CK-12 FlexBook

6th Grade NGSS

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Contents

CONCEPT 1 Nature of Science

- Define science.
- State the goal of science.
- Describe how science advances.

Does the word *science* make you think of high-tech labs and researchers in white coats like the ones in this picture? This is often an accurate image of science but not always. If you look up science in a dictionary, you would find that it comes from a Latin word that means "having knowledge." However, this isn't an adequate definition either.

What is Science?

Science is more about gaining knowledge than it is about simply having knowledge. **Science** is a way of learning about the natural world that is based on evidence and logic. In other words, science is a process, not just a body of facts. Through the process of science, our knowledge of the world advances.

The Goal of Science

Scientists may focus on very different aspects of the natural world. For example, some scientists focus on the world of tiny objects, such as atoms and molecules. Other scientists devote their attention to huge objects, such as the sun and other stars. But all scientists have at least one thing in common. They want to understand how and why things happen. Achieving this understanding is the goal of science.

Have you ever experienced the thrill of an exciting fireworks show like the one pictured in the **Figure** 1.1? Fireworks show how the goal of science leads to discovery. Fireworks were invented at least 2000 years ago in China, but explaining how and why they work didn't happen until much later. It wasn't until scientists had learned about elements and chemical reactions that they could explain what caused fireworks to create brilliant bursts of light and deep rumbling booms.

FIGURE 1.1
Fireworks were invented long before scientists could actually explain how and why they explode.

How Science Advances

Sometimes learning about science is frustrating because scientific knowledge is always changing. But that's also what makes science exciting. Occasionally, science moves forward in giant steps. More commonly, however, science advances in baby steps.

Giant steps in science may occur if a scientist introduces a major new idea. For example, in 1666, Isaac Newton introduced the idea that gravity is universal. People had long known that things fall to the ground because they are attracted by Earth. But Newton proposed that everything in the universe exerts a force of attraction on everything else. This idea is known as Newton's law of universal gravitation.

Q: How do you think Newton's law of universal gravitation might have influenced the advancement of science?

A: Newton's law allowed scientists to understand many different phenomena. It explains not only why things always fall down toward the ground or roll downhill. It also explains the motion of many other objects. For example, it explains why planets orbit the sun. The idea of universal gravity even helped scientists discover the planets Neptune and Pluto. The caption and diagram in the **Figure** 1.2 explain how.

Baby steps in science occur as small bits of evidence gradually accumulate. The accumulating evidence lets scientists refine and expand on earlier ideas. For example, the scientific idea of the atom was introduced in the early 1800s. But scientists came to understand the structure of the atom only as evidence accumulated over the next two centuries. Their understanding of atomic structure continues to expand today.

The advancement of science is sometimes a very bumpy road. New knowledge and ideas aren't always accepted at first, and scientists may be mocked for their ideas. The idea that Earth's continents drift on the planet's surface is a good example. This idea was first proposed by a scientist named Alfred Wegener in the early 1900s. Wegener also proposed that all of the present continents had once formed one supercontinent, which he named Pangaea. You can see a sketch of Pangaea in **Figure** 1.3. Other scientists not only rejected Wegener's ideas, but ridiculed Wegener for even suggesting them. It wasn't until the 1950s that enough evidence had accumulated for scientists to realize that

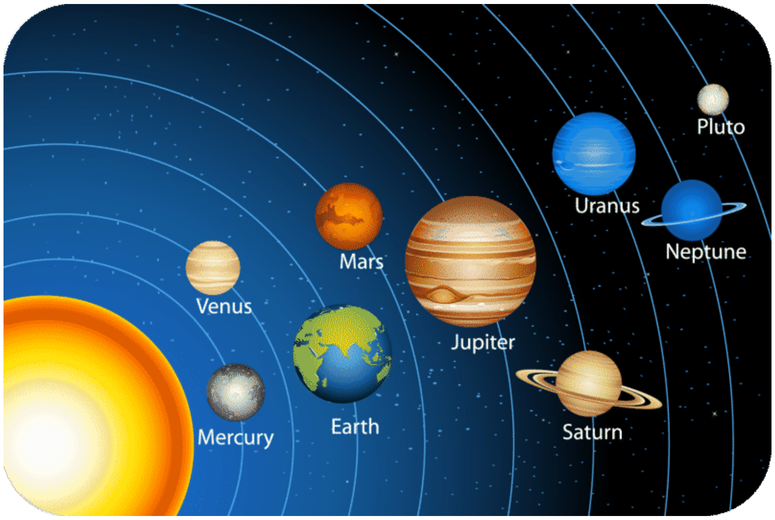

FIGURE 1.2
In the early 1800s, astronomers noticed a wobble in Uranus' orbit around the sun. They predicted that the wobble was caused by the pull of gravity of another, not-yet-discovered planet. Scientists searched the skies for the "missing" planet. When they discovered Neptune in 1846, they thought they had found their missing planet. After the astronomers took into account the effects of Neptune's gravity, they saw that Uranus still had an unexplained wobble. They predicted that there must be another planet beyond Neptune. That planet, now called Pluto, was finally discovered in 1930. Of special note, as of 2006, the International Astronomical Union (IAU) demoted Pluto from its planet status as it does not meet one of the criteria for planetary standards.

Wegener had been right. Unfortunately, Wegener did not live long enough to see his ideas accepted.

FIGURE 1.3
This map shows the supercontinent Pangaea, which was first proposed by Alfred Wegener. Pangaea included all of the separate continents we know today. Scientists now know that the individual continents drifted apart to their present locations over millions of years.

Q: What types of evidence might support Wegener's ideas?

A: Several types of evidence support Wegener's ideas. For example, similar fossils and rock formations have been found on continents that are now separated by oceans. It is also now known that Earth's crust consists of rigid plates that slide over molten rock below them. This explains how continents can drift. Even the shapes of today's continents show how they once fit together, like pieces of a giant jigsaw puzzle.

Summary

- Science is a way of learning about the natural world that is based on evidence and logic.
- The goal of science is to understand how and why things happen.
- Science advances as new evidence accumulates and allows scientists to replace, refine, or expand on accepted ideas about the natural world.

Review

1. Define science.
2. What is the goal of science?
3. Use examples to show how science may advance.

Resources

MEDIA

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References

1. Image copyright Dudarev Mikhail, 2012. . Used under license from Shutterstock.com
2. Image copyright vectomart, 2012. .
3. Image copyright plena, 2012; modified by CK-12 Foundation - Zachary Wilson. . Used under license from Shutterstock.com

CONCEPT 2 Scientific Method

- Explain how scientific questions are answered using scientific method.

How many angels can dance on the head of a pin?

This is a question that has been pondered over the centuries. Can it be answered using scientific method? Is it a scientific question?

The Goal of Science

The goal of science is to answer questions about the natural world. Scientific questions must be testable. Which of these two questions is a good scientific question and which is not?

- What is the age of our planet Earth?
- How many angels can dance on the head of a pin?

The first is a good scientific question that can be answered by radiometrically dating rocks among other techniques. The second cannot be answered using data, so it is not a scientific question.

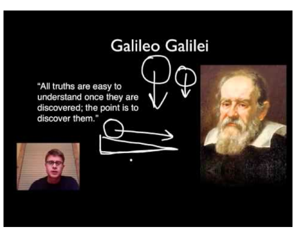
Scientific Method

Scientists use the **scientific method** to answer questions. The scientific method is a series of steps that help to investigate a question.

Often, students learn that the scientific method is a linear process that goes like this:

- Ask a question. The question is based on one or more observations or on data from a previous experiment.
- Do some background research.
- Create a hypothesis.
- Do experiments or make observations to test the hypothesis.
- Gather the data.
- Formulate a conclusion.

The process doesn't always go in a straight line. A scientist might ask a question, then do some background research and discover that the question needed to be asked a different way, or that a different question should be asked.



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Ask A Question

Now, let's ask a scientific question. Remember that it must be testable.

We learned above that average global temperature has been rising since record keeping began in 1880. We know that carbon dioxide is a **greenhouse gas**. Greenhouse gases trap heat in the atmosphere. This leads us to a question:

Question: Is the amount of carbon dioxide in Earth's atmosphere changing?

This is a good scientific question because it is testable.

How has carbon dioxide in the atmosphere changed over those 50-plus years (see **Figure** 2.1)? About how much has atmospheric CO_2 risen between 1958 and 2011 in parts per million?

Answer a Question

So we've answered the question using data from research that has already been done. If scientists had not been monitoring CO_2 levels over the years, we'd have had to start these measurements now.

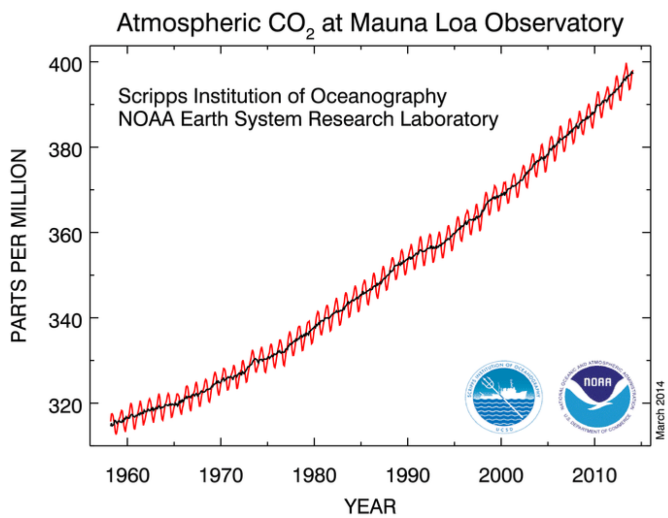

FIGURE 2.1
Atmospheric carbon dioxide has been increasing at Mauna Loa Observatory in Hawaii since 1958. The small ups and downs of the red line are seasonal variations. The black line is the annual average.

Because this question can be answered with data, it is testable.

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Summary

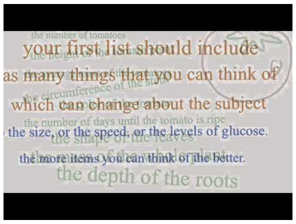
- Scientists use scientific method to answer questions about the natural world.
- First, scientists ask a question that they want to answer.
- Background research is essential for better understanding the question and being able to move to the next step.

Review

1. What features does a question need to have to be a good science question?
2. Create a list of three questions that are good science questions. Create a list of three questions that are not science questions.
3. Look at the graph of atmospheric CO_2 over time in the **Figure** 2.1. As close as you can determine, how much has the atmospheric CO_2 content risen since 1958? Levels are about 400 ppm now.

Explore More

Use this resource to answer the questions that follow.



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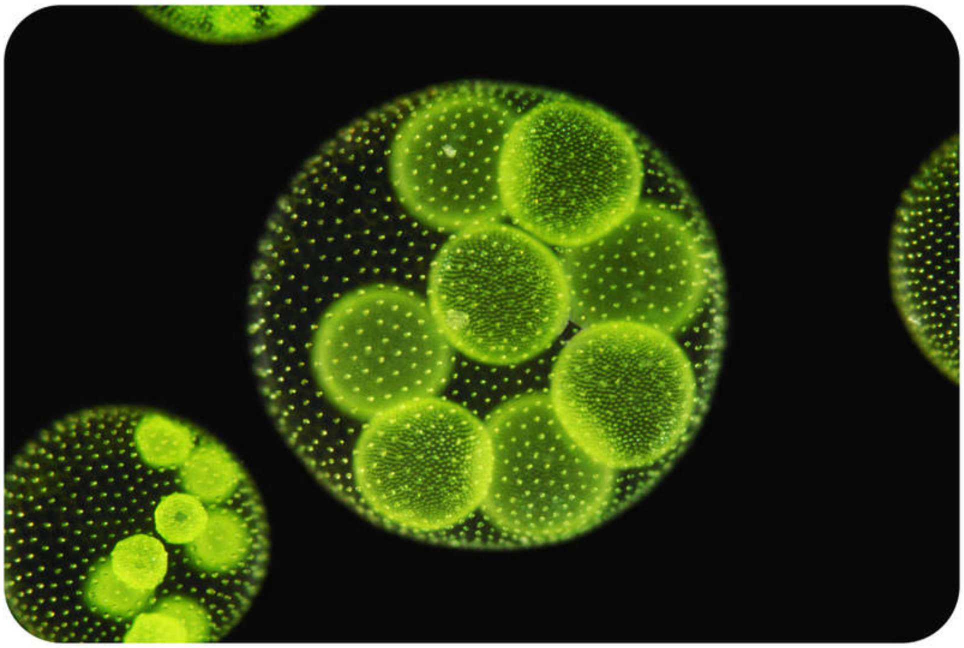
1. Why is a scientific question different from any other question?
2. What is an inference? What is an observation?
3. Describe the two types of observations.
4. How does the speaker recommend you do first? Where do you get the dependent and independent variables?
5. Give an example of a question using an independent and dependent variable and the topic of tomato plants.
6. What is a hypothesis?

References

1. Dr. Pieter Tans, NOAA/ESRL (www.esrl.noaa.gov/gmd/ccgg/trends/) and Dr. Ralph Keeling, Scripps Institution of Oceanography (scrippsco2.ucsd.edu/). Graph of atmospheric carbon dioxide at Mauna Loa Observatory . Public Domain

CONCEPT 3 Importance of the Atmosphere

- Define the atmosphere.
- Describe the roles the atmosphere plays on Earth.



Why is the atmosphere important?

Why is Earth the only planet in the solar system known to have life? The main reason is Earth's atmosphere. Organisms need the gases in the atmosphere to live. Water is also essential for life. Water vapor is one of the gases in the atmosphere. Green algae, like in this photo, are primitive life.

The Atmosphere

The **atmosphere** is a mixture of gases that surrounds the planet. We also call it air. The gases in the atmosphere include nitrogen, oxygen, and carbon dioxide. Along with water vapor, the atmosphere allows life to survive. Without it, Earth would be a harsh, barren world.

The Atmosphere's Importance

We are lucky to have an atmosphere on Earth. The atmosphere supports life and is also needed for the water cycle and weather. The gases of the atmosphere even allow us to hear.

The Atmosphere and Living Things

Most of the atmosphere is nitrogen, but it doesn't do much. Carbon dioxide and oxygen are the gases in the atmosphere that are needed for life.

- Plants need carbon dioxide for **photosynthesis**. They use sunlight to change carbon dioxide and water into food. The process releases oxygen. Without photosynthesis, there would be very little oxygen in the air.
- Other living things depend on plants for food. These organisms need the oxygen plants release to get energy out of the food. Even plants need oxygen for this purpose.

The Atmosphere and the Sun's Rays

The atmosphere protects living things from the Sun's most harmful rays. Gases reflect or absorb the strongest rays of sunlight (**Figure** 3.1).

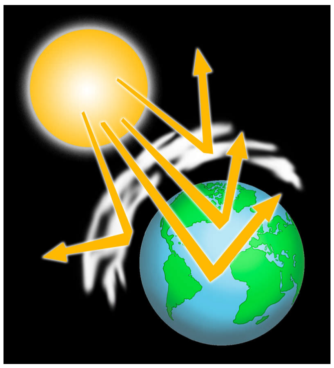


FIGURE 3.1
The atmosphere shields Earth from the most harmful solar rays.

The Atmosphere and Earth's Temperature

Gases in the atmosphere surround Earth like a blanket. They keep the temperature in a range that can support life. The gases keep out some of the Sun's scorching heat during the day. At night, they hold the heat close to the surface, so it doesn't radiate out into space.

The Atmosphere and Earth's Water

The image below shows the role of the atmosphere in the water cycle (**Figure** 3.2). Water vapor rises from Earth's surface into the atmosphere. As it rises, it cools. The water vapor may then condense into water droplets and form clouds. If enough water droplets collect in clouds, they may come together to form droplets. The droplets will fall as rain. This how freshwater gets from the atmosphere back to Earth's surface.

The Atmosphere and Weather

Without the atmosphere, there would be no clouds or rain. In fact, there would be no weather at all. Most weather occurs because the atmosphere heats up more in some places than others.

The Atmosphere and Weathering

Weather makes life interesting. Weather also causes weathering. Weathering is the slow wearing down of rocks on Earth's surface. Wind-blown sand scours rocks like sandpaper. Glaciers of ice scrape across rock surfaces like a file. Even gentle rain may seep into rocks and slowly dissolve them. If the water freezes, it expands. This eventually causes the rocks to crack. Without the atmosphere, none of this weathering would happen. Rocks at the surface would be pristine and unaltered.

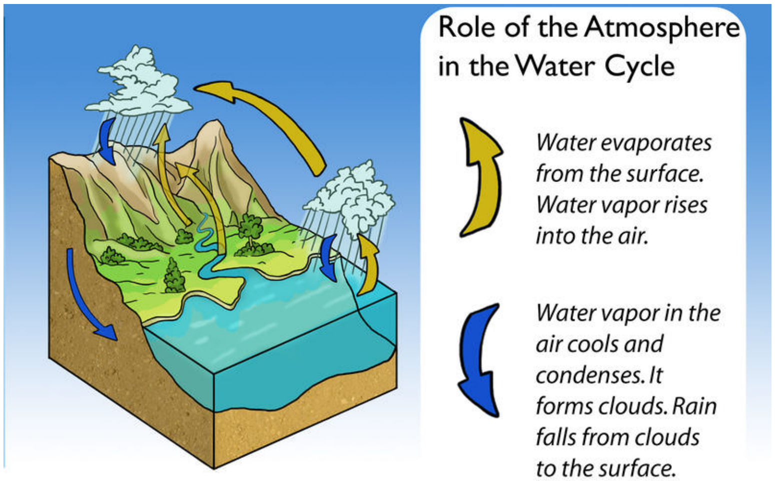


FIGURE 3.2
The atmosphere is a big part of the water cycle. What do you think would happen to Earth's water without it?

The Atmosphere and Sound

Sound is a form of energy that travels in waves. Sound waves cannot travel through empty space, but they can travel through gases. Gases in the air allow us to hear most of the sounds in our world. Because of air, you can hear birds singing, horns tooting, and friends laughing. Without the atmosphere, the world would be a silent, eerie place.

Summary

- The atmosphere is made of gases that are essential for photosynthesis and other life activities.
- The atmosphere is a crucial part of the water cycle. It is an important reservoir for water, and the source of precipitation.
- The atmosphere moderates Earth's temperature. Weather takes place in the atmosphere.
- Without air, Earth would be silent.

Review

1. What gases are used and expelled by photosynthesis and respiration?
2. How does the atmosphere keep Earth's temperature moderate?
3. How does the atmosphere play an important role in the water cycle?

Explore More

Use the resource below to answer the questions that follow.

MEDIA
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1. What is the atmosphere?

2. Where does weather occur?
3. What does the atmosphere protect us from? Which layer?
4. What would happen if we didn't have the protective layer in the previous question?
5. What happens in the mesosphere?
6. What is made in the thermosphere?

References

1. Laura Guerin. The atmosphere shields Earth from the most harmful solar rays . CC BY-NC 3.0
2. Laura Guerin. The atmosphere is a big part of the water cycle . CC BY-NC 3.0

Concept 4 Composition of the Atmosphere

- Describe the composition of the atmosphere.

Just what is air?

Air is easy to forget about. We usually can't see it, taste it, or smell it. We can only feel it when it moves. But air is actually made of molecules of many different gases. It also contains tiny particles of solid matter.

Gases in Air

The figure below shows the main gases in air (**Figure** 4.1). Nitrogen and oxygen make up 99% of air. Argon and carbon dioxide make up much of the rest. These percentages are the same just about everywhere in the atmosphere.

Air also includes water vapor. The amount of water vapor varies from place to place. That's why water vapor isn't included in the figure above. It can make up as much as 4% of the air.

Water Vapor

Humidity is the amount of water vapor in the air. Humidity varies from place to place. It also varies in the same place from season to season. On a summer day in Atlanta, Georgia, humidity is high. The air feels very heavy and sticky. On a winter day in Flagstaff, Arizona, humidity is low. The air sucks moisture out of your nose and lips. Humidity can change rapidly if a storm comes in. Humidity can vary over a short distance, like near a lake. Even when humidity is at its highest, water vapor makes up only about 4% of the atmosphere.

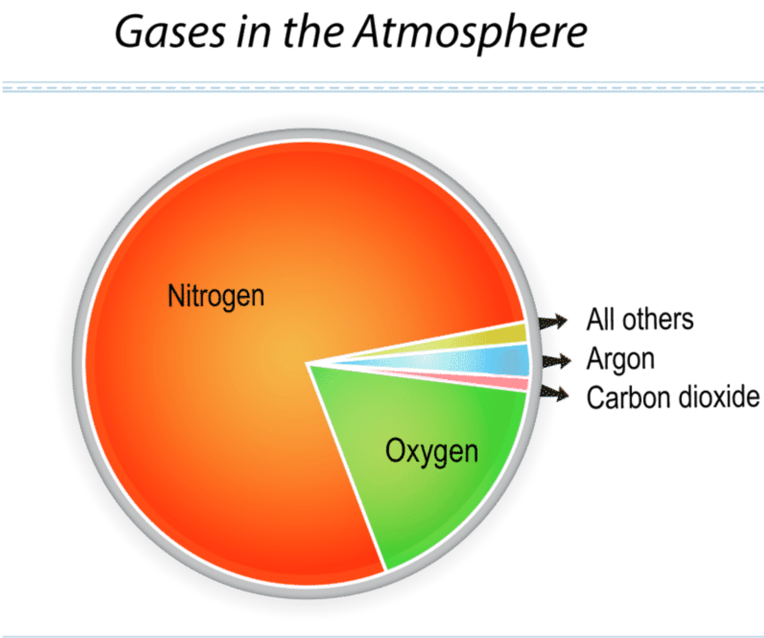


FIGURE 4.1
This graph identifies the most common gases in air.

Greenhouse Gases

Greenhouse gases trap heat in the atmosphere. This is essential so that Earth has a more moderate temperature. Without greenhouse gases, nighttime temperatures would be frigid. Natural greenhouse gases include carbon dioxide, methane, water vapor, and ozone. CFCs and some other man-made compounds are also greenhouse gases. Human activities may increase the amount of greenhouse gases, like carbon dioxide, in the atmosphere.

Particles in the Air

Air includes many tiny particles. The **particulates** may consist of dust, soil, salt, smoke, or ash. Some particulates pollute the air and may make it unhealthy to breathe. But having particles in the air is very important. Tiny particles are needed for water vapor to condense on. Without particles, water vapor could not condense. Then clouds could not form, and Earth would have no rain.

Summary

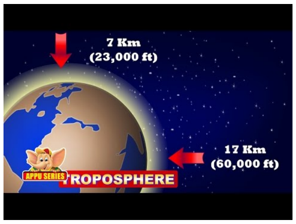
- The major atmospheric gases are nitrogen and oxygen. The atmosphere also contains minor amounts of other gases, including carbon dioxide.
- Greenhouse gases trap heat in the atmosphere. These gases include carbon dioxide, methane, water vapor, and ozone.
- Not everything in the atmosphere is gas. Particulates are particles that are important as the nucleus of raindrops and snowflakes.

Review

1. What are the two major atmospheric gases? What are the important minor gases?
2. What are particulates? Why are they important?
3. What is humidity? How much humidity is in the air on a tremendously hot and humid day?

Explore More

Use the resource below to answer the questions that follow.



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1. What does the atmosphere contain?
2. How much nitrogen does the atmosphere contain?
3. How much oxygen does the atmosphere contain?
4. What does the atmosphere do?
5. How many layers does the atmosphere have?
6. List the layers of the atmosphere and two characteristics of each layer.

References

1. Hana Zavadska. The composition of the atmosphere . CC BY-NC 3.0

CONCEPT 5 Greenhouse Effect

- Describe the greenhouse effect.
- Explain how human actions contribute to the greenhouse effect.

How does the atmosphere resemble a greenhouse?

Farmers use greenhouses to extend the growing season. A greenhouse traps heat. Days that are too cool for a growing plant can be made to be just right. Similar to a greenhouse, greenhouse gases in the atmosphere keep Earth warm.

The Greenhouse Effect

When sunlight heats Earth's surface, some of the heat radiates back into the atmosphere. Some of this heat is absorbed by gases in the atmosphere. This is the **greenhouse effect**, and it helps to keep Earth warm. The greenhouse effect allows Earth to have temperatures that can support life.

Gases that absorb heat in the atmosphere are called **greenhouse gases**. They include carbon dioxide and water vapor. Human actions have increased the levels of greenhouse gases in the atmosphere (**Figure** 5.1). The added gases have caused a greater greenhouse effect. How do you think this affects Earth's temperature?

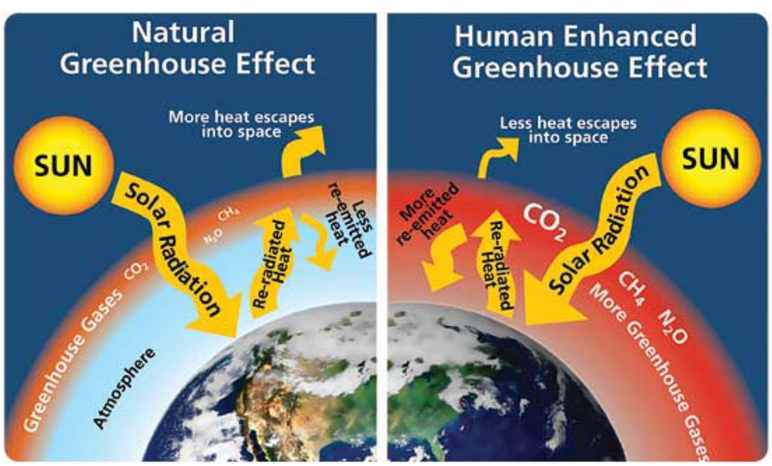

FIGURE 5.1
Human actions have increased the natural greenhouse effect.

Like a blanket on a sleeping person, greenhouse gases act as insulation for the planet. The warming of the atmosphere is because of **insulation** by greenhouse gases. Greenhouse gases are the component of the atmosphere that moderate Earth's temperatures.

Greenhouse Gases

Greenhouse gases include CO_2, H_2O, methane, O_3, nitrous oxides (NO and NO_2), and chlorofluorocarbons (CFCs). All are a normal part of the atmosphere except CFCs. The table below shows how each greenhouse gas naturally enters the atmosphere (**Table** 5.1).

TABLE 5.1: How Greenhouse Gases Enter the Atmosphere

Greenhouse Gas	Source
Carbon dioxide	Respiration, volcanic eruptions, decomposition of plant material; burning of fossil fuels
Methane	Decomposition of plant material under some conditions, biochemical reactions in stomachs
Nitrous oxide	Produced by bacteria
Ozone	Atmospheric processes
Chlorofluorocarbons	Not naturally occurring; made by humans

Different greenhouse gases have different abilities to trap heat. For example, one methane molecule traps 23 times as much heat as one CO_2 molecule. One CFC-12 molecule (a type of CFC) traps 10,600 times as much heat as one CO_2. Still, CO_2 is a very important greenhouse gas, because it is much more abundant in the atmosphere.

Summary

- Greenhouse gases include CO_2, H_2O, methane, O_3, nitrous oxides (NO and NO_2), and chlorofluorocarbons (CFCs).
- Greenhouse gases trap heat in the troposphere. Some greenhouse gases can trap more heat than others.
- Levels of greenhouse gases in the atmosphere are increasing due to human activities.

Review

1. What is insulation? What effect does insulation have on global temperature?
2. What is the greenhouse effect?
3. How does Earth's atmosphere resemble a greenhouse?

References

1. Courtesy of Will Elder, National Park Service. Diagram of the natural and human enhanced greenhouse effect . Public Domain

Concept 6 Introduction to Energy Resources

- Define energy, fuel and heat.
- Understand how energy changes form.

How can a trip to an amusement park be a learning experience?

Amusement parks use the laws of physics to generate fun! Gravity, energy, centrifugal forces are all harnessed on various rides. Which is your favorite?

Energy

Energy is the ability to move. Energy can also change matter from one state to another (for example, from solid to liquid). Every living thing needs energy to live and grow.

What makes energy available whenever you need it? If you unplug a lamp, the light goes off. The lamp does not have a supply of energy to keep itself lit. The lamp uses electricity that comes through the outlet as its source of energy. The electricity comes from a power plant. The power plant has a source of energy to produce this electricity.

Fuel

The energy to make the electricity comes from fuel. Fuel stores the energy and releases it when it is needed. **Fuel** is any material that can release energy in a chemical change. The food you eat acts as a fuel for your body. Gasoline and diesel fuel are fuels that provide the energy for most cars, trucks, and buses. But there are many different kinds of fuel.

For fuel to be useful, its energy must be released in a way that can be controlled.

Heat

When fuel is burned, most of the energy is released as **heat**. Some of this heat can be used to do work. Heat cooks food or warms your house. Sometimes the heat is just waste heat. It still heats the environment, though.

Heat from a wood fire can boil a pot of water. If you put an egg in the pot, you can eat a hard boiled egg in 15 minutes (cool it down first!). The energy to cook the egg was stored in the wood. The wood got that energy from the Sun when it was part of a tree. The Sun generated the energy by nuclear fusion. You started the fire with a match. The head of the match stores energy as chemical energy. That energy lights the wood on fire. The fire burns as long as there is energy in the wood. Once the wood has burned up, there is no energy left in it. The fire goes out.

Using Energy

Your body gets its energy from food, but that is only a small part of the energy you use every day. Cooking your food takes energy, and so does keeping it cold in the refrigerator or the freezer. The same is true for heating or cooling your home. Whether you are turning on a light in the kitchen or riding in a car to school, you are using energy. Billions of people all around the world use energy, so there is a huge demand for resources to provide all of this energy. Why do we need so much energy? The main reason is that almost everything that happens on Earth involves energy.

FIGURE 6.1

This lantern festival uses hundreds of candles for light.

The Sources of Earth's Energy

Almost all energy comes from the Sun. Plants make food energy from sunlight. Fossil fuels are made of the remains of plants and animals that stored the Sun's energy millions of years ago.

The Sun heats some areas more than others, which causes wind. The Sun's energy also drives the water cycle, which moves water over the surface of Earth. Both wind and water power can be used as renewable resources.

Earth's internal heat does not depend on the Sun for energy. This heat comes from remnant heat when the planet formed. It also comes from the decay of radioactive elements. Radioactivity is an important source of energy.

Summary

- Energy is the ability to do work or change matter.
- Energy from the Sun drives atmospheric processes on Earth, which leads to wind.
- Ancient energy from the Sun is stored in fossil fuels.

Review

1. What is energy?
2. What does it mean to say that energy changes matter from one state to another?
3. What are fuel and heat?
4. Where does the lamp in the room you're in now get its energy?

References

1. John Shedrick. This lantern festival uses hundreds of candles for light . CC BY 2.0

CONCEPT 7 Fossil Fuel Formation

- Describe the formation of fossil fuels.

Where is the energy coming from to power this bumper car?

Bumper cars usually run on electricity. Much of the electricity we use comes from fossil fuels. Coal or other fuels are burned in a power plant. This powers a generator and creates electricity. So the car is probably running on fossil fuels!

Formation of Fossil Fuels

Fossil fuels are made from plants and animals that lived hundreds of millions of years ago. The plants used energy from the Sun to form energy-rich carbon compounds. As the plants and animals died, their remains settled onto the ground and at the bottom of the sea. Layer upon layer of organic material was laid down. Eventually, the layers were buried very deeply. They experienced intense heat and pressure. Over millions of years, the organic material turned into fossil fuels.

Fossil fuels are compounds of carbon and hydrogen, called **hydrocarbons** (**Figure** 7.1).

Hydrocarbons can be solid, liquid, or gas. The solid form is coal. The liquid form is petroleum, or crude oil. The gaseous form is natural gas.

The solar energy stored in fossil fuels is a rich source of energy. But because they take so long to form, they are nonrenewable.

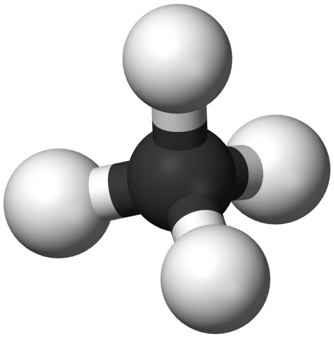

FIGURE 7.1
Hydrocarbons are made of carbon and hydrogen atoms. This molecule with one carbon and four hydrogen atoms is methane.

Summary

- Hydrocarbons are molecules made of one carbon and four hydrogen atoms.
- Ancient living organisms died and were buried quickly. Their remains were altered by intense heat and pressure. This formed fossil fuels.
- Fossil fuels include solid coal, liquid petroleum, and liquid natural gas.

Review

1. Why are coal, petroleum, and natural gas called fossil fuels?
2. How do fossil fuels form?
3. Where did the energy in a fossil fuel come from originally?

References

1. Ben Mills (Wikimedia: Benjah-bmm27). Structure of methane . Public Domain

CONCEPT 8 Fossil Fuel Reserves

- Describe the alternative fossil fuels.
- Know their environmental impacts.

Take a trip to Washington, D.C.?

People are always protesting in our nation's capital. That's part of liberty, part of democracy. The people in this photo are protesting against the Keystone XL pipeline. Other people in other locations may be protesting for the pipeline. The Keystone Pipeline would bring crude oil from tar sands to the United States. People in favor say the oil from tar sands will bring down energy costs and provide jobs. People opposed say that the environmental consequences are not worth the benefits.

Alternative Fossil Fuels

Easy-to-reach fossil fuel sources are being used up. Technologies are being developed to get at harder-to-reach sources. Also, ways to tap into alternative sources of fossil fuels are increasingly being developed. These sources include oil shale and tar sands.

Oil Shale

Oil shale is rock with oil dispersed through it. The oil has not collected in reservoirs. Oil shale is mined in open pit mines. To extract the oil from the rock, the rock is first crushed and heated to very high temperatures. Water is washed over the rock, which converts the fuel to petroleum. The petroleum can then be extracted from the rock. You can see an example of an oil shale facility below (**Figure** 8.1).

Most of the world's oil shale is spread out in large areas of Wyoming, Utah, and Colorado. In this region, water is scarce. Since the oil shale is spread over a large area, mining would be environmentally destructive.

FIGURE 8.1
An image of an oil shale facility in Colorado.

Tar Sands

Tar sands are rocky materials mixed with very thick oil. The tar is too thick to pump, and so tar sands are strip-mined. Hot water and caustic soda are used to separate the oil from the rock. This creates a slurry, which is shaken. The oil floats to the top and is skimmed off.

About 75% of the tar sands in the world are in Venezuela and Alberta, Canada (**Figure** 8.2). Large areas of land are degraded when tar sands are mined. A tremendous amount of waste rock is produced from mining tar sands.

FIGURE 8.2
A satellite image of an oil-sands mine in Canada.

Consequences of Using Alternative Fossil Fuels

Surface mining causes environmental damage. A lot of water may be needed. The water may be degraded. For oil to be removed from shale, the water must be heated. This requires energy. Tar sands and oil shale fuels create more pollutants than other fossil fuels. Extracting usable energy from oil shale and tar sands produces more greenhouse gases.

Keystone XL Pipeline

The Keystone XL Pipeline would transport oil from the oil sands in Alberta, Canada. The oil would travel into the United States. In the U.S. it would be refined. The pipeline is controversial. A leak could cause damage to wildlife habitat. A leak could also release enough oil to contaminate the Ogallala Aquifer. The Aquifer is crucial to agriculture and urban development in the Midwestern U.S. When burned, the fuel from the oil sands would increase pollutants. Greenhouse gases into the atmosphere would increase. The future of the pipeline is currently on hold.

Summary

- Easy to get at fossil fuels are running out, but there are other sources that are harder to get at that are still available.
- Oil shales and tar sands are two of the alternative sources of fossil fuels that are much in the news.
- The need for fossil fuels continues to grow as people in the developed world use more, and more people in the developing world want them.

Review

1. What are oil shales? How is oil extracted from them?
2. What are tar sands? How is oil extracted from them?
3. What are the environmental hazards of using these two fuel sources?

Explore More

Use the resource below to answer the questions that follow.

MEDIA
Click image to the left or use the URL below.
URL: https://www.ck12.org/flx/render/embeddedobject/1560

1. How much oil from oil shale is there in the United States?
2. How much oil shale is there compared with the rest of the world?
3. How does the amount of oil in oil shale in the U.S. compare with proven oil reserves in the Middle East?
4. Where is the Green River Formation? Why are scientists interested in this formation?
5. What is oil shale? What form is the oil in?

References

1. Courtesy of U.S. Dep't of the Interior, U.S. Geological Survey. An image of an oil shale facility in Colorado . Public Domain
2. Courtesy of NASA's Earth Observatory. A satellite image of an oil-sands mine in Canada . Public Domain

CONCEPT 9 Renewable vs Non-Renewable Energy Resources

- Define renewable resource and non-renewable resource.
- Compare and contrast renewable and non-renewable resources.
- Identify renewable and non-renewable resources.

Is your amusement park's energy source renewable?

Nearly all amusement parks use non-renewable energy. However, a few are now starting to use renewable energy. The Crealy Great Adventure Park in Devon, England, is going solar! Solar panels will be able to generate enough energy to power most of the park in the summer. When there is extra energy, it will supply the grid. Imagine what an amusement park could do if it were located in a sunny place!

Types of Energy Resources

Energy resources can be put into two categories—renewable or non-renewable. **Non-renewable resources** are used faster than they can be replaced. **Renewable resources** can be replaced as quickly as they are used. Renewable resources may also be so abundant that running out is impossible.

The difference between non-renewable and renewable resources is like the difference between ordinary batteries and rechargeable ones. If a flashlight with ordinary batteries goes dead, the batteries need to be replaced. But if the flashlight has rechargeable batteries, the batteries can be placed in a charger. The charger transfers energy from an outlet into the batteries. Once recharged, the batteries can be put back into the flashlight. Rechargeable batteries can be used again and again (**Figure** 9.1). In this way, the energy in the rechargeable batteries is renewable.

Types of Non-Renewable Resources

Fossil fuels include coal, oil, and natural gas. Fossil fuels are the greatest energy source for modern society. Millions

FIGURE 9.1
Rechargeable batteries are renewable because they can be refilled with energy. Is the energy they are refilled with always renewable?

of years ago, plants used energy from the Sun to form carbon compounds. These compounds were later transformed into coal, oil, or natural gas. Fossil fuels take millions of years to form. For this reason, they are non-renewable. We will use most fossil fuels up in a matter of decades. Burning fossil fuels releases large amounts of pollution. The most important of these may be the greenhouse gas, carbon dioxide.

Types of Renewable Resources

Renewable energy resources include solar, water, wind, biomass, and geothermal power. These resources are usually replaced at the same rate that we use them. Scientists know that the Sun will continue to shine for billions of years. So we can use the solar energy without it ever running out. Water flows from high places to lower ones. Wind blows from areas of high pressure to areas of low pressure. We can use the flow of wind and water to generate power. We can count on wind and water to continue to flow! Burning wood (**Figure** 9.2), is an example of biomass energy. Changing grains into biofuels is biomass energy. Biomass is renewable because we can plant new trees or crops to replace the ones we use. Geothermal energy uses water that was heated by hot rocks. There are always more hot rocks available to heat more water.

FIGURE 9.2
Wood is a renewable resource, but forest ecosystems need time to replenish.

Even renewable resources can be used unsustainably. We can cut down too many trees without replanting. We might need grains for food rather than biofuels. Some renewable resources are too expensive to be widely used. As the technology improves and more people use renewable energy, the prices will come down. The cost of renewable resources will go down relative to fossil fuels as we use fossil fuels up. In the long run renewable resources will need to make up a large amount of what we use.

Important Things to Consider About Energy Resources

Before we put effort into increasing the use of an energy source, we should consider two things. Is there a practical way to turn the resource into useful form of energy? For example, it is not practical if we don't get much more energy from burning a fuel than we put into making it. For example, what if it took more energy to make solar panels than we could get from the solar panels once they were working? Then solar energy would not be worth pursuing until better solar panels were developed.

What happens when we turn the resource into energy? What happens when we use that resource? Mining the resource may cause a lot of health problems or environmental damage. Using the resource may create a large amount of pollution. In this case, that fuel may also not be the best choice for an energy resource.

KQED: Climate Watch: Unlocking the Grid

Today we rely on electricity more than ever, but the resources that currently supply our power are finite. The race is on to harness more renewable resources, but getting all that clean energy from production sites to homes and businesses is proving to be a major challenge.

MEDIA

Click image to the left or use the URL below.

URL: https://www.ck12.org/flx/render/embeddedobject/116510

Summary

- Non-renewable resources are used faster than they can be replaced. Once they're gone, they are, for all practical purposes, gone.
- Renewable resources are so abundant or are replaced so rapidly that, for all practical purposes, they can't run out.
- Fossil fuels are the most commonly used non-renewable resources. Renewable resources include solar, wind, hydro, and (possibly) biomass.
- Many factors must be considered when deciding whether or not to use a resource.

Review

1. What is a renewable resource? Give three examples.
2. What is a non-renewable resource? Give three examples.
3. Can a renewable resource become non-renewable?

References

1. William Booz (Flickr:billbooz). Rechargeable batteries are a source of renewable energies . CC BY 2.0
2. Jon Sullivan. Wood is a renewable resource, but forest ecosystems need time to replenish . Public Domain

CONCEPT 10 Density

- Define density.
- Use physical measurements to calculate density.
- Use density values to calculate mass or volume.

How do logs stay afloat in water?

After trees are cut, logging companies often move these materials down a river to a sawmill where they can be shaped into building materials or other products. The logs float on the water because they are less dense than the water they are in. Knowledge of density is important in the characterization and separation of materials. Information about density allows us to make predictions about the behavior of matter.

Density

A golf ball and a table tennis ball are about the same size. However, the golf ball is much heavier than the table tennis ball. Now imagine a similar size ball made out of lead. That would be very heavy indeed! What are we comparing? By comparing the mass of an object relative to its size, we are studying a property called **density.** Density is the ratio of the mass of an object to its volume.

$$\text{Density} = \frac{\text{mass}}{\text{volume}}$$

Density is an intensive property, meaning that it does not depend on the amount of material present in the sample. Water has a density of 1.0 g/mL. That density is the same whether you have a small glass of water or a swimming pool full of water. Density is a property that is constant for the particular identity of the matter being studied.

The SI units of density are kilograms per cubic meter (kg/m^3), since the kg and the m are the SI units for mass and length respectively. In everyday usage in a laboratory, this unit is awkwardly large. Most solids and liquids have densities that are conveniently expressed in grams per cubic centimeter (g/cm^3). Since a cubic centimeter is equal to a milliliter, density units can also be expressed as g/mL. Gases are much less dense than solids and liquids, so their densities are often reported in g/L. Densities of some common substances at 20°C are listed in **Table** 10.1

TABLE 10.1: Densities of Some Common Substances

Liquids and Solids	Density at 20°C (g/ml)	Gases	Density at 20°C (g/L)
Ethanol	0.79	Hydrogen	0.084
Ice (0°C)	0.917	Helium	0.166
Corn oil	0.922	Air	1.20
Water	0.998	Oxygen	1.33
Water (4°C)	1.000	Carbon dioxide	1.83
Corn syrup	1.36	Radon	9.23
Aluminum	2.70		
Copper	8.92		
Lead	11.35		
Mercury	13.6		
Gold	19.3		

Since most materials expand as temperature increases, the density of a substance is temperature dependent and usually decreases as temperature increases.

You know that ice floats in water and it can be seen from the table that ice is less dense. Alternatively, corn syrup, being denser, would sink if placed into water.

Sample Problem: Density Calculations

An 18.2 g sample of zinc metal has a volume of 2.55 cm^3. Calculate the density of zinc.

Step 1: List the known quantities and plan the problem.

Known

- mass = 18.2 g
- volume = 2.55 cm^3

Unknown

- density = ? g/cm^3

Use the equation for density, $D = \frac{m}{V}$, to solve the problem.

Step 2: Calculate

$$D = \frac{m}{V} = \frac{18.2 \text{ g}}{2.55 \text{ cm}^3} = 7.14 \text{ g/cm}^3$$

Step 3: Think about your result.

If 1 cm^3 of zinc has a mass of about 7 grams, then 2 and a half cm^3 will have a mass about 2 and a half times as great. Metals are expected to have a density greater than that of water and zinc's density falls within the range of the other metals listed above

Since density values are known for many substances, density can be used to determine an unknown mass or an unknown volume. Dimensional analysis will be used to ensure that units cancel appropriately.

Sample Problem: Using Density to Determine Mass and Volume

1. What is the mass of 2.49 cm^3 of aluminum?
2. What is the volume of 50.0 g of aluminum?

Step 1: List the known quantities and plan the problem.

Known

- density = 2.70 g/cm^3
- 1. volume = 2.49 cm^3
- 2. mass = 50.0 g

Unknown

- 1. mass = ? g
- 2. volume = ? cm^3

Use the equation for density, $D = \frac{m}{V}$, and dimensional analysis to solve each problem.

Step 2: Calculate

1. $2.49 \text{ cm}^3 \times \frac{2.70 \text{ g}}{1 \text{ cm}^3} = 6.72 \text{ g}$
2. $50.0 \text{ g} \times \frac{1 \text{ cm}^3}{2.70 \text{ g}} = 18.5 \text{ cm}^3$

In problem 1, the mass is equal to the density multiplied by the volume. In problem 2, the volume is equal to the mass divided by the density.

Step 3: Think about your results.

Because a mass of 1 cm^3 of aluminum is 2.70 g, the mass of about 2.5 cm^3 should be about 2.5 times larger. The 50 g of aluminum is substantially more than its density, so that amount should occupy a relatively large volume.

MEDIA

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MEDIA

Click image to the left or use the URL below.

URL: https://www.ck12.org/flx/render/embeddedobject/184194

Summary

- Density is the ratio of the mass of an object to its volume.
- Gases are less dense that either solids or liquids
- Both liquid and solid materials can have a variety of densities
- For liquids and gases, the temperature will affect the density to some extent.

Review

1. Define "density."
2. Are gases more or less dense that liquids or solids at room temperature?
3. How does temperature affect the density of a material?
4. A certain liquid sample has a volume of 14.7 mL and a mass of 22.8 grams. Calculate the density.
5. A material with a density of 2.7 grams/mL occupies 35.6 mL. How many grams of the material are there?
6. A certain material has a density of 19.3 g/mL. What is the material?

- **density:** The ratio of the mass of an object to its volume. Density $= \frac{\text{mass}}{\text{volume}}$. Density is an intensive property, meaning that it does not depend on the amount of material present in the sample.

References

1. Tony Hisgett (Flickr:ahisgett). http://www.flickr.com/photos/hisgett/220279395/ .

CONCEPT 11 Pressure and Density of the Atmosphere

- Define air density and air pressure.
- Explain how they change with increasing altitude.

Have your ears ever popped?

If your ears have ever "popped," you have experienced a change in air pressure. Ears "pop" because the air pressure is different on the inside and the outside of your ears.

Properties of Air

We usually can't sense the air around us unless it is moving. But air has the same basic properties as other matter. For example, air has mass, volume, and, of course, density.

Density of Air

Density is mass per unit volume. Density is a measure of how closely molecules are packed together. The closer together they are, the greater the density. Since air is a gas, the molecules can pack tightly or spread out.

The density of air varies from place to place. Air density depends on several factors. One is temperature. Like other materials, warm air is less dense than cool air. Since warmer molecules have more energy, they are more active. The molecules bounce off each other and spread apart. Another factor that affects the density of air is altitude.

Altitude and Density

Altitude is height above sea level. The density of air decreases with height. There are two reasons: at higher altitudes, there is less air pushing down from above, and gravity is weaker farther from Earth's center. So at higher altitudes, air molecules can spread out more, and air density decreases (**Figure** 11.1).

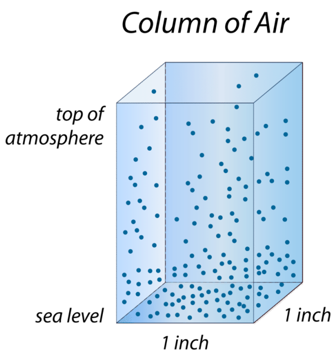


FIGURE 11.1

This drawing represents a column of air. The column rises from sea level to the top of the atmosphere. Where does air have the greatest density?

Air Pressure

Because air is a gas, its molecules have a lot of energy. Air molecules move a lot and bump into things. For this reason, they exert pressure. **Air pressure** is defined as the weight of the air pressing against a given area.

At sea level, the atmosphere presses down with a force of about 1 kilogram per square centimeter (14.76 pounds per square inch). If you are standing at sea level, you have more than a ton of air pressing against you. Why doesn't the pressure crush you? Air presses in all directions at once. Other molecules of air are pushing back.

Altitude and Air Pressure

Like density, the pressure of the air decreases with altitude. There is less air pressing down from above the higher up you go. Look at the bottle pictured below (**Figure** 11.2). It was drained by a hiker at the top of a mountain. Then the hiker screwed the cap on the bottle and carried it down to sea level. At the lower altitude, air pressure crushed it. Can you explain why?

Summary

- Air density and pressure decrease with increasing altitude.
- Ears pop as air pressures inside and outside of the ear equalize.
- Gravity pulls more air molecules toward the center of the planet.

Review

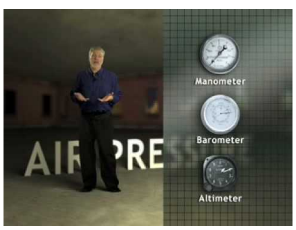
1. Why does air density decrease with increasing altitude?
2. Why does temperature decrease with increasing altitude in the troposphere?

FIGURE 11.2
At high altitude the air pressure is the same inside and outside the bottle. At sea level, the pressure is greater outside than inside the bottle. The greater outside pressure crushes the bottle.

3. Why are we not crushed by the weight of the atmosphere on our shoulders?

Explore More

Use the resource below to answer the questions that follow.



MEDIA
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URL: https://www.ck12.org/flx/render/embeddedobject/1574

1. What is pressure?
2. What causes air molecules to have pressure?
3. Where does the atmosphere end? What is out past the atmosphere?
4. What is air pressure?
5. What is the elevation and air pressure in Key West, Florida?
6. What is the elevation on Mt. Everest? Why do climbers often use extra oxygen up there?
7. Why does air pressure change with altitude?

References

1. Hana Zavadska. Drawing of a column of air . CC BY-NC 3.0
2. User:Quantockgoblin/Wikimedia Commons. Water bottle collapsing due to greater air pressure at lower alt itudes . Public Domain

CONCEPT 12 Circulation in the Atmosphere

- Explain why atmospheric circulation occurs.

Where can you go to experience wind?

Wind is one of the most obviously dynamic features of our dynamic planet. For a long time Mt. Washington in New Hampshire was known as the windiest place on Earth. It no longer is called that, but it's still plenty windy. A wind speed of 231 miles per hour was recorded on the mountain in April 1934. In a 200 mph wind, you would not be able to stand up. Temperatures due to wind chill would be outrageously cold!

Atmospheric Circulation

Wind is just moving air. You can't really see it. Whether it's a gentle breeze or strong wind, you are most aware of air when it moves (**Figure** 12.1). You can feel its molecules press against you. You can see things, like dirt and leaves, moving in the wind. And you can see object moving, like flags and trees, as a result of the wind.

Why Air Moves

Air movement takes place in the troposphere. This is the lowest layer of the atmosphere. Air moves because of differences in heating. These differences create convection currents and winds (**Figure** 12.2).

- Air in the troposphere is warmer near the ground. The warm air rises because it is light. The light, rising air creates an area of low air pressure at the surface.

FIGURE 12.1
How can you tell the wind is blowing in these photos?

- The rising air cools as it reaches the top of the troposphere. The air gets denser, so it sinks to the surface. The sinking, heavy air creates an area of high air pressure near the ground.
- Air always flows from an area of higher pressure to an area of lower pressure. Air flowing over Earth's surface is called **wind**. The greater the difference in pressure, the stronger the wind blows.

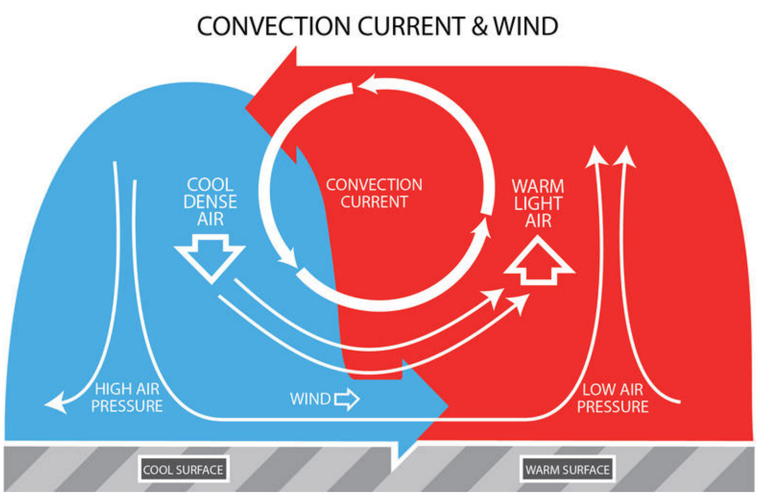


FIGURE 12.2
Differences in air temperature cause convection currents and wind.

Summary

- Warm air rises because it is less dense. This creates an area of low pressure.
- Cool air sinks because it is denser. This creates an area of high pressure.
- Wind blows from areas of high pressure to areas of low pressure.

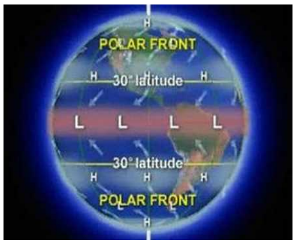
Review

1. Diagram and label the parts of a convection cell in the troposphere.

2. Why does warm air rise? Why does cool air sink?
3. What creates wind?

Explore More

Use the resource below to answer the questions that follow.



MEDIA
Click image to the left or use the URL below.
URL: https://www.ck12.org/flx/render/embeddedobject/1594

1. Where is insolation strongest?
2. What type of pressure occurs at the Equator? Why?
3. What type of pressure occurs at the poles? Why?
4. What are Hadley cells?
5. How do surface winds move?
6. What happens at the polar front?
7. How does air move differently at high altitudes?

References

1. From left to right: Julian Lim (Flickr:julianlimjl); Nico Nelson; Euan Morrison (Flickr:euan1234). Effects of the wind blowing . CC BY 2.0
2. Christopher Auyeung. Diagram of a convection cell . CC BY-NC 3.0

CONCEPT 13 Effect of Atmospheric Circulation on Climate

- Explain how climate relates to the global winds.
- Describe how atmospheric circulation influences precipitation.

Would you like to go to the horse latitudes?

Imagine you're on a sailing ship that's carrying horses among other cargo. You want to go from Spain to northern South America. For a smooth ride west, you need to get the ship into the trade winds. But where the trade winds and the westerlies meet is a zone where air flows vertically downward. It's hard to get through there in a sailing ship. So your ship gets stuck. For weeks. There's no more water or food for the horses so you throw them overboard. Some people think this is where the horse latitudes got their name.

More Effects of Latitude on Climate

We saw that the amount of solar radiation an area receives depends on its latitude. The amount of solar radiation affects the temperature of a region. Latitude has other effects on climate.

Latitude and Prevailing Winds

Global air currents cause global winds. The figure below shows the direction that these winds blow (**Figure** 13.1). Global winds are the prevailing, or usual, winds at a given latitude. The winds move air masses, which causes weather.

The direction of prevailing winds determines which type of air mass usually moves over an area. For example, a west wind might bring warm moist air from over an ocean. An east wind might bring cold dry air from over a mountain range. Which wind prevails has a big effect on the climate. What if the prevailing winds are westerlies? The westerlies blow from nearer the Equator to farther from the Equator. How would they affect the climate?

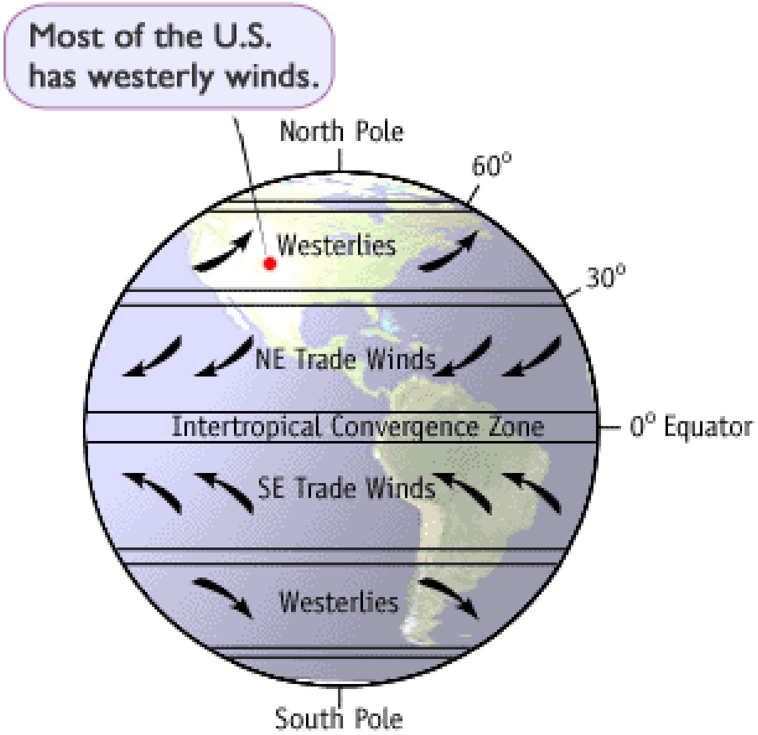


FIGURE 13.1
The usual direction of the wind where you live depends on your latitude. This determines where you are in the global wind belts.

Latitude and Precipitation

Global air currents affect precipitation. How they affect it varies with latitude (**Figure** 13.2). Where air rises, it cools and there is precipitation. Where air sinks, it warms and causes evaporation. These patterns are part of the global wind belts.

"Five Factors that Affect Climate" takes a very thorough look at what creates the climate zones. The climate of a region allows certain plants to grow, creating an ecological biome.

MEDIA
Click image to the left or use the URL below.
URL: https://www.ck12.org/flx/render/embeddedobject/1588

Summary

- Prevailing winds are the result of atmospheric circulation cells. They influence the climate of a region.
- Rising and sinking air can influence the precipitation of a region.
- Atmospheric circulation cells create the general climate of a region.

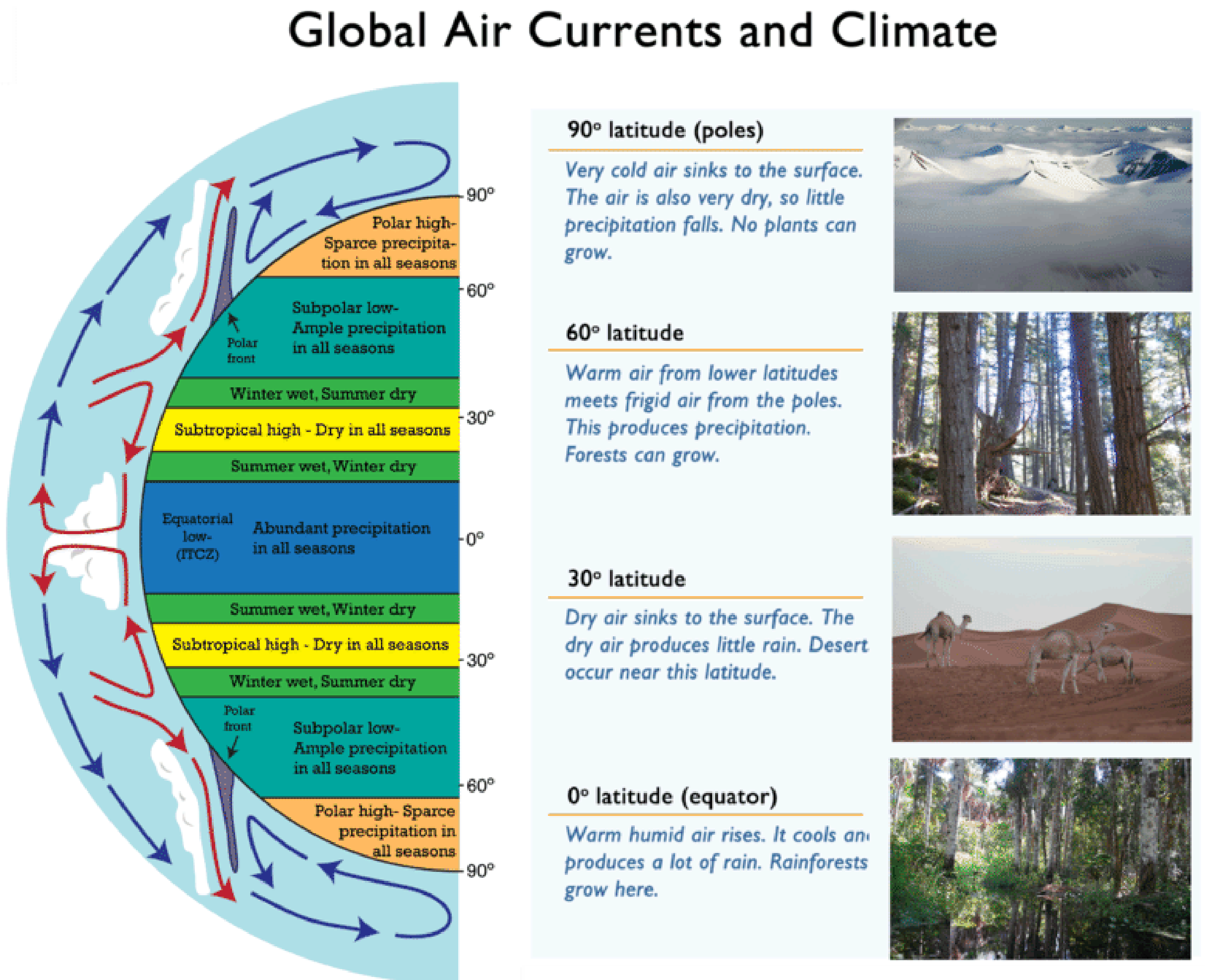


FIGURE 13.2

Global air currents are shown on the left. You can see how they affect climate on the right.

Review

1. What are prevailing winds? How do they affect climate?
2. Where is there not much wind?
3. How do atmospheric circulation cells affect precipitation?

References

1. Courtesy of National Park Services and Parks as Classroom. Map of atmospheric circulation cells . Public Domain
2. Global Circulation Diagram: CK-12 Foundation - Christopher Auyeung; Snow: Kitty Terwolbeck; Forest: Thomas Quine (Flickr:quinet); Desert: John Yavuz Can; Rainforest: Ivan Mlinaric. Map of global air curren

CONCEPT 14 How Ocean Currents Moderate Climate

- Describe how surface ocean currents moderate climate.
- Explain how the Gulf Stream alters climate in the British Isles.

How do ocean currents create giant redwoods?

The California Current brings cool water south along the western United States. Cool water contacting warmer water creates fog. This creates a favorable habitat for the giant redwoods of the northern California coast.

Surface Currents and Climate

Large ocean currents can have a big impact on climate, especially of nearby coasts. The Equator and the poles have very different climates today. But these regions would be much more different without ocean surface currents. These currents move heat around the globe. The best known of these is the **Gulf Stream**, which warms parts of Europe. But other currents also alter near-shore climates. Like the Gulf Stream, the Kushiro Current warms Japan. Cooler currents that move from the polar regions to the Equator also alter climate.

The Gulf Stream

The Gulf Stream carries warm water from near the Equator up the eastern coast of North America. Look at the map below (**Figure** 14.1); it shows how the Gulf Stream warms both the water and land along the coast.

The warm water then flows across the Atlantic Ocean to Europe. The Gulf Stream's warm waters raise temperatures in the North Sea. The warmer ocean temperatures raise the air temperatures over land. The difference is between 3 to 6°C (5 to 11°F). London, U.K., for example, is about six degrees farther south than Quebec, Canada. However, London's average January temperature is nearly 16°C (28°F) warmer. London also gets a lot of rain (**Figure** 14.2).

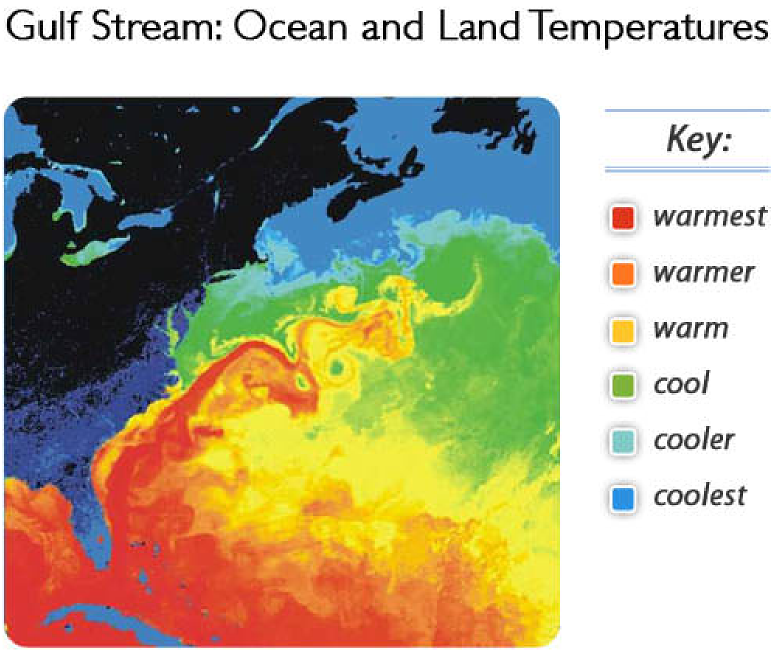


FIGURE 14.1
In this satellite photo, different colors indicate the temperatures of water and land. The warm Gulf Stream can be seen snaking up eastern North America.

Air traveling over the warm Gulf Stream water picks up moisture. Quebec is much drier but much snowier (**Figure** 14.3).

FIGURE 14.2
London, England, in winter.

FIGURE 14.3
Quebec City, Quebec, in winter.

Summary

- Water in the Gulf Stream warms as it travels along the Equator. The Gulf Stream brings warm water north along the United States. It then travels across the northern Atlantic to the British Isles.
- The Gulf Stream creates a relatively warm wet climate for the British Isles. This compares with the frigid Quebec at about the same latitude.
- Ocean currents transfer heat from the Equator toward the poles. This moderates Earth's temperature.

Review

1. Why is England relatively mild and rainy in winter for its latitude? Why is central Canada, at the same latitude and during the same season, relatively dry and frigid?
2. Where else do you think ocean currents might moderate global climate?
3. What would Earth be like if ocean water did not move?

Explore More

Use the resource below to answer the questions that follow.

MEDIA
Click image to the left or use the URL below.
URL: https://www.ck12.org/flx/render/embeddedobject/1634

1. What occurred in the Atacoma desert in July 2011? Why was this noteworthy?
2. What was the weather like in Australia in August and September 2011?
3. What happened in the summer of 2011 in the United States?
4. How many temperature records were broken in 2011 in the U.S.?
5. Why are scientists monitoring the Arctic ice?
6. What are the effects of the ice melt?
7. How is the Gulf Stream affected by the melting of the Arctic ice?

References

1. Courtesy of NASA, modified by CK-12 Foundation. Satellite image of the Gulf Stream . Public Domain
2. Image copyright Len Green, 2014. London during the winter .
3. Flickr:bill_comstock. Quebec during the winter .

CONCEPT 15 Distribution of Water on Earth

- Know where Earth's water is located.

Where is Earth's Water?

Here's a photo of Earth from space again. It's pretty easy to see where most of Earth's water is. It's in the oceans. Nearly all of Earth's water is in the seas. Although it's extremely useful for ocean ecosystems, it's not very useful for people. So where is the water that we can use?

Where Is Earth's Freshwater?

Most of Earth's water is salt water in the oceans. As seen below, only 3 percent of Earth's water is fresh (**Figure** 15.1). **Freshwater** is water that contains little or no dissolved salt. Most freshwater is frozen in ice caps and glaciers. Glaciers cover the peaks of some tall mountains. For example, the Cascades Mountains in North America and the Alps Mountains in Europe are capped with ice. Ice caps cover vast areas of Antarctica and Greenland. Chunks of ice frequently break off ice caps. They form icebergs that float in the oceans.

Only a tiny fraction of Earth's freshwater is in the liquid state. Most liquid freshwater is under the ground in layers of rock. Of freshwater on the surface, the majority occurs in lakes and soil. What percentage of freshwater on the surface is found in living things?

Water can remain in a particular location for a long time. This is known as a **reservoir**. Reservoirs for water include oceans, glaciers, ponds, or even the atmosphere. A water molecule may pass through a reservoir very quickly or

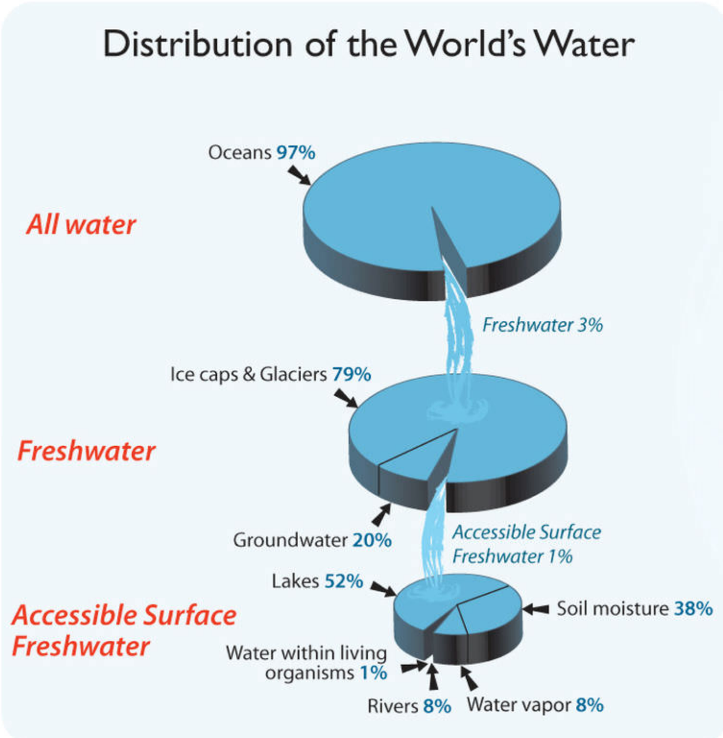


FIGURE 15.1
What percentage of Earth's surface freshwater is water vapor in the air?

may remain for much longer. The amount of time a molecule stays in a reservoir is known as its **residence time**. The residence time of water in the ocean is 3,200 years. Of course, not every molecule stays that long. That number is an average for all molecules.

Summary

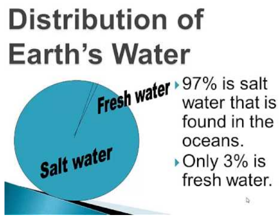
- Of Earth's water, 97% is in the oceans.
- Of the remaining 3%, much is trapped in ice and glaciers.
- A substance is stored in a reservoir. The amount of time it stays in that reservoir is its residence time.

Review

1. Earth has a tremendous amount of water. So why is water sometimes a scarce resource?
2. What are the reservoirs for water?
3. What is residence time? What does it mean to say the residence time of water in the atmosphere is nine days?

Explore More

Use this resource to answer the questions that follow.



MEDIA

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1. How much of Earth's surface is covered with water? What is most of this water in?
2. What percent of Earth's water is salty? How much is fresh water?
3. Of all of the fresh water, what percentage is ice, what is shallow groundwater, what is deep groundwater, what is in lakes and rivers and what is in the atmosphere as water vapor?
4. How much of Earth's fresh water is available for human consumption?

References

1. Hana Zavadska. Diagram of the distribution of Earth's water . CC BY-NC 3.0

Concept 16 States of Water

- Describe the water molecule.
- Identify the three states of water.

What are the three states of water in this photo?

Water is present as liquid, solid, and gas in this photo. We take water for granted here on Earth because there is a lot of it!

The Water Molecule

A molecule of water (**Figure** 16.1) is made of three atoms bonded together. Two of these atoms are hydrogen and one atom is oxygen. The hydrogen ions have a positive electrical charge. The oxygen atom has a negative electrical charge. The hydrogen atoms are located on one side and the oxygen atom on the other. This means that the side with the hydrogen ions has a slightly positive charge. The other side, the side without the hydrogen ions, has a slightly negative charge. The water molecule is a **polar molecule**.

Water has remarkable properties. Water expands when it freezes, even though all other substances contract. This means that in the winter ice on a pond or lake will float. Water has high surface tension because polar molecules tend to stick together. That's why drops stick together or some bugs can walk on the surface of a pond. Without water, life might not be able to exist on Earth. If it did exist, it would not be as diverse or as complex.

Three States of Matter

Water is the only substance on Earth that is present in all three states of matter. This means that water is present as a solid, liquid, and gas. Earth is the only planet with a significant amount of water present in all three states. All three phases may be present in a single location or in a region. The three phases are solid (ice or snow), liquid (water), and gas (**water vapor**). See ice, water, and clouds pictured below (**Figure** 16.2).

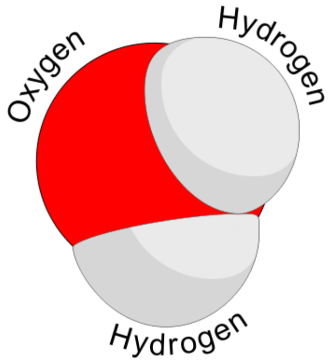


FIGURE 16.1
A water molecule. The side with the hydrogen atoms has a slightly positive charge. The side with the oxygen atom has a slightly negative charge.

FIGURE 16.2
(A) Ice floating in the sea. Can you find all three phases of water in this image? (B) Liquid water. (C) Water vapor is invisible, but clouds that form when water vapor condenses are not.

Summary

- Water is a polar molecule. On one side there is a positive electrical charge. On the other side there is a negative charge.
- Water is the only substance on Earth that is stable in all three states.
- Earth is the only planet in the solar system that has water in all three states.

Review

1. What is a polar molecule?
2. What are the three states of matter?
3. What are some of the remarkable properties of water?

Explore More

Use the resource below to answer the questions that follow.

MEDIA

Click image to the left or use the URL below.

URL: https://www.ck12.org/flx/render/embeddedobject/1635

1. What is water made of?
2. Explain how water becomes a solid.
3. What happens when a solid melts?
4. How do molecules move in a liquid?
5. What are the major differences between a solid, a liquid, and a gas.

References

1. User:Booyabazooka/Wikipedia. Diagram of a water molecule . Public Domain
2. (A) Natalie Lucier; (B) Gareth Haywood; (C) Lynn Greyling. Ice, liquid, and water vapor are the three phase s of water . (A) CC BY 2.0; (B) CC BY 2.0; (C) Public Domain

CONCEPT 17 Processes of the Water Cycle

- Describe reservoirs of the water cycle.
- Describe the processes that carry water between reservoirs.

Where have these water molecules been?

Did you ever wonder where the water molecules you drink came from? Were some of the molecules trapped in a glacier? Flowing along the bottom of the ocean? Up high in a thundercloud? Maybe a water molecule that you drink today once quenched the thirst of a dinosaur. It's all entirely possible.

The Water Cycle

The **water cycle** (**Figure** 17.1) is the movement of water through the oceans, atmosphere, land, and living things. The water cycle is powered by energy from the Sun.

Water keeps cycling. The water cycle repeats over and over again. Each water molecule has probably been around for billions of years. That's because Earth's water is constantly recycled.

Processes in the Water Cycle

Water keeps changing state as it goes through the water cycle. This means that it can be a solid, liquid, or gas. How does water change state? How does it keep moving through the cycle? As seen above (**Figure** 17.1), several processes are involved.

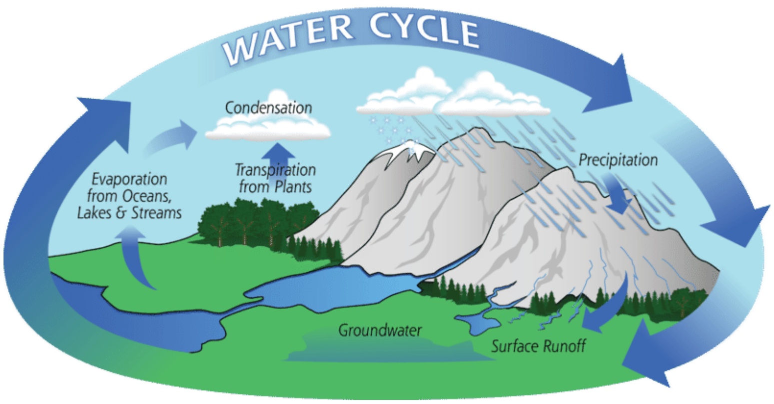


FIGURE 17.1
The water cycle has no beginning or end. Water just keeps moving along.

- **Evaporation** changes liquid water to water vapor. Energy from the Sun causes water to evaporate. Most evaporation is from the oceans because they cover so much area. The water vapor rises into the atmosphere.
- **Transpiration** is like evaporation because it changes liquid water to water vapor. In transpiration, plants release water vapor through their leaves (**Figure** 17.2). This water vapor rises into the atmosphere.

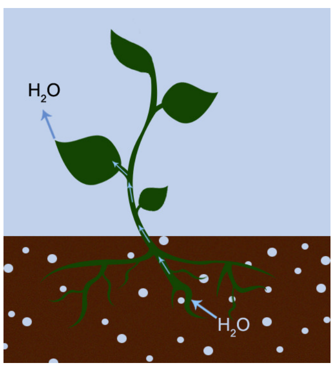
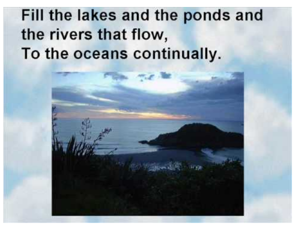


FIGURE 17.2
Liquid water is taken up by plant roots. The plant releases water vapor into the atmosphere. This is transpiration.

- **Condensation** changes water vapor to liquid water. As air rises higher into the atmosphere, it cools. Cool air can hold less water vapor than warm air. So some of the water vapor condenses into water droplets. Water droplets may form clouds. Below is an example of condensation (**Figure** 17.3).

- **Precipitation** is water that falls from clouds to Earth's surface. Water droplets in clouds fall to Earth when they become too large to stay aloft. The water falls as rain if the air is warm. If the air is cold, the water may freeze and fall as snow, sleet, or hail. Most precipitation falls into the oceans. Some falls on land.
- **Runoff** is precipitation that flows over the surface of the land. This water may travel to a river, lake, or ocean. Runoff may pick up fertilizer and other pollutants and deliver them to a water body. In this way, runoff may pollute bodies of water.
- **Infiltration** is the process by which water soaks into the ground. Some of the water may seep deep underground. Some may stay in the soil, where plants can absorb it with their roots.

FIGURE 17.3
A bottle that comes out of the refrigerator is cold. It cools the air near the bottle. Cooler air can hold less water so water vapor condenses onto the bottle.



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Summary

- The water cycle recognizes all of the reservoirs of water. It also describes the processes that carry water between the reservoirs.
- Water changes state by evaporation, condensation, and sublimation.
- Plants release water through their leaves by transpiration.

Review

1. What is transpiration?
2. How are evaporation and condensation the same? How are they different?
3. What is the role of the major reservoirs in the water cycle?

References

1. Courtesy of NASA/Atmospheric Infrared Sounder. Diagram of the water cycle . CC BY 2.0
2. Zappy's. Plant drawing up water and releasing water vapor through transpiration . CC BY-NC 3.0
3. Beatrice Murch (Flickr:blmurch). Condensation on a cold bottle . CC BY 2.0

CONCEPT 18 Heat

- Define heat.
- Explain how thermal energy is transferred.

This chef is taking corn bread out of a hot oven. What happened to the batter when it was put in the oven? Did the hot oven add "heat energy" to the batter? Not exactly. Contrary to popular belief, heat is not a form of energy.

What Is Heat?

Heat is the transfer of thermal energy between substances. Thermal energy is the kinetic energy of moving particles of matter, measured by their temperature. Thermal energy always moves from matter with greater thermal energy to matter with less thermal energy, so it moves from warmer to cooler substances. You can see this in the **Figure** 18.1. Faster-moving particles of the warmer substance bump into and transfer some of their energy to slower-moving particles of the cooler substance. Thermal energy is transferred in this way until both substances have the same thermal energy and temperature.

Q: How is thermal energy transferred in an oven?

A: Thermal energy of the hot oven is transferred to the cooler food, raising its temperature.

Cooling Down by Heating Up

How do you cool down a glass of room-temperature cola? You probably add ice cubes to it, as in the **Figure** 18.2. You might think that the ice cools down the cola, but in fact, it works the other way around. The warm cola heats up the ice. Thermal energy from the warm cola is transferred to the much colder ice, causing it to melt. The cola loses thermal energy in the process, so its temperature falls.

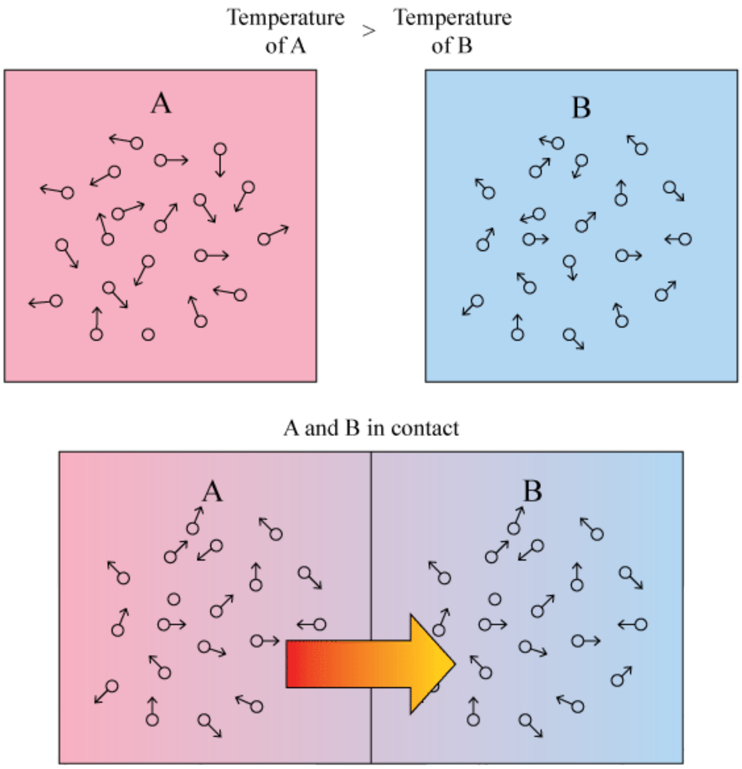


FIGURE 18.1

FIGURE 18.2

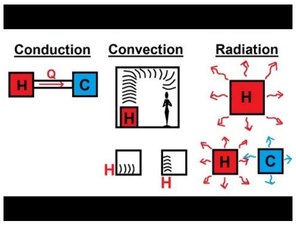
Summary

- Heat is the transfer of thermal energy between substances. Thermal energy is the kinetic energy of moving particles of matter, measured by their temperature.
- Thermal energy always moves from warmer to cooler substances until both substances have the same temperature.

Review

1. Define heat.
2. Describe how thermal energy is transferred.
3. Hot cocoa is poured into a cold mug. Apply the concept of heat to explain what happens next.

Resources



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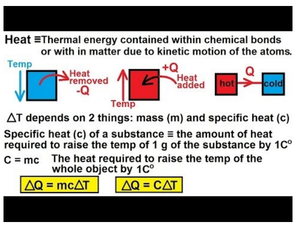

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URL: https://www.ck12.org/flx/render/embeddedobject/187448

References

1. Zachary Wilson. Diagram illustrating transfer of thermal energy . CC BY-NC 3.0
2. Simon Cousins. Ice cubes in cola cause the cola to lose thermal energy . CC BY 2.0

CONCEPT 19 Transfer of Thermal Energy

Lesson Objectives

- Describe the conduction of thermal energy.
- Explain how convection transfers thermal energy. (Advanced Topic)
- Give an example of the radiation of thermal energy. (Advanced Topic)

Lesson Vocabulary

- conduction
- convection (Advanced Topic)
- convection current (Advanced Topic)
- thermal conductor
- thermal insulator

Introduction

Did you ever cook over a campfire? The man in **Figure** 19.1 is cooking his lunch. He waits as his food absorbs energy. First, the energy from the fire needs to heat the water. Soon, all the water in the pot will be boiling hot. The man also feels warm. He feels the heat from the flames. He feels the warmth even though he is not touching the flames. Thermal energy is transferred from the fire to his hands.

FIGURE 19.1

Thermal energy from the fire is transferred to the pot and water and to the man sitting by the fire.

Conduction

You may know that electricity flows through wires. Wires are good conductors of electricity. Heat too can be transferred, or conducted, through some types of materials. The term **conduction** refers to the transfer of energy. Conduction occurs when energy is passed between objects.

The transfer of thermal energy is called **heat**. Particles of matter are in constant motion. Sometimes they collide with other particles. When they do, they transfer some of their energy. The energy is transferred from particle to particle. It is sort of like a row of dominoes falling over. In this process, thermal energy moves through a substance. It can even move into other nearby substances.

In **Figure** 19.1, conduction occurs between particles of the metal in the pot. It also occurs between particles of the pot and the water. **Figure** 19.2 shows additional examples of conduction.

FIGURE 19.2
How is thermal energy transferred in each of these examples?

Thermal Conductors

Have you ever walked on hot pavement? Perhaps you jumped onto the grass to escape the heat? Why did the grass seem cooler? The grass and pavement are both in the Sun? Maybe it has to do with how well they conduct energy.

Think about a cooking utensil. Have you noticed some have wood or plastic handles? Do you know why? Think about the grass and the pavement on that sunny day.

It's all about the type of matter. Some types of matter are good at allowing heat to flow through them. Other types of matter, or materials, are good insulators. They resist the flow of heat through them, meaning they are not good conductors of heat.

Materials that are good conductors of heat are called **thermal conductors**. Metals allow heat to flow through them easily. That's why the metal pot in the **Figure** 19.1 quickly gets hot all over. This happens even if the fire is only at the bottom of the pot. The heat moves easily throughout the metal pot. The pot is able to get hot all over. It doesn't just get hot on the bottom. In **Figure** 19.2, the curling iron heats up almost instantly. It is able to transfer thermal energy to the strands of hair that it touches.

Thermal Insulators

Some materials are able to resist the transfer of heat. These materials are poor conductors of heat. Therefore, they are called **thermal insulators**. **Figure** 19.3 shows several examples. Fluffy yellow insulation inside the roof of a home is full of air. The air prevents the transfer of thermal energy. In air (a gas) the molecules are further apart. The transfer of heat is much more difficult. Again, think about that row of dominoes. If they are close together and they start to fall, the motion is quick. If they are placed further apart, the falling motion is slower. You can try this by having some domino races.

For the same reason, house insulation keeps the heat out of the house on hot days and in the house on cold days. The trapped air (a gas) is slow to transfer thermal energy. A puffy down jacket keeps you warm in the winter for the same reason. Its feather filling holds trapped air. The trapped air prevents energy transfer from your warm body to the cold air outside. Solids like plastic and wood are also good thermal insulators. That's why pot handles and cooking utensils are often made of these materials.

KQED: Darfur Stoves Project

Not everyone in the world has a stove in their kitchen. In some countries, people must search for wood. They use the wood to build fires. They then cook their food over the fire. In Darfur, Sudan, many women are living in refugee camps. They must walk many hours to collect firewood. This places them at great risk of violent attacks. Researchers at Lawrence Berkeley National Laboratory have engineered a more efficient wood-burning stove. This new type of

FIGURE 19.3
Thermal insulators have many practical uses. Can you think of others?

stove greatly reduces the amount of firewood needed. How do you think this helps the women of Darfur?

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Convection (Advanced Topic)

Convection is another way thermal energy is transferred. In convection, heat is transferred by particles moving through a fluid. Heat is transferred from warmer to cooler areas. That's how energy is transferred in the soup in **Figure** 19.3. Particles of soup near the bottom of the pot get hot first. They have more energy so they spread out and become less dense. With lower density, these particles rise to the top of the pot (see **Figure** 19.4). By the time they reach the top of the pot, they have cooled off. They have less energy to move apart. As a result, they become more dense. With greater density, the particles sink to the bottom of the pot. The cycle repeats over and over again. This loop of moving particles is called a **convection current**.

Convection currents move thermal energy through many fluids. Heat is transferred though molten rock (a semi-

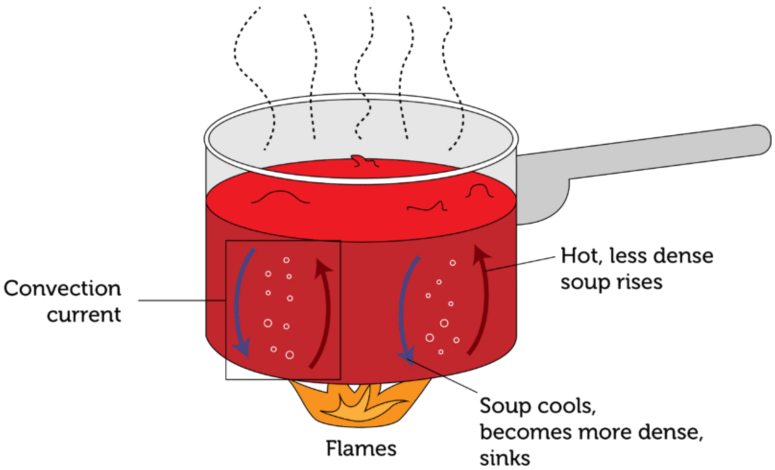


FIGURE 19.4
Convection currents carry thermal energy throughout the soup in the pot.

liquid) inside the Earth. Water in the oceans circulates because of this process. Even the air in the atmosphere transfers heat in this way. In the atmosphere, convection currents create wind. You can see one way this happens in **Figure** 19.5. Land heats up and cools off faster. Therefore, land is warmer during the day and cooler at night than water. Air close to the surface gains or loses heat as well. Warm air rises because it is less dense. When it does, cool air moves in to take its place. This creates a convection current that carries air from the warmer to the cooler area.

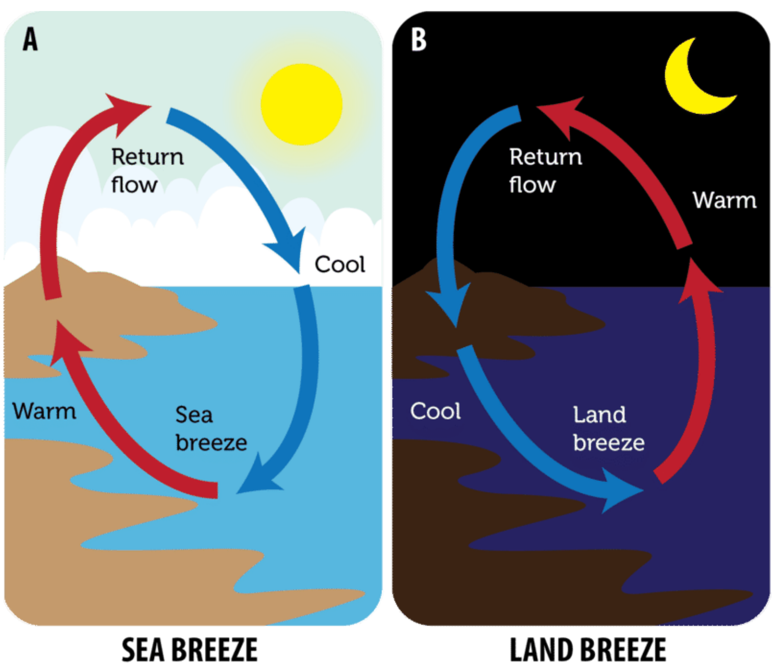


FIGURE 19.5
A sea breeze blows toward land during the day, and a land breeze blows toward water at night. Why does the wind change direction after the sun goes down?

Radiation (Advanced Topic)

Both conduction and convection transfer energy through matter. Radiation is the only way of transferring energy that doesn't require matter. Radiation is the transfer of energy by waves. These waves can travel through empty space. When these waves reach objects, they transfer energy to the objects. This causes them to warm up. This is how the Sun's energy reaches Earth and heats its surface (see **Figure** 19.6). Radiation is also how thermal energy from a campfire warms people nearby. You might be surprised to learn that all objects radiate thermal energy. This even includes you. In fact, when a room is full of people, it may feel noticeably warmer. This is because of all the thermal energy the people radiate!

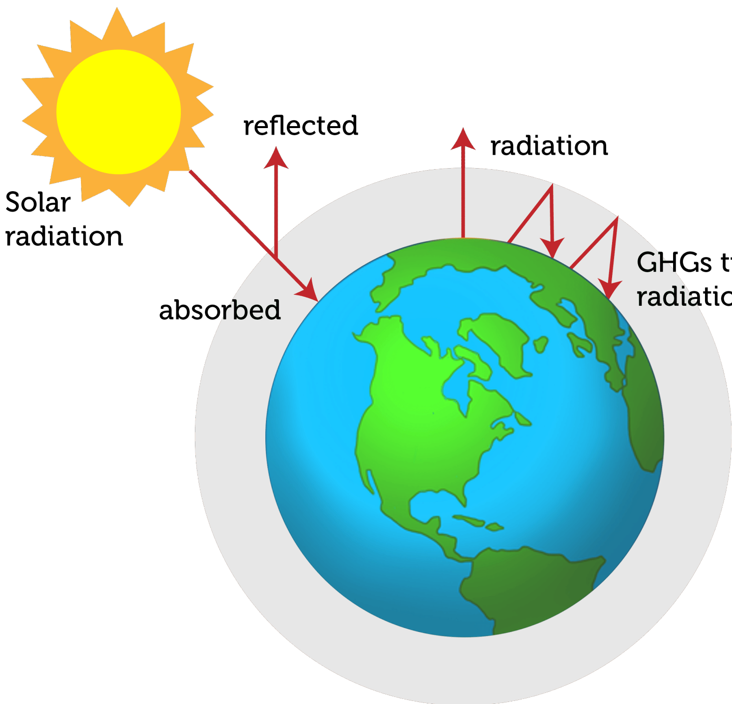


FIGURE 19.6
Earth is warmed by energy that radiates from the sun. Earth radiates some of the energy back into space. Greenhouse gases (GHGs) trap much of the re-radiated energy, causing an increase in the temperature of the atmosphere close to the surface.

Lesson Summary

- Conduction is the transfer of thermal energy. It occurs between objects or substances that are touching. Thermal conductors are materials that are good conductors of heat. Thermal insulators are materials that are poor conductors of heat. Both conductors and insulators have important uses.
- Convection is the transfer of thermal energy. This occurs as particles move within a fluid. The fluid may be a liquid or a gas. The particles within the fluid transfer energy by moving from warmer to cooler areas. They move in loops. These loops are called convection currents.
- Radiation is the transfer of thermal energy by waves. These waves can travel through empty space. When the waves reach objects, the heat is transferred to the objects. Radiation is how the Sun warms the Earth's surface.

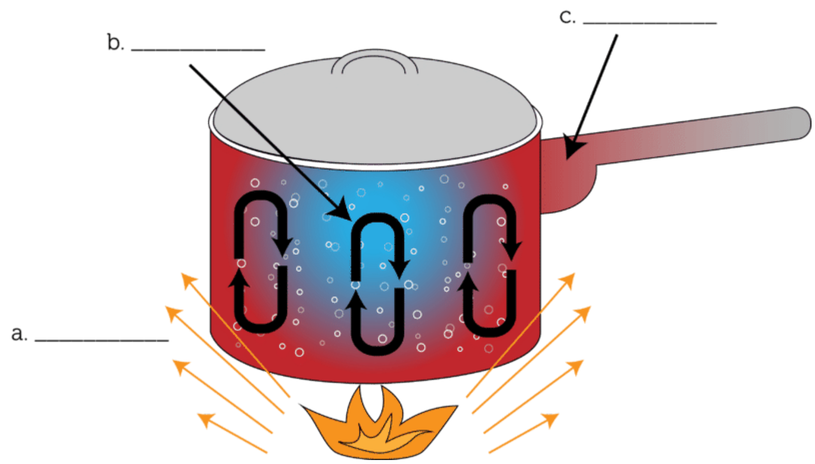
Lesson Review Questions

Recall

1. Define conduction.
2. Define convection.
3. Define the radiation of thermal energy.

Apply Concepts

4. Fill in each blank in the diagram below with the correct method of heat transfer.



5. How could you insulate an ice cube to keep it from melting? What material(s) would you use?

Think Critically

6. Why does convection occur only in fluids?
7. A friend tells you that insulation keeps out the cold. Explain why this statement is incorrect. What should your friend have said?

Points to Consider

Thermal energy is very useful. For example, we use thermal energy to keep our homes warm and our motor vehicles moving.

- How does thermal energy heat a house? What devices and systems are involved?
- How does thermal energy run a car? How does burning gas in the engine cause the wheels to turn?

External Resources

By clicking a link below, you will leave the CK-12 site and open an external site in a new tab. This page will remain open in the original tab.

http://www.sciencehelpdesk.com/unit/science2/3

References

1. Erik Halfacre. http://www.flickr.com/photos/erikhalfacre/8730126558/ . CC BY 2.0
2. Ice in hands: Visit Greenland (Flickr:greenland_com); Woman with iron: Maegan Tintari. Ice in hands: http://www.flickr.com/photos/ilovegreenland/6099497074/; Woman with iron: http://www.flickr.com/photos/lovemaegan/6324422379/ . CC BY 2.0
3. Insulation: Flickr:Epic Fireworks; Child in jacket: Mark Baylor; Soup: Simon Doggett. Insulation: http://www.flickr.com/photos/epicfireworks/4603519682/; Child in jacket: http://www.flickr.com/photos/baylors/5283466866/; Soup: www.flickr.com/photos/90037546@N00/3156066767/ . CC BY 2.0
4. Christopher Auyeung. CK-12 Foundation . CC BY-NC 3.0
5. Christopher Auyeung. CK-12 Foundation . CC BY-NC 3.0
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CONCEPT 20 Introduction to Weather

- Learn what factors make up weather.
- Understand what causes weather.

What's the weather like?

The United States is a big country. With two coasts and a large land mass in between, there's a chance for every kind of weather. In the next few sections we'll visit places that have the type of weather we're interested in studying.

What Is Weather?

All **weather** takes place in the atmosphere. Nearly all of it in the lower atmosphere. **Weather** refers to the conditions of the atmosphere at a given time and place. **Climate** is the average of weather over a long time.

Imagine your grandmother who lives in a distant place calls you up. She asks what your weather is like today. What would you say? Is it warm or cold? Sunny or cloudy? Calm or windy? Clear or rainy? What features of weather are important to mention?

A location's weather depends on:

- air temperature.
- air pressure.
- fog.
- humidity.
- cloud cover.

- precipitation.
- wind speed and direction.

All of these characteristics are directly related to the amount of energy that is in the system, and where that energy is. The ultimate source of this energy is the Sun.

Weather is what we experience from day to day, or minute to minute. Weather can change rapidly.

What Causes Weather?

Weather occurs because of unequal heating of the atmosphere. The source of heat is the Sun. The general principles behind weather can be stated simply:

- The Sun heats Earth's surface more in some places than in others.
- Where it is warm, heat from the Sun warms the air close to the surface. If there is water at the surface, it may cause some of the water to evaporate.
- Warm air is less dense, so it rises. When this happens, more dense air flows in to take its place. The flowing surface air is wind.
- The rising air cools as it goes higher in the atmosphere. If it is moist, the water vapor may condense. Clouds may form, and precipitation may fall.

Summary

- A region's weather depends on its air temperature, air pressure, humidity, precipitation, wind speed and direction, and other factors.
- Climate is the long-term average of weather.
- Weather can change in minutes, but climate changes very slowly.

Review

1. Compare and contrast weather and climate.
2. What factors account for a location's weather?
3. Describe how unequal heating causes weather.

CONCEPT 21 Weather

Lesson 1: Weather and Atmospheric Water

- **Common Misconception: Humidity**

Students may have some misunderstandings when it comes to humidity. They probably have heard that relative humidity is the amount of moisture in the air compared to what the air can hold. While this demonstrates a basic understanding of humidity, it does not accurately explain what is happening. Air does not have an attractive force with the water to "hold" it. Water molecules are lighter and move faster than nitrogen and oxygen.

Lesson 2: Changing Weather

- **Common Misconception: Fronts**

Students may have the impression, from looking at weather maps, that a front is a thin wall of weather. This is not the case. The map needs to represent the front in a visual manner. The actual weather conditions associated with the front may stretch for miles beyond the edge of the front.

Lesson 3: Storms

- **Common Misconception: Water Spout or Tornado**

Some students may have seen photographs of water spouts and assume that they are merely tornadoes that form over the water. This is not the cases. A true waterspout forms in a different type of cloud than a tornado. Water spouts form in cumulus clouds, tornadoes forming cumulonimbus clouds.

- **Common Misconception: Tornadoes and Cities**

Students may have heard that tornadoes do not hit cities. This is not the case. Cities such as Dallas, Nashville, Oklahoma City, and St Louis have all experienced at least one hurricane. It is true, however, that cities take up a small portion of the land area. So therefore the chances of a tornado hitting a city are smaller than a rural area. It is also believed that an urban area gives off excess heat, which may deflect smaller hurricanes.

Lesson 4: Weather Forecasting

- **Common Misconception: Learning Weather Forecasting**

Students may think of weather forecasting as a topic that can be studied and learned and mastered. This is not the case. Explain to students that forecasting is not an exact science. The weather is constantly changing and there is always some degree of uncertainly in weather data. Learning to forecast and to make good interpretations of data is a personal and individual skill. There are things that are taught but there are other things about weather forecasting that cannot be taught.

CONCEPT 22 Collecting Weather Data

- Describe how scientists collect information about weather.

What does a meteorologist need before he or she can forecast the weather?

Data! A meteorologist needs data about the current conditions. There are many types of instruments available for collecting that data. According to the World Meteorological Organization (WMO), a 5-day weather forecast today is as reliable as a 2-day forecast was 20 years ago.

Predicting the Weather

Weather is very difficult to predict. That's because it's very complex, and many factors are involved. Slight changes in even one factor can cause a big change in the weather. Still, certain "rules of thumb" generally apply. These "rules" help meteorologists forecast the weather. For example, low pressure is likely to bring stormy weather. So if a center of low pressure is moving your way, you can expect a storm.

People often complain when the weather forecast is wrong. Weather forecasts today, however, are much more accurate than they were just 20 years ago. Scientists who study and forecast the weather are called meteorologists. How do they predict the weather?

The first thing they need is data. Their data comes from various instruments.

Weather Instruments

Weather instruments measure weather conditions. One of the most important conditions is air pressure, which is measured with a **barometer** (**Figure** 22.1). There are also a number of other commonly used weather instruments (**Figure** 22.2):

- A **thermometer** measures temperature.
- An **anemometer** measures wind speed.
- A **rain gauge** measures the amount of rain.
- A **hygrometer** measures humidity.
- A **wind vane** shows wind direction.
- A **snow gauge** measures the amount of snow.

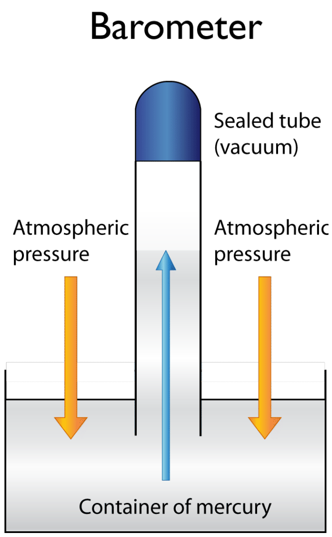


FIGURE 22.1
The greater the air pressure outside the tube, the higher the mercury rises inside the tube. Mercury can rise in the tube, because there's no air pressing down on it.

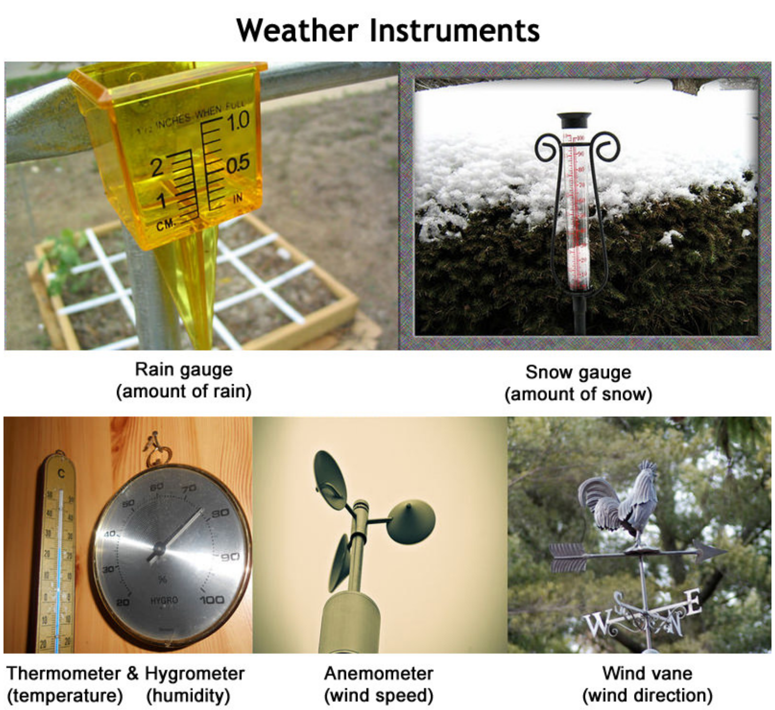


FIGURE 22.2
Some of the most commonly used weather instruments.

Collecting Data

Weather instruments collect data from all over the world at thousands of weather stations (**Figure** 22.3). Many are on land, but some float in the oceans on buoys. There's probably at least one weather station near you.

Other weather devices are needed to collect weather data in the atmosphere. They include weather balloons, satellites, and **radar** (**Figure** 22.3).

FIGURE 22.3
Weather stations collect data on land and sea. Weather balloons, satellites, and radar collect data in the atmosphere.

Weather stations contain many instruments for measuring weather conditions. The **weather balloon** (**Figure** 22.3) will rise into the atmosphere until it bursts. As it rises, it will gather weather data and send it to the surface. Many **weather satellites** orbit Earth. They constantly collect and transmit weather data from high above the surface. A radar device sends out radio waves in all directions. The waves bounce off water in the atmosphere and then return to the sender. The radar data shows where precipitation is falling. It's raining in the orange-shaded area shown above.

Using Computers

What do meteorologists do with all that weather data? They use it in weather models. The models analyze the data and predict the weather. The models require computers. That's because so many measurements and calculations are involved.

Summary

- Various instruments measure weather conditions: thermometers measure air temperature, and barometers measure air pressure.
- Satellites monitor weather from above.

- Radar is used to monitor precipitation.

Review

1. What can a barometer tell you about the coming weather?
2. Why is weather prediction better than it used to be?
3. What is the purpose of a weather satellite?

Explore More

Use the resource below to answer the questions that follow.

MEDIA
Click image to the left or use the URL below.
URL: https://www.ck12.org/flx/render/embeddedobject/1605

1. Why is weather difficult to predict?
2. What is the Afternoon Constellation? What does it do?
3. What are the three important characteristics of clouds?
4. What are the basic shapes of clouds?
5. What is fog?
6. Why is it important to study clouds?
7. What will Cloudsat do?

References

1. Hana Zavadska. Diagram of a barometer . CC BY-NC 3.0
2. Rain: Flickr:wssssst; Snow: KaCey97007; Thermometer/Hygrometer: Karl-Ludwig G. Poggemann (Flickr:quapan); Anemometer: Aidan (Flickr:asgw); Wind vane: Flickr:BobMacInnes. Pictures of a rain gauge, snow gauge, thermometer, hygrometer, anemometer, and wind vane . CC BY 2.0
3. Weather Station: Courtesy of Scott Bauer, USDA; Weather Balloon: Wolke; Weather Satellite, Weather Radar: Courtesy of NOAA. Weather stations, balloons, satellites, and radar are used to make weather forecasts . Public Domain

CONCEPT 23 Weather Fronts

- Define different types of fronts.
- Explain how fronts create changes in weather.

What happens when one air mass meets another?

This sight is common when one air mass meets another. You can almost see one air mass being pushed up over the other. When two air masses meet, the result is often a storm. Have you been to the Midwestern United States in the spring? This is a common sight.

Fronts

When cold air masses move south from the poles, they run into warm air masses moving north from the tropics. The boundary between two air masses is called a **front**. Air masses usually don't mix at a front. The differences in temperature and pressure cause clouds and precipitation. Types of fronts include cold, warm, occluded, and stationary fronts.

Cold Fronts

A **cold front** forms when a cold air mass runs into a warm air mass (**Figure** 23.1). The cold air mass moves faster than the warm air mass. So the cold air mass lifts the warm air mass out of its way. As the warm air rises, its water vapor condenses. Clouds form, and precipitation falls. If the warm air is very humid, precipitation can be heavy. Temperature and pressure differences between the two air masses cause winds. Winds may be very strong along a cold front.

As the fast-moving cold air mass keeps advancing, so does the cold front. Cold fronts often bring sudden changes in the weather. There may be a thin line of storms right at the front that moves as it moves. In the spring and summer,

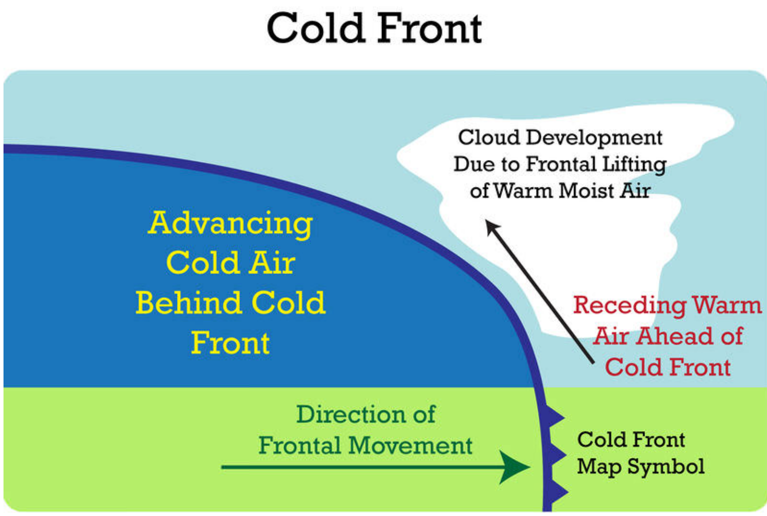


FIGURE 23.1
Cold fronts often bring stormy weather.

the storms may be thunderstorms and tornadoes. In the late fall and winter, the storms may bring snow. After a cold front passes, the cold air mass behind it brings cooler temperatures. The air is likely to be less humid as well. Can you explain why?

Warm Fronts

When a warm air mass runs into a cold air mass, it creates a **warm front** (**Figure** 23.2). The warm air mass is moving faster than the cold air mass. The warm air mass then flows up over the cold air mass. As the warm air rises, it cools. This brings about clouds and sometimes light precipitation. Warm fronts move slowly and cover a wide area. After a warm front passes, the warm air mass behind it brings warmer temperatures. The warm air is also likely to be more humid.

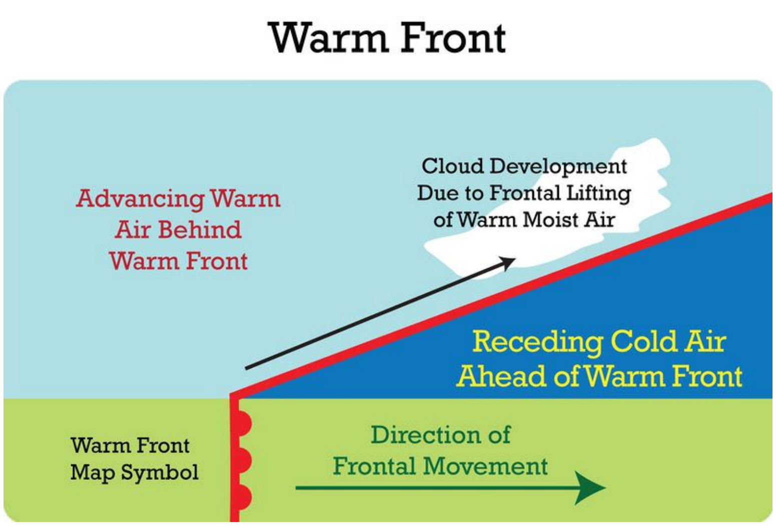


FIGURE 23.2
Warm fronts generally bring cloudy weather.

Occluded Fronts

With an **occluded front**, a warm air mass becomes trapped between two cold air masses. The warm air is lifted up above the cold air (**Figure** 23.3). Cloudy weather and precipitation along the front are typical.

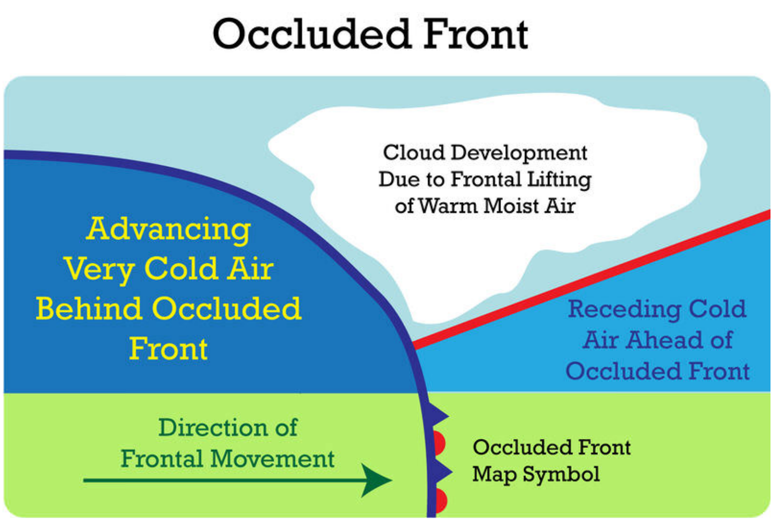


FIGURE 23.3
How does an occluded front differ from a warm or cold front?

Stationary Fronts

Sometimes two air masses stop moving when they meet. These stalled air masses create a **stationary front**. Such a front may bring clouds and precipitation to the same area for many days.

Summary

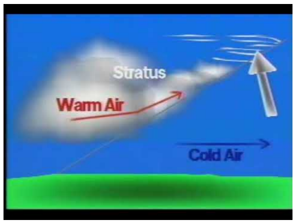
- Much of the weather occurs at fronts, where air masses meet.
- In a warm front, a warm air mass slides over a cold air mass. In a cold front, a cold air mass slides under a warm air mass.
- An occluded front has three air masses: cold, warm, and cold.

Review

1. What characteristics give warm fronts and cold fronts their names?
2. Describe a warm front. What weather is found with a warm front?
3. Describe a cold front. What weather is found with a cold front?
4. How does an occluded front form?

Explore More

Use the resource below to answer the questions that follow.



MEDIA

Click image to the left or use the URL below.

URL: https://www.ck12.org/flx/render/embeddedobject/1601

1. What is a front?
2. How does a cold front form?
3. What forms along a cold front?
4. How does a warm front form?
5. What type of clouds form at warm fronts?
6. What type of precipitation is produced from a warm front?
7. What is a stationary front?
8. What type of weather can occur at an occluded front?

References

1. Christopher Auyeung. Diagram of a cold front . CC BY-NC 3.0
2. Christopher Auyeung. Diagram of a warm front . CC BY-NC 3.0
3. Christopher Auyeung. Diagram of an occluded front . CC BY-NC 3.0

Concept 24 Weather versus Climate

- Define climate, and know how it is different from weather.

Where in Hawaii do you want to go?

Look at a list of cities with the best climate in the United States. Hawaii is well represented. Now look at a list of cities with the worst climate in the United States. (You know where this is going, don't you?) Yes, Hawaii is also represented. Kona and Hilo are both on the Big Island. Hilo is on the windward side where the trade winds bring in moisture from the Pacific. Kona is on the leeward side, beyond the high volcanic mountains. This city lies within the rain shadow. Guess which city is more popular with tourists?

What is Climate?

Almost anything can happen with the weather. Climate, however, is more predictable. **Climate** is the long-term average of weather in a particular spot. Good climate is why we choose to vacation in Hawaii in February (usually on the leeward side). Of course, the weather is not guaranteed to be good! A location's climate considers the same characteristics as its weather. These are its air temperature, humidity, wind speed and direction, and the type, quantity, and frequency of precipitation. For climate, these things are averaged over time.

During the mid- to late-twentieth century, California received an enormous influx of new residents. Many of these people came from the northeastern United States. They were sick of the cold, snow, and rain. Southern California, especially near the coast, has a nearly perfect climate. The average lows and highs in San Diego year round are in the 50s, 60s, and 70s (**Figure** 24.1).

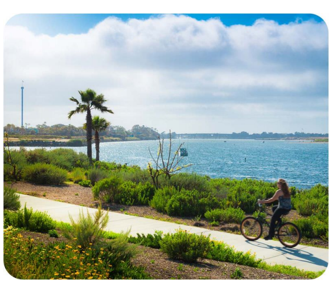


FIGURE 24.1
A bike path along Mission Bay in San Diego, California.

The climate for a particular place is steady. Changes occur only very slowly. Climate is determined by many factors, including the angle of the Sun, the likelihood of cloud cover, and the air pressure. All of these factors are related to the amount of solar energy that hits that location over time.

The climate of a region depends on its position relative to many things. These factors are described in the next sections.

Summary

- Climate is the long-term average of weather.
- Climate changes very slowly.
- Climate depends on a number of factors such as air temperature, humidity, wind speed and direction, and the type, quantity, and frequency of precipitation.

Explore More

Use the resource below to answer the questions that follow.

- **What Is Climate?** at http://www.youtube.com/watch?v=bjwmrg__ZVw (2:51)

MEDIA
Click image to the left or use the URL below.
URL: https://www.ck12.org/flx/render/embeddedobject/58908

1. What is the difference between weather and climate?
2. Describe a temperate climate.
3. Where are arid climates found?
4. What creates a climate system?
5. What drives climate?
6. What do greenhouse gases do?
7. What are the main greenhouse gases?
8. What would Earth be like without the greenhouse effect?

Review

1. What is climate?
2. Why did California receive a large influx of new residents?
3. How does climate change?
4. What factors determine climate?

References

1. Image copyright Dancestrokes, 2013. A sunny day in San Diego, California . Used under license from Shutterstock.com

Concept 25 Organization of Living Things

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

How would you classify a horse?

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

Classification of Life

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

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

Linnaean System of Classification

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

Carolus (Carl) Linnaeus (1707-1778) (**Figure** 25.1) built on Aristotle's work to create his own classification system. He invented the way we name organisms today, with each organism having a two word name. Linnaeus is considered the inventor of modern **taxonomy**, the science of naming and grouping organisms.

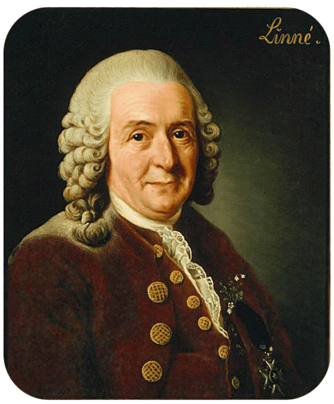


FIGURE 25.1

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

Linnaeus developed **binomial nomenclature**, a way to give a scientific name to every organism. In this system, each organism receives a two-part name in which the first word is the **genus** (a group of species), and the second word refers to one species in that genus. For example, a coyote's species name is *Canis latrans*. *Latrans* is the species and *Canis* is the genus, a larger group that includes dogs, wolves, and other dog-like animals. Here is another example: the red maple, *Acer rubra*, and the sugar maple, *Acer saccharum*, are both in the same genus and they look similar (**Figure** 25.2). Notice that the genus is capitalized and the species is not, and that the whole scientific name is in italics. Tigers *(Panthera tigris)* and lions *(Panthera leo)* have the same genus name, but are obviously different species. The names may seem strange, but the names are written in a language called Latin.

FIGURE 25.2

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

Modern Classification

Modern taxonomists have reordered many groups of organisms since Linnaeus. The main categories that biologists use are listed here from the most specific to the least specific category (**Figure** 25.3). All organisms can be classified into one of three **domains**, the least specific grouping. The three domains are Bacteria, Archaea, and Eukarya. The Kingdom is the next category after the Domain. All life is divided among six kingdoms: Kingdom Bacteria, Kingdom Archaea, Kingdom Protista, Kingdom Plantae, Kingdom Fungi, and Kingdom Animalia.

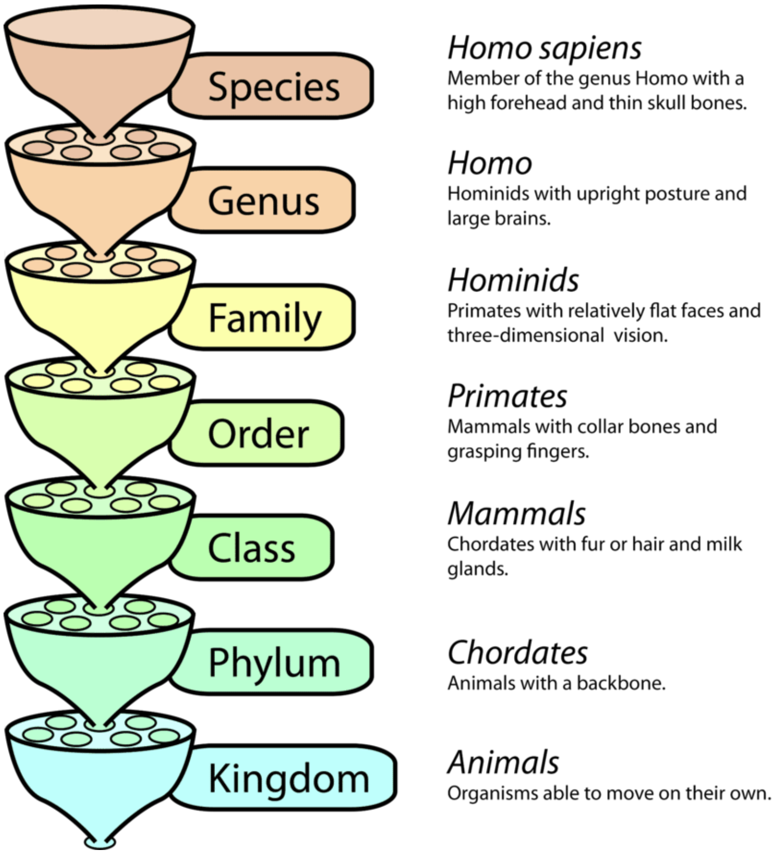


FIGURE 25.3

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

Defining a Species

Even though naming species is straightforward, deciding if two organisms are the same species can sometimes be difficult. Linnaeus defined each species by the distinctive physical characteristics shared by these organisms. But two members of the same species may look quite different. For example, people from different parts of the world sometimes look very different, but we are all the same species (**Figure** 25.4).

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

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.

FIGURE 25.4
These children are all members of the same species, *Homo sapiens*.

Explore More

Use the resources below to answer the following questions.

Explore More I

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

MEDIA
Click image to the left or use the URL below.
URL: https://www.ck12.org/flx/render/embeddedobject/57478

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

Explore More II

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

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

Review

1. Who is the inventor of the modern classification system?

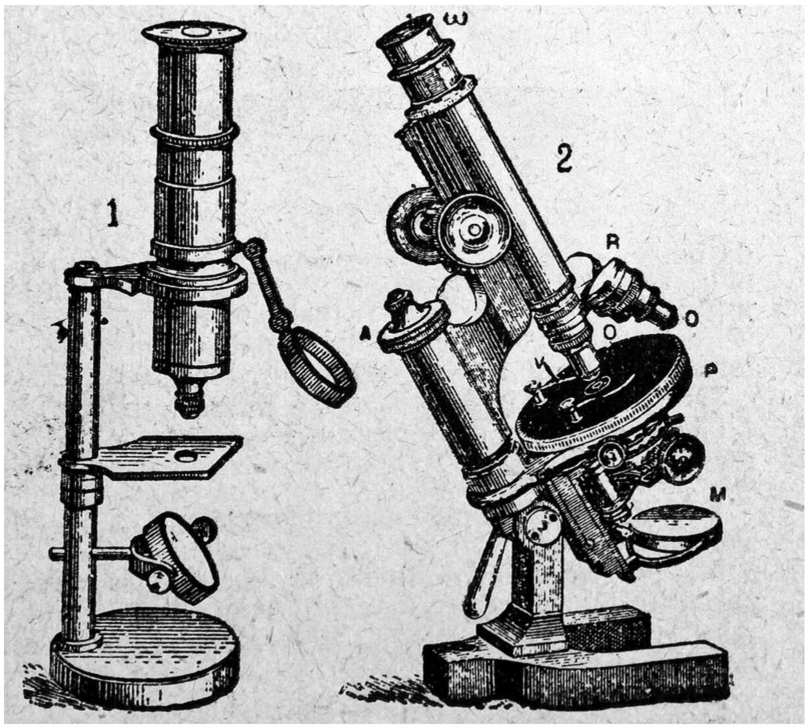
2. List the classification categories for organisms from the broadest category to the most specific.
3. What is meant by binomial nomenclature?
4. Define a species.

References

1. Alexander Roslin. Portrait of Carl Linnaeus, the inventor of modern taxonomy . Public Domain
2. Left to right: Evelyn Fitzgerald; Liz West; Flickr:DaraKero_F. Leaves from the green and red maple tree, and a maple seed . CC BY 2.0
3. Peter Halasz, modified by CK-12 Foundation. Diagram of the classification categories for organisms . CC BY-NC 3.0
4. Image copyright Monkey Business Images, 2014. This group of children are all members of the same species . Used under license from Shutterstock.com

CONCEPT 26 Discovery of Cells - Advanced

- Identify the scientists that first observed cells.
- Describe the first cells identified.



What was needed to discover the cell?

The microscope of course. Objects that were too small to be seen with the human eye were unknown until the microscope was developed. Once this instrument was developed, a whole new field of science was initiated.

Discovery of Cells

If you look at living organisms under a **microscope** you will see they are made up of cells. The word *cell*, derived from the Latin word *cellula* meaning small compartment, was first used by Robert Hooke, a British biologist and early **microscopist**. Hooke looked at thin slices of cork under a microscope. The structure he saw looked like a honeycomb as it was made up of many tiny units. Hooke's drawing is shown in **Figure** 26.1. In 1665 Hooke published his book *Micrographia,* in which he wrote:

... I could exceedingly plainly perceive it to be all perforated and porous, much like a Honey-comb, but that the pores of it were not regular.... these pores, or cells, ... were indeed the first *microscopical* pores I ever saw, and perhaps, that were ever seen, for I had not met with any Writer or Person, that had made any mention of them before this...

During the 1670s, the Dutch tradesman Antony van Leeuwenhoek, shown in **Figure** 26.2, used microscopes to observe many microbes and body cells. Leeuwenhoek developed an interest in microscopy and ground his own

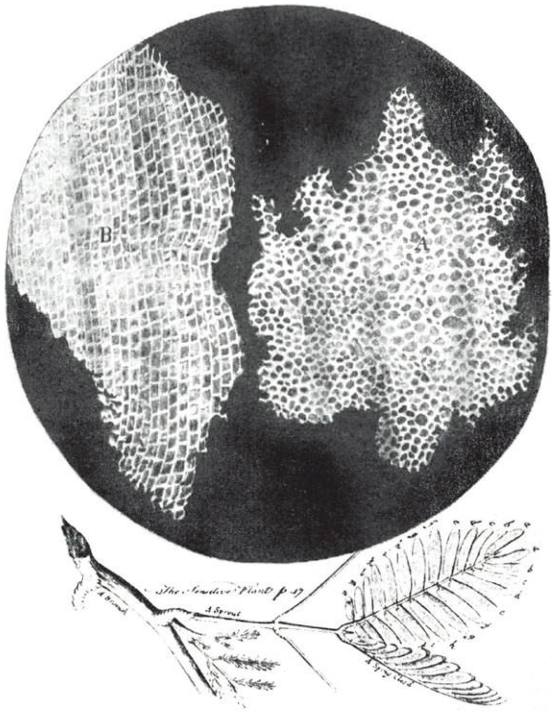


FIGURE 26.1
This figure is a drawing of the structure of cork from *Micrographia* as it appeared under the microscope to Robert Hooke.

lenses to make simple microscopes. Leeuwenhoek was so good at making lenses that his simple microscopes were able to magnify much more clearly than the compound microscopes of his day. His microscope's increased ability to magnify over 200x is comparable to a modern compound light microscope. **Compound microscopes**, which are microscopes that use more than one lens, had been invented around 1595 by Zacharias Jansen, a Dutch spectacle-maker. Several people, including Robert Hooke, had built compound microscopes and were making important discoveries with them during Leeuwenhoek's time.

Fortunately, Leeuwenhoek took great care in writing detailed reports of what he saw under his microscope. He was the first person to report observations of many microscopic organisms. Some of his discoveries included tiny animals such as ciliates, foraminifera, roundworms, and rotifers, shown in **Figure** 26.3. He discovered blood cells and was the first person to see living sperm cells. In 1683, Leeuwenhoek wrote to the Royal Society of London about his observations on the plaque between his own teeth, "a little white matter, which is as thick as if 'twere batter." He called the creatures he saw in the plaque *animacules,* or tiny animals. This report was among the first observations on living bacteria ever recorded.

Summary

- Before the development of microscopes, the existence of cellular life was unknown.
- By examining a piece of cork, Robert Hooke first saw and named cells.
- Antony van Leeuwenhoek was the first person to see living cells.

Review

1. Describe the contributions of Hooke and Leeuwenhoek to cell biology.

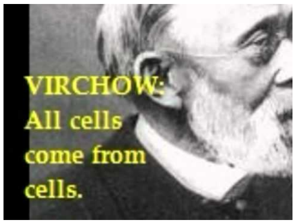
FIGURE 26.2
Antony van Leeuwenhoek (1632-1723). His carefully crafted microscopes and insightful observations of microbes led to the title the "Father of Microscopy."

FIGURE 26.3
A rotifer, the microscopic organism Leeuwenhoek saw under his microscope.

2. What enabled Leeuwenhoek to observe things that nobody else had seen before?

Explore More

Use this resource to answer the questions that follow.



MEDIA

Click image to the left or use the URL below.

URL: https://www.ck12.org/flx/render/embeddedobject/139342

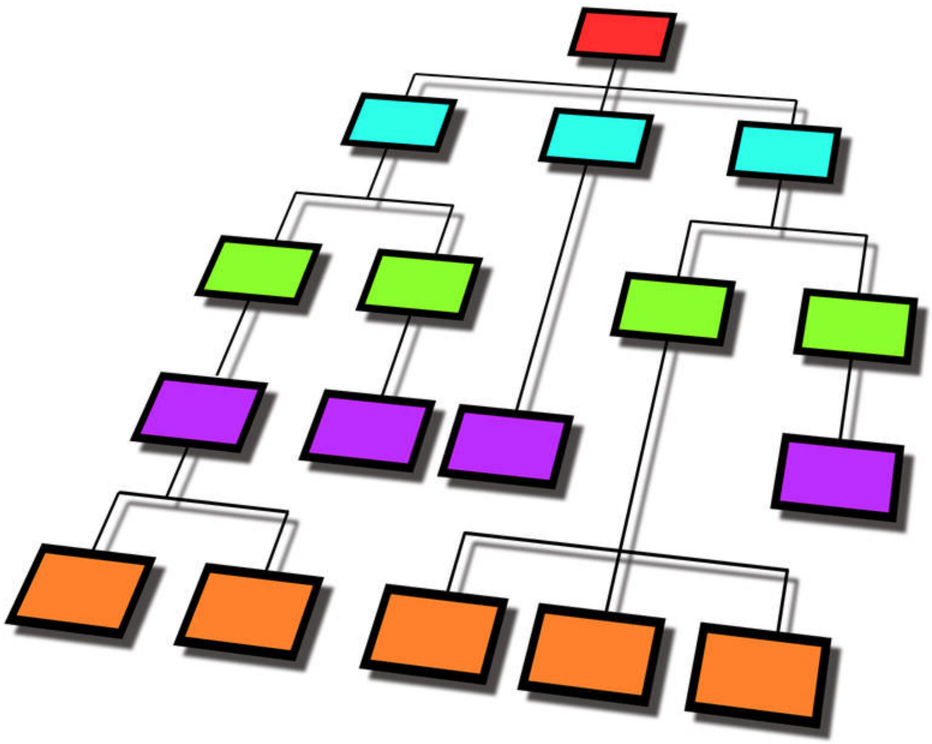
1. How did Hooke first observe cells?
2. What did Leeuwenhoek look at through his microscope?

References

1. Robert Hooke, Micrographia, 1665. Suber cells and mimosa leaves. . Public Domain
2. J. Verkolje. http://commons.wikimedia.org/wiki/File:Antoni_van_Leeuwenhoek.png . Public Domain
3. Damián H. Zanette. http://commons.wikimedia.org/wiki/File:Bdelloidea1_w.jpg . Public Domain

CONCEPT 27 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.

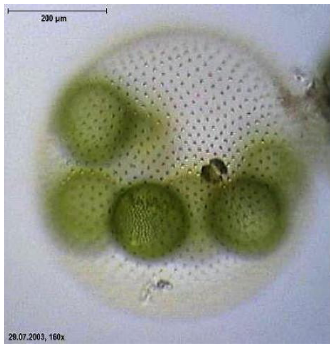


FIGURE 27.1

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** 27.1, 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** 27.1, 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** 27.1, differ in that their individual cells are free-living and can survive on their own if separated from the colony.

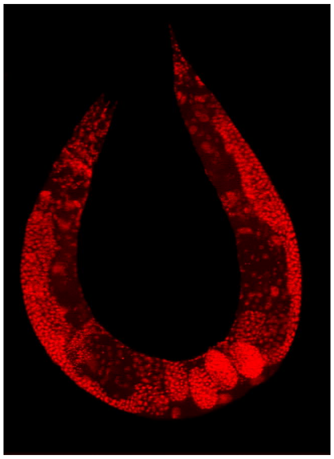


FIGURE 27.2

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** 27.2, 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.

Explore More

Use these resources to answer the questions that follow.

Explore More I

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

1. Why are multicellular organisms highly organized?
2. What is a tissue?
3. How many tissue types are there in animals?

Explore More 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.

References

1. Dr. Ralf Wagner. Volvox algae colony . CC BY 3.0
2. 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

CONCEPT 28 Prokaryotic and Eukaryotic Cells

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

Are bacteria cells like our cells?

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

Prokaryotic and Eukaryotic

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

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

Eukaryotic Cells

Eukaryotic cells usually have multiple **chromosomes**, composed of DNA and protein. Some eukaryotic species have just a few chromosomes, others have close to 100 or more. These chromosomes are protected within the nucleus. In addition to a nucleus, eukaryotic cells include other membrane-bound structures called **organelles**. Organelles allow eukaryotic cells to be more specialized than prokaryotic cells. Pictured below are the organelles of eukaryotic cells (**Figure** 28.1), including the **mitochondria**, **endoplasmic reticulum**, and **Golgi apparatus**. These will be discussed in additional concepts.

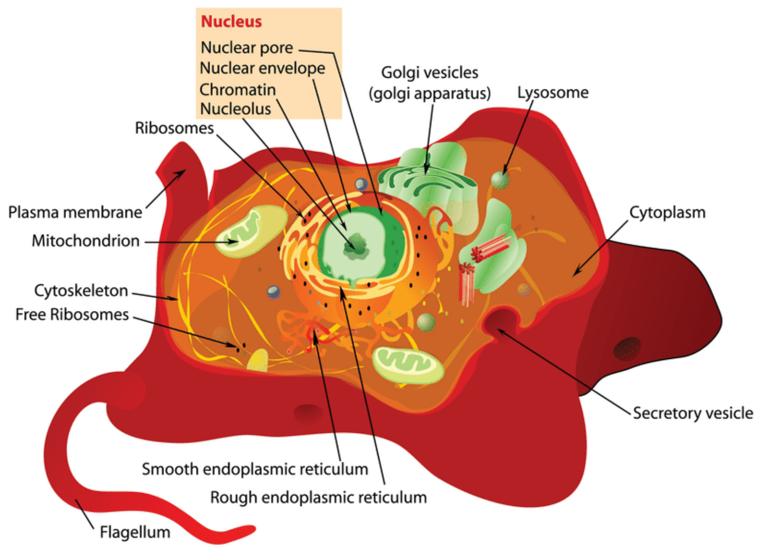


FIGURE 28.1

Eukaryotic cells contain a nucleus and various other special compartments surrounded by membranes, called organelles. The nucleus is where the DNA (chromatin) is stored. Organelles give eukaryotic cells more functions than prokaryotic cells.

Prokaryotic Cells

Prokaryotic cells (**Figure** 28.2) are usually smaller and simpler than eukaryotic cells. They do not have a nucleus or other membrane-bound organelles. In prokaryotic cells, the DNA, or genetic material, forms a single large circle that coils up on itself. The DNA is located in the main part of the cell.

TABLE 28.1: Comparison of Prokaryotic and Eukaryotic Cells

	Prokaryotic Cells	**Eukaryotic Cells**
Nucleus	No	Yes
DNA	Single circular piece of DNA	Multiple chromosomes
Membrane-Bound Organelles	No	Yes
Examples	Bacteria	Plants, animals, fungi

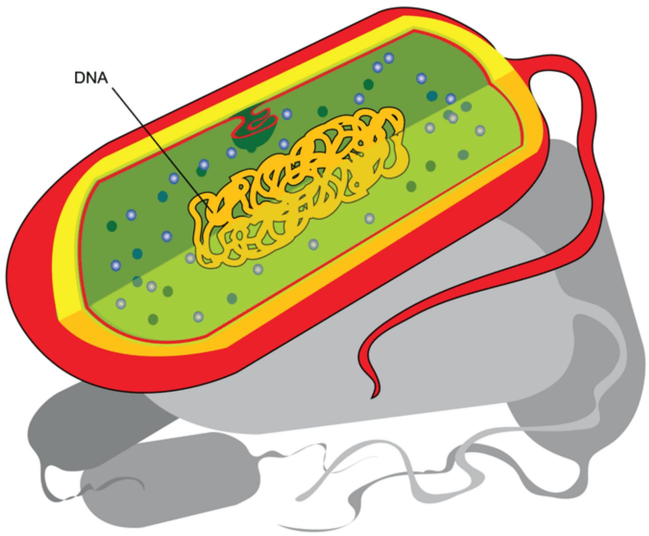


FIGURE 28.2
Prokaryotes do not have a nucleus. Instead, their genetic material is located in the main part of the cell.

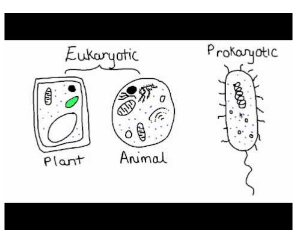
Summary

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

Explore More

Use the resource below to answer the questions that follow.

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



MEDIA
Click image to the left or use the URL below.
URL: https://www.ck12.org/flx/render/embeddedobject/57353

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

Review

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

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

References

1. Mariana Ruiz Villarreal (LadyofHats), modified by CK-12 Foundation. Organelles of a eukaryotic cell .
2. Mariana Ruiz Villarreal (LadyofHats), modified by CK-12 Foundation. Diagram of a prokaryotic cell . Public Domain

CONCEPT 29 Cell Structures

Lesson Objectives

- Describe the structure and functions of the cell membrane.
- Identify the parts and roles of the cytoplasm and cytoskeleton.
- List organelles in eukaryotic cells and their special jobs.
- Describe structures found in plant cells but not animal cells.

Lesson Vocabulary

- ATP (adenosine triphosphate)
- cell wall
- central vacuole
- centriole
- cytoskeleton
- endoplasmic reticulum (ER)
- Golgi apparatus
- lysosome
- mitochondrion (mitochondria, plural)
- vacuole
- vesicle

Introduction

In some ways, a cell resembles a plastic bag full of Jell-O. Its basic structure is a cell membrane filled with cytoplasm. The cytoplasm of a eukaryotic cell is like Jell-O containing mixed fruit. It also contains a nucleus and other organelles.

Figure 29.1 shows the structures inside a typical eukaryotic cell. The model cell in the figure represents an animal cell. Refer to the model as you read about the structures below. You can also explore the structures in the interactive animal cell at this link:

Cell Membrane

The cell membrane is like the bag holding the Jell-O. It encloses the cytoplasm of the cell. It forms a barrier between the cytoplasm and the environment outside the cell. The function of the cell membrane is to protect and support the cell. It also controls what enters or leaves the cell. It allows only certain substances to pass through. It keeps other substances inside or outside the cell.

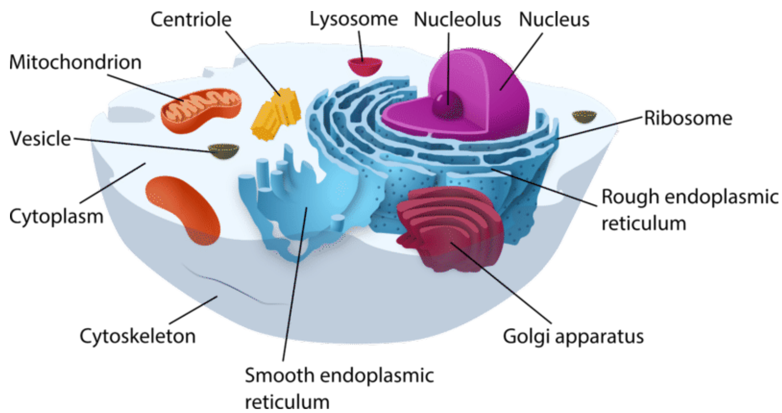


FIGURE 29.1
Model of an animal cell

Structure of the Cell Membrane

The structure of the cell membrane explains how it can control what enters and leaves the cell. The membrane is composed mainly of two layers of phospholipids. **Figure** 29.2 shows how the phospholipids are arranged in the cell membrane. Each phospholipid molecule has a head and two tails. The heads are "water loving" (hydrophilic), and the tails are "water fearing" (hydrophobic). The water-loving heads are on the outer surfaces of the cell membrane. They point toward the watery cytoplasm within the cell or the watery fluid that surrounds the cell. The water-fearing tails are in the middle of the cell membrane.

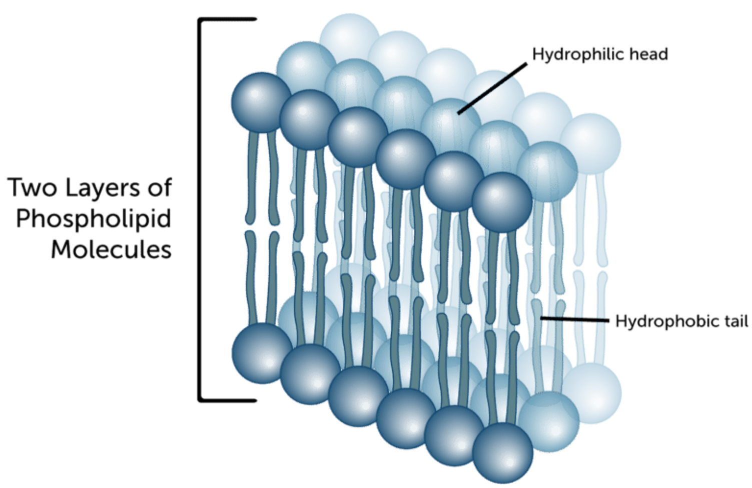


FIGURE 29.2
Arrangement of phospholipids in a cell membrane

How the Cell Membrane Works

Hydrophobic molecules "like" to be near other hydrophobic molecules. They "fear" being near hydrophilic molecules. The opposite is true of hydrophilic molecules. They "like" to be near other hydrophilic molecules. They "fear" being near hydrophobic molecules. These "likes" and "fears" explain why some molecules can pass through the cell membrane while others cannot.

- Hydrophobic molecules can pass through the cell membrane. That's because they like the hydrophobic interior of the membrane and fear the hydrophilic exterior of the membrane.

- Hydrophilic molecules can't pass through the cell membrane. That's because they like the hydrophilic exterior of the membrane and fear the hydrophobic interior of the membrane.

You can see how this works in the video at this link: http://www.youtube.com/watch?v=p6NNEetG0Cw .

MEDIA

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Cytoplasm and Cytoskeleton

Cytoplasm is everything inside the cell membrane (except the nucleus if there is one). It includes the watery, gel-like cytosol. It also includes other structures. The water in the cytoplasm makes up about two-thirds of the cell's weight. It gives the cell many of its properties.

Roles of Cytoplasm

Why does a cell have cytoplasm? Cytoplasm has several important functions. These include:

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

Cytoskeleton

Crisscrossing the cytoplasm is a structure called the **cytoskeleton**. It consists of thread-like filaments and tubules. The cytoskeleton is like a cellular "skeleton." It helps the cell keep its shape. It also holds cell organelles in place within the cytoplasm.

Figure 29.3 shows several cells. In the figure, the filaments of their cytoskeletons are colored green. The tubules are colored red. The blue dots are the cell nuclei.

Organelles

Eukaryotic cells contain a nucleus and several other types of organelles. These structures carry out many vital cell functions.

Nucleus

The nucleus is the largest organelle in a eukaryotic cell. It contains most of the cell's DNA. DNA, in turn, contains the genetic code. This code "tells" the cell which proteins to make and when to make them. You can see a diagram of a cell nucleus in Figure 29.4. Besides DNA, the nucleus contains a structure called a nucleolus. Its function is to

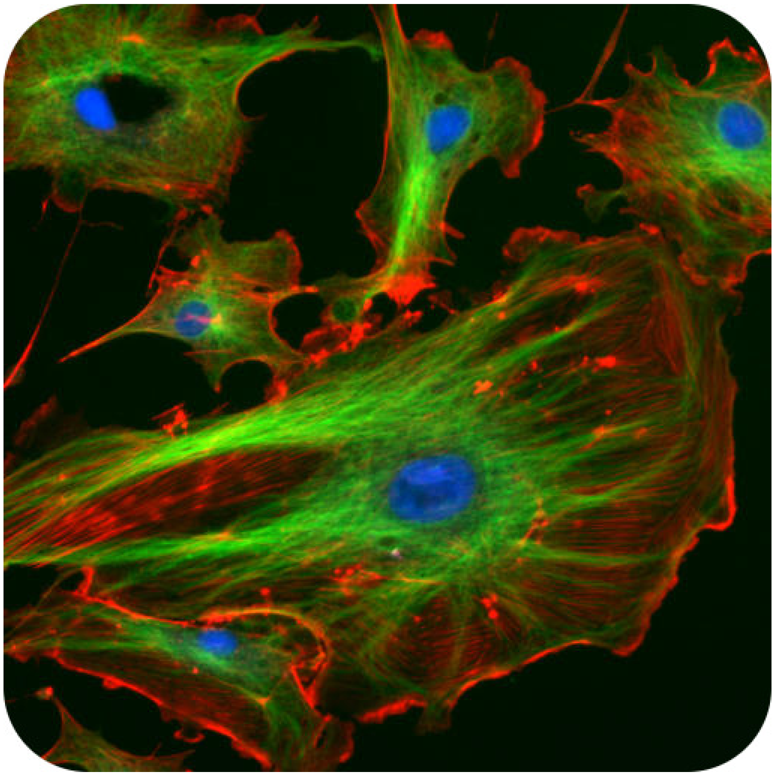


FIGURE 29.3
Cytoskeleton and nuclei of cells

form ribosomes. The membrane enclosing the nucleus is called the nuclear envelope. The envelope has tiny holes, or pores, in it. The pores allow substances to move into and out of the nucleus.

Mitochondrion

The **mitochondrion (mitochondria, plural)** is an organelle that makes energy available to the cell. It's like the power plant of a cell. It uses energy in glucose to make smaller molecules called **ATP (adenosine triphosphate)**. ATP packages energy in smaller amounts that cells can use.

Think about buying a bottle of water from a vending machine. The machine takes only quarters, and you have only dollar bills. The dollar bills won't work in the vending machine. Glucose is like a dollar bill. It contains too much energy for cells to use. ATP is like a quarter. It contains just the right amount of energy for use by cells.

Ribosomes

A ribosome is a small organelle where proteins are made. It's like a factory in the cell. It gathers amino acids and joins them together into proteins. Unlike other organelles, the ribosome is not surrounded by a membrane. As a result, some scientists do not classify it as an organelle. Ribosomes may be found floating in the cytoplasm. Some ribosomes are located on the surface of another organelle, the endoplasmic reticulum.

Endoplasmic Reticulum

The **endoplasmic reticulum (ER)** is an organelle that helps make and transport proteins and lipids. It's made of folded membranes. Bits of membrane can pinch off to form tiny sacs called vesicles. The vesicles carry proteins or lipids away from the ER.

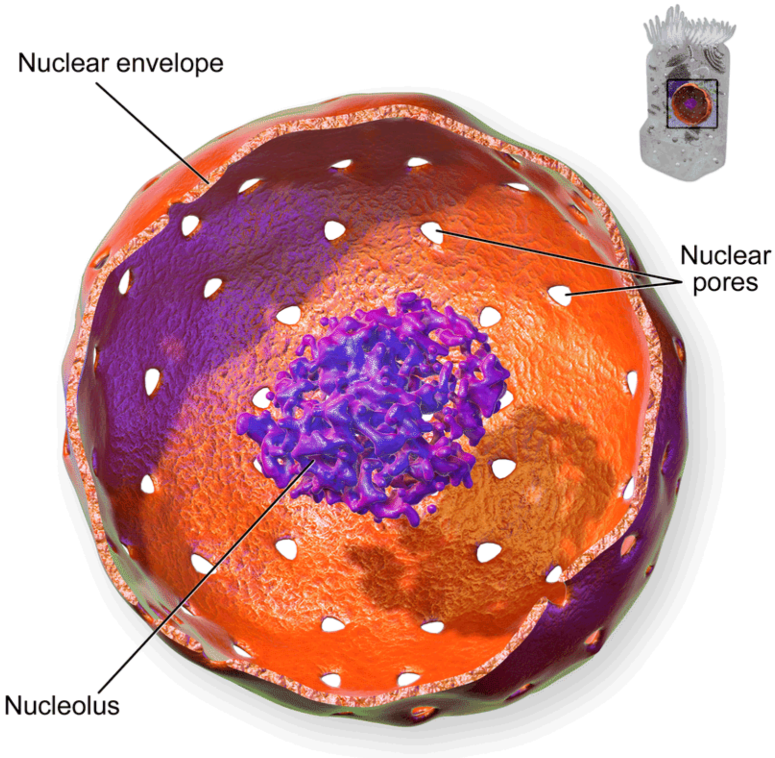


FIGURE 29.4
Nucleus of a eukaryotic cell

There are two types of endoplasmic reticulum. They are called rough endoplasmic reticulum (RER) and smooth endoplasmic reticulum (SER). Both types are shown in **Figure** 29.5.

NOTE: Crop to include only part 'a' of the original image.]

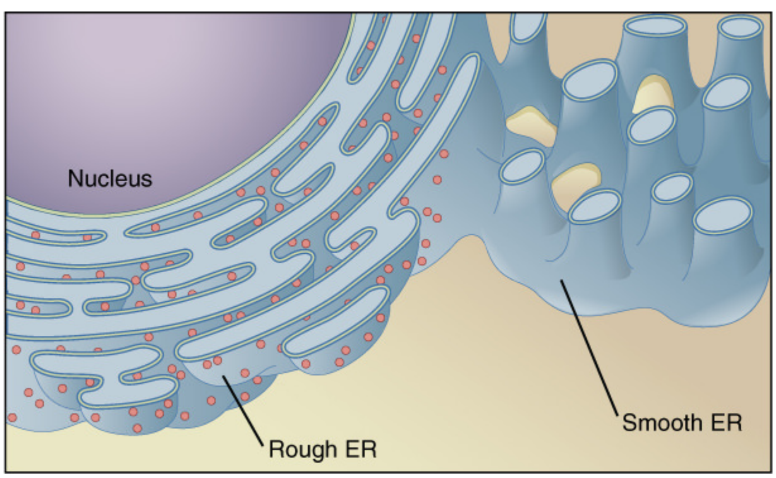


FIGURE 29.5
RER and SER are located outside the cell nucleus. The red dots on the RER are ribosomes.

Golgi Apparatus

The **Golgi apparatus** is a large organelle that sends proteins and lipids where they need to go. It's like a post office. It receives molecules from the endoplasmic reticulum. It packages and labels the molecules. Then it sends them where they are needed. Some molecules are sent to different parts of the cell. Others are sent to the cell membrane for transport out of the cell. Small bits of membrane pinch off the Golgi apparatus to enclose and transport the proteins and lipids. You can see a Golgi apparatus at work in this animation:

http://www.johnkyrk.com/golgiAlone.html

Vesicles and Vacuoles

Both **vesicles** and **vacuoles** are sac-like organelles. They store and transport materials in the cell. They are like movable storage containers.

- Some vacuoles are used to isolate materials that are harmful to the cell. Other vacuoles are used to store needed substances such as water.
- Vesicles are much smaller than vacuoles and have a variety of functions. Some vesicles pinch off from the membranes of the endoplasmic reticulum and Golgi apparatus. These vesicles store and transport proteins and lipids. Other vesicles are used as chambers for biochemical reactions.

Lysosomes

A **lysosome** is an organelle that recycles unneeded molecules. It uses enzymes to break down the molecules into their components. Then the components can be reused to make new molecules. Lysosomes are like recycling centers.

Centrioles

Centrioles are organelles that are found only in animal cells. They are located near the nucleus. They help organize the DNA in the nucleus before cell division takes place. They ensure that the DNA divides correctly when the cell divides.

Special Structures in Plant Cells

All but one of the structures described above are found in plant cells as well as animal cells. The only exception is centrioles, which are not found in plant cells. Plant cells have three additional structures that are not found in animals cells. These include a cell wall, large central vacuole, and organelles called plastids. You can see these structures in the model of a plant cell in **Figure** 29.6. You can also see them in the interactive plant cell at this link:

http://www.cellsalive.com/cells/cell_model.htm

Cell Wall

The **cell wall** is a rigid layer that surrounds the cell membrane of a plant cell. It's made mainly of the complex carbohydrate called cellulose. The cell wall supports and protects the cell. The cell wall isn't solid like a brick wall. It has tiny holes in it called pores. The pores let water, nutrients, and other substances move into and out of the cell.

Central Vacuole

Most plant cells have a large **central vacuole**. It can make up as much as 90 percent of a plant cell's total volume. The central vacuole is like a large storage container. It may store substances such as water, enzymes, and salts. It

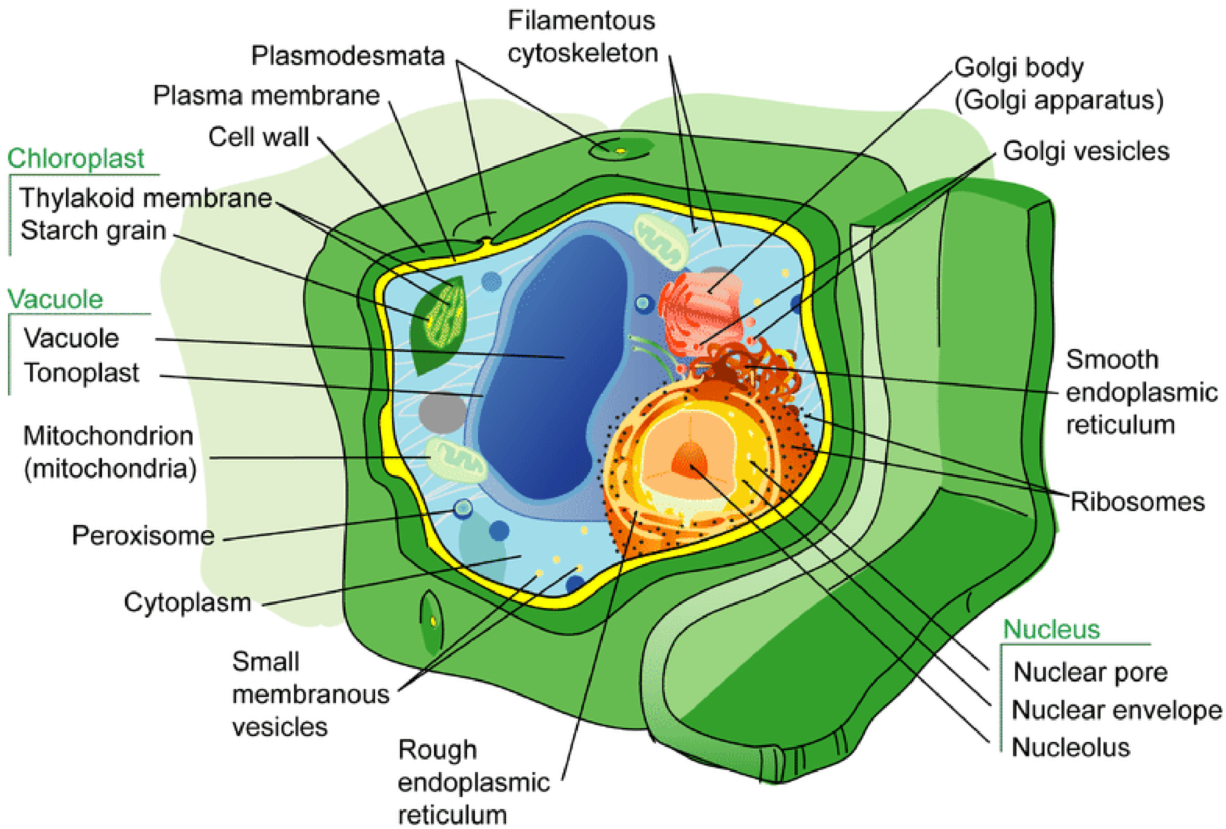


FIGURE 29.6
Model of a plant cell

may have other roles as well. For example, the central vacuole helps stems and leaves hold their shape. It may also contain pigments that give flowers their colors.

Plastids

Plastids are organelles in plant cells that may have various jobs. The main types of plastids are chloroplasts, chromoplasts, and leucoplasts.

- Chloroplasts are plastids that contain chlorophyll. Chlorophyll is a green pigment. It gives plants their green color. Photosynthesis takes place in chloroplasts. They capture sunlight and use its energy to make glucose.
- Chromoplasts are plastids that contain other pigments. These other pigments give flowers and fruits their colors.
- Leucoplasts are plastids that make or store other molecules. For example, some leucoplasts make amino acids. Other leucoplasts store starch or oil.

Lesson Summary

- The cell membrane consists of two layers of phospholipids. It encloses the cytoplasm and controls what enters and leaves the cell.
- The cytoplasm consists of watery cytosol and cell structures. It has several functions. The cytoskeleton is the "skeleton" of the cell. It helps the cell keep its shape.
- Eukaryotic cells contain a nucleus and other organelles. They include the mitochondrion, endoplasmic reticulum, Golgi apparatus, vesicles, vacuoles, lysosomes, and—in animal cells—centrioles. Each type of organelle has a special function.
- Plant cells have several structures not found in animal cells. They include a cell wall, large central vacuole, and plastids such as chloroplasts.

Lesson Review Questions

Recall

1. Describe the composition of the cytoplasm and list its functions.
2. What is the cytoskeleton? What does it do?
3. Identify three organelles in eukaryotic cells and state their roles.

Apply Concepts

4. Why is the nucleus like the control center of a cell?

Think Critically

5. Explain how the structure of the cell membrane controls what enters and leaves the cell.
6. Compare and contrast plant and animal cells.

Points to Consider

Molecules that enter or leave a cell must pass through the cell membrane. Some of these molecules may be hydrophilic. Other may be too large to squeeze between the phospholipid molecules of the membrane.

1. How might hydrophilic molecules pass through the cell membrane?
2. How might very large molecules pass through the cell membrane?

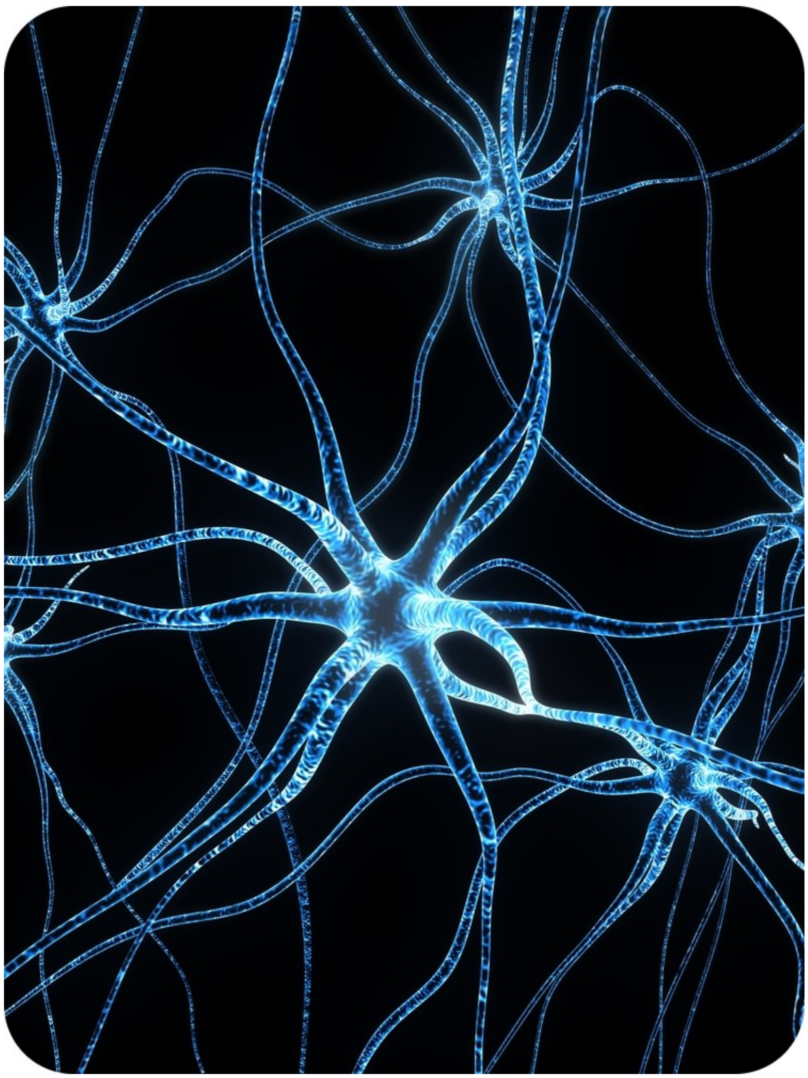
References

1. User:Kelvinsong/Wikimeida Commons. Model of an animal cell . Public Domain
2. Christopher Auyeung. Phospholipids in a membrane . CC BY-NC 3.0
3. Courtesy of the National Institute of Health (NIH). Cytoskeleton and nuclei of cells . Public Domain

4. BruceBlaus. Eukaryotic nucleus . CC-BY 3.0
5. OpenStax College. Drawing of the endoplasmic reticulum . CC-BY 3.0
6. Mariana Ruiz Villarreal (User:LadyofHats/Wikimedia Commons). http://commons.wikimedia.org/wiki/File:Plant_cell_structure_svg.svg . Public Domain

CONCEPT 30 Organization of the Human Body

- List the levels of organization in the human body.
- Define cell, tissue, organ, and organ system.
- Identify the four types of tissues that make up the body.
- Give examples of organ systems and their functions.



Do cells work together?

Cells, like these nerve cells, do not work in isolation. To send orders from your brain to your legs, for example, signals pass through many nerve cells. These cells work together to perform a similar function. Just as muscle cells work together, bone cells and many other cells do as well. A group of similar cells that work together is known as a tissue.

Organization of Your Body: Cells, Tissues, Organs

Cells are grouped together to carry out specific functions. A group of cells that work together form a **tissue**. Your body has four main types of tissues, as do the bodies of other animals. These tissues make up all structures and contents of your body. An example of each tissue type is pictured in the **Figure** 30.1.

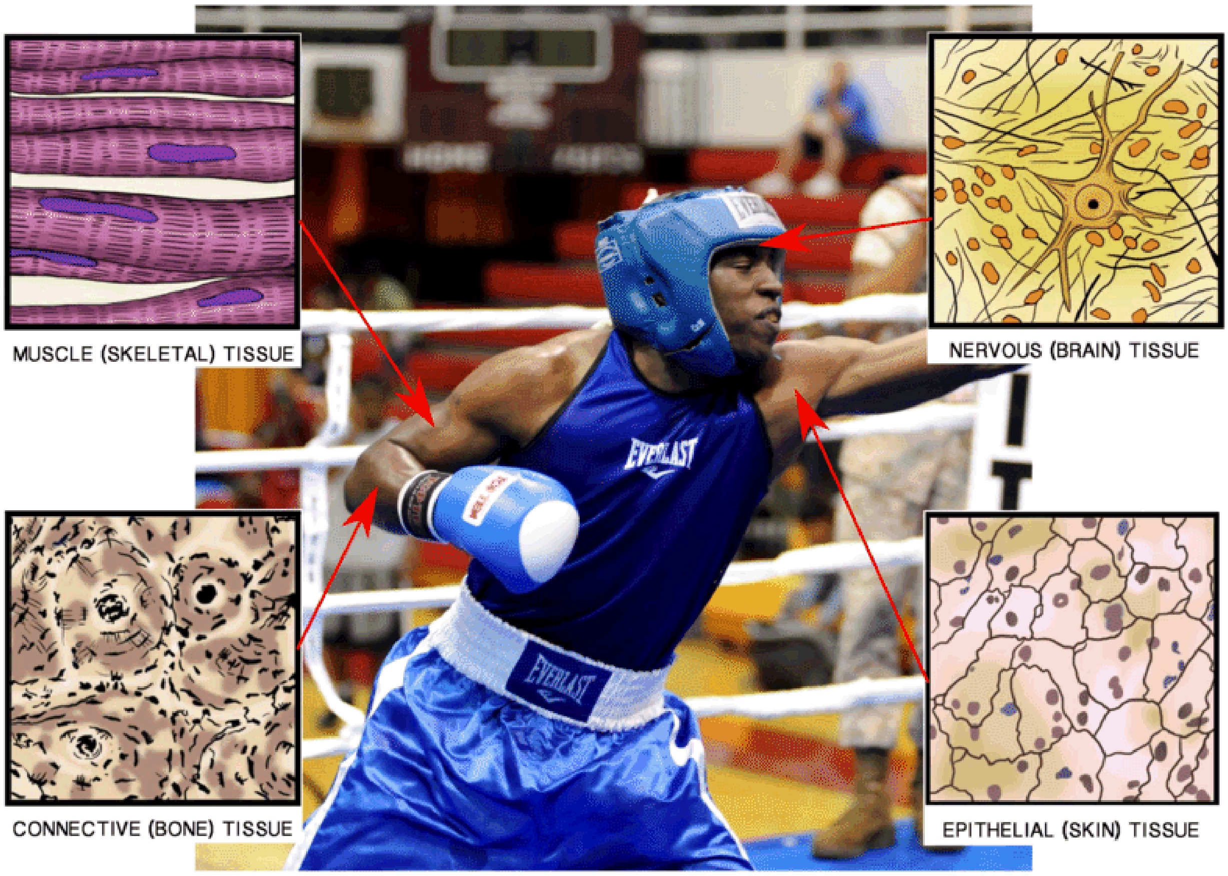


FIGURE 30.1

Your body has four main types of tissue: nervous tissue, epithelial tissue, connective tissue, and muscle tissue. They are found throughout your body.

1. **Epithelial tissue** is made up of layers of tightly packed cells that line the surfaces of the body. Examples of epithelial tissue include the skin, the lining of the mouth and nose, and the lining of the digestive system.
2. **Connective tissue** is made up of many different types of cells that are all involved in supporting and binding other tissues of the body. Examples include tendon, cartilage, and bone. Blood is also classified as a specialized connective tissue.
3. **Muscle tissue** is made up of bands of cells that contract and allow movement.
4. **Nervous tissue** is made up of nerve cells that sense stimuli and transmit signals. Nervous tissue is found in nerves, the spinal cord, and the brain.

Groups of Tissues Form Organs

A single tissue alone cannot do all the jobs that are needed to keep you alive and healthy. Two or more tissues working together can do a lot more. An **organ** is a structure made of two or more tissues that work together. The heart (**Figure** 30.2) is made up of the four types of tissues.

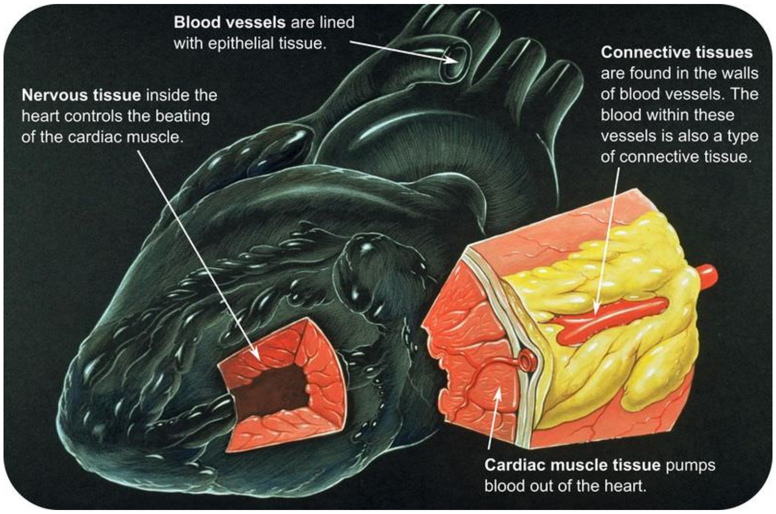


FIGURE 30.2
The four different tissue types work together in the heart as they do in the other organs.

Groups of Organs Form Organ Systems

Your heart pumps blood around your body. But how does your heart get blood to and from every cell in your body? Your heart is connected to blood vessels such as veins and arteries. Organs that work together form an **organ system**. Together, your heart, blood, and blood vessels form your **cardiovascular system**.

What other organ systems can you think of?

Organ Systems Work Together

Your body's 12 organ systems are shown below (**Table** 30.1). Your organ systems do not work alone in your body. They must all be able to work together.

For example, one of the most important functions of organ systems is to provide cells with oxygen and nutrients and to remove toxic waste products such as carbon dioxide. A number of organ systems, including the cardiovascular and respiratory systems, all work together to do this.

TABLE 30.1: Major Organ Systems of the Human Body

Organ System	**Major Tissues and Organs**	**Function**
Cardiovascular	Heart; blood vessels; blood	Transports oxygen, hormones, and nutrients to the body cells. Moves wastes and carbon dioxide away from cells.
Lymphatic	Lymph nodes; lymph vessels	Defend against infection and disease, moves lymph between tissues and the blood stream.

TABLE 30.1: (continued)

Organ System	Major Tissues and Organs	Function
Digestive	Esophagus; stomach; small intestine; large intestine	Digests foods and absorbs nutrients, minerals, vitamins, and water.
Endocrine	Pituitary gland, hypothalamus; adrenal glands; ovaries; testes	Produces **hormones** that communicate between cells.
Integumentary	Skin, hair, nails	Provides protection from injury and water loss, physical defense against infection by microorganisms, and temperature control.
Muscular	Cardiac (heart) muscle; skeletal muscle; smooth muscle; tendons	Involved in movement and heat production.
Nervous	Brain, spinal cord; nerves	Collects, transfers, and processes information.
Reproductive	Female: uterus; vagina; fallopian tubes; ovaries Male: penis; testes; seminal vesicles	Produces gametes (sex cells) and sex hormones.
Respiratory	Trachea, larynx, pharynx, lungs	Brings air to sites where gas exchange can occur between the blood and cells (around body) or blood and air (lungs).
Skeletal	Bones, cartilage; ligaments	Supports and protects soft tissues of body; produces blood cells; stores minerals.
Urinary	Kidneys; urinary bladder	Removes extra water, salts, and waste products from blood and body; controls pH; controls water and salt balance.
Immune	Bone marrow; spleen; white blood cells	Defends against diseases.

Summary

- The levels of organization in the human body include: cells, tissues, organs, and organ systems.
- There are four tissue types in the body: epithelial tissue, connective tissue, muscle tissue, and nervous tissue.

Explore More

Use the resources below to answer the following questions.

- **Human Body Plan** at http://vimeo.com/37349968 (2:28)

MEDIA

Click image to the left or use the URL below.

URL: https://www.ck12.org/flx/render/embeddedobject/57507

1. What kind of symmetry does the human body plan show? Explain what this means.
2. How does this symmetry extend to our senses?
3. How much of our body is made of muscle? What does this muscle do?
4. How are oxygen and nutrients delivered to the cells of the body?
5. What controls all the activity on the body? How much energy does this organ use?

Go here to see the placement of some organs and body parts. See how fast you can assemble the systems.

- **All Systems Go** at http://sciencenetlinks.com/interactives/systems.html

Review

1. What are the four levels of organization in an organism?
2. List the four types of tissues that make up the human body.
3. Describe epithelial tissue.
4. Give two examples of connective tissue.
5. What is the role of the nervous system?
6. What is the role of the cardiovascular system?

References

1. Boxer: U.S. Army (Flickr:familymwr); Illustrations: Laura Guerin. The four main types of tissue are nervous tissue, epithelial tissue, connective tissue, and muscle tissue . Boxer: CC BY 2.0; Illustrations: CC BY-NC 3.0
2. Patrick J. Lynch, medical illustrator; C. Carl Jaffe, MD, cardiologist. Illustration of how the four tissue types work together in the heart . CC BY 2.5

CONCEPT 31 Nervous System

- Define nerve.
- Describe the role of a nerve.
- Explain the functions of the nervous system.

What body system helps you learn?

As these girls are studying, many processes are taking place. Their eyes have to take in the words on the page, and their brains have to process the meaning of the words. The brain also has to assimilate the knowledge so it can be retrieved at a later time. All these processes are controlled by the nervous system.

Introduction to the Nervous System

Michelle was riding her scooter when she hit a hole in the street and started to lose control. She thought she would fall, but, in the blink of an eye, she shifted her weight and kept her balance. Her heart was pounding, but at least she didn't get hurt. How was she able to react so quickly? Michelle can thank her nervous system for that (**Figure** 31.1).

The **nervous system,** together with the **endocrine system,** controls all the other **organ systems.** The nervous system sends one type of signal around the body, and the endocrine system sends another type of signal around the body. The endocrine system makes and releases chemical messenger molecules, or hormones, which tell other body parts that a change or a reaction is necessary. So what type of signal does the nervous system send?

Controlling muscles and maintaining balance are just two of the roles of the nervous system. The nervous system also lets you:

- Sense your surroundings with your eyes and other sense organs.
- Sense the environment inside of your body, including temperature.
- Control your internal body systems and keep them in balance.
- Prepare your body to fight or flee in an emergency.

FIGURE 31.1
Staying balanced when riding a scooter requires control over the body's muscles. The nervous system controls the muscles and maintains balance.

- Use language, think, learn, and remember.

The nervous system works by sending and receiving electrical signals. The main organs of the nervous system are the brain and the spinal cord. The signals are carried by **nerves** in the body, similar to the wires that carry electricity all over a house. The signals travel from all over the body to the spinal cord and up to the brain, as well as moving in the other direction. For example, when Michelle started to fall off her scooter, her nervous system sensed that she was losing her balance. It responded by sending messages from her brain to muscles in her body. Some muscles tightened while others relaxed. Maybe these actions moved her hips or her arms. The nervous system, working together with the muscular and skeletal systems, allowed Michelle to react to the situation. As a result, Michelle's body became balanced again. The messages released by the nervous system traveled through nerves. Just like the electricity that travels through wires, nerve quickly carry the electrical messages around the body.

Think about how quickly all this happens. It has to be really fast, otherwise Michelle would not have been able to react. What would happen if a car pulled out unexpectedly in front of Michelle? A signal would have to go from her eyes to her brain and then to her muscles. What allows the nervous system to react so fast. It starts with the special cell of the nervous system, the neuron.

Summary

- The nervous system sends electrical messages throughout the body and controls all other body systems.
- The nervous system allows you to think, learn, sense your surroundings, and control your internal body systems.

Explore More

Use the resource below to answer the questions that follow.

- **Nervous System** at http://www.getbodysmart.com/ap/nervoussystem/menu/menu.html

1. What are the major organs of the nervous system?
2. What does the somatic nervous system do? Why is a system like this useful to organisms?
3. What does the autonomic nervous system do? How does it differ from the somatic nervous system?

Review

1. What are three functions of the nervous system?
2. What type of signals does the nervous system send? What carries these signals?
3. What are the main organs of the nervous system?

References

1. Flickr:FaceMePLS. Staying balanced on a scooter requires control of the body's muscles and awareness of th e surroundings . CC BY 2.0

CONCEPT 32 Ecosystems

- Define and describe an ecosystem.
- Give examples of biotic and abiotic factors.
- Explain the relationship between producers and consumers.
- Summarize the importance of biogeochemical cycles.

What nonliving things are essential for life?

Living organisms cannot exist without the nonliving aspects of the environment. For example: air, water, and sunlight, which are all nonliving, are all essential to living organisms. Both nonliving and living things make up an ecosystem.

What is an Ecosystem?

Ecology is the study of ecosystems. That is, ecology is the study of how living organisms interact with each other and with the nonliving part of their environment. An **ecosystem** consists of all the nonliving factors and living organisms interacting in the same **habitat**. Recall that living organisms are **biotic factors**. The biotic factors of an ecosystem include all the **populations** in a habitat, such as all the species of plants, animals, and fungi, as well as all the micro-organisms. Also recall that the nonliving factors are called **abiotic factors**. Abiotic factors include temperature, water, soil, and air.

You can find an ecosystem in a large body of fresh water or in a small aquarium. You can find an ecosystem in a large thriving forest or in a small piece of dead wood. Examples of ecosystems are as diverse as the rainforest, the savanna, the tundra, or the desert (**Figure** 32.1). The differences in the abiotic factors, such as differences in temperature, rainfall, and soil quality, found in these areas greatly contribute to the differences seen in these ecosystems. Ecosystems can include well known sites, such as the Great Barrier Reef off the coast of Australia and the Greater Yellowstone Ecosystem of Yellowstone National Park, which actually includes a few different ecosystems, some with geothermal features, such as Old Faithful geyser.

FIGURE 32.1
Desert Botanical Gardens in Phoenix, Arizona.

Ecosystems need energy. Many ecosystems get their energy in the form of sunlight, which enters the ecosystem through **photosynthesis**. This energy then flows through the ecosystem, passed from **producers** to **consumers**. Plants are producers in many ecosystems. Energy flows from plants to the herbivores that eat the plants, and then to carnivores that eat the herbivores. The flow of energy depicts interactions of organisms within an ecosystem.

Matter is also recycled in ecosystems. **Biogeochemical cycles** recycle nutrients, like carbon and nitrogen, so they are always available. These nutrients are used over and over again by organisms. Water is also continuously recycled. The flow of energy and the recycling of nutrients and water are examples of the interactions between organisms and the interactions between the biotic and abiotic factors of an ecosystem.

Summary

- An ecosystem consists of all the living things and nonliving things interacting in the same area.
- Matter is also recycled in ecosystems; recycling of nutrients is important so they can always be available

Explore More

Use the resource below to answer the questions that follow.

- **How Ecosystems Work** at http://www.youtube.com/watch?v=o_RBHfjZsUQ (3:24)

MEDIA
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1. How do land plants generate the energy they need for their metabolic energy? What do they do with excess energy?

2. Where do scavengers in an ecosystem obtain their energy from? How can scavenging be a beneficial strategy for an organism?
3. What is the role of decomposers?
4. What kind of problems can you foresee if every speck of carbon were turned into biomass? Why?
5. Complete this statement: Energy ___________ through an ecosystem, whereas nutrients are ____________.

Review

1. Define an ecosystem.
2. Distinguish between abiotic and biotic factors. Give examples of each.
3. Where does the energy come from for many ecosystems?
4. Name two nutrients that are recycled through an ecosystem.

References

1. Kevin Dooley. The Baja desert is an example of an ecosystem . CC BY 2.0

CONCEPT 33 Adaptation and Evolution of Populations

- Define adaptation.
- Explain mutations.

Why would an organism match its background? Wouldn't it be better to stand out?

An organism that blends with its background is more likely to avoid predators. If it survives, it is more likely to have offspring. Those offspring are more likely to blend into their backgrounds. This butterfly appears to be well adapted to its environment. It is less likely to be eaten by a bird than a butterfly that stands out against the tree.

Variation and Adaptation

Every organism is different from every other organism. Every organism's genes are different, too.

Variations

There are **variations** in the traits of a population. For example, there are lots of variations in the color of human hair. Hair can be blonde, brown, black, or even red. Hair color is a trait determined by genes.

Mutations

At some time in the past, a variation probably came from a mutation. A **mutation** is a random change in an organism's genes (**Figure** 33.1). Mutations are natural. Some are harmful, but many are neutral. If a mutation is harmful, the organism may not live to reproduce. If the mutation is beneficial, that organism may have a better chance to survive. An organism that survives is likely to have offspring. If it does, it may pass the mutation on to its offspring. The offspring may be more likely to survive.

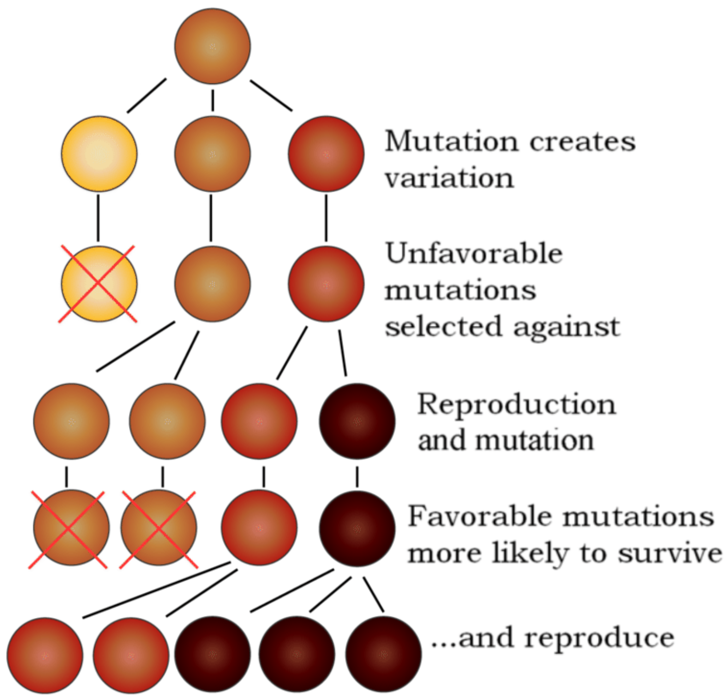


FIGURE 33.1
Genetic mutation is central to the creation of biological diversity.

Adaptations

Some of the characteristics an organism has may help it survive. These characteristics are called **adaptations**. Some adaptations are better than others.

Many adaptations protect organisms from the external environment (**Figure** 33.2).

FIGURE 33.2
Cacti have thick, water-retaining bodies that help them conserve water.

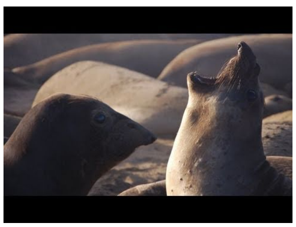
Other adaptations help an organism move or gather food. Reindeer have sponge-like hooves that help them walk on snowy ground without slipping and falling. Fish at the bottom of the ocean are tiny and use very little energy because there is very little food. Organisms have special features that help them avoid being eaten. Some plants have poisonous or foul-tasting substances in them that keep animals from eating them. Their brightly colored flowers serve as a warning. The same is true of some frogs, which can be poisonous (**Figure** 33.3)

FIGURE 33.3
Poison dart frogs have toxins in their skin. Their bright colors warn potential predators not to take a bite!

How Adaptations Develop

Adaptations develop this way. Think about a population of oak trees. Imagine that a fungus has arrived from Asia to North America. Most of the North American oak trees are killed by the fungus. But a few oak trees have a mutation that allows them to survive the fungus. Those oak trees are better adapted to the new environment than the others. Those trees have a better chance of surviving. They will probably reproduce. The trees may pass on the favorable mutation to their offspring. The other trees will die. Eventually, the population of oak trees will change. Most of the trees will have the trait to survive the fungus. This is an adaptation. Over time, traits that help an organism survive become more common. Traits that hinder survival eventually disappear.

Thousands of northern elephant seals—some weighing up to 4,500 pounds—make an annual migration to breed each winter at Año Nuevo State Reserve in California. Marine biologists are using high-tech tools to explore the secrets of these amazing creatures.



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Summary

- Different members of a population have different genes for the same trait.
- Some of these differences are due to mutations.
- Some traits allow an individual organism to be better adapted to its environment. That individual will be more likely to survive and to reproduce.

Review

1. How do adaptations develop?
2. What does it mean to say that an organism is well adapted to its environment?

3. What is a mutation?

References

1. Hana Zavadska. An explanation of how adaptations develop . CC BY-NC 3.0
2. CK-12 Foundation - Miles Orchinik. Cacti have thick, water-retaining bodies that help them conserve water . CC BY-NC 3.0
3. Adrian Pingstone (Wikimedia: Arpingstone). Brightly colored poison dart frogs have toxins in their skin . Public Domain

CONCEPT 34 Mendel's Pea Plants

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

Why do you look like your family?

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

Mendel's Experiments

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

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

In the late 1850s, an Austrian monk named Gregor Mendel (**Figure** 34.1) performed the first genetics experiments.

To study genetics, Mendel chose to work with pea plants because they have easily identifiable traits (**Figure** 34.2). For example, pea plants are either tall or short, which is an easy trait to observe. Furthermore, pea plants grow quickly, so he could complete many experiments in a short period of time.

Mendel also used pea plants because they can either **self-pollinate** or be **cross-pollinated**. Self-pollination means that only one flower is involved; the flower's own pollen lands on the female sex organs. Cross pollination is done by hand by moving pollen from one flower to the stigma of another (just like bees do naturally). As a result, one plant's sex cells combine with another plant's sex cells. This is called a "cross." These crosses produce **offspring**

FIGURE 34.1
Gregor Mendel, the "father" of genetics.

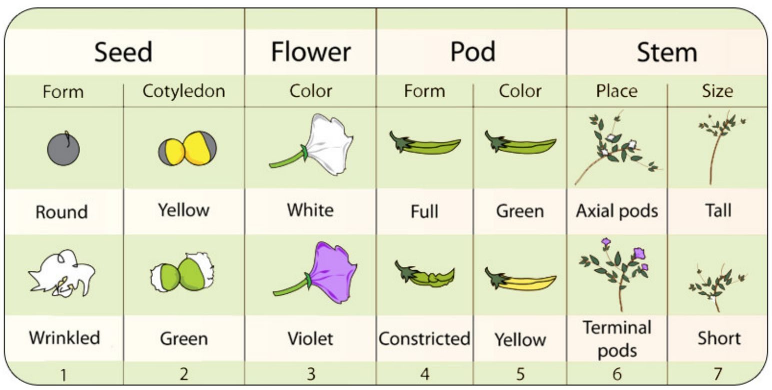


FIGURE 34.2
Characteristics of pea plants.

(or "children"), just like when male and female animals mate. Since Mendel could move pollen between plants, he could carefully control and then observe the results of crosses between two different types of plants.

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

Mendel's First Experiment

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

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

For example, he crossed purple flowered-plants and white flowered-plants. Do you think the colors blended? No, they did not. Just like the previous experiment, all offspring in this cross (the F1 generation) were one color: purple. In the F2 generation, 75% of plants had purple flowers and 25% had white flowers (**Figure** 34.3). There was no blending of traits in any of Mendel's experiments.

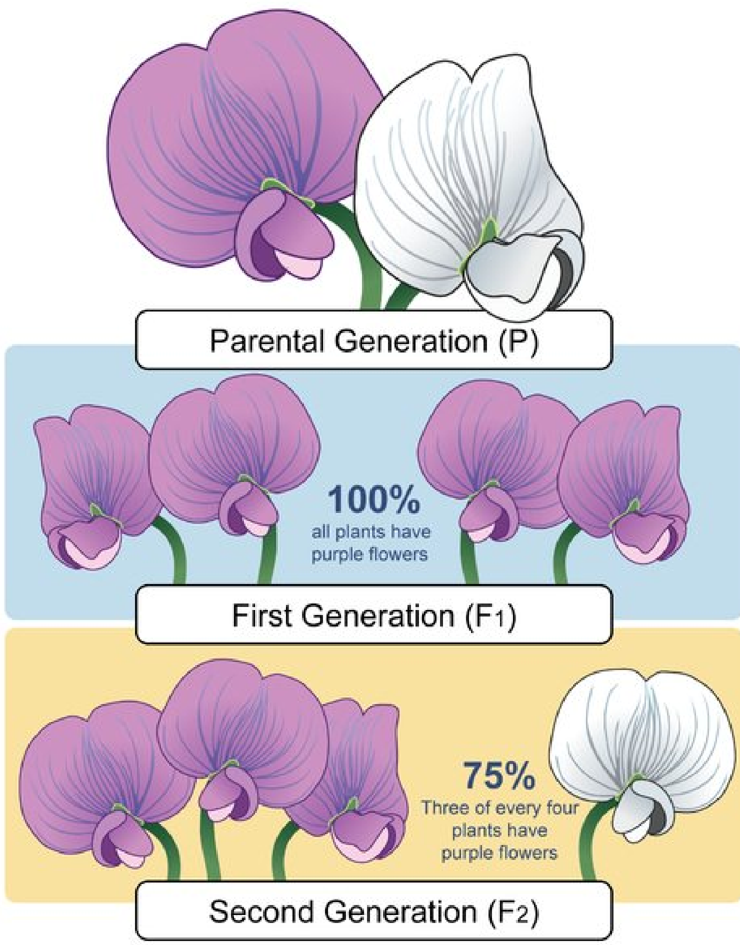


FIGURE 34.3
The results of Mendel's experiment with purple flowered and white flowered-plants numerically matched the results of his experiments with other pea plant traits.

Summary

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

Explore More

Use the resource below to answer the questions that follow.

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

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

5. You breed two green wrinkled plants. Will will the next generation look like?

Review

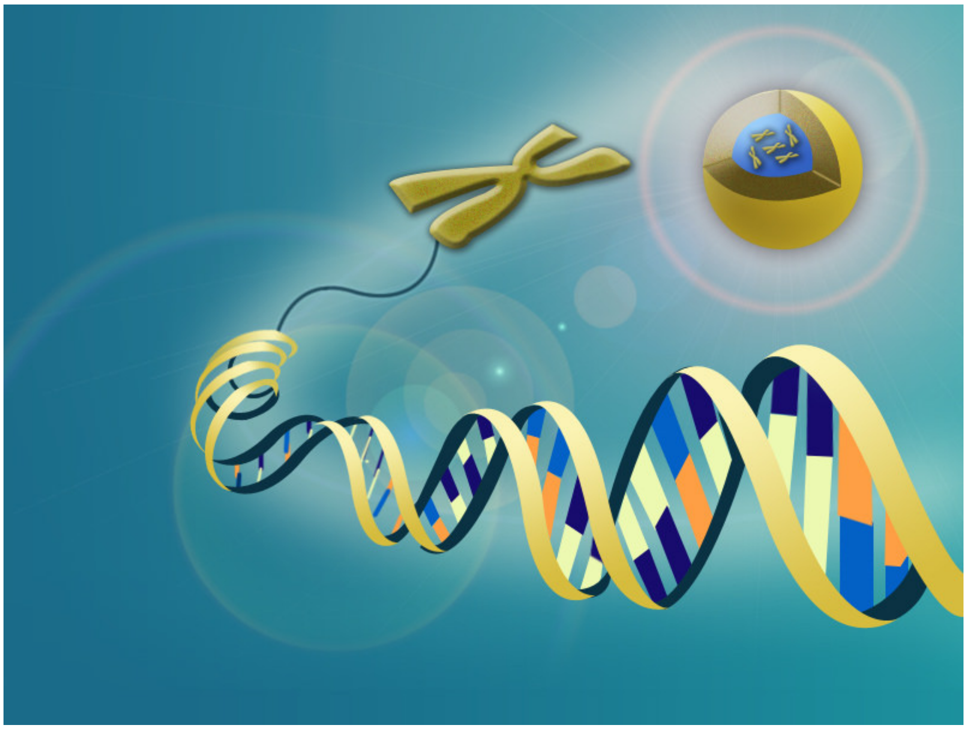
1. What is genetics?
2. Why did Mendel choose to study pea plants?
3. How did Mendel's experiments disprove the idea that we are simply a "blend" of our parents' traits?
4. What were the results Mendel consistently identified in his experiments?

References

1. Erik Nordenskiöld. Portrait of Gregor Mendel . Public Domain
2. Rupali Raju. The Laws of Heredity . CC BY-NC 3.0
3. Mariana Ruiz Villarreal (LadyofHats) for CK-12 Foundation. Result of Mendel's experiment with purple and white flowered plants . CC BY-NC 3.0

CONCEPT 35 Modern Genetics

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



Did Mendel know about DNA?

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

Modern Genetics

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

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

Traits, Genes, and Alleles

Recall that our DNA is wound into **chromosomes**. Each of our chromosomes contains a long chain of DNA that encodes hundreds, if not thousands, of genes. Each of these genes can have slightly different versions from individual to individual. These variants of genes are called **alleles**. Each parent only donates one allele for each gene to an offspring.

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

Genotype and Phenotype

Genotype is a way to describe the combination of alleles that an individual has for a certain gene (**Table** 35.1). For each gene, an organism has two alleles, one on each chromosome of a homologous pair of chromosomes (think of it as one allele from Mom, one allele from Dad). The genotype is represented by letter combinations, such as *TT*, *Tt*, and *tt*.

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

TABLE 35.1: Genotypes

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

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

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

What is the phenotype of a pea plant that is homozygous dominant *(TT)* for the tall trait? Tall. What is the phenotype of a pea plant that is heterozygous *(Tt)?* It is also tall. The answer is yes, two different genotypes can result in the same phenotype. Remember, the recessive phenotype will be expressed only when the dominant allele is absent, or when an individual is homozygous recessive *(tt)* (**Figure** 35.1).

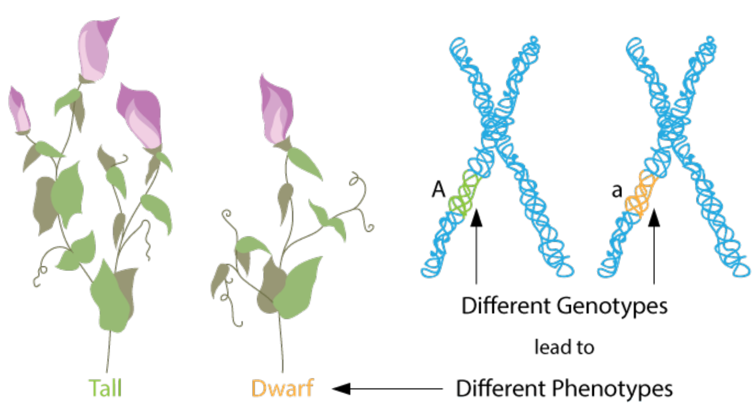


FIGURE 35.1
Different genotypes (*AA*, *Aa*, *aa* or *TT*, *Tt*, *tt*) will lead to different phenotypes, or different appearances of the organism.

Summary

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

Explore More

Use the resources below to answer the questions that follow.

Explore More I

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

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

Explore More II

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

MEDIA

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

Review

1. What is an allele?
2. What is the type of allele that only affects the phenotype in the homozygous condition?
3. If two individuals have a certain phenotype, does that mean they must have the same genotype?
4. A tall, green plant is homozygous for each trait. If T is the tall allele, and G is the green allele, what is the genotype and the phenotype of this plant?

References

1. Zachary Wilson. Different genotypes will lead to different phenotypes of an organism . CC BY-NC 3.0

CONCEPT 36 Effect of Environment on Genetics - Advanced

- Outline how heredity and environment can interact to affect phenotype.

What do these twins have in common?

Almost all their DNA. In fact, all their nuclear DNA. Some of their mitochondrial DNA may have slight variations. So that would mean that genetic studies involving twins can be potentially very rewarding.

Effects of Environment on Phenotype

Genes play an important part in influencing phenotype, but genes are not the only influence. Environmental conditions, such as temperature and availability of nutrients can affect phenotypes. For example, temperature affects coat color in Siamese cats.

FIGURE 36.1

The dark "points" on this Siamese cat are caused by a gene that codes for a temperature-sensitive enzyme. The enzyme, which causes a darkening of the cat's fur, is active only in the cooler parts of the body such as the tail, feet, ears, and area around the nose.

The pointed pattern is a form of partial albinism, which results from a mutation in an enzyme that is involved in melanin production. The mutated enzyme is heat-sensitive; it fails to work at normal body temperatures. However, it is active in cooler areas of the skin. This results in dark coloration in the coolest parts of the cat's body, such as the lower limbs and the face, as shown in **Figure** 36.1. The cat's face is cooled by the passage of air through the nose. Generally adult Siamese cats living in warm climates have lighter coats than those in cooler climates.

Height in humans is a complex phenotype influenced by many genes, but it is also influenced by nutrition. A person who eats a diet poor in nutrients will not grow as tall as they would have had they eaten a more nutritious diet.

Environmental Trigger

Does everyone who smokes develop lung cancer? No, of course not. Is it possible to get lung cancer without smoking? Sadly, yes it is. That's not to say there is no relationship between the two: smoking is still the leading cause of lung cancer. But it does suggest that a person's genetic background has a role in this process. Apart form true single gene disorders, environmental factors, or **environmental triggers**, may determine the development of disease in individuals genetically predisposed to a particular condition. Environmental triggers may include stress, physical and mental abuse, diet, exposure to toxins, pathogens, and radiation. Many cancers are thought to have an environmental component. It has been suggested that environmental factors play a role in autism as well. Asthma is obviously triggered under certain environmental conditions.

Twin Studies

The classical twin design compares the similarity of identical and fraternal twins.

Scientists often study the effects of environment on phenotype by studying identical twins. Identical twins have the same genes, so phenotypic differences between twins often have an environmental cause. **Twin studies** help understand the relative importance of environmental and genetic influences on individual traits and behaviors. Twins are a valuable source of information concerning the relationship between genes and environment. As **monozygotic twins** (identical) share their nuclear DNA, their **polymorphisms**, the nucleotide differences that make their DNA unique, are common to the two individuals. This means that any phenotypic variation, such as in height, intelligence, or any other measurable trait, is due to the environment. What is different about the experiences of the twins? What unique experiences might one twin have that the other twin did not have? By comparing phenotypes of hundreds of twins, researchers can understand the roles of genetics, shared environment and unique experiences in the formation and development of specific traits.

Dizygotic twins (fraternal or non-identical) share only about half of their polymorphisms. These twins are helpful to study as they tend to share many aspects of their environment. As they are born in the same place, usually within a few minutes of each other, they share many environmental conditions. They had the same *in utero* environment, they usually have a similar or the same parenting style during their childhood, and a similar or the same education. Similarities during childhood usually occur with wealth, culture, and their community.

Modern twin studies have shown that almost all human traits are at least partly influenced by genetic differences. Some characteristics, such as height, show a strong genetic influence, while other characteristics have an intermediate level of genetic influence, such as with intelligence. Some characteristics have a much more complex genetic relationship, with evidence for different genes affecting different aspects of the trait. Autism, with its wide spectrum of severity, is such an example.

Summary

- An organism's phenotype can be influenced by environmental conditions.
- Environmental triggers play a role in the development of disease in individuals genetically predisposed to that disease.

FIGURE 36.2
Autism has a wide phenotypic spectrum of disability. Twin studies have been instrumental in demonstrating an environmental component in autism.

- Twin studies help scientists understand the relative importance of environmental and genetic influences on individual traits and behaviors.

Review

1. Outline the relationship between environment and phenotype.
2. What is an environmental trigger? Give an example.
3. What do twin studies provide?
4. What is the difference between monozygotic twins and dizygotic twins?

References

1. Robert Couse-Baker. http://www.flickr.com/photos/29233640@N07/4214232333/ . CC BY 2.0
2. Image copyright Andrii Kondiuk, 2014. http://www.shutterstock.com . Used under license from Shutterstock.com