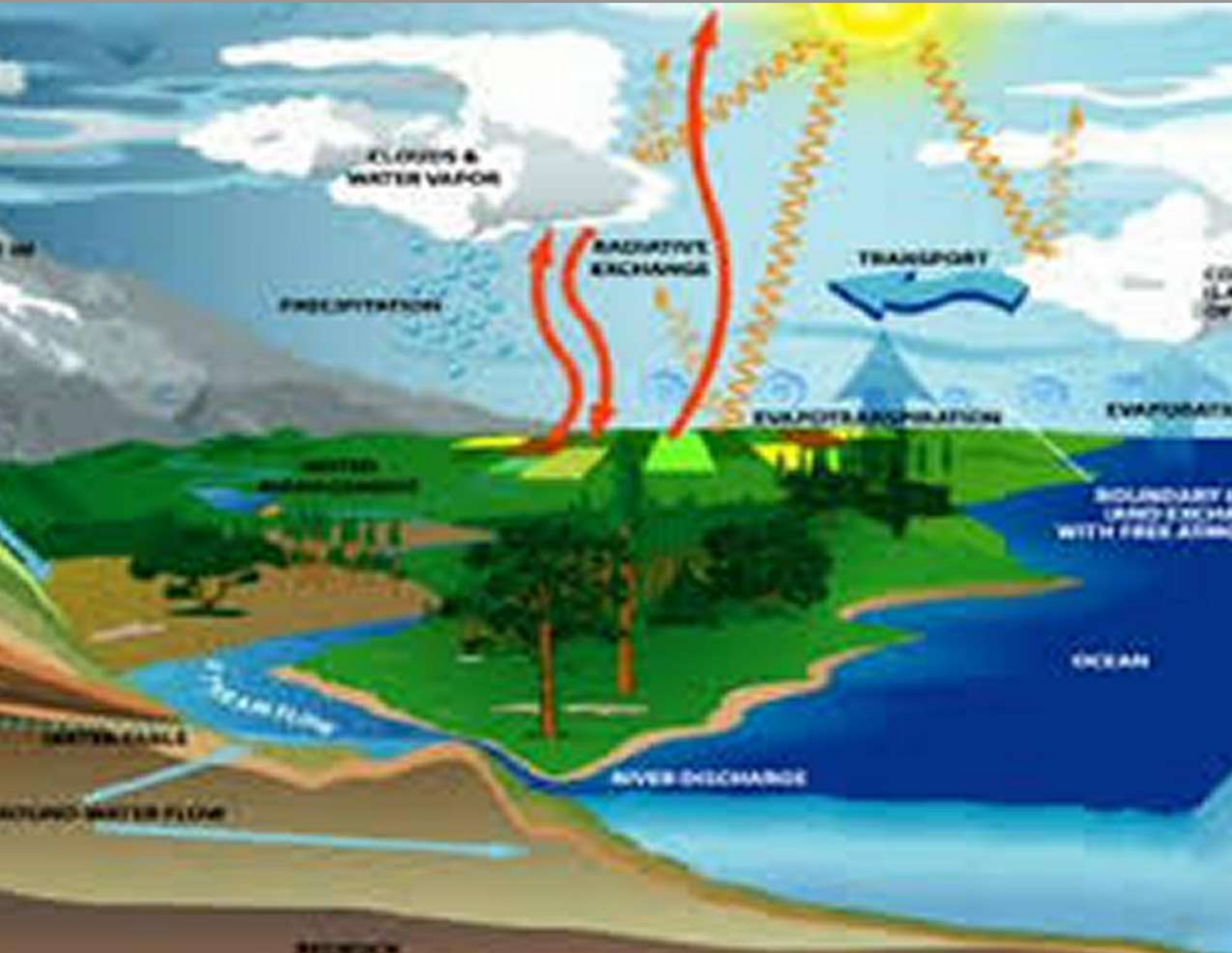
Creekside - 2nd nine weeks - 6th grade Earth Science - 2014-15



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Contents

CONCEPT 1 Weathering and Erosion

- Define weathering and erosion.

What is the history of this rock face?

Walnut Canyon, just outside Flagstaff, Arizona, is a high desert landscape displaying cliff dwellings built 700 years ago by a long gone people. On the opposite side from the trail around the mesa is this incredible rock. In this rock you can see that the rock has slumped, and also see signs of mechanical weathering (fractures) and chemical weathering (dissolution). If you get a chance, go see the rock (and the cliff dwellings) for yourself.

Weathering

Weathering is the process that changes solid rock into sediments. Sediments were described in the chapter "Materials of Earth's Crust." With weathering, rock is disintegrated. It breaks into pieces. Once these sediments are separated from the rocks, **erosion** is the process that moves the sediments.

While plate tectonics forces work to build huge mountains and other landscapes, the forces of weathering gradually wear those rocks and landscapes away. Together with erosion, tall mountains turn into hills and even plains. The Appalachian Mountains along the east coast of North America were once as tall as the Himalayas.

Weathering Takes Time

No human being can watch for millions of years as mountains are built, nor can anyone watch as those same mountains gradually are worn away. But imagine a new sidewalk or road. The new road is smooth and even. Over hundreds of years, it will completely disappear, but what happens over one year? What changes would you see? (**Figure** 1.1). What forces of weathering wear down that road, or rocks or mountains over time?

- Animations of different types of weathering processes can be found here: http://www.geography.ndo.co.uk/animationsweathering.htm# .

FIGURE 1.1
A once smooth road surface has cracks and fractures, plus a large pothole.

Summary

- Weathering breaks down Earth materials into smaller pieces.
- Erosion transports those pieces to other locations.
- Weathering and erosion modify Earth's surface landscapes over time.

Explore More

Use this resource to answer the questions that follow.

http://www.ux1.eiu.edu/~cfjps/1300/weathering.html

1. What is weathering?
2. What is mechanical weathering?

3. What is chemical weathering?
4. What is erosion?
5. Describe frost wedging.
6. What is abrasion?
7. List the types of chemical weathering.
8. What factors can influence chemical weathering?

Review

1. What is weathering?
2. How is weathering different from erosion?
3. Why does weathering take so much time?

References

1. Miguel Tremblay. Weathering leads to potholes in roads. Public Domain

CONCEPT 2 Influences on Weathering

- Identify and explain factors that influence the rate and intensity of weathering.

What circumstances allow for the most intense weathering?

The rate and intensity of weathering depend on the climate of a region and the rocks materials that are being weathered. Material in Baraboo, Wisconsin weathers a lot more readily than similar material in Sedona, Arizona.

Rock and Mineral Type

Different rock types weather at different rates. Certain types of rock are very resistant to weathering. Igneous rocks, especially intrusive igneous rocks such as granite, weather slowly because it is hard for water to penetrate them. Other types of rock, such as limestone, are easily weathered because they dissolve in weak acids.

Rocks that resist weathering remain at the surface and form ridges or hills. Shiprock in New Mexico is the throat of a volcano that's left after the rest of the volcano eroded away. The rock that's left behind is magma that cooled relatively slowly and is harder than the rock that had surrounded it.

Different minerals also weather at different rates. Some minerals in a rock might completely dissolve in water, but the more resistant minerals remain. In this case, the rock's surface becomes pitted and rough. When a less resistant mineral dissolves, more resistant mineral grains are released from the rock. A beautiful example of this effect is the "Stone Forest" in China, see the video below:

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URL: http://www.ck12.org/flx/render/embeddedobject/4779

FIGURE 2.1
The Shiprock formation in northwest New Mexico is the central plug of resistant lava from which the surrounding rock weathered and eroded away.

Climate

A region's **climate** strongly influences weathering. Climate is determined by the temperature of a region plus the amount of precipitation it receives. Climate is weather averaged over a long period of time. Chemical weathering increases as:

- Temperature increases: Chemical reactions proceed more rapidly at higher temperatures. For each 10^{o}C increase in average temperature, the rate of chemical reactions doubles.
- Precipitation increases: More water allows more chemical reactions. Since water participates in both mechanical and chemical weathering, more water strongly increases weathering.

So how do different climates influence weathering? A cold, dry climate will produce the lowest rate of weathering. A warm, wet climate will produce the highest rate of weathering. The warmer a climate is, the more types of vegetation it will have and the greater the rate of biological weathering (**Figure** 2.2). This happens because plants and bacteria grow and multiply faster in warmer temperatures.

FIGURE 2.2
Wet, warm tropical areas have the most weathering.

Resources from Weathering

Some resources are concentrated by weathering processes. In tropical climates, intense chemical weathering carries away all soluble minerals, leaving behind just the least soluble components. The aluminum oxide, bauxite, forms this way and is our main source of aluminum ore.

Summary

- Different materials weather at different rates and intensities under the same conditions.
- Different climate conditions cause the same materials to weather different intensities.

Explore More

Use this resource to answer the questions that follow.

Rock types on the Isle of Sky - Geological Landforms

http://www.youtube.com/watch?v=l-Y6588DnQg

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1. What type of rocks make up most of the Isle of Skye?
2. What other types of rocks are found on the island?
3. Why do the dikes on the hillside stick out of the hill?
4. What two processes shape the landscape of the island?
5. What are the primary sources of weathering on Skye?
6. How is scree produced?
7. How does weathering affect granite?
8. What is responsible for the topography of the island?
9. Which rocks are more resistant to weathering? How does that affect the topography?

Review

1. What types of rocks weather most readily? What types weather least readily?
2. What climate types cause more intense weathering? What climate types cause less intense weathering?
3. How does the aluminum resource bauxite form?

References

1. bowie snodgrass. The Shiprock formation in New Mexico formed after the surrounding rock eroded away. CC BY 2.0
2. Flickr:finchlake2000. Wet, warm tropical areas have the most weathering. CC BY 2.0

CONCEPT 3 Soil Erosion

- Explain how human activities cause soil erosion.

What would cause such a tremendous dust storm?

Farmers were forced off their lands during the Dust Bowl in the 1930s when the rains stopped and the topsoil blew off these former grasslands. A wind storm blew huge amounts of soil into the air in Texas on April 14, 1935. This scene was repeated throughout the central United States.

Causes of Soil Erosion

The agents of soil erosion are the same as the agents of all types of erosion: water, wind, ice, or gravity. Running water is the leading cause of soil erosion, because water is abundant and has a lot of power. Wind is also a leading cause of soil erosion because wind can pick up soil and blow it far away.

Activities that remove vegetation, disturb the ground, or allow the ground to dry are activities that increase erosion. What are some human activities that increase the likelihood that soil will be eroded?

Farming

Agriculture is probably the most significant activity that accelerates soil erosion because of the amount of land that is farmed and how much farming practices disturb the ground (**Figure** 3.1). Farmers remove native vegetation and then plow the land to plant new seeds. Because most crops grow only in spring and summer, the land lies fallow during the winter. Of course, winter is also the stormy season in many locations, so wind and rain are available to wash soil away. Tractor tires make deep grooves, which are natural pathways for water. Fine soil is blown away by wind.

The soil that is most likely to erode is the nutrient-rich topsoil, which degrades the farmland.

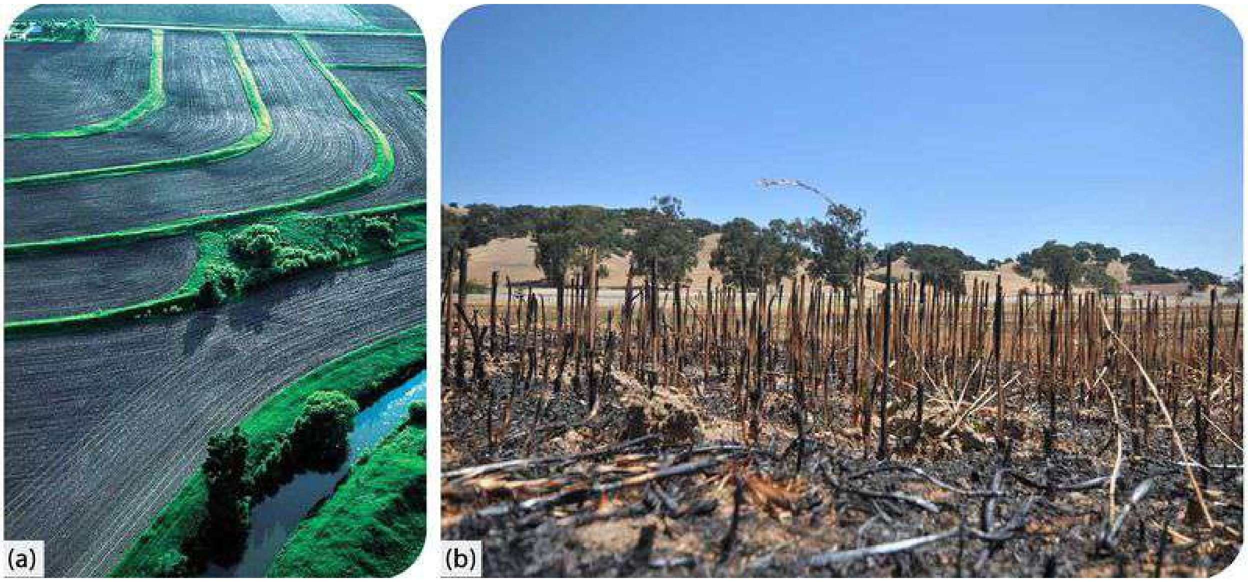

FIGURE 3.1

(a) The bare areas of farmland are especially vulnerable to erosion. (b) Slash-and-burn agriculture leaves land open for soil erosion and is one of the leading causes of soil erosion in the world.

Grazing

Grazing animals (**Figure** 3.2) wander over large areas of pasture or natural grasslands eating grasses and shrubs. Grazers expose soil by removing the plant cover for an area. They also churn up the ground with their hooves. If too many animals graze the same land area, the animals' hooves pull plants out by their roots. A land is overgrazed if too many animals are living there.

FIGURE 3.2

Grazing animals can cause erosion if they are allowed to overgraze and remove too much or all of the vegetation in a pasture.

Logging and Mining

Logging removes trees that protect the ground from soil erosion. The tree roots hold the soil together and the tree canopy protects the soil from hard falling rain. Logging results in the loss of **leaf litter**, or dead leaves, bark, and branches on the forest floor. Leaf litter plays an important role in protecting forest soils from erosion (**Figure** 3.3).

FIGURE 3.3
Logging exposes large areas of land to erosion.

Much of the world's original forests have been logged. Many of the tropical forests that remain are currently the site of logging because North America and Europe have already harvested many of their trees (**Figure** 3.4). Soils eroded from logged forests clog rivers and lakes, fill estuaries, and bury coral reefs.

Surface mining disturbs the land (**Figure** 3.5) and leaves the soil vulnerable to erosion.

Construction

Constructing buildings and roads churns up the ground and exposes soil to erosion. In some locations, native landscapes, such as forest and grassland, are cleared, exposing the surface to erosion (in some locations the land that will be built on is farmland). Near construction sites, dirt, picked up by the wind, is often in the air. Completed construction can also contribute to erosion (**Figure** 3.6).

Recreational Activities

Recreational activities may accelerate soil erosion. Off-road vehicles disturb the landscape and the area eventually develops bare spots where no plants can grow. In some delicate habitats, even hikers' boots can disturb the ground, so it's important to stay on the trail (**Figure** 3.7).

Soil erosion is as natural as any other type of erosion, but human activities have greatly accelerated soil erosion. In some locations soil erosion may occur about 10 times faster than its natural rate. Since Europeans settled in North America, about one-third of the topsoil in the area that is now the United States has eroded away.

Summary

- Although soil erosion is a natural process, human activities have greatly accelerated it.

FIGURE 3.4

Deforested swatches in Brazil show up as gray amid the bright red tropical rainforest.

FIGURE 3.5

(a) Disturbed land at a coal mine pit in Germany. (b) This coal mine in West Virginia covers more than 10,000 acres (15.6 square miles). Some of the exposed ground is being reclaimed by planting trees.

- The agents of soil erosion are the same as of other types of erosion: water, ice, wind, and gravity.
- Soil erosion is more likely where the ground has been disturbed by agriculture, grazing animals, logging, mining, construction, and recreational activities.

FIGURE 3.6
Urban areas and parking lots result in less water entering the ground. Water runs off the parking lot onto nearby lands and speeds up erosion in those areas.

FIGURE 3.7
(a) ATV'S churn up the soil, accelerating erosion. (b) Hiking trails may become eroded.

Practice

1. Why do farmers till the soil?
2. What is the major problem with tilling?
3. What were other costs from soil erosion in the 20th century (note that the video incorrectly says 19th century)?
4. How does climate change affect soil degradation?
5. What is the solution? How does it work?
6. What is the benefit of this strategy?
7. What is the benefit from better farming practices?

Review

1. What is soil erosion? Why did soil erosion accelerate so greatly during the Dust Bowl?
2. How do human activities accelerate soil erosion? Since soil erosion is a natural process, is this bad?
3. What is the consequence of the acceleration of soil erosion?

References

1. (a) Courtesy of Lynn Betts, US Department of Agriculture; (b) Image copyright Frank Fennema, 2014. Bare areas of farmland, and slash-and-bun agriculture lead to soil erosion. (a) Public Domain; (b) Used under license from Shutterstock.com
2. Courtesy of the National Resources Conservation Service. Sheep and goats can overgraze and cause soil erosion. Public Domain
3. Lucas Corrigan. Logging exposes large areas of land to erosion. CC BY 2.0
4. Courtesy of NASA/GSFC/METI/ERSDAC/JAROS and US/Japan ASTER Science Team. Deforested swatches in Brazil show up as gray amid the bright red tropical rainforest. Public Domain
5. (a) Alice Wiegand (User:Lyzzy/Wikimedia Commons); (b) Courtesy of Robert Simmon and NASA. Surface mining can lead to soil erosion, but the land can be reclaimed by planting trees. (a) CC BY 2.5; (b) Public Domain
6. User:Ingolfson/Wikimedia Commons. Urban areas and parking lots result in less water entering the ground. Public Domain
7. (a) Jim Simonson; (b) Image copyright Neil Bradfield, 2014. ATVs and hiking can cause soil erosion. (a) CC BY 2.0; (b) Used under license from Shutterstock.com

CONCEPT 4 Soil and Water Resources

- Describe the components of soil.
- Summarize the importance of soil.
- Describe threats to soil and water resources.
- Discuss consequences of excess runoff.

Could this land be used for agriculture?

Probably not. The quality of soil is very important in determining what can grow in a particular area. Good soil is not so easy to come by. Soil should be considered another resource that we, as a population, must strive to protect.

Soil and Water Resources

Theoretically, soil and water are renewable resources. However, they may be ruined by careless human actions.

Soil

Soil is a mixture of eroded rock, minerals, partly decomposed organic matter, and other materials. It is essential for plant growth, so it is the foundation of terrestrial ecosystems. Soil is important for other reasons as well. For example, it removes toxins from water and breaks down wastes.

Although renewable, soil takes a very long time to form—up to hundreds of millions of years. So, for human purposes, soil is a nonrenewable resource. It is also constantly depleted of nutrients through careless use, and eroded by wind and water. For example, misuse of soil caused a huge amount of it to simply blow away in the 1930s during the Dust Bowl (see **Figure** 4.1). Soil must be used wisely to preserve it for the future. Conservation practices include contour plowing and terracing. Both reduce soil erosion. Soil also must be protected from toxic wastes.

Water

Water is essential for all life on Earth. For human use, water must be fresh. Of all the water on Earth, only 1 percent is fresh, liquid water. Most of the rest is either salt water in the ocean or ice in glaciers and ice caps.

FIGURE 4.1
The Dust Bowl occurred between 1933 and 1939 in Oklahoma and other southwestern U.S. states. Plowing had exposed prairie soil. Drought turned the soil to dust. Intense dust storms blew away vast quantities of the soil. Much of the soil blew all the way to the Atlantic Ocean.

Although water is constantly recycled through the **water cycle**, it is in danger. Over-use and pollution of freshwater threaten the limited supply that people depend on. Already, more than 1 billion people worldwide do not have adequate freshwater. With the rapidly growing human population, the water shortage is likely to get worse.

KQED: Are We in Danger of Running Out of Water?

California's population is growing by 600,000 people a year, but much of the state receives as much annual rainfall as Morocco. With fish populations crashing, global warming, and the demands of the country's largest agricultural industry, the pressures on our water supply are increasing. Is the U.S.'s largest population in danger of running out of water? See http://www.kqed.org/quest/television/state-of-thirst-californias-water-future for additional information.

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Too Much of a Good Thing

Water pollution comes from many sources. One of the biggest sources is runoff. **Runoff** picks up chemicals such as fertilizer from agricultural fields, lawns, and golf courses. It carries the chemicals to bodies of water. The added nutrients from fertilizer often cause excessive growth of algae, creating **algal blooms** (see **Figure** 4.2). The algae use up oxygen in the water so that other aquatic organisms cannot survive. This has occurred over large areas of the ocean, creating **dead zones**, where low oxygen levels have killed all ocean life. A very large dead zone exists in the

Gulf of Mexico. Measures that can help prevent these problems include cutting down on fertilizer use. Preserving wetlands also helps because wetlands filter runoff water.

FIGURE 4.2
Algal Bloom. Nutrients from fertilizer in runoff caused this algal bloom.

Summary

- Soil and water are renewable resources but may be ruined by careless human actions. Soil can be depleted of nutrients. It can also be eroded by wind or water.
- Over-use and pollution of freshwater threaten the limited supply that people depend on.

Explore More

Explore More I

Use this resources to answer the questions that follow.

- http://www.hippocampus.org/Biology → Non-Majors Biology → Search: **Human Impacts on Biogeochemical Cycles**

1. What happens when fertilizer ends up in waterways?
2. Describe eutrophication.
3. What has happened at the mouth of the Mississippi River?

Explore More II

- **Will There Be Enough Fresh Water?** at http://www.concord.org/activities/will-there-be-enough-fresh-water .

Review

1. What is soil?
2. Why is soil considered a nonrenewable resource?
3. How much water is drinkable?
4. Why would you expect a dead zone to start near the mouth of a river, where the river flows into a body of water?

References

1. Left: National Oceanic and Atmospheric Administration; Right: U.S. Department of Agriculture. Images of the Dust Bowl. Public Domain
2. Dr. Jennifer L. Graham/U.S. Geological Survey. Nutrients in fertilizer cause an algal bloom. Public Domain

CONCEPT 5 States of Water

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

H - two - O. Why is something so simple so important?

Water is the most important substance on Earth. Think about all the things you use water for? If your water access were restricted what would you miss about it?

The Water Molecule

Water is simply two atoms of hydrogen and one atom of oxygen bonded together (**Figure** 5.1). The hydrogen ions are on one side of the oxygen ion, making water a **polar molecule**. This means that one side, the side with the hydrogen ions, has a slightly positive electrical charge. The other side, the side without the hydrogen ions, has a slightly negative charge.

Despite its simplicity, water has remarkable properties. Water expands when it freezes, has high surface tension (because of the polar nature of the molecules, they tend to stick together), and others. Without water, life might not be able to exist on Earth and it certainly would not have the tremendous complexity and diversity that we see.

Three States of Matter

Water is the only substance on Earth that is present in all three states of matter – as a solid, liquid or gas. (And Earth is the only planet where water is present in all three states.) Because of the ranges in temperature in specific locations around the planet, 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 (**Figure** 5.2).

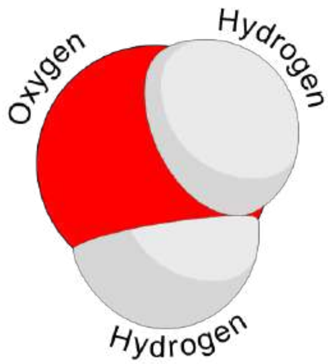


FIGURE 5.1
A water molecule. The hydrogen atoms have a slightly positive charge, and the oxygen atom has a slightly negative charge.

FIGURE 5.2
(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 with a more positive charge on one side and a more negative charge on the other side.
- 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.

Explore More

Use this resource to answer the questions that follow.

https://www.youtube.com/watch?v=HVT3Y3_gHGg Watch to 5:50.

1. What is the only substance that occurs naturally on Earth in all three states of matter?
2. Why do scientists look for water in other places in the solar system?
3. Describe the bond that keeps the water molecule together.
4. What does it mean to say that the water molecule is polar?
5. What are hydrogen bonds?
6. Why does water form a droplet if it is placed on waxed paper or teflon?
7. Why does water experience adhesion rather than cohesion with glass?

8. What causes water in a straw to rise higher than the surface level of the water in the beaker the tube is in?
9. Why is water such a great solvent?
10. Why doesn't oil mix with water?

Review

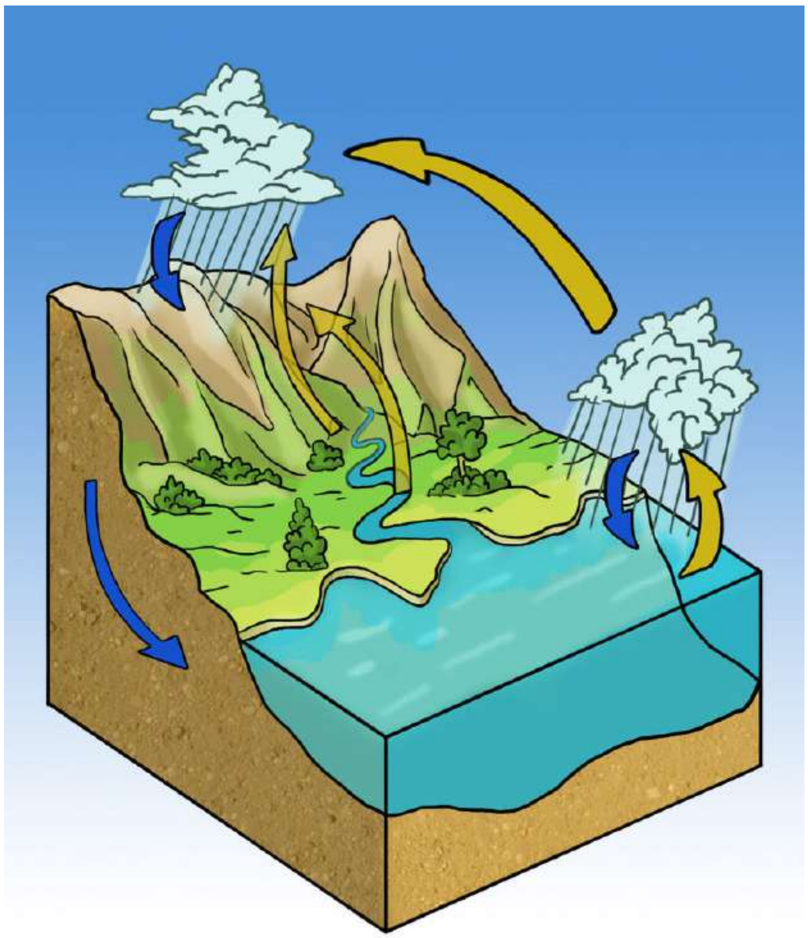
1. What is a polar molecule?
2. What makes water a polar molecule?
3. What are the three states that a substance can have?
4. Where in the solar system is water found in all three states?

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 phases of water. (A) CC BY 2.0; (B) CC BY 2.0; (C) Public Domain

CONCEPT 6 Water Cycle

- Define biogeochemical cycle.
- Compare an exchange pool to a reservoir.
- Describe the water cycle and its processes.
- Compare evaporation to sublimation and to transpiration.
- Explain the roles of condensation and precipitation in the water cycle.



Where does the water come from that is needed by your cells?

Unlike energy, matter is not lost as it passes through an ecosystem. Instead, matter, including water, is recycled. This recycling involves specific interactions between the biotic and abiotic factors in an ecosystem. Chances are, the water you drank this morning has been around for millions of years, or more.

The Water Cycle

The chemical elements and water that are needed by organisms continuously recycle in ecosystems. They pass through biotic and abiotic components of the biosphere. That's why their cycles are called **biogeochemical cycles**. For example, a chemical might move from organisms (*bio*) to the atmosphere or ocean (*geo*) and back to organisms again. Elements or water may be held for various periods of time in different parts of a cycle.

- Part of a cycle that holds an element or water for a short period of time is called an **exchange pool**. For example, the atmosphere is an exchange pool for water. It usually holds water (in the form of water vapor) for just a few days.
- Part of a cycle that holds an element or water for a long period of time is called a **reservoir**. The ocean is a reservoir for water. The deep ocean may hold water for thousands of years.

Water on Earth is billions of years old. However, individual water molecules keep moving through the water cycle. The **water cycle** is a global cycle. It takes place on, above, and below Earth's surface, as shown in **Figure** 6.1.

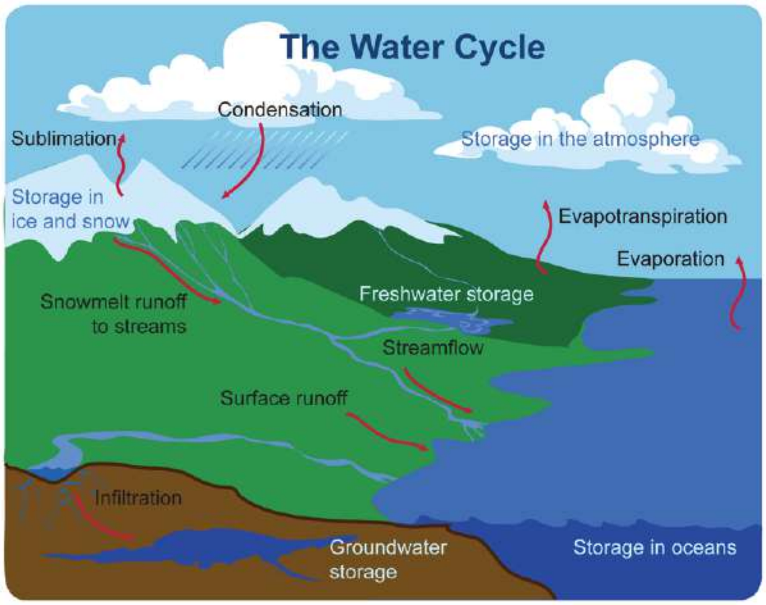


FIGURE 6.1
Like other biogeochemical cycles, there is no beginning or end to the water cycle. It just keeps repeating.

During the water cycle, water occurs in three different states: gas (water vapor), liquid (water), and solid (ice). Many processes are involved as water changes state in the water cycle.

See *Watercourses* at http://www.hippocampus.org/HippoCampus/Earth%20Science?loadLeftClass=Course&loadLeftId=153&loadTopicId=10689 . for a nice description of the flow of water.

Evaporation, Sublimation, and Transpiration

Water changes to a gas by three different processes:

1. **Evaporation** occurs when water on the surface changes to water vapor. The sun heats the water and gives water molecules enough energy to escape into the atmosphere.
2. **Sublimation** occurs when ice and snow change directly to water vapor. This also happens because of heat from the sun.
3. **Transpiration** occurs when plants release water vapor through leaf pores called stomata (see **Figure** 6.2).

Condensation and Precipitation

Rising air currents carry water vapor into the atmosphere. As the water vapor rises in the atmosphere, it cools and condenses. **Condensation** is the process in which water vapor changes to tiny droplets of liquid water. The water droplets may form clouds. If the droplets get big enough, they fall as **precipitation**—rain, snow, sleet, hail, or

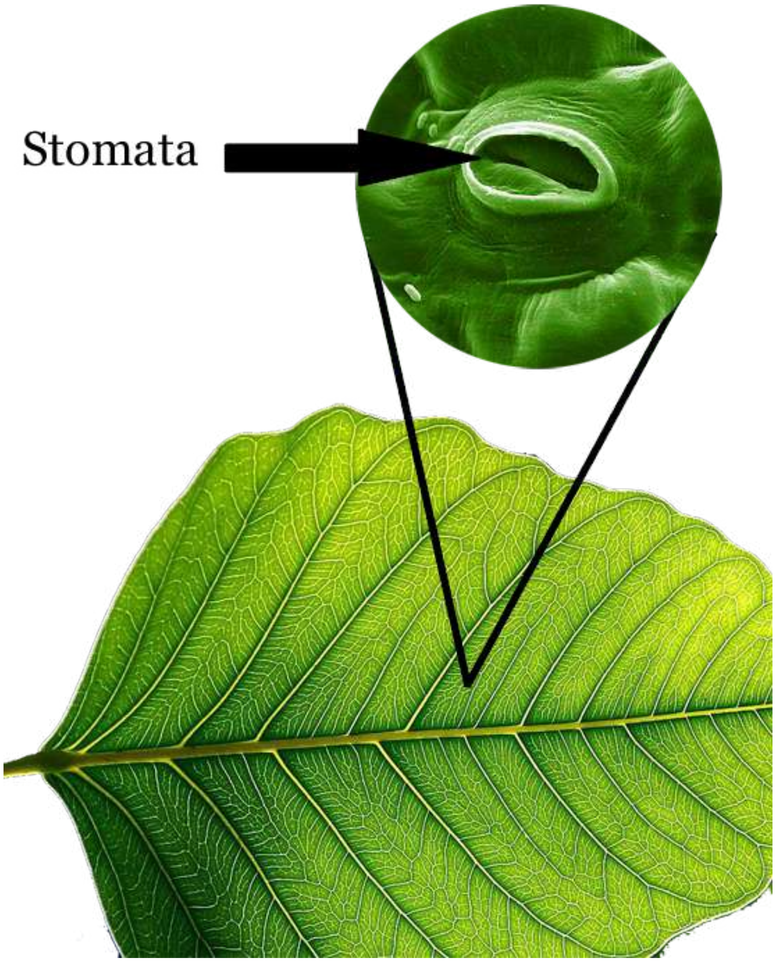


FIGURE 6.2
Plant leaves have many tiny stomata. They release water vapor into the air.

freezing rain. Most precipitation falls into the ocean. Eventually, this water evaporates again and repeats the water cycle. Some frozen precipitation becomes part of ice caps and glaciers. These masses of ice can store frozen water for hundreds of years or longer.

Groundwater and Runoff

Precipitation that falls on land may flow over the surface of the ground. This water is called **runoff**. It may eventually flow into a body of water. Some precipitation that falls on land may soak into the ground, becoming **groundwater**. Groundwater may seep out of the ground at a spring or into a body of water such as the ocean. Some groundwater may be taken up by plant roots. Some may flow deeper underground to an **aquifer**. This is an underground layer of rock that stores water, sometimes for thousands of years.

The water cycle is demonstrated at http://www.youtube.com/watch?v=iohKd5FWZOE (4:00).

The "Water Cycle Jump" can be viewed at http://www.youtube.com/watch?v=BayExatv8lE . (1:31).

KQED: Tracking Raindrops

We all rely on the water cycle, but how does it actually work? Scientists at University of California Berkeley are embarking on a new project to understand how global warming is affecting our fresh water supply. And they're doing it by tracking individual raindrops in Mendocino and north of Lake Tahoe. See http://www.kqed.org/quest/television/tracking-raindrops for more information.

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Summary

- Chemical elements and water are recycled through biogeochemical cycles. The cycles include both biotic and abiotic parts of ecosystems.
- The water cycle takes place on, above, and below Earth's surface. In the cycle, water occurs as water vapor, liquid water, and ice. Many processes are involved as water changes state in the cycle.
- The atmosphere is an exchange pool for water. Ice masses, aquifers, and the deep ocean are water reservoirs.

Explore More

Use these resources to answer the questions that follow.

- **The Water Cycle** at [http://studyjams.scholastic.com/studyjams/jams/science/ecosystems/water-cycle.htm http://studyjams.scholastic.com/studyjams/jams/science/ecosystems/water-cycle.htm}.

1. Give four examples of precipitation.
2. How does this resource define the water cycle?
3. What does evaporation do?
4. What is transpiration?
5. What is condensation?

Review

1. What is a biogeochemical cycle? Name an example.
2. Identify and define two processes by which water naturally changes from a solid or liquid to a gas.
3. Define exchange pool and reservoir, and identify an example of each in the water cycle.
4. Assume you are a molecule of water. Describe one way you could go through the water cycle, starting as water vapor in the atmosphere.

References

1. Mariana Ruiz Villarreal (LadyofHats) for CK-12 Foundation. The water cycle takes place on, above, and below Earth's surface. CC BY-NC 3.0
2. Stomata: Dartmouth Electron Microscope Facility; Leaf: Jon Sullivan. Tiny stomata are found on a plant leaf. Public Domain

CONCEPT 7 Processes of the Water Cycle

- Describe the water cycle and describe the processes that carry water between reservoirs.
- Define the processes by which water changes state and explain the role each plays in the water cycle.

Where have these water molecules been?

Because of the unique properties of water, water molecules can cycle through almost anywhere on Earth. The water molecule found in your glass of water today could have erupted from a volcano early in Earth's history. In the intervening billions of years, the molecule probably spent time in a glacier or far below the ground. The molecule surely was high up in the atmosphere and maybe deep in the belly of a dinosaur. Where will that water molecule go next?

The Water Cycle

The movement of water around Earth's surface is the **hydrological (water) cycle** (**Figure** 7.1). Water inhabits reservoirs within the cycle, such as ponds, oceans, or the atmosphere. The molecules move between these reservoirs by certain processes, including condensation and precipitation. There are only so many water molecules and these molecules cycle around. If climate cools and glaciers and ice caps grow, there is less water for the oceans and sea level will fall. The reverse can also happen.

The following section looks at the reservoirs and the processes that move water between them.

Solar Energy

The Sun, many millions of kilometers away, provides the energy that drives the water cycle. Our nearest star directly impacts the water cycle by supplying the energy needed for evaporation.

Oceans

Most of Earth's water is stored in the oceans, where it can remain for hundreds or thousands of years.

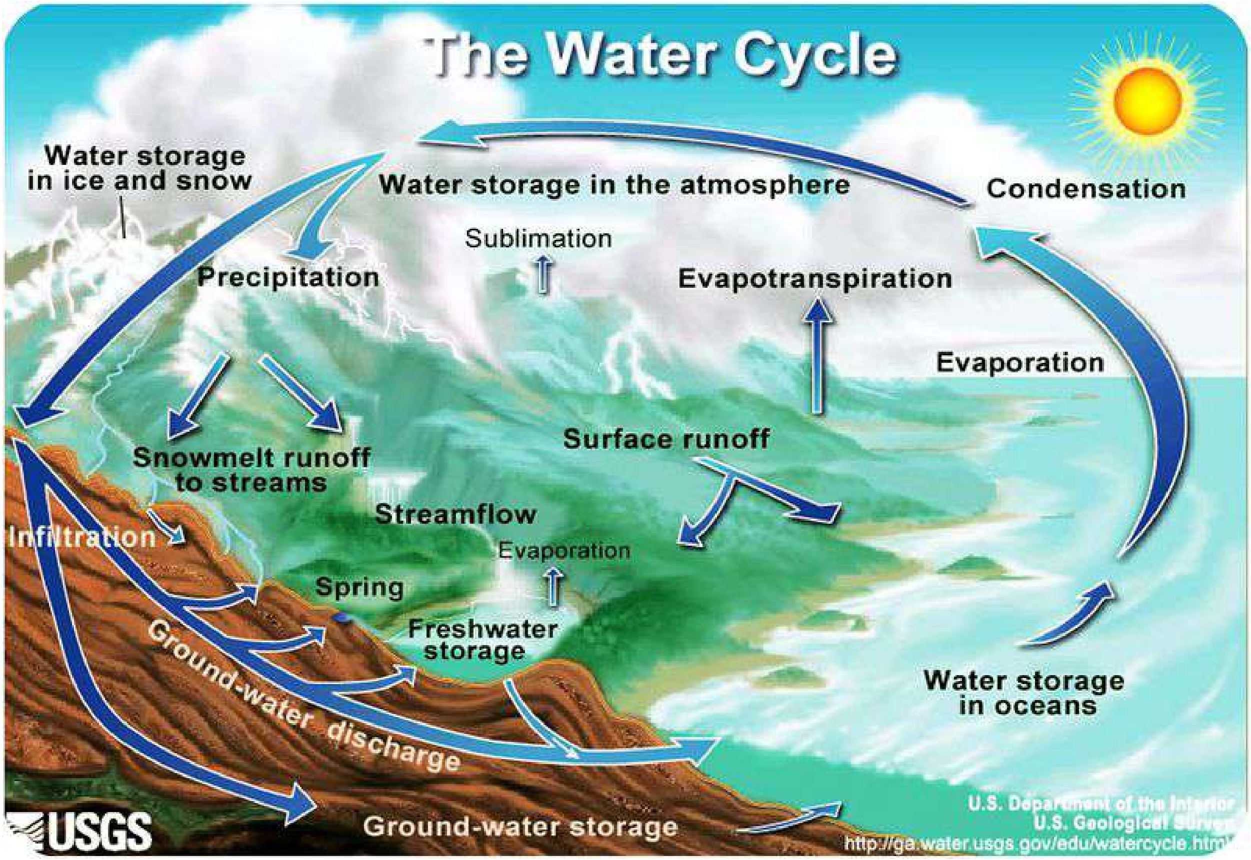


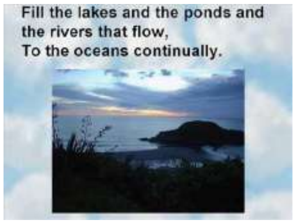
FIGURE 7.1
Because it is a cycle, the water cycle has no beginning and no end.

Atmosphere

Water changes from a liquid to a gas by **evaporation** to become water vapor. The Sun's energy can evaporate water from the ocean surface or from lakes, streams, or puddles on land. Only the water molecules evaporate; the salts remain in the ocean or a fresh water reservoir.

The water vapor remains in the atmosphere until it undergoes **condensation** to become tiny droplets of liquid. The droplets gather in clouds, which are blown about the globe by wind. As the water droplets in the clouds collide and grow, they fall from the sky as precipitation. **Precipitation** can be rain, sleet, hail, or snow. Sometimes precipitation falls back into the ocean and sometimes it falls onto the land surface.

For a little fun, watch this video. This water cycle song focuses on the role of the Sun in moving H_2O from one reservoir to another. The movement of all sorts of matter between reservoirs depends on Earth's internal or external sources of energy: http://www.youtube.com/watch?v=Zx_1g5pGFLI (2:38).



MEDIA

Click image to the left for use the URL below.

URL: http://www.ck12.org/flx/render/embeddedobject/1623

This animation shows the annual cycle of monthly mean precipitation around the world: http://en.wikipedia.org/wiki/File:MeanMonthlyP.gif .

Streams and Lakes

When water falls from the sky as rain it may enter streams and rivers that flow downward to oceans and lakes. Water that falls as snow may sit on a mountain for several months. Snow may become part of the ice in a glacier, where it may remain for hundreds or thousands of years. Snow and ice may go directly back into the air by sublimation, the process in which a solid changes directly into a gas without first becoming a liquid. Although you probably have not seen water vapor undergoing **sublimation** from a glacier, you may have seen dry ice sublimate in air.

Snow and ice slowly melt over time to become liquid water, which provides a steady flow of fresh water to streams, rivers, and lakes below. A water droplet falling as rain could also become part of a stream or a lake. At the surface, the water may eventually evaporate and reenter the atmosphere.

Soil

A significant amount of water infiltrates into the ground. Soil moisture is an important reservoir for water (**Figure** 7.2). Water trapped in soil is important for plants to grow.

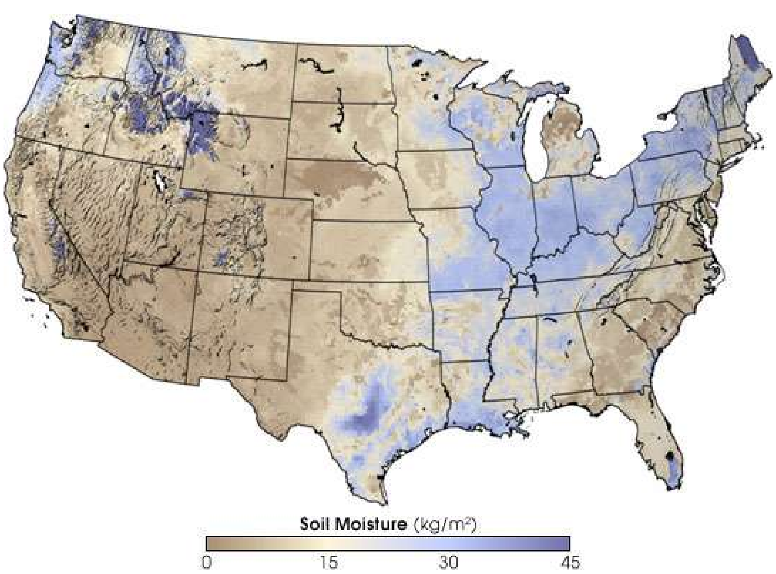


FIGURE 7.2

The moisture content of soil in the United States varies greatly.

Groundwater

Water may seep through dirt and rock below the soil and then through pores infiltrating the ground to go into Earth's groundwater system. Groundwater enters aquifers that may store fresh water for centuries. Alternatively, the water may come to the surface through springs or find its way back to the oceans.

Biosphere

Plants and animals depend on water to live. They also play a role in the water cycle. Plants take up water from the soil and release large amounts of water vapor into the air through their leaves (**Figure** 7.3), a process known as **transpiration**.

An online guide to the hydrologic cycle from the University of Illinois is found here: http://ww2010.atmos.uiuc.edu/%28Gh%29/guides/mtr/hyd/home.rxml .

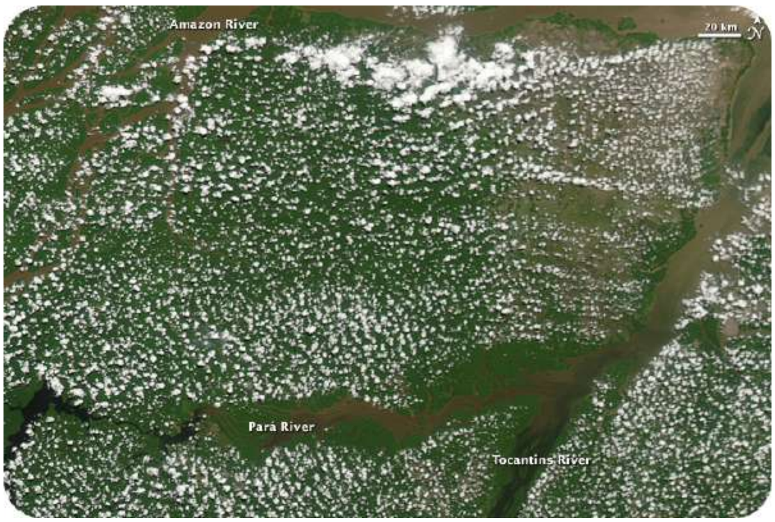


FIGURE 7.3

Clouds form above the Amazon Rainforest even in the dry season because of moisture from plant transpiration.

How the water cycle works and how rising global temperatures will affect the water cycle, especially in California, are the topics of this Quest video.

Watch it at http://www.kqed.org/quest/television/tracking-raindrops/.

MEDIA

Click image to the left for use the URL below.

URL: http://www.ck12.org/flx/render/embeddedobject/60926

Human Uses

People also depend on water as a natural resource. Not content to get water directly from streams or ponds, humans create canals, aqueducts, dams, and wells to collect water and direct it to where they want it (**Figure** 7.4).

Summary

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

FIGURE 7.4
Pont du Gard in France is an ancient aqueduct and bridge that was part of a well-developed system that supplied water around the Roman empire.

Explore More

Use this resource to answer the questions that follow.

https://www.youtube.com/watch?v=8NwS86wtmlM

1. How often is water added to the Earth system?
2. How can the two parts of the water cycle be summarized?
3. What are the major reservoirs for water?
4. What is precipitation?
5. Where does snow melt go?
6. As rain falls onto land, what can happen to it?
7. How long does water stay in groundwater?
8. How does water get back into the atmosphere?
9. How do plants engage in transpiration?

Review

1. What is transpiration?
2. Describe when and how sublimation occurs.
3. What is the role of the major reservoirs in the water cycle?

References

1. Courtesy of US Geological Survey. Diagram of the water cycle. Public Domain
2. Courtesy of NASA's Earth Observatory. Map of the moisture content of soil in the United States. Public Domain
3. Courtesy of Jeff Schmaltz/NASA's Earth Observatory. Clouds forming above the Amazon Rainforest due to transpiration. Public Domain
4. Image copyright Filip Fuxa, 2014. Pont du Gard is an aqueduct in France.

CONCEPT 8 Water Distribution

- Describe how water is distributed across the globe.
- Explain the causes and consequences of water scarcity.

Will water cause the next war?

Wars have been fought over oil, but many people predict that the next war will be fought over water. Certainly, water is becoming scarcer.

Water Distribution

Water is unevenly distributed around the world. Large portions of the world, such as much of northern Africa, receive very little water relative to their population (**Figure** 8.1). The map shows the number of months in which there is little rainfall in each region. In developed nations, water is stored, but in underdeveloped nations, water storage may be minimal.

Over time, as population grows, rainfall totals will change, resulting in less water per person in some regions. In 2025, many nations, even developed nations, are projected to have less water per person than now

Water Shortages

Water scarcity is a problem now and will become an even larger problem in the future as water sources are reduced or polluted and population grows. In 1995, about 40% of the world's population faced water scarcity. Scientists estimate that by the year 2025, nearly half of the world's people won't have enough water to meet their daily needs. Nearly one-quarter of the world's people will have less than 500 m^3 of water to use in an entire year. That amount is less water in a year than some people in the United States use in one day.

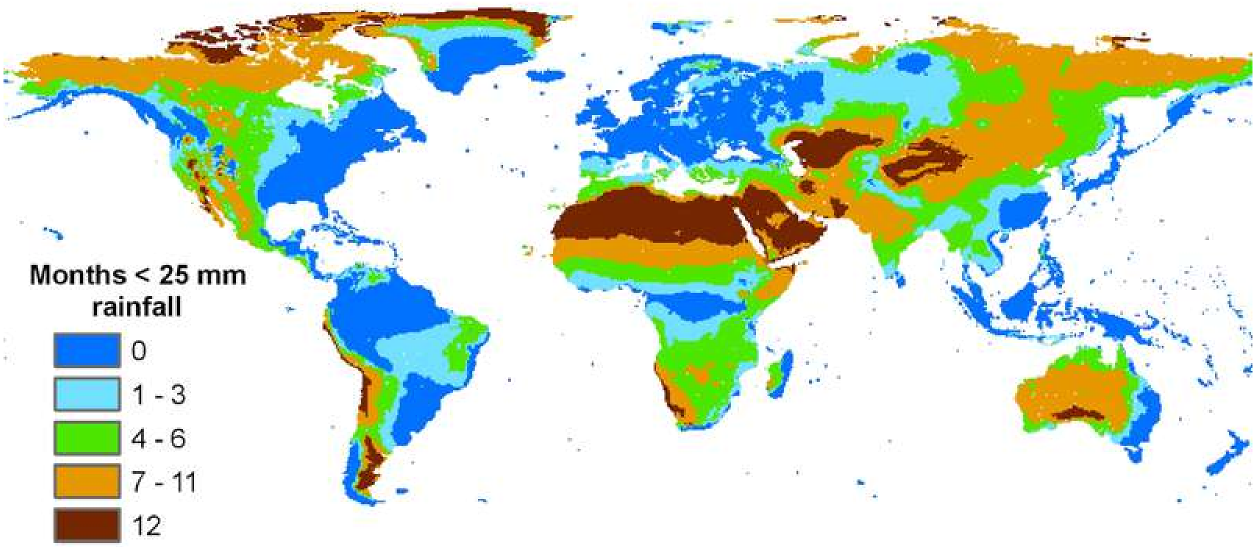


FIGURE 8.1
Some regions have very little rainfall per month.

Droughts

Droughts occur when a region experiences unusually low precipitation for months or years (**Figure** 8.2). Periods of drought may create or worsen water shortages.

Human activities can contribute to the frequency and duration of droughts. For example, deforestation keeps trees from returning water to the atmosphere by transpiration; part of the water cycle becomes broken. Because it is difficult to predict when droughts will happen, it is difficult for countries to predict how serious water shortages will be each year.

FIGURE 8.2
Extended periods with lower than normal rainfall cause droughts.

Effect of Changing Climate

Global warming will change patterns of rainfall and water distribution. As the Earth warms, regions that currently receive an adequate supply of rain may shift. Regions that rely on snowmelt may find that there is less snow and the melt comes earlier and faster in the spring, causing the water to run off and not be available through the dry summers. A change in temperature and precipitation would completely change the types of plants and animals that can live successfully in that region.

Water Scarcity

Water scarcity can have dire consequences for the people, the economy, and the environment. Without adequate water, crops and livestock dwindle and people go hungry. Industry, construction, and economic development is halted, causing a nation to sink further into poverty. The risk of regional conflicts over scarce water resources rises. People die from diseases, thirst, or even in war over scarce resources.

California's population is growing by hundreds of thousands of people a year, but much of the state receives as much annual rainfall as Morocco. With fish populations crashing, global warming, and the demands of the country's largest agricultural industry, the pressures on our water supply are increasing.

Find out more at http://science.kqed.org/quest/video/state-of-thirst-californias-water-future/ .

MEDIA

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URL: http://www.ck12.org/flx/render/embeddedobject/447

Conflicts Over Water

As water supplies become scarce, conflicts will arise between the individuals or nations that have enough clean water and those that do not (**Figure** 8.3). Some of today's greatest tensions are happening in places where water is scarce. Water disputes may add to tensions between countries where differing national interests and withdrawal rights have been in conflict. Just as with energy resources today, wars may erupt over water.

Water disputes are happening along 260 different river systems that cross national boundaries. Some of these disputes are potentially very serious. International water laws, such as the Helsinki Rules, help interpret water rights among countries.

Summary

- A lot of the problem with water is that it is not evenly distributed across the planet.
- Many of the world's people live with water scarcity, and that percentage will increase as populations increase and climate changes.
- Some people predict that, just as wars are fought over energy now, future wars will be fought over water.

Practice

Use these resources to answer the questions that follow.

https://www.youtube.com/watch?v=6XvBxC9XMpE

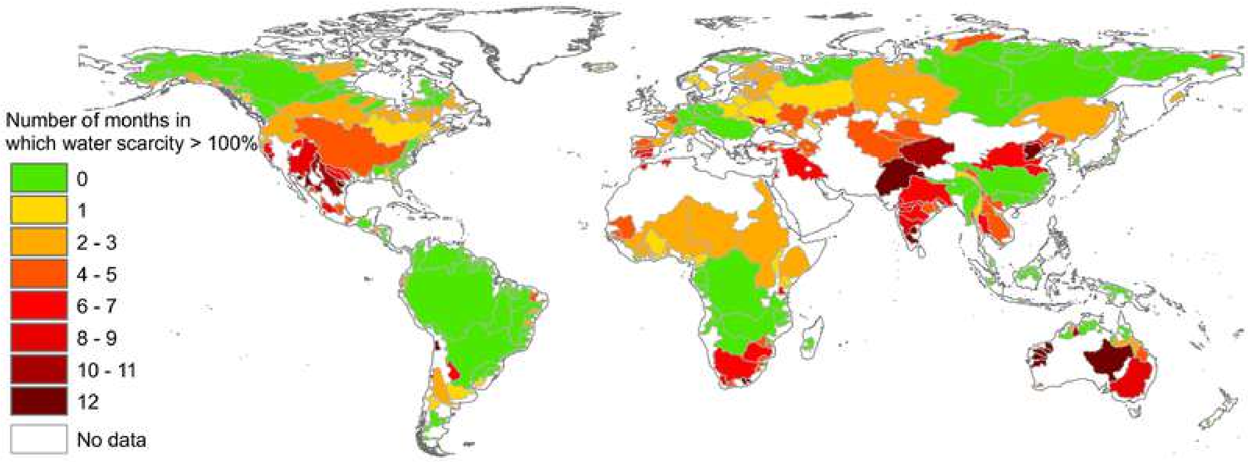


FIGURE 8.3

Many regions already experience water scarcity. This map shows the number of months in which the amount of water that is used exceeds the availability of water that can be used sustainably. This is projected to get worse as demand increases.

1. What does the water footprint of a product refer to?
2. What is the water footprint of developed nations, like the United States and southern Europe, per capita compared with developing nations? How about compared with the global average?
3. What is the water footprint of the United Kingdom and other northern European countries compared with the global average? How about with the developing nations?
4. What is used as the water footprint cap? Is that sustainable?
5. Besides living within the water footprint cap, what should governments do?
6. How can the issue of water equity be addressed?

Review

1. How will changing climate affect the availability and distribution of water?
2. How do human activities affect the occurrence of droughts?
3. How do so many people live with so little water?

References

1. PR Hunter, AM MacDonald, RC Carter. Map of the world showing average rainfall. CC BY 2.5
2. Tomas Castelazo. Picture of drought cracked land. CC BY 3.0
3. AY Hoekstra, MM Mekonnen, et al.. Map of the world showing areas of water scarcity. CC BY 2.5

CONCEPT 9 Introduction to Groundwater

- Define aquifer and explain how aquifers form and recharge.

Is there always water flowing beneath the land surface?

Although this may seem surprising, water beneath the ground is commonplace, moving slowly and silently through an aquifer and then bubbling to the surface at a spring. Groundwater is an extremely important source of water in many parts of the world where development and agriculture outmatch the amount of water available from rainfall and streams.

Aquifer

Groundwater resides in **aquifers**, porous rock and sediment with water in between. Water is attracted to the soil particles, and **capillary action**, which describes how water moves through porous media, moves water from wet soil to dry areas.

Aquifers are found at different depths. Some are just below the surface and some are found much deeper below the land surface. A region may have more than one aquifer beneath it and even most deserts are above aquifers. The source region for an aquifer beneath a desert is likely to be far away, perhaps in a mountainous area.

Recharge

The amount of water that is available to enter groundwater in a region, called **recharge**, is influenced by the local climate, the slope of the land, the type of rock found at the surface, the vegetation cover, land use in the area, and water retention, which is the amount of water that remains in the ground. More water goes into the ground where there is a lot of rain, flat land, porous rock, exposed soil, and where water is not already filling the soil and rock.

Fossil Water

The residence time of water in a groundwater aquifer can be from minutes to thousands of years. Groundwater is often called "fossil water" because it has remained in the ground for so long, often since the end of the ice ages.

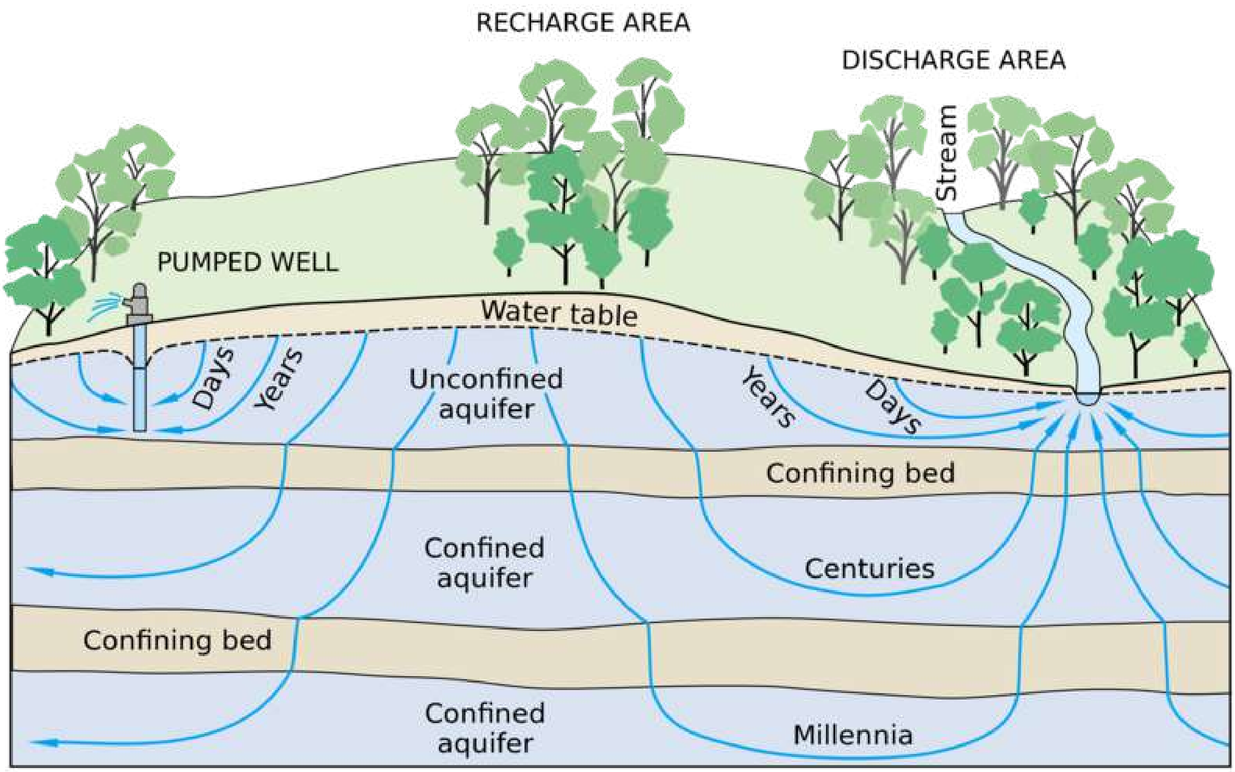


FIGURE 9.1

A diagram of groundwater flow through aquifers showing residence times. Deeper aquifers typically contain older "fossil water."

Summary

- Groundwater is in aquifers, a porous and permeable rock layer.
- Groundwater recharges in wet regions.
- Much groundwater is from the end of the ice ages, so it is called fossil water.

Explore More

Use this resource to answer the questions that follow.

1. What is surface water?
2. What is groundwater?
3. What is groundwater stored in?
4. What is the largest aquifer in the United States?

5. What is the top of the aquifer called?
6. What is the area above and the area below the water table called?
7. How does water end up in groundwater?
8. How long can water stay in the aquifer?
9. How does groundwater reach the surface naturally? ’
10. How does surface water become groundwater?
11. What do humans do with groundwater?
12. Under what conditions could humans drain aquifers?

Review

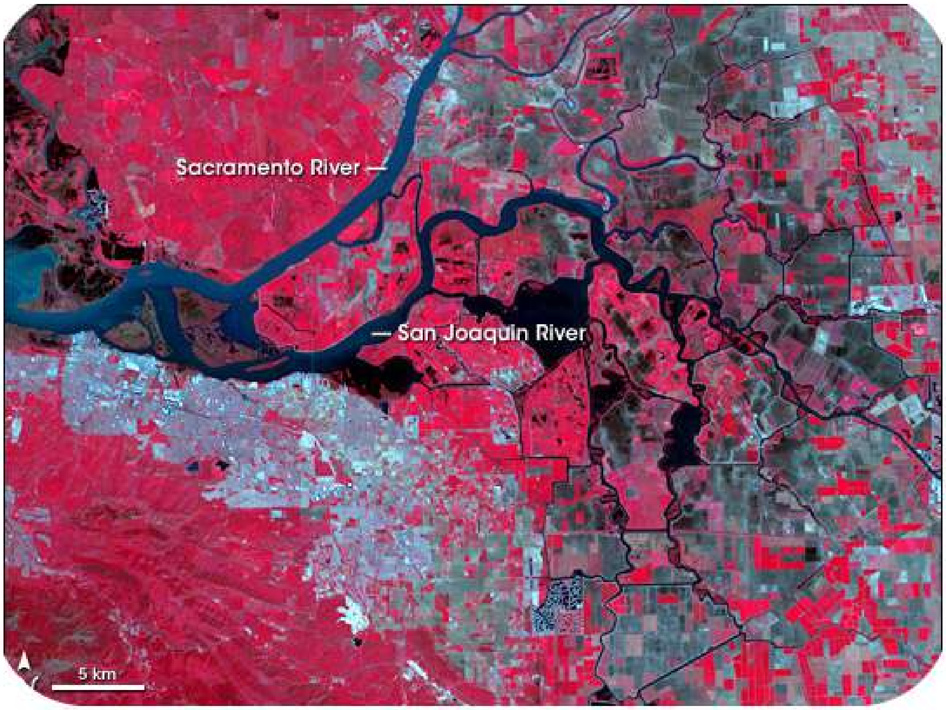
1. How does water move through an aquifer?
2. Where does groundwater come from in a region that has very little rainfall?
3. If groundwater is used, how will there be more? Is there always the same amount of water in an aquifer.

References

1. Courtesy of T.C. Winter, J.W. Harvey, O.L. Franke, and W.M. Alley, US Geological Survey. Diagram of an aquifer and groundwater flow. Public Domain

Concept 10 Streams and Rivers

- Define stream and describe its parts and stages.



Do you see the Sacramento and San Joaquin Rivers?

The farmland in the Central Valley of California is among the most productive in the world. Besides good soil and a mild climate, the region has a lot of water. Streams drain off of the Sierra Nevada mountains to the east and join the mighty Sacramento and San Joaquin Rivers in the Central Valley. How many of the features that are discussed below can you find in this image?

Streams

Streams are bodies of water that have a current; they are in constant motion. Geologists recognize many categories of streams depending on their size, depth, speed, and location. Creeks, brooks, tributaries, bayous, and rivers are all streams. In streams, water always flows downhill, but the form that downhill movement takes varies with rock type, topography, and many other factors. Stream erosion and deposition are extremely important creators and destroyers of landforms.

Rivers are the largest streams. People have used rivers since the beginning of civilization as a source of water, food, transportation, defense, power, recreation, and waste disposal.

With its high mountains, valleys and Pacific coastline, the western United States exhibits nearly all of the features common to rivers and streams. The photos below are from the western states of Montana, California and Colorado.

Parts of a Stream

A stream originates at its source. A source is likely to be in the high mountains where snows collect in winter and melt in summer, or a source might be a spring. A stream may have more than one source.

Two streams come together at a **confluence**. The smaller of the two streams is a **tributary** of the larger stream (**Figure** 10.1).

FIGURE 10.1
The confluence between the Yellowstone River and one of its tributaries, the Gardiner River, in Montana.

The point at which a stream comes into a large body of water, like an ocean or a lake, is called the **mouth**. Where the stream meets the ocean or lake is an **estuary** (**Figure** 10.2).

FIGURE 10.2
The mouth of the Klamath River creates an estuary where it flows into the Pacific Ocean in California.

The mix of fresh and salt water where a river runs into the ocean creates a diversity of environments where many different types of organisms create unique ecosystems.

Stages of Streams

As a stream flows from higher elevations, like in the mountains, towards lower elevations, like the ocean, the work of the stream changes. At a stream's **headwaters**, often high in the mountains, gradients are steep (**Figure** 10.3). The stream moves fast and does lots of work eroding the stream bed.

FIGURE 10.3
Headwaters of the Roaring Fork River in Colorado.

As a stream moves into lower areas, the gradient is not as steep. Now the stream does more work eroding the edges of its banks. Many streams develop curves in their channels called **meanders** (**Figure** 10.4).

FIGURE 10.4
The East River meanders through Crested Butte, Colorado.

As the river moves onto flatter ground, the stream erodes the outer edges of its banks to carve a **floodplain**, which is a flat, level area surrounding the stream channel (**Figure** 10.5).

FIGURE 10.5
A green floodplain surrounds the Red Rock River as it flows through Montana.

Base level is where a stream meets a large body of standing water, usually the ocean, but sometimes a lake or pond.

Streams work to down cut in their stream beds until they reach base level. The higher the elevation, the farther the stream is from where it will reach base level and the more cutting it has to do. The ultimate base level is sea level.

Divides

A **divide** is a topographically high area that separates a landscape into different water basins (**Figure** 10.6). Rain that falls on the north side of a ridge flows into the northern drainage basin and rain that falls on the south side flows into the southern drainage basin. On a much grander scale, entire continents have divides, known as **continental divides**.

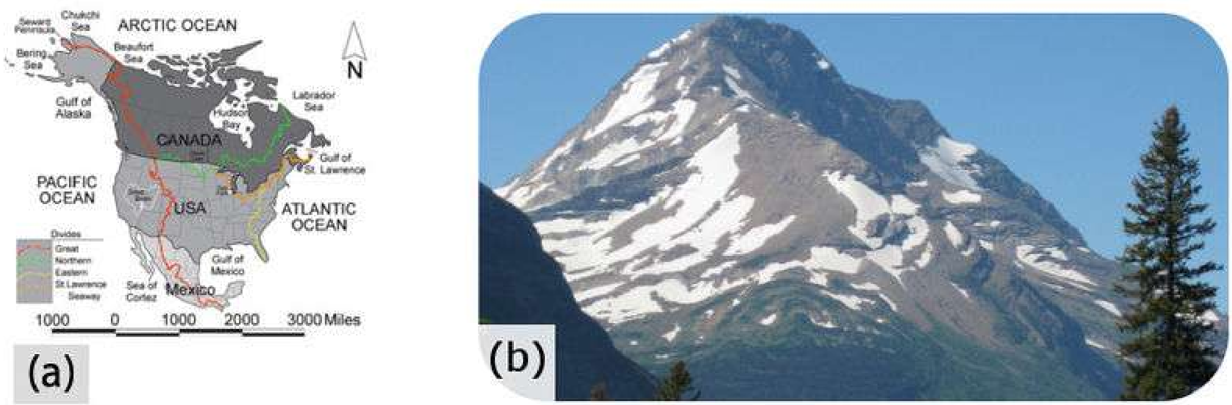


FIGURE 10.6

(a) The divides of North America. In the Rocky Mountains in Colorado, where does a raindrop falling on the western slope end up? How about on the eastern slope? (b) At Triple Divide Peak in Montana water may flow to the Pacific, the Atlantic, or Hudson Bay depending on where it falls. Can you locate where in the map of North America this peak sits?

Summary

- A moving body of water of any size is a stream.
- A tributary begins at its headwaters on one side of a divide, comes together with another tributary at a confluence, and empties out at an estuary.
- Base level is where a large body of water is located; sea level is the ultimate base level.

Explore More

Use the resources below to answer the questions that follow.

- **Streams and Rivers** at http://www.youtube.com/watch?v=TxI9gTvNY0M (3:45)

MEDIA
Click image to the left for use the URL below.
URL: http://www.ck12.org/flx/render/embeddedobject/1633

1. Does the geology shape the river's path or does the river's path shape the geology? Explain.
2. Where is water speed and weight the greatest? What happens there?
3. Where is the water speed the slowest? What happens there?
4. What shape is created by this fast moving water?

- **Minnesota River Sediment** at http://www.youtube.com/watch?v=FvZcDTFXguY (2:59)

MEDIA
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URL: http://www.ck12.org/flx/render/embeddedobject/4770

4. What has destabilized the Minnesota River area? What was the result of that?
5. Why are there waterfalls in some places and ravines in others?
6. Where does most of the sediment end up?
7. Why are some sources of sediment considered to be augmented by human activity?

Review

1. Very little land is below sea level and all of it does not drain to the sea. Why not?
2. What happens to two drops of water that fall on opposite sides of a divide?
3. What happens to a river's floodplain if the river is dammed?

References

1. Mike Cline. Confluence of the Yellowstone River and the Gardiner River. Public Domain
2. Courtesy of the US Army Corps of Engineers. The mouth of the Klamath River. Public Domain
3. Flickr:TheBoyFromFindlay. The headwaters of the Roaring Fork River. CC BY 2.0
4. Image copyright George Aldridge, 2014. The East River meanders through Crested Butte, Colorado. Used under license from Shutterstock.com
5. Courtesy of USDA/NRCS - National Cartography Geospatial Center. The Red Rock River floodplain. Public Domain
6. (a) Courtesy of National Atlas of the United States; (b) Thomas Kriese. Map of the continental divides of North America. (a) Public Domain; (b) CC BY 2.0

CONCEPT 11 Ponds and Lakes

- Describe the characteristics and zones of ponds and lakes.

Why is Lake Tahoe so large and clear?

Block faulting in the eastern Sierra Nevada Mountains created a basin that filled with water. This created beautiful Lake Tahoe, which straddles the California-Nevada border. The lake has been exceedingly clear though its history, although now development around the lake has resulted in some loss of clarity.

Ponds

Ponds are small bodies of fresh water that usually have no outlet; ponds are often are fed by underground springs. Like lakes, ponds are bordered by hills or low rises so the water is blocked from flowing directly downhill.

Lakes

Lakes are larger bodies of water. Lakes are usually fresh water, although the Great Salt Lake in Utah is just one exception. Water usually drains out of a lake through a river or a stream and all lakes lose water to evaporation.

Lakes form in a variety of different ways: in depressions carved by glaciers, in calderas (**Figure** 11.1), and along tectonic faults, to name a few. Subglacial lakes are even found below a frozen ice cap.

As a result of geologic history and the arrangement of land masses, most lakes are in the Northern Hemisphere. In fact, more than 60% of all the world's lakes are in Canada — most of these lakes were formed by the glaciers that covered most of Canada in the last Ice Age (**Figure** 11.2).

Lakes are not permanent features of a landscape. Some come and go with the seasons, as water levels rise and fall. Over a longer time, lakes disappear when they fill with sediments, if the springs or streams that fill them diminish, or if their outlets grow because of erosion. When the climate of an area changes, lakes can either expand or shrink (**Figure** 11.3). Lakes may disappear if precipitation significantly diminishes.

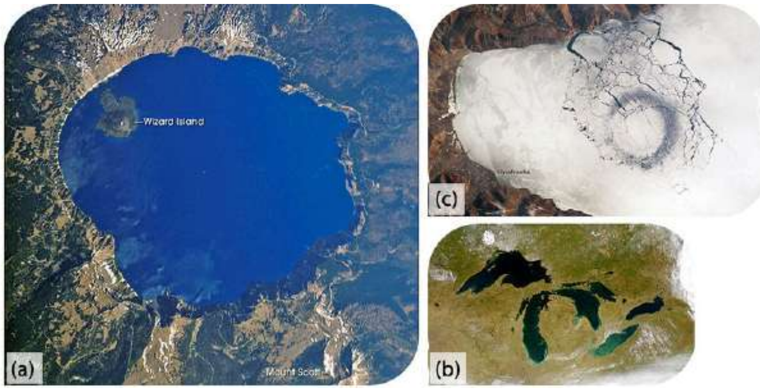


FIGURE 11.1

(a) Crater Lake in Oregon is in a volcanic caldera. Lakes can also form in volcanic craters and impact craters. (b) The Great Lakes fill depressions eroded as glaciers scraped rock out from the landscape. (c) Lake Baikal, ice coated in winter in this image, formed as water filled up a tectonic faults.

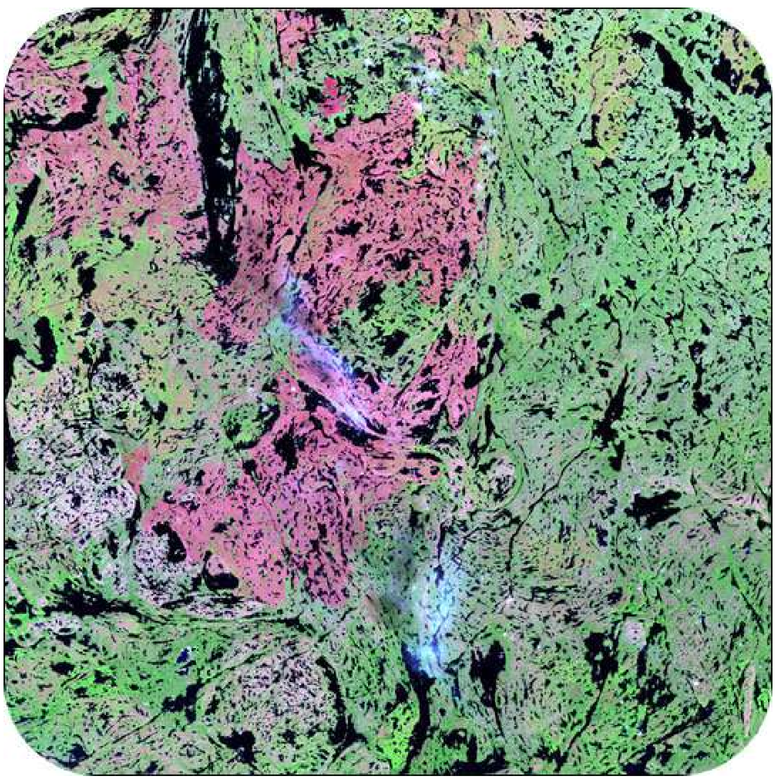


FIGURE 11.2

Lakes near Yellowknife were carved by glaciers during the last Ice Age.

Large lakes have tidal systems and currents, and can even affect weather patterns. The Great Lakes in the United States contain 22% of the world's fresh surface water (**Figure** 11.1). The largest them, Lake Superior, has a tide that rises and falls several centimeters each day. The Great Lakes are large enough to alter the weather system in Northeastern United States by the "lake effect," which is an increase in snow downwind of the relatively warm lakes. The Great Lakes are home to countless species of fish and wildlife.

Many lakes are not natural, but are human-made. People dam a stream in a suitable spot and then let the water back up behind it, creating a lake. These lakes are called "reservoirs."

Summary

- Ponds are small water bodies often fed by springs.

FIGURE 11.3
The Badwater Basin in Death Valley contains water in wet years. The lake basin is a remnant from when the region was much wetter just after the Ice Ages.

- A lake may form in many locations, including a volcanic crater, where a glacier has carved out a depression, or a fault zone.
- Lakes have surface, open-water, and deep-water zones.

Explore More

Use this resource to answer the questions that follow.

https://www.youtube.com/watch?v=X26ocQkhNH4

1. What are the names for the zones: nearshore; open water; deep water; bottom surface
2. Why does a large lake harbor a lot of life?
3. What is a typical temperate zone lake like in the summer? What is the temperature structure?
4. What is a typical temperate zone lake like in the autumn? What is the temperature structure?
5. What is a typical temperate zone lake like in the winter? What is the temperature structure?
6. What is different about a lake in a tropical region?
7. Why doesn't a lake live forever?

Review

1. What is the reason that Earth has many more lakes than is normal during Earth's history? What will happen as climate warms?
2. What are some of the ways lakes can form?
3. What is the difference between ponds and lakes? How are they similar?

References

1. (a) Courtesy of NASA's Earth Observatory; (b) Courtesy of SeaWiFS Project, NASA/Goddard Space Flight Center, and ORBIMAGE; (c) Courtesy of NASA's Earth Observatory. Pictures of Carter Lake, the Great Lakes, and Lake Baikal. (a) Public Domain; (b) Public Domain; (c) Public Domain

2. Courtesy of US Geological Survey. Satellite image of lakes near Yellowknife. Public Domain
3. Courtesy of Robert Simmon/NASA's Earth Observatory. Satellite image of the Badwater Basin in Death Valley. Public Domain

CONCEPT 12 Importance of the Oceans

• Describe the important roles of oceans as related to climate, the water cycle, and biodiversity.

Just what is down there?

Mostly the oceans are cold, dark and have extremely high pressure. Except at the very top, they are completely inhospitable to humans. Even this humpback whale can only dive to about 700 feet, so there's a lot about the ocean it doesn't know. Earth would not be the same planet without its oceans.

Oceans Moderate Climate

The oceans, along with the atmosphere, keep temperatures fairly constant worldwide. While some places on Earth get as cold as -70^{o}C and others as hot as 55^{o}C, the range is only 125^{o}C. On Mercury temperatures go from -180^{o}C to 430^{o}C, a range of 610^{o}C.

The oceans, along with the atmosphere, distribute heat around the planet. The oceans absorb heat near the Equator and then move that solar energy to more polar regions. The oceans also moderate climate within a region. At the same latitude, the temperature range is smaller in lands nearer the oceans than away from the oceans. Summer temperatures are not as hot, and winter temperatures are not as cold, because water takes a long time to heat up or cool down.

Water Cycle

The oceans are an essential part of Earth's water cycle. Since they cover so much of the planet, most evaporation comes from oceans and most precipitation falls on oceans.

Biologically Rich

The oceans are home to an enormous amount of life. That is, they have tremendous biodiversity (**Figure** 12.1). Tiny ocean plants, called phytoplankton, create the base of a food web that supports all sorts of life forms. Marine life makes up the majority of all biomass on Earth. (**Biomass** is the total mass of living organisms in a given area.) These organisms supply us with food and even the oxygen created by marine plants.

FIGURE 12.1
Polar bears are well adapted to frigid Arctic waters.

Summary

- Oceans moderate Earth's temperature by not changing temperature rapidly and by distributing heat around the planet.
- Oceans are an enormous reservoir for water in the water cycle.
- Oceans have tremendous biodiversity and the majority of all biomass on Earth.

Making Connections

MEDIA
Click image to the left for use the URL below.
URL: http://www.ck12.org/flx/render/embeddedobject/98794

Explore More

Use this resource to answer the questions that follow.

http://cmore.soest.hawaii.edu/oceanacidification/documents/PML_TechnicalSheet_high_CO2_world.pdf Use pages 1 2.

1. How much of Earth's surface do the ocean's cover? How much of global primary productivity comes from the oceans?
2. How do the oceans regulate the Earth system?
3. What are the ocean's living and non-living resources?
4. What social and economic goods and services does the ocean provide?
5. What do ocean currents transport as they travel around the globe?
6. What does carbon dioxide do in the oceans?
7. If a lot of the carbon dioxide that has been released in the past 150 years has entered the deep ocean, when might it cause temperatures to rise and why?
8. How are marine organisms used for food and biotechnology?
9. What other resources are found in the ocean?
10. How does the ocean provide defense from storms?

Review

1. What organisms form the base of the ocean food web?
2. How do the oceans moderate Earth's temperature?
3. What role do oceans play in the water cycle?

References

1. Erica Peterson. Polar bear swimming in the Arctic Ocean. CC BY 2.0

CONCEPT 13 Glaciers

- Describe the formation, movement, and characteristics of glaciers.

Can solid ice really move?

Yes! Ice that moves downslope is called a "glacier." Glaciers move extremely slowly along the land surface. They may survive for thousands of years.

Where are the Glaciers?

Nearly all glacial ice, 99%, is contained in ice sheets in the polar regions, particularly Antarctica and Greenland.

Glaciers often form in the mountains because higher altitudes are colder and more likely to have snow that falls and collects. Every continent, except Australia, hosts at least some glaciers in the high mountains.

Types of Glaciers

The types of glaciers are:

- **Continental glaciers** are large ice sheets that cover relatively flat ground. These glaciers flow outward from where the greatest amounts of snow and ice accumulate.
- **Alpine (valley) glaciers** flow downhill from where the snow and ice accumulates through mountains along existing valleys.
- **Ice caps** are large glaciers that cover a larger area than just a valley, possibly an entire mountain range or region. Glaciers come off of ice caps into valleys.

FIGURE 13.1
The Greenland ice cap covers the entire landmass.

Glacial Growth

Formation

Glaciers grow when more snow falls near the top of the glacier, in the **zone of accumulation**, than is melted from lower down in the glacier, in the **zone of ablation**. These two zones are separated by the equilibrium line.

Snow falls and over time converts to granular ice known as firn. Eventually, as more snow and ice collect, the firn becomes denser and converts to glacial ice.

Water is too warm for a glacier to form, so they form only on land. A glacier may run out from land into water, but it usually breaks up into icebergs that eventually melt into the water.

Movement

Whether an ice field moves or not depends on the amount of ice in the field, the steepness of the slope and the roughness of the ground surface. Ice moves where the pressure is so great that it undergoes plastic flow. Ice also slides at the bottom, often lubricated by water that has melted and travels between the ground and the ice.

The speed of a glacier ranges from extremely fast, where conditions are favorable, to nearly zero.

Because the ice is moving, glaciers have **crevasses**, where cracks form in the ice as a result of movement. The large crevasse at the top of an alpine glacier where ice that is moving is separated from ice that is stuck to the mountain above is called a **bergschrund**.

FIGURE 13.2
Crevasses in a glacier are the result of movement.

Shrinking

Glaciers are melting back in many locations around the world. When a glacier no longer moves, it is called an ice sheet. This usually happens when it is less than 0.1 km2 in area and 50 m thick.

Glacier National Park

Many of the glaciers in Glacier National Park have shrunk and are no longer active. Summer temperatures have risen rapidly in this part of the country and so the rate of melting has picked up. Whereas Glacier National Park had 150 glaciers in 1850, there are only about 25 today. Recent estimates are that the park will have no active glaciers as early as 2020.

FIGURE 13.3
This satellite image shows Grinnell Glacier, Swiftcurrent Glacier, and Gem Glacier in 2003 with an outline of the extent of the glaciers as they were in 1950. Although it continues to be classified as a glacier, Gem Glacier is only 0.020 km^2 (5 acres) in area, only one-fifth the size of the smallest active glaciers.

Glaciers as a Resource

In regions where summers are long and dry, melting glaciers in mountain regions provide an important source of water for organisms and often for nearby human populations.

Summary

- Glaciers are ice that moves because the amount of snow and ice that collects in the zone of accumulation exceeds the amount that melts off in the zone of ablation.
- Continental glaciers form in a central location with ice moving outward in all directions. Alpine glaciers form in high mountains and travel through valleys.
- Because glaciers move, they have characteristic features like crevasses and bergschrunds.

Explore More

Use the resource below to answer the questions that follow.

- **Yosemite Nature Notes: Glaciers** at http://youtu.be/mgnzSTY5zRg (8:35)

MEDIA
Click image to the left for use the URL below.
URL: http://www.ck12.org/flx/render/embeddedobject/1625

1. Where are glaciers found in Yosemite National Park?
2. What is the largest glacier in Yosemite National Park?
3. What is the environment on and around a glacier like?
4. What are the dangers on glaciers?
5. What is a crevasse? What creates it?
6. What is a glacier?
7. Describe the bergschrund.
8. What is the challenge with protecting glaciers in Yosemite National Park?

Review

1. Compare and contrast alpine glaciers, continental glaciers, and ice caps.
2. With a glacier that is melting back, what is happening in the zone of accumulation and the zone of ablation? What is happening to the equilibrium line?
3. How do glaciers serve as a water resource for people and organisms in the summertime?

References

1. Image copyright Robin Heal, 2014. Dog sled on the Greenland ice cap. Used under license from Shutterstock.com

2. Image copyright Zocchi Roberto, 2014. Crevasses in a glacier are the result of movement. Used under license from Shutterstock.com
3. Courtesy of Robert Simmon, NASA's Earth Observatory, using ALI data from the EO-1 team and Global Land Ice Measurements from Space. Satellite image of Glacier National Park, and its shrinking glaciers. Public Domain

Concept 14 Seawater Chemistry

- Describe the composition of seawater.
- Explain the relationship between the composition of seawater and its properties.

What is salt?

Besides making food taste better, salt is important for the human diet. Before refrigeration, salt was essential for curing and preserving food. Even in antiquity people built access roads they called "salt roads" so that they could obtain this essential mineral. What is salt? It's what you get when you evaporate seawater!

Composition of Ocean Water

Remember that H_2O is a polar molecule, so it can dissolve many substances (**Figure** 14.1). Salts, sugars, acids, bases, and organic molecules can all dissolve in water.

Salinity

Where does the salt in seawater come from? As water moves through rock and soil on land it picks up ions. This is the flip side of weathering. Salts comprise about 3.5% of the mass of ocean water, but the salt content, or **salinity**, is different in different locations.

What would the salinity be like in an estuary? Where seawater mixes with fresh water, salinity is lower than average.

What would the salinity be like where there is lots of evaporation? Where there is lots of evaporation but little circulation of water, salinity can be much higher. The Dead Sea has 30% salinity — nearly nine times the average salinity of ocean water (**Figure** 14.2). Why do you think this water body is called the Dead Sea?

In some areas, dense saltwater and less dense freshwater mix, and they form an immiscible layer, just like oil and water. One such place is a "cenote", or underground cave, very common in certain parts of Central America. Check out the video below:

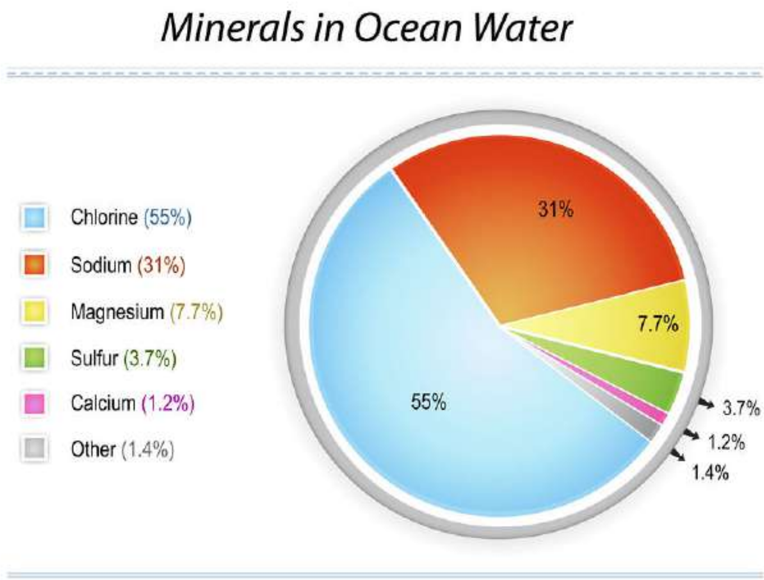
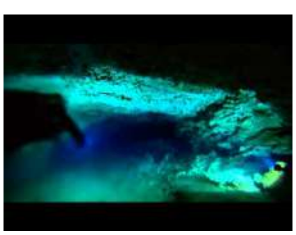


FIGURE 14.1
Ocean water is composed of many substances, many of them salts such as sodium, magnesium, and calcium chloride.

FIGURE 14.2
Because of the increased salinity, the water in the Dead Sea is very dense, it has such high salinity that people can easily float in it!

http://www.youtube.com/watch?v=dHn80f3lAUs



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URL: http://www.ck12.org/flx/render/embeddedobject/4775

Interactive ocean maps can show salinity, temperature, nutrients, and other characteristics: http://earthguide.ucsd.edu/earthguide/diagrams/levitus/index.html .

Density

With so many dissolved substances mixed in seawater, what is the **density** (mass per volume) of seawater relative to fresh water?

Water density increases as:

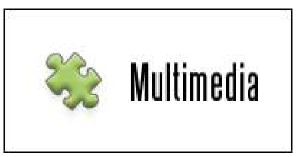
- salinity increases
- temperature decreases
- pressure increases

Differences in water density are responsible for deep ocean currents, as will be discussed in the "Deep Ocean Currents" concept.

Summary

- Water moving through rock and soil picks up ions that end up as salts in large water bodies.
- Ocean water contains salts, sugars, acids, bases, and organic molecules.
- Water density increases as salinity and pressure increase, or as temperature decreases.

Making Connections



MEDIA
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Explore More

Use the resource below to answer the questions that follow.

- **Ocean Chemistry** at http://www.youtube.com/watch?v=KUadxcKtH-g (4:58)

MEDIA
Click image to the left for use the URL below.
URL: http://www.ck12.org/flx/render/embeddedobject/4776

1. What happens to water as it cools?
2. What plays a crucial role in ocean movement?
3. What does algae require?
4. What do diatoms require?
5. Why is calcium important to organisms in the oceans?

6. Why is phosphate required?
7. How does carbon enter the oceans?
8. What is a dead zone?
9. Where is nitrogen fixed in the ocean?
10. Where does the iron in oceans come from?
11. Why are there plans to seed areas of the ocean with iron?

Review

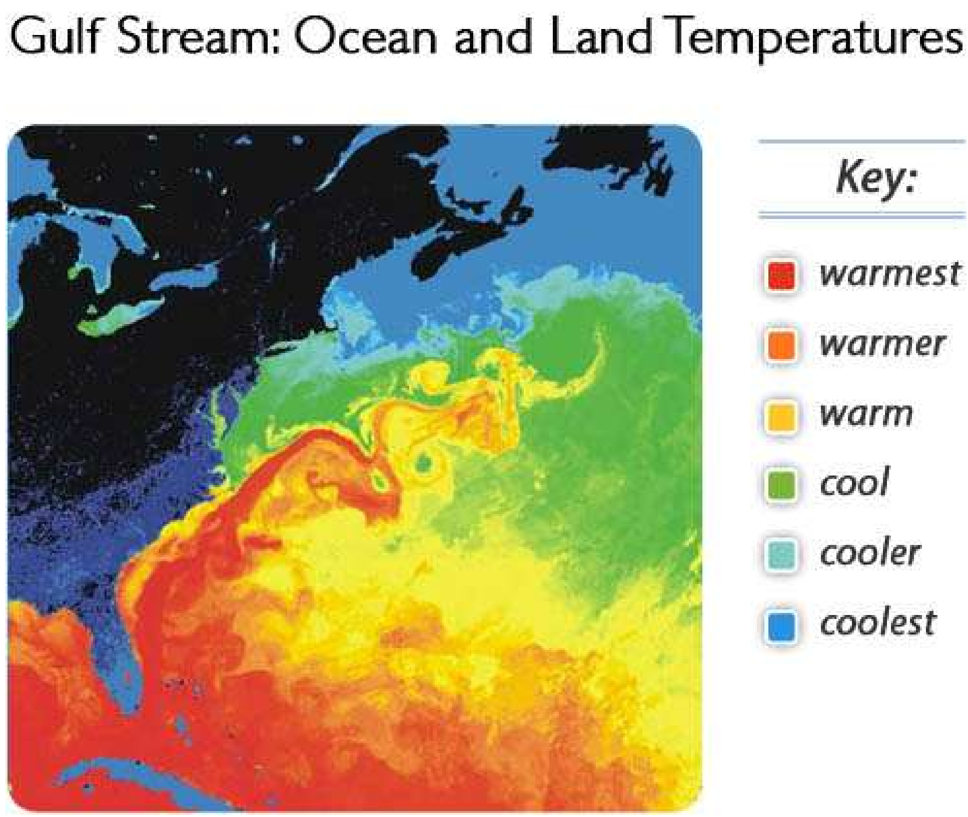
1. Streams aren't salty, so why is the ocean salty?
2. In a region of the ocean where evaporation is high, what happens to the density of the water and why? What does the water do?
3. What would need to happen for the all of the oceans to become more saline?

References

1. Eric Ong and Hana Zavadska. Graph of elements in seawater. CC BY-NC 3.0
2. Adam Baker. Man floating on the Dead Sea. CC BY 2.0

CONCEPT 15 How Ocean Currents Moderate Climate

- Explain how ocean currents like the Gulf Stream influence Earth's climate.



Why is northwestern Europe relatively warm?

The Gulf Stream waters do a lot for Europe. The equatorial warmth this current brings to the North Atlantic moderates temperatures in northern Europe. In a satellite image of water temperature in the western Atlantic it is easy to pick out the Gulf Stream, which brings warmer waters from the Equator up the coast of eastern North America.

Effect on Global Climate

Surface currents play an enormous role in Earth's climate. Even though the Equator and poles have very different climates, these regions would have more extremely different climates if ocean currents did not transfer heat from the equatorial regions to the higher latitudes.

The Gulf Stream is a river of warm water in the Atlantic Ocean, about 160 kilometers wide and about a kilometer deep. Water that enters the Gulf Stream is heated as it travels along the Equator. The warm water then flows up the east coast of North America and across the Atlantic Ocean to Europe (see opening image). The energy the Gulf Stream transfers is enormous: more than 100 times the world's energy demand.

The Gulf Stream's warm waters raise temperatures in the North Sea, which raises the air temperatures over land between 3 to 6°C (5 to 11°F). London, U.K., for example, is at about six degrees further south than Quebec, Canada.

However, London's average January temperature is 3.8°C (38°F), while Quebec's is only -12°C (10°F). Because air traveling over the warm water in the Gulf Stream picks up a lot of water, London gets a lot of rain. In contrast, Quebec is much drier and receives its precipitation as snow.

FIGURE 15.1
London, England in winter.

FIGURE 15.2
Quebec City, Quebec in winter.

Summary

- Water in the Gulf Stream travels along the Equator and is heated as it goes.
- The Gulf Stream brings warm water north along the Atlantic coast of the United States and then across the northern Atlantic to the British Isles.
- A tremendous amount of energy is transferred from the equatorial regions to the polar regions by ocean currents.

Explore More

Use this resource to answer the questions that follow.

https://www.youtube.com/watch?v=J7kIGdhW9jQ

1. What drives ocean and atmospheric circulation? What does the ocean store more of than the atmosphere?
2. What are surface ocean currents driven by? What are deeper ocean currents driven by?
3. What is the importance of upwelling nutrients in the ocean?
4. What causes El Nino and La Nina? What happens during these events?
5. How does heat exchange between ocean surface and atmosphere influence climate?
6. How do hurricanes form in the oceans? Where does the heat come from to power them?
7. What kind of life would be on Earth if there were no oceans?

Review

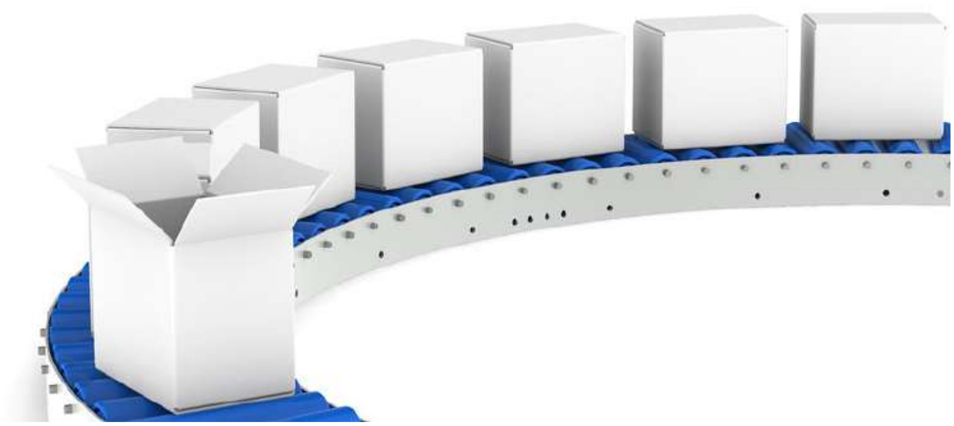
1. Explain why England is relatively mild and rainy in winter but central Canada, at the same latitude and during the same season, is dry and frigid.
2. Where else do you think ocean currents might moderate global climate?
3. What would Earth be like if ocean water did not move?

References

1. Mikey. London during the winter. CC BY 2.0
2. Flickr:abdallahh. Quebec during the winter. CC BY 2.0

CONCEPT 16 Deep Ocean Currents

- Describe the processes that drive deep ocean currents.



How are ocean currents like a conveyor belt?

Seawater doesn't just circulate around the surface, it moves through the deep sea. Just like at the surface, normal circulation patterns transport much of the water. Seawater is moved as if on a conveyor through the surface and deep ocean, a trip that takes hundreds of years.

Deep Currents

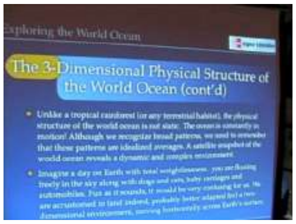
Thermohaline circulation drives deep ocean circulation. Thermo means heat and haline refers to salinity. Differences in temperature and in salinity change the density of seawater. So thermohaline circulation is the result of density differences in water masses because of their different temperature and salinity.

What is the temperature and salinity of very dense water? Lower temperature and higher salinity yield the densest water. When a volume of water is cooled, the molecules move less vigorously, so same number of molecules takes up less space and the water is denser. If salt is added to a volume of water, there are more molecules in the same volume, so the water is denser.

Downwelling

Changes in temperature and salinity of seawater take place at the surface. Water becomes dense near the poles. Cold polar air cools the water and lowers its temperature, increasing its salinity. Fresh water freezes out of seawater to become sea ice, which also increases the salinity of the remaining water. This very cold, very saline water is very dense and sinks. This sinking is called **downwelling**.

This video lecture discusses the vertical distribution of life in the oceans. Seawater density creates currents, which provide different habitats for different creatures: http://www.youtube.com/watch?v=LA1jxeXDsdA (6:12).



MEDIA

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Two things then happen. The dense water pushes deeper water out of its way and that water moves along the bottom of the ocean. This deep water mixes with less dense water as it flows. Surface currents move water into the space vacated at the surface where the dense water sank (**Figure** 16.1). Water also sinks into the deep ocean off of Antarctica.

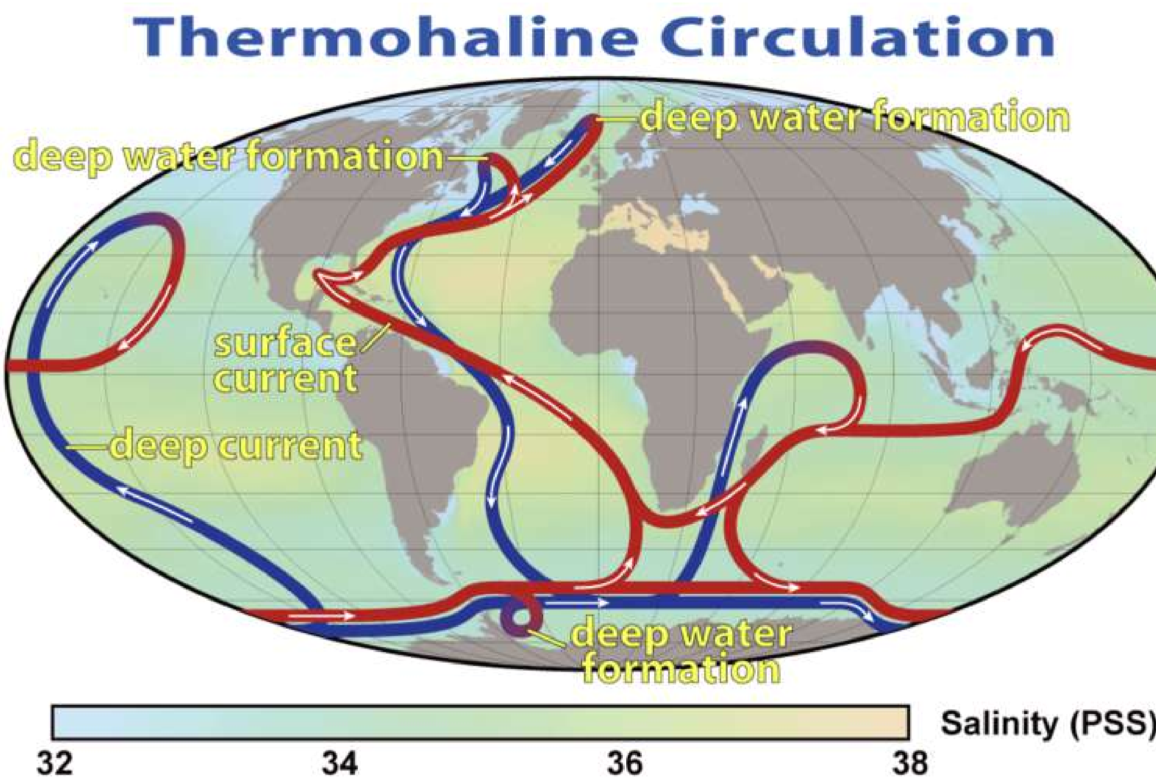

FIGURE 16.1

Cold water (blue lines) sinks in the North Atlantic, flows along the bottom of the ocean and upwells in the Pacific or Indian. The water then travels in surface currents (red lines) back to the North Atlantic. Deep water also forms off of Antarctica.

Upwelling

Since unlimited amounts of water cannot sink to the bottom of the ocean, water must rise from the deep ocean to the surface somewhere. This process is called **upwelling** (**Figure** 16.2).

Generally, upwelling occurs along the coast when wind blows water strongly away from the shore. This leaves a void that is filled by deep water that rises to the surface.

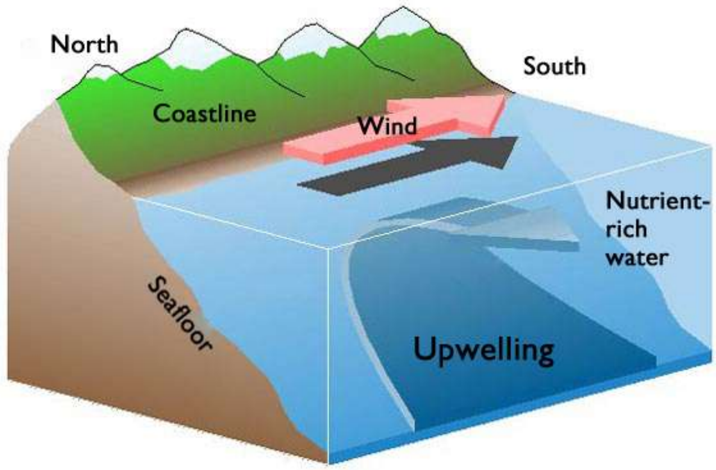

FIGURE 16.2
Upwelling forces denser water from below to take the place of less dense water at the surface that is pushed away by the wind.

Upwelling is extremely important where it occurs. During its time on the bottom, the cold deep water has collected nutrients that have fallen down through the water column. Upwelling brings those nutrients to the surface. Those nutrients support the growth of plankton and form the base of a rich ecosystem. California, South America, South Africa, and the Arabian Sea all benefit from offshore upwelling.

An animation of upwelling is seen here: http://oceanservice.noaa.gov/education/kits/currents/03coastal4.html .

Upwelling also takes place along the Equator between the North and South Equatorial Currents. Winds blow the surface water north and south of the Equator, so deep water undergoes upwelling. The nutrients rise to the surface and support a great deal of life in the equatorial oceans.

Summary

- Cooling or evaporation of fresh water from the sea surface makes surface water dense and causes it to sink.
- Downwelling of cold, dense water drives thermohaline circulation.
- Upwelling takes place at some coastlines or along the Equator and brings cool, nutrient-rich water to the surface.

Making Connections

MEDIA
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URL: http://www.ck12.org/flx/render/embeddedobject/65181

Explore More

Use this resource to answer the questions that follow.

https://www.youtube.com/watch?v=SnKoo3WhJu0 Watch to 6:45

1. When ice forms from seawater what is the composition of the ice? How does that change the composition of seawater nearby?
2. What are the characteristics of the seawater that is left behind? What happens to it as a result of these characteristics?
3. What do the Antarctic Bottom Water and the North Atlantic Deep Water contain and why? Why does cold water trap more gas?
4. Why are the cold polar regions so rich in life?

Review

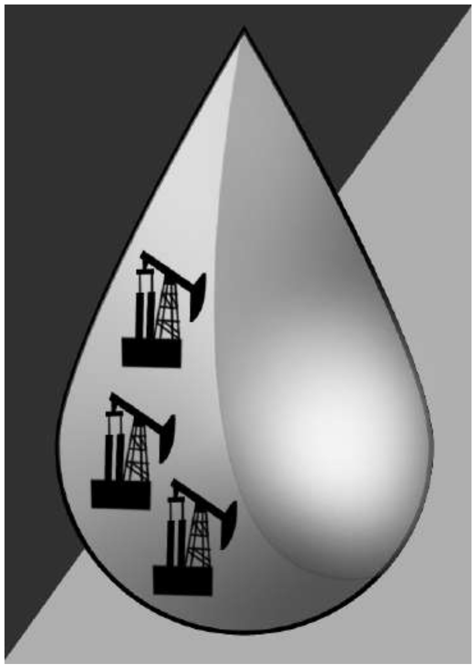
1. Why is upwelling important?
2. How does downwelling drive thermohaline circulation?
3. What would happen if water in the north Pacific no longer became cold and dense enough to sink?

References

1. Courtesy of Robert Simmon, NASA, and minor modifications made by Robert A. Rohde. Map of Thermohaline Circulation. Public Domain
2. Courtesy of Sanctuary Quest 2002, NOAA/OER. Diagram of upwelling. Public Domain

CONCEPT 17 Renewable and Nonrenewable Resources

- Define natural resource.
- Give examples of natural resources.
- Distinguish between renewable and nonrenewable resources.



Renewable or nonrenewable, what's the difference?

That's like asking the difference between having an endless supply and having a limited supply. Will this planet eventually run out of oil? Probably. So oil is a nonrenewable resource.

Renewable and Nonrenewable Resources

A **natural resource** is something supplied by nature that helps support life. When you think of natural resources, you may think of minerals and fossil fuels. However, ecosystems and the services they provide are also natural resources. **Biodiversity** is a natural resource as well.

Renewable Resources

Renewable resources can be replenished by natural processes as quickly as humans use them. Examples include sunlight and wind. They are in no danger of being used up (see **Figure** 17.1). Metals and other minerals are renewable too. They are not destroyed when they are used and can be recycled.

Living things are considered to be renewable. This is because they can reproduce to replace themselves. However, they can be over-used or misused to the point of extinction. To be truly renewable, they must be used sustainably. **Sustainable use** is the use of resources in a way that meets the needs of the present and also preserves the resources for future generations.

FIGURE 17.1
Wind is a renewable resource. Wind turbines like this one harness just a tiny fraction of wind energy.

Nonrenewable Resources

Nonrenewable resources are natural resources that exist in fixed amounts and can be used up. Examples include fossil fuels such as petroleum, coal, and natural gas. These fuels formed from the remains of plants over hundreds of millions of years. We are using them up far faster than they could ever be replaced. At current rates of use, petroleum will be used up in just a few decades and coal in less than 300 years. Nuclear power is also considered to be a nonrenewable resource because it uses up uranium, which will sooner or later run out. It also produces harmful wastes that are difficult to dispose of safely.

Summary

- Renewable resources can be replaced by natural processes as quickly as humans use them. Examples include sunlight and wind.
- Nonrenewable resources exist in fixed amounts. They can be used up. Examples include fossil fuels such as coal.

Explore More

Use this resource to answer the questions that follow.

- http://www.hippocampus.org/Biology → Non-Majors Biology → Search: **Human Impacts on Biogeochemical Cycles**

1. What was the energy source for much of the Industrial Revolution? How were these fuels made?
2. Why are carbon dioxide levels rising in the atmosphere?

Review

1. Define natural resource. Give an example.
2. Distinguish between renewable and nonrenewable resources and give examples.
3. Infer factors that determine whether a natural resource is renewable or nonrenewable.

FIGURE 17.2
Gasoline is made from crude oil. The crude oil pumped out of the ground is a black liquid called petroleum, which is a nonrenewable resource.

FIGURE 17.3
Coal is another nonrenewable resource.

References

1. Patrick Finnegan. Wind turbines use a renewable resource. CC BY 2.0
2. Flickr:Images_of_Money. Fueling a car using gas. CC BY 2.0
3. Richard Lewis. Lumps of coal. CC BY 2.0

Concept 18 Nonrenewable Resources

- Describe and give examples of nonrenewable resources.
- Explain why nuclear power is a nonrenewable resource.

Could we all run out of gasoline?

Yes, we will use up all our gasoline eventually. Gasoline is derived from oil. Oil deposits were formed over hundreds of millions of years. They cannot be quickly replenished. Oil is an example of a nonrenewable resource.

Nonrenewable Resources

A **nonrenewable resource** is a natural resource that is consumed or used up faster than it can be made by nature. Two main types of nonrenewable resources are fossil fuels and nuclear power. **Fossil fuels**, such as petroleum, coal, and natural gas, formed from plant and animal remains over periods from 50 to 350 million years ago. They took millions of years to form. Humans have been consuming fossil fuels for less than 200 years, yet remaining reserves of oil can supply our needs only until around the year 2055. Natural gas can only supply us until around 2085. Coal will last longer, until around the year 2250. That is why it is so important to develop alternate forms of energy, especially for our cars. Today, electric cars are becoming more and more common. What would happen if we ran out of gasoline? Alternative use of energy, especially in transportation, must become a standard feature of all cars and trucks and planes by the middle of the century.

Nuclear power is the use of nuclear energy (**nuclear fission**) to create energy inside of a nuclear reactor (**Figure** 18.1). Nuclear power is developed from atoms in certain elements, such as uranium. Currently, there are limited uranium fuel supplies, which will last to about the year 2100 (or longer) at current rates of use. However, new technologies could make some uranium fuel reserves more useful.

Population growth, especially in developing countries, should make people think about how fast they are consuming resources. Governments around the world should seriously consider these issues. Developing nations will also

FIGURE 18.1

Aerial photo of the Bruce Nuclear Generating Station near Kincardine, Ontario.

increase demands on natural resources as they build more factories (**Figure** 18.2). Improvements in technology, conservation of resources, and controls in population growth could all help to decrease the demand on natural resources.

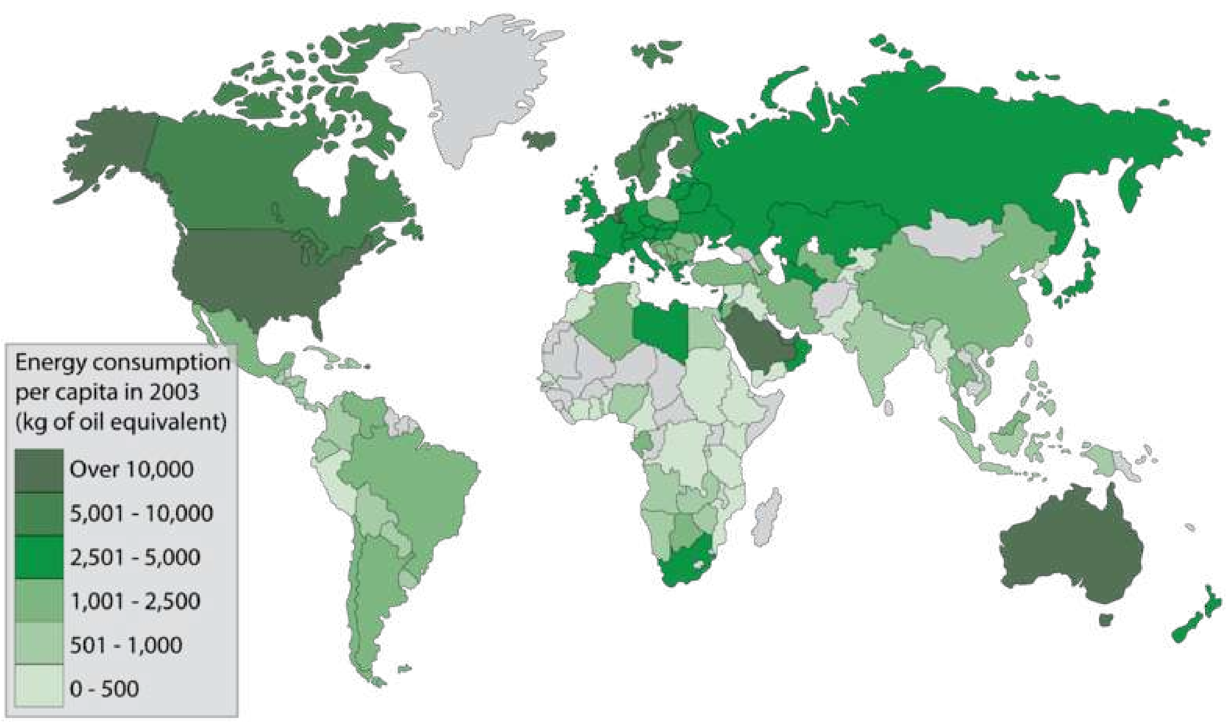


FIGURE 18.2

Per capita energy consumption (2003) shows the unequal distribution of wealth, technology, and energy use.

Vocabulary

- **fossil fuels**: Remains of long-dead organisms that now serve as an energy source, such as oil, coal, or natural gas.
- **nonrenewable resource**: Natural resource that is used up faster than it can be made by nature.
- **nuclear fission**: Nuclear reaction or a radioactive decay process in which the nucleus of an atom splits into smaller parts, often producing free neutrons and photons in the form of gamma rays, and releasing a very large amount of energy.
- **nuclear power**: Electricity generated through the use nuclear energy (fission) inside a nuclear reactor.

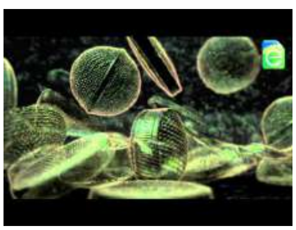
Summary

- Nonrenewable resources are being used up faster than they can be made by nature.
- Nonrenewable resources include fossil fuels and nuclear power.

Explore More

Use the resource below to answer the questions that follow.

- **Formation of Fossil Fuels** at http://www.youtube.com/watch?v=_8VqWKZIPrM (2:26)



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1. How does the formation of coal differ from the formation of oil? How these are processes the same?
2. Why are researchers looking for ways to speed up the production of fuel from plant matter?
3. Where does natural gas come from?
4. When you burn fossils fuels, they release $C0_2$ into the atmosphere. Based on how long it takes fossil fuels to form, when was the last time that the carbon molecule in the $C0_2$ was in the atmosphere? How does this situation differ from someone cutting down a ten-year-old tree and burning it in his/her fireplace? What are the consequences for the atmosphere.

Review

1. What is a nonrenewable resource? What are two main types?
2. When did fossil fuels form?
3. Why nuclear power considered a nonrenewable resource?

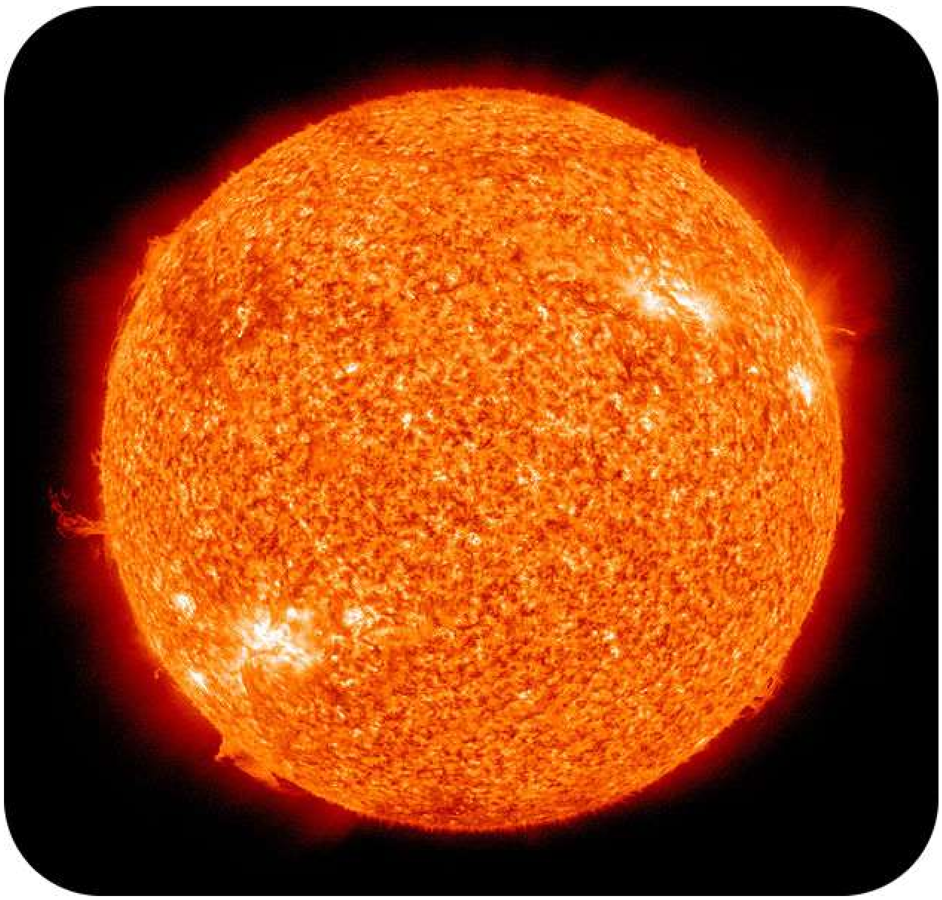
References

1. Chuck Szmurlo (Wikimedia: Cszmurlo). Nuclear power is generated using a nonrenewable resource. CC BY 2.5

2. Zachary Wilson. The amount of energy consumed by each country varies greatly around the world. CC BY-NC 3.0 (map in public domain)

CONCEPT 19 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.



What is the source of nearly all of Earth's energy?

The source of nearly all energy on Earth is our star, the Sun. Solar energy feeds almost all life on Earth, is trapped in fossil fuels, and is the reason wind blows and water flows. Earth's other big source of energy is the planet's internal heat.

Types of Energy Resources

Energy resources are either renewable or non-renewable. **Non-renewable resources** are used faster than they can be replaced, so the supply available to society is limited. **Renewable resources** will not run out because they are replaced as quickly as they are used (see example in **Figure** 19.1). Can you think of some renewable and non-renewable energy sources?

FIGURE 19.1
An old windmill in the Netherlands.

Non-Renewable Resources

Fossil fuels — coal, oil, and natural gas — are the most common example of non-renewable energy resources. Fossil fuels are formed from fossils, the partially decomposed remains of once living plants and animals. These fossils took millions of years to form. When fossil fuels are burned for energy, they release pollutants into the atmosphere. Fossil fuels also release carbon dioxide and other greenhouse gases, which are causing global temperatures to rise.

Renewable Resources

Renewable energy resources include solar, water, wind, biomass, and geothermal. These resources are either virtually limitless like the Sun, which will continue to shine for billions of years, or will be replaced faster than we can use them. Amounts of falling water or wind will change over the course of time, but they are quite abundant. Biomass energy, like wood for fire, can be replaced quickly.

The use of renewable resources may also cause problems. Some are expensive, while some, such as trees, have other uses. Some cause environmental problems. As the technology improves and more people use renewable energy, the prices may come down. At the same time, as we use up fossil fuels such as coal, oil, and natural gas, these non-renewable resources will become more expensive. At some point, even if renewable energy costs are high, non-renewable energy will be even more expensive. Ultimately, we will have to use renewable sources.

Important Things to Consider about Energy Resources

With both renewable and non-renewable resources, there are at least two important things to consider. One is that we have to have a practical way to turn the resource into a useful form of energy. The other is that we have to consider what happens when we turn the resource into energy.

For example, if we get much less energy from burning a fuel than we put into making it, then that fuel is probably not a practical energy resource. On the other hand, if another fuel gives us large amounts of energy but creates large amounts of pollution, that fuel also may not be the best choice for an energy resource.

Electrical Grids

No matter what the source, once it is generated electricity has go move from place to place. It does so by an electrical grid. Many communities have electrical grids that were built decades ago. These grids are inefficient and have high failure rates.

The electrical grids of the future are likely to be **smart grids**. Smart grids start with electricity production from one or more power generation sources. The electricity is streamed through multiple networks out to millions of consumers. Smart meters are placed with the consumers. They supply information on the state of the electrical system. Operators know within minutes if the power goes out, rather than having to wait for phone calls from consumers. Smart meters measure consumption and assist consumers in using power when it is more economical, even turning on or off appliances in homes or workplaces to smooth demand. Smart grids are essential for integrating renewable energy sources, such as solar and wind, into the network because they have highs and lows in their supply.

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.

Find out more at http://www.kqed.org/quest/television/climate-watch-unlocking-the-grid .

MEDIA

Click image to the left for use the URL below.

URL: http://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.
- A resource may take so much energy to harness that it doesn't provide much net energy.

Making Connections

MEDIA

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Practice

Use this resource to answer the questions that follow.

https://www.youtube.com/watch?v=q5JEiqy6WLs

1. What is renewable energy?
2. Which energy resources are renewable and why?
3. Which energy resources are non-renewable and why?

Review

1. What does it mean that a form of energy might take more energy to harness than it provides?
2. Are renewable resources always renewable, or can they become non-renewable?
3. Why aren't renewable resources used for everything that we use energy for?

References

1. Hans Pama. An old windmill in the Netherlands. CC BY 2.0

CONCEPT 20 Wind Power

- Explain how wind energy is harnessed and used, and describe its consequences.

What does "NIMBY" stand for?

Not in my backyard. As much as any type of power source, wind power pits people who are concerned about the environment against, well, people who are concerned about the environment. Some people want the benefits of clean wind power but don't want the turbines in their vicinity.

Wind Energy

Energy from the Sun also creates wind, which can be used as wind power. The Sun heats different locations on Earth by different amounts. Air that becomes warm rises and then sucks cooler air into that spot. The movement of air from one spot to another along the ground creates wind. Since wind is moving, it has kinetic energy.

Wind power is the fastest growing renewable energy source in the world. Windmills are now seen in many locations, either individually or, more commonly, in large fields.

"Wind Powering America" follows the development of wind power in the United States over the past several years: http://www.windpoweringamerica.gov/wind_installed_capacity.asp .

Wind Power Use

Wind is the source of energy for wind power. Wind has been used for power for centuries. For example, windmills were used to grind grain and pump water. Sailing ships traveled by wind power long before ships were powered by fossil fuels. Wind can be used to generate electricity, as the moving air spins a turbine to create electricity (**Figure** 20.1).

FIGURE 20.1
Wind turbines like the ones shown here turn wind into electricity without creating pollution.

This animation shows how wind power works: http://www.energysavers.gov/your_home/electricity/index.cfm/mytopic=10501 .

Consequences of Wind Power

Wind power has many advantages. It does not burn, so it does not release pollution or carbon dioxide. Also, wind is plentiful in many places. Wind, however, does not blow all of the time, even though power is needed all of the time. Just as with solar power, engineers are working on technologies that can store wind power for later use.

Windmills are expensive and wear out quickly. A lot of windmills are needed to power a region, so nearby residents may complain about the loss of a nice view if a wind farm is built. Coastlines typically receive a lot of wind, but wind farms built near beaches may cause unhappiness for local residents and tourists.

The Cape Wind project off of Cape Cod, Massachusetts has been approved but is generating much controversy. Opponents are in favor of green power but not at that location. Proponents say that clean energy is needed and the project would supply 75% of the electricity needed for Cape Cod and nearby islands (**Figure** 20.2).

California was an early adopter of wind power. Windmills are found in mountain passes, where the cooler Pacific Ocean air is sucked through on its way to warmer inland valleys. Large fields of windmills can be seen at Altamont Pass in the eastern San Francisco Bay Area, San Gorgonio Pass east of Los Angeles, and Tehachapi Pass at the southern end of the San Joaquin Valley.

Summary

- Wind contains energy, which can move a turbine and generate electricity.
- Wind power is clean and does not release greenhouse gases, but some people complain about the spread of windmills across certain locations.
- Wind has been used as a local energy source for centuries and is now being scaled up for use regionally.

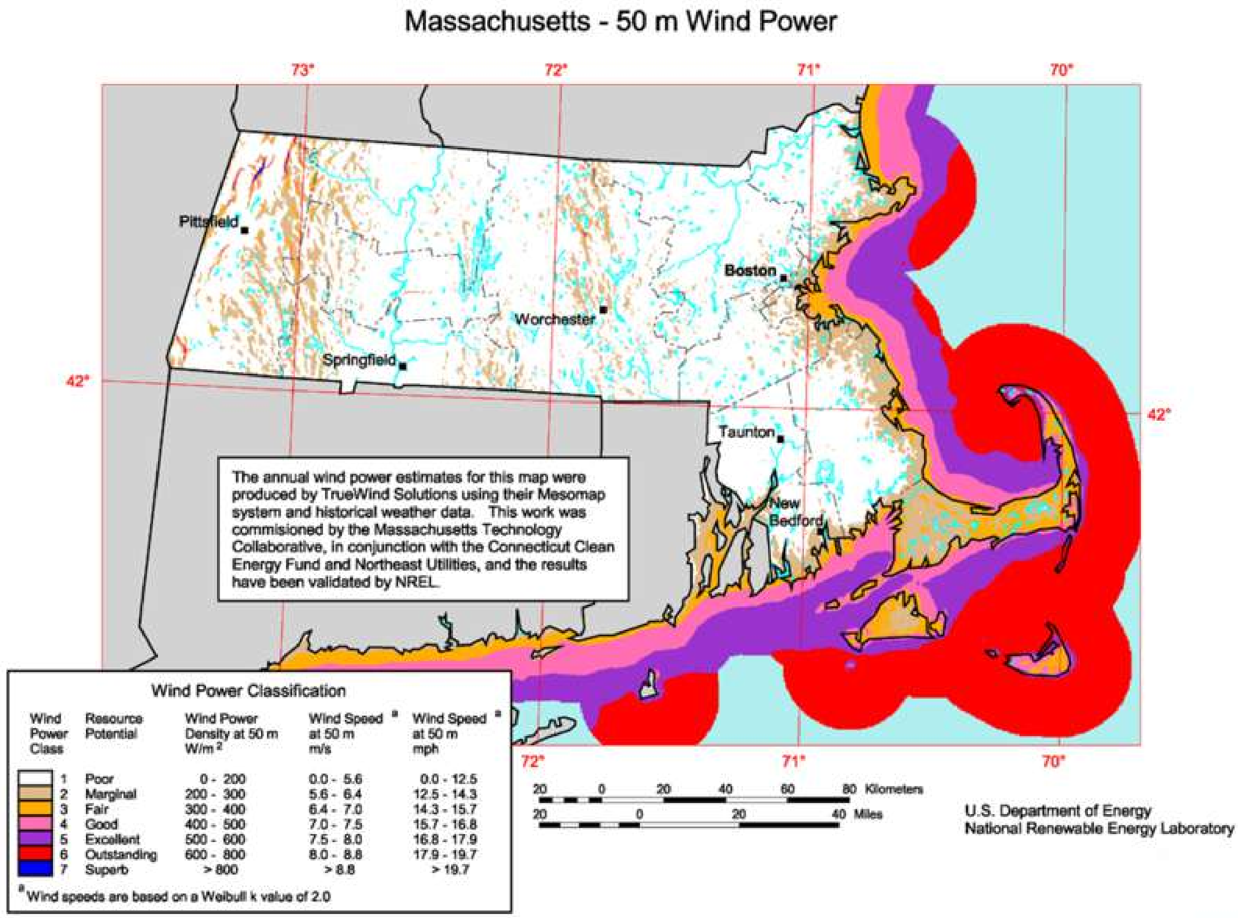

FIGURE 20.2

Cape Wind off of Cape Cod in Massachusetts receives a great deal of wind (red color) but is also popular with tourists for its beauty.

Practice

Use this resource to answer the questions that follow.

https://www.youtube.com/watch?v=EYYHfMCw-FI

1. Think about what you know about local winds. Why would a desert near tall mountains be a good place for wind turbines?
2. How does a wind turbine capture energy?
3. Why are turbines high in the sky?
4. Are all wind farms on land?

Review

1. Describe what causes wind and how wind energy can be harnessed.

2. What are some of the downsides of using wind power?
3. Why do you think that wind is the fastest growing non-renewable energy source?

References

1. Andre Engels. Wind turbines provide electricity. CC BY 2.0
2. Courtesy of National Renewable Energy Laboratory/US Department of Energy. Cape Wind off of Cape Cod in Massachusetts. Public Domain

CONCEPT 21 Wind Waves

- Describe the characteristics of ocean waves.
- Explain how wind forms ocean waves.

If ocean waves are caused by wind, how can there be strong waves on calm days?

Waves form where there are winds. Energy from the wind is transferred to the water and then that is transferred to nearby water molecules. The wave moves as a transfer of energy across the sea. Once the wave starts, it doesn't need more wind to keep it going.

Ocean Waves

Waves have been discussed in previous concepts in several contexts: seismic waves traveling through the planet, sound waves traveling through seawater, and ocean waves eroding beaches. Waves transfer energy, and the size of a wave and the distance it travels depends on the amount of energy that it carries. This concept studies the most familiar waves, those on the ocean's surface.

Building Big Waves

Ocean waves originate from wind blowing – steady winds or high storm winds – over the water. Sometimes these winds are far from where the ocean waves are seen. What factors create the largest ocean waves?

The largest wind waves form when the wind

- is very strong
- blows steadily for a long time
- blows over a long distance

The wind could be strong, but if it gusts for just a short time, large waves won't form.

Wind blowing across the water transfers energy to that water. The energy first creates tiny ripples, which make an uneven surface for the wind to catch so that it may create larger waves. These waves travel across the ocean out of the area where the wind is blowing.

Remember that a wave is a transfer of energy. Do you think the same molecules of water that start out in a wave in the middle of the ocean later arrive at the shore? The molecules are not the same, but the energy is transferred across the ocean.

Shape of a Wave

Water molecules in waves make circles or ellipses (**Figure** 21.1). Energy transfers between molecules, but the molecules themselves mostly bob up and down in place.

In this animation, a water bottle bobs in place like a water molecule: http://www.onr.navy.mil/Focus/ocean/motion/waves1.htm .

An animation of motion in wind waves from the Scripps Institution of Oceanography: http://earthguide.ucsd.edu/earthguide/diagrams/waves/swf/wave_wind.html .

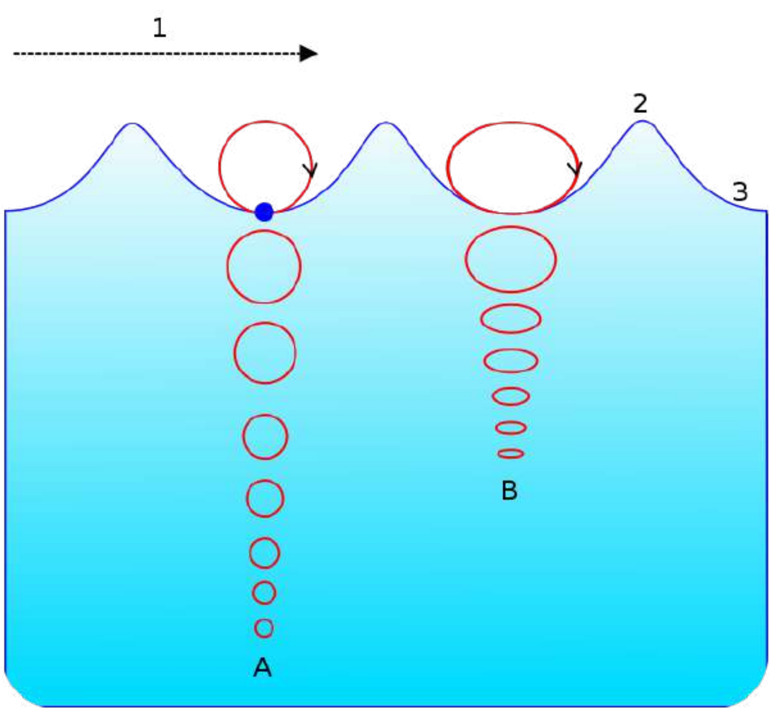

FIGURE 21.1
The circles show the motion of a water molecule in a wind wave. Wave energy is greatest at the surface and decreases with depth. "A" shows that a water molecule travels in a circular motion in deep water. "B" shows that molecules in shallow water travel in an elliptical path because of the ocean bottom.

An animation of a deep water wave is seen here: http://en.wikipedia.org/wiki/File:Deep_water_wave.gif .

An animation of a shallow water wave is seen here: http://commons.wikimedia.org/wiki/File:Shallow_water_wave.gif .

Waves Break

When does a wave break? Do waves only break when they reach shore? Waves break when they become too tall to be supported by their base. This can happen at sea but happens predictably as a wave moves up a shore. The energy at the bottom of the wave is lost by friction with the ground, so that the bottom of the wave slows down but the top of the wave continues at the same speed. The crest falls over and crashes down.

Storm Surge

Some of the damage done by storms is from **storm surge**. Water piles up at a shoreline as storm winds push waves into the coast. Storm surge may raise sea level as much as 7.5 m (25 ft), which can be devastating in a shallow land area when winds, waves, and rain are intense.

A wild video of "Storm Surge" can be seen on National Geographic Videos, Environment Video, Natural Disasters, Landslides, and more: http://video.nationalgeographic.com/video/player/environment/ .

Maverick waves are massive. Learning how they are generated can tell scientists a great deal about how the ocean creates waves and especially large waves.

Learn more by watching this video at http://www.kqed.org/quest/television/science-of-big-waves.

MEDIA

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URL: http://www.ck12.org/flx/render/embeddedobject/116517

Summary

- The largest wind waves are built when a strong wind blows for a long time over a large area.
- When a wave breaks onshore it is not the water but the energy that has traveled from where the wave formed.
- A wave breaks when it is too tall to be supported by its base, which is common as a wave moves up the shore.

Explore More

Use these resources to answer the questions that follow.

http://channel.nationalgeographic.com/channel/videos/development-of-ocean-waves/

1. What does an ocean wave transport?
2. Where does a wave begin? What condition is necessary?
3. What happens first and why is this necessary?
4. What happens after more wind energy is added?
5. What travels in a wave? What evidence is there that this is what's happening?
6. What happens when the wave arrives at the shore?
7. Where is the energy released? What can this energy do?

Review

1. What causes a wave to break? Does this only happen along a shore?
2. When a hurricane reaches land, the damage done to coastal development often depends on how high the tide is. Why would this make a difference?
3. Describe how a wave that forms in the central Pacific travels to and breaks at the beach in San Diego, California.

References

1. User:Vargklo/Wikipedia. Diagram of how an ocean wave travels. Public Domain

CONCEPT 22 Solar Power

- Explain how solar energy is collected and used.

Since so much of the energy we use came ultimately from the Sun, why don't we just get our power directly from the Sun?

That's a good question. Can you answer it?

Solar Energy

Energy from the Sun comes from the lightest element, hydrogen, fusing together to create the second lightest element, helium. Nuclear fusion on the Sun releases tremendous amounts of solar energy. The energy travels to the Earth, mostly as visible light. The light carries the energy through the empty space between the Sun and the Earth as **radiation**.

Solar Power Use

Solar energy has been used for power on a small scale for hundreds of years, and plants have used it for billions of years. Unlike energy from fossil fuels, which almost always come from a central power plant or refinery, solar power can be harnessed locally (**Figure** 22.1). A set of solar panels on a home's rooftop can be used to heat water for a swimming pool or can provide electricity to the house.

Society's use of solar power on a larger scale is just starting to increase. Scientists and engineers have very active, ongoing research into new ways to harness energy from the Sun more efficiently. Because of the tremendous amount of incoming sunlight, solar power is being developed in the United States in southeastern California, Nevada, and Arizona.

Solar power plants turn sunlight into electricity using a large group of mirrors to focus sunlight on one place, called a receiver (**Figure** 22.2). A liquid, such as oil or water, flows through this receiver and is heated to a high temperature

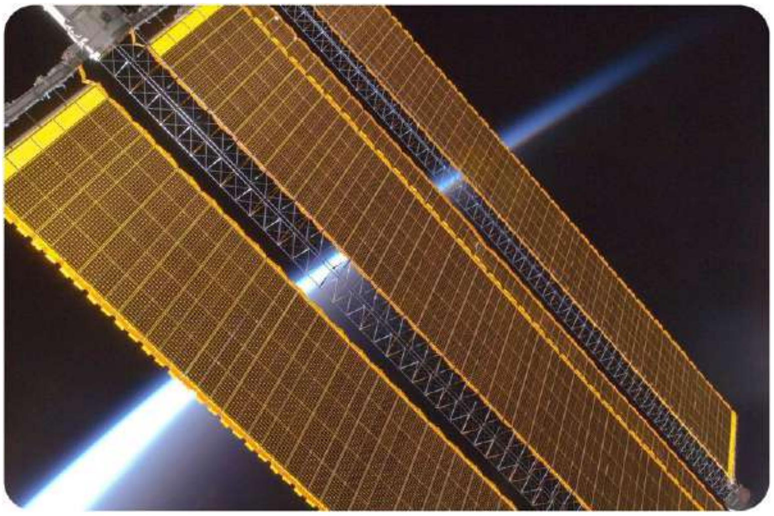


FIGURE 22.1
Solar panels supply power to the International Space Station.

by the focused sunlight. The heated liquid transfers its heat to a nearby object that is at a lower temperature through a process called **conduction**. The energy conducted by the heated liquid is used to make electricity.

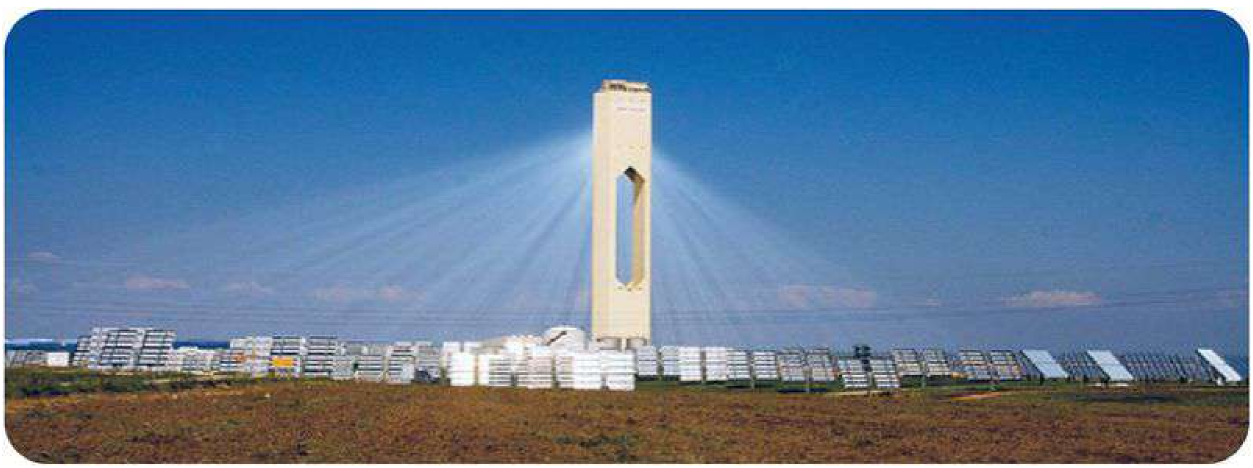


FIGURE 22.2
This solar power plant uses mirrors to focus sunlight on the tower in the center. The sunlight heats a liquid inside the tower to a very high temperature, producing energy to make electricity.

A video of how solar energy can be concentrated so that it can be used for power: http://www1.eere.energy.gov/multimedia/video_csp.html .

Consequences of Solar Power Use

Solar energy has many benefits. It is extremely abundant, widespread, and will never run out. But there are problems with the widespread use of solar power.

- Sunlight must be present. Solar power is not useful in locations that are often cloudy or dark. However, storage technology is being developed.
- The technology needed for solar power is still expensive. An increase in interested customers will provide incentive for companies to research and develop new technologies and to figure out how to mass-produce existing technologies (**Figure** 22.3).
- Solar panels require a lot of space. Fortunately, solar panels can be placed on any rooftop to supply at least some of the power required for a home or business.

FIGURE 22.3
This experimental car is one example of the many uses that engineers have found for solar energy.

Summary

- Solar energy is the result of nuclear fusion in our nearest star.
- A liquid is heated and moves that energy by conduction.
- Solar power is expensive, but as demand increases technology improves and costs decrease.

Practice

Use this resource to answer the questions that follow.

https://www.youtube.com/watch?v=4uPVZUTLAvA

1. How effective could solar energy be as a power source?
2. How are fossil fuels solar power? How are wind and hydroelectric power sources from the sun?
3. What do we use to collect solar energy?
4. How do photovoltaic panel work?
5. What is one of the advantages of solar power over power that is generated at large plants?
6. What is the advantage of using mirrors to concentrate solar energy?
7. What is the expensive part of photovoltaics? What is the expensive part of concentrated solar power?
8. How do you get the best of both those technologies?
9. What could we do to keep solar power working at night? What's the problem with this?
10. Rather than discounting solar power because it is expensive, what is another way to look at this?

Review

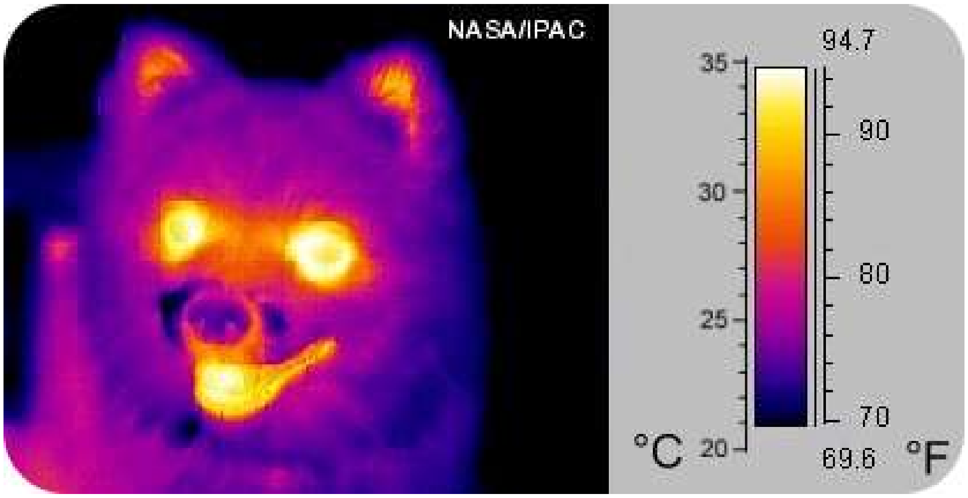
1. How is solar power collected on a large scale?
2. What are some of the downsides of depending on solar energy?
3. What are some of the positive sides of using solar energy?

References

1. Courtesy of NASA. Solar array panels on International Space Station. Public Domain
2. Flickr:afloresm. A solar power tower is used to concentrate the solar energy collected by many solar panels. CC BY 2.0
3. Daniel Borman (Flickr:borman818). Picture of a solar car. CC BY 2.0

CONCEPT 23 Solar Energy on Earth

- Describe different types of solar energy, including ultraviolet and infrared.



What's wrong with this dog?

Nothing! The sensor is detecting infrared radiation from the dog — in other words, heat. The Sun emits infrared radiation among other wavelengths too.

Energy From the Sun

Most of the energy that reaches the Earth's surface comes from the Sun (**Figure** 23.1). About 44% of solar radiation is in the visible light wavelengths, but the Sun also emits infrared, ultraviolet, and other wavelengths.

Ultraviolet

Of the solar energy that reaches the outer atmosphere, **ultraviolet (UV)** wavelengths have the greatest energy. Only about 7% of solar radiation is in the UV wavelengths. The three types are:

- UVC: the highest energy ultraviolet, does not reach the planet's surface at all.
- UVB: the second highest energy, is also mostly stopped in the atmosphere.
- UVA: the lowest energy, travels through the atmosphere to the ground.

Infrared

The remaining solar radiation is the longest wavelength, **infrared**. Most objects radiate infrared energy, which we feel as heat.

Some of the wavelengths of solar radiation traveling through the atmosphere may be lost because they are absorbed by various gases (**Figure** 23.2). Ozone completely removes UVC, most UVB, and some UVA from incoming sunlight. O_2, CO_2, and H_2O also filter out some wavelengths.

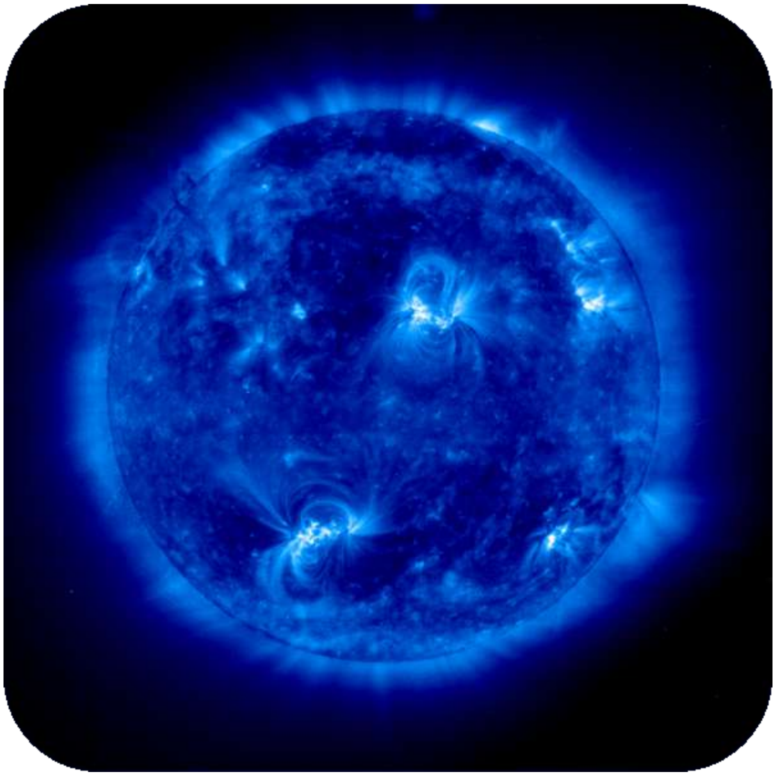


FIGURE 23.1
An image of the Sun taken by the SOHO spacecraft. The sensor is picking up only the 17.1 nm wavelength, in the ultraviolet wavelengths.

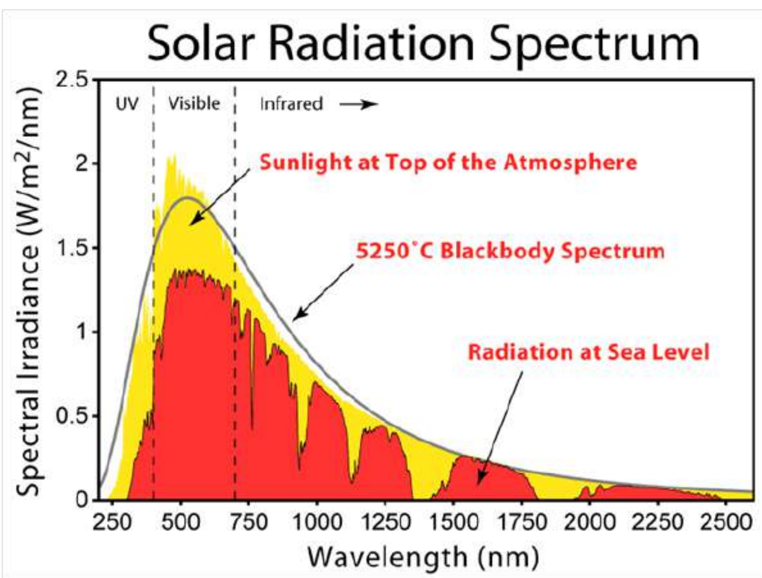


FIGURE 23.2
Atmospheric gases filter some wavelengths of incoming solar energy. Yellow shows the energy that reaches the top of the atmosphere. Red shows the wavelengths that reach sea level. Ozone filters out the shortest wavelength UV and oxygen filters out most infrared.

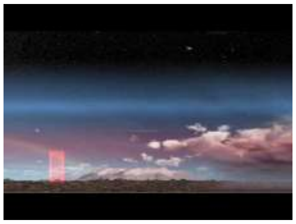
Summary

- Ultraviolet radiation has the highest energy; infrared the lowest.
- Ultraviolet is divided into three categories based on wavelength: UVC, with the highest energy, UVB, and UVA, with the lowest energy.
- Infrared has longer wavelengths than red light and is felt as heat.

Explore More

Use these resources to answer the questions that follow.

http://www.youtube.com/watch?v=i8caGm9Fmh0



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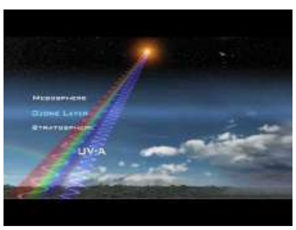
1. What is infrared light?
2. How can we sense infrared light?
3. What can be used to see infrared light?
4. What happens to infrared radiation when it get to the Earth?
5. What heats the lower atmosphere?
6. What is the Earth's radiation budget? What happens if the radiation budget is out of balance?
7. What does near infrared measure?
8. What can studying infrared tell us about the Earth?

Ultraviolet Waves

http://www.youtube.com/watch?v=QW5zeVy8aE0



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URL: http://www.ck12.org/flx/render/embeddedobject/1587

1. What are ultraviolet waves?
2. What are three regions of ultraviolet waves?
3. Describe UVA.
4. What problem can UVB cause?
5. Why don't UVC rays reach the Earth?
6. What have scientists discovered with ultraviolet waves?

Review

1. Why does more solar radiation of all wavelengths come into the exosphere than reaches Earth's surface?
2. Why does ultraviolet radiation, especially UVC, damage life?
3. Look at the **Figure** 23.2. What happens to the highest wavelengths of energy at Earth's surface?

References

1. Courtesy of SOHO and NASA. Ultraviolet image of the Sun. Public Domain

2. Courtesy of the US Government. The solar radiation spectrum. Public Domain