingests food, the stomach crushes and liquifies it, the pancreas and gall bladder make and release digestive enzymes, and the intestines absorb nutrients into the blood.

### Summary

- Single-celled organisms are able to carry out all the processes of life without help from other cells.
- Multicellular organisms carry out their life processes through division of labor. They have specialized cells that do specific jobs.
- The Colonial Theory proposes that cooperation among cells of the same species led to the development of a multicellular organism.
- Multicellular organisms, depending on their complexity, may be organized from cells to tissues, organs, and organ systems.

## Practice

Use these resources to answer the questions that follow.

### Practice I

- http://www.hippocampus.org/Biology → Non-Majors Biology → Search: **Tissues**

1. Why are multicellular organisms highly organized?
2. What is a tissue?

### Practice II

- http://www.hippocampus.org/Biology → Non-Majors Biology → Search: **Organs and Systems**

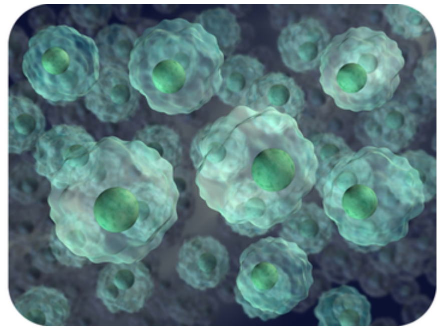
1. What is the difference between an organ and an organ system?
2. How many organ systems do humans have?

## Review

1. What is a multicellular organism?
2. What is a cell feature that distinguishes a colonial organism from a multicellular organism?
3. What is the difference between a cell and a tissue?
4. Describe the top two levels of organization of an organism.

# 3.3 Prokaryotic and Eukaryotic Cells

- Give examples of prokaryotic and eukaryotic cells.
- Compare and contrast prokaryotic and eukaryotic cells.



**How many different types of cells are there?**

There are many different types of cells. For example, in you there are blood cells and skin cells and bone cells and even bacteria. Here we have drawings of bacteria and human cells. Can you tell which depicts various types of bacteria? However, all cells - whether from bacteria, human, or any other organism - will be one of two general types. In fact, all cells other than bacteria will be one type, and bacterial cells will be the other. And it all depends on how the cell stores its DNA.

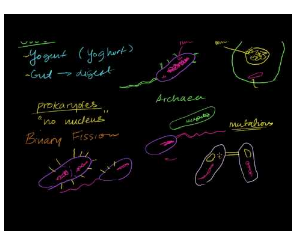
## Two Types of Cells

There is another basic cell structure that is present in many but not all living cells: the nucleus. The **nucleus** of a cell is a structure in the cytoplasm that is surrounded by a membrane (the nuclear membrane) and contains DNA. Based on whether they have a nucleus, there are two basic types of cells: prokaryotic cells and eukaryotic cells. You can watch animations of both types of cells at the link below. http://www.learnerstv.com/animation/animation.php?ani=162&cat=biology

### Prokaryotic Cells

**Prokaryotic cells** are cells without a nucleus. The DNA in prokaryotic cells is in the cytoplasm rather than enclosed within a nuclear membrane. Prokaryotic cells are found in single-celled organisms, such as bacteria, like the one shown in **Figure** 3.4. Organisms with prokaryotic cells are called **prokaryotes**. They were the first type of organisms to evolve and are still the most common organisms today.

Bacteria are described in the following video http://www.youtube.com/watch?v=TDoGrbpJJ14 (18:26).

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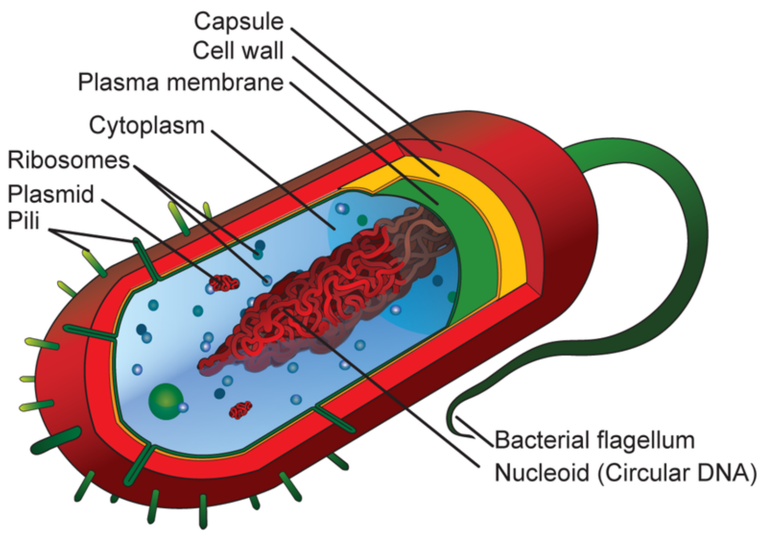



FIGURE 3.4

Prokaryotic Cell. This diagram shows the structure of a typical prokaryotic cell, a bacterium. Like other prokaryotic cells, this bacterial cell lacks a nucleus but has other cell parts, including a plasma membrane, cytoplasm, ribosomes, and DNA. Identify each of these parts in the diagram.

### Eukaryotic Cells

**Eukaryotic cells** are cells that contain a nucleus. A typical eukaryotic cell is shown in **Figure** 3.5. Eukaryotic cells are usually larger than prokaryotic cells, and they are found mainly in multicellular organisms. Organisms with eukaryotic cells are called **eukaryotes**, and they range from fungi to people.

Eukaryotic cells also contain other organelles besides the nucleus. An **organelle** is a structure within the cytoplasm that performs a specific job in the cell. Organelles called mitochondria, for example, provide energy to the cell, and organelles called vacuoles store substances in the cell. Organelles allow eukaryotic cells to carry out more functions than prokaryotic cells can. This allows eukaryotic cells to have greater cell specificity than prokaryotic cells. Ribosomes, the organelle where proteins are made, are the only organelles in prokaryotic cells.

In some ways, a cell resembles a plastic bag full of Jell-O. Its basic structure is a plasma membrane filled with cytoplasm. Like Jell-O containing mixed fruit, the cytoplasm of the cell also contains various structures, such as a nucleus and other organelles. You can also explore the structures of an interactive animal cell at this link: http://www.cellsalive.com/cells/cell_model.htm .

### Summary

- Prokaryotic cells are cells without a nucleus.
- Eukaryotic cells are cells that contain a nucleus.
- Eukaryotic cells have other organelles besides the nucleus. The only organelles in a prokaryotic cell are ribosomes.

### Practice

Use these resources to answer the questions that follow.

### Practice I

- http://www.hippocampus.org/Biology → Biology for AP* → Search: **Prokaryotes and Eukaryotes**

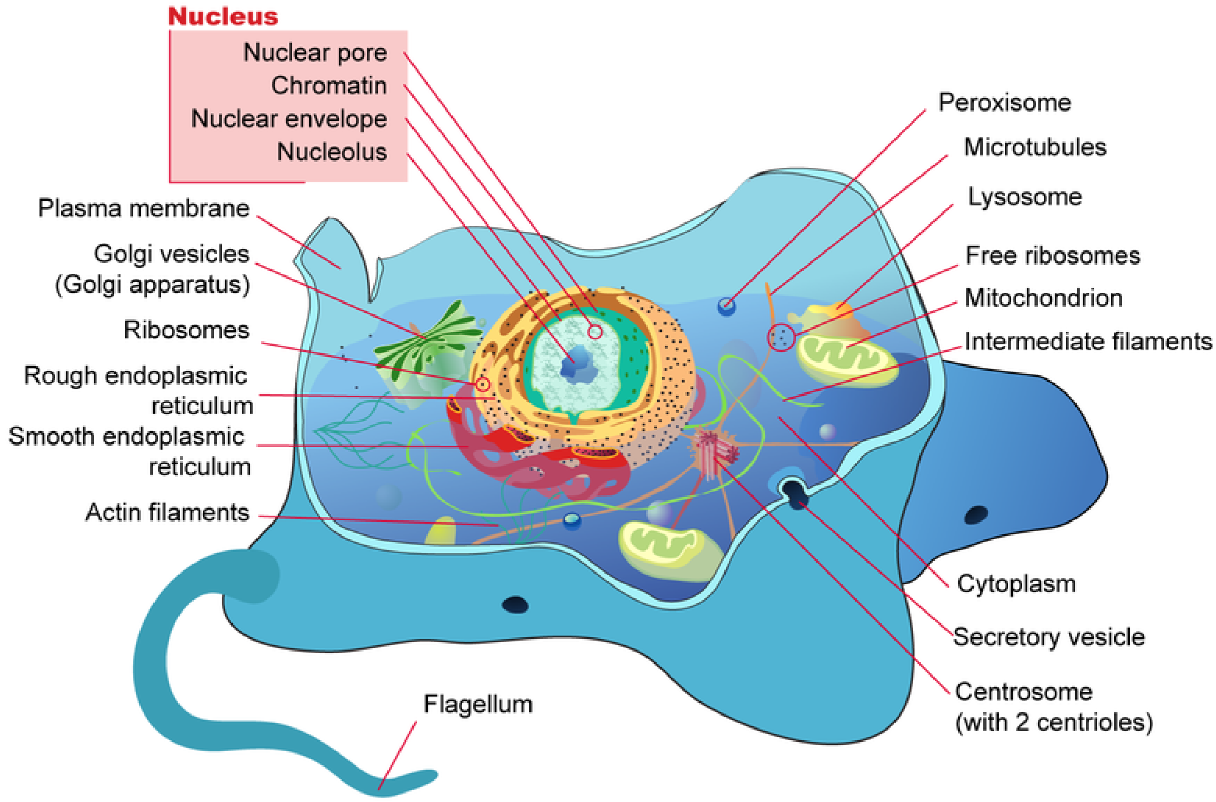



FIGURE 3.5

Eukaryotic Cell. Compare and contrast the eukaryotic cell shown here with the prokaryotic cell. What similarities and differences do you see?

1. What is the general difference between prokaryotic and eukaryotic cells?
2. Which cells have a nucleus?
3. Prokaryotes include members of which Domain(s)?
4. Why are prokaryotes described as having a relatively simple structure?
5. Define organelle.
6. List three organelles specific to eukaryotic cells.
7. What is one difference between plant cells and animal cells?
8. What is the main function of the chloroplast?
9. What does endosymbiosis refer to?

### Practice II

- **Typical Animal Cell** at http://www.wisc-online.com/Objects/ViewObject.aspx?ID=AP11403 .

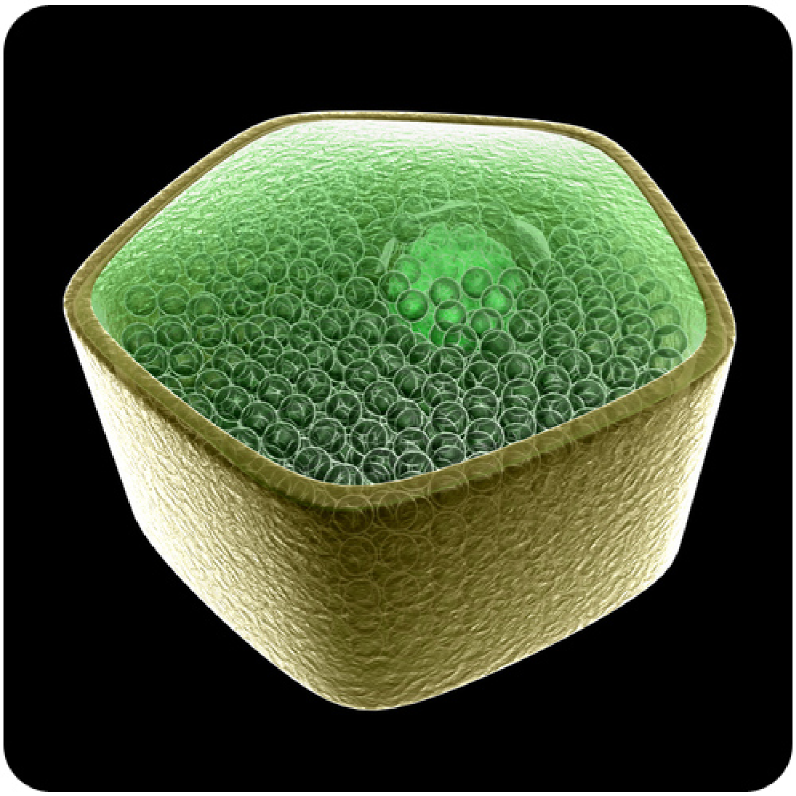
### Review

1. What is the cell nucleus?

2. What is the main difference between prokaryotic and eukaryotic cells?
3. Give an example of a prokaryotic cell.
4. Define organelle.
5. What is the advantage of having organelles?

# 3.4 Plant Cell Structures

- List the special structures of plant cells.
- Explain the function of the cell wall.
- Summarize the role of the central vacuole.
- Describe the structure and function of a chloroplast.



**What do plants have to do that animals don't?**

Many plant cells are green. Why? Plant cells also usually have a distinct shape. The rigid exterior around the cells is necessary to allow the plants to grow upright. Animal cells do not have these rigid exteriors. There are other distinct differences between plant and animal cells. These will be the focus of this concept.

## Plant Cells

### Special Structures in Plant Cells

Most organelles are common to both animal and plant cells. However, plant cells also have features that animal cells do not have: a cell wall, a large central vacuole, and plastids such as chloroplasts.

Plants have very different lifestyles from animals, and these differences are apparent when you examine the structure of the plant cell. Plants make their own food in a process called **photosynthesis**. They take in carbon dioxide ($CO_2$) and water ($H_2O$) and convert them into sugars. The features unique to plant cells can be seen in **Figure** 3.6.

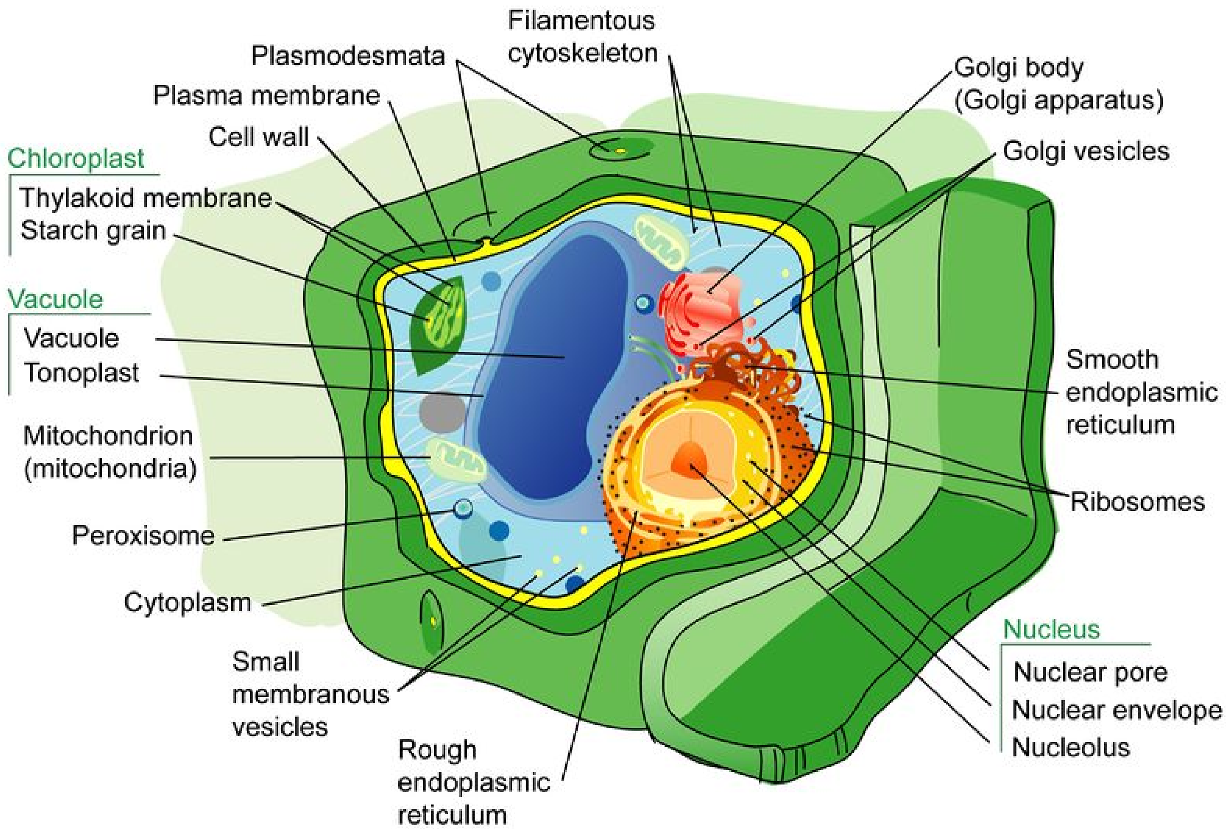



FIGURE 3.6

In addition to containing most of the organelles found in animal cells, plant cells also have a cell wall, a large central vacuole, and plastids. These three features are not found in animal cells.

### The Cell Wall

A **cell wall** is a rigid layer that is found outside the cell membrane and surrounds the cell. The cell wall contains not only cellulose and protein, but other polysaccharides as well. The cell wall provides structural support and protection. Pores in the cell wall allow water and nutrients to move into and out of the cell. The cell wall also prevents the plant cell from bursting when water enters the cell.

Microtubules guide the formation of the plant cell wall. Cellulose is laid down by enzymes to form the primary cell wall. Some plants also have a secondary cell wall. The secondary wall contains a lignin, a secondary cell component in plant cells that have completed cell growth/expansion.

### The Central Vacuole

Most mature plant cells have a **central vacuole** that occupies more than 30% of the cell's volume. The central vacuole can occupy as much as 90% of the volume of certain cells. The central vacuole is surrounded by a membrane called the **tonoplast**. The central vacuole has many functions. Aside from storage, the main role of the vacuole is to maintain turgor pressure against the cell wall. Proteins found in the tonoplast control the flow of water into and out of the vacuole. The central vacuole also stores the pigments that color flowers.

The central vacuole contains large amounts of a liquid called cell sap, which differs in composition to the cell cytosol. Cell sap is a mixture of water, enzymes, ions, salts, and other substances. Cell sap may also contain toxic byproducts that have been removed from the cytosol. Toxins in the vacuole may help to protect some plants from being eaten.

### Plastids

Plant **plastids** are a group of closely related membrane-bound organelles that carry out many functions. They are responsible for photosynthesis, for storage of products such as starch, and for the synthesis of many types of molecules that are needed as cellular building blocks. Plastids have the ability to change their function between these and other forms. Plastids contain their own DNA and some ribosomes, and scientists think that plastids are descended from photosynthetic bacteria that allowed the first eukaryotes to make oxygen. The main types of plastids and their functions are:

- **Chloroplasts** are the organelle of photosynthesis. They capture light energy from the sun and use it with water and carbon dioxide to make food (sugar) for the plant. The arrangement of chloroplasts in a plant's cells can be seen in **Figure** 3.7.
- **Chromoplasts** make and store pigments that give petals and fruit their orange and yellow colors.
- **Leucoplasts** do not contain pigments and are located in roots and non-photosynthetic tissues of plants. They may become specialized for bulk storage of starch, lipid, or protein. However, in many cells, leucoplasts do not have a major storage function. Instead, they make molecules such as fatty acids and many amino acids.

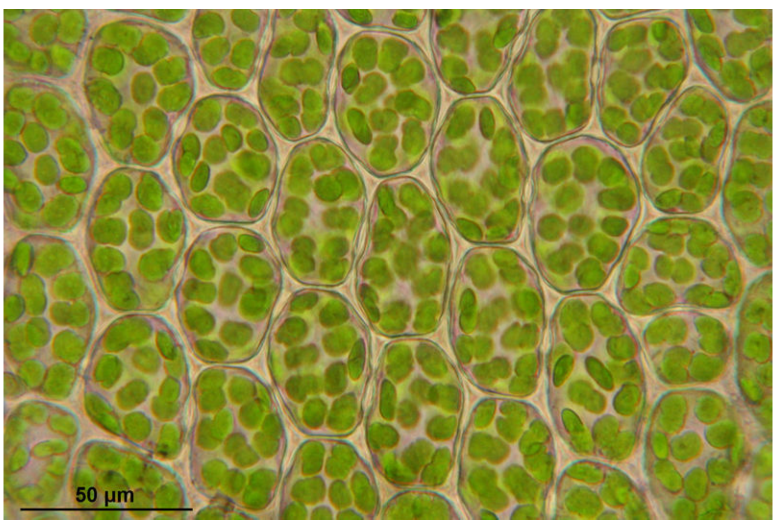



FIGURE 3.7
Plant cells with visible chloroplasts.

### Chloroplasts

**Chloroplasts** capture light energy from the sun and use it with water and carbon dioxide to produce sugars for food. Chloroplasts look like flat discs and are usually 2 to 10 micrometers in diameter and 1 micrometer thick. A model of a chloroplast is shown in **Figure** 3.8. The chloroplast is enclosed by an inner and an outer phospholipid membrane. Between these two layers is the intermembrane space. The fluid within the chloroplast is called the **stroma**, and it contains one or more molecules of small, circular DNA. The stroma also has ribosomes. Within the stroma are stacks of **thylakoids**, sub-organelles that are the site of photosynthesis. The thylakoids are arranged in stacks called

**grana** (singular: granum). A thylakoid has a flattened disk shape. Inside it is an empty area called the thylakoid space or lumen. Photosynthesis takes place on the thylakoid membrane.

Within the thylakoid membrane is the complex of proteins and light-absorbing pigments, such as chlorophyll and carotenoids. This complex allows capture of light energy from many wavelengths because chlorophyll and carotenoids both absorb different wavelengths of light. These will be further discussed in the "Photosynthesis" concept.

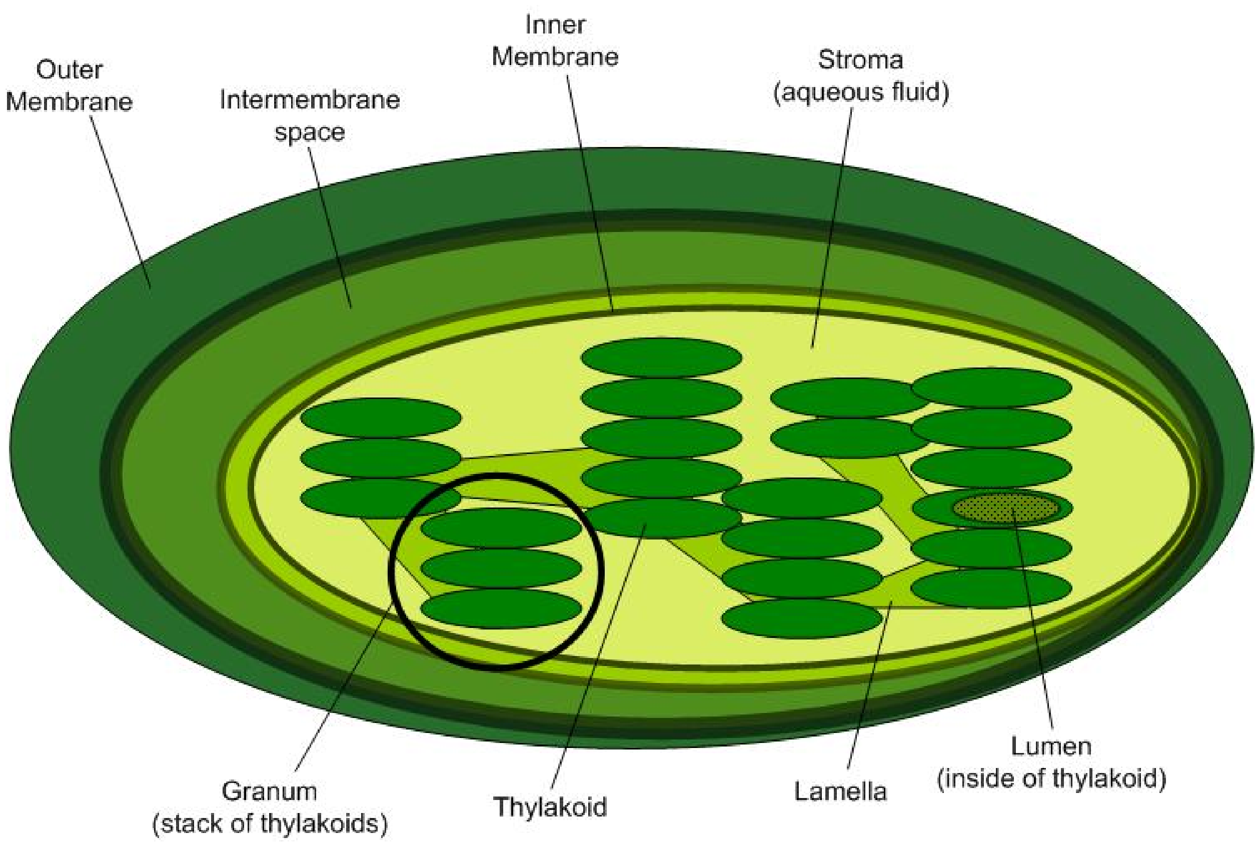



FIGURE 3.8

The internal structure of a chloroplast, with a granal stack of thylakoids circled.

## Summary

- Plant cells have a cell wall, a large central vacuole, and plastids such as chloroplasts.
- The cell wall is a rigid layer that is found outside the cell membrane and surrounds the cell, providing structural support and protection.
- The central vacuole maintains turgor pressure against the cell wall.
- Chloroplasts capture light energy from the sun and use it with water and carbon dioxide to produce sugars for food.

## Practice

Use these resources to answer the questions that follow.

### Practice I

- http://www.hippocampus.org/Biology → Biology for AP* → Search: **Prokaryotes and Eukaryotes**

1. List the three distinguishing features of a plant cell. Describe their roles.
2. In addition to plants, what other organisms have chloroplasts?
3. How is the vacuole related to plant death?

### Practice II

- **Eucaryotic Cell Interactive Animation: Plant Cell** at http://www.cellsalive.com/cells/cell_model.htm .

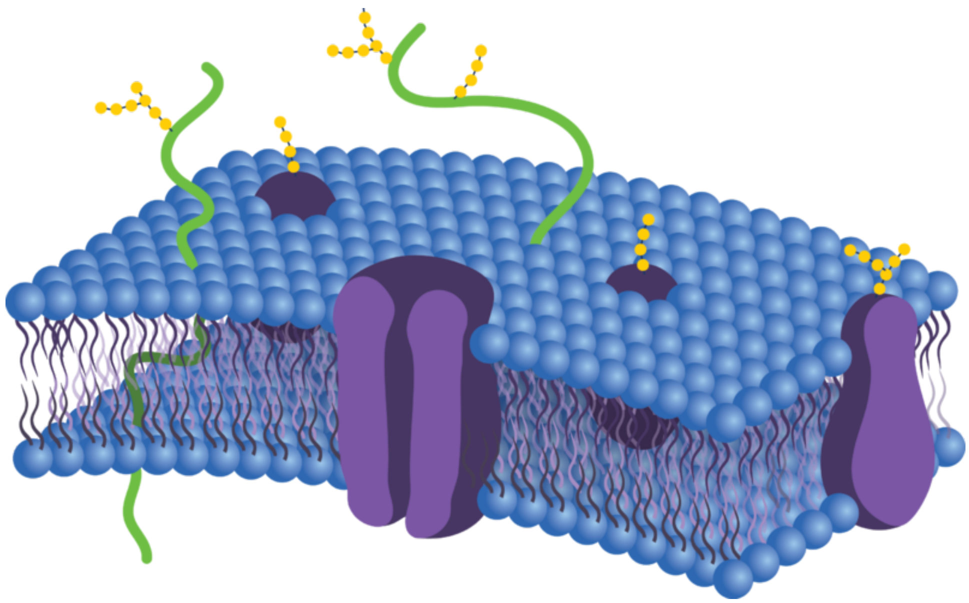
## Review

1. List three structures that are found in plant cells but not in animal cells.
2. Identify two functions of plastids in plant cells.
3. What are the roles of the cell wall and the central vacuole?

- Describe the chloroplast structure.

# 3.5 Phospholipid Bilayers

- Explain semipermeability.
- Summarize the structure of a phospholipid.
- Describe the structure and function of the plasma membrane.



**All cells have a plasma membrane. This membrane surrounds the cell. So what is its role?**

Can molecules enter and leave the cell? Yes. Can anything or everything enter or leave? No. So, what determines what can go in or out? Is it the nucleus? The DNA? Or the plasma membrane?

## The Plasma Membrane

The **plasma membrane** (also known as the **cell membrane**) forms a barrier between the cytoplasm inside the cell and the environment outside the cell. It protects and supports the cell and also controls everything that enters and leaves the cell. It allows only certain substances to pass through, while keeping others in or out. The ability to allow only certain molecules in or out of the cell is referred to as selective permeability or **semipermeability**. To understand how the plasma membrane controls what crosses into or out of the cell, you need to know its composition.

The plasma membrane is discussed at http://www.youtube.com/watch?v=-aSfoB8Cmic (6:16).

### A Phospholipid Bilayer

The plasma membrane is composed mainly of phospholipids, which consist of fatty acids and alcohol. The phospholipids in the plasma membrane are arranged in two layers, called a **phospholipid bilayer**. As shown in **Figure** 3.9, each phospholipid molecule has a head and two tails. The head "loves" water ( **hydrophilic**) and the tails "hate" water ( **hydrophobic**). The water-hating tails are on the interior of the membrane, whereas the water-loving heads point outwards, toward either the cytoplasm or the fluid that surrounds the cell.

Molecules that are hydrophobic can easily pass through the plasma membrane, if they are small enough, because they are water-hating like the interior of the membrane. Molecules that are hydrophilic, on the other hand, cannot pass through the plasma membrane—at least not without help—because they are water-loving like the exterior of the membrane, and are therefore excluded from the interior of the membrane.

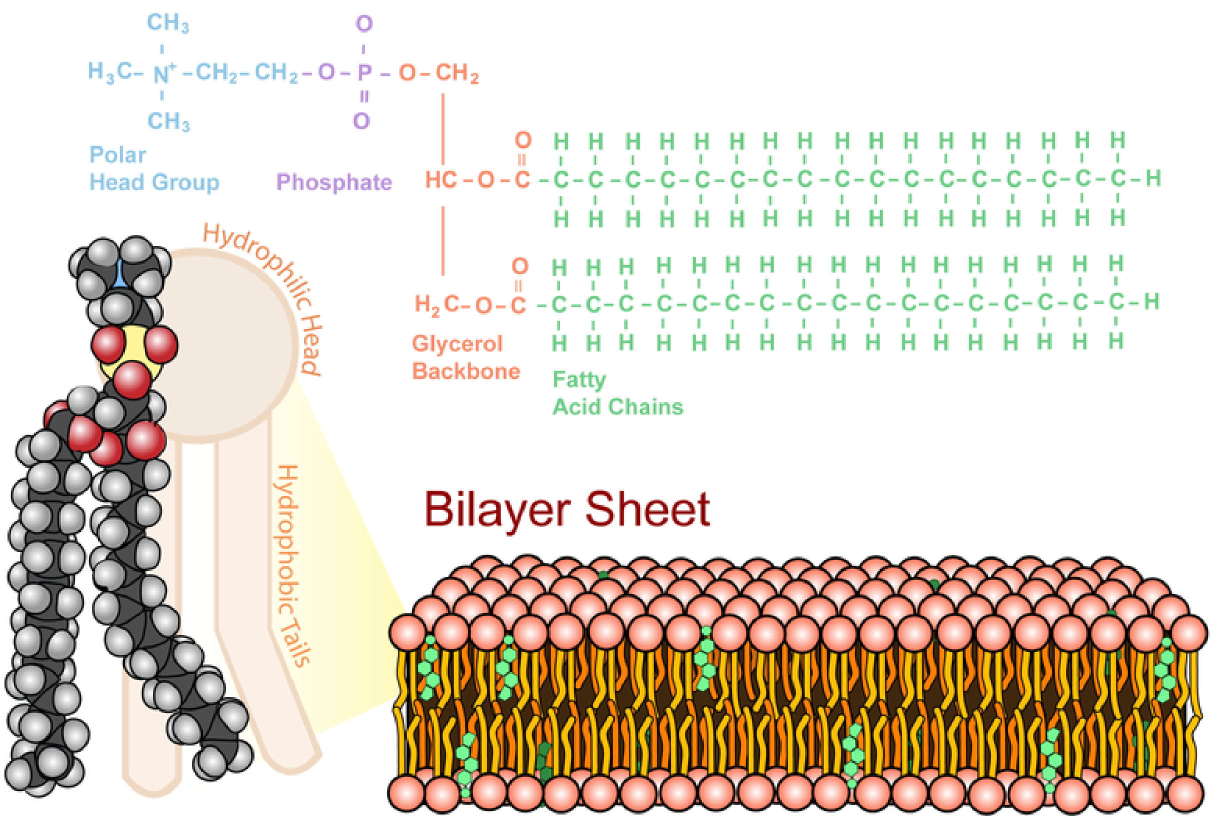



FIGURE 3.9

Phospholipid Bilayer. The phospholipid bilayer consists of two layers of phospholipids, with a hydrophobic, or water-hating, interior and a hydrophilic, or water-loving, exterior. The hydrophilic (polar) head group and hydrophobic tails (fatty acid chains) are depicted in the single phospholipid molecule. The polar head group and fatty acid chains are attached by a 3-carbon glycerol unit.

See *Insights into cell membranes via dish detergent* at http://ed.ted.com/lessons/insights-into-cell-membranes-via-dish-detergent-ethan-perlstein for additional information on the cell membrane.

## Summary

- The plasma membrane forms a barrier between the cytoplasm and the environment outside the cell. The plasma membrane has selective permeability.
- The plasma membrane is primarily composed of phospholipids arranged in a bilayer, with the hydrophobic tails on the interior of the membrane, and the hydrophilic heads pointing outwards.

## Practice

Use these resources to answer the questions that follow.

- **Construction of the Cell Membrane** at http://www.wisc-online.com/Objects/ViewObject.aspx?ID=AP1101 .

1. What are the two main components of the cell membrane?
2. Describe the types of proteins that live in the cell membrane.
3. Describe the orientation of the phospholipid molecule in the cell membrane.

- **Cell Membranes** at http://johnkyrk.com/cellmembrane.html .

1. Are *all* cells surrounded by a membrane?
2. Why are phospholipids considered an amphipathic molecule?
3. What is a glycolipid?
4. Describe the role of cholesterol in the cell membrane.

- http://www.hippocampus.org/Biology → Non-Majors Biology → Search: **Plasma Membrane Structure**

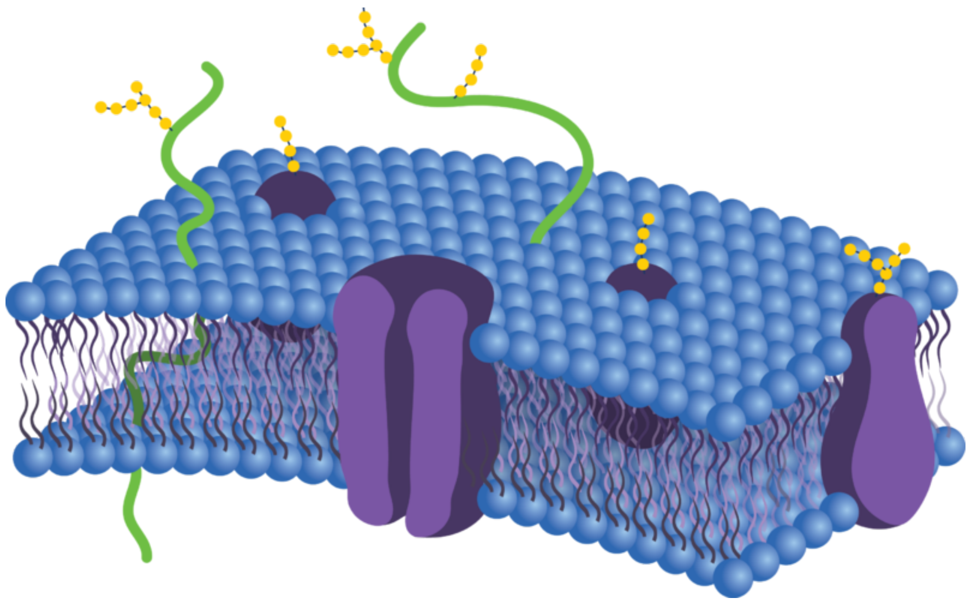
1. What are the roles of the plasma membrane?
2. What is the difference between hydrophilic and hydrophobic?
3. What are the functions of proteins associated with the cell membrane?
4. Why is the structure of the cell membrane described as "fluid mosaic"?

## Review

1. Describe the role of the plasma membrane.
2. What is meant by semipermeability?
3. Describe the composition of the plasma membrane.
4. Explain why hydrophobic molecules can easily cross the plasma membrane, while hydrophilic molecules cannot.

# 3.6 Membrane Proteins

- Distinguish between integral and peripheral membrane proteins.
- Describe the structure and function of the membrane proteins.
- Summarize the Fluid Mosaic Model.



**Can anything or everything move in or out of the cell?**

No. It is the semipermeable plasma membrane that determines what can enter and leave the cell. So, if not everything can cross the membrane, how do certain things get across?

## Membrane Proteins

The plasma membrane contains molecules other than phospholipids, primarily other lipids and proteins. The green molecules in **Figure** 3.10, for example, are the lipid cholesterol. Molecules of cholesterol help the plasma membrane keep its shape. Many of the proteins in the plasma membrane assist other substances in crossing the membrane.

The plasma membranes also contain certain types of proteins. A **membrane protein** is a protein molecule that is attached to, or associated with, the membrane of a cell or an organelle. Membrane proteins can be put into two groups based on how the protein is associated with the membrane.

**Integral membrane proteins** are permanently embedded within the plasma membrane. They have a range of important functions. Such functions include channeling or transporting molecules across the membrane. Other integral proteins act as cell receptors. Integral membrane proteins can be classified according to their relationship with the bilayer:

- Transmembrane proteins span the entire plasma membrane. Transmembrane proteins are found in all types of biological membranes.
- Integral monotopic proteins are permanently attached to the membrane from only one side.

Some integral membrane proteins are responsible for cell adhesion (sticking of a cell to another cell or surface). On the outside of cell membranes and attached to some of the proteins are carbohydrate chains that act as labels that identify the cell type. Shown in **Figure** 3.10 are two different types of membrane proteins and associated molecules.

**Peripheral membrane proteins** are proteins that are only temporarily associated with the membrane. They can be easily removed, which allows them to be involved in cell signaling. Peripheral proteins can also be attached to integral membrane proteins, or they can stick into a small portion of the lipid bilayer by themselves. Peripheral membrane proteins are often associated with ion channels and transmembrane receptors. Most peripheral membrane proteins are hydrophilic.

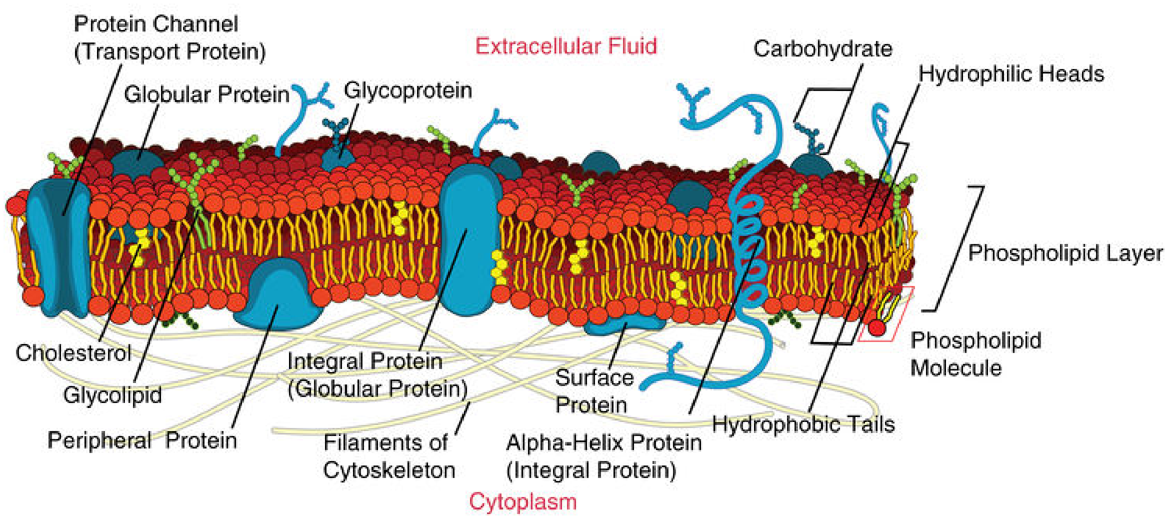



FIGURE 3.10

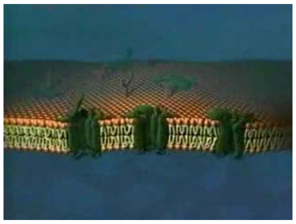
Some of the membrane proteins make up a major transport system that moves molecules and ions through the polar phospholipid bilayer.

### The Fluid Mosaic Model

In 1972 S.J. Singer and G.L. Nicolson proposed the now widely accepted **Fluid Mosaic Model** of the structure of cell membranes. The model proposes that integral membrane proteins are embedded in the phospholipid bilayer, as seen in **Figure** 3.10. Some of these proteins extend all the way through the bilayer, and some only partially across it. These membrane proteins act as transport proteins and receptors proteins.

Their model also proposed that the membrane behaves like a fluid, rather than a solid. The proteins and lipids of the membrane move around the membrane, much like buoys in water. Such movement causes a constant change in the "mosaic pattern" of the plasma membrane.

A further description of the Fluid Mosaic Model can be viewed at http://www.youtube.com/watch?v=Qqsf_UJcfBc (1:27).



MEDIA

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URL: http://www.ck12.org/flx/render/embeddedobject/94255

### Extensions of the Plasma Membrane

The plasma membrane may have extensions, such as whip-like **flagella** or brush-like **cilia**. In single-celled organisms, like those shown in **Figure** 3.11, the membrane extensions may help the organisms move. In multicellular organisms, the extensions have other functions. For example, the cilia on human lung cells sweep foreign particles and mucus toward the mouth and nose.

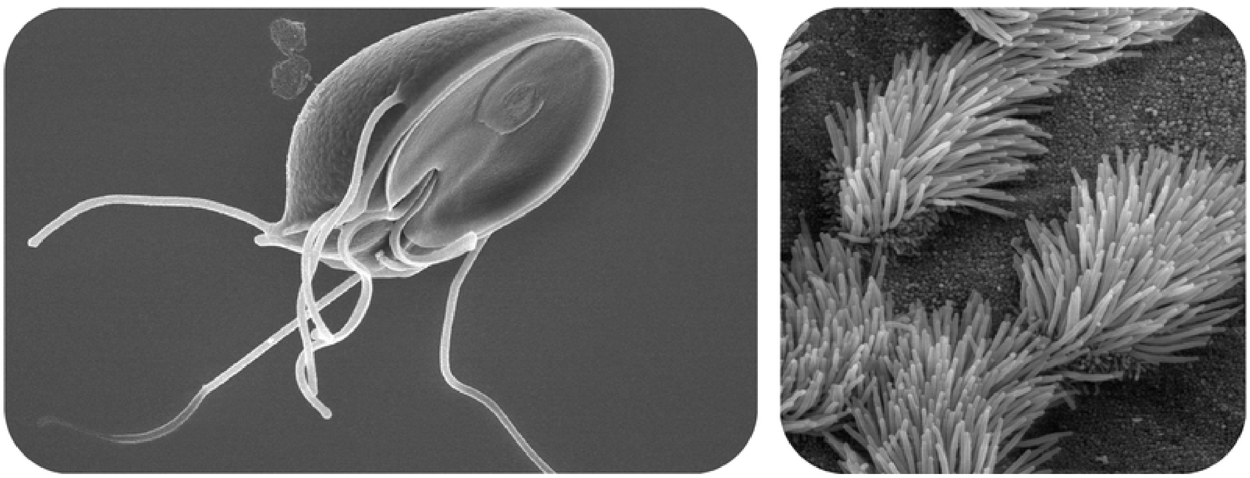


FIGURE 3.11

Flagella and Cilia. Cilia and flagella are extensions of the plasma membrane of many cells.

## Summary

- The plasma membrane has many proteins that assist other substances in crossing the membrane.
- The Fluid Mosaic Model depicts the biological nature of the plasma membrane.
- Cilia and flagella are extensions of the plasma membrane.

## Practice

Use these resources to answer the questions that follow.

- **Cell Membranes** at http://johnkyrk.com/cellmembrane.html .

1. What is the major role of many membrane proteins?

2. How much of a cell's genetic material may code for membrane proteins?
3. What are transmembrane proteins, and what is their main function?
4. How can a protein "tunnel" form through the membrane?
5. How can a protein "channel" form through the membrane?

- **Construction of the Cell Membrane** at http://www.wisc-online.com/Objects/ViewObject.aspx?ID=AP1101 .

1. How may water molecules enter the cell?
2. How may ions enter the cell?
3. What type(s) of protein(s) identify the cell?

- http://www.hippocampus.org/Biology → Biology for AP* → Search: **Membrane Structure**

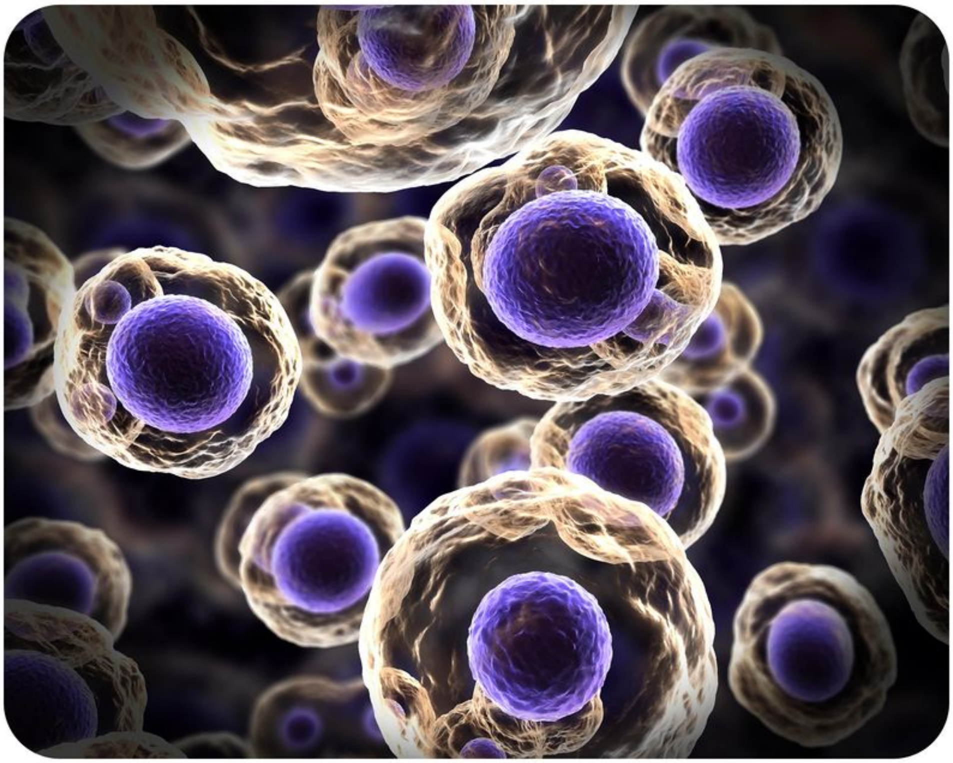
1. Why do phospholipid molecules form a double layer in the membrane?
2. What is the function of cholesterol in the membrane?
3. What is the difference between integral and peripheral membrane proteins?
4. Describe the main features of the fluid mosaic model.
5. What is a transmembrane protein? Explain how are they oriented in the membrane.
6. How do bacterial $\alpha$-toxin proteins damage membranes?
7. What happens when cells can no longer control the movement of materials across their membrane?

## Review

1. What is the main difference between the two main types of proteins associated with the plasma membrane?
2. What are two functions of integral membrane proteins?
3. Discuss the Fluid Mosaic Model.
4. What are flagella and cilia?

# 3.7 Cell Nucleus

- Outline the form and function of the nucleus.
- Summarize the structure and function of the nuclear envelope.
- Explain the role of the nucleolus.



**Where does the DNA live?**

The answer depends on if the cell is prokaryotic or eukaryotic. The main difference between the two types of cells is the presence of a nucleus. And in eukaryotic cells, DNA lives in the nucleus.

## The Nucleus

The **nucleus** is a membrane-enclosed organelle found in most eukaryotic cells. The nucleus is the largest organelle in the cell and contains most of the cell's genetic information (mitochondria also contain DNA, called mitochondrial DNA, but it makes up just a small percentage of the cell's overall DNA content). The genetic information, which contains the information for the structure and function of the organism, is found encoded in DNA in the form of genes. A **gene** is a short segment of DNA that contains information to encode an RNA molecule or a protein strand. DNA in the nucleus is organized in long linear strands that are attached to different proteins. These proteins help the DNA coil up for better storage in the nucleus. Think how a string gets tightly coiled up if you twist one end while holding the other end. These long strands of coiled-up DNA and proteins are called **chromosomes.** Each chromosome contains many genes. The function of the nucleus is to maintain the integrity of these genes and to control the activities of the cell by regulating gene expression. **Gene expression** is the process by which the information in a gene is "decoded" by various cell molecules to produce a functional gene product, such as a protein molecule or an RNA molecule.

The degree of DNA coiling determines whether the chromosome strands are short and thick or long and thin. Between cell divisions, the DNA in chromosomes is more loosely coiled and forms long, thin strands called **chromatin**. Before the cell divides, the chromatin coil up more tightly and form chromosomes. Only chromosomes stain clearly enough to be seen under a microscope. The word chromosome comes from the Greek word *chroma* (color), and *soma* (body), due to its ability to be stained strongly by dyes.

### The Nuclear Envelope

The **nuclear envelope** is a double membrane of the nucleus that encloses the genetic material. It separates the contents of the nucleus from the cytoplasm. The nuclear envelope is made of two lipid bilayers, an inner membrane and an outer membrane. The outer membrane is continuous with the rough endoplasmic reticulum. Many tiny holes called **nuclear pores** are found in the nuclear envelope. These nuclear pores help to regulate the exchange of materials (such as RNA and proteins) between the nucleus and the cytoplasm.

### The Nucleolus

The nucleus of many cells also contains a non-membrane bound organelle called a **nucleolus**, shown in **Figure** 3.12. The nucleolus is mainly involved in the assembly of ribosomes. **Ribosomes** are organelles made of protein and ribosomal RNA (rRNA), and they build cellular proteins in the cytoplasm. The function of the rRNA is to provide a way of decoding the genetic messages within another type of RNA (called mRNA), into amino acids. After being made in the nucleolus, ribosomes are exported to the cytoplasm, where they direct protein synthesis.

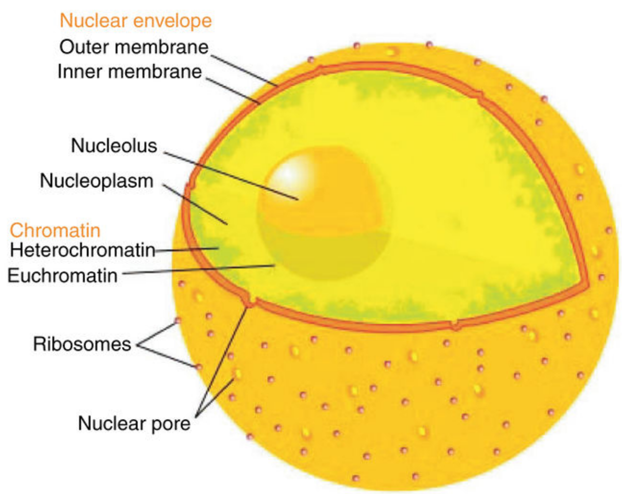



FIGURE 3.12

The eukaryotic cell nucleus. Visible in this diagram are the ribosome-studded double membranes of the nuclear envelope, the DNA (as chromatin), and the nucleolus. Within the cell nucleus is a viscous liquid called nucleoplasm, similar to the cytoplasm found outside the nucleus. The chromatin (which is normally invisible), is visible in this figure only to show that it is spread throughout the nucleus.

### Summary

- The nucleus is a membrane-enclosed organelle, found in most eukaryotic cells, which stores the genetic material (DNA).

- The nucleus is surrounded by a double lipid bilayer, the nuclear envelope, which is embedded with nuclear pores.
- The nucleolus is inside the nucleus, and is where ribosomes are made.

## Practice

Use this resource to answer the questions that follow.

- http://www.hippocampus.org/Biology → Biology for AP* → Search: **Cellular Organelles**

1. How big is a typical nucleus?
2. Describe the structure and role of the nuclear envelope.
3. What is a nuclear pore?
4. What is chromatin?
5. What is the difference between nucleoplasm and cytoplasm?
6. What occurs in the nucleolus?

## Review

1. What is the role of the nucleus of a eukaryotic cell?
2. Describe the nuclear membrane.
3. What are nuclear pores?
4. What is the role of the nucleolus?

# 3.8 Ribosomes and Mitochondria

- Explain the structure and function of the ribosome.
- Summarize the structure and function of mitochondria.

**Sperm cells and muscle cells need lots of energy. What do they have in common?**

They have lots of mitochondria. Mitochondria are called the power plants of the cell, as these organelles are where most of the cell's energy is produced. Cells that need lots of energy have lots of mitochondria.

## Other Organelles

In addition to the nucleus, eukaryotic cells have many other organelles, including ribosomes and mitochondria. Ribosomes are present in all cells.

### Ribosomes

**Ribosomes** are small organelles and are the sites of protein synthesis (or assembly). They are made of ribosomal protein and ribosomal RNA, and are found in both eukaryotic and prokaryotic cells. Unlike other organelles, ribosomes are not surrounded by a membrane. Each ribosome has two parts, a large and a small subunit, as shown in **Figure** 3.13. The subunits are attached to one another. Ribosomes can be found alone or in groups within the cytoplasm. Some ribosomes are attached to the endoplasmic reticulum (ER) (as shown in **Figure** 3.14), and others are attached to the nuclear envelope.

**Ribozymes** are RNA molecules that catalyze chemical reactions, such as translation. **Translation** is the process of ordering the amino acids in the assembly of a protein, and translation will be discussed more in another concept.

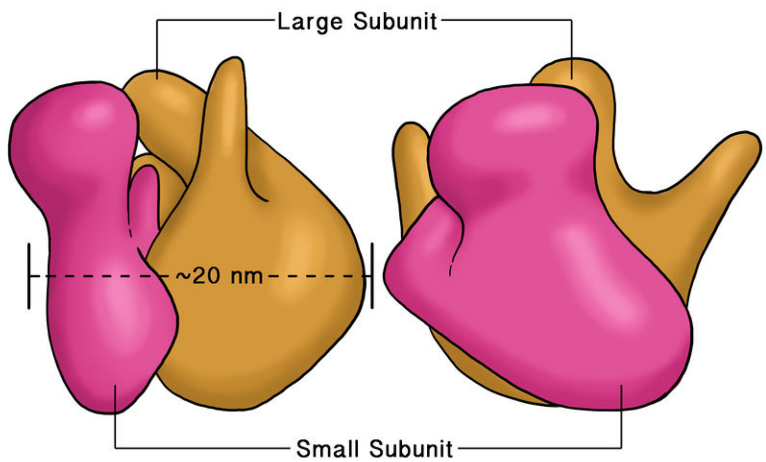



FIGURE 3.13
The two subunits that make up a ribosome, small organelles that are intercellular protein factories.

Briefly, the ribosomes interact with other RNA molecules to make chains of amino acids called polypeptide chains, due to the peptide bond that forms between individual amino acids. Polypeptide chains are built from the genetic instructions held within a messenger RNA (mRNA) molecule. Polypeptide chains that are made on the rough ER (discussed below) are inserted directly into the ER and then are transported to their various cellular destinations. Ribosomes on the rough ER usually produce proteins that are destined for the cell membrane.

Ribosomes are found in both eukaryotic and prokaryotic cells. Ribosomes are not surrounded by a membrane. The other organelles found in eukaryotic cells are surrounded by a membrane.

### Mitochondria

A mitochondrion ( **mitochondria**, plural), is a membrane-enclosed organelle that is found in most eukaryotic cells. Mitochondria are called the "power plants" of the cell because they are the sites of cellular respiration, where they use energy from organic compounds to make ATP (adenosine triphosphate). **ATP** is the cell's energy source that is used for such things such as movement and cell division. Some ATP is made in the cytosol of the cell, but most of it is made inside mitochondria. The number of mitochondria in a cell depends on the cell's energy needs. For example, active human muscle cells may have thousands of mitochondria, while less active red blood cells do not have any.

As **Figure** 3.14 **(a)** and **(b)** show, a mitochondrion has two phospholipid membranes. The smooth outer membrane separates the mitochondrion from the cytosol. The inner membrane has many folds, called **cristae**. The fluid-filled inside of the mitochondrion, called **matrix**, is where most of the cell's ATP is made.

Although most of a cell's DNA is contained in the cell nucleus, mitochondria have their own DNA. Mitochondria are able to reproduce asexually, and scientists think that they are descended from prokaryotes. According to the endosymbiotic theory, mitochondria were once free-living prokaryotes that infected ancient eukaryotic cells. The invading prokaryotes were protected inside the eukaryotic host cell, and in turn the prokaryote supplied extra ATP to its host.

### Summary

- Ribosomes are small organelles and are the site of protein synthesis. Ribosomes are found in all cells.
- Mitochondria are where energy from organic compounds is used to make ATP.

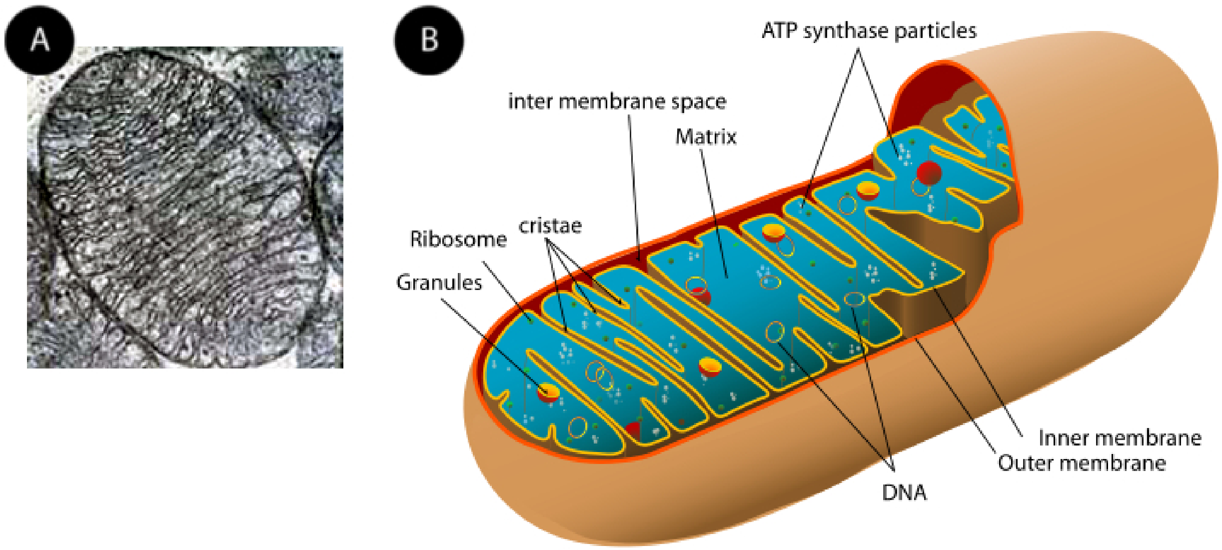



FIGURE 3.14
**(a):** Electron micrograph of a single mitochondrion, within which you can see many cristae. Mitochondria range from 1 to 10 $\mu$m in size. **(b):** This model of a mitochondrion shows the organized arrangement of the inner and outer membranes, the protein matrix, and the folded inner mitochondrial membranes.

## Practice

Use this resource to answer the questions that follow.

- http://www.hippocampus.org/Biology → Biology for AP* → Search: **Cellular Organelles**

1. What happens at the ribosome?
2. Describe the structure of a ribosome.
3. How many ribosomes could a cell have?
4. Where in the cell are ribosomes located?
5. Why is the mitochondrion referred to as the "power plant" of the cell?
6. Describe the structure of a mitochondrion. What is the cristae?
7. What is located in the mitochondrial matrix?
8. How many mitochondria does a typical liver cell have?

## Review

1. What is the function of a ribosome?
2. What is a significant difference between the structure of a ribosome and other organelles?
3. Identify the reason why mitochondria are called "power plants" of the cell.
4. Describe the structure of a mitochondrion.

# 3.9 Other Cell Organelles

- Summarize the structure and function of the endoplasmic reticulum.
- Distinguish rough ER from smooth ER.
- Explain the function of the Golgi apparatus.
- Define the roles of vesicles and vacuoles.
- Distinguish transport vesicles, from lysosomes, and from peroxisomes.
- Describe the function of centrioles.

**Does a cell have its own ER?**

Yes, but in this case, the ER is not just for emergencies. True, there might be times when the cell responds to emergency conditions and the functions of the ER may be needed, but usually the cell's ER is involved in normal functions. Proteins are also made on the outside of the ER, and this starts a whole process of protein transport, both around the inside of the cell and to the cell membrane and out.

## Other Organelles

In addition to the nucleus, eukaryotic cells have many other organelles, including the endoplasmic reticulum, Golgi apparatus, vesicles, vacuoles, and centrioles.

### Endoplasmic Reticulum

The **endoplasmic reticulum (ER)** (plural, reticuli) is a network of phospholipid membranes that form hollow tubes, flattened sheets, and round sacs. These flattened, hollow folds and sacs are called cisternae. The ER has two major functions:

- Transport: Molecules, such as proteins, can move from place to place inside the ER, much like on an intracellular highway.
- Synthesis: Ribosomes that are attached to ER, similar to unattached ribosomes, make proteins. Lipids are also produced in the ER.

There are two types of endoplasmic reticulum, rough endoplasmic reticulum (RER) and smooth endoplasmic reticulum (SER).

- **Rough endoplasmic reticulum** is studded with ribosomes, which gives it a "rough" appearance. These ribosomes make proteins that are then transported from the ER in small sacs called transport vesicles. The transport vesicles pinch off the ends of the ER. The rough endoplasmic reticulum works with the Golgi apparatus to move new proteins to their proper destinations in the cell. The membrane of the RER is continuous with the outer layer of the nuclear envelope.
- **Smooth endoplasmic reticulum** does not have any ribosomes attached to it, and so it has a smooth appearance. SER has many different functions, some of which include lipid synthesis, calcium ion storage, and drug detoxification. Smooth endoplasmic reticulum is found in both animal and plant cells and it serves different functions in each. The SER is made up of tubules and vesicles that branch out to form a network. In some cells there are dilated areas like the sacs of RER. Smooth endoplasmic reticulum and RER form an interconnected network.

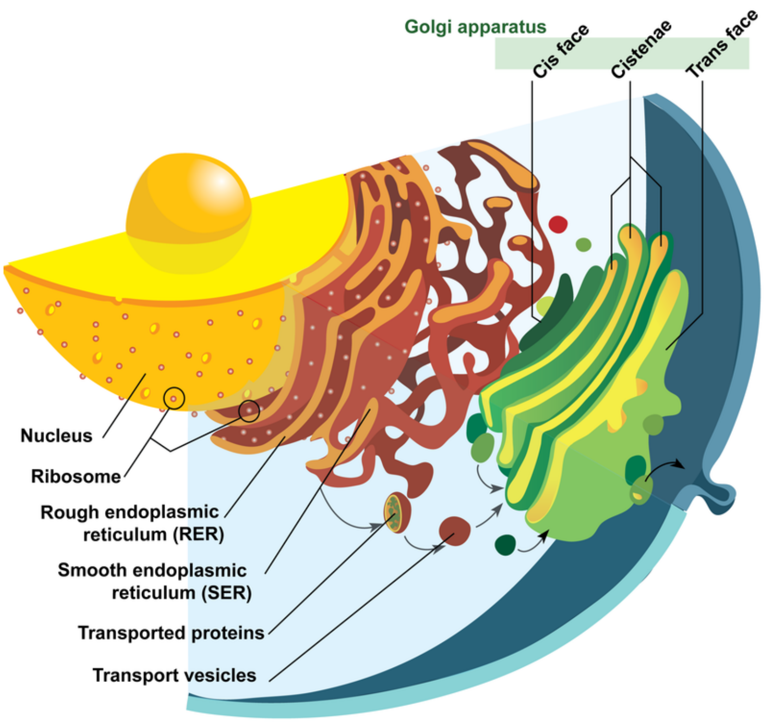



FIGURE 3.15

Image of nucleus, endoplasmic reticulum and Golgi apparatus, and how they work together. The process of secretion from endoplasmic reticuli to Golgi apparatus is shown.

## Golgi Apparatus

The **Golgi apparatus** is a large organelle that is usually made up of five to eight cup-shaped, membrane-covered discs called cisternae, as shown in **Figure** 3.15. The cisternae look a bit like a stack of deflated balloons. The Golgi apparatus modifies, sorts, and packages different substances for secretion out of the cell, or for use within the cell. The Golgi apparatus is found close to the nucleus of the cell, where it modifies proteins that have been delivered in transport vesicles from the RER. It is also involved in the transport of lipids around the cell. Pieces of the Golgi membrane pinch off to form vesicles that transport molecules around the cell. The Golgi apparatus can be thought of as similar to a post office; it packages and labels "items" and then sends them to different parts of the cell. Both plant and animal cells have a Golgi apparatus. Plant cells can have up to several hundred Golgi stacks scattered throughout the cytoplasm. In plants, the Golgi apparatus contains enzymes that synthesize some of the cell wall polysaccharides.

### Vesicles

A **vesicle** is a small, spherical compartment that is separated from the cytosol by at least one lipid bilayer. Many vesicles are made in the Golgi apparatus and the endoplasmic reticulum, or are made from parts of the cell membrane. Vesicles from the Golgi apparatus can be seen in **Figure** 3.15. Because it is separated from the cytosol, the space inside the vesicle can be made to be chemically different from the cytosol. Vesicles are basic tools of the cell for organizing metabolism, transport, and storage of molecules. Vesicles are also used as chemical reaction chambers. They can be classified by their contents and function.

- **Transport vesicles** are able to move molecules between locations inside the cell. For example, transport vesicles move proteins from the rough endoplasmic reticulum to the Golgi apparatus.
- **Lysosomes** are vesicles that are formed by the Golgi apparatus. They contain powerful enzymes that could break down (digest) the cell. Lysosomes break down harmful cell products, waste materials, and cellular debris and then force them out of the cell. They also digest invading organisms such as bacteria. Lysosomes also break down cells that are ready to die, a process called autolysis.
- **Peroxisomes** are vesicles that use oxygen to break down toxic substances in the cell. Unlike lysosomes, which are formed by the Golgi apparatus, peroxisomes self-replicate by growing bigger and then dividing. They are common in liver and kidney cells that break down harmful substances. Peroxisomes are named for the hydrogen peroxide ($H_2O_2$) that is produced when they break down organic compounds. Hydrogen peroxide is toxic, and in turn is broken down into water ($H_2O$) and oxygen ($O_2$) molecules.

### Vacuoles

**Vacuoles** are membrane-bound organelles that can have secretory, excretory, and storage functions. Many organisms will use vacuoles as storage areas and some plant cells have very large vacuoles. Vesicles are much smaller than vacuoles and function in transporting materials both within and to the outside of the cell.

### Centrioles

**Centrioles** are rod-like structures made of short microtubules. Nine groups of three microtubules make up each centriole. Two perpendicular centrioles make up the **centrosome**. Centrioles are very important in cellular division, where they arrange the mitotic spindles that pull the chromosome apart during mitosis.

## Summary

- The endoplasmic reticulum (ER) is involved in the synthesis of lipids and synthesis and transport of proteins.
- The Golgi apparatus modifies, sorts, and packages different substances for secretion out of the cell, or for use within the cell.
- Vesicles are also used as chemical reaction chambers. Transport vesicles, lysosomes, and peroxisomes are types of vesicles.
- Vacuoles have secretory, excretory, and storage functions.
- Centrioles are made of short microtubules and are very important in cell division.

## Practice

Use these resources to answer the questions that follow.

### Practice I

- http://www.hippocampus.org/Biology → Biology for AP* → Search: **Cellular Organelles**

1. Where in the cell are the endoplasmic reticulum and Golgi apparatus located?
2. What are the roles of the ER, the Golgi apparatus, and the lysosome?
3. How do proteins move from the ER to the Golgi apparatus?
4. Why do digestive enzymes have to be located in a lysosome and not the cytosol?
5. What is the main difference between a lysosome and a peroxisome?

### Practice II

- **Eucaryotic Cell Interactive Animation: Animal Cell** at http://www.cellsalive.com/cells/cell_model.htm .

### Review

1. List five organelles eukaryotes have that prokaryotes do not have.
2. Explain how the following organelles ensure that a cell has the proteins it needs: nucleus, rough ER, vesicles, and Golgi apparatus.
3. What is the main difference between rough endoplasmic reticulum and smooth endoplasmic reticulum?
4. Describe the three types of vesicles.

# 3.10 References


1. (a) Courtesy of the US Government; (b) Weerapong Prasongchean. Images of cytoskeleton and microfilaments. Public Domain
2. Dr. Ralf Wagner. Volvox algae colony. CC BY 3.0
3. The Evolution of Self-Fertile Hermaphroditism: The Fog Is Clearing. PLoS Biol 3(1): e30. doi:10.1371/journal.pbio.00300 Stained red nuclei in roundworm. CC BY 2.5
4. Mariana Ruiz Villarreal (User:LadyofHats/Wikimedia Commons). A diagram of a typical prokaryotic cell and its structure. Public Domain
5. Mariana Ruiz Villarreal (User:LadyofHats/Wikimedia Commons). A diagram of the parts of a typical eukaryotic cell. Public Domain
6. Mariana Ruiz Villarreal (User:LadyofHats/Wikimedia Commons). Organelles in a plant cell. Public Domain
7. User:HermannSchachner/Wikimedia Commons. Chloroplasts in plant cells. Public Domain
8. User:It'sJustMe/Wikipedia. Thylakoids and granum inside chloroplast. Public Domain
9. Mariana Ruiz Villarreal (LadyofHats) for the CK-12 Foundation. The phospholipid bilayer, the structure of the plasma membrane. CC BY-NC 3.0
10. Mariana Ruiz Villarreal (User:LadyofHats/Wikimedia Commons). Types of proteins contained in the plasma membrane. Public Domain
11. Flagella: Courtesy of Dr. Stan Erlandsen/Centers for Disease Control and Prevention (Image #11643); Cilia: Courtesy of Charles Daghlian. Flagella and cilia in the plasma membrane. Public Domain
12. Mariana Ruiz Villarreal (User:LadyofHats/Wikimedia Commons). Organelles in a cell. Public Domain
13. Laura Guerin. Subunits of a ribosome. CC BY-NC 3.0
14. (a) Courtesy of the National Institutes of Health; (b) Mariana Ruiz Villarreal (User:LadyofHats/Wikimedia Commons). Electron micrograph and illustration of a mitochondrion. Public Domain
15. Mariana Ruiz Villarreal (LadyofHats), modified for CK-12 Foundation. Nucleus, endoplasmic reticulum, and Golgi apparatus. Public Domain

# Concept 4 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?

## 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 3.1**).

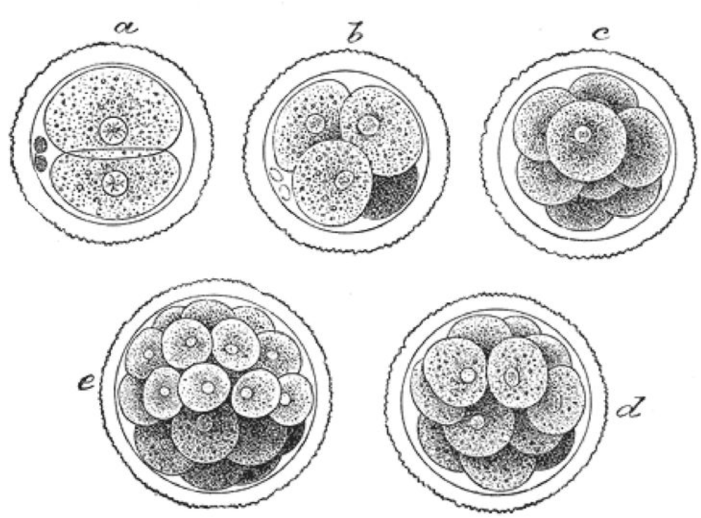



FIGURE 4.1

Figure 3.1 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 3.2**).

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

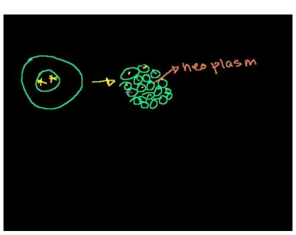
1. Interphase: The stage when the cell mostly performs its "everyday" functions. For example, it is when a kidney cell does what a kidney cell is supposed to do.
2. Mitosis: The stage when the cell prepares to become two cells.

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.
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.

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/user/khanacademy#p/c/7A9646BC5110CF64/11/RZhL7LDPk8w . (12:36).




MEDIA

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Assignment

While watching the video, answer the following questions in your SLJ. Answers are found in the wiki.

1. _________ is when a cell stops dividing when other cells are in the "neighborhood".

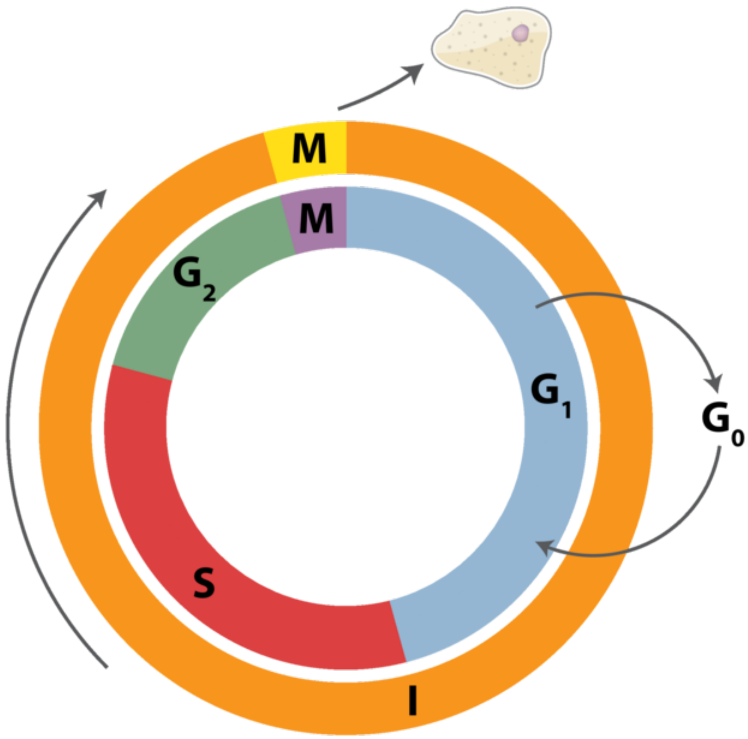



FIGURE 4.2
Figure 3.2 The cell cycle is the repeated process of growth and division. Notice that most of the cell cycle is spent in interphase (G1, S, and G2) (I). G0 is a resting state of the cell cycle.

2. A defective cell destroys itself to make way for healthy cells. This is called _________ .
3. The body makes approximately _________ new cells per day.
4. A body of cells with a defect has replicated. This is called a _________ or tumor.
5. If the tumor is not replicating out of control and not affecting the nearby environment, it is called _________ .
6. If the tubor has "super growth", is invasive, and breaks off and travels to other parts of the body, it has _________.
7. Another way to describe cancer is broken _________ .

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 3.3**.

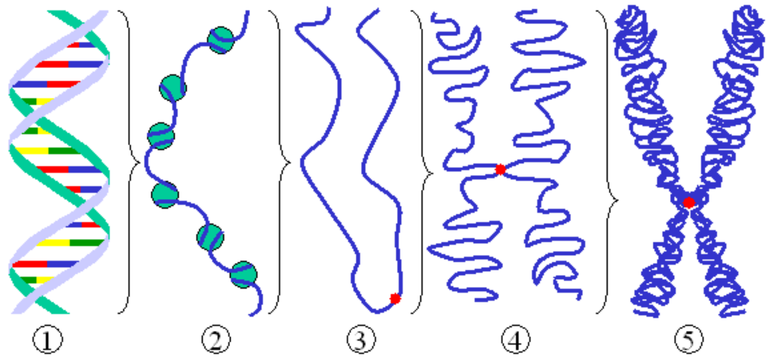



FIGURE 4.3

Figure 3.3 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 3.4**):

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.

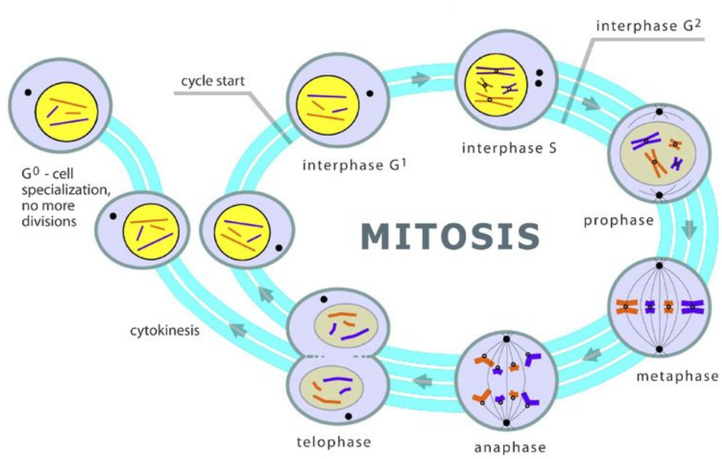


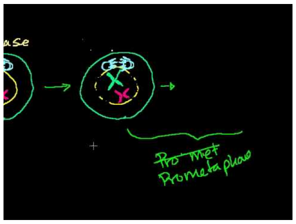

FIGURE 4.4

Figure 3.4 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.

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 3.5** is a representation of dividing plant cells.

The phases of mitosis are discussed in the video: http://www.youtube.com/user/khanacademy#p/c/7A9646BC5110CF64/8/LLKX_4DHE3I (20:42).

Assisgnment: Take notes while watching the video. Specifically, draw and label the illustrations in your SLJ. Colored pencils will be helpful.



MEDIA

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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&feature=related

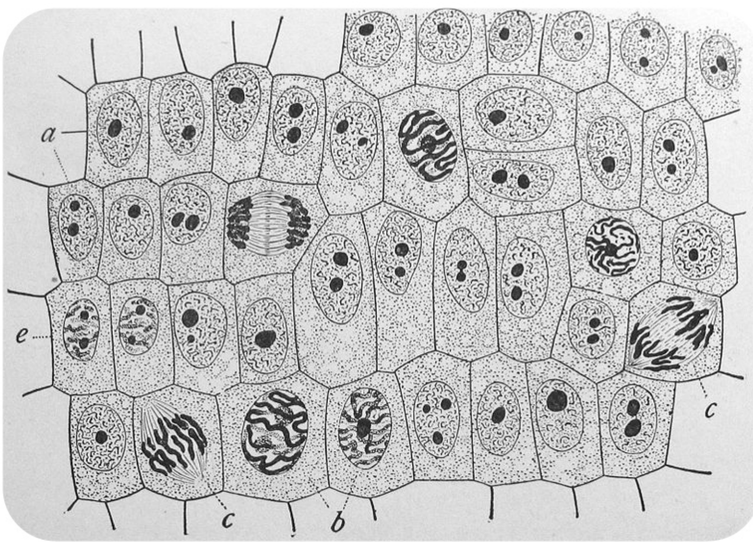
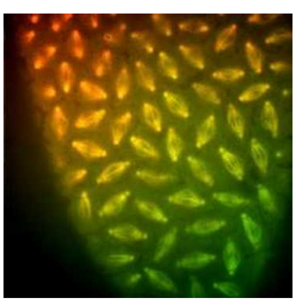



FIGURE 4.5

Figure 3.5 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&feature=related (0:19).



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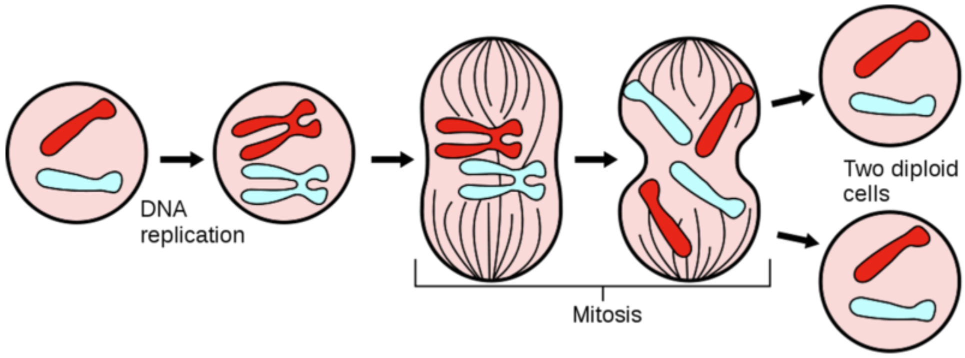
## Lesson Summary

- 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.




### Further Reading / Supplemental Links

- http://en.wikipedia.org/wiki/Mitosis
- http://www.biology.arizona.edu/Cell_bio/tutorials/cell_cycle/cells3.html
- http://biology.clc.uc.edu/courses/bio104/mitosis.htm
- http://en.wikipedia.org/wiki/Cell_cycle

### Points to Consider

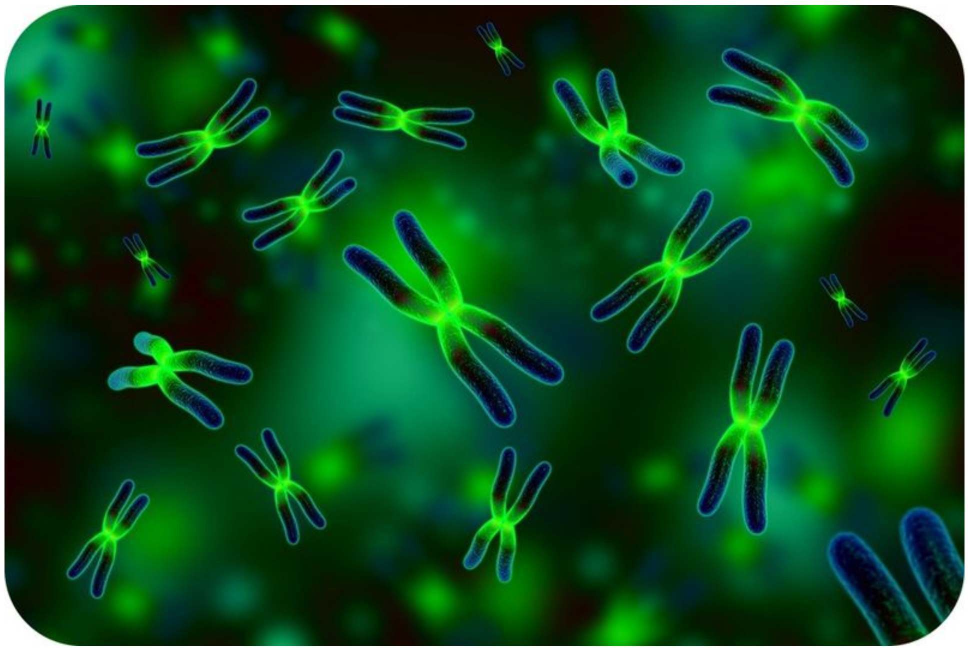
- There are many diseases due to mutations in the DNA. These are known as genetic disorders, and many can be passed onto the next generation. Can you name a genetic disorder?
- Your DNA contains the instructions to make you. So is everyone's DNA different? Can it be used to distinguish individuals, like a fingerprint?

## References

1. . http://commons.wikimedia.org/wiki/Image:Gray9.png . Public Domain
2. CK12. . CC-BY-SA 3.0
3. Magnus Manske. http://commons.wikimedia.org/wiki/Image:Chromatin_chromosome.png . GNU-FDL
4. Marek Kultys. http://commons.wikimedia.org/wiki/File:Mitosis_diagram.jpg . CC-BY-SA 3.0
5. Edmund Beecher Wilson. http://commons.wikimedia.org/wiki/Image:Wilson1900Fig2.jpg . Public Domain

# CONCEPT 5 Meiosis

- List the stages of meiosis and explain what happens in each stage.



**Do you have ALL your parents' chromosomes?**

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

## Introduction to Meiosis

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

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

### Haploid vs. Diploid

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

### Overview of Meiosis

Before meiosis begins, DNA replication occurs, so each chromosome contains two sister chromatids that are identical to the original chromosome. Meiosis ( **Figure** 5.1) is divided into two divisions: Meiosis I and Meiosis II. Each division can be divided into the same phases: prophase, metaphase, anaphase, and telophase. Cytokinesis follows telophase each time. Between the two cell divisions, DNA replication does not occur. Through this process, one diploid cell will divide into four haploid cells.

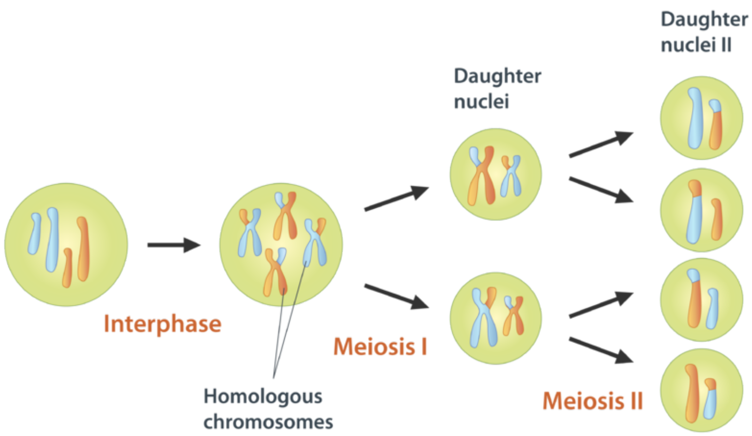



FIGURE 5.1
Overview of Meiosis. During meiosis, four haploid cells are created from one diploid parent cell.

### Meiosis I

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

1. Prophase I: The homologous chromosomes line up together. During this time, a process that only happens in meiosis can occur. This process is called **crossing-over** ( **Figure** 5.2), which is the exchange of DNA between homologous chromosomes. Crossing-over forms new combinations of alleles on the resulting chromosome. Without crossing-over, the offspring would always inherit all of the alleles on one of the homologous chromosomes. Also during prophase I, the **spindle** forms, the chromosomes condense as they coil up tightly, and the nuclear envelope disappears.
2. Metaphase I: The homologous chromosomes line up in their pairs in the middle of the cell. Chromosomes from the mother or from the father can each attach to either side of the spindle. Their attachment is random, so all of the chromosomes from the mother or father do not end up in the same gamete. The gamete will contain some chromosomes from the mother and some chromosomes from the father.
3. Anaphase I: The homologous chromosomes are separated as the spindle shortens, and begin to move to opposite sides of the cell.
4. Telophase I: The spindle fibers dissolves, but a new nuclear envelope does not need to form. This is because, after cytokinesis, the nucleus will immediately begin to divide again. No DNA replication occurs between meiosis I and meiosis II because the chromosomes are already duplicated. After cytokinesis, two haploid cells result, each with chromosomes made of sister chromatids.

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

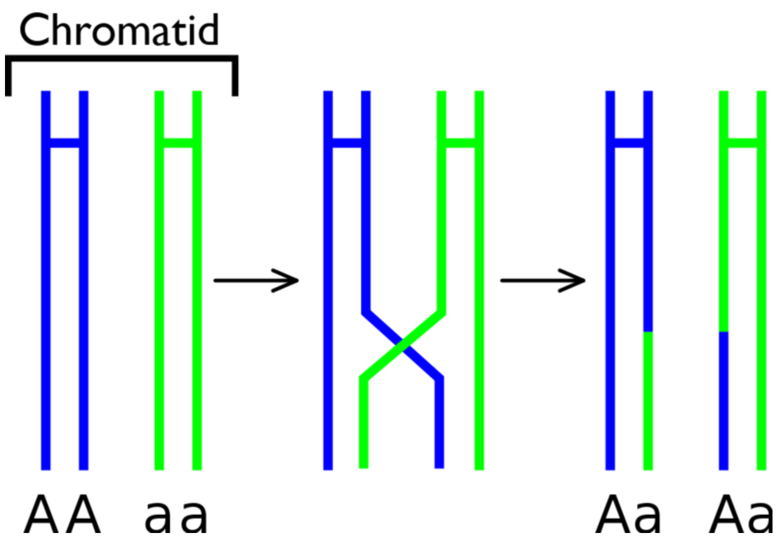



FIGURE 5.2
During crossing-over, segments of DNA are exchanged between non-sister chromatids of homologous chromosomes. Notice how this can result in an allele (A) on one chromosome being moved onto the other chromosome.

### Meiosis II

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

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

After cytokinesis, each cell has divided again. Therefore, meiosis results in four haploid genetically unique daughter cells, each with half the DNA of the parent cell ( **Figure** 5.3). In human cells, the parent cell has 46 chromosomes, so the cells produced by meiosis have 23 chromosomes. These cells will become gametes.

### Vocabulary

- **allele**: Alternate form of a gene.
- **crossing-over**: Exchange of DNA between homologous chromosomes that occurs during prophase I of meiosis.
- **diploid**: Having two sets of chromosomes; *2n*.
- **gamete**: Reproductive cell, such as sperm or egg.
- **haploid**: Having one set of chromosomes, as in sperm and egg; *n*.
- **homologous chromosomes**: Pair of chromosomes that have the same size and shape and contain the same genes, but different alleles.
- **meiosis**: Process of cell division during which the chromosome number is halved in order to produce gametes.
- **sexual reproduction**: Process of forming a new individual from two parents.
- **spindle**: Structure that helps separate the sister chromatids during mitosis; also separates homologous chromosomes during meiosis.

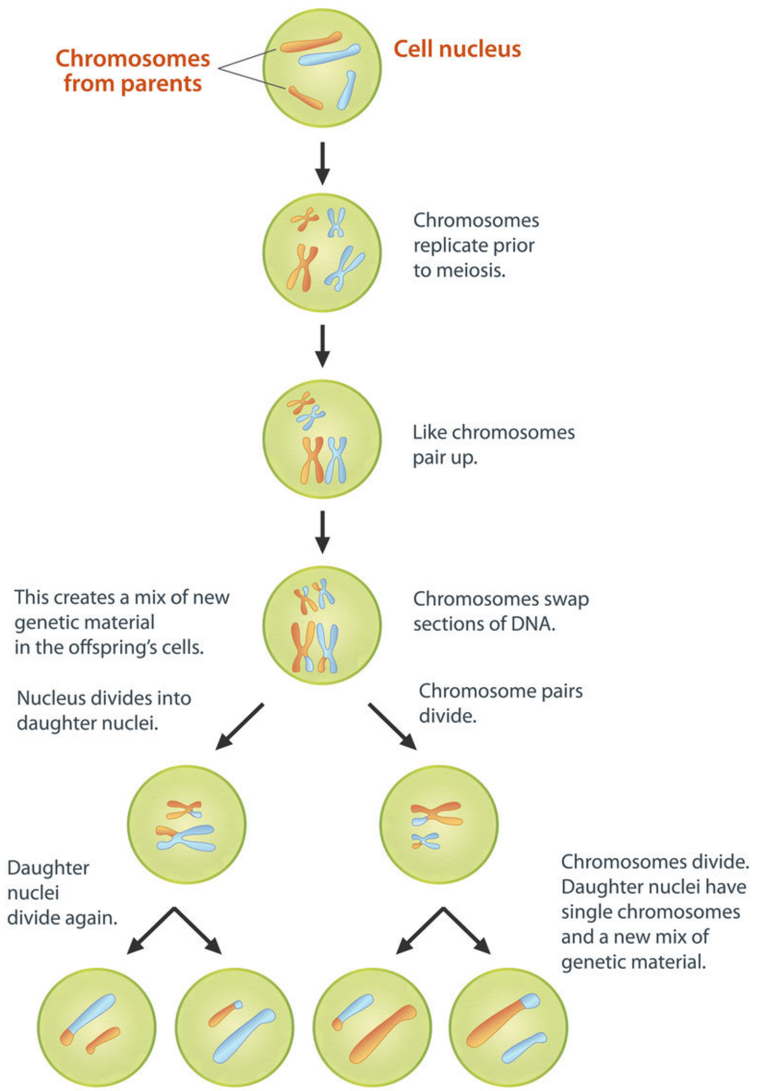



FIGURE 5.3
An overview of meiosis.

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

## Summary

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

## Practice

Use the resource below to answer the questions that follow.

- **Meiosis** on YouTube at http://www.youtube.com/watch?v=kVMb4Js99tA (2:58)

MEDIA

Click image to the left for use the URL below.

URL: http://www.ck12.org/flx/render/embeddedobject/57362

1. How does a diploid organism differ from a haploid organism?
2. When does recombination of chromatids occur? What effect does recombination of chromatids have on the diversity of offspring?
3. What happens during metaphase I of meiosis? How does this compare to the metaphase of mitosis?
4. What is the product of meiosis?

- **Identify meiosic phases** at http://www.neok12.com/quiz/CELDIV08

## Review

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

# References

1. CK-12 Foundation - Hana Zavadska. . CC-BY-NC-SA 3.0
2. Masur (Wikimedia). . Public Domain
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# CONCEPT 6 Earth's Composition

- Identify Earth's internal layers in two different ways.
- Describe the characteristics of Earth's layers.

Learning Objectives:

- Explain 2 ways scientists define the Earth's layers.
- Identify the five physical layers of the Earth.

FIGURE 6.1
Figure 1: Cross section of the Earth.

## Compositional Layers of the Earth

**As you look at the ground, you often see soil and rock and a variety of living things: plants, animals, and micro-organisms. However, if we could cut Earth open, we'd see the several distinct layers. In Figure 1, there appears to be 4 layers: inner core, outer core, mantle, and crust. Often people will combine the inner and outer core and just call it the core. This makes up the three compositional layers of the Earth.**

### The Crust

The crust is the outermost layer of the Earth. It can be 5 to 100 km thick depending on the location and surface features. As you can see in Figure 2 above, the areas where continents are located are much thicker than areas where there is ocean. Oceanic crust is typically more dense than continental crust due to the composition of the rock.

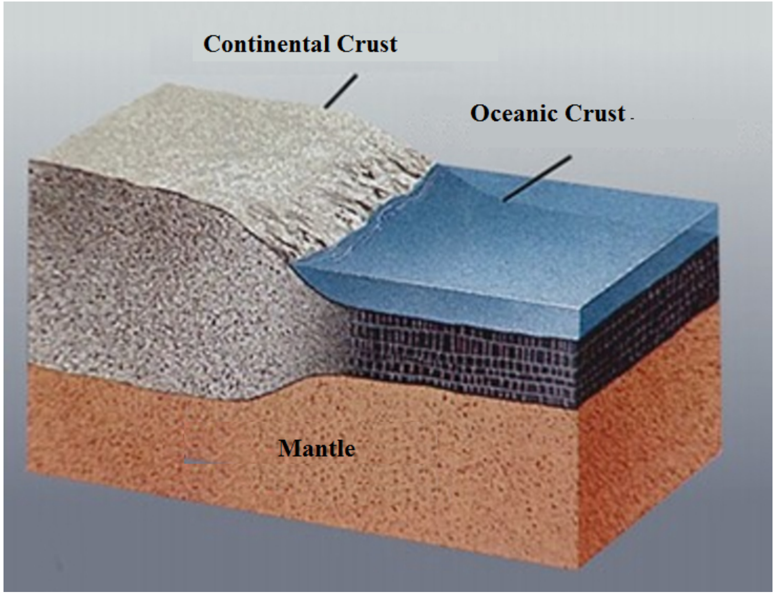



FIGURE 6.2
Figure 2

Continental crust usually ranges from 20-70 km thick. Oceanic crust usually ranges from 4-9 km thick. Most of the crust is composed of rock that is formed after molten rock has cooled. Despite these thicknesses, humans have never drilled all the way through the crust. The closest anyone has gotten was 1,415 m (1.4 km) into oceanic crust.

### The Mantle

As you saw in Figure 2 above, the mantle is below the crust. The approximate thickness of the mantle is 2,900 km. Even though we have never observed the mantle directly, scientists have been able to infer the composition of based on observations of volcanoes. It is in these locations that molten rock from the mantle flows to the surface. Scientists believe that the magma is composed of mostly iron and magnesium.

### The Core

The core is the innermost layer of the Earth. It is about 7,000km thick and goes all the way to the center of the earth. This layer is the most difficult to study since it cannot be reached. Scientists believe that the core is composed of mostly iron and nickel. They have used the data from how seismic waves (from earthquakes) travel through the core to determine this information.

## Layers by Physical Properties

Even though we've talked about the three compositional layers of the earth, scientists recognize a total of five physical layers as pictured below ( **Figure** 6.3 3).

The crust and upper part of the mantle comprises the **lithosphere** ( label 4 above). Because the average temperature of the lithosphere is about 0ºC, the material is brittle and solid. It is easily cracked or broken. The lithosphere is not able to flow or move easily, which is often what causes breaking to occur. The places where the lithosphere has broken, make up the boundaries of plates. These plates float atop the asthenosphere.

The **asthenosphere** (as THE nuh sfihr) makes up part of the upper mantle as well, and has an average temperature of 500ºC. While the lithosphere is solid and can't flow, the asthenosphere (label 5 above) is solid but can flow. Can

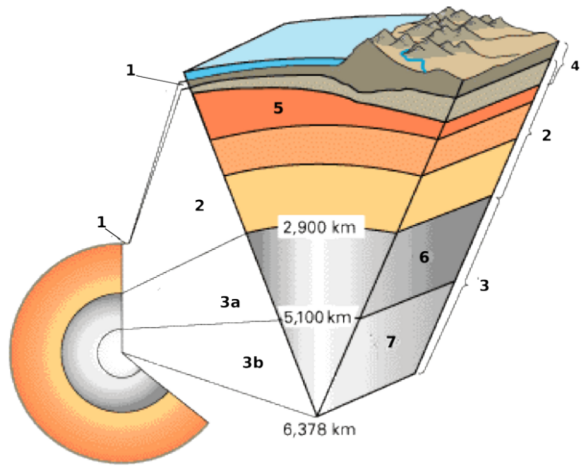



FIGURE 6.3

Figure 3: A cross section of Earth showing the following layers: (1) crust (2) mantle (3a) outer core (3b) inner core (4) lithosphere (5) asthenosphere (6) outer core (7) inner core.

you think of a solid that can flow? Consider toothpaste, silly putty, or hot plastic that hasn't melted. The plastic is really easy to bend, and the silly putty will take the shape of its container over time. Because of this property, the asthenosphere is classified differently than the lithosphere.

The lower mantle is also known as the **mesophere**. The average temperature of this layer is about 2000ºC. It is the bottom portion of the mantle that isn't included in the lithosphere or asthenosphere. The temperature of the mesosphere is significantly higher than that of the asthenosphere. Despite these higher temperatures, the mesophere is still solid because of the intense pressure from the weight of the earth.

The core is made up of the inner and the outer core. The outer core of the Earth is liquid iron and nickel. Scientists believe that this liquid outer core is responsible for Earth's magnetic field. The average temperature of the outer core is 5000ºC, which is definitely hot enough to melt iron and nickel.

The inner core is mostly made of iron. The extremely high temperatures (7000ºC) of the inner core would normally melt the metal, but it is under extreme pressure which prevents the molecules from moving much, causing it to remain solidified.

This animation shows the layers by composition and by mechanical properties: http://earthguide.ucsd.edu/eoc/teachers/t_tectonics/p_layers.html .

## Vocabulary

- **asthenosphere**: Layer below the lithosphere, made of a portion of the upper mantle; the asthenosphere can flow.
- **core**: Innermost, densest layer of a celestial body.
- **crust**: Rocky outer layer of the Earth's surface.
- **lithosphere**: Layer of solid, brittle rock that makes up the Earth's surface.
- **mantle**: Middle layer of the Earth; made of hot rock.
- **Mesosphere:** the lower portion of the mantle, between the asthenosphere and the outer core

## Summary

- By composition, Earth is divided into core, mantle, and crust.
- By physical properties, the crust and upper mantle are divided into lithosphere and asthenosphere with the mesosphere and outer core and inner core.

### Practice

Use the resource below to answer the questions that follow.

- **NASA SCI Files-Layers of the Earth** at http://www.youtube.com/watch?v=BnpF0ndXk-8 (3:51)

MEDIA

Click image to the left for use the URL below.

URL: http://www.ck12.org/flx/render/embeddedobject/58890

1. What is the core?
2. Explain the core's structure.
3. What is the mantle?
4. What is the crust?
5. Why does the Earth have layers?

### Review

1. What are the the layers of Earth based on composition. Where are they located?
2. What is the composition of the different layers?
3. How do the lithosphere and asthenosphere differ from each other?
4. Create a concept map using the following terms: crust, mantle, core, lithosphere, asthenosphere, mesosphere, outer core, inner core.

## References

1. . . CC BY-NC-SA
2. . . CC BY-NC-SA
3. Courtesy of the US Geological Survey. . Public Domain

# CONCEPT 7 Using Earth's Magnetic Field

- Describe Earth's magnetic field.
- Explain how Earth's magnetic field protects organisms from solar radiation.
- Describe how some animals use Earth's magnetic field for navigation.

You may recognize the eerie green glow in this cold northern sky as the northern lights, or aurora borealis. But do you know what causes the northern lights? Earth's magnetic field is a major factor.

## Earth's Magnetic Field

Like a bar magnet, planet Earth has north and south magnetic poles and a **magnetic field** over which it exerts magnetic force. Earth's magnetic field is called the magnetosphere. You can see it in the **Figure** 7.1.

## Like an Umbrella

The sun gives off radiation in solar winds. You can see solar winds in the model above. Notice what happens to solar winds when they reach the magnetosphere. They are deflected almost completely by Earth's magnetic field. Radiation in solar wind would wash over Earth and kill most living things were it not for the magnetosphere. It protects Earth's organisms from radiation like an umbrella protects you from rain.

**Q:** Now can you explain the northern lights?

**A:** Energetic particles in solar wind collide with atoms in the atmosphere over the poles, and energy is released in the form of light. The swirling patterns of light follow lines of magnetic force in the magnetosphere.

## Finding the Way

Another benefit of Earth's magnetic field is its use for navigation. People use compasses to detect Earth's magnetic north pole and tell direction. Many animals have natural "compasses" that work just as well. For example, the loggerhead turtles in the **Figure** 7.2 sense the direction and strength of Earth's magnetic field and use it to navigate

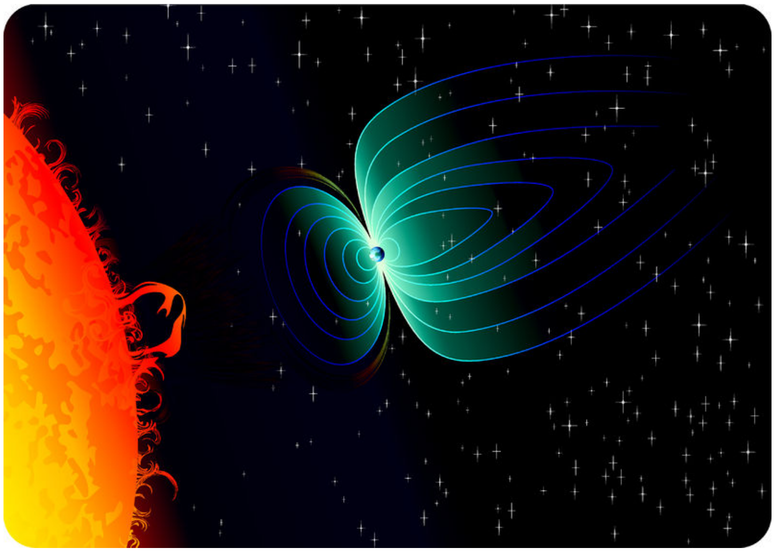


FIGURE 7.1

along migration routes. Many migratory bird species can also sense the magnetic field and use it for navigation. Recent research suggests that they may have structures in their eyes that let them see Earth's magnetic field as a visual pattern. You can learn more at this URL: http://www.smithsonianmag.com/science-nature/How-Do-Birds-Find-Their-Way-Home.html

**Q:** In the past, Earth's magnetic poles have switched places and reversed Earth's magnetic field. How might a magnetic reversal affect loggerhead turtle navigation?

**A:** You can find out at this URL: http://www.pbs.org/wgbh/nova/nature/magnetic-impact-on-animals.html

## Summary

- Earth has north and south magnetic poles and a magnetic field called the magnetosphere.
- The magnetosphere protects Earth's organisms from solar radiation.
- Some organisms—including humans with compasses—use Earth's magnetic field for navigation.

## Vocabulary

- **magnetic field**: Area around a magnet where it exerts magnetic force.

## Practice

At the following URL, explore the interaction between a compass and Earth's magnetic field. Move the compass around the planet and observe what happens to the needle. Also observe what happens to the compass when you flip polarity (in other words, when a magnetic field reversal occurs). Describe your observations.

http://phet.colorado.edu/en/simulation/magnet-and-compass

## Review

1. Make a sketch of Earth's magnetic field.
2. Explain the northern lights in terms of Earth's magnetic field.

FIGURE 7.2

3. How is a loggerhead turtle like a compass?

## References


1. daulon. . Used under license from Shutterstock.com
2. Benjamin Albiach Galan. . Used under license from Shutterstock.com

# Concept 8 Plate Tectonics

## Lesson Objectives

- Describe what a plate is and how scientists can recognize its edges.
- Explain how the plates move by convection in the mantle.
- Describe the three types of plate boundaries and the features of each type of boundary.
- Describe how plate tectonics processes lead to changes in Earth's surface features.

## Vocabulary

- continental rifting
- convergent plate boundary
- divergent plate boundary
- hotspot
- island arc
- plate
- plate boundary
- plate tectonics
- subduction
- transform fault
- transform plate boundary

## Introduction

The theory of plate tectonics explains most of the features of Earth's surface. Plate tectonics helps us to understand where and why mountains form. Using the theory, we know where new ocean floor will be created and where it will be destroyed. We know why earthquakes and volcanic eruptions happen where they do. We even can search for mineral resources using information about past plate motions. Plate tectonics is the key that unlocks many of the mysteries of our amazing planet.

## Earth's Tectonic Plates

What is the "plate" in plate tectonics? This question was answered due to war, in this case the Cold War.

Although seismographs had been around for decades, during the 1950s and especially in the early 1960s, scientists set up seismograph networks to see if enemy nations were testing atomic bombs. Seismographs record seismic waves. Modern seismographs are sensitive enough to detect nuclear explosions. While watching for enemy atom bomb tests, the seismographs were also recording all of the earthquakes that were taking place around the planet.

Earthquakes are not spread evenly around the planet, but are found mostly in certain regions. In the oceans, earthquakes are found along mid-ocean ridges and in and around deep sea trenches. Earthquakes are extremely common all around the Pacific Ocean basin and often occur near volcanoes. The intensity of earthquakes and volcanic eruptions around the Pacific led scientists to name this region the Pacific Ring of Fire ( **Figure 4.1**). Earthquakes are also common in the world's highest mountains, the Himalaya Mountains of Asia, and across the Mediterranean region.

Scientists noticed that the earthquake epicenters were located along the mid-ocean ridges, trenches and large faults that mark the edges of large slabs of Earth's lithosphere ( **Figure 4.2**). They named these large slabs of lithosphere

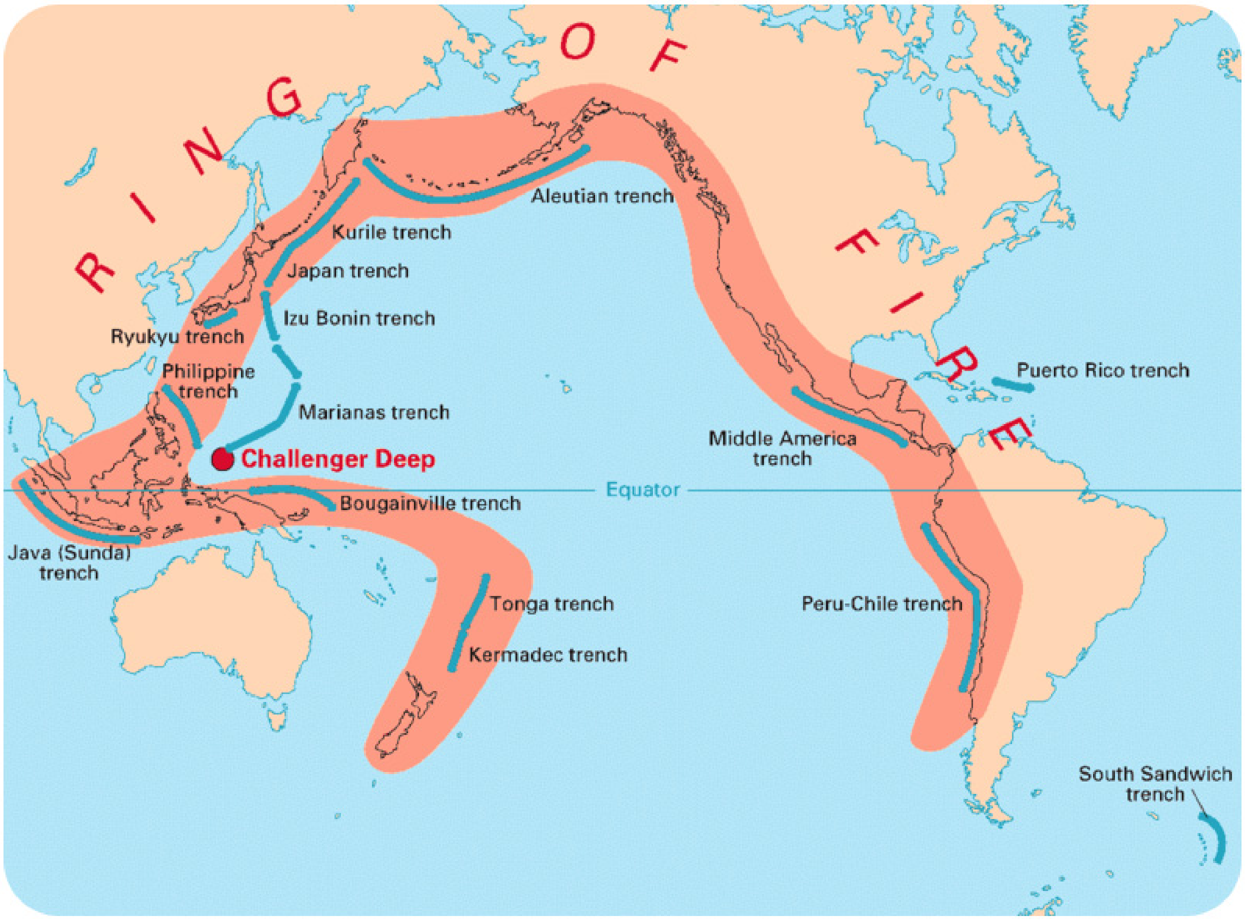



FIGURE 8.1

Figure 4.1 The bold pink swatch outlines the volcanoes and active earthquake areas found around the Pacific Ocean basin, which is called the Pacific Ring of Fire.

**plates**. The movements of the plates were then termed **plate tectonics**. A single plate can be made of all oceanic lithosphere or all continental lithosphere, but nearly all plates are made of a combination of both.

The lithosphere is divided into a dozen major and several minor plates. The plates' edges can be drawn by the connecting the dots that are earthquakes epicenters. Scientists have named each of the plates and have determined the direction that each is moving ( **Figure 4.3**). Plates move around the Earth's surface at a rate of a few centimeters a year, about the same rate fingernails grow.

### How Plates Move

Convection within the Earth's mantle causes the plates to move. At this point it would help to think of a convection cell as a rectangle or oval ( **Figure 4.4**). Each side of the rectangle is a limb of the cell. The convection cell is located in the mantle. The base is deep in the mantle and the top is near the crust. There is a limb of mantle material moving on one side of the rectangle, one limb moving horizontally across the top of the rectangle, one limb moving downward on the other side of the rectangle, and the final limb moving horizontally to where the material begins to move upward again.

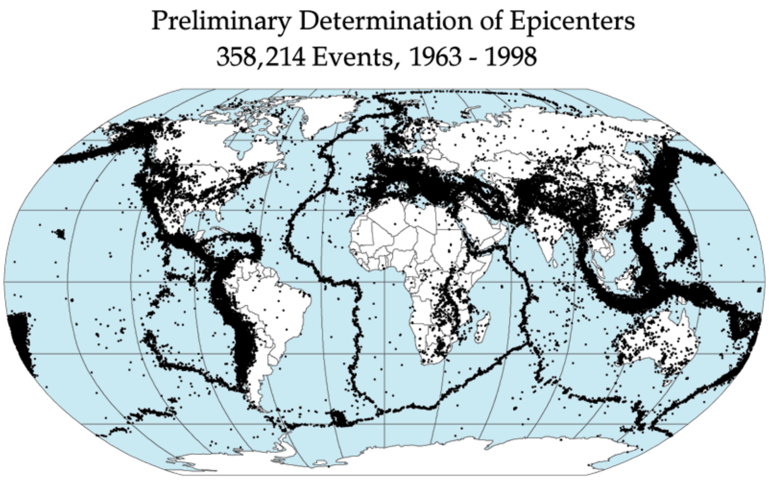



FIGURE 8.2

Figure 4.2 A map of earthquake epicenters shows that earthquakes are found primarily in lines that run up the edges of some continents, through the centers of some oceans, and in patches in some land areas.

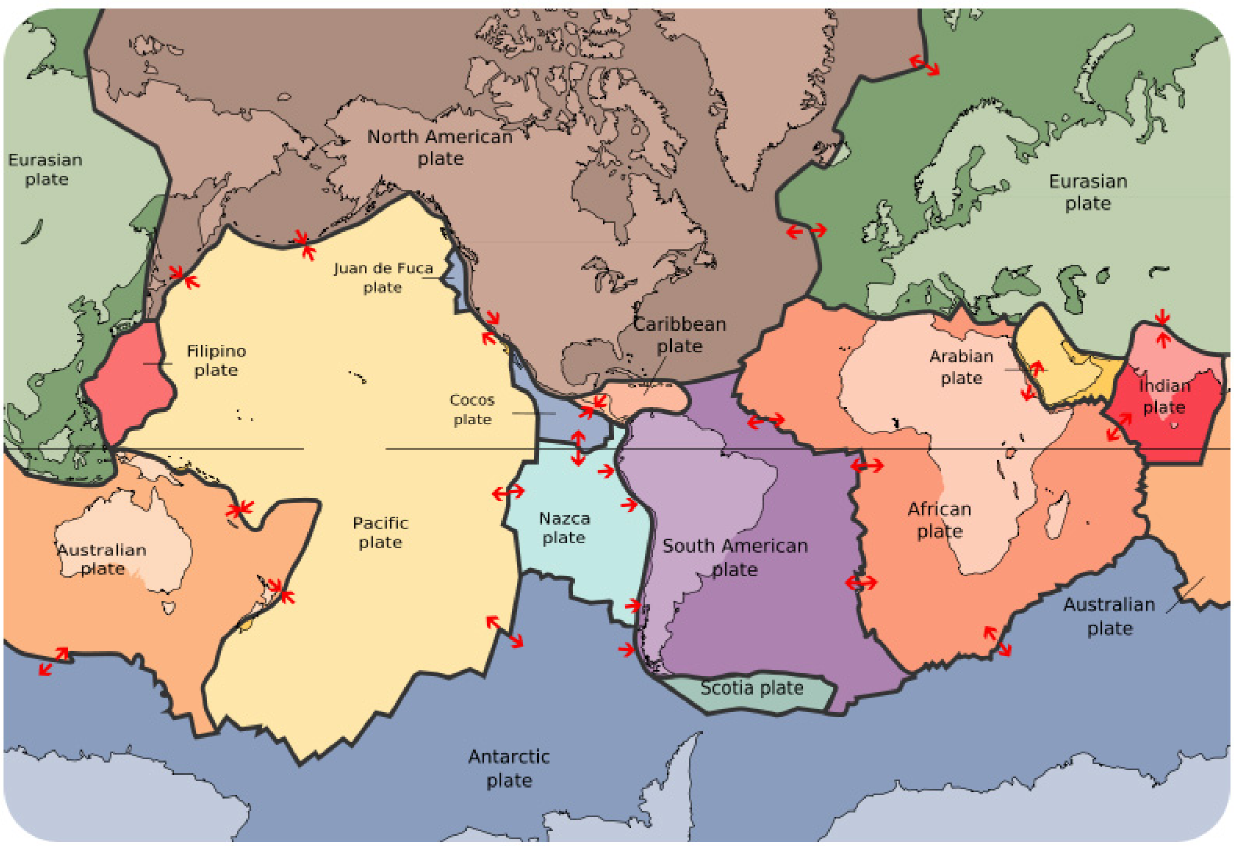



FIGURE 8.3

Figure 4.3 The lithospheric plates and their names. The arrows show whether the plates are moving apart, moving together, or sliding past each other.

Now picture two convection cells side-by-side in the mantle. The rising limbs of material from the two adjacent cells reach the base of the crust at the mid-ocean ridge. Some of the hot magma melts and creates new ocean crust. This seafloor moves off the axis of the mid-ocean ridge in both directions when still newer seafloor erupts. The oceanic plate moves outward due to the eruption of new oceanic crust at the mid-ocean ridge.

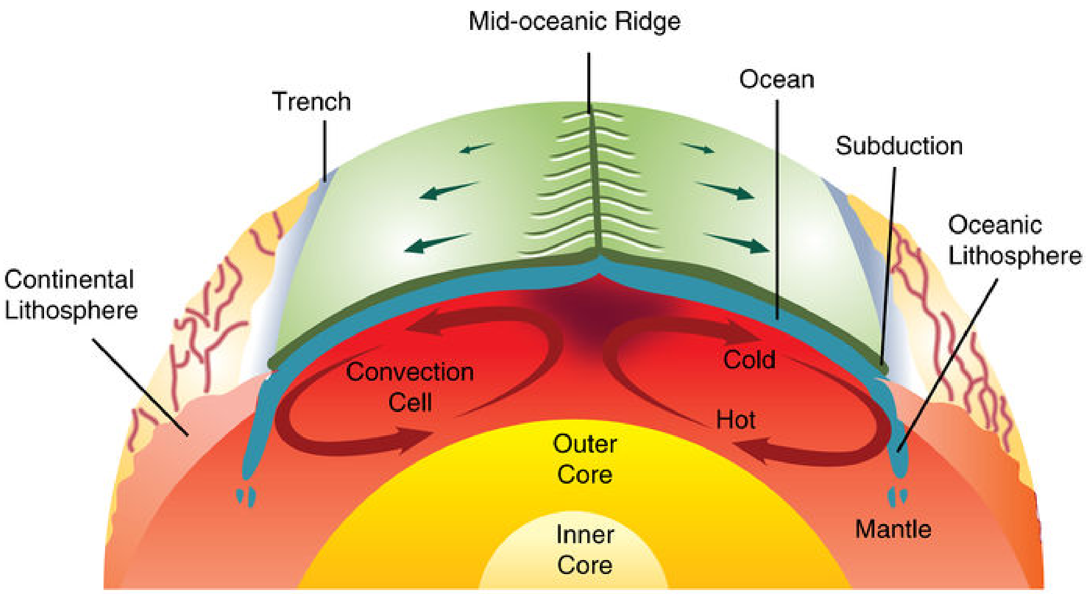



FIGURE 8.4

Figure 4.4 Convection in the mantle is the driving force of plate tectonics. Hot material rises at mid-ocean ridges and sinks at deep sea trenches, which keeps the plates moving along the Earth's surface.

Beneath the moving crust is the laterally moving top limb of the mantle convection cells. Each convection cell is moving seafloor away from the ridge in opposite directions. This horizontal mantle flow moves with the crust across the ocean basin and away from the ridge. As the material moves horizontally, the seafloor thickens and both the new crust and the mantle beneath it cool. Where the limbs of the convection cells plunge down into the deeper mantle, oceanic crust is dragged into the mantle as well. This takes place at the deep sea trenches. As the crust dives into the mantle its weight drags along the rest of the plate and pulls it downward. The last limbs of the convection cells flow along the core. The material is heated and so is ready to rise again when it reaches the rising limb of the convection cell. As you can see, each convection cell is found beneath a different lithospheric plate and is responsible for the movement of that plate.

## Plate Boundaries

Back at the planet's surface, the edges where two plates meet are known as **plate boundaries.** Most geologic activity, including volcanoes, earthquakes, and mountain building, takes place at plate boundaries where two enormous pieces of solid lithosphere interact.

Think about two cars moving around a parking lot. In what three ways can those cars move relative to each other? They can move away from each other, they can move toward each other, or they can drive past each other. These three types of relative motion also define the three types of plate boundaries:

- **Divergent plate boundaries:** the two plates move away from each other.
- **Convergent plate boundaries:** the two plates move towards each other.
- **Transform plate boundaries:** the two plates slip past each other.

What happens at plate boundaries depends on which direction the two plates are moving relative to each other. It also depends on whether the lithosphere on the two sides of the plate boundary is oceanic crust, continental crust, or one piece of each type. The type of plate boundary and the type of crust found on each side of the boundary determines what sort of geologic activity will be found there: earthquakes, volcanoes, or mountain building.

### Divergent Plate Boundaries

Plates move apart, or diverge, at mid-ocean ridges where seafloor spreading forms new oceanic crust. At these mid-ocean ridges, lava rises, erupts, and cools. Magma cools more slowly beneath the lava mostly forming the igneous intrusive rock gabbro. The entire ridge system, then, is igneous. Earthquakes are also common at mid-ocean ridges since the movement of magma and oceanic crust result in crustal shaking. Although the vast majority of mid-ocean ridges are located deep below the sea, we can see where the Mid-Atlantic Ridge surfaces at the volcanic island of Iceland ( **Figure 4.5**).

FIGURE 8.5

Figure 4.5 The Leif the Lucky Bridge straddles the Mid-Atlantic ridge separating the North American and Eurasian plates on Iceland.

Although it is uncommon, a divergent plate boundary can also occur within a continent. This is called **continental rifting** ( **Figure 4.6**). Magma rises beneath the continent, causing it to thin, break, and ultimately split up. As the continental crust breaks apart, oceanic crust erupts in the void. The East African Rift is currently splitting eastern Africa away from the African continent.

### Convergent Plate Boundaries

What happens when two plates converge depends on the types of crust that are colliding. Convergence can take place between two slabs of continental crust, two slabs of oceanic crust, or between one continental and one oceanic slab. Most often, when two plates collide, one or both are destroyed.

FIGURE 8.6

Figure 4.6 The Arabian, Indian, and African plates are rifting apart, forming the Great Rift Valley in Africa. The Dead Sea fills the rift with seawater.

When oceanic crust converges with continental crust, the denser oceanic plate plunges beneath the continental plate. This process occurs at the oceanic trenches and is called **subduction** ( **Figure 4.7**). The entire region is known as a subduction zone **.** Subduction zones have a lot of intense earthquakes and volcanic eruptions. The subducting plate causes melting in the mantle. The magma rises and erupts, creating volcanoes. These volcanoes are found in a line above the subducting plate. The movement of crust and magma causes earthquakes. The Andes Mountains, which line the western edge of South America, are a continental arc. The volcanoes are the result of the Nazca plate subducting beneath the South American plate ( **Figure 4.8**).

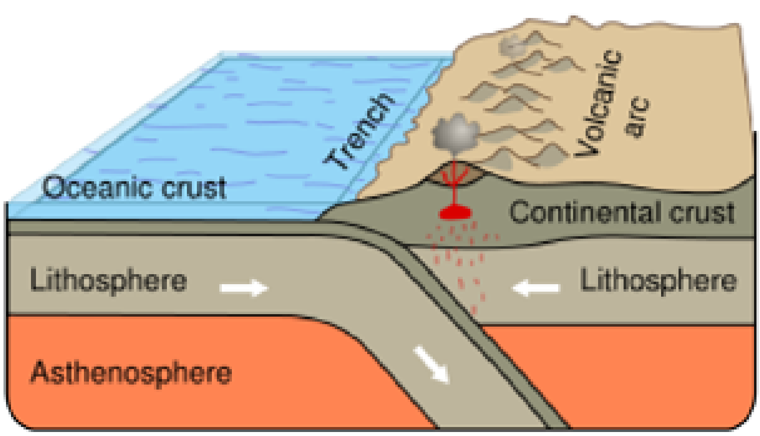



FIGURE 8.7

Figure 4.7 Subduction of an oceanic plate beneath a continental plate forms a line of volcanoes known as a continental arc and causes earthquakes.

The volcanoes of northeastern California—Lassen Peak, Mount Shasta, and Medicine Lake volcano—along with

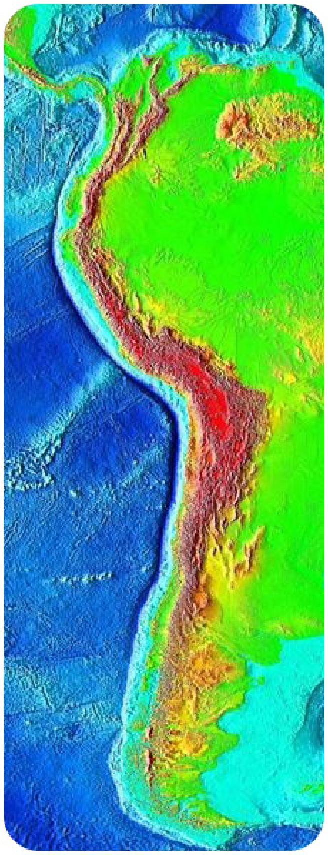


FIGURE 8.8

Figure 4.8 This satellite image shows the trench lining the western margin of South America where the Nazca plate is subducting beneath the South American plate. The resulting Andes Mountains line western South America and are seen as brown and red uplands in this image.

the rest of the Cascade Mountains of the Pacific Northwest, are the result of subduction of the Juan de Fuca plate beneath the North American plate ( **Figure 4.9**). Mount St. Helens, which erupted explosively on May 18, 1980, is the most famous and currently the most active of the Cascades volcanoes.

When two oceanic plates converge, the older, denser plate will sink beneath the other plate and plunge into the mantle. As the plate is pushed deeper into the mantle, it melts, which forms magma. As the magma rises it forms volcanoes in a line known as an **island arc**, which is a line of volcanic islands ( **Figure 4.10**).

The Japanese, Indonesian, and Philippine islands are examples of island arc volcanoes. The volcanic islands are set off from the mainland in an arc shape as seen in this satellite image of Japan ( **Figure 4.11**).

When two continental plates collide, they are too thick to subduct. Just like if you put your hands on two sides of a sheet of paper and bring your hands together, the material has nowhere to go but up ( **Figure 4.12**)! Some of the world's largest mountains ranges are created at continent-continent convergent plate boundaries. In these locations, the crust is too thick for magma to penetrate so there are no volcanoes, but there may be magma. Metamorphic rocks are common due to the stress the continental crust experiences. As you might think, with enormous slabs of crust smashing together, continent-continent collisions bring on numerous earthquakes.

The world's highest mountains, the Himalayas, are being created by a collision between the Indian and Eurasian plates ( **Figure 4.13**). The Appalachian Mountains are the remnants of a large mountain range that was created when North America collided into Eurasia.

A video on how the Rocky Mountains formed: (5:16) http://youtu.be/tJk9cFz152s

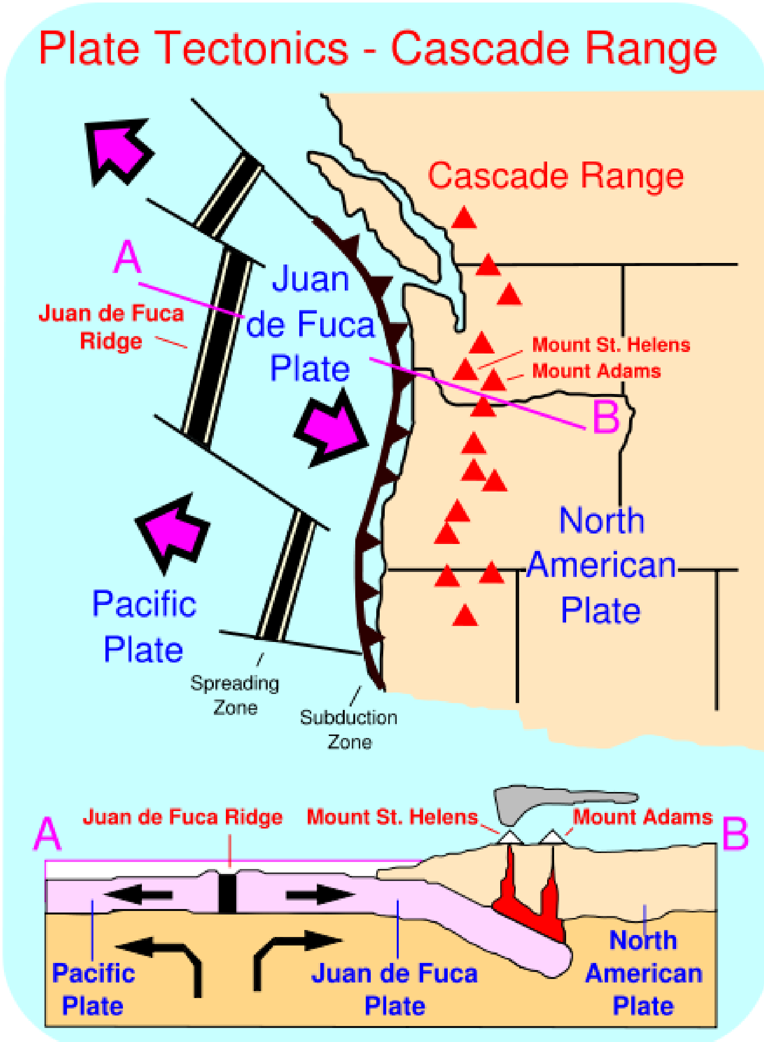



FIGURE 8.9

Figure 4.9 The Cascade Mountains of the Pacific Northwest are formed by the subduction of the Juan de Fuca plate beneath the North American plate. The Juan de Fuca plate forms near the shoreline at the Juan de Fuca ridge.

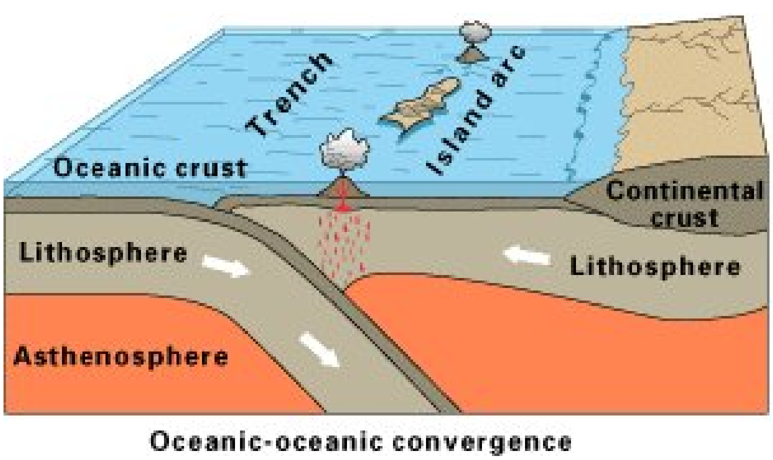



FIGURE 8.10

Figure 4.10 A convergent plate boundary subduction zone between two plates of oceanic lithosphere. Melting of the subducting plate causes volcanic activity and earthquakes.

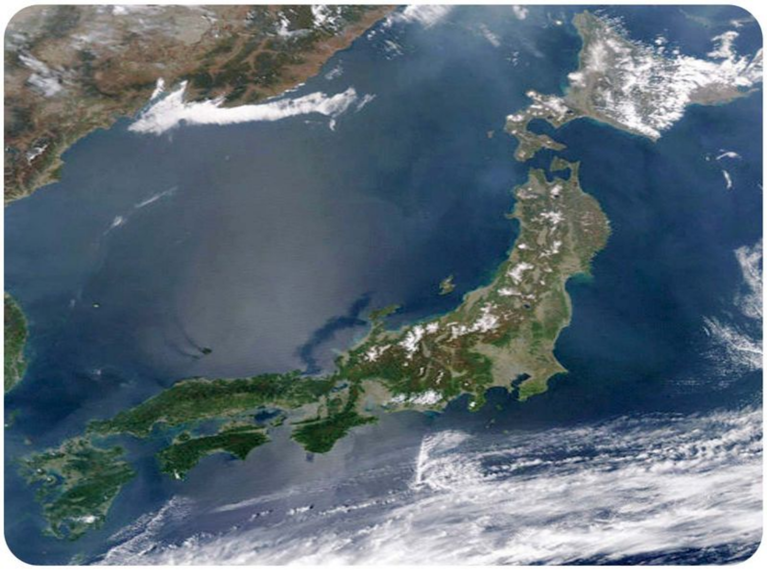


FIGURE 8.11
Figure 4.11 Japan is an island arc composed of volcanoes off the Asian mainland, as seen in this satellite image.

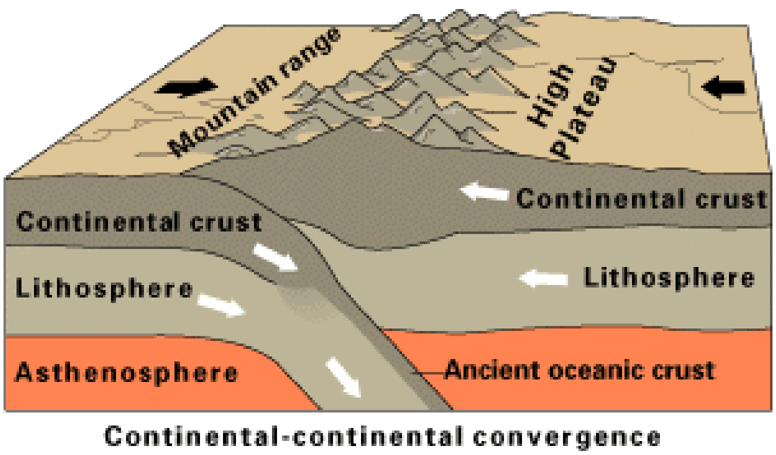
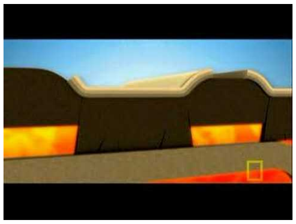



FIGURE 8.12
Figure 4.12 When two plates of continental crust collide, the material pushes upward forming a high mountain range. The remnants of subducted oceanic crust remain beneath the continental convergence zone.

FIGURE 8.13
Figure 4.13 The Himalaya Mountains are the result of the collision of the Indian Plate with the Eurasian Plate, seen in this photo from the International Space Station. The high peak in the center is world's tallest mountain, Mount Everest (8,848 meters; 29,035 feet).



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URL: http://www.ck12.org/flx/render/embeddedobject/104013

### Transform Plate Boundaries

Transform plate boundaries are seen as **transform faults.** At these earthquake faults, two plates move past each other in opposite directions. Where transform faults bisect continents, there are massive earthquakes. The world's most notorious transform fault is the 1,300 kilometer (800 mile) long San Andreas Fault in California ( **Figure 4.14**). This is where the Pacific and North American plates grind past each other, sometimes with disastrous consequences.

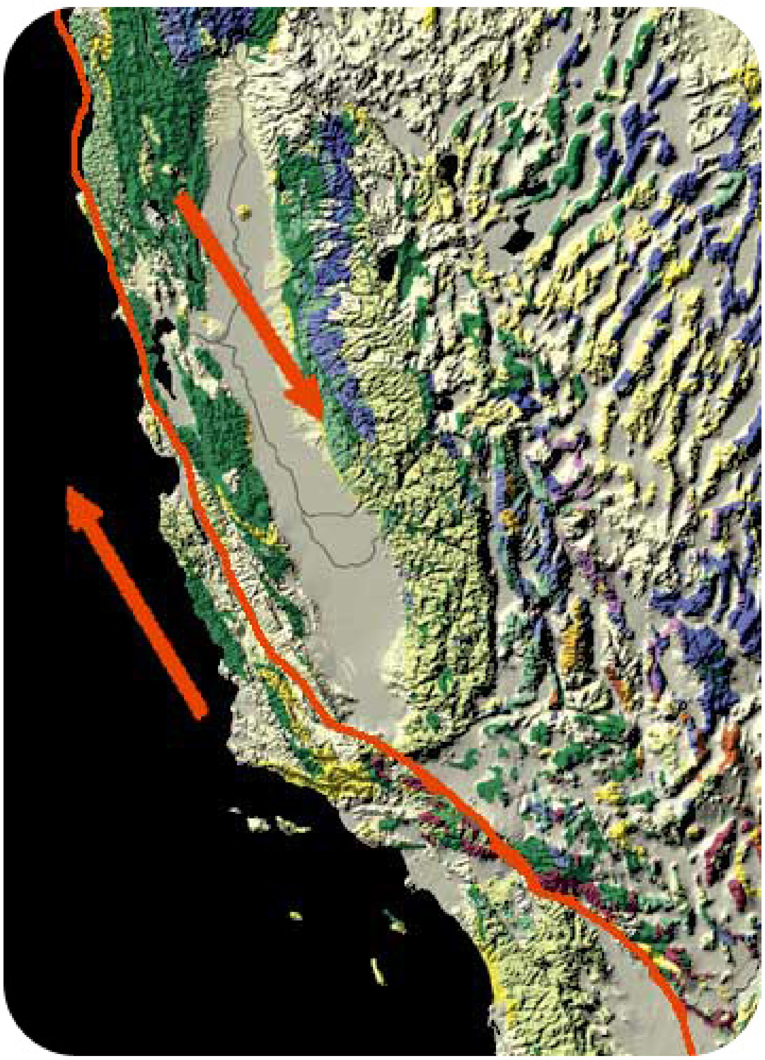

FIGURE 8.14

Figure 4.14 At the San Andreas Fault in California, the Pacific Plate is sliding northeast relative to the North American plate, which is moving southwest. At the northern end of the picture, the transform boundary turns into a subduction zone.

California is very geologically active. A transform plate boundary creates the San Andreas Fault. A convergent plate boundary between an oceanic plate and a continental plate creates the Cascades volcanoes. Just offshore, the Juan de Fuca ridge is subducting beneath the North American plate at a divergent plate boundary.

Two great interactive animations of plate boundaries: http://www.learner.org/interactives/dynamicearth/plate.html and http://www.learner.org/interactives/dynamicearth/slip2.html

### Intraplate Activity

While it is true that most geological activity takes place along plate boundaries, some is found away from the edges of plates. This is known as intraplate activity **.** Much of this intraplate activity is found at **hotspots**. Hotspot volcanoes form as plumes of hot magma rise from deep in the mantle.The most common intraplate volcanoes are above hotspots that lie beneath oceanic plates. Hotspot volcanoes arise because plumes of hot material that come from deep in the mantle rise through the overlying mantle and crust. When the magma reaches the plate above, it erupts, forming a volcano. Since the hotspot is stable, when the oceanic plate moves over it, and it erupts again, another volcano is created in line with the first. With time, there is a line of volcanoes; the youngest is directly above the hot spot and the oldest is furthest away. Recent research suggests that hotspots are not as stable as scientists once thought, but some larger ones still appear to be.

The Hawaiian Islands are a beautiful example of a chain of hotspot volcanoes. Kilauea volcano on the south side of the Big Island of Hawaii lies above the Hawaiian hot spot. The Big Island is on the southeastern end of the Hawaiian chain. Mauna Loa volcano, to the northwest, is older than Kilauea and is still erupting, but at a lower rate. Hawaii is the youngest island in the chain. As you follow the chain to the west, the islands get progressively older because they are further from the hotspot ( **Figure 4.15**).

A video on plate tectonics (2:05): http://science.discovery.com/tv-shows/greatest-discoveries/videos/100-greatest-discoveries-plate-tectonics.htm


MEDIA

Click image to the left for use the URL below.

### Lesson Summary

- Convection in the mantle drives the movement of the plates of lithosphere over the Earth's surface. New oceanic crust forms at the ridge and pushes the older seafloor away from the ridge horizontally.
- Plates interact at three different types of plate boundaries: divergent, convergent and transform fault boundaries, where most of the Earth's geologic activity takes place.
- These processes are responsible for the geographic features we see.

### Points to Consider

- On the map in Figure 4.3 above, the arrows show the directions that the plates are going. The Atlantic has a mid-ocean ridge, where seafloor spreading is taking place. The Pacific ocean has many deep sea trenches, where subduction is taking place. What is the future of the Atlantic plate? What is the future of the Pacific plate?
- Using your hands and words, explain to someone how plate tectonics works. Be sure you describe how continents drift and how seafloor spreading provides a mechanism for continental movement.
- Now that you know about plate tectonics, where do you think would be a safe place to live if you wanted to avoid volcanic eruptions and earthquakes?

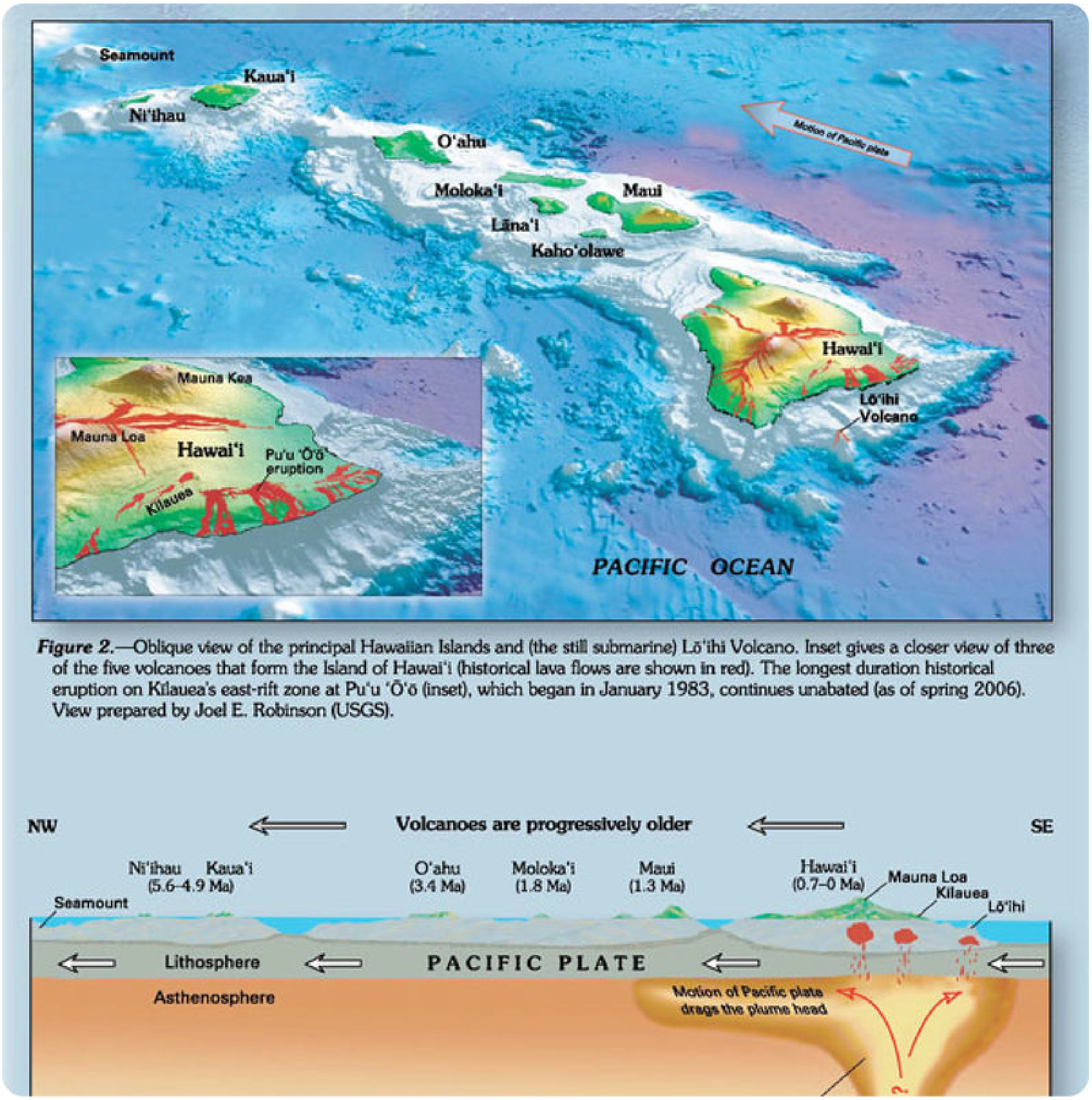


FIGURE 8.15

Figure 4.15 This view of the Hawaiian islands shows the youngest islands in the southeast and the oldest in the northwest. Kilauea volcano, which makes up the southeastern side of the Big Island of Hawaii, is located above the Hawaiian hotspot.

## References

1. . . GNU-FDL
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12. . . GNU-FDL
13. . . GNU-FDL
14. USGS. . Public Domain
15. USGS. . Public Domain

# CONCEPT 9 The Rock Cycle

- Explain the processes of the rock cycle.

**Is this what geologists mean by the rock cycle?**

Okay, maybe not. The rock cycle shows how any type of rock can become any other type of rock. The three rock types are joined together by the processes that change one to another.

## The Rock Cycle

All rocks can change. In fact, any rock can change to become any other type of rock. These changes usually happen very slowly. Some changes happen below Earth's surface. Some changes happen above ground. These changes are all part of the rock cycle. The **rock cycle** describes each of the main types of rocks, how they form, and how they change.

The figure below shows how the three main rock types are related to each other ( **Figure** 9.1). The arrows within the circle show how one type of rock may change to rock of another type. These are the processes that change one rock type to another rock type.

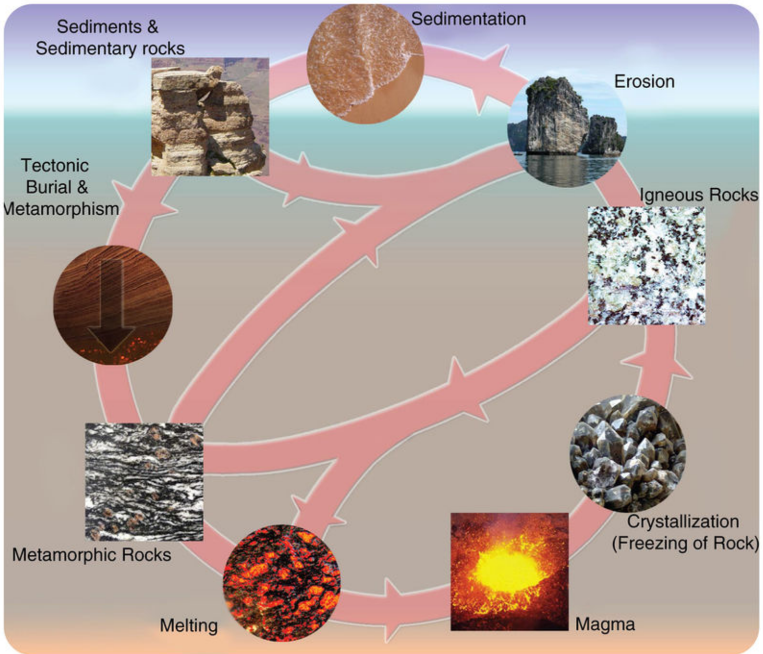


FIGURE 9.1
The Rock Cycle.

### Processes of the Rock Cycle

There are three main processes that can change rock:

- Cooling and crystallization. Deep within the Earth, temperatures can get hot enough to create magma. As magma cools, crystals grow, forming an igneous rock. The crystals grow larger if the magma cools slowly, as it does if it remains deep within the Earth. If the magma cools quickly, the crystals will be very small. When crystals form from magma it is called **crystallization**.

- Weathering and erosion. Water, wind, ice, and even plants and animals all act to wear down rocks. Over time they can break larger rocks into sediments. Rocks break down by the process called **weathering**. Moving water, wind, and glaciers then carry these pieces from one place to another. This is called **erosion**. The sediments are eventually dropped, or **deposited**, somewhere. This process is called **sedimentation**. The sediments may then be compacted and cemented together. This forms a sedimentary rock. This whole process can take hundreds or thousands of years.

- Metamorphism. This long word means "to change form." A rock undergoes metamorphism if it is exposed to extreme heat and pressure within the crust. With **metamorphism**, the rock does not melt all the way. The rock changes due to heat and pressure. A metamorphic rock may have a new mineral composition and/or texture.

An interactive rock cycle diagram can be found here: http://www.classzone.com/books/earth_science/terc/content/investigations/es0602/es0602page02.cfm?chapter_no=investigation

The rock cycle really has no beginning or end. It just continues. The processes involved in the rock cycle take place over hundreds, thousands, or even millions of years. Even though for us rocks are solid and unchanging, they slowly change all the time.

### Vocabulary

- **crystallization**: Formation of mineral grains from cooling magma.

- **erosion**: Transport of weathered materials and sediments by water, wind, ice, or gravity.
- **metamorphism**: Solid state change in an existing rock due to high temperature and/or pressure that creates a metamorphic rock.
- **sedimentation**: Dropping of sediments into a deposit.
- **weathering**: Chemical or physical breakdown of rocks, soils, or minerals at Earth's surface.

### Summary

- The three main rock types are igneous, metamorphic, and sedimentary.
- The three processes that change one rock to another are crystallization, metamorphism, and erosion and sedimentation.
- Any rock can transform into any other rock by passing through one or more of these processes. This creates the rock cycle.

### Practice

Use the resource below to answer the questions that follow.

- **The Rock Cycle in Depth** at

MEDIA
Click image to the left for use the URL below.
URL: http://www.ck12.org/flx/render/embeddedobject/1610

1. List 2 examples of igneous rocks.
2. List 2 examples of sedimentary rocks.
3. List 2 examples of metamorphic rocks.
4. Can an igneous rock become a sedimentary rock? Can a sedimentary rock become a metamorphic rock?
5. Draw an diagram of the rock cycle. Include the processes that transform rocks from one type to another.

### Review

1. What processes create igneous rocks?
2. What processes create metamorphic rocks?
3. What processes create sedimentary rocks?

## References

1. Woudloper/Woodwalker; modified by CK-12 Foundation. The Rock Cycle. Public Domain

# CONCEPT 10 Soil Formation

- Describe the factors that affect soil formation: weathering, climate, parent rock, slope, time and biological activity.

**How are these two soils different?**

What color is the soil on the left? What color is the soil on the right? Why do you think they differ so much in color? Which soil do you think is better for growing things? See below to find out!

## Soil Formation

How well soil forms and what type of soil forms depends on several different factors, which are described below.

- An animation of how weathering makes soil is found here: http://courses.soil.ncsu.edu/resources/soil_classification_genesis/mineral_weathering/mineral_weathering.swf .

Soil development takes a very long time. It may take hundreds or even thousands of years to form the fertile upper layer of soil. Soil scientists estimate that in the very best soil forming conditions, soil forms at a rate of about 1mm/year. In poor conditions, it may take thousands of years!

### Weathering

Soil formation requires weathering. Where there is less weathering, soils are thinner. However, soluble minerals may be present. Where there is intense weathering, soils may be thick. Minerals and nutrients would have been washed out.

### Climate

Climate is the most important factor determining soil type. Given enough time, a climate will produce a particular type of soil. The original rock type does not matter. Two rocks of the same type will form a different soil type in each different climate. This is true because most rocks on Earth are made of the same eight elements. When the rock breaks down to become soil, the soil is the same.

The same climate factors that lead to high weathering also produce more soil.

- More rain weathers minerals and rocks more. Rain allows chemical reactions especially in the top layers of the soil.
- More rain can dissolve more rock. More rain can carry away more material. As material is carried away, new surfaces are exposed. This also increases the rate of weathering.
- Higher temperatures increase the rate of chemical reactions. This also increases soil formation.
- In warmer regions, plants and bacteria grow faster. Plants and animals weather material and produce soils. In tropical regions, where temperature and precipitation are consistently high, thick soils form. Arid regions have thin soils.

Soil type also influences the type of vegetation that can grow in the region. We can identify climate types by the types of plants that grow there.

### Parent Rock

The original rock is the source of the inorganic portion of the soil. Mechanical weathering breaks rock into smaller pieces. Chemical reactions change the rock's minerals.

Soil may form in place or from material that has been moved.

- **Residual soil** forms in place. The underlying rock breaks down to form the layers of soil above it. Only about one-third of the soils in the United States are residual.
- **Transported soil** has come in from somewhere else. Sediments can be transported into an area by glaciers, wind, water, or gravity. Soils form from the loose particles that have been transported and deposited.

### Slope

Weathered material washes off steep slopes and so does not stay in place to form soil. Soil forms where land areas are flat or gently undulating.

### Time

Soils thicken as the amount of time available for weathering increases. The longer the amount of time that soil remains in a particular area, the thicker it will be.

### Biological Activity

Biological activity produces the organic material in soil. **Humus** forms from the remains of plants and animals. It is an extremely important part of the soil. Humus coats the mineral grains. It binds them together into clumps that hold the soil together. This gives the soil its structure. Soils with high humus are better able to hold water. Soils rich with organic materials hold nutrients better and are more fertile. These soils are more easily farmed.

The color of soil indicates its fertility. Black or dark brown soils are rich in nitrogen and contain a high percentage of organic materials. Soils that are nitrogen poor and low in organic material might be gray, yellow, or red ( **Figure** 10.1). Soil with low organic material is not good for growing plants.

- An animation of how different types of weathering affect different minerals in soil: http://courses.soil.ncsu.edu/resources/soil_classification_genesis/mineral_weathering/elemental_change.swf .

FIGURE 10.1
This sandy soil shows evidence of very little organic activity. Plants grow, but are far apart and short-lived. This means that little soil can form. The soil that's there has little organic content.

### Vocabulary

- **humus**: Partially decayed remains of plants and animals; forms the organic portion of soil.
- **residual soil**: Soil that forms from the bedrock upon which it lies.
- **transported soil**: Soil that forms from weathered components transported to a different area.

### Summary

- Many factors affect soil formation. Some are climate, rock type, slope, time, and biological activity. Differences in these factors may produce different types of soil.
- Soil type determines what can grow in a region.
- Humus is the decayed remains of living organisms. Humus makes soil fertile.

### Practice

Use the resource below to answer the questions that follow.

- **The Five Factors of Soil Formation** at http://www.youtube.com/watch?v=bTzslvAD1Es (9:28)

MEDIA
Click image to the left for use the URL below.
URL: http://www.ck12.org/flx/render/embeddedobject/1617

1. Which chemical property most contributes to soil formation and what effects does it have?
2. Which physical properties most contributes to soil formation and what effect does it have?
3. How does relief affect soil formation?
4. What do the scientists say is the succession that occurs in soil development?

5. How does the slope that has been deglaciated for 50 years differ from the nearby slope that has been glacier free for thousands of years?
6. How does agricultural development affect the timing of soil formation?
7. Why do scientists who study soils need a new set of terms to describe soils?

### Review

1. Why is climate more important than rock type for determining the type of soil that forms?
2. How would you create a very thick, organic-rich soil?
3. How would you create a very thin, sandy soil?
4. Why is time important for soil formation?

## References

1. Mike Baird. An area with sandy soil and low fertility. CC BY 2.0

# CHAPTER 11 MS Erosion and Deposition

## Chapter Outline



This photo shows Horseshoe Bend on the Colorado River as it flows through the Grand Canyon. Notice the trees growing along the river's edge. They look tiny from the top of the canyon. They show how deep the canyon is. The Colorado River carved this spectacular canyon down through layer upon layer of rock. How can water cut through rock? How did the horseshoe shape form? In this chapter, you'll find answers to questions like these. You'll learn how moving water and other natural forces shape Earth's surface, sometimes in spectacular ways.

*Paxson Woelber. www.flickr.com/photos/paxson_woelber/8077922348/. CC BY 2.0*

# 11.1 Erosion and Deposition by Flowing Water

## Lesson Objectives

- Explain how flowing water causes erosion and deposition.
- Describe how runoff, streams, and rivers change Earth's surface.
- Identify features caused by groundwater erosion and deposition.

## Vocabulary

- alluvial fan
- cave
- delta
- deposition
- erosion
- floodplain
- levee
- meander
- oxbow lake
- saltation
- sinkhole
- suspension
- traction

## Introduction

Erosion and deposition are responsible for many landforms. **Erosion** is the transport of sediments. Agents of erosion include flowing water, waves, wind, ice, or gravity. Eroded material is eventually dropped somewhere else. This is called **deposition**.

## How Flowing Water Causes Erosion and Deposition

Flowing water is a very important agent of erosion. Flowing water can erode rocks and soil. Water dissolves minerals from rocks and carries the ions. This process happens really slowly. But over millions of years, flowing water dissolves massive amounts of rock.

Moving water also picks up and carries particles of soil and rock. The ability to erode is affected by the velocity, or speed, of the water. The size of the eroded particles depends on the velocity of the water. Eventually, the water deposits the materials. As water slows, larger particles are deposited. As the water slows even more, smaller particles are deposited. The graph in **Figure** 11.1 shows how water velocity and particle size influence erosion and deposition.

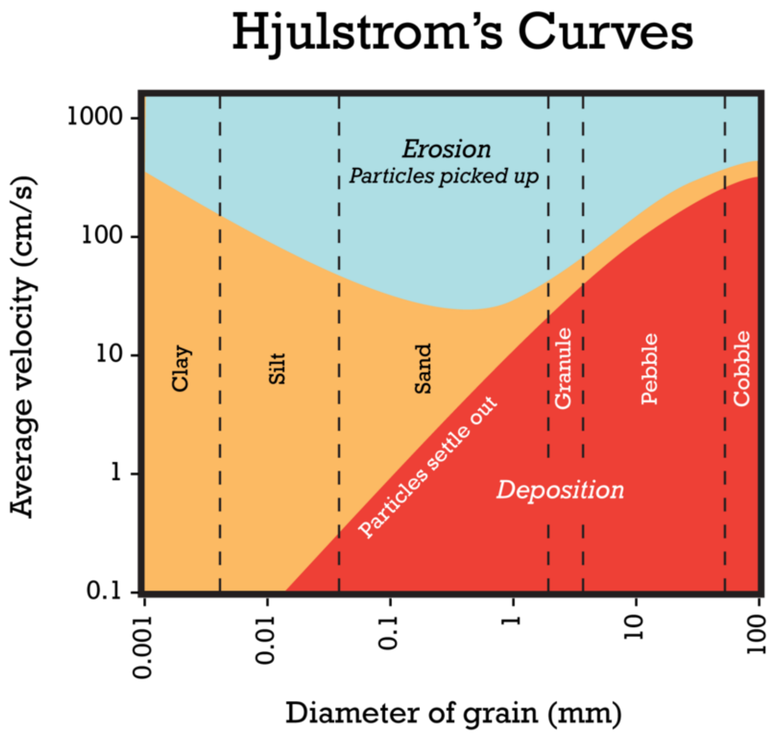


FIGURE 11.1

Flowing water erodes or deposits particles depending on how fast the water is moving and how big the particles are.

## Water Speed and Erosion

Faster-moving water has more energy. Therefore, it can carry larger particles. It can carry more particles. What causes water to move faster? The slope of the land over which the water flows is one factor. The steeper the slope, the faster the water flows. Another factor is the amount of water that's in the stream. Streams with a lot of water flow faster than streams that are nearly dry.

## Particle Size and Erosion

The size of particles determines how they are carried by flowing water. This is illustrated in **Figure** 11.2.

- Minerals that dissolve in water form salts. The salts are carried in solution. They are mixed thoroughly with the water.
- Small particles, such as clay and silt, are carried in **suspension**. They are mixed throughout the water. These particles are not dissolved in the water.
- Somewhat bigger particles, such as sand, are moved by **saltation**. The particles move in little jumps near the stream bottom. They are nudged along by water and other particles.
- The biggest particles, including gravel and pebbles, are moved by **traction**. In this process, the particles roll or drag along the bottom of the water.

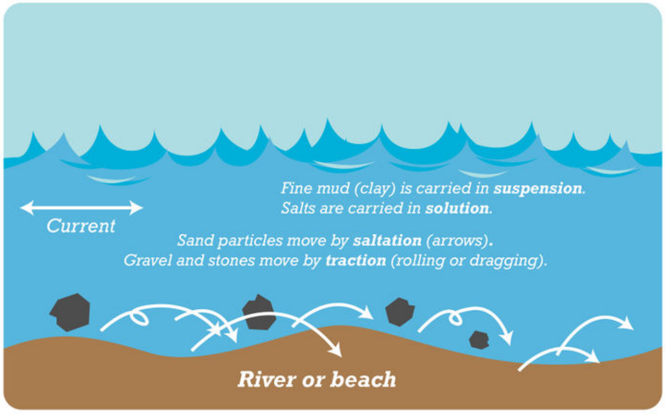


FIGURE 11.2
How Flowing Water Moves Particles. How particles are moved by flowing water depends on their size.

### Deposition by Water

Flowing water slows down when it reaches flatter land or flows into a body of still water. What do you think happens then? The water starts dropping the particles it was carrying. As the water slows, it drops the largest particles first. The smallest particles settle out last.

## Erosion and Deposition by Surface Water

Water that flows over Earth's surface includes runoff, streams, and rivers. All these types of flowing water can cause erosion and deposition.

### Erosion by Runoff

When a lot of rain falls in a short period of time, much of the water is unable to soak into the ground. Instead, it runs over the land. Gravity causes the water to flow from higher to lower ground. As the runoff flows, it may pick up loose material on the surface, such as bits of soil and sand.

Runoff is likely to cause more erosion if the land is bare. Plants help hold the soil in place. The runoff water in **Figure** 11.3 is brown because it eroded soil from a bare, sloping field. Can you find evidence of erosion by runoff where you live? What should you look for?

FIGURE 11.3
Erosion by Runoff. Runoff has eroded small channels through this bare field.

Much of the material eroded by runoff is carried into bodies of water, such as streams, rivers, ponds, lakes, or oceans. Runoff is an important cause of erosion. That's because it occurs over so much of Earth's surface.

### Erosion by Mountain Streams

Streams often start in mountains, where the land is very steep. You can see an example in **Figure** 11.4. A mountain stream flows very quickly because of the steep slope. This causes a lot of erosion and very little deposition. The rapidly falling water digs down into the stream bed and makes it deeper. It carves a narrow, V-shaped channel.

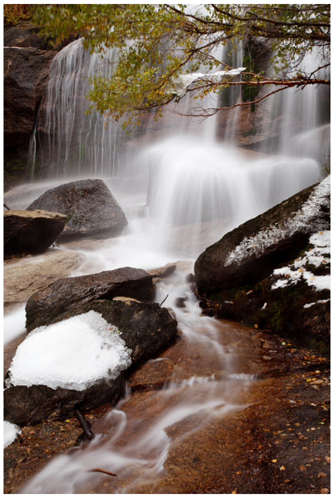

FIGURE 11.4
Mountain Stream. This mountain stream races down a steep slope.

### How a Waterfall Forms

Mountain streams may erode waterfalls. As shown in **Figure** 11.5, a waterfall forms where a stream flows from an area of harder to softer rock. The water erodes the softer rock faster than the harder rock. This causes the stream bed to drop down, like a step, creating a waterfall. As erosion continues, the waterfall gradually moves upstream.

### Erosion by Slow-Flowing Rivers

Rivers flowing over gentle slopes erode the sides of their channels more than the bottom. Large curves, called **meanders**, form because of erosion and deposition by the moving water. The curves are called meanders because they slowly "wander" over the land. You can see how this happens in **Figure** 11.6.

As meanders erode from side to side, they create a **floodplain**. This is a broad, flat area on both sides of a river. Eventually, a meander may become cut off from the rest of the river. This forms an **oxbow lake**, like the one in **Figure** 11.6.

### Deposition by Streams and Rivers

When a stream or river slows down, it starts dropping its sediments. Larger sediments are dropped in steep areas, but smaller sediments can still be carried. Smaller sediments are dropped as the slope becomes less steep.

#### Alluvial Fans

In arid regions, a mountain stream may flow onto flatter land. The stream comes to a stop rapidly. The deposits form an **alluvial fan**, like the one in **Figure** 11.7.

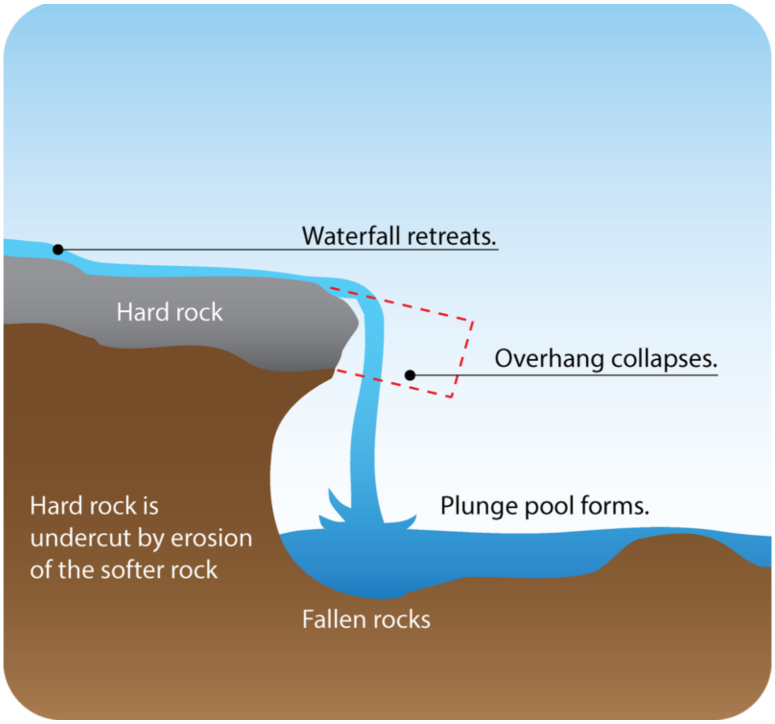


FIGURE 11.5
How a Waterfall Forms and Moves. Why does a waterfall keep moving upstream?

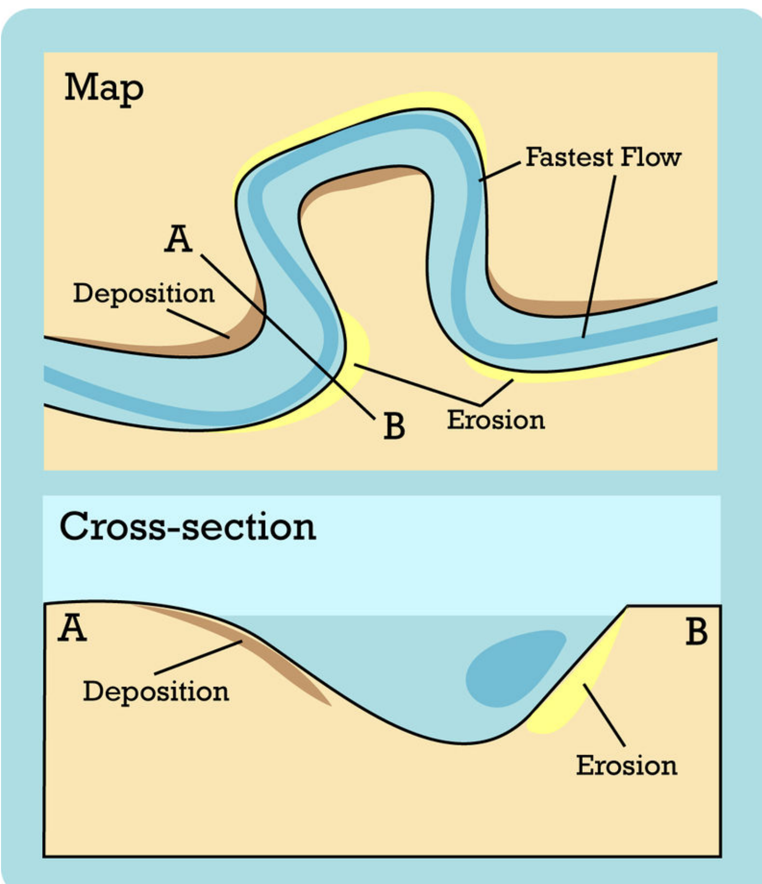


FIGURE 11.6
Meanders form because water erodes the outside of curves and deposits eroded material on the inside. Over time, the curves shift position.

FIGURE 11.7
An alluvial fan in Death Valley, California (left), Nile River Delta in Egypt (right).

#### Deltas

Deposition also occurs when a stream or river empties into a large body of still water. In this case, a **delta** forms. A delta is shaped like a triangle. It spreads out into the body of water. An example is shown in **Figure** 11.7.

### Deposition by Flood Waters

A flood occurs when a river overflows it banks. This might happen because of heavy rains.

#### Floodplains

As the water spreads out over the land, it slows down and drops its sediment. If a river floods often, the floodplain develops a thick layer of rich soil because of all the deposits. That's why floodplains are usually good places for growing plants. For example, the Nile River in Egypt provides both water and thick sediments for raising crops in the middle of a sandy desert.

#### Natural Levees

A flooding river often forms natural levees along its banks. A **levee** is a raised strip of sediments deposited close to the water's edge. You can see how levees form in **Figure** 11.8. Levees occur because floodwaters deposit their biggest sediments first when they overflow the river's banks.

## Erosion and Deposition by Groundwater

Some water soaks into the ground. It travels down through tiny holes in soil. It seeps through cracks in rock. The water moves slowly, pulled deeper and deeper by gravity. Underground water can also erode and deposit material.

### Caves

As groundwater moves through rock, it dissolves minerals. Some rocks dissolve more easily than others. Over time, the water may dissolve large underground holes, or **caves**. Groundwater drips from the ceiling to the floor of a cave. This water is rich in dissolved minerals. When the minerals come out of solution, they are deposited. They build up on the ceiling of the cave to create formations called stalactites. A stalactite is a pointed, icicle-like mineral deposit that forms on the ceiling of a cave. They drip to the floor of the cave and harden to form stalagmites. A stalagmite is a more rounded mineral deposit that forms on the floor of a cave ( **Figure** 11.9). Both types of formations grow in size as water keeps dripping and more minerals are deposited.

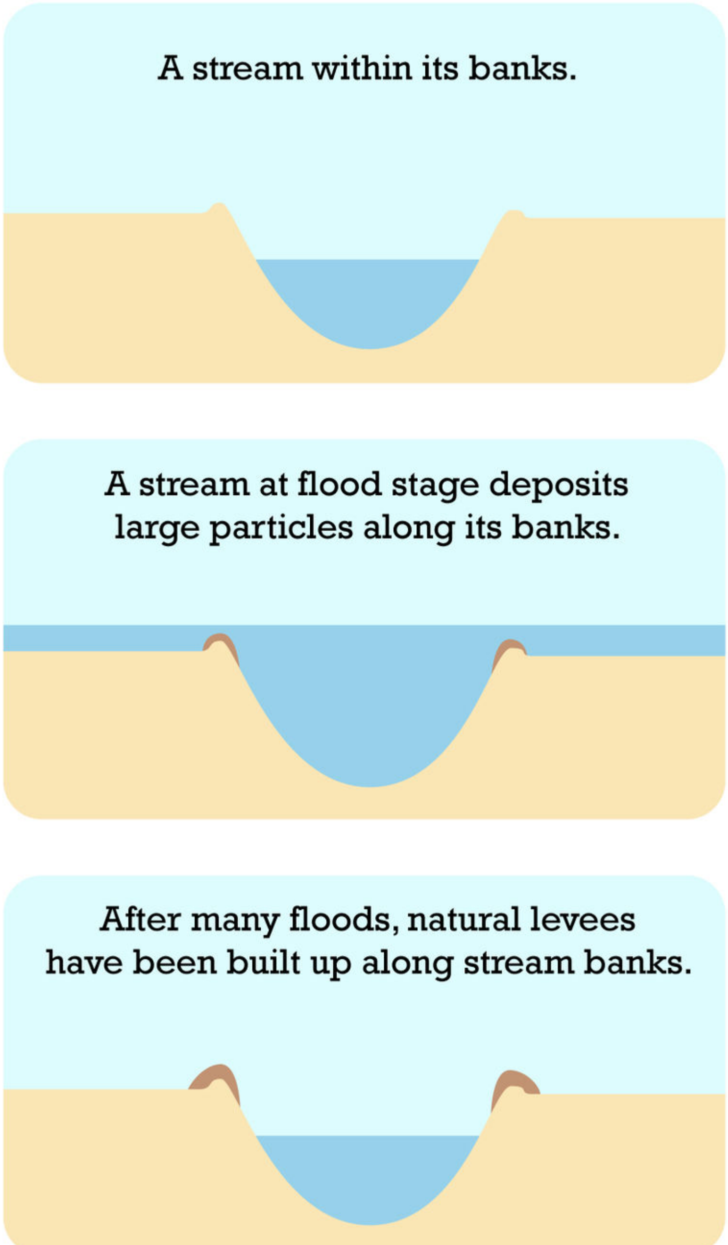


FIGURE 11.8
This diagram shows how a river builds natural levees along its banks.

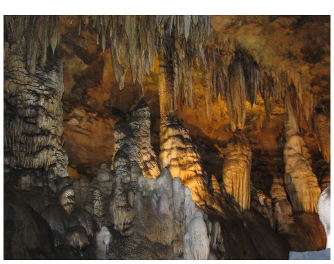

FIGURE 11.9
This cave has both stalactites and stalagmites.

### Sinkholes

As erosion by groundwater continues, the ceiling of a cave may collapse. The rock and soil above it sink into the ground. This forms a **sinkhole** on the surface. You can see an example of a sinkhole in **Figure** 11.10. Some sinkholes are big enough to swallow vehicles and buildings.

FIGURE 11.10
A sinkhole.

## Lesson Summary

- Water flowing over Earth's surface or underground causes erosion and deposition.
- Water flowing over a steeper slope moves faster and causes more erosion.
- How water transports particles depends on their size. When water slows down, it starts depositing sediment, starting with the largest particles first.
- Runoff erodes the land after a heavy rain. It picks up sediment and carries most of it to bodies of water. Mountain streams erode narrow, V-shaped valleys and waterfalls.
- Erosion and deposition by slow-flowing rivers creates broad floodplains and meanders.
- Deposition by streams and rivers may form alluvial fans and deltas. Floodwaters may deposit natural levees.
- Erosion and deposition by groundwater can form caves and sinkholes. Stalactites and stalagmites are mineral deposits that build up in caves as water continues to drip.

## Lesson Review Questions

### Recall

1. Define erosion.

2. What is deposition?

3. When does flowing water deposit the sediment it is carrying?

4. What happens to the sediment eroded by runoff?
5. Describe how a waterfall forms?
6. What are meanders?

### Apply Concepts

7. Make a table that relates particle size to the way particles are transported by flowing water.
8. Create a sketch that shows effects of groundwater erosion and deposition.

### Think Critically

9. Explain why mountain streams erode V-shaped valleys.
10. What might be pros and cons of living on the floodplain of a river?

## Points to Consider

Ocean waves are another form of moving water. They also cause erosion and deposition.

- How do waves erode shorelines?
- What landforms are deposited by waves?

# 11.2 Erosion and Deposition by Waves

## Lesson Objectives

- Explain how waves cause erosion of shorelines.
- Describe features formed by wave deposition.
- Identify ways to protect shorelines from wave erosion.

## Vocabulary

- barrier island
- breakwater
- groin
- longshore drift
- sandbar
- sea arch
- sea stack
- spit

## Introduction

Have you ever stood on a sandy ocean beach and let the waves wash over your feet? If you have, then you probably felt the sand being washed out from under your feet by the outgoing waves. This is an example of wave erosion. What are waves? Why do they cause erosion? And what happens to the sand that waves wash away from the beach?

## What Are Waves?

All waves are the way energy travels through matter. Ocean waves are energy traveling through water. They form when wind blows over the surface of the ocean. Wind energy is transferred to the sea surface. Then, the energy is carried through the water by the waves. **Figure** 11.11 shows ocean waves crashing against rocks on a shore. They pound away at the rocks and anything else they strike.

Three factors determine the size of ocean waves:

1. The speed of the wind.
2. The length of time the wind blows.
3. The distance the wind blows.

The faster, longer, and farther the wind blows, the bigger the waves are. Bigger waves have more energy.

FIGURE 11.11
Ocean waves transfer energy from the wind through the water. This gives waves the energy to erode the shore.

## Wave Erosion

Runoff, streams, and rivers carry sediment to the oceans. The sediment in ocean water acts like sandpaper. Over time, they erode the shore. The bigger the waves are and the more sediment they carry, the more erosion they cause.

### Landforms From Wave Erosion

Erosion by waves can create unique landforms ( **Figure** 11.12).

- Wave-cut cliffs form when waves erode a rocky shoreline. They create a vertical wall of exposed rock layers.
- **Sea arches** form when waves erode both sides of a cliff. They create a hole in the cliff.
- **Sea stacks** form when waves erode the top of a sea arch. This leaves behind pillars of rock.


FIGURE 11.12
Over millions of years, wave erosion can create wave-cut cliffs (A), sea arches (B), or sea stacks (C).

## Wave Deposition

Eventually, the sediment in ocean water is deposited. Deposition occurs where waves and other ocean motions slow. The smallest particles, such as silt and clay, are deposited away from shore. This is where water is calmer. Larger particles are deposited on the beach. This is where waves and other motions are strongest.

### Beaches

In relatively quiet areas along a shore, waves may deposit sand. Sand forms a beach, like the one in **Figure** 11.13. Many beaches include bits of rock and shell. You can see a close-up photo of beach deposits in **Figure** 11.14.

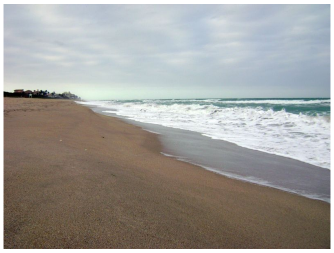

FIGURE 11.13
Sand deposited along a shoreline creates a beach.

FIGURE 11.14
Beach deposits usually consist of small pieces of rock and shell in addition to sand.

### Longshore Drift

Most waves strike the shore at an angle. This causes **longshore drift**. Longshore drift moves sediment along the shore. Sediment is moved up the beach by an incoming wave. The wave approaches at an angle to the shore. Water then moves straight offshore. The sediment moves straight down the beach with it. The sediment is again picked up by a wave that is coming in at an angle. This motion is show in **Figure** 11.15 and at the link below.

http://oceanica.cofc.edu/an%20educator'sl%20guide%20to%20folly%20beach/guide/driftanimation.htm

### Landforms Deposited by Waves

Deposits from longshore drift may form a spit. A **spit** is a ridge of sand that extends away from the shore. The end of the spit may hook around toward the quieter waters close to shore. You can see a spit in **Figure** 11.16.

Waves may also deposit sediments to form **sandbars** and **barrier islands**. You can see examples of these landforms in **Figure** 11.17.

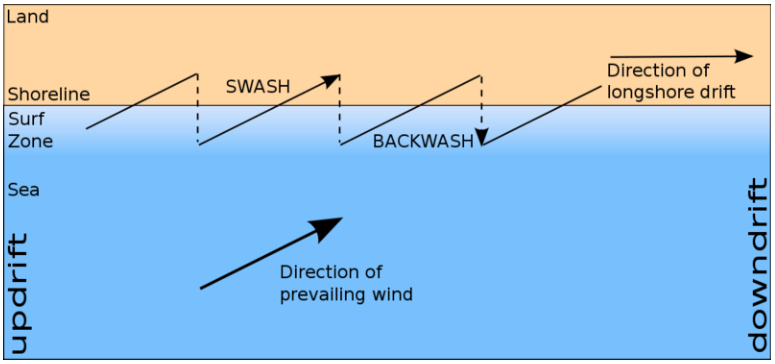


FIGURE 11.15
Longshore drift carries particles of sand and rock down a coastline.

FIGURE 11.16
Spit from Space. Farewell Spit in New Zealand is clearly visible from space. This photo was taken by an astronaut orbiting Earth.


FIGURE 11.17
Wave-Deposited Landforms. These landforms were deposited by waves. (A) Sandbars connect the small islands on this beach on Thailand. (B) A barrier island is a long, narrow island. It forms when sand is deposited by waves parallel to a coast. It develops from a sandbar that has built up enough to break through the water's surface. A barrier island helps protect the coast from wave erosion.

## Protecting Shorelines

Shores are attractive places to live and vacation. But development at the shore is at risk of damage from waves. Wave erosion threatens many homes and beaches on the ocean. This is especially true during storms, when waves may be much larger than normal.

### Breakwaters

Barrier islands provide natural protection to shorelines. Storm waves strike the barrier island before they reach the shore. People also build artificial barriers, called **breakwaters**. Breakwaters also protect the shoreline from incoming waves. You can see an example of a breakwater in **Figure** 11.18. It runs parallel to the coast like a barrier island.

FIGURE 11.18
A breakwater is an artificial barrier island. How does it help protect the shoreline?

### Groins

Longshore drift can erode the sediment from a beach. To keep this from happening, people may build a series of groins. A **groin** is wall of rocks or concrete that juts out into the ocean perpendicular to the shore. It stops waves from moving right along the beach. This stops the sand on the upcurrent side and reduces beach erosion. You can see how groins work in **Figure** 11.19.

## Lesson Summary

- Ocean waves are energy traveling through water. They are caused mainly by wind blowing over the water.
- Sediment in ocean water acts like sandpaper. Over time, it erodes the shore. It can create unique landforms, such as wave-cut cliffs, sea arches, and sea stacks.
- Deposits by waves include beaches. They may shift along the shoreline due to longshore drift. Other wave deposits are spits, sand bars, and barrier islands.
- Breakwaters are structures that protect the coast like barrier islands. Groins are structures that help prevent longshore drift from eroding a beach.

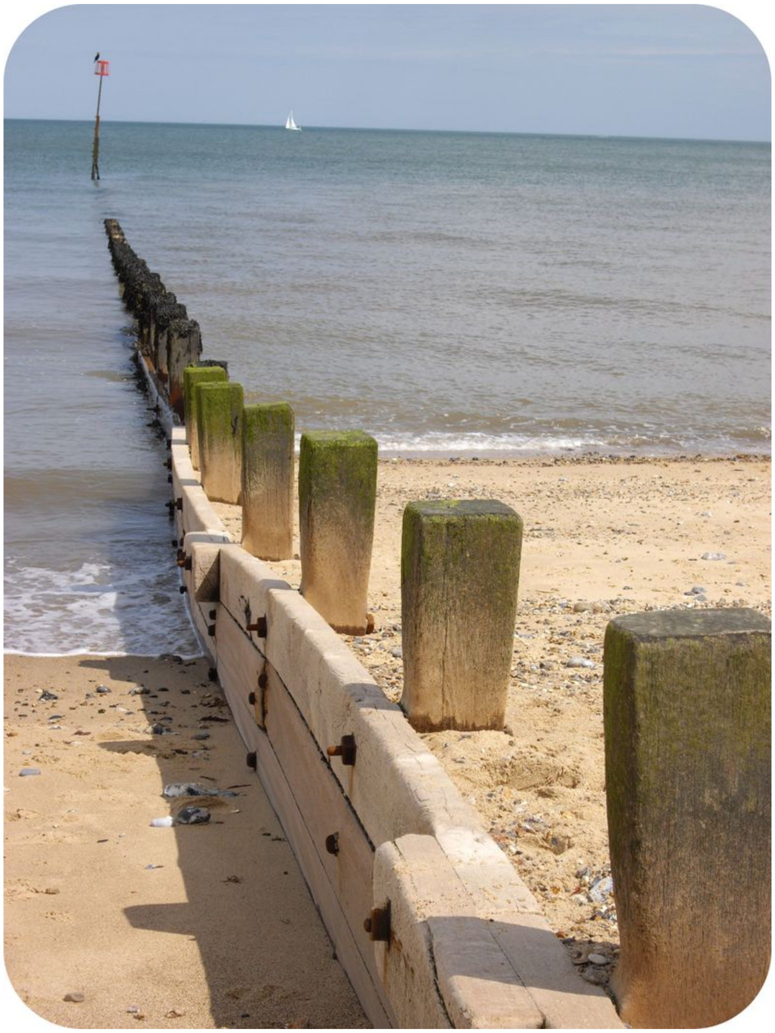

FIGURE 11.19
A groin is built perpendicular to the shoreline. Sand collects on the upcurrent side.

## Lesson Review Questions

### Recall

1. What are waves?
2. How do ocean waves cause erosion?
3. Identify three types of landforms created by wave erosion.
4. What is a spit? How does it form?

### Apply Concepts

5. Create a diagram to illustrate the concept of longshore drift.

### Think Critically

6. Why are the smallest particles on a beach usually sand?
7. Explain how a barrier island helps protect the coast from wave erosion.
8. Compare and contrast how breakwaters and groins protect shorelines.

## Points to Consider

Moving air, like moving water, causes erosion. Moving air is called wind.

- How does wind cause erosion? Does the wind carry particles in the same ways that moving water does?
- What landforms are deposited by the wind?

# 11.3 Erosion and Deposition by Wind

## Lesson Objectives

- Explain how wind causes erosion.
- Describe sediments deposited by wind.
- Identify ways to prevent wind erosion.

## Vocabulary

- loess
- sand dune

## Introduction

Wind is only air moving over Earth's surface, but it can cause a lot of erosion. Look at **Figure** 11.20. It will give you an idea of just how much erosion wind can cause. The dust storm in the photo occurred in Arizona. All that dust in the air was picked up and carried by the wind. The wind may carry the dust for hundreds of kilometers before depositing it.

FIGURE 11.20
Dust storm over Arizona desert. Have you ever experienced a dust storm like this one?

## Wind Erosion

Dust storms like the one in **Figure** 11.20 are more common in dry climates. The soil is dried out and dusty. Plants may be few and far between. Dry, bare soil is more easily blown away by the wind than wetter soil or soil held in place by plant roots.

### How the Wind Moves Particles

Like flowing water, wind picks up and transports particles. Wind carries particles of different sizes in the same ways that water carries them. You can see this in **Figure** 11.21.

- Tiny particles, such as clay and silt, move by suspension. They hang in the air, sometimes for days. They may be carried great distances and rise high above the ground.
- Larger particles, such as sand, move by saltation. The wind blows them in short hops. They stay close to the ground.
- Particles larger than sand move by traction. The wind rolls or pushes them over the surface. They stay on the ground.

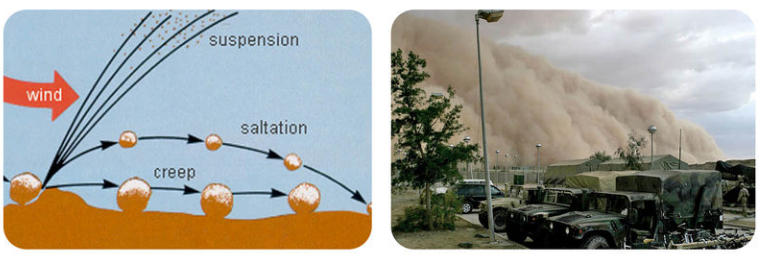


FIGURE 11.21
Wind transports particles in different ways depending on their size (left). A dust storm in the Middle East (right).

### Abrasion

Did you ever see workers sandblasting a building to clean it? Sand is blown onto the surface to scour away dirt and debris. Wind-blown sand has the same effect. It scours and polishes rocks and other surfaces. Wind-blown sand may carve rocks into interesting shapes. You can see an example in **Figure** 11.22. This form of erosion is called abrasion. It occurs any time rough sediments are blown or dragged over surfaces. Can you think of other ways abrasion might occur?

## Wind Deposition

Like water, when wind slows down it drops the sediment it's carrying. This often happens when the wind has to move over or around an obstacle. A rock or tree may cause wind to slow down. As the wind slows, it deposits the largest particles first. Different types of deposits form depending on the size of the particles deposited.

### Deposition of Sand

When the wind deposits sand, it forms small hills of sand. These hills are called **sand dunes**. For sand dunes to form, there must be plenty of sand and wind. Sand dunes are found mainly in deserts and on beaches. You can see

FIGURE 11.22
Sand blown by fierce winds have carved this rock in to an interesting shape.

examples of sand dunes in **Figure** 11.23.

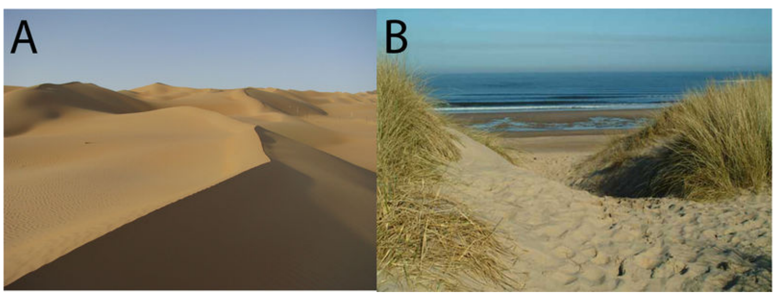


FIGURE 11.23
Sand dunes form where the wind deposits sand. (A) Desert sand dunes. (B) Sand dunes line many beaches like this one in Australia.

## How Sand Dunes Form

What causes a sand dune to form? It starts with an obstacle, such as a rock. The obstacle causes the wind to slow down. The wind then drops some of its sand. As more sand is deposited, the dune gets bigger. The dune becomes the obstacle that slows the wind and causes it to drop its sand. The hill takes on the typical shape of a sand dune, shown in **Figure** 11.24.


FIGURE 11.24
A sand dune has a gentle slope on the side the wind blows from. The opposite side has a steep slope. This side is called the slip face.

### Migration of Sand Dunes

Once a sand dune forms, it may slowly migrate over the land. The wind moves grains of sand up the gently sloping side of the dune. This is done by saltation. When the sand grains reach the top of the dune, they slip down the steeper side. The grains are pulled by gravity. The constant movement of sand up and over the dune causes the dune to move along the ground. It always moves in the same direction that the wind usually blows. Can you explain why?

### Loess

When the wind drops fine particles of silt and clay, it forms deposits called **loess**. Loess deposits form vertical cliffs. Loess can become a thick, rich soil. That's why loess deposits are used for farming in many parts of the world. You can see an example of loess in **Figure** 11.25.

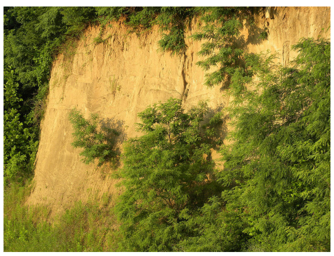

FIGURE 11.25
Loess cliffs in Mississippi.

## Preventing Wind Erosion

It's very important to control wind erosion of soil. Good soil is a precious resource that takes a long time to form. Covering soil with plants is one way to reduce wind erosion. Plants and their roots help hold the soil in place. They also help the soil retain water so it is less likely to blow away.

Planting rows of trees around fields is another way to reduce wind erosion. The trees slow down the wind, so it doesn't cause as much erosion. Fences like the one in **Figure** 11.26 serve the same purpose. The fence in the figure is preventing erosion and migration of sand dunes on a beach.

## Lesson Summary

- Dry, bare soil is more likely to be eroded by the wind than moist soil or soil covered with plants. How wind carries particles depends on their size. The sediment in wind causes erosion by abrasion.
- Sand dunes form when the wind deposits sand. Loess form when the wind deposits clay and silt.
- Wind erosion can be prevented by keeping the ground covered with plants. They help hold the soil in place. Rows of trees and fences can help by slowing the wind.

FIGURE 11.26
Protecting Sand Dunes from Wind Erosion. Many beaches uses fences like this one to reduce wind erosion of sand. If plants start growing on the dunes, they help hold the sand in place.

## Lesson Review Questions

### Recall

1. How does the wind carry particles of sand?
2. What is abrasion?
3. What are sand dunes? Where are they found?
4. Describe loess.
5. Identify two ways to reduce wind erosion.

### Apply Concepts

6. Wind-blown snow forms drifts that are similar to sand dunes. Apply lesson concepts to infer how you could reduce snowdrifts in a driveway.

### Think Critically

7. Compare and contrast how the wind transports clay, sand, and pebbles.
8. Explain why a sand dune migrates.

## Points to Consider

Abrasion is the main way that wind causes erosion. The next lesson explains how glaciers cause erosion.

- How do you think glaciers cause erosion?
- Do you think glaciers might erode by abrasion, like the wind?

# 11.4 Erosion and Deposition by Glaciers

## Lesson Objectives

- Describe how continental and valley glaciers form.
- Explain how glaciers cause erosion.
- Identify landforms deposited by glaciers.

## Vocabulary

- continental glacier
- glacial till
- glacier
- moraine
- plucking
- valley glacier

## Introduction

**Glaciers** are masses of flowing ice. Today, they cover only about 10 percent of Earth's surface. They are getting smaller and smaller as Earth's temperature rises. But just 12,000 years ago, glaciers dipped as far south as Chicago and New York City. Much of Europe was also covered with glaciers at that time.

Glaciers erode and leave behind telltale landforms. These landforms are like clues. They show the direction a glacier flowed and how far it advanced. Did glaciers leave clues where you live? Would you know what to look for?

## How Glaciers Form

Glaciers form when more snow falls than melts each year. Over many years, layer upon layer of snow compacts and turns to ice. There are two different types of glaciers: continental glaciers and valley glaciers. Each type forms some unique features through erosion and deposition. An example of each type is pictured in **Figure** 11.27.

- A **continental glacier** is spread out over a huge area. It may cover most of a continent. Today, continental glaciers cover most of Greenland and Antarctica. In the past, they were much more extensive.
- A **valley glacier** is long and narrow. Valley glaciers form in mountains and flow downhill through mountain river valleys.


FIGURE 11.27
(A) The continent of Antarctica is covered with a continental glacier. (B) A valley glacier in the Canadian Rockies. (C) The surface of a valley glacier.

## Erosion by Glaciers

Like flowing water, flowing ice erodes the land and deposits the material elsewhere. Glaciers cause erosion in two main ways: plucking and abrasion.

- **Plucking** is the process by which rocks and other sediments are picked up by a glacier. They freeze to the bottom of the glacier and are carried away by the flowing ice.
- Abrasion is the process in which a glacier scrapes underlying rock. The sediments and rocks frozen in the ice at the bottom and sides of a glacier act like sandpaper. They wear away rock. They may also leave scratches and grooves that show the direction the glacier moved.

### Erosion by Valley Glaciers

Valley glaciers form several unique features through erosion. You can see some of them in **Figure** 11.28.

- As a valley glacier flows through a V-shaped river valley, it scrapes away the sides of the valley. It carves a U-shaped valley with nearly vertical walls. A line called the trimline shows the highest level the glacier reached.
- A cirque is a rounded hollow carved in the side of a mountain by a glacier. The highest cliff of a cirque is called the headwall.
- An arête is a jagged ridge that remains when cirques form on opposite sides of a mountain. A low spot in an arête is called a col.
- A horn is a sharp peak that is left behind when glacial cirques are on at least three sides of a mountain.

FIGURE 11.28
Features Eroded by Valley Glaciers. Erosion by valley glaciers forms the unique features shown here.

## Deposition by Glaciers

Glaciers deposit their sediment when they melt. They drop and leave behind whatever was once frozen in their ice. It's usually a mixture of particles and rocks of all sizes, called **glacial till**. Water from the melting ice may form lakes or other water features. **Figure** 11.29 shows some of the landforms glaciers deposit when they melt.

- **Moraine** is sediment deposited by a glacier. A ground moraine is a thick layer of sediments left behind by a retreating glacier. An end moraine is a low ridge of sediments deposited at the end of the glacier. It marks the greatest distance the glacier advanced.
- A drumlin is a long, low hill of sediments deposited by a glacier. Drumlins often occur in groups called drumlin fields. The narrow end of each drumlin points in the direction the glacier was moving when it dropped the sediments.
- An esker is a winding ridge of sand deposited by a stream of meltwater. Such streams flow underneath a retreating glacier.
- A kettle lake occurs where a chunk of ice was left behind in the sediments of a retreating glacier. When the ice melted, it left a depression. The meltwater filled it to form a lake.

## Lesson Summary

- Glaciers are masses of flowing ice. Continental glaciers are huge. They may spread out over much of a continent. Valley glaciers are long and narrow. They form in mountains and flow through mountain river valleys.

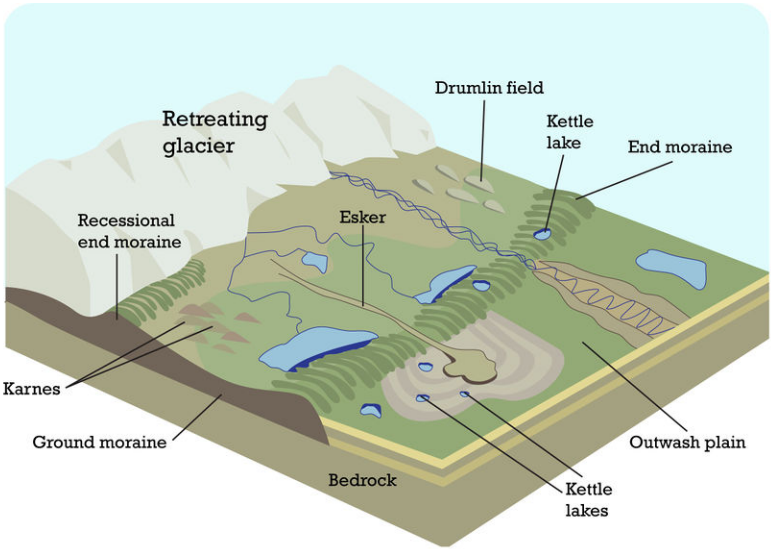


FIGURE 11.29
Take a look at the glacial deposits. How far did the glacier in the diagram advance before it started retreating?

- Glaciers cause erosion by plucking and abrasion. Valley glaciers form several unique features through erosion, including cirques, arêtes, and horns.
- Glaciers deposit their sediment when they melt. Landforms deposited by glaciers include drumlins, kettle lakes, and eskers.

## Lesson Review Questions

### Recall

1. What is a glacier?
2. Describe how glaciers form.
3. Identify the two main ways glaciers cause erosion.
4. Name and describe three unique features eroded by valley glaciers.
5. What is glacial till?

### Apply Concepts

6. Create a lesson to teach younger students how a kettle lake forms. Outline your lesson.

### Think Critically

7. Compare and contrast valley and continental glaciers and how they change Earth's surface.
8. Areas once covered by glaciers may have large boulders called erratics, like the one in the photo below. Infer why erratics typically consist of a different type of rock than the bedrock where they are found.

## Points to Consider

So far in this chapter, you've read how moving water, air, and ice shape Earth's surface. Water and ice move because of gravity.

- Do you think gravity can erode and deposit sediment without the help of water or ice?
- How might gravity alone shape Earth's surface?

# 11.5 Erosion and Deposition by Gravity

## Lesson Objectives

- Identify causes and effects of landslides and mudslides.
- Explain how slump and creep occur.

## Vocabulary

- creep
- landslide
- mass movement
- mudslide
- slump

## Introduction

Gravity is responsible for erosion by flowing water and glaciers. That's because gravity pulls water and ice downhill. These are ways gravity causes erosion indirectly. But gravity also causes erosion directly. Gravity can pull soil, mud, and rocks down cliffs and hillsides. This type of erosion and deposition is called **mass movement**. It may happen suddenly. Or it may occur very slowly, over many years.

## Landslides and Mudslides

The most destructive types of mass movement are landslides and mudslides. Both occur suddenly.

### Landslides

A **landslide** happens when a large amount of soil and rock suddenly falls down a slope because of gravity. You can see an example in **Figure** 11.30. A landslide can be very destructive. It may bury or carry away entire villages.

A landslide is more likely if the soil has become wet from heavy rains. The wet soil becomes slippery and heavy. Earthquakes often trigger landslides. The shaking ground causes soil and rocks to break loose and start sliding. If a landslide flows into a body of water, it may cause a huge wave called a tsunami.

FIGURE 11.30
This 2001 landslide in El Salvador (Central America) was started by an earthquake. Soil and rocks flowed down a hillside and swallowed up houses in the city below.

### Mudslides

A **mudslide** is the sudden flow of mud down a slope because of gravity. Mudslides occur where the soil is mostly clay. Like landslides, mudslides usually occur when the soil is wet. Wet clay forms very slippery mud that slides easily. You can see an example of a mudslide in **Figure** 11.31.

FIGURE 11.31
Mudslide. A mudslide engulfs whatever is in its path.

## Other Types of Mass Movement

Two other types of mass movement are slump and creep. Both may move a lot of soil and rock. However, they usually aren't as destructive as landslides and mudslides.

### Slump

**Slump** is the sudden movement of large blocks of rock and soil down a slope. You can see how it happens in **Figure** 11.32. All the material moves together in big chunks. Slump may be caused by a layer of slippery, wet clay underneath the rock and soil on a hillside. Or it may occur when a river undercuts a slope. Slump leaves behind crescent-shaped scars on the hillside.

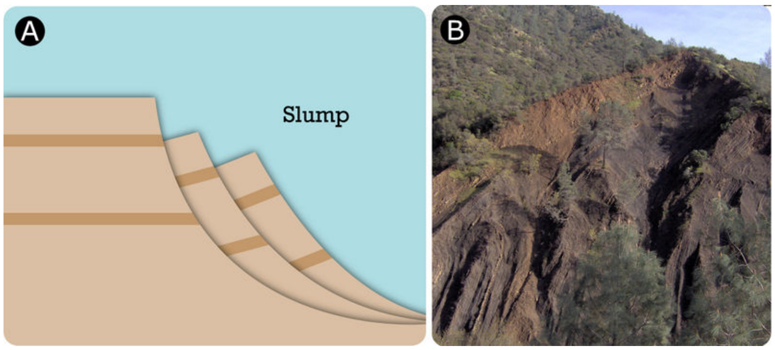


FIGURE 11.32
Slump takes place suddenly, like a landslide. How does slump differ from a landslide?

### Creep

**Creep** is the very slow movement of rock and soil down a hillside. Creep occurs so slowly you can't see it happening. You can only see the effects of creep after years of movement. This is illustrated in **Figure** 11.33. The slowly moving ground causes trees, fence posts, and other structures on the surface to tilt downhill.

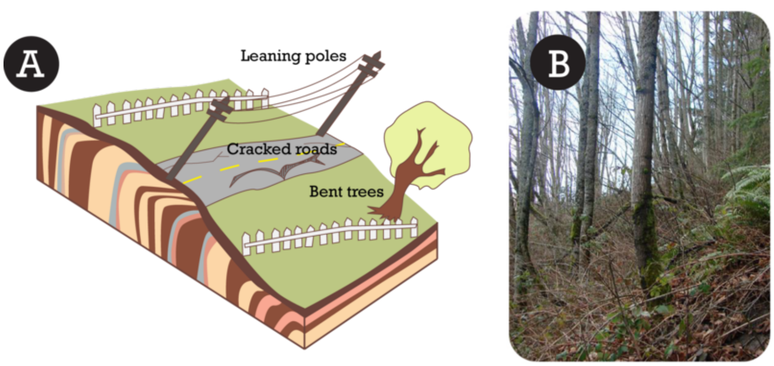


FIGURE 11.33
Creep is seen on a hillside. What evidence shows creep has occurred?

Creep usually takes place where the ground freezes and thaws frequently. Soil and rock particles are lifted up when the ground freezes. When the ground thaws, the particles settle down again. Each time they settle down, they move a tiny bit farther down the slope because of gravity.

## Lesson Summary

- Gravity can pull soil, mud, and rocks down cliffs and hillsides. This is called mass movement. The most destructive types of mass movement are landslides and mudslides. They occur suddenly and without warming. They engulf everything in their path.

- Two other types of mass movement are slump and creep. They usually aren't as destructive as landslides and mudslides. Slump is the sudden movement of large blocks of rock and soil down a slope. Creep is the very slow movement of rock and soil down a slope. It causes trees, fence posts, and other structures to tilt downhill.

## Lesson Review Questions

### Recall

1. Define mass movement.
2. List four types of mass movement.
3. What is a landslide?
4. What factors increase the chances of landslides occurring?
5. What type of soil forms mudslides?

### Apply Concepts

6. Assume you are riding in a car down a road or street. Suddenly, you see evidence of creep. Describe it.

### Think Critically

7. Relate earthquakes to mass movement.
8. Compare and contrast slump and creep.

## Points to Consider

Erosion and deposition are always changing Earth's surface.

- Do you think that the same forces that cause erosion today —moving water, wind, ice, and gravity —were also at work in the past?
- How might observations of erosion and deposition today help us understand Earth's history?

Image for Lesson 10.4, Lesson Review Question 8: Flickr:jhoc. http://www.flickr.com/photos/22400437@N03/2658071097/ . CC BY 2.0.

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# CHAPTER 12 Motion

## Chapter Outline



A frog flicks out its long tongue to catch insects. In this photo, you can't actually see the frog's tongue moving. But even if you were to witness it in person, you still wouldn't be able to see it. That's because a frog's tongue moves incredibly fast. It travels out and back in about 0.15 seconds, too fast for the human eye to detect. Other organisms can also move at very high speeds. For example, the fastest land animal, the cheetah, can sprint at an amazing 120 kilometers (75 miles) per hour. Speed is one way of measuring motion. What is motion, and what are other ways of measuring it? In this chapter, you'll find out.

# 12.1 Distance and Direction

## Lesson Objectives

- Define motion, and relate it to frame of reference.
- Describe how to measure distance.
- Explain how to represent direction.

## Lesson Vocabulary

- distance
- frame of reference
- motion
- vector

## Introduction

You can see several examples of people or things in motion in **Figure** 12.1. You can probably think of many other examples. You know from experience what motion is, so it may seem like a straightforward concept. **Motion** can also be defined simply, as a change in position. But if you think about examples of motion in more depth, you'll find that the idea of motion is not quite as simple and straightforward as it seems.

## Frame of Reference

Assume that a school bus, like the one in **Figure** 12.2, passes by as you stand on the sidewalk. It's obvious to you that the bus is moving. It is moving relative to you and the trees across the street. But what about to the children inside the bus? They aren't moving relative to each other. If they look only at the other children sitting near them, they will not appear to be moving. They may only be able to tell that the bus is moving by looking out the window and seeing you and the trees whizzing by.

This example shows that how we perceive motion depends on our frame of reference. **Frame of reference** refers to something that is not moving with respect to an observer that can be used to detect motion. For the children on the bus, if they use other children riding the bus as their frame of reference, they do not appear to be moving. But if they use objects outside the bus as their frame of reference, they can tell they are moving. What is your frame of reference if you are standing on the sidewalk and see the bus go by? How can you tell the bus is moving? The video at the URL below illustrates other examples of how frame of reference is related to motion.

http://www.youtube.com/watch?v=7FYBG5GSklU (6:45)

FIGURE 12.1
These are just a few examples of people or things in motion. If you look around, you're likely to see many more.

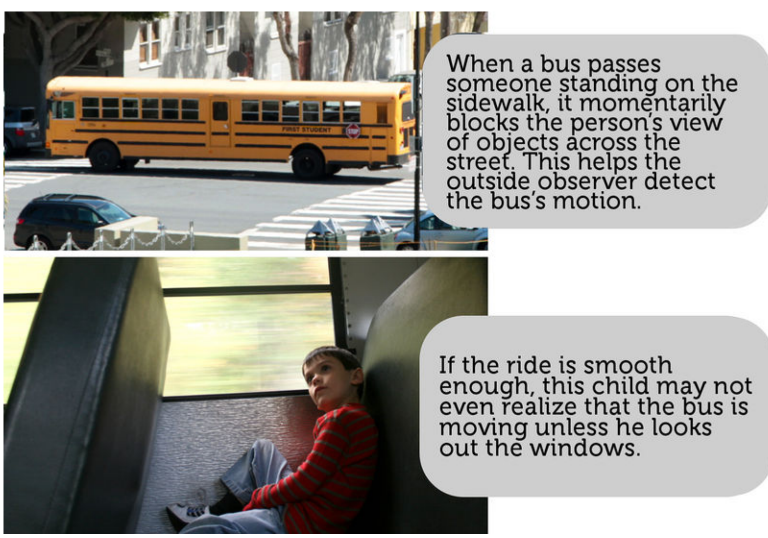



FIGURE 12.2
To a person outside the bus, the bus's motion is obvious. To children riding the bus, its motion may not be as obvious.

MEDIA
Click image to the left for use the URL below.
URL: http://www.ck12.org/flx/render/embeddedobject/5019

## Distance

Did you ever go to a track meet like the one pictured in **Figure** 12.3? Running events in track include 100-meter sprints and 2000-meter races. Races are named for their distance. **Distance** is the length of the route between two points. The length of the route in a race is the distance between the starting and finishing lines. In a 100-meter sprint, for example, the distance is 100 meters.

FIGURE 12.3
These students are running a 100-meter sprint.

### SI Unit for Distance

The SI unit for distance is the meter (1 m = 3.28 ft). Short distances may be measured in centimeters (1 cm = 0.01 m). Long distances may be measured in kilometers (1 km = 1000 m). For example, you might measure the distance a frog's tongue moves in centimeters and the distance a cheetah moves in kilometers.

### Using Maps to Measure Distance

Maps can often be used to measure distance. Look at the map in **Figure** 12.4. Find Mia's house and the school. You can use the map key to directly measure the distance between these two points. The distance is 2 kilometers. Measure it yourself to see if you agree.

## Direction

Things don't always move in straight lines like the route from Mia's house to the school. Sometimes they change direction as they move. For example, the route from Mia's house to the post office changes from west to north at the school (see **Figure** 12.4). To find the total distance of a route that changes direction, you must add up the distances traveled in each direction. From Mia's house to the school, for example, the distance is 2 kilometers. From the school to the post office, the distance is 1 kilometer. Therefore, the total distance from Mia's house to the post office is 3 kilometers.

**You Try It!**

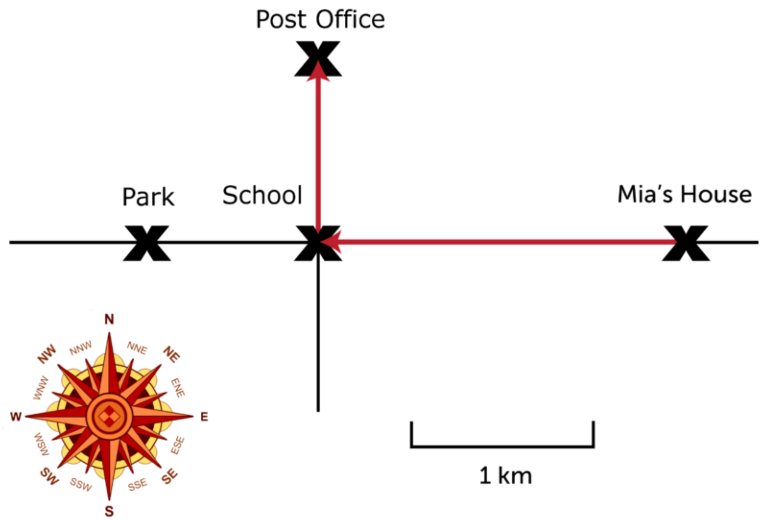
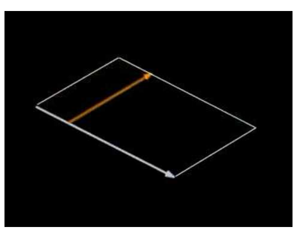



FIGURE 12.4
This map shows the routes from Mia's house to the school, post office, and park.

*Problem:* What is the distance from the post office to the park in **Figure** 12.4?

Direction is just as important as distance in describing motion. For example, if Mia told a friend how to reach the post office from her house, she couldn't just say, "go 3 kilometers." The friend might end up at the park instead of the post office. Mia would have to be more specific. She could say, "go west for 2 kilometers and then go north for 1 kilometer." When both distance and direction are considered, motion is a vector. A **vector** is a quantity that includes both size and direction. A vector is represented by an arrow. The length of the arrow represents distance. The way the arrow points shows direction. The red arrows in **Figure** 12.4 are vectors for Mia's route to the school and post office. If you want to learn more about vectors, watch the videos at these URLs:

- http://www.youtube.com/watch?v=B-iBbcFwFOk (5:27)



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- http://www.youtube.com/watch?v=tSOz3xaHKLs

**You Try It!**

*Problem:* Draw vectors to represent the route from the post office to the park in **Figure** 12.4.

## Lesson Summary

- Motion is a change of position. The perception of motion depends on a person's frame of reference.
- Distance is the length of the route between two points. The SI unit for distance is the meter (m).
- Direction is just as important as distance in describing motion. A vector is a quantity that has both size and direction. It can be used to represent the distance and direction of motion.

## Lesson Review Questions

### Recall

1. Define motion.
2. What is distance?
3. Describe how a vector represents distance and direction.

### Apply Concepts

4. In **Figure** 12.4, what is the distance from Mia's house to the park?
5. Draw vectors to represent the following route from point A to point B:
   a. Starting at point A, go 2 km east.
   b. Then go 1 km south.
   c. Finally, go 3 km west to point B.

### Think Critically

6. Explain how frame of reference is related to motion.

## Points to Consider

A snail might travel 2 centimeters in a minute. A cheetah might travel 2 kilometers in the same amount of time. The distance something travels in a given amount of time is its speed.

- How could you calculate the speed of a snail or cheetah?
- Speed just takes distance and time into account. How might direction be considered as well?

# 12.2 Speed and Velocity

## Lesson Objectives

- Outline how to calculate the speed of a moving object.
- Explain how velocity differs from speed.

## Lesson Vocabulary

- speed
- velocity

## Introduction

Did you ever play fast-pitch softball? If you did, then you probably have some idea of how fast the pitcher throws the ball. For a female athlete, like the one in **Figure** 12.5, the ball may reach a speed of 120 km/h (about 75 mi/h). For a male athlete, the ball may travel even faster. The speed of the ball makes it hard to hit. If the ball changes course, the batter may not have time to adjust the swing to meet the ball.

FIGURE 12.5

In fast-pitch softball, the pitcher uses a "windmill" motion to throw the ball. This is a different technique than other softball pitches. It explains why the ball travels so fast.

## Speed

**Speed** is an important aspect of motion. It is a measure of how fast or slow something moves. It depends on how far something travels and how long it takes to travel that far. Speed can be calculated using this general formula:

$$\text{speed} = \frac{\text{distance}}{\text{time}}$$

A familiar example is the speed of a car. In the U.S., this is usually expressed in miles per hour (see **Figure** 12.6). If your family makes a car trip that covers 120 miles and takes 3 hours, then the car's speed is:

$$\text{speed} = \frac{120\text{ mi}}{3\text{ h}} = 40\text{ mi/h}$$

The speed of a car may also be expressed in kilometers per hour (km/h). The SI unit for speed is meters per second (m/s).


FIGURE 12.6
Speed limit signs like this one warn drivers to reduce their speed on dangerous roads.

### Instantaneous vs. Average Speed

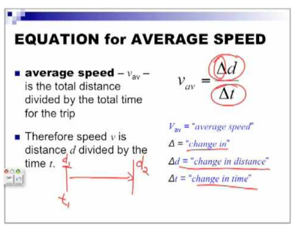
When you travel by car, you usually don't move at a constant speed. Instead you go faster or slower depending on speed limits, traffic, traffic lights, and many other factors. For example, you might travel 65 miles per hour on a highway but only 20 miles per hour on a city street (see **Figure** 12.7). You might come to a complete stop at traffic lights, slow down as you turn corners, and speed up to pass other cars. The speed of a moving car or other object at a given instant is called its instantaneous speed. It may vary from moment to moment, so it is hard to calculate.

It's easier to calculate the average speed of a moving object than the instantaneous speed. The average speed is the total distance traveled divided by the total time it took to travel that distance. To calculate the average speed, you can use the general formula for speed that was given above. Suppose, for example, that you took a 75-mile car trip with your family. Your instantaneous speed would vary throughout the trip. If the trip took a total of 1.5 hours, your average speed for the trip would be:

FIGURE 12.7
Cars race by in a blur of motion on an open highway but crawl at a snail's pace when they hit city traffic.

$$\text{average speed} = \frac{75\text{ mi}}{1.5\text{ h}} = 50\text{ mi/h}$$

You can see a video about instantaneous and average speed and how to calculate them at this URL: http://www.youtube.com/watch?v=a8tIBrj84II (7:18).

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**You Try It!**

*Problem:* Terri rode her bike very slowly to the top of a big hill. Then she coasted back down the hill at a much faster speed. The distance from the bottom to the top of the hill is 3 kilometers. It took Terri 15 minutes to make the round trip. What was her average speed for the entire trip?

## Distance-Time Graphs

The motion of an object can be represented by a distance-time graph like the one in **Figure** 12.8. A distance-time graph shows how the distance from the starting point changes over time. The graph in **Figure** 12.8 represents a bike trip. The trip began at 7:30 AM (A) and ended at 12:30 PM (F). The rider traveled from the starting point to a destination and then returned to the starting point again.

## Slope Equals Speed

In a distance-time graph, the speed of the object is represented by the slope, or steepness, of the graph line. If the line is straight, like the line between A and B in **Figure** 12.8, then the speed is constant. The average speed can be calculated from the graph. The change in distance (represented by $\Delta$d) divided by the change in time (represented by $\Delta$t):

$$\text{speed} = \frac{\Delta \text{d}}{\Delta \text{t}}$$

For example, the speed between A and B in **Figure** 12.8 is:

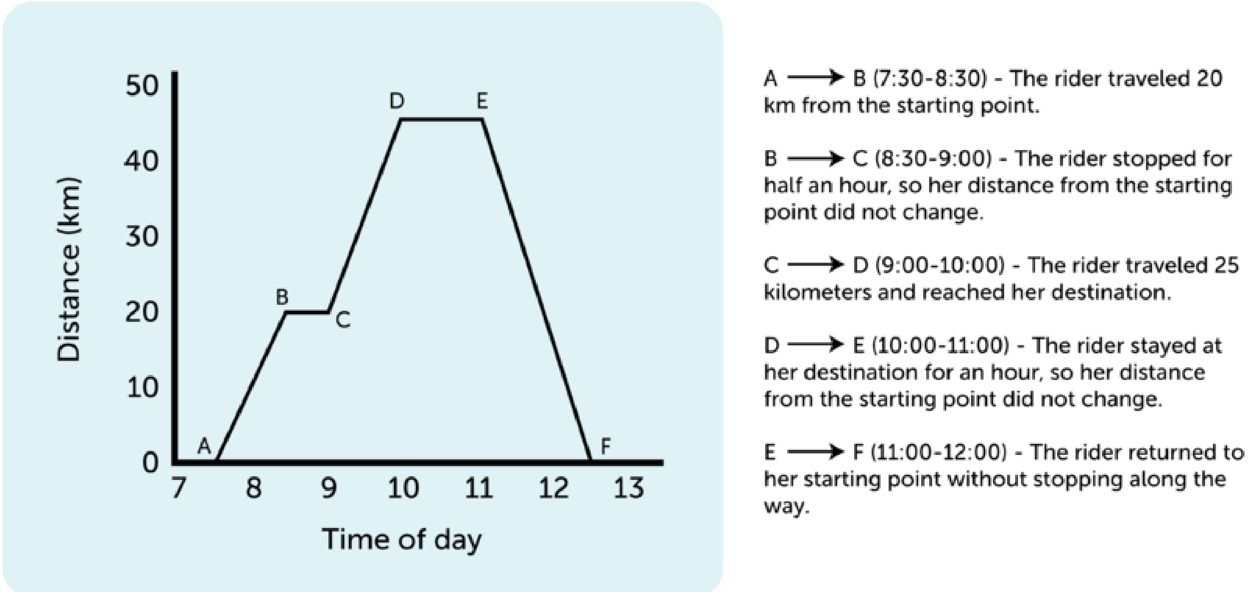


FIGURE 12.8
This graph shows how far a bike rider is from her starting point at 7:30 AM until she returned at 12:30 PM.

$$\text{speed} = \frac{\Delta \text{d}}{\Delta \text{t}} = \frac{20 \text{ km} - 0 \text{ km}}{8{:}30 - 7{:}30 \text{ h}} = \frac{20 \text{ km}}{1 \text{ h}} = 20 \text{ km/h}$$

If the graph line is horizontal, as it is between B and C, then the slope and the speed are zero:

$$\text{speed} = \frac{\Delta \text{d}}{\Delta \text{t}} = \frac{20 \text{ km} - 20 \text{ km}}{9{:}00 - 8{:}30 \text{ h}} = \frac{0 \text{ km}}{0.5 \text{ h}} = 0 \text{ km/h}$$

**You Try It!**

*Problem:* In **Figure** 12.8, calculate the speed of the rider between C and D.

### Calculating Distance from Speed and Time

If you know the speed of a moving object, you can also calculate the distance it will travel in a given amount of time. To do so, you would use this version of the general speed formula:

$$\text{distance} = \text{speed} \times \text{time}$$

For example, if a car travels at a speed of 60 km/h for 2 hours, then the distance traveled is:

$$\text{distance} = 60 \text{ km/h} \times 2 \text{ h} = 120 \text{ km}$$

**You Try It!**

*Problem:* If Maria runs at a speed of 2 m/s, how far will she run in 60 seconds?

## Velocity

Speed tells you only how fast an object is moving. It doesn't tell you the direction the object is moving. The measure of both speed and direction is called **velocity**. Velocity is a vector that can be represented by an arrow. The length of the arrow represents speed, and the way the arrow points represents direction. The three arrows in **Figure** 12.9 represent the velocities of three different objects. Vectors A and B are the same length but point in different directions. They represent objects moving at the same speed but in different directions. Vector C is shorter than vector A or B but points in the same direction as vector A. It represents an object moving at a slower speed than A or B but in the same direction as A. If you're still not sure of the difference between speed and velocity, watch the cartoon at this URL: http://www.youtube.com/watch?v=mDcaeO0WxBI (2:10).

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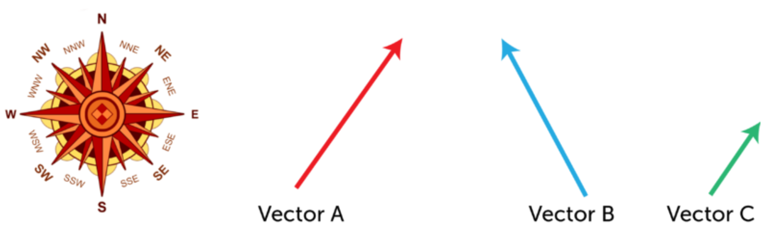


FIGURE 12.9

These vectors show both the speed and direction of motion.

In general, if two objects are moving at the same speed and in the same direction, they have the same velocity. If two objects are moving at the same speed but in different directions (like A and B in **Figure** 12.9), they have different velocities. If two objects are moving in the same direction but at a different speed (like A and C in **Figure** 12.9), they have different velocities. A moving object that changes direction also has a different velocity, even if its speed does not change.

## Lesson Summary

- Speed is a measure of how fast or slow something moves. It depends on the distance traveled and how long it takes to travel that distance. The average speed of an object is calculated as the change in distance divided by the change in time.
- Velocity is a measure of both speed and direction. It is a vector that can be represented by an arrow. Velocity changes with a change in speed, a change in direction, or both.

## Lesson Review Questions

### Recall

1. What is speed? How is it calculated?
2. Define velocity.

### Apply Concepts

3. Sam ran a 2000-meter race. He started at 9:00 AM and finished at 9:05 AM. He started out fast but slowed down toward the end. Calculate Sam's average speed during the race.
4. Create a distance-time graph to represent a typical trip from your home to school or some other route you travel often. You may estimate distances and times.

### Think Critically

5. Explain how a distance-time graph represents speed.
6. Compare and contrast speed and velocity.
7. Is speed a vector? Why or why not?

## Points to Consider

In this chapter, you read that the speed of a moving object equals the distance traveled divided by the time it takes to travel that distance. Speed may vary from moment to moment as an object speeds up or slows down. In the next lesson, "Acceleration," you will learn how to measure changes in speed over time.

- Do you know what a change in speed or direction is called?
- Why might measuring changes in speed or direction be important?

# 12.3 Acceleration

## Lesson Objectives

- Define acceleration.
- Explain how to calculate acceleration.
- Describe velocity-time graphs.

## Lesson Vocabulary

- acceleration

## Introduction

Imagine the thrill of riding on a roller coaster like the one in **Figure** 12.10. The coaster crawls to the top of the track and then flies down the other side. It also zooms around twists and turns at breakneck speeds. These changes in speed and direction are what make a roller coaster ride so exciting. Changes in speed or direction are called **acceleration**.

FIGURE 12.10

Did you ever ride on a roller coaster like this one? It's called the "Blue Streak" for a reason. As it speeds around the track, it looks like a streak of blue.

## Defining Acceleration

Acceleration is a measure of the change in velocity of a moving object. It shows how quickly velocity changes. Acceleration may reflect a change in speed, a change in direction, or both. Because acceleration includes both a size (speed) and direction, it is a vector.

People commonly think of acceleration as an increase in speed, but a decrease in speed is also acceleration. In this case, acceleration is negative. Negative acceleration may be called deceleration. A change in direction without a change in speed is acceleration as well. You can see several examples of acceleration in **Figure** 12.11.


FIGURE 12.11
How is velocity changing in each of these pictures?

If you are accelerating, you may be able to feel the change in velocity. This is true whether you change your speed or your direction. Think about what it feels like to ride in a car. As the car speeds up, you feel as though you are being pressed against the seat. The opposite occurs when the car slows down, especially if the change in speed is sudden. You feel yourself thrust forward. If the car turns right, you feel as though you are being pushed to the left. With a left turn, you feel a push to the right. The next time you ride in a car, notice how it feels as the car accelerates in each of these ways. For an interactive simulation about acceleration, go to this URL: http://phet.colorado.edu/en/simulation/moving-man .

## Calculating Acceleration

Calculating acceleration is complicated if both speed and direction are changing. It's easier to calculate acceleration when only speed is changing. To calculate acceleration without a change in direction, you just divide the change in velocity (represented by Δv) by the change in time (represented by Δt). The formula for acceleration in this case is:

$$\text{Acceleration} = \frac{\Delta \text{v}}{\Delta \text{t}}$$

Consider this example. The cyclist in **Figure** 12.12 speeds up as he goes downhill on this straight trail. His velocity changes from 1 meter per second at the top of the hill to 6 meters per second at the bottom. If it takes 5 seconds for him to reach the bottom, what is his acceleration, on average, as he flies down the hill?

$$\text{Acceleration} = \frac{\Delta \text{v}}{\Delta \text{t}} = \frac{6 \text{ m/s} - 1 \text{ m/s}}{5 \text{ s}} = \frac{5 \text{ m/s}}{5 \text{ s}} = \frac{1 \text{ m/s}}{1 \text{ m}} = 1 \text{ m/s}^2$$

In words, this means that for each second the cyclist travels downhill, his velocity increases by 1 meter per second (on average). The answer to this problem is expressed in the SI unit for acceleration: $\text{m/s}^2$ ("meters per second squared").

FIGURE 12.12
Gravity helps this cyclist increase his downhill velocity.

**You Try It!**

*Problem:* Tranh slowed his skateboard as he approached the street. He went from 8 m/s to 2 m/s in a period of 3 seconds. What was his acceleration?

## Velocity-Time Graphs

The acceleration of an object can be represented by a velocity–time graph like the one in **Figure** 12.13. A velocity-time graph shows how velocity changes over time. It is similar to a distance-time graph except the $y-$axis represents velocity instead of distance. The graph in **Figure** 12.13 represents the velocity of a sprinter on a straight track. The runner speeds up for the first 4 seconds of the race, then runs at a constant velocity for the next 3 seconds, and finally slows to a stop during the last 3 seconds of the race.

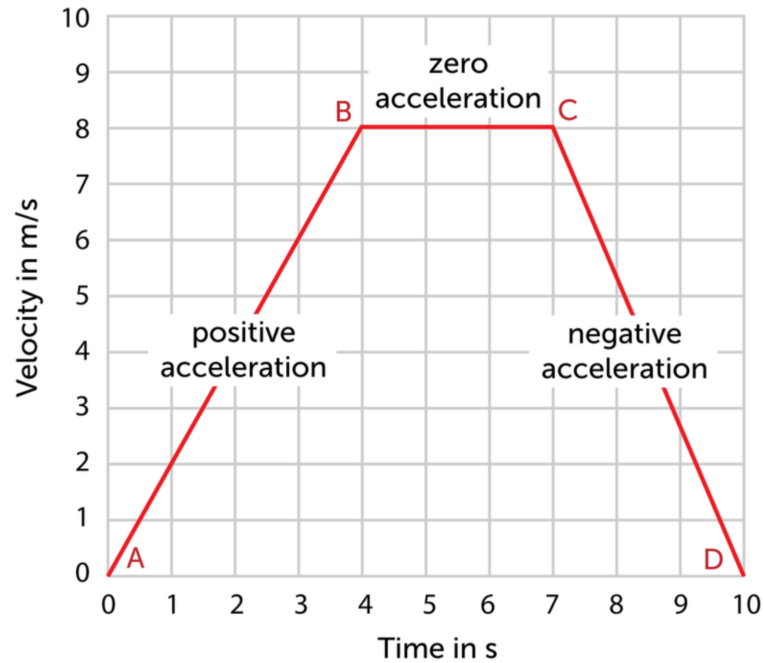


FIGURE 12.13
This graph shows how the velocity of a runner changes during a 10-second sprint.

In a velocity-time graph, acceleration is represented by the slope of the graph line. If the line slopes upward, like the line between A and B in **Figure** 12.13, velocity is increasing, so acceleration is positive. If the line is horizontal, as it is between B and C, velocity is not changing, so acceleration is zero. If the line slopes downward, like the line between C and D, velocity is decreasing, so acceleration is negative. You can review the concept of acceleration as well as other chapter concepts by watching the musical video at this URL: http://www.youtube.com/watch?v=4CWlNoNpXCc .

## Lesson Summary

- Acceleration is a measure of the change in velocity of a moving object. It shows how quickly velocity changes and whether the change is positive or negative. It may reflect a change in speed, a change in direction, or both.
- To calculate acceleration without a change in direction, divide the change in velocity by the change in time.
- The slope of a velocity-time graph represents acceleration.

## Lesson Review Questions

### Recall

1. What is acceleration?
2. How is acceleration calculated?
3. What does the slope of a velocity-time graph represent?

### Apply Concepts

4. The velocity of a car on a straight road changes from 0 m/s to 6 m/s in 3 seconds. What is its acceleration?

### Think Critically

5. Because of the pull of gravity, a falling object accelerates at 9.8 $m/s^2$. Create a velocity-time graph to represent this motion.

## Points to Consider

Acceleration occurs when a force is applied to a moving object.

- What is force? What are some examples of forces?
- What forces might change the velocity of a moving object? (*Hint*: Read the caption to **Figure** 12.12.)

# 12.4 References


1. Train: John H. Gray; Cyclist: Flickr:DieselDemon; Inchworm: Clinton Charles Robertson; Hummingbird: Kevin Cole; Cartwheeler: Clemens v. Vogelsang (Flickr:vauvau); Meteor: Ed Sweeney (Flickr:Navicore). Train: http://www.flickr.com/photos/8391775@N05/3494460809/; Cyclist: http://www.flickr.com/photos/28096801@N05/3530472429/; Inchworm: http://www.flickr.com/photos/dad_and_clint/3571033947/; Hummingbird: http://www.flickr.com/photos/kevcole/2840250013/; Cartwheeler: http://www.flickr.com/photos/vauvau/8057026163/; Meteor: http://www.flickr.com/photos/edsweeney/4111291263/ . CC BY 2.0
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# CHAPTER 13 Forces

## Chapter Outline



Each of these basketball players is trying to push the ball. One player is trying to push it into the basket, and the other player is trying to push it away from the basket. If both players push the ball at the same time, where will it go? It depends on which player pushes the ball with greater force. Forces like this come into play in every sport, whether it's kicking a soccer ball, throwing a baseball, or spiking a volleyball. Forces are involved not only in sports such as these but in every motion in our daily lives. In this chapter, you'll see how forces affect the motion of everything from basketballs to planets.

# 13.1 What Is Force?

## Lesson Objectives

- Define force, and give examples of forces.
- Describe how forces combine and affect motion.

## Lesson Vocabulary

- force
- net force
- newton (N)

## Introduction

Any time the motion of an object changes, a force has been applied. Force can cause a stationary object to start moving or a moving object to accelerate. The moving object may change its speed, its direction, or both. How much an object's motion changes when a force is applied depends on the strength of the force and the object's mass. You can explore the how force, mass, and acceleration are related by doing the activity at the URL http://www.harcourtschool.com/activity/newton/ . This will provide you with a good hands-on introduction to the concept of force in physics.

## Defining Force

**Force** is defined as a push or a pull acting on an object. Examples of forces include friction and gravity. Both are covered in detail later in this chapter. Another example of force is applied force. It occurs when a person or thing applies force to an object, like the girl pushing the swing in **Figure** 13.1. The force of the push causes the swing to move.

FIGURE 13.1
When this girl pushes the swing away from her, it causes the swing to move in that direction.

### Force as a Vector

Force is a vector because it has both size and direction. For example, the girl in **Figure** 13.1 is pushing the swing away from herself. That's the direction of the force. She can give the swing a strong push or a weak push. That's the size, or strength, of the force. Like other vectors, forces can be represented with arrows. **Figure** 13.2 shows some examples. The length of each arrow represents the strength of the force, and the way the arrow points represents the direction of the force. How could you use an arrow to represent the girl's push on the swing in **Figure** 13.1?

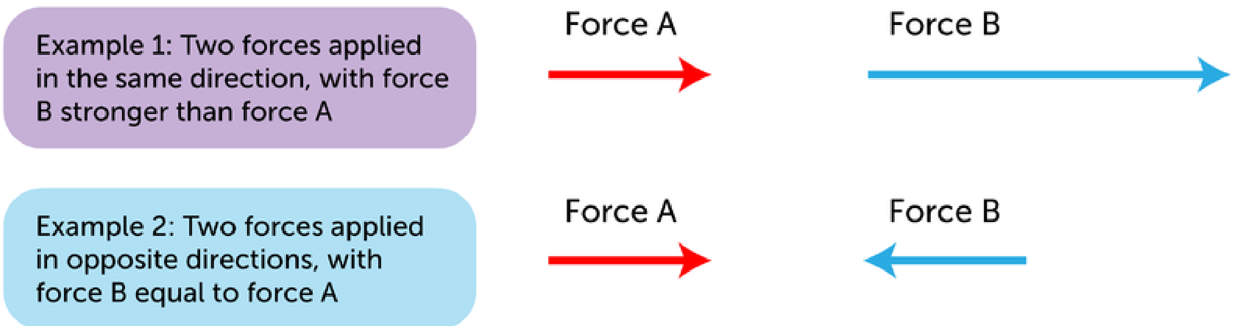



FIGURE 13.2
Forces can vary in both strength and direction.

### SI Unit of Force

The SI unit of force is the newton (N). One newton is the amount of force that causes a mass of 1 kilogram to accelerate at 1 m/s$^2$. Thus, the newton can also be expressed as kg·m/s$^2$. The newton was named for the scientist Sir Isaac Newton, who is famous for his law of gravity. You'll learn more about Sir Isaac Newton later in the chapter.

## Combining Forces

More than one force may act on an object at the same time. In fact, just about all objects on Earth have at least two forces acting on them at all times. One force is gravity, which pulls objects down toward the center of Earth. The other force is an upward force that may be provided by the ground or other surface.

Consider the example in **Figure** 13.3. A book is resting on a table. Gravity pulls the book downward with a force of 20 newtons. At the same time, the table pushes the book upward with a force of 20 newtons. The combined forces acting on the book —or any other object —are called the **net force**. This is the overall force acting on an object that takes into account all of the individual forces acting on the object. You can learn more about the concept of net force at this URL: http://www.mansfieldct.org/schools/mms/staff/hand/lawsunbalancedforce.htm .

### Forces Acting in Opposite Directions

When two forces act on an object in opposite directions, like the book on the table, the net force is equal to the difference between the two forces. In other words, one force is subtracted from the other to calculate the net force.

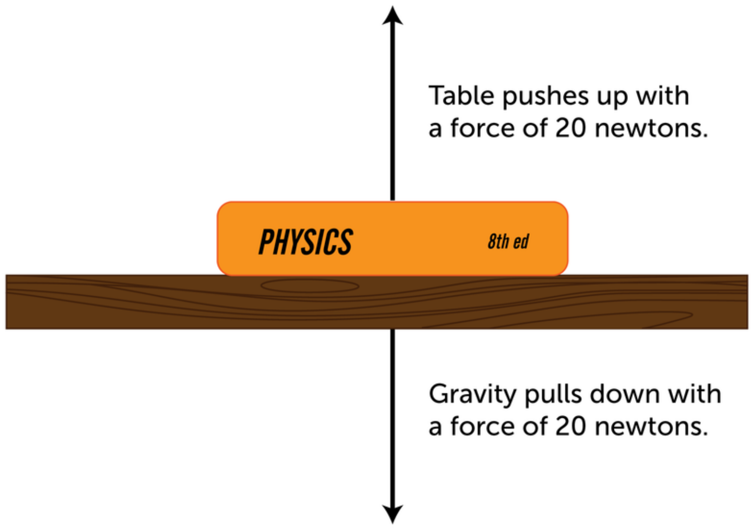



FIGURE 13.3
A book resting on a table is acted on by two opposing forces.

If the opposing forces are equal in strength, the net force is zero. That's what happens with the book on the table. The upward force minus the downward force equals zero (20 N up - 20 N down = 0 N). Because the forces on the book are balanced, the book remains on the table and doesn't move.

In addition to these downward and upward forces, which generally cancel each other out, forces may push or pull an object in other directions. Look at the dogs playing tug-of-war in **Figure** 13.4. One dog is pulling on the rope with a force of 10 newtons to the left. The other dog is pulling on the rope with a force of 12 newtons to the right. These opposing forces are not equal in strength, so they are unbalanced. When opposing forces are unbalanced, the net force is greater than zero. The net force on the rope is 2 newtons to the right, so the rope will move to the right.

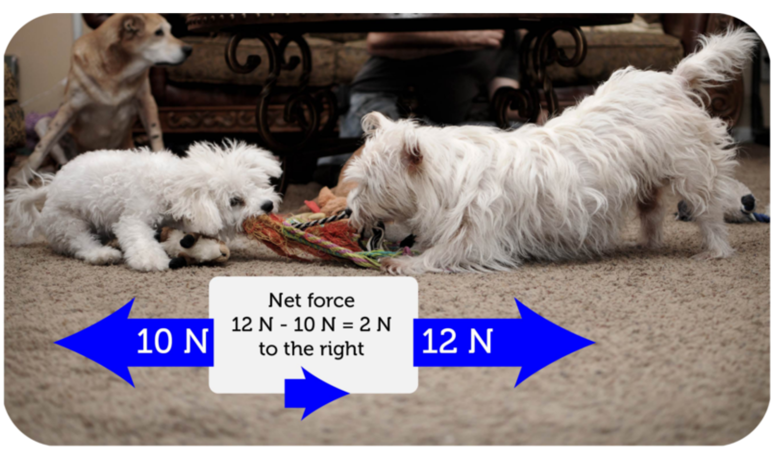



FIGURE 13.4
When unbalanced forces are applied to an object in opposite directions, the smaller force is subtracted from the larger force to yield the net force.

## Forces Acting in the Same Direction

Two forces may act on an object in the same direction. You can see an example of this in **Figure** 13.5. After the man on the left lifts up the couch, he will push the couch to the right with a force of 25 newtons. At the same time, the man to the right is pulling the couch to the right with a force of 20 newtons. When two forces act in the same direction, the net force is equal to the sum of the forces. This always results in a stronger force than either of the individual forces alone. In this case, the net force on the couch is 45 newtons to the right, so the couch will move to the right.

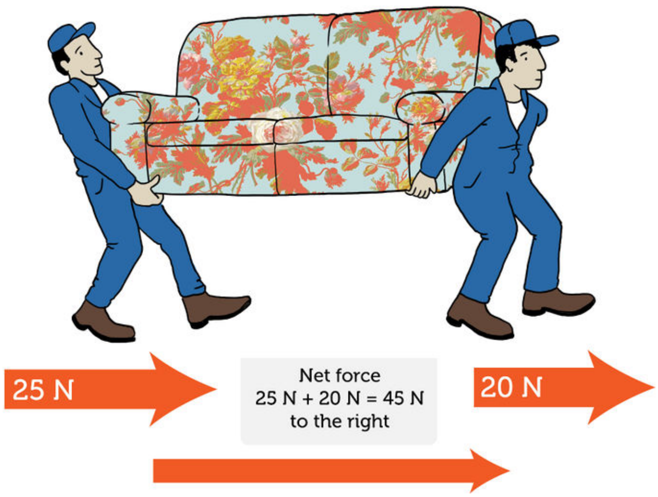
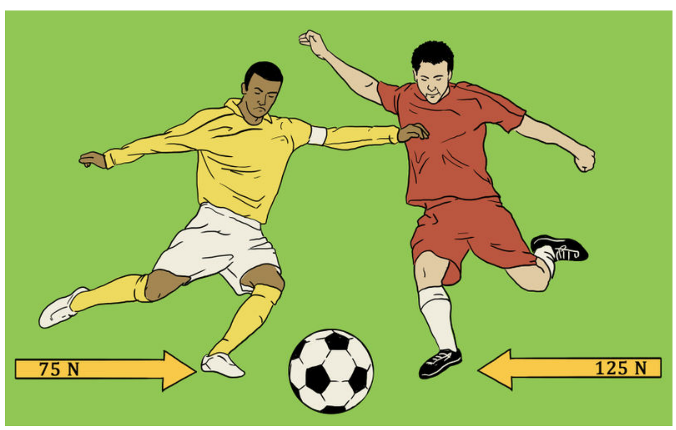



FIGURE 13.5
When two forces are applied to an object in the same direction, the two forces are added to yield the net force.

**You Try It!**




*Problem*: The boys in the drawing above are about to kick the soccer ball in opposite directions. What will be the net force on the ball? In which direction will the ball move?

If you need more practice calculating net force, go to this URL: http://www.physicsclassroom.com/class/newtlaws/U2L2d.cfm .

## Lesson Summary

- Force is a push or a pull acting on an object. Examples of force include friction and gravity. Force is a vector because it has both size and direction. The SI unit of force is the newton (N).
- The combined forces acting on an object are called the net force. When forces act in opposite directions, they are subtracted to yield the net force. When they act in the same direction, they are added to yield the net force.

## Lesson Review Questions

### Recall

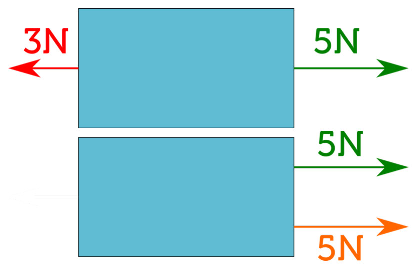
1. Define force. Give an example of a force.
2. What is a newton?
3. What is net force?
4. Describe an example of balanced forces and an example of unbalanced forces.

### Apply Concepts

5. What is the net force acting on the block in each diagram below?

a.

b.




### Think Critically

6. Explain how forces are related to motion.

## Points to Consider

In the next lesson, "Friction," you will read about the force of friction. You experience this force every time you walk. It prevents your feet from slipping out from under you.

- How would you define friction?
- What do you think causes this force?

# 13.2 Friction

## Lesson Objectives

- Describe friction and how it opposes motion.
- Identify types of friction.

## Lesson Vocabulary

- fluid
- friction

## Introduction

Did you ever rub your hands together to warm them up, like the girl in **Figure** 13.6? Why does this make your hands warmer? The answer is friction.

FIGURE 13.6
This girl is using friction to make her hands warmer.

## What Is Friction?

**Friction** is a force that opposes motion between two surfaces that are touching. Friction can work for or against us. For example, putting sand on an icy sidewalk increases friction so you are less likely to slip. On the other hand, too much friction between moving parts in a car engine can cause the parts to wear out. Other examples of friction are illustrated in **Figure** 13.7. You can see an animation showing how friction opposes motion at this URL: http://www.darvill.clara.net/enforcemot/friction.htm .


FIGURE 13.7

Sometimes friction is useful. Sometimes it's not.

### Why Friction Occurs

Friction occurs because no surface is perfectly smooth. Even surfaces that look smooth to the unaided eye appear rough or bumpy when viewed under a microscope. Look at the metal surfaces in **Figure** 13.8. The metal foil is so smooth that it is shiny. However, when highly magnified, the surface of metal appears to be very bumpy. All those mountains and valleys catch and grab the mountains and valleys of any other surface that contacts the metal. This creates friction.

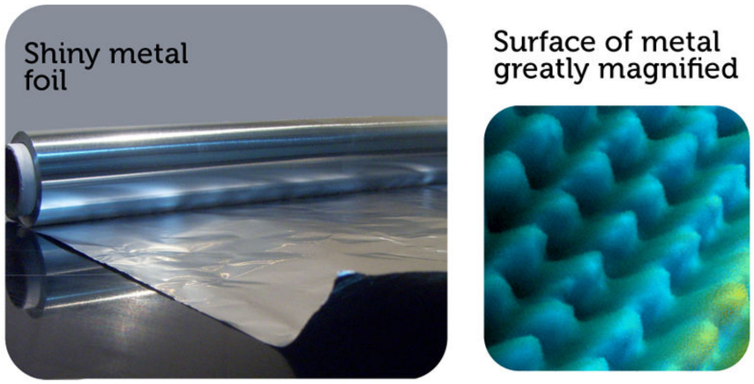



FIGURE 13.8
The surface of metal looks very smooth unless you look at it under a high-powered microscope.

### Factors That Affect Friction

Rougher surfaces have more friction between them than smoother surfaces. That's why we put sand on icy sidewalks and roads. The blades of skates are much smoother than the soles of shoes. That's why you can't slide as far across ice with shoes as you can with skates (see **Figure** 13.9). The rougher surface of shoes causes more friction and slows you down. Heavier objects also have more friction because they press together with greater force. Did you ever try to push boxes or furniture across the floor? It's harder to overcome friction between heavier objects and the floor than it is between lighter objects and the floor.

FIGURE 13.9
The knife-like blades of speed skates minimize friction with the ice.

### Friction Produces Heat

You know that friction produces heat. That's why rubbing your hands together makes them warmer. But do you know why the rubbing produces heat? Friction causes the molecules on rubbing surfaces to move faster, so they have more heat energy. Heat from friction can be useful. It not only warms your hands. It also lets you light a match (see **Figure** 13.10). On the other hand, heat from friction can be a problem inside a car engine. It can cause the car to overheat. To reduce friction, oil is added to the engine. Oil coats the surfaces of moving parts and makes them slippery so there is less friction.


FIGURE 13.10
When you rub the surface of a match head across the rough striking surface on the matchbox, the friction produces enough heat to ignite the match.

## Types of Friction

There are different ways you could move heavy boxes. You could pick them up and carry them. You could slide them across the floor. Or you could put them on a dolly like the one in **Figure** 13.11 and roll them across the floor. This example illustrates three types of friction: static friction, sliding friction, and rolling friction. Another type of friction is fluid friction. All four types of friction are described below. In each type, friction works opposite the direction of the force applied to a move an object. You can see a video demonstration of the different types of friction at this URL: http://www.youtube.com/watch?v=0bXpYblzkR0 (1:07).

FIGURE 13.11
A dolly with wheels lets you easily roll boxes across the floor.

### Static Friction

Static friction acts on objects when they are resting on a surface. For example, if you are walking on a sidewalk, there is static friction between your shoes and the concrete each time you put down your foot (see **Figure** 13.12). Without this static friction, your feet would slip out from under you, making it difficult to walk. Static friction also allows you to sit in a chair without sliding to the floor. Can you think of other examples of static friction?

FIGURE 13.12
Static friction between shoes and the sidewalk makes it possible to walk without slipping.

### Sliding Friction

Sliding friction is friction that acts on objects when they are sliding over a surface. Sliding friction is weaker than static friction. That's why it's easier to slide a piece of furniture over the floor after you start it moving than it is to get it moving in the first place. Sliding friction can be useful. For example, you use sliding friction when you write with a pencil and when you put on your bike's brakes.

### Rolling Friction

Rolling friction is friction that acts on objects when they are rolling over a surface. Rolling friction is much weaker than sliding friction or static friction. This explains why it is much easier to move boxes on a wheeled dolly than by carrying or sliding them. It also explains why most forms of ground transportation use wheels, including cars, 4-wheelers, bicycles, roller skates, and skateboards. Ball bearings are another use of rolling friction (see **Figure** 13.13). They allow parts of a wheel or other machine to roll rather than slide over one another.

### Fluid Friction

Fluid friction is friction that acts on objects that are moving through a fluid. A **fluid** is a substance that can flow and take the shape of its container. Fluids include liquids and gases. If you've ever tried to push your open hand through the water in a tub or pool, then you've experienced fluid friction between your hand and the water. When a skydiver is falling toward Earth with a parachute, fluid friction between the parachute and the air slows the descent (see **Figure** 13.14). Fluid pressure with the air is called air resistance. The faster or larger a moving object is, the

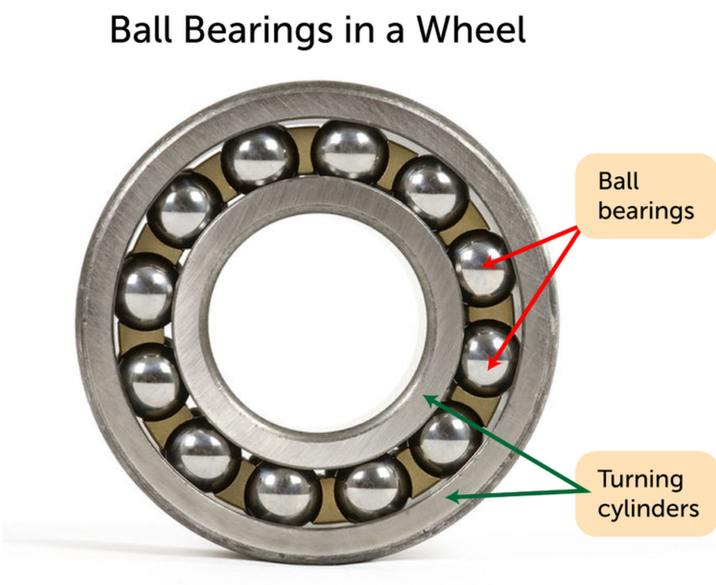



FIGURE 13.13
The ball bearings in this wheel reduce friction between the inner and outer cylinders when they turn.

greater is the fluid friction resisting its motion. The very large surface area of a parachute, for example, has greater air resistance than a skydiver's body.

## Lesson Summary

- Friction is a force that opposes motion between two surfaces that are touching. Friction occurs because no surface is perfectly smooth. Friction is greater when objects have rougher surfaces or are heavier so they press together with greater force.
- Types of friction include static friction, sliding friction, rolling friction, and fluid friction. Fluid friction with air is called air resistance.

## Lesson Review Questions

### Recall

1. What is friction?
2. List factors that affect friction.
3. How does friction produce heat?

### Apply Concepts

4. Identify two forms of friction that oppose the motion of a moving car.

FIGURE 13.14
Fluid friction of the parachute with the air slows this skydiver as he falls.

### Think Critically

5. Explain why friction occurs.
6. Compare and contrast the four types of friction described in this lesson.

## Points to Consider

A skydiver like the one in **Figure** 13.14 falls to the ground despite the fluid friction of his parachute with the air. Another force pulls him toward Earth. That force is gravity, which is the topic of the next lesson.

- What do you already know about gravity?
- What do you think causes gravity?

# 13.3 Gravity

## Lesson Objectives

- Define gravity.
- State Newton's law of universal gravitation.
- Explain how gravity affects the motion of objects.

## Lesson Vocabulary

- gravity
- law of universal gravitation
- orbit
- projectile motion

## Introduction

Long, long ago, when the universe was still young, an incredible force caused dust and gas particles to pull together to form the objects in our solar system (see **Figure** 13.15). From the smallest moon to our enormous sun, this force created not only our solar system, but all the solar systems in all the galaxies of the universe. The force is gravity.

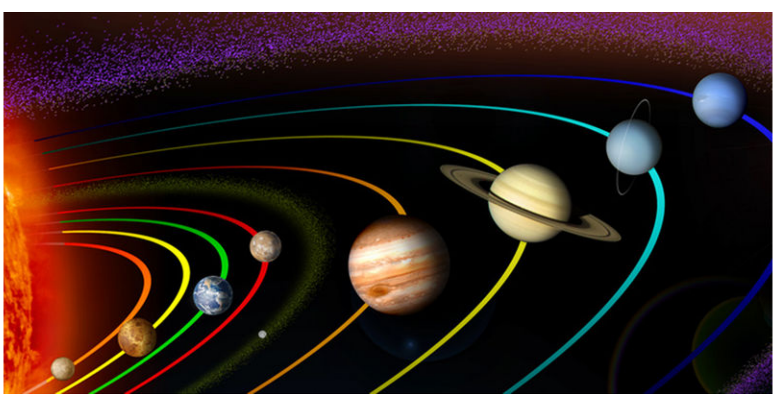


FIGURE 13.15
Gravity helped to form our solar system and all the other solar systems in the universe.

## Defining Gravity

**Gravity** has traditionally been defined as a force of attraction between two masses. According to this conception of gravity, anything that has mass, no matter how small, exerts gravity on other matter. The effect of gravity is that objects exert a pull on other objects. Unlike friction, which acts only between objects that are touching, gravity also acts between objects that are not touching. In fact, gravity can act over very long distances.

### Earth's Gravity

You are already very familiar with Earth's gravity. It constantly pulls you toward the center of the planet. It prevents you and everything else on Earth from being flung out into space as the planet spins on its axis. It also pulls objects above the surface, from meteors to skydivers, down to the ground. Gravity between Earth and the moon and between Earth and artificial satellites keeps all these objects circling around Earth. Gravity also keeps Earth moving around the sun.

### Gravity and Weight

Weight measures the force of gravity pulling on an object. Because weight measures force, the SI unit for weight is the **newton (N)**. On Earth, a mass of 1 kilogram has a weight of about 10 newtons because of the pull of Earth's gravity On the moon, which has less gravity, the same mass would weigh less. Weight is measured with a scale, like the spring scale in **Figure** 13.16. The scale measures the force with which gravity pulls an object downward.

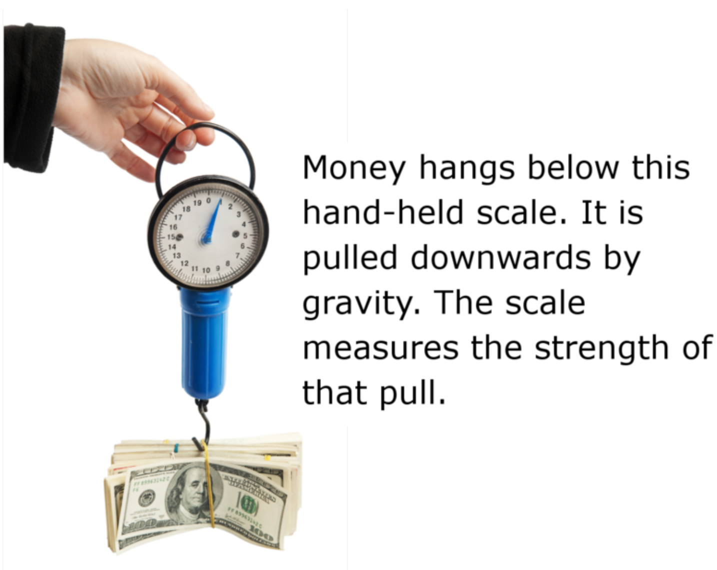



FIGURE 13.16
A scale measures the pull of gravity on an object.

## Law of Gravity

People have known about gravity for thousands of years. After all, they constantly experienced gravity in their daily lives. They knew that things always fall toward the ground. However, it wasn't until Sir Isaac Newton developed his law of gravity in the late 1600s that people really began to understand gravity. Newton is pictured in **Figure** 13.17.

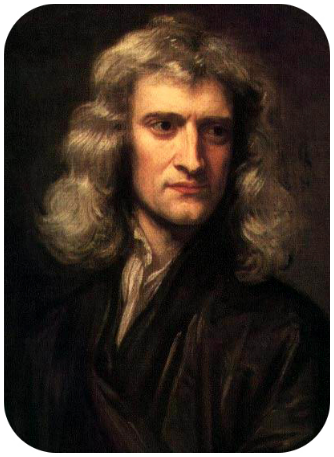


FIGURE 13.17
Sir Isaac Newton discovered that gravity is universal.

### Newton's Law of Universal Gravitation

Newton was the first one to suggest that gravity is universal and affects all objects in the universe. That's why his law of gravity is called the **law of universal gravitation**. Universal gravitation means that the force that causes an apple to fall from a tree to the ground is the same force that causes the moon to keep moving around Earth. Universal gravitation also means that while Earth exerts a pull on you, you exert a pull on Earth. In fact, there is gravity between you and every mass around you —your desk, your book, your pen. Even tiny molecules of gas are attracted to one another by the force of gravity.

Newton's law had a huge impact on how people thought about the universe. It explains the motion of objects not only on Earth but in outer space as well. You can learn more about Newton's law of gravity in the video at this URL: http://www.youtube.com/watch?v=O-p8yZYxNGc .

### Factors That Influence the Strength of Gravity

Newton's law also states that the strength of gravity between any two objects depends on two factors: the masses of the objects and the distance between them.

- Objects with greater mass have a stronger force of gravity. For example, because Earth is so massive, it attracts you and your desk more strongly than you and your desk attract each other. That's why you and the desk remain in place on the floor rather than moving toward one another.
- Objects that are closer together have a stronger force of gravity. For example, the moon is closer to Earth than it is to the more massive sun, so the force of gravity is greater between the moon and Earth than between the moon and the sun. That's why the moon circles around Earth rather than the sun. This is illustrated in **Figure** 13.18.

You can apply these relationships among mass, distance, and gravity by designing your own roller coaster at this URL: http://www.learner.org/interactives/parkphysics/coaster/ .

### Einstein's Theory of Gravity

Newton's idea of gravity can predict the motion of most but not all objects. In the early 1900s, Albert Einstein came up with a theory of gravity that is better at predicting how all objects move. Einstein showed mathematically that gravity is not really a force in the sense that Newton thought. Instead, gravity is a result of the warping, or curving,

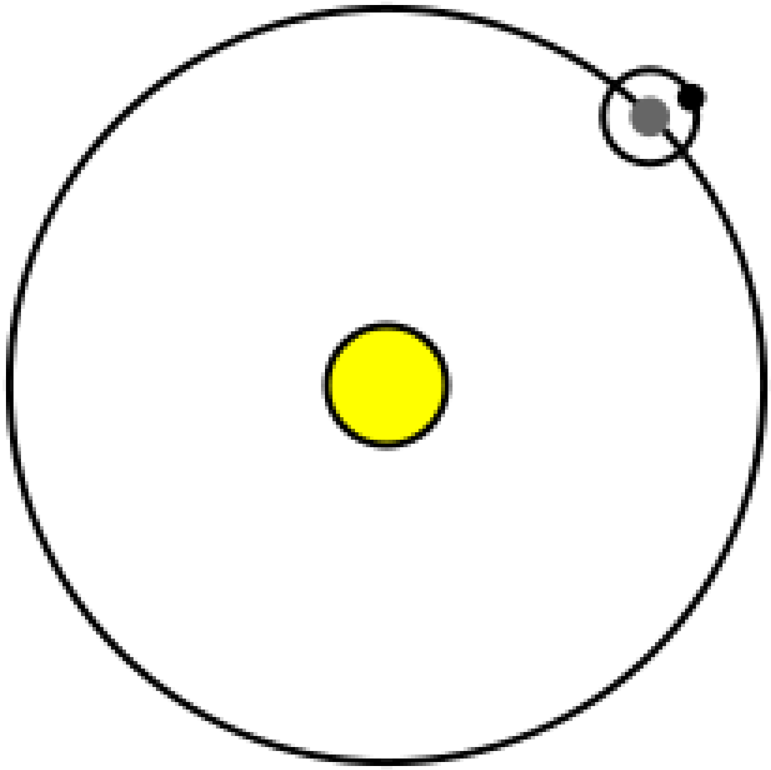


FIGURE 13.18
The moon keeps moving around Earth rather than the sun because it is much closer to Earth.

of space and time. Imagine a bowling ball pressing down on a trampoline. The surface of the trampoline would curve downward instead of being flat. Einstein theorized that Earth and other very massive bodies affect space and time around them in a similar way. This idea is represented in **Figure** 13.19. According to Einstein, objects curve toward one another because of the curves in space and time, not because they are pulling on each other with a force of attraction as Newton thought. You can see an animation of Einstein's theory of gravity at this URL: http://einstein.stanford.edu/Media/Einsteins_Universe_Anima-Flash.html . To learn about recent research that supports Einstein's theory of gravity, go to this URL: http://www.universetoday.com/85401/gravity-probe-b-confirms-two-of-einsteins-space-time-theories/ .

## Gravity and Motion

Regardless of what gravity is —a force between masses or the result of curves in space and time —the effects of gravity on motion are well known. You already know that gravity causes objects to fall down to the ground. Gravity affects the motion of objects in other ways as well.

### Acceleration Due to Gravity

When gravity pulls objects toward the ground, it causes them to accelerate. Acceleration due to gravity equals 9.8 $m/s^2$. In other words, the velocity at which an object falls toward Earth increases each second by 9.8 m/s. Therefore, after 1 second, an object is falling at a velocity of 9.8 m/s. After 2 seconds, it is falling at a velocity of 19.6 m/s (9.8 m/s $\times$ 2), and so on. This is illustrated in **Figure** 13.20. You can compare the acceleration due to gravity on Earth, the moon, and Mars with the interactive animation called "Freefall" at this URL: http://jersey.uoregon.edu/vlab/ .

You might think that an object with greater mass would accelerate faster than an object with less mass. After all, its

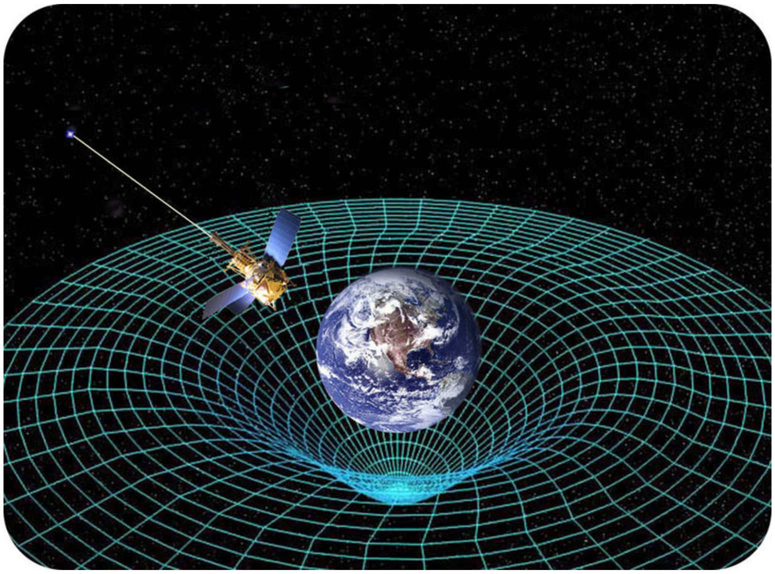


FIGURE 13.19
Einstein thought that gravity is the effect of curves in space and time around massive objects such as Earth. He proposed that the curves in space and time cause nearby objects to follow a curved path. How does this differ from Newton's idea of gravity?

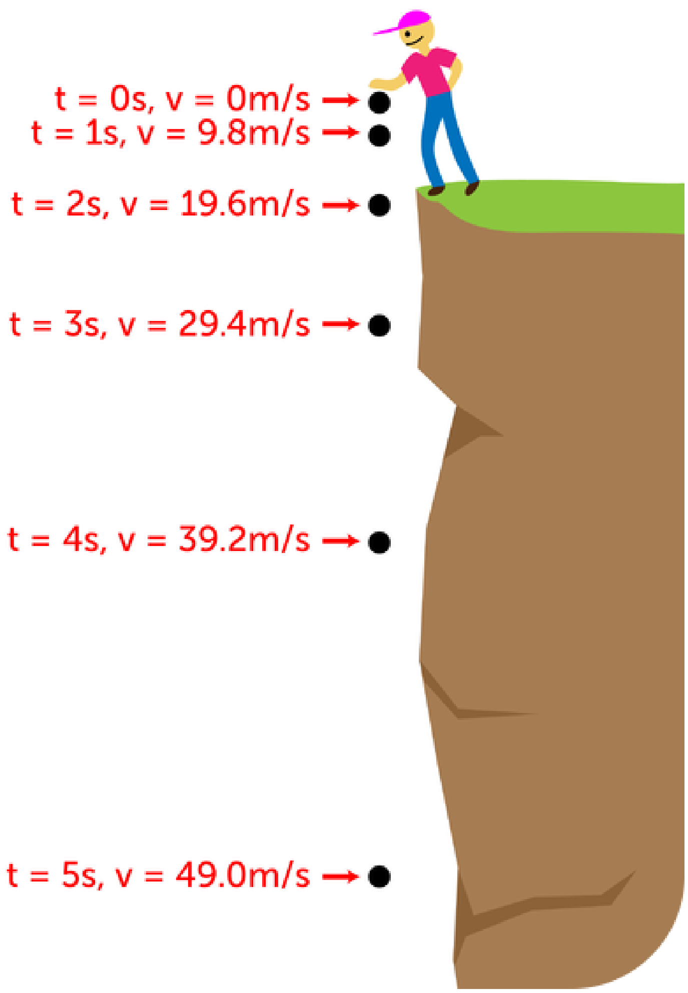



FIGURE 13.20
A boy drops an object at time t = 0 s. At time t = 1 s, the object is falling at a velocity of 9.8 m/s. What is its velocity by time t = 5 ?

greater mass means that it is pulled by a stronger force of gravity. However, a more massive object accelerates at the same rate as a less massive object. The reason? The more massive object is harder to move because of its greater mass. As a result, it ends up moving at the same acceleration as the less massive object.

Consider a bowling ball and a basketball. The bowling ball has greater mass than the basketball. However, if you were to drop both balls at the same time from the same distance above the ground, they would reach the ground together. This is true of all falling objects, unless air resistance affects one object more than another. For example, a falling leaf is slowed down by air resistance more than a falling acorn because of the leaf's greater surface area. However, if the leaf and acorn were to fall in the absence of air (that is, in a vacuum), they would reach the ground at the same time.

### Projectile Motion

Earth's gravity also affects the acceleration of objects that start out moving horizontally, or parallel to the ground. Look at **Figure** 13.21. A cannon shoots a cannon ball straight ahead, giving the ball horizontal motion. At the same time, gravity pulls the ball down toward the ground. Both forces acting together cause the ball to move in a curved path. This is called **projectile motion**.

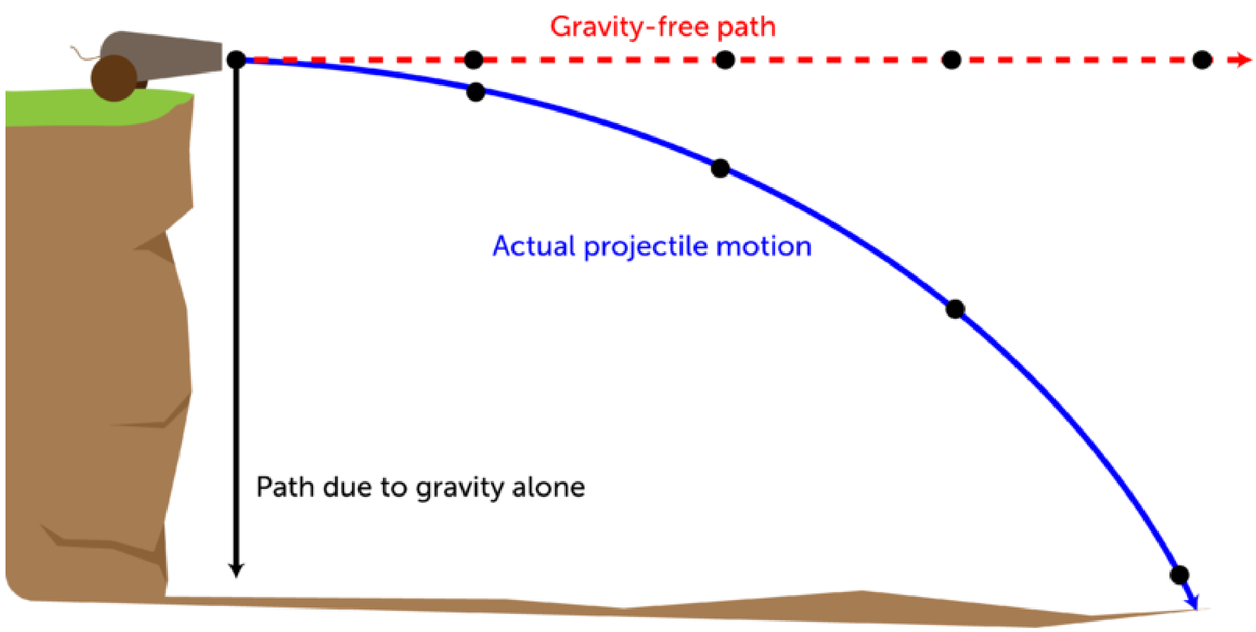



FIGURE 13.21
The cannon ball moves in a curved path because of the combined horizontal and downward forces.

Projectile motion also applies to other moving objects, such as arrows shot from a bow. To hit the bull's eye of a target with an arrow, you actually have to aim for a spot above the bull's eye. That's because by the time the arrow reaches the target, it has started to curve downward toward the ground. **Figure** 13.22 shows what happens if you aim at the bull's eye instead of above it. You can access interactive animations of projectile motion at these URLs:

- http://phet.colorado.edu/en/simulation/projectile-motion
- http://jersey.uoregon.edu/vlab/ *(Select the applet entitled "Cannon.")*

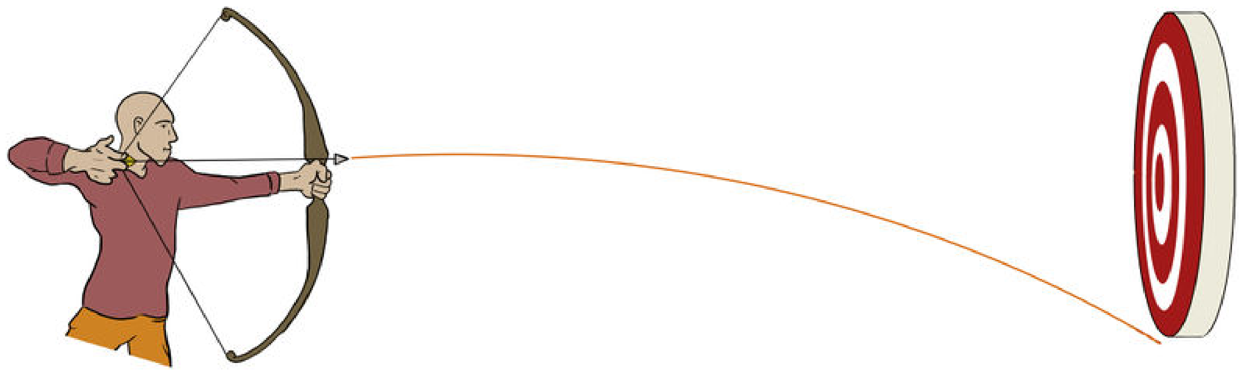


FIGURE 13.22

Aiming at the center of a target is likely to result in a hit below the bull's eye.

## Orbital Motion

The moon moves around Earth in a circular path called an **orbit**. Why doesn't Earth's gravity pull the moon down to the ground instead? The moon has enough forward velocity to partly counter the force of Earth's gravity. It constantly falls toward Earth, but it stays far enough away from Earth so that it actually falls around the planet. As a result, the moon keeps orbiting Earth and never crashes into it. The diagram in **Figure** 13.23 shows how this happens. You can explore gravity and orbital motion in depth with the animation at this URL: http://phet.colorado.edu/en/simulation/gravity-and-orbits .

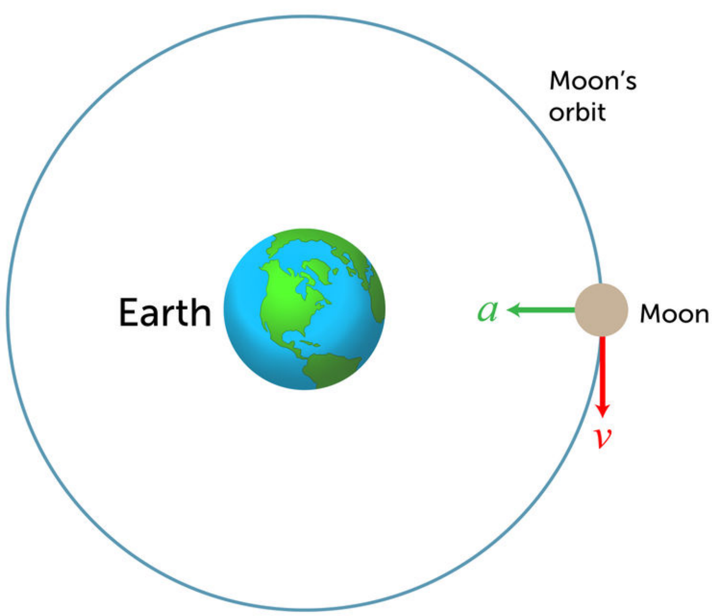



FIGURE 13.23

In this diagram, "v" represents the forward velocity of the moon, and "a" represents the acceleration due to gravity. The line encircling Earth shows the moon's actual orbit, which results from the combination of "v" and "a."

You can see an animated version of this diagram at: http://en.wikipedia.org/wiki/File:Orbital_motion.gif .

## Lesson Summary

- Gravity is traditionally defined as a force of attraction between two masses. Weight measures the force of gravity and is expressed in newtons (N).
- According to Newton's law of universal gravitation, gravity is a force of attraction between all objects in the universe, and the strength of gravity depends on the masses of the objects and the distance between them. Einstein's theory of gravity states that gravity is an effect of curves in space and time around massive objects such as Earth.
- Gravity causes falling objects to accelerate at 9.8 $m/s^2$. Gravity also causes projectile motion and orbital motion.

## Lesson Review Questions

### Recall

1. What is the traditional definition of gravity?
2. How is weight related to gravity?
3. Summarize Newton's law of universal gravitation.
4. Describe Einstein's idea of gravity.

### Apply Concepts

5. Create a poster to illustrate the concept of projectile motion.

### Think Critically

6. In the absence of air, why does an object with greater mass fall toward Earth at the same acceleration as an object with less mass?
7. Explain why the moon keeps orbiting Earth.

## Points to Consider

The scale you saw in **Figure** 13.16 contains a spring. When an object hangs from the scale, the spring exerts an upward force that partly counters the downward force of gravity. The type of force exerted by a spring is called elastic force, which is the topic of the next lesson.

- Besides springs, what other objects do you think might exert elastic force?
- What other ways might you use elastic force?

# 13.4 Elastic Force

## Lesson Objectives

- Define elasticity and elastic force.
- Describe uses of elastic force.

## Lesson Vocabulary

- elastic force
- elasticity

## Introduction

The boy in **Figure** 13.24 has a newspaper route. Every morning, he rolls up newspapers for his customers and puts rubber bands around them. The rubber bands keep the newspapers tightly rolled up so it is easy to toss them onto porches and driveways as the boy rides by on his bike. Rubber bands are useful for this purpose because they are elastic.

FIGURE 13.24
A stretchy rubber band holds this newspaper in a tight roll.

## Elasticity and Elastic Force

Something that is elastic can return to its original shape after being stretched or compressed. This property is called **elasticity**. As you stretch or compress an elastic material, it resists the change in shape. It exerts a counter force in the opposite direction. This force is called **elastic force**. Elastic force causes the material to spring back to its original shape as soon as the stretching or compressing force is released. You can watch a demonstration of elastic force at this URL: http://www.youtube.com/watch?v=fFtM9JznLh8 (3:57).

MEDIA

Click image to the left for use the URL below.

URL: http://www.ck12.org/flx/render/embeddedobject/5024

## Using Elastic Force

Elastic force can be very useful. You probably use it yourself every day. A few common uses of elastic force are pictured in **Figure** 13.25. Did you ever use a resistance band like the one in the figure? When you pull on the band, it stretches but doesn't break. The resistance you feel when you pull on it is elastic force. The resistance of the band to stretching is what gives your muscles a workout. After you stop pulling on the band, it returns to its original shape, ready for the next workout.

Springs like the ones in **Figure** 13.26 also have elastic force when they are stretched or compressed. And like stretchy materials, they return to their original shape when the stretching or compressing force is released. Because of these properties, springs are used in scales to measure weight. They also cushion the ride in a car and provide springy support beneath a mattress. Can you think of other uses of springs?

## Lesson Summary

- Elasticity is the ability of a material to return to its original shape after being stretched or compressed. Elastic force is the counter force that resists the stretching or compressing of an elastic material.
- Elastic force is very useful. It is used in rubber bands, bungee cords, and bed springs, to name just a few uses.

## Lesson Review Questions

### Recall

1. What is elasticity?
2. Describe elastic force.
3. Identify uses of elastic force.


FIGURE 13.25
All these items are useful because they can be stretched and then return to their original shape.

FIGURE 13.26
Springs are useful because they return to their original shape after being stretched or compressed.

## Apply Concepts

4. Think of a way you could demonstrate elastic force to a younger student. Describe the procedure you would follow and the materials you would use.

### Think Critically

5. Explain how springs are used in scales to measure weight.

## Points to Consider

In this chapter, you read about Newton's law of universal gravitation. Newton developed several other laws as well. In the next chapter, "Newton's Laws of Motion," you'll read about his three laws of motion. Recall what you already know about motion.

- What is motion? What are examples of motion?
- What causes changes in motion? What are changes in motion called?

# 13.5 References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# CHAPTER 14 Newton's Laws of Motion

## Chapter Outline



The sprinter in this photo is pushing off from the blocks at the start of a race. The blocks provide a counter force so she can take off in a hurry. With great effort, she will go from motionless to top speed in just a few seconds. She won't slow down until she crosses the finish line. By then, she will be going so fast that it will take her almost as much time to come to a full stop as it did to run the race.

No doubt you've experienced motions like these, even if you've never run a race. But do you know what explains these motions? For example, do you know why it's as hard to stop running as it is to start? These and other aspects of motion are explained by three laws of motion. The laws were developed by Sir Isaac Newton in the late 1600s. You'll learn about Newton's laws of motion in this chapter and how and why objects move as they do.

# 14.1 Newton's First Law

## Lesson Objectives

- State Newton's first law of motion.
- Define inertia, and explain its relationship to mass.

## Lesson Vocabulary

- inertia
- Newton's first law of motion

## Introduction

The amusement park ride pictured in **Figure** 14.1 keeps changing direction as it zooms back and forth. Each time it abruptly switches direction, the riders are forced to the opposite side of the car. What force causes this to happen? In this lesson, you'll find out.

FIGURE 14.1

Amusement park rides like this one are exciting because of the strong forces the riders feel.

## Force and Motion

**Newton's first law of motion** states that an object's motion will not change unless an unbalanced force acts on the object. If the object is at rest, it will stay at rest. If the object is in motion, it will stay in motion and its velocity will remain the same. In other words, neither the direction nor the speed of the object will change as long as the net force acting on it is zero. You can watch a video about Newton's first law at this URL: http://videos.howstuffworks.com/discovery/29382-assignment-discovery-newtons-first-law-video.htm .

Look at the pool balls in **Figure** 14.2. When a pool player pushes the pool stick against the white ball, the white ball is set into motion. Once the white ball is rolling, it rolls all the way across the table and stops moving only after it crashes into the cluster of colored balls. Then, the force of the collision starts the colored balls moving. Some may roll until they bounce off the raised sides of the table. Some may fall down into the holes at the edges of the table. None of these motions will occur, however, unless that initial push of the pool stick is applied. As long as the net force on the balls is zero, they will remain at rest.

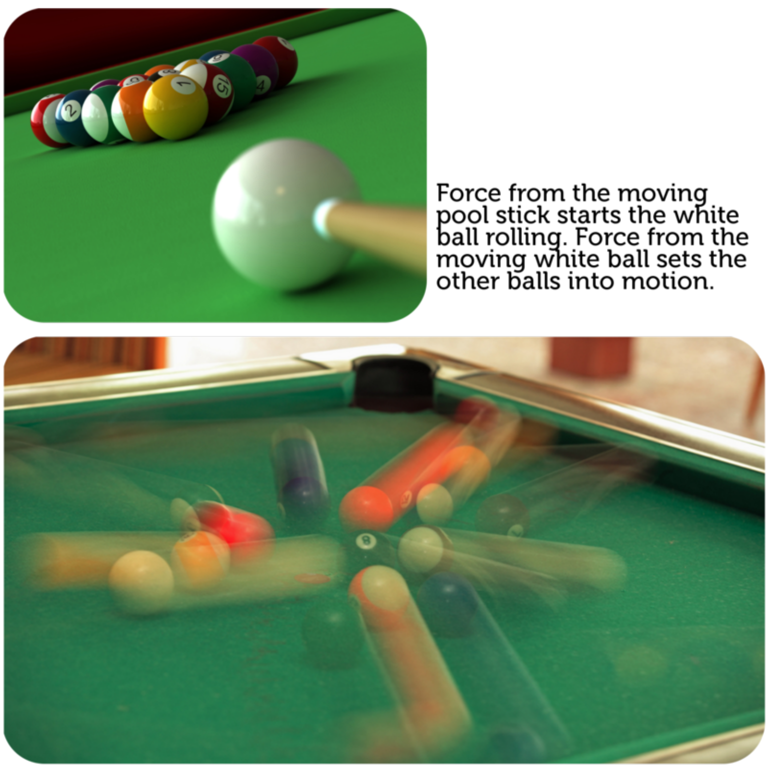


FIGURE 14.2
Pool balls remain at rest until an unbalanced force is applied to them. After they are in motion, they stay in motion until another force opposes their motion.

## Inertia

Newton's first law of motion is also called the law of inertia. **Inertia** is the tendency of an object to resist a change in its motion. If an object is already at rest, inertia will keep it at rest. If the object is already moving, inertia will keep it moving.

Think about what happens when you are riding in a car that stops suddenly. Your body moves forward on the seat. Why? The brakes stop the car but not your body, so your body keeps moving forward because of inertia. That's why it's important to always wear a seat belt. Inertia also explains the amusement park ride in **Figure** 14.1. The car keeps changing direction, but the riders keep moving in the same direction as before. They slide to the opposite side of the car as a result. You can see an animation of inertia at this URL: http://www.physicsclassroom.com/mmedia/newtlaws/cci.cfm .

### Inertia and Mass

The inertia of an object depends on its mass. Objects with greater mass also have greater inertia. Think how hard it would be to push a big box full of books, like the one in **Figure** 14.3. Then think how easy it would be to push the box if it was empty. The full box is harder to move because it has greater mass and therefore greater inertia.

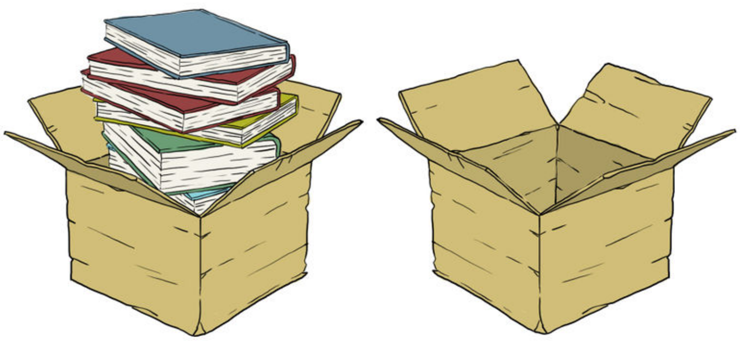

FIGURE 14.3
The tendency of an object to resist a change in its motion depends on its mass. Which box has greater inertia?

### Overcoming Inertia

To change the motion of an object, inertia must be overcome by an unbalanced force acting on the object. Until the soccer player kicks the ball in **Figure** 14.4, the ball remains motionless on the ground. However, when the ball is kicked, the force on it is suddenly unbalanced. The ball starts moving across the field because its inertia has been overcome.

FIGURE 14.4
Force must be applied to overcome the inertia of a soccer ball at rest.

Once objects start moving, inertia keeps them moving without any additional force being applied. In fact, they won't stop moving unless another unbalanced force opposes their motion. What if the rolling soccer ball is not kicked by another player or stopped by a fence or other object? Will it just keep rolling forever? It would if another unbalanced force did not oppose its motion. Friction —in this case rolling friction with the ground —will oppose the motion of the rolling soccer ball. As a result, the ball will eventually come to rest. Friction opposes the motion of all moving objects, so, like the soccer ball, all moving objects eventually come to a stop even if no other forces oppose their motion.

## Lesson Summary

- Newton's first law of motion states that an object's motion will not change unless an unbalanced force acts on the object. If the object is at rest, it will stay at rest. If the object is in motion, it will stay in motion.
- Inertia is the tendency of an object to resist a change in its motion. The inertia of an object depends on its mass. Objects with greater mass have greater inertia. To overcome inertia, an unbalanced force must be applied to an object.

## Lesson Review Questions

### Recall

1. State Newton's first law of motion.
2. Define inertia.
3. How does an object's mass affect its inertia?

### Apply Concepts

4. Assume you are riding a skateboard and you run into a curb. Your skateboard suddenly stops its forward motion. Apply the concept of inertia to this scenario, and explain what happens next.

### Think Critically

5. Why is Newton's first law of motion also called the law of inertia?

## Points to Consider

In this lesson, you read that the mass of an object determines its inertia. You also learned that an unbalanced force must be applied to an object to overcome its inertia, whether it is moving or at rest. An unbalanced force causes an object to accelerate.

- Predict how the mass of an object affects its acceleration when an unbalanced force is applied to it.
- How do you think the acceleration of an object is related to the strength of the unbalanced force acting on it?

# 14.2 Newton's Second Law

## Lesson Objectives

- State Newton's second law of motion.
- Identify the relationship between acceleration and weight.

## Lesson Vocabulary

- Newton's second law of motion

## Introduction

A car's gas pedal, like the one in **Figure** 14.5, is sometimes called the accelerator. That's because it controls the acceleration of the car. Pressing down on the gas pedal gives the car more gas and causes the car to speed up. Letting up on the gas pedal gives the car less gas and causes the car to slow down. Whenever an object speeds up, slows down, or changes direction, it accelerates. Acceleration is a measure of the change in velocity of a moving object. Acceleration occurs whenever an object is acted upon by an unbalanced force.

FIGURE 14.5
The car pedal on the right controls the amount of gas the engine gets. How does this affect the car's acceleration?

## Acceleration, Force, and Mass

Newton determined that two factors affect the acceleration of an object: the net force acting on the object and the object's mass. The relationships between these two factors and motion make up **Newton's second law of motion**. This law states that the acceleration of an object equals the net force acting on the object divided by the object's mass. This can be represented by the equation:

$$\text{Acceleration} = \frac{\text{Net force}}{\text{Mass}}, \text{ or}$$
$$a = \frac{F}{m}$$

You can watch a video about how Newton's second law of motion applies to football at this URL: http://science360.gov/obj/video/58e62534-e38d-430b-bfb1-c505e628a2d4 .

## Direct and Inverse Relationships

Newton's second law shows that there is a direct relationship between force and acceleration. The greater the force that is applied to an object of a given mass, the more the object will accelerate. For example, doubling the force on the object doubles its acceleration. The relationship between mass and acceleration, on the other hand, is an inverse relationship. The greater the mass of an object, the less it will accelerate when a given force is applied. For example, doubling the mass of an object results in only half as much acceleration for the same amount of force.

Consider the example of a batter, like the boy in **Figure** 14.6. The harder he hits the ball, the greater will be its acceleration. It will travel faster and farther if he hits it with more force. What if the batter hits a baseball and a softball with the same amount of force? The softball will accelerate less than the baseball because the softball has greater mass. As a result, it won't travel as fast or as far as the baseball.

FIGURE 14.6

Hitting a baseball with greater force gives it greater acceleration. Hitting a softball with the same amount of force results in less acceleration. Can you explain why?

## Calculating Acceleration

The equation for acceleration given above can be used to calculate the acceleration of an object that is acted on by an unbalanced force. For example, assume you are pushing a large wooden trunk, like the one shown in **Figure** 14.7. The trunk has a mass of 10 kilograms, and you are pushing it with a force of 20 newtons. To calculate the acceleration of the trunk, substitute these values in the equation for acceleration:

$$a = \frac{F}{m} = \frac{20 \text{ N}}{10 \text{ kg}} = \frac{2 \text{ N}}{\text{kg}}$$

Recall that one newton (1 N) is the force needed to cause a 1-kilogram mass to accelerate at 1 $\text{m/s}^2$. Therefore, force can also be expressed in the unit $\text{kg}\cdot\text{m/s}^2$. This way of expressing force can be substituted for newtons in the solution to the problem:

$$a = \frac{2 \text{ N}}{\text{kg}} = \frac{2 \text{ kg} \cdot \text{m/s}^2}{\text{kg}} = 2 \text{ m/s}^2$$

Why are there no kilograms in the final answer to this problem? The kilogram units in the numerator and denominator of the fraction cancel out. As a result, the answer is expressed in the correct units for acceleration: m/s$^2$.

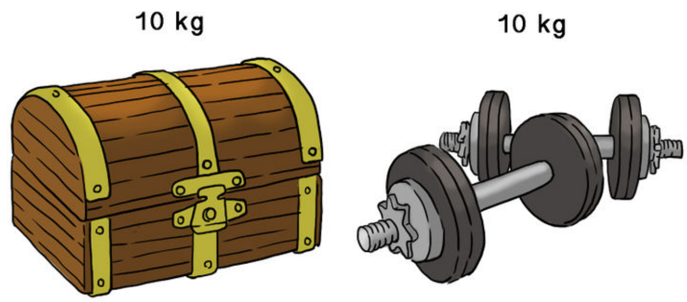


FIGURE 14.7
This empty trunk has a mass of 10 kilograms. The weights also have a mass of 10 kilograms. If the weights are placed in the trunk, what will be its mass? How will this affect its acceleration?

**You Try It!**

*Problem:* Assume that you add the weights to the trunk in **Figure** 14.7. If you push the trunk and weights with a force of 20 N, what will be the trunk's acceleration?

Need more practice? You can find additional problems at this URL: http://www.auburnschools.org/ajhs/lmcrowe/Week%2014/WorksheetPracticeProblemsforNewtons2law.pdf .

## Acceleration and Weight

Newton's second law of motion explains the weight of objects. Weight is a measure of the force of gravity pulling on an object of a given mass. It's the force (F) in the acceleration equation that was introduced above:

$$a = \frac{F}{m}$$

This equation can also be written as:

$$F = m \times a$$

The acceleration due to gravity of an object equals 9.8 m/s$^2$, so if you know the mass of an object, you can calculate its weight as:

$$F = m \times 9.8 \text{ m/s}^2$$

As this equation shows, weight is directly related to mass. As an object's mass increases, so does its weight. For example, if mass doubles, weight doubles as well. You can learn more about weight and acceleration at this URL: http://www.nasa.gov/mov/192448main_018_force_equals_mass_time.mov .

**Problem Solving**

*Problem:* Daisy has a mass of 35 kilograms. How much does she weigh?

*Solution:* Use the formula: $F = m \times 9.8 \text{ m/s}^2$.

$F = 35 \text{ kg} \times 9.8 \text{ m/s}^2 = 343.0 \text{ kg} \cdot \text{m/s}^2 = 343.0 \text{ N}$

**You Try It!**

*Problem:* Daisy's dad has a mass is 70 kg, which is twice Daisy's mass. Predict how much Daisy's dad weighs. Then calculate his weight to see if your prediction is correct.

**Helpful Hints**

The equation for calculating weight ($F = m \times a$) works only when the correct units of measurement are used.

- Mass must be in kilograms (kg).
- Acceleration must be in m/s$^2$.
- Weight (F) is expressed in kg·m/s$^2$ or in newtons (N).

## Lesson Summary

- Newton's second law of motion states that the acceleration of an object equals the net force acting on the object divided by the object's mass.
- Weight is a measure of the force of gravity pulling on an object of a given mass. It equals the mass of the object (in kilograms) times the acceleration due to gravity (9.8 m/s$^2$).

## Lesson Review Questions

### Recall

1. State Newton's second law of motion.
2. Describe how the net force acting on an object is related to its acceleration.
3. If the mass of an object increases, how is its acceleration affected, assuming the net force acting on the object remains the same?
4. What is weight?

### Apply Concepts

5. Tori applies a force of 20 newtons to move a bookcase with a mass of 40 kg. What is the acceleration of the bookcase?
6. Ollie has a mass of 45 kilograms. What is his weight in newtons?

### Think Critically

7. If you know your weight in newtons, how could you calculate your mass in kilograms? What formula would you use?

## Points to Consider

Assume that a 5-kilogram skateboard and a 50-kilogram go-cart start rolling down a hill. Both are moving at the same speed. You and a friend want to stop before they plunge into a pond at the bottom of the hill.

- Which will be harder to stop: the skateboard or the go-cart?
- Can you explain why?

# 14.3 Newton's Third Law

## Lesson Objectives

- State Newton's third law of motion.
- Describe momentum and the conservation of momentum.

## Lesson Vocabulary

- law of conservation of momentum
- momentum
- Newton's third law of motion

## Introduction

Look at the skateboarders in **Figure** 14.8. When they push against each other, it causes them to move apart. The harder they push together, the farther apart they move. This is an example of Newton's third law of motion.

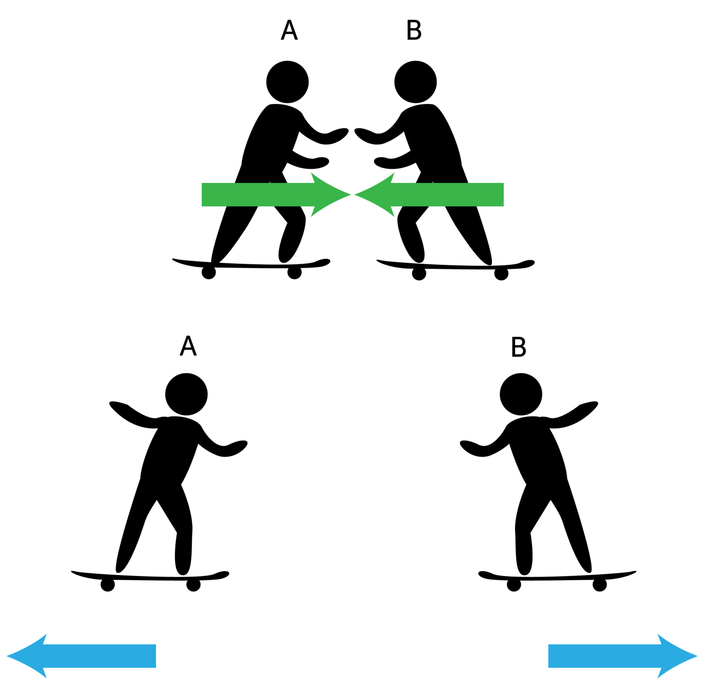


FIGURE 14.8

A and B move apart by first pushing together.

## Action and Reaction

**Newton's third law of motion** states that every action has an equal and opposite reaction. This means that forces always act in pairs. First an action occurs, such as the skateboarders pushing together. Then a reaction occurs that is equal in strength to the action but in the opposite direction. In the case of the skateboarders, they move apart, and the distance they move depends on how hard they first pushed together. You can see other examples of actions and reactions in **Figure** 14.9. You can watch a video about actions and reactions at this URL: http://www.nasa.gov/mov/192449main_019_law_of_action.mov .


FIGURE 14.9
Each example shown here includes an action and reaction.

You might think that actions and reactions would cancel each other out like balanced forces do. Balanced forces, which are also equal and opposite, cancel each other out because they act on the same object. Action and reaction forces, in contrast, act on different objects, so they don't cancel each other out and, in fact, often result in motion. For example, in **Figure** 14.9, the kangaroo's action acts on the ground, but the ground's reaction acts on the kangaroo. As a result, the kangaroo jumps away from the ground. One of the action-reaction examples in the **Figure** 14.9 does not result in motion. Do you know which one it is?

## Momentum

What if a friend asked you to play catch with a bowling ball, like the one pictured in **Figure** 14.10? Hopefully, you would refuse to play! A bowling ball would be too heavy to catch without risk of injury —assuming you could even throw it. That's because a bowling ball has a lot of mass. This gives it a great deal of momentum. **Momentum** is a property of a moving object that makes the object hard to stop. It equals the object's mass times its velocity. It can be represented by the equation:

$$\text{Momentum} = \text{Mass} \times \text{Velocity}$$

This equation shows that momentum is directly related to both mass and velocity. An object has greater momentum if it has greater mass, greater velocity, or both. For example, a bowling ball has greater momentum than a softball when both are moving at the same velocity because the bowling ball has greater mass. However, a softball moving at a very high velocity —say, 100 miles an hour —would have greater momentum than a slow-rolling bowling ball. If an object isn't moving at all, it has no momentum. That's because its velocity is zero, and zero times anything is zero.


FIGURE 14.10
A bowling ball and a softball differ in mass. How does this affect their momentum?

## Calculating Momentum

Momentum can be calculated by multiplying an object's mass in kilograms (kg) by its velocity in meters per second (m/s). For example, assume that a golf ball has a mass of 0.05 kg. If the ball is traveling at a velocity of 50 m/s, its momentum is:

$$\text{Momentum} = 0.05 \text{ kg} \times 50 \text{ m/s} = 2.5 \text{ kg} \cdot \text{m/s}$$

Note that the SI unit for momentum is kg·m/s.

**Problem Solving**

*Problem:* What is the momentum of a 40-kg child who is running straight ahead with a velocity of 2 m/s?

*Solution:* The child has momentum of: 40 kg $\times$ 2 m/s = 80 kg·m/s.

**You Try It!**

*Problem:* Which football player has greater momentum?

Player A: mass = 60 kg; velocity = 2.5 m/s

Player B: mass = 65 kg; velocity = 2.0 m/s

### Conservation of Momentum

When an action and reaction occur, momentum is transferred from one object to the other. However, the combined momentum of the objects remains the same. In other words, momentum is conserved. This is the **law of conservation of momentum**.

Consider the example of a truck colliding with a car, which is illustrated in **Figure** 14.11. Both vehicles are moving in the same direction before and after the collision, but the truck is moving faster than the car before the collision occurs. During the collision, the truck transfers some of its momentum to the car. After the collision, the truck is moving slower and the car is moving faster than before the collision occurred. Nonetheless, their combined momentum is the same both before and after the collision. You can see an animation showing how momentum is conserved in a head-on collision at this URL: http://www.physicsclassroom.com/mmedia/momentum/cthoi.cfm .

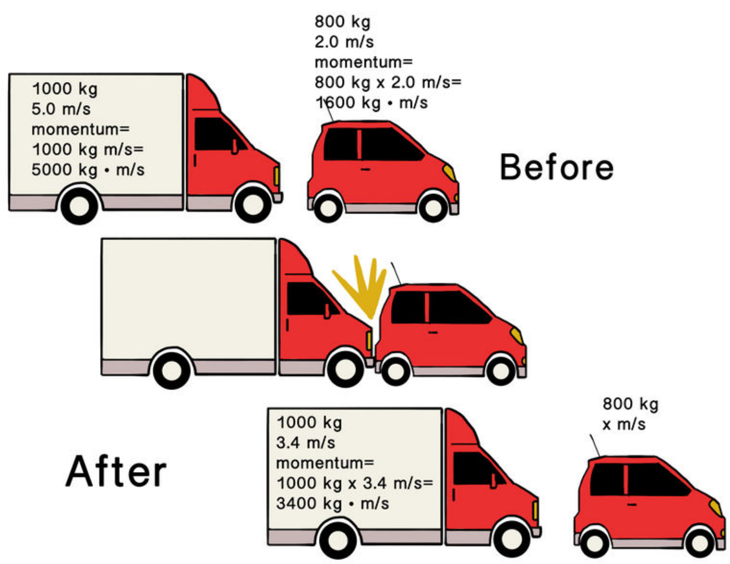


FIGURE 14.11
How can you tell momentum has been conserved in this collision?

## Lesson Summary

- Newton's third law of motion states that every action has an equal and opposite reaction.
- Momentum is a property of a moving object that makes it hard to stop. It equals the object's mass times its velocity. When an action and reaction occur, momentum may be transferred from one object to another, but their combined momentum remains the same. This is the law of conservation of momentum.

## Lesson Review Questions

### Recall

1. State Newton's third law of motion.
2. Define momentum.

3. If you double the velocity of a moving object, how is its momentum affected?

### Apply Concepts

4. A large rock has a mass of 50 kg and is rolling downhill at 3 m/s. What is its momentum?
5. Create a diagram to illustrate the transfer and conservation of momentum when a moving object collides with a stationary object.

### Think Critically

6. The reaction to an action is an equal and opposite force. Why doesn't this yield a net force of zero?
7. Momentum is a property of an object, but it is different than a physical or chemical property, such as boiling point or flammability. How is momentum different?

## Points to Consider

In this chapter, you learned about forces and motions of solid objects, such as balls and cars. In the next chapter, "Fluid Forces," you will learn about forces in fluids, which include liquids and gases.

- How do fluids differ from solids?
- What might be examples of forces in fluids? For example, what force allows some objects to float in water?

# 14.4 References


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# Concept 15 Types of Energy

## Lesson Objectives

- Relate energy to work.
- Describe kinetic energy.
- Identify two types of potential energy.
- Give examples of energy conversions between potential and kinetic energy.

## Lesson Vocabulary

- energy conversion
- potential energy

## Introduction

Did you ever babysit younger children, like the children in **Figure** 15.1? If you did, then you probably noticed that young children are often very active. They seem to be in constant motion. It may be hard to keep up with their boundless energy. What is energy, and where does it come from? Read on to find out.

FIGURE 15.1
Young children seem to be full of energy.

## Defining Energy

The concept of energy was first introduced in the chapter "States of Matter," where it is defined as the ability to cause change in matter. Energy can also be defined as the ability to do work. Work is done whenever a force is used to move matter. When work is done, energy is transferred from one object to another. For example, when the batter in **Figure** 15.2 uses energy to swing the bat, she transfers energy to the bat. The moving bat, in turn, transfers energy to the ball. Like work, energy is measured in the joule (J), or newton·meter (N·m).

FIGURE 15.2
It takes energy to swing a bat. Where does the batter get her energy?

Energy exists in different forms, which you can read about in the lesson "Forms of Energy" later in the chapter. Some forms of energy are mechanical, electrical, and chemical energy. Most forms of energy can also be classified as kinetic or potential energy. Kinetic and potential forms of mechanical energy are the focus of this lesson. Mechanical energy is the energy of objects that are moving or have the potential to move.

## Kinetic Energy

What do all the photos in **Figure** 15.3 have in common? All of them show things that are moving. Kinetic energy is the energy of moving matter. Anything that is moving has kinetic energy — from the atoms in matter to the planets in solar systems. Things with kinetic energy can do work. For example, the hammer in the photo is doing the work of pounding the nail into the board. You can see a cartoon introduction to kinetic energy and its relation to work at this URL: http://www.youtube.com/watch?v=zhX01toLjZs .

The amount of kinetic energy in a moving object depends on its mass and velocity. An object with greater mass or greater velocity has more kinetic energy. The kinetic energy of a moving object can be calculated with the equation:

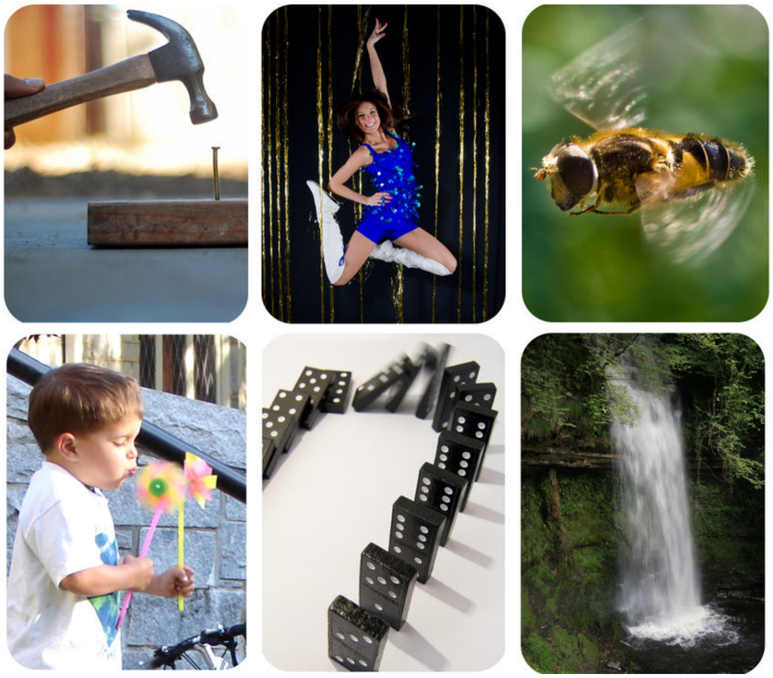

FIGURE 15.3

All of these photos show things that have kinetic energy because they are moving.

$$\text{Kinetic Energy (KE)} = \frac{1}{2}\text{mass} \times \text{velocity}^2$$

This equation for kinetic energy shows that velocity affects kinetic energy more than mass does. For example, if mass doubles, kinetic energy also doubles. But if velocity doubles, kinetic energy increases by a factor of four. That's because velocity is squared in the equation. You can see for yourself how mass and velocity affect kinetic energy by working through the problems below.

**Problem Solving**

*Problem:* Juan has a mass of 50 kg. If he is running at a velocity of 2 m/s, how much kinetic energy does he have?

*Solution:* Use the formula: $\text{KE} = \frac{1}{2}\text{mass} \times \text{velocity}^2$

$$\begin{aligned}\text{KE} &= \frac{1}{2} \times 50 \text{ kg} \times (2 \text{ m/s}^2)\\ &= 100 \text{ kg} \cdot \text{m}^2/\text{s}^2 = 100 \text{ N} \cdot \text{ m, or } 100 \text{ J}\end{aligned}$$

**You Try It!**

*Problem:* What is Juan's kinetic energy if he runs at a velocity of 4 m/s?

*Problem:* Juan's dad has a mass of 100 kg. How much kinetic energy does he have if he runs at a velocity of 2 m/s?

## Potential Energy

Did you ever see a scene like the one in **Figure** 15.4? In many parts of the world, trees lose their leaves in autumn. The leaves turn color and then fall from the trees to the ground. As the leaves are falling, they have kinetic energy.

While they are still attached to the trees they also have energy, but it's not because of motion. Instead, they have stored energy, called **potential energy**. An object has potential energy because of its position or shape. For example leaves on trees have potential energy because they could fall due to the pull of gravity.

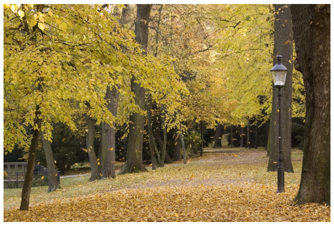

FIGURE 15.4
Before leaves fall from trees in autumn, they have potential energy. Why do they have the potential to fall?

## Gravitational Potential Energy

Potential energy due to the position of an object above Earth is called gravitational potential energy. Like the leaves on trees, anything that is raised up above Earth's surface has the potential to fall because of gravity. You can see examples of people with gravitational potential energy in **Figure** 15.5.

FIGURE 15.5
All three of these people have gravitational potential energy. Can you think of other examples?

Gravitational potential energy depends on an object's weight and its height above the ground. It can be calculated with the equation:

$$\text{Gravitational potential energy (GPE)} = \text{weight} \times \text{height}$$

Consider the diver in **Figure** 15.5. If he weighs 70 newtons and the diving board is 5 meters above Earth's surface, then his potential energy is:

$$\text{GPE} = 70 \text{ N} \times 5 \text{ m} = 350 \text{ N} \cdot \text{ m, or } 350 \text{ J}$$

**You Try It!**

*Problem:* Kris is holding a 2-kg book 1.5 m above the floor. What is the gravitational potential energy of the book?

## Elastic Potential Energy

Potential energy due to an object's shape is called elastic potential energy. This energy results when elastic objects are stretched or compressed. Their elasticity gives them the potential to return to their original shape. For example, the rubber band in **Figure** 15.6 has been stretched, but it will spring back to its original shape when released. Springs like the handspring in the figure have elastic potential energy when they are compressed. What will happen when the handspring is released?

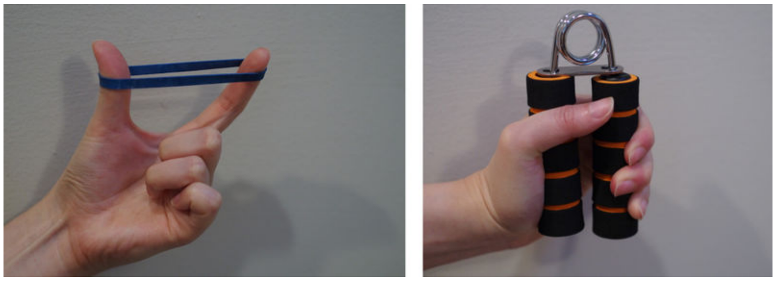

FIGURE 15.6
Changing the shape of an elastic material gives it potential energy.

## Energy Conversion

Remember the diver in **Figure** 15.5? What happens when he jumps off the diving board? His gravitational potential energy changes to kinetic energy as he falls toward the water. However, he can regain his potential energy by getting out of the water and climbing back up to the diving board. This requires an input of kinetic energy. These changes in energy are examples of **energy conversion**, the process in which energy changes from one type or form to another.

### Conservation of Energy

The law of conservation of energy applies to energy conversions. Energy is not used up when it changes form, although some energy may be used to overcome friction, and this energy is usually given off as heat. For example, the diver's kinetic energy at the bottom of his fall is the same as his potential energy when he was on the diving board, except for a small amount of heat resulting from friction with the air as he falls.

### Examples of Energy Conversions

There are many other examples of energy conversions between potential and kinetic energy. **Figure** 15.7 describes how potential energy changes to kinetic energy and back again on swings and trampolines. You can see an animation of changes between potential and kinetic energy on a ramp at the URL below. Can you think of other examples?

http://www.physicsclassroom.com/mmedia/energy/ie.cfm

## Lesson Summary

- Energy is the ability to do work. When work is done, energy is transferred from one object to another. Energy can exist in different forms, such as electrical and chemical energy. Most forms of energy can also be classified as kinetic or potential energy.
- Kinetic energy is the energy of moving matter. Things with kinetic energy can do work. Kinetic energy depends on an object's mass and velocity.

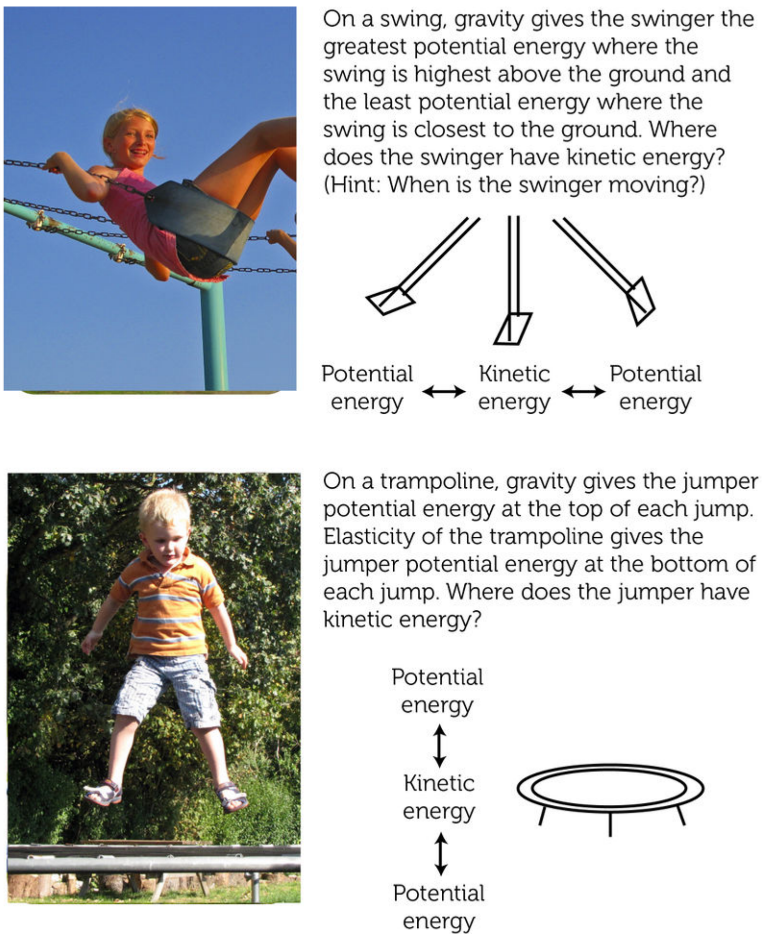


FIGURE 15.7

Energy continuously changes back and forth between potential and kinetic energy on a swing or trampoline.

- Potential energy is the energy stored in an object because of its position or shape. It includes gravitational potential energy and elastic potential energy. Gravitational potential energy depends on an object's weight and height above the ground.
- Energy conversion occurs when energy changes from one type or form of energy to another. Energy often changes between potential and kinetic energy. Energy is always conserved during energy conversions.

## Lesson Review Questions

### Recall

1. Define kinetic energy and give an example.
2. What is potential energy?
3. Describe how energy changes on a swing.

### Apply Concepts

4. Explain how energy changes in the spring toy below when it goes down stairs.

### Think Critically

5. How is energy related to work?
6. Compare and contrast gravitational potential energy and elastic potential energy.

## Points to Consider

The examples of kinetic and potential energy you read about in this lesson are types of mechanical energy. Mechanical energy is one of several forms of energy you can read about in the next lesson, "Forms of Energy."

- Based on the examples in this lesson, how would you define mechanical energy?
- What might be other examples of mechanical energy?

## References

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