unit 2

# Earth's Atmosphere and Beyond

# How Are Bats & Tornadoes Connected?

(background)A.T. Willett/Image Bank/Getty Images, (b)Stephen Dalton/Animals Animals

NATIONAL GEOGRAPHIC

Bats are able to find food and avoid obstacles without using their vision. They do this by producing high-frequency sound waves which bounce off objects and return to the bat. From these echoes, the bat is able to locate obstacles and prey. This process is called echolocation. If the reflected waves have a higher frequency than the emitted waves, the bat senses the object is getting closer. If the reflected waves have a lower frequency, the object is moving away. This change in frequency is called the Doppler effect. Like echolocation, sonar technology uses sound waves and the Doppler effect to determine the position and motion of objects. Doppler radar also uses the Doppler effect, but with radar waves instead of sound waves. Higher frequency waves indicate if an object, such as a storm, is coming closer, while lower frequencies indicate if it is moving away. Meteorologists use frequency shifts indicated by Doppler radar to detect the formation of tornadoes and to predict where they will strike.

## unit projects

Visit **green.msscience.com/unit_project** to find project ideas and resources. Projects include:

- **Technology** Predict and track the weather of a city in a different part of the world, and compare it to your local weather pattern.
- **Career** Explore weather-related careers while investigating different types of storms. Compare and contrast career characteristics and history.
- **Model** Research animal behavior to discover if animals are able to predict the weather. Present your samples of weather-predicting proverbs as a collection, or use them in a folklore tale.

WebQuest ***Hurricanes!*** investigates a variety of tropical storms, their source of energy, classifications, and destructive forces.

A.T. Willett/Image Bank/Getty Images

chapter 4

# Atmosphere

**The BIG Idea**

**Earth's atmosphere helps regulate the absorption and distribution of energy received from the Sun.**

## SECTION 1
### Earth's Atmosphere
***Main Idea*** Earth's atmosphere is a thin layer of air that forms a protective covering around the planet.

## SECTION 2
### Energy Transfer in the Atmosphere
***Main Idea*** Earth's atmosphere helps control how much of the Sun's radiation is absorbed or lost to space.

## SECTION 3
### Air Movement
***Main Idea*** Uneven heating of Earth's surface leads to a change in pressure that causes air to move.

S.P. Gillette/CORBIS

## Fresh mountain air?

On top of Mt. Everest the air is a bit thin. Without breathing equipment, an average person quickly would become dizzy, then unconscious, and eventually would die. In this chapter you'll learn what makes the atmosphere at high altitudes different from the atmosphere we are used to.

**Science Journal** Write a short article describing how you might prepare to climb Mt. Everest.

# Start-Up Activities

## Launch LAB

### Observe Air Pressure

The air around you is made of billions of molecules. These molecules are constantly moving in all directions and bouncing into every object in the room, including you. Air pressure is the result of the billions of collisions of molecules into these objects. Because you usually do not feel molecules in air hitting you, do the lab below to see the effect of air pressure.

1. Cut out a square of cardboard about 10 cm from the side of a cereal box.
2. Fill a glass to the brim with water.
3. Hold the cardboard firmly over the top of the glass, covering the water, and invert the glass.
4. Slowly remove your hand holding the cardboard in place and observe.
5. **Think Critically** Write a paragraph in your Science Journal describing what happened to the cardboard when you inverted the glass and removed your hand. How does air pressure explain what happened?

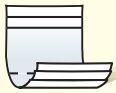
## FOLDABLES™ Study Organizer

### Earth's Atmospheric Layers

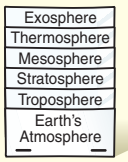
Make the following Foldable to help you visualize the five layers of Earth's atmosphere.

**STEP 1** **Collect** 3 sheets of paper and layer them about 1.25 cm apart vertically. Keep the edges level.

**STEP 2** **Fold** up the bottom edges of the paper to form 6 equal tabs.



**STEP 3** **Fold** the paper and crease well to hold the tabs in place. Staple along the fold. **Label** each tab.




**Find Main Ideas** Label the tabs *Earth's Atmosphere, Troposphere, Stratosphere, Mesosphere, Thermosphere,* and *Exosphere* from bottom to top as shown. As you read the chapter, write information about each layer of Earth's atmosphere under the appropriate tab.

Science Online

Preview this chapter's content and activities at green.msscience.com



S.P. Gillette/CORBIS

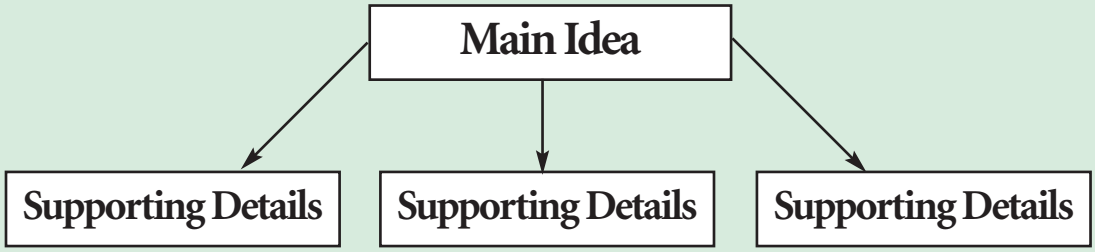
# Get Ready to Read

## Identify the Main Idea

**1 Learn It!** Main ideas are the most important ideas in a paragraph, section, or chapter. Supporting details are facts or examples that explain the main idea. Understanding the main idea allows you to grasp the whole picture.

**2 Picture It!** Read the following paragraph. Draw a graphic organizer like the one below to show the main idea and supporting details.

> In addition to gases, Earth's atmosphere contains small, solid particles such as dust, salt, and pollen. Dust particles get into the atmosphere when wind picks them up off the ground and carries them along. Salt is picked up from ocean spray. Plants give off pollen that becomes mixed throughout part of the atmosphere.
>
> *—from page 91*




**3 Apply It!** Pick a paragraph from another section of this chapter and diagram the main ideas as you did above.

## Reading Tip

The main idea is often the first sentence in a paragraph but not always.

# Target Your Reading

**Use this to focus on the main ideas as you read the chapter.**

1 **Before you read** the chapter, respond to the statements below on your worksheet or on a numbered sheet of paper.

- Write an **A** if you **agree** with the statement.
- Write a **D** if you **disagree** with the statement.

2 **After you read** the chapter, look back to this page to see if you've changed your mind about any of the statements.

- If any of your answers changed, explain why.
- Change any false statements into true statements.
- Use your revised statements as a study guide.

| Before You Read A or D | | Statement | After You Read A or D |
|---|---|---|---|
| | 1 | Earth's atmosphere is mostly oxygen. | |
| | 2 | Air pressure is greater near Earth's surface and decreases higher in the atmosphere. | |
| | 3 | The ozone layer absorbs most of the harmful infrared radiation that enters the atmosphere. | |
| | 4 | Conduction is the transfer of heat by the flow of material. | |
| | 5 | In the atmosphere, cold, dense air sinks, causing hot, less dense air to rise. | |
| | 6 | Wind is the movement of air from an area of lower pressure to an area of higher pressure. | |
| | 7 | Earth's surface is heated evenly by the Sun. | |
| | 8 | Earth's rotation affects the direction in which air and water move. | |
| | 9 | Jet streams are legally defined zones in the atmosphere where only jets are allowed to travel. | |

Science Online

Print out a worksheet of this page at green.msscience.com

section 1

# Earth's Atmosphere

as you read

## What You'll Learn

- **Identify** the gases in Earth's atmosphere.
- **Describe** the structure of Earth's atmosphere.
- **Explain** what causes air pressure.

## Why It's Important

The atmosphere makes life on Earth possible.

**Review Vocabulary**

**pressure:** force exerted on an area

**New Vocabulary**

- atmosphere
- troposphere
- ionosphere
- ozone layer
- ultraviolet radiation
- chlorofluorocarbon

## Importance of the Atmosphere

Earth's **atmosphere,** shown in **Figure 1,** is a thin layer of air that forms a protective covering around the planet. If Earth had no atmosphere, days would be extremely hot and nights would be extremely cold. Earth's atmosphere maintains a balance between the amount of heat absorbed from the Sun and the amount of heat that escapes back into space. It also protects life-forms from some of the Sun's harmful rays.

## Makeup of the Atmosphere

Earth's atmosphere is a mixture of gases, solids, and liquids that surrounds the planet. It extends from Earth's surface to outer space. The atmosphere is much different today from what it was when Earth was young.

Earth's early atmosphere, produced by erupting volcanoes, contained nitrogen and carbon dioxide, but little oxygen. Then, more than 2 billon years ago, Earth's early organisms released oxygen into the atmosphere as they made food with the aid of sunlight. These early organisms, however, were limited to layers of ocean water deep enough to be shielded from the Sun's harmful rays, yet close enough to the surface to receive sunlight. Eventually, a layer rich in ozone ($O_3$) that protects Earth from the Sun's harmful rays formed in the upper atmosphere. This protective layer eventually allowed green plants to flourish all over Earth, releasing even more oxygen. Today, a variety of life forms, including you, depends on a certain amount of oxygen in Earth's atmosphere.

**Figure 1** Earth's atmosphere, as viewed from space, is a thin layer of gases. The atmosphere keeps Earth's temperature in a range that can support life.

NASA

## Gases in the Atmosphere

Today's atmosphere is a mixture of the gases shown in **Figure 2.** Nitrogen is the most abundant gas, making up 78 percent of the atmosphere. Oxygen actually makes up only 21 percent of Earth's atmosphere. As much as four percent of the atmosphere is water vapor. Other gases that make up Earth's atmosphere include argon and carbon dioxide.

The composition of the atmosphere is changing in small but important ways. For example, car exhaust emits gases into the air. These pollutants mix with oxygen and other chemicals in the presence of sunlight and form a brown haze called smog. Humans burn fuel for energy. As fuel is burned, carbon dioxide is released as a by-product into Earth's atmosphere. Increasing energy use may increase the amount of carbon dioxide in the atmosphere.

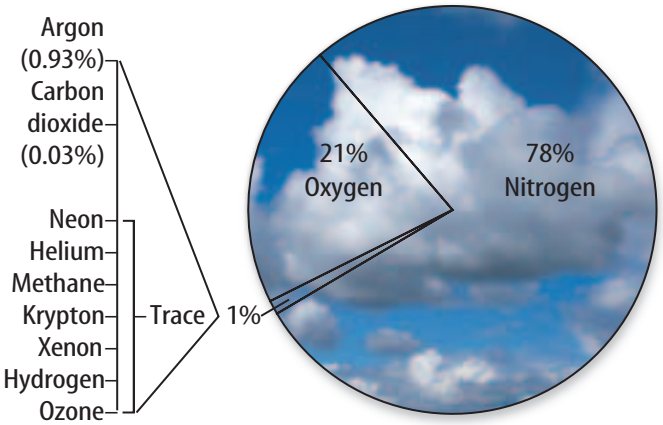



**Figure 2** This circle graph shows the percentages of the gases, excluding water vapor, that make up Earth's atmosphere.
**Determine** *Approximately what fraction of Earth's atmosphere is oxygen?*

## Solids and Liquids in Earth's Atmosphere

In addition to gases, Earth's atmosphere contains small, solid particles such as dust, salt, and pollen. Dust particles get into the atmosphere when wind picks them up off the ground and carries them along. Salt is picked up from ocean spray. Plants give off pollen that becomes mixed throughout part of the atmosphere.

The atmosphere also contains small liquid droplets other than water droplets in clouds. The atmosphere constantly moves these liquid droplets and solids from one region to another. For example, the atmosphere above you may contain liquid droplets and solids from an erupting volcano thousands of kilometers from your home, as illustrated in **Figure 3.**

**Figure 3** Solids and liquids can travel large distances in Earth's atmosphere, affecting regions far from their source.

On June 12, 1991, Mount Pinatubo in the Philippines erupted, causing liquid droplets to form in Earth's atmosphere.

Droplets of sulfuric acid from volcanoes can produce spectacular sunrises.


(l)Frank Rossotto/The Stock Market/CORBIS, (r)Larry Lee/CORBIS

## Layers of the Atmosphere

What would happen if you left a glass of chocolate milk on the kitchen counter for a while? Eventually, you would see a lower layer with more chocolate separating from upper layers with less chocolate. Like a glass of chocolate milk, Earth's atmosphere has layers. There are five layers in Earth's atmosphere, each with its own properties, as shown in **Figure 4.** The lower layers include the troposphere and stratosphere. The upper atmospheric layers are the mesosphere, thermosphere, and exosphere. The troposphere and stratosphere contain most of the air.

**Lower Layers of the Atmosphere** You study, eat, sleep, and play in the **troposphere** which is the lowest of Earth's atmospheric layers. It contains 99 percent of the water vapor and 75 percent of the atmospheric gases. Rain, snow, and clouds occur in the troposphere, which extends up to about 10 km.

The stratosphere, the layer directly above the troposphere, extends from 10 km above Earth's surface to about 50 km. As **Figure 4** shows, a portion of the stratosphere contains higher levels of a gas called ozone. Each molecule of ozone is made up of three oxygen atoms bonded together. Later in this section you will learn how ozone protects Earth from the Sun's harmful rays.

**Science Online**

**Topic: Earth's Atmospheric Layers**

Visit green.msscience.com for Web links to information about layers of Earth's atmosphere.

**Activity** Locate data on recent ozone layer depletion. Graph your data.

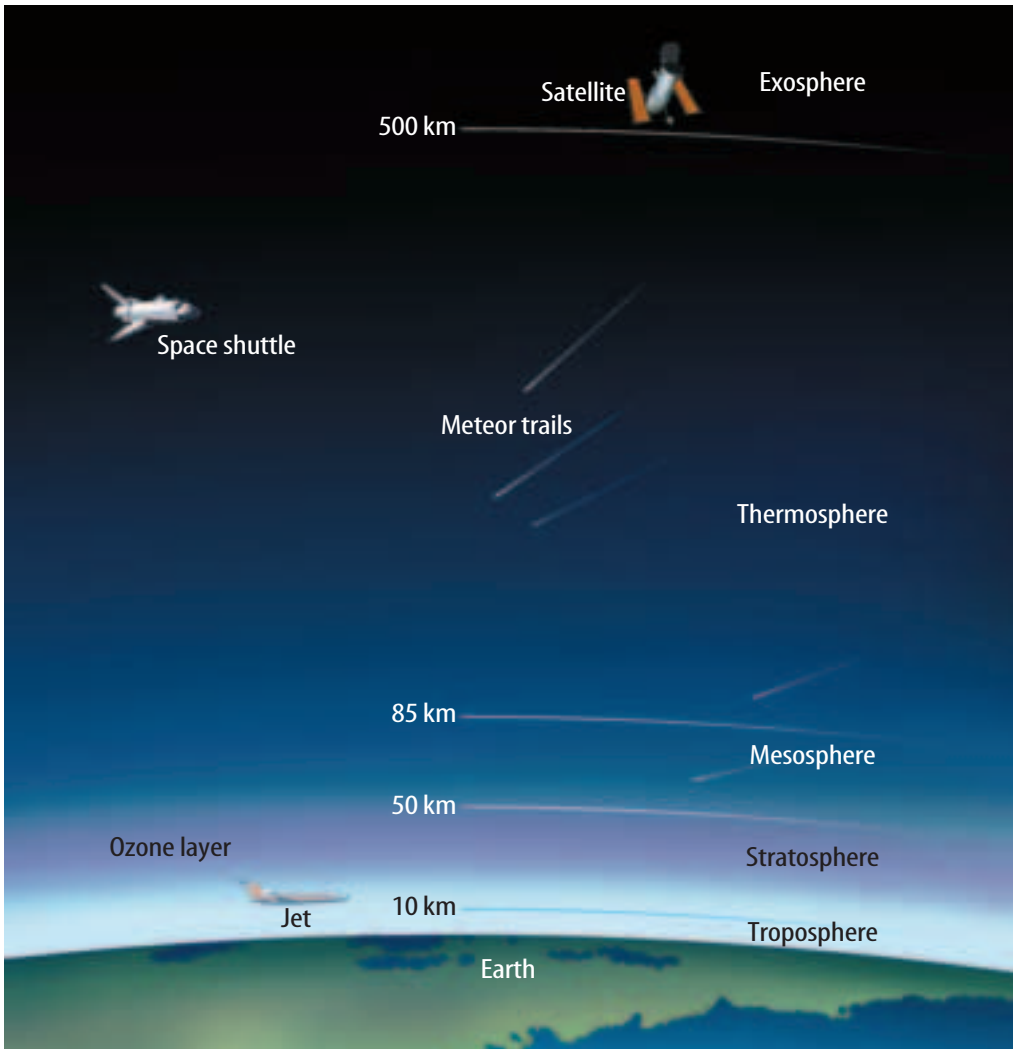



**Figure 4** Earth's atmosphere is divided into five layers.
**Describe** *the layer of the atmosphere in which you live.*

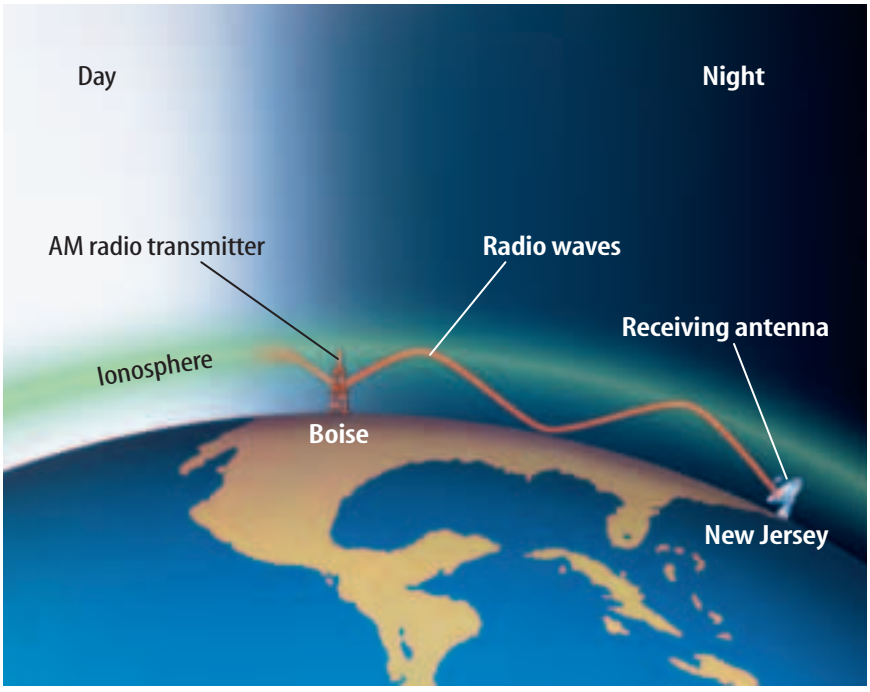



**Figure 5** During the day, the ionosphere absorbs radio transmissions. This prevents you from hearing distant radio stations. At night, the ionosphere reflects radio waves. The reflected waves can travel to distant cities.
**Describe** *what causes the ionosphere to change between day and night.*

## Upper Layers of the Atmosphere

Beyond the stratosphere are the mesosphere, thermosphere, and exosphere. The mesosphere extends from the top of the stratosphere to about 85 km above Earth. If you've ever seen a shooting star, you might have witnessed a meteor in the mesosphere.

The thermosphere is named for its high temperatures. This is the thickest atmospheric layer and is found between 85 km and 500 km above Earth's surface.

Within the mesosphere and thermosphere is a layer of electrically charged particles called the **ionosphere** (i AH nuh sfihr). If you live in New Jersey and listen to the radio at night, you might pick up a station from Boise, Idaho. The ionosphere allows radio waves to travel across the country to another city, as shown in **Figure 5.** During the day, energy from the Sun interacts with the particles in the ionosphere, causing them to absorb AM radio frequencies. At night, without solar energy, AM radio transmissions reflect off the ionosphere, allowing radio transmissions to be received at greater distances.

The space shuttle in **Figure 6** orbits Earth in the exosphere. In contrast to the troposphere, the layer you live in, the exosphere has so few molecules that the wings of the shuttle are useless. In the exosphere, the spacecraft relies on bursts from small rocket thrusters to move around. Beyond the exosphere is outer space.

**Reading Check** ***How does the space shuttle maneuver in the exosphere?***

**Figure 6** Wings help move aircraft in lower layers of the atmosphere. The space shuttle can't use its wings to maneuver in the exosphere because so few molecules are present.

**Figure 7** Air pressure decreases as you go higher in Earth's atmosphere.

## Atmospheric Pressure

Imagine you're a football player running with the ball. Six players tackle you and pile one on top of the other. Who feels the weight more—you or the player on top? Like molecules anywhere else, atmospheric gases have mass. Atmospheric gases extend hundreds of kilometers above Earth's surface. As Earth's gravity pulls the gases toward its surface, the weight of these gases presses down on the air below. As a result, the molecules nearer Earth's surface are closer together. This dense air exerts more force than the less dense air near the top of the atmosphere. Force exerted on an area is known as pressure.

Like the pile of football players, air pressure is greater near Earth's surface and decreases higher in the atmosphere, as shown in **Figure 7.** People find it difficult to breathe in high mountains because fewer molecules of air exist there. Jets that fly in the stratosphere must maintain pressurized cabins so that people can breathe.

**Reading Check** *Where is air pressure greater—in the exosphere or in the troposphere?*

## Applying Science

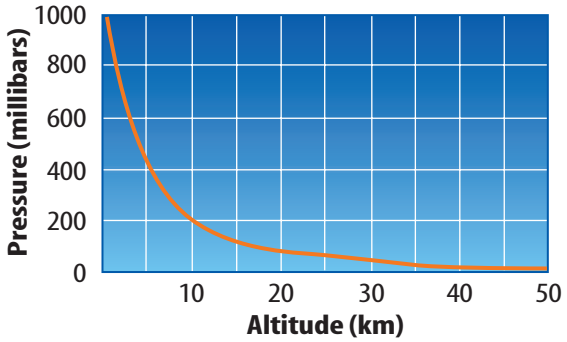
### How does altitude affect air pressure?

Atmospheric gases extend hundreds of kilometers above Earth's surface, but the molecules that make up these gases are fewer and fewer in number as you go higher. This means that air pressure decreases with altitude.

#### Identifying the Problem

The graph on the right shows these changes in air pressure. Note that altitude on the graph goes up only to 50 km. The troposphere and the stratosphere are represented on the graph, but other layers of the atmosphere are not. By examining the graph, can you understand the relationship between altitude and pressure?

**Air Pressure Changes with Altitude**




#### Solving the Problem

1. Estimate the air pressure at an altitude of 5 km.
2. Does air pressure change more quickly at higher altitudes or at lower altitudes?


Laurence Fordyce/CORBIS

# Temperature in Atmospheric Layers

The Sun is the source of most of the energy on Earth. Before it reaches Earth's surface, energy from the Sun must pass through the atmosphere. Because some layers contain gases that easily absorb the Sun's energy while other layers do not, the various layers have different temperatures, illustrated by the red line in **Figure 8.**

Molecules that make up air in the troposphere are warmed mostly by heat from Earth's surface. The Sun warms Earth's surface, which then warms the air above it. When you climb a mountain, the air at the top is usually cooler than the air at the bottom. Every kilometer you climb, the air temperature decreases about 6.5°C.

Molecules of ozone in the stratosphere absorb some of the Sun's energy. Energy absorbed by ozone molecules raises the temperature. Because more ozone molecules are in the upper portion of the stratosphere, the temperature in this layer rises with increasing altitude.

Like the troposphere, the temperature in the mesosphere decreases with altitude. The thermosphere and exosphere are the first layers to receive the Sun's rays. Few molecules are in these layers, but each molecule has a great deal of energy. Temperatures here are high.

Mini LAB

## Determining if Air Has Mass

**Procedure**

1. On a **pan balance,** find the mass of an **inflatable ball** that is completely deflated.
2. Hypothesize about the change in the mass of the ball when it is inflated.
3. Inflate the ball to its maximum recommended inflation pressure.
4. Determine the mass of the fully inflated ball.

**Analysis**

1. What change occurs in the mass of the ball when it is inflated?
2. Infer from your data whether air has mass.

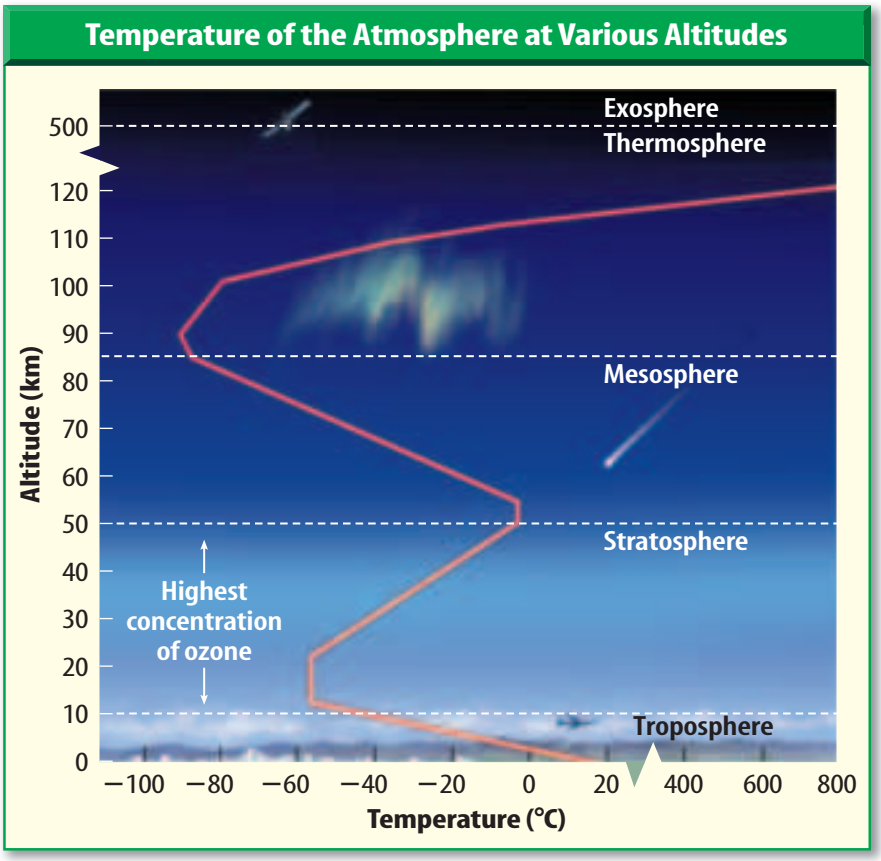



**Figure 8** The division of the atmosphere into layers is based mainly on differences in temperature.
**Determine** *Does the temperature increase or decrease with altitude in the mesosphere?*

**Effects of UV Light on Algae** Algae are organisms that use sunlight to make their own food. This process releases oxygen to Earth's atmosphere. Some scientists suggest that growth is reduced when algae are exposed to ultraviolet radiation. Infer what might happen to the oxygen level of the atmosphere if increased ultraviolet radiation damages some algae.

## The Ozone Layer

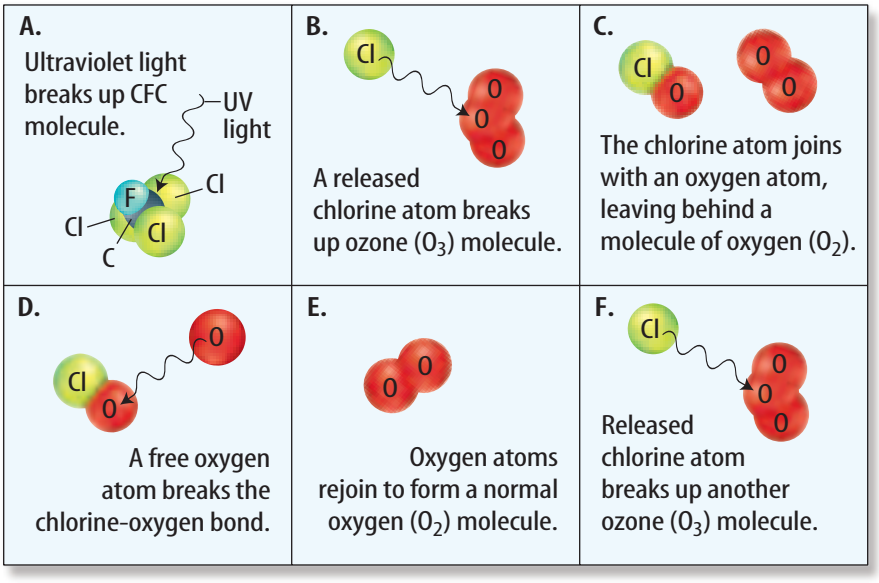
Within the stratosphere, about 19 km to 48 km above your head, lies an atmospheric layer called the **ozone layer.** Ozone is made of oxygen. Although you cannot see the ozone layer, your life depends on it.

The oxygen you breathe has two atoms per molecule, but an ozone molecule is made up of three oxygen atoms bound together. The ozone layer contains a high concentration of ozone and shields you from the Sun's harmful energy. Ozone absorbs most of the ultraviolet radiation that enters the atmosphere. **Ultraviolet radiation** is one of the many types of energy that come to Earth from the Sun. Too much exposure to ultraviolet radiation can damage your skin and cause cancer.

**CFCs** Evidence exists that some air pollutants are destroying the ozone layer. Blame has fallen on **chlorofluorocarbons** (CFCs), chemical compounds used in some refrigerators, air conditioners, and aerosol sprays, and in the production of some foam packaging. CFCs can enter the atmosphere if these appliances leak or if they and other products containing CFCs are improperly discarded.

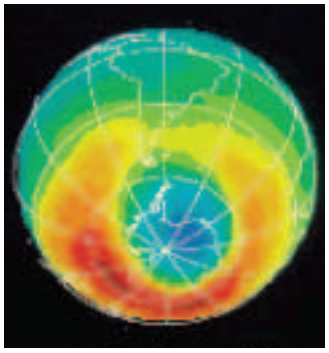
Recall that an ozone molecule is made of three oxygen atoms bonded together. Chlorofluorocarbon molecules, shown in **Figure 9,** destroy ozone. When a chlorine atom from a chlorofluorocarbon molecule comes near a molecule of ozone, the ozone molecule breaks apart. One of the oxygen atoms combines with the chlorine atom, and the rest form a regular, two-atom molecule. These compounds don't absorb ultraviolet radiation the way ozone can. In addition, the original chlorine atom can continue to break apart thousands of ozone molecules. The result is that more ultraviolet radiation reaches Earth's surface.

**Figure 9** Chlorofluorocarbon (CFC) molecules once were used in refrigerators and air conditioners. Each CFC molecule has three chlorine atoms. One atom of chlorine can destroy approximately 100,000 ozone molecules.

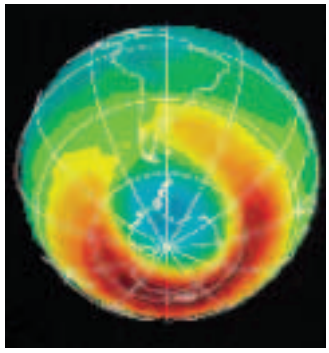




Doug Martin



October 1980



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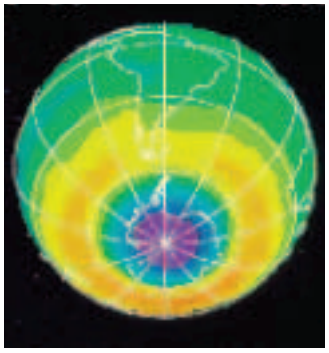

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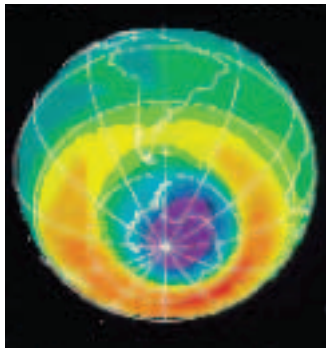


September 1999

**Figure 10** These images of Antarctica were produced using data from a NASA satellite. The lowest values of ozone concentration are shown in dark blue and purple. These data show that the size of the seasonal ozone hole over Antarctica has grown larger over time.

INTEGRATE Health

**The Ozone Hole** The destruction of ozone molecules by CFCs seems to cause a seasonal reduction in ozone over Antarctica called the ozone hole. Every year beginning in late August or early September the amount of ozone in the atmosphere over Antarctica begins to decrease. By October, the ozone concentration reaches its lowest values and then begins to increase again. By December, the ozone hole disappears. **Figure 10** shows how the ozone hole over Antarctica has changed. In the mid-1990s, many governments banned the production and use of CFCs. Since then, the concentration of CFCs in the atmosphere has started to decrease.

## section 1 review

### Summary

#### Layers of the Atmosphere

- The atmosphere is a mixture of gases, solids, and liquids.
- The atmosphere has five layers—troposphere, stratosphere, mesosphere, thermosphere, and exosphere.
- The ionosphere is made up of electrically charged particles.

#### Atmospheric Pressure and Temperature

- Atmospheric pressure decreases with distance from Earth.
- Because some layers absorb the Sun's energy more easily than others, the various layers have different temperatures.

#### Ozone Layer

- The ozone layer absorbs most UV light.
- Chlorofluorocarbons (CFCs) break down the ozone layer.

### Self Check

1. **Describe** How did oxygen come to make up 21 percent of Earth's present atmosphere?
2. **Infer** While hiking in the mountains, you notice that it is harder to breathe as you climb higher. Explain.
3. **State** some effects of a thinning ozone layer.
4. **Think Critically** Explain why, during the day, the radio only receives AM stations from a nearby city, while at night, you're able to hear a distant city's stations.

### Applying Skills

5. **Interpret Scientific Illustrations** Using **Figure 2,** determine the total percentage of nitrogen and oxygen in the atmosphere. What is the total percentage of argon and carbon dioxide?
6. **Communicate** The names of the atmospheric layers end with the suffix *-sphere,* a word that means "ball." Find out what *tropo-, meso-, thermo-,* and *exo-* mean. Write their meanings in your Science Journal and explain if the layers are appropriately named.



NASA/GSFC

LAB

# Evaluating Sunscreens

Without protection, sun exposure can damage your health. Sunscreens protect your skin from UV radiation. In this lab, you will draw inferences using different sunscreen labels.

## Real-World Question

How effective are various brands of sunscreens?

### Goals

- **Draw inferences** based on labels on sunscreen brands.
- **Compare** the effectiveness of different sunscreen brands for protection against the Sun.
- **Compare** the cost of several sunscreen brands.

### Materials

variety of sunscreens of different brand names

### Safety Precautions

## Procedure

1. Make a data table in your Science Journal using the following headings: *Brand Name, SPF, Cost per Milliliter,* and *Misleading Terms.*
2. The Sun Protection Factor (SPF) tells you how long the sunscreen will protect you. For example, an SPF of 4 allows you to stay in the Sun four times longer than if you did not use sunscreen. Record the SPF of each sunscreen on your data table.
3. **Calculate** the cost per milliliter of each sunscreen brand.
4. Government guidelines say that terms like *sunblock* and *waterproof* are misleading because sunscreens can't block the Sun's rays, and they do wash off in water. List misleading terms in your data table for each brand.

| Sunscreen Assessment | | | |
|---|---|---|---|
| Brand Name | | | |
| SPF | | | |
| Cost per Milliliter | | | |
| Misleading Terms | | | |

Do not write in this book.

## Conclude and Apply

1. **Explain** why you need to use sunscreen.
2. **Evaluate** A minimum of SPF 15 is considered adequate protection for a sunscreen. An SPF greater than 30 is considered by government guidelines to be misleading because sunscreens wash or wear off. Evaluate the SPF of each sunscreen brand.
3. **Discuss** Considering the cost and effectiveness of all the sunscreen brands, discuss which you consider to be the best buy.

### Communicating Your Data

Create a poster on the proper use of sunscreens, and provide guidelines for selecting the safest product.



Michael Newman/PhotoEdit, Inc.

section 2

# Energy Transfer in the Atmosphere

## Energy from the Sun

The Sun provides most of Earth's energy. This energy drives winds and ocean currents and allows plants to grow and produce food, providing nutrition for many animals. When Earth receives energy from the Sun, three different things can happen to that energy, as shown in **Figure 11.** Some energy is reflected back into space by clouds, particles, and Earth's surface. Some is absorbed by the atmosphere or by land and water on Earth's surface.

## Heat

Heat is energy that flows from an object with a higher temperature to an object with a lower temperature. Energy from the Sun reaches Earth's surface and heats it. Heat then is transferred through the atmosphere in three ways—radiation, conduction, and convection, as shown in **Figure 12.**

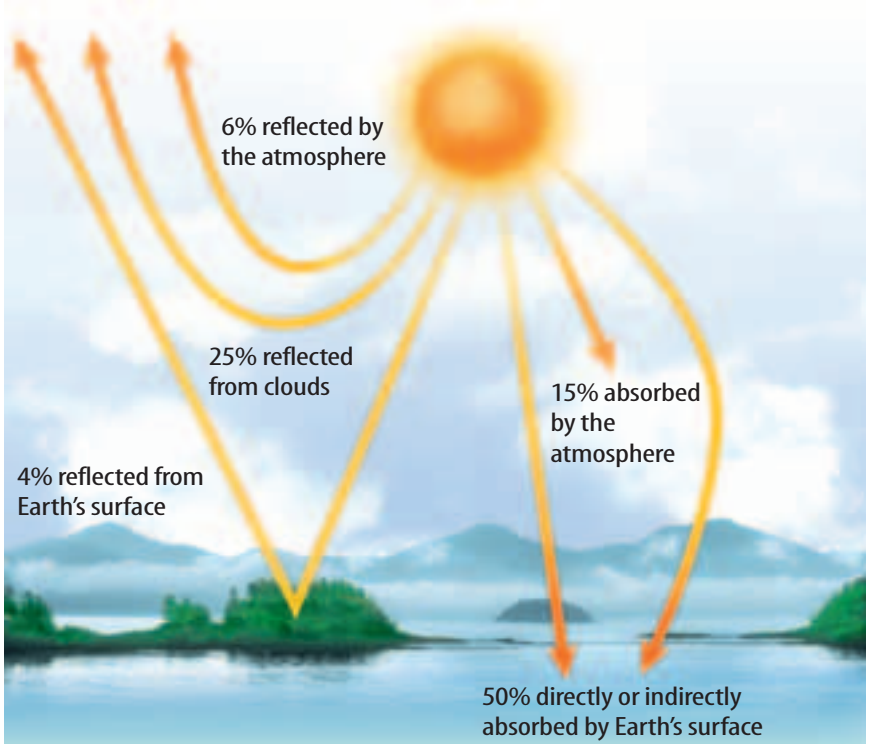



**Figure 11** The Sun is the source of energy for Earth's atmosphere. Thirty-five percent of incoming solar radiation is reflected back into space.
**Infer** *how much is absorbed by Earth's surface and atmosphere.*

as you read

### What You'll Learn

- **Describe** what happens to the energy Earth receives from the Sun.
- **Compare and contrast** radiation, conduction, and convection.
- **Explain** the water cycle and its effect on weather patterns and climate.

### Why It's Important

The Sun provides energy to Earth's atmosphere, allowing life to exist.

### Review Vocabulary

**evaporation:** when a liquid changes to a gas at a temperature below the liquid's boiling point

### New Vocabulary

- radiation
- conduction
- convection
- hydrosphere
- condensation

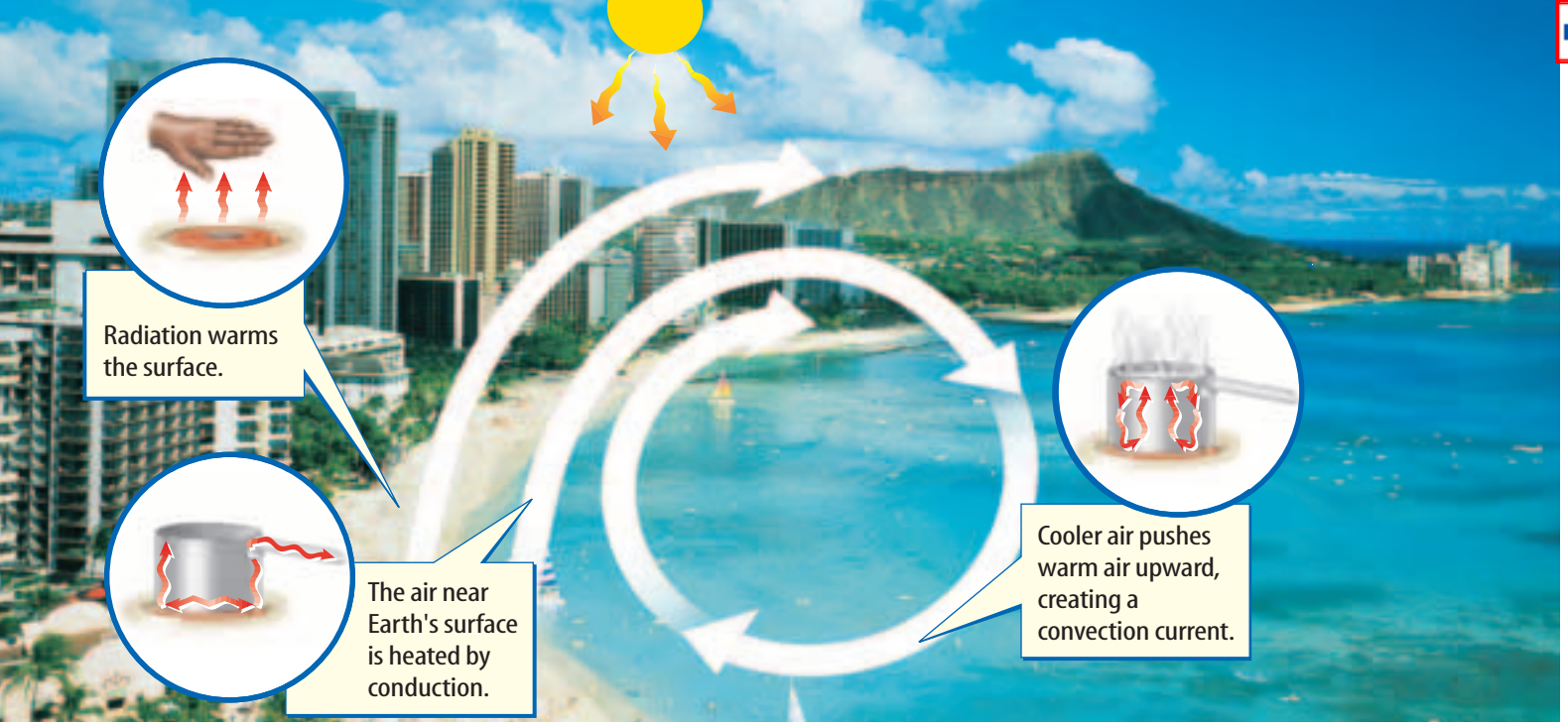



**Figure 12** Heat is transferred within Earth's atmosphere by radiation, conduction, and convection.

**Radiation** Sitting on the beach, you feel the Sun's warmth on your face. How can you feel the Sun's heat even though you aren't in direct contact with it? Energy from the Sun reaches Earth in the form of radiant energy, or radiation. **Radiation** is energy that is transferred in the form of rays or waves. Earth radiates some of the energy it absorbs from the Sun back toward space. Radiant energy from the Sun warms your face.

**Reading Check** *How does the Sun warm your skin?*

**Conduction** If you walk barefoot on a hot beach, your feet heat up because of conduction. **Conduction** is the transfer of energy that occurs when molecules bump into one another. Molecules are always in motion, but molecules in warmer objects move faster than molecules in cooler objects. When objects are in contact, energy is transferred from warmer objects to cooler objects.

Radiation from the Sun heated the beach sand, but direct contact with the sand warmed your feet. In a similar way, Earth's surface conducts energy directly to the atmosphere. As air moves over warm land or water, molecules in air are heated by direct contact.

**Convection** After the atmosphere is warmed by radiation or conduction, the heat is transferred by a third process called convection. **Convection** is the transfer of heat by the flow of material. Convection circulates heat throughout the atmosphere. How does this happen?

INTEGRATE Physics

**Specific Heat** Specific heat is the amount of heat required to raise the temperature of one kilogram of a substance one degree Celsius. Substances with high specific heat absorb a lot of heat for a small increase in temperature. Land warms faster than water does. Infer whether soil or water has a higher specific heat value.

When air is warmed, the molecules in it move apart and the air becomes less dense. Air pressure decreases because fewer molecules are in the same space. In cold air, molecules move closer together. The air becomes more dense and air pressure increases. Cooler, denser air sinks while warmer, less dense air rises, forming a convection current. As **Figure 12** shows, radiation, conduction, and convection together distribute the Sun's heat throughout Earth's atmosphere.

## The Water Cycle

**Hydrosphere** is a term that describes all the waters of Earth. The constant cycling of water within the atmosphere and the hydrosphere, as shown in **Figure 13,** plays an important role in determining weather patterns and climate types.

Energy from the Sun causes water to change from a liquid to a gas by a process called evaporation. Water that evaporates from lakes, streams, and oceans enters Earth's atmosphere. If water vapor in the atmosphere cools enough, it changes back into a liquid. This process of water vapor changing to a liquid is called **condensation.**

Clouds form when condensation occurs high in the atmosphere. Clouds are made up of tiny water droplets that can collide to form larger drops. As the drops grow, they fall to Earth as precipitation. This completes the water cycle within the hydrosphere. Classification of world climates is commonly based on annual and monthly averages of temperature and precipitation that are strongly affected by the water cycle.

Mini LAB

### Modeling Heat Transfer

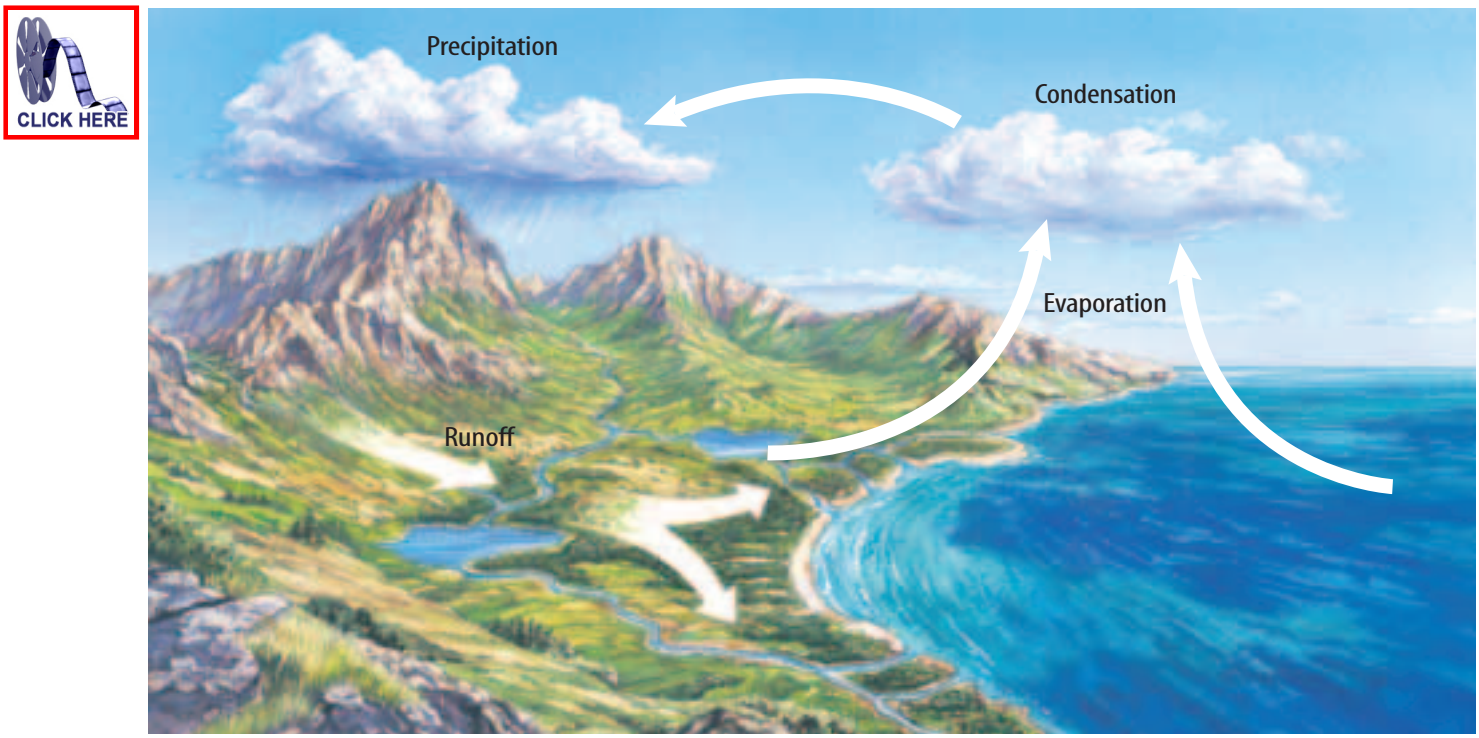
**Procedure**

1. Cover the outside of an empty **soup can,** with **black construction paper.**
2. Fill the can with **cold water** and feel it with your fingers.
3. Place the can in sunlight for 1 h, then pour the water over your fingers.

**Analysis**

1. Does the water in the can feel warmer or cooler after placing the can in sunlight?
2. What types of heat transfer did you model?

Try at Home




CLICK HERE

**Figure 13** In the water cycle, water moves from Earth to the atmosphere and back to Earth again.

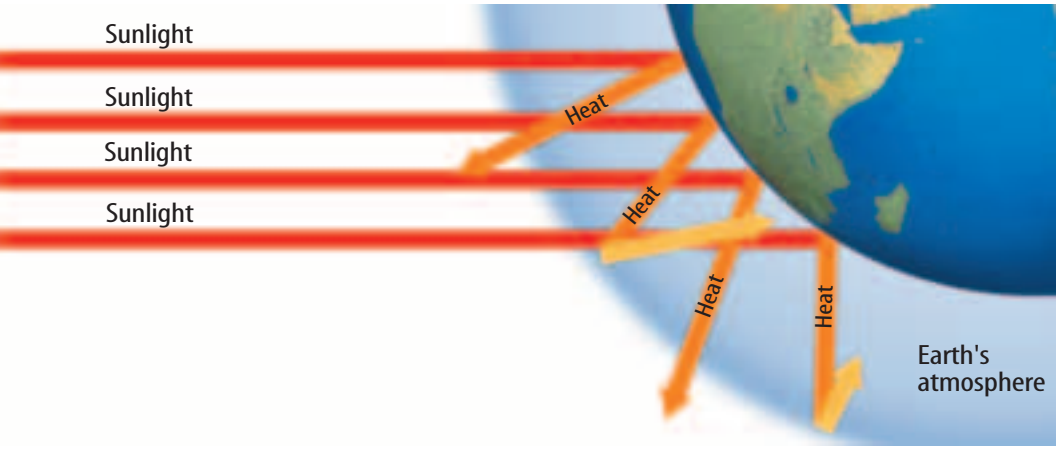



**Figure 14** Earth's atmosphere creates a delicate balance between energy received and energy lost. **Infer** *What could happen if the balance is tipped toward receiving more energy than it does now?*

## Earth's Atmosphere is Unique

On Earth, radiation from the Sun can be reflected into space, absorbed by the atmosphere, or absorbed by land and water. Once it is absorbed, heat can be transferred by radiation, conduction, or convection. Earth's atmosphere, shown in **Figure 14,** helps control how much of the Sun's radiation is absorbed or lost.

**Reading Check** ***What helps control how much of the Sun's radiation is absorbed on Earth?***

Why doesn't life exist on Mars or Venus? Mars is a cold, lifeless world because its atmosphere is too thin to support life or to hold much of the Sun's heat. Temperatures on the surface of Mars range from 35°C to −170°C. On the other hand, gases in Venus's dense atmosphere trap heat coming from the Sun. The temperature on the surface of Venus is 470°C. Living things would burn instantly if they were placed on Venus's surface. Life on Earth exists because the atmosphere holds just the right amount of the Sun's energy.

## section 2 review

### Summary

**Energy From the Sun**

- The Sun's radiation is either absorbed or reflected by Earth.
- Heat is transferred by radiation (waves), conduction (contact), or convection (flow).

**The Water Cycle**

- The water cycle affects climate.
- Water moves between the hydrosphere and the atmosphere through a continual process of evaporation and condensation.

**Earth's Atmosphere is Unique**

- Earth's atmosphere controls the amount of solar radiation that reaches Earth's surface.

### Self Check

1. **State** how the Sun transfers energy to Earth.
2. **Contrast** the atmospheres of Earth and Mars.
3. **Describe** briefly the steps included in the water cycle.
4. **Explain** how the water cycle is related to weather patterns and climate.
5. **Think Critically** What would happen to temperatures on Earth if the Sun's heat were not distributed throughout the atmosphere?

### Applying Math

6. **Solve One-Step Equations** Earth is about 150 million km from the Sun. The radiation coming from the Sun travels at 300,000 km/s. How long does it take for radiation from the Sun to reach Earth?


Science Online green.msscience.com/self_check_quiz

section 3

# Air Movement

## Forming Wind

Earth is mostly rock or land, with three-fourths of its surface covered by a relatively thin layer of water, the oceans. These two areas strongly influence global wind systems. Uneven heating of Earth's surface by the Sun causes some areas to be warmer than others. Recall that warmer air expands, becoming lower in density than the colder air. This causes air pressure to be generally lower where air is heated. Wind is the movement of air from an area of higher pressure to an area of lower pressure.

**Heated Air** Areas of Earth receive different amounts of radiation from the Sun because Earth is curved. **Figure 15** illustrates why the equator receives more radiation than areas to the north or south. The heated air at the equator is less dense, so it is displaced by denser, colder air, creating convection currents.

This cold, denser air comes from the poles, which receive less radiation from the Sun, making air at the poles much cooler. The resulting dense, high-pressure air sinks and moves along Earth's surface. However, dense air sinking as less-dense air rises does not explain everything about wind.

### as you read

#### What You'll Learn

- **Explain** why different latitudes on Earth receive different amounts of solar energy.
- **Describe** the Coriolis effect.
- **Explain** how land and water surfaces affect the overlying air.

#### Why It's Important

Wind systems determine major weather patterns on Earth.

#### Review Vocabulary

**density:** mass per unit volume

#### New Vocabulary

- Coriolis effect
- jet stream
- sea breeze
- land breeze

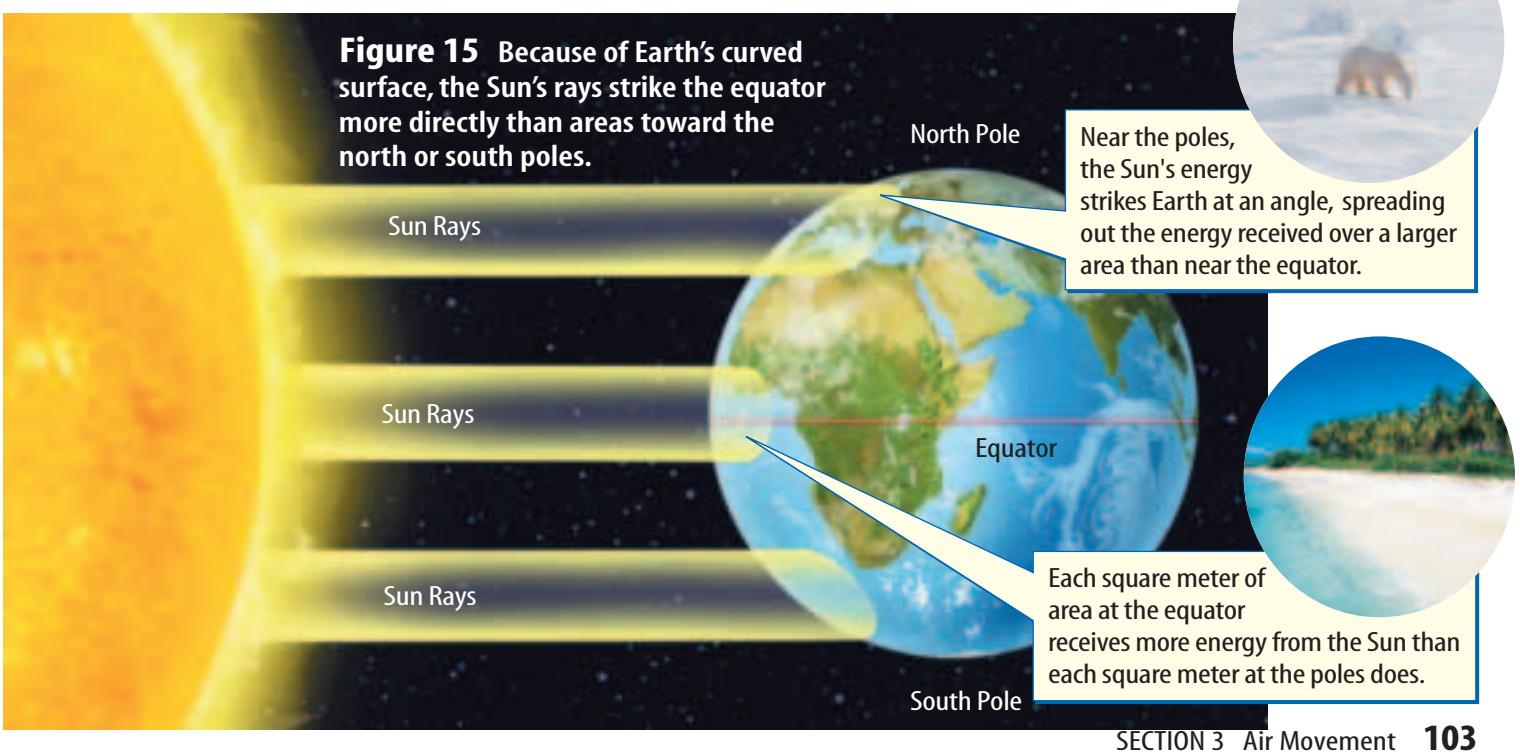



**Figure 15** Because of Earth's curved surface, the Sun's rays strike the equator more directly than areas toward the north or south poles.



(t)Dan Guravich/Photo Researchers, (b)Bill Brooks/Masterfile

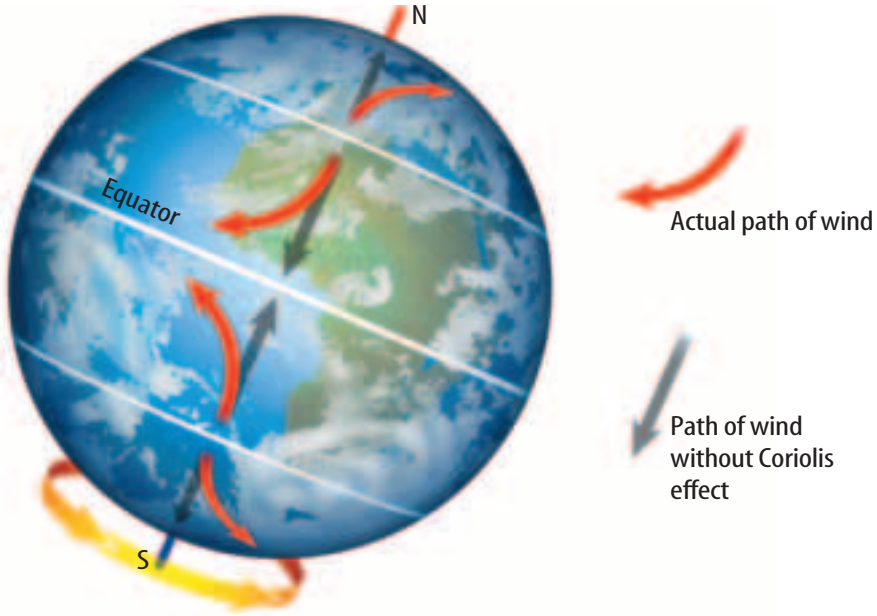



**Figure 16** The Coriolis effect causes moving air to turn to the right in the northern hemisphere and to the left in the southern hemisphere.
**Explain** *What causes this to happen?*

**The Coriolis Effect** What would happen if you threw a ball to someone sitting directly across from you on a moving merry-go-round? Would the ball go to your friend? By the time the ball got to the opposite side, your friend would have moved and the ball would appear to have curved.

Like the merry-go-round, the rotation of Earth causes moving air and water to appear to turn to the right north of the equator and to the left south of the equator. This is called the **Coriolis** (kohr ee OH lus) **effect.** It is illustrated in **Figure 16.** The flow of air caused by differences in the amount of solar radiation received on Earth's surface and by the Coriolis effect creates distinct wind patterns on Earth's surface. These wind systems not only influence the weather, they also determine when and where ships and planes travel most efficiently.

## Global Winds

How did Christopher Columbus get from Spain to the Americas? The *Nina,* the *Pinta,* and the *Santa Maria* had no source of power other than the wind in their sails. Early sailors discovered that the wind patterns on Earth helped them navigate the oceans. These wind systems are shown in **Figure 17.**

Sometimes sailors found little or no wind to move their sailing ships near the equator. It also rained nearly every afternoon. This windless, rainy zone near the equator is called the doldrums. Look again at **Figure 17.** Near the equator, the Sun heats the air and causes it to rise, creating low pressure and little wind. The rising air then cools, causing rain.

**Reading Check** ***What are the doldrums?***

Science Online

**Topic: Global Winds**
Visit green.msscience.com for Web links to information about global winds.

**Activity** Make a model of Earth showing the locations of global wind patterns.

NATIONAL GEOGRAPHIC

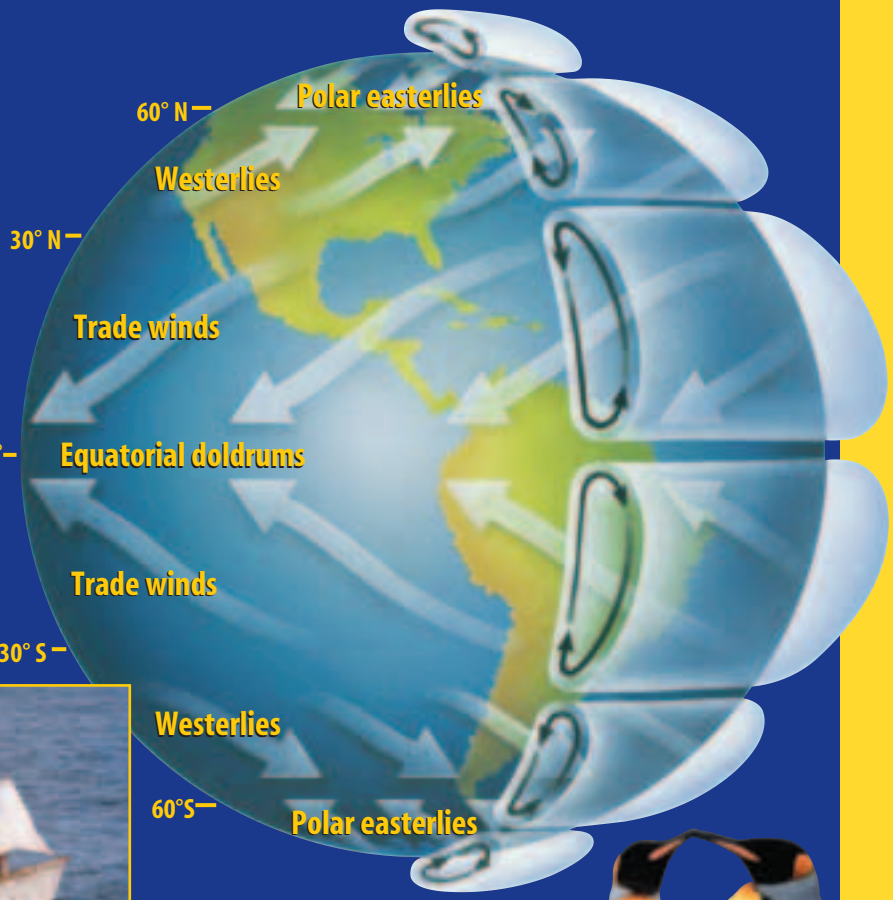
# VISUALIZING GLOBAL WINDS

## Figure 17

The Sun's uneven heating of Earth's surface forms giant loops, or cells, of moving air. The Coriolis effect deflects the surface winds to the west or east, setting up belts of prevailing winds that distribute heat and moisture around the globe.

**A WESTERLIES** Near 30° north and south latitude, Earth's rotation deflects air from west to east as air moves toward the polar regions. In the United States, the westerlies move weather systems, such as this one along the Oklahoma-Texas border, from west to east.

**B DOLDRUMS** Along the equator, heating causes air to expand, creating a zone of low pressure. Cloudy, rainy weather, as shown here, develops almost every afternoon.



**C TRADE WINDS** Air warmed near the equator travels toward the poles but gradually cools and sinks. As the air flows back toward the low pressure of the doldrums, the Coriolis effect deflects the surface wind to the west. Early sailors, in ships like the one above, relied on these winds to navigate global trade routes.

**D POLAR EASTERLIES** In the polar regions, cold, dense air sinks and moves away from the poles. Earth's rotation deflects this wind from east to west.



(cw from top)Gene Moore/PhotoTake NYC/PictureQuest, Phil Schermeister/CORBIS, Joel W. Rogers, Kevin Schafer/CORBIS

**Surface Winds** Air descending to Earth's surface near 30° north and south latitude creates steady winds that blow in tropical regions. These are called trade winds because early sailors used their dependability to establish trade routes.

Between 30° and 60° latitude, winds called the prevailing westerlies blow in the opposite direction from the trade winds. Prevailing westerlies are responsible for much of the movement of weather across North America.

Polar easterlies are found near the poles. Near the north pole, easterlies blow from northeast to southwest. Near the south pole, polar easterlies blow from the southeast to the northwest.

**Winds in the Upper Troposphere** Narrow belts of strong winds, called **jet streams,** blow near the top of the troposphere. The polar jet stream forms at the boundary of cold, dry polar air to the north and warmer, more moist air to the south, as shown in **Figure 18.** The jet stream moves faster in the winter because the difference between cold air and warm air is greater. The jet stream helps move storms across the country.

Jet pilots take advantage of the jet streams. When flying eastward, planes save time and fuel. Going west, planes fly at different altitudes to avoid the jet streams.

## Local Wind Systems

Global wind systems determine the major weather patterns for the entire planet. Smaller wind systems affect local weather. If you live near a large body of water, you're familiar with two such wind systems—sea breezes and land breezes.

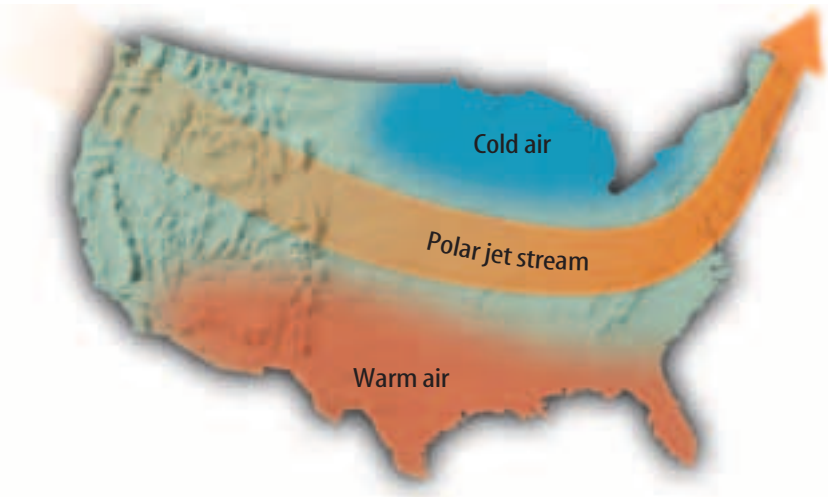



**Figure 18** The polar jet stream affecting North America forms along a boundary where colder air lies to the north and warmer air lies to the south. It is a swiftly flowing current of air that moves in a wavy west-to-east direction and is usually found between 10 km and 15 km above Earth's surface.

Flying from Boston to Seattle may take 30 min longer than flying from Seattle to Boston.

**Think Critically** *Why would it take longer to fly from east to west than it would from west to east?*

Bill Brooks/Masterfile

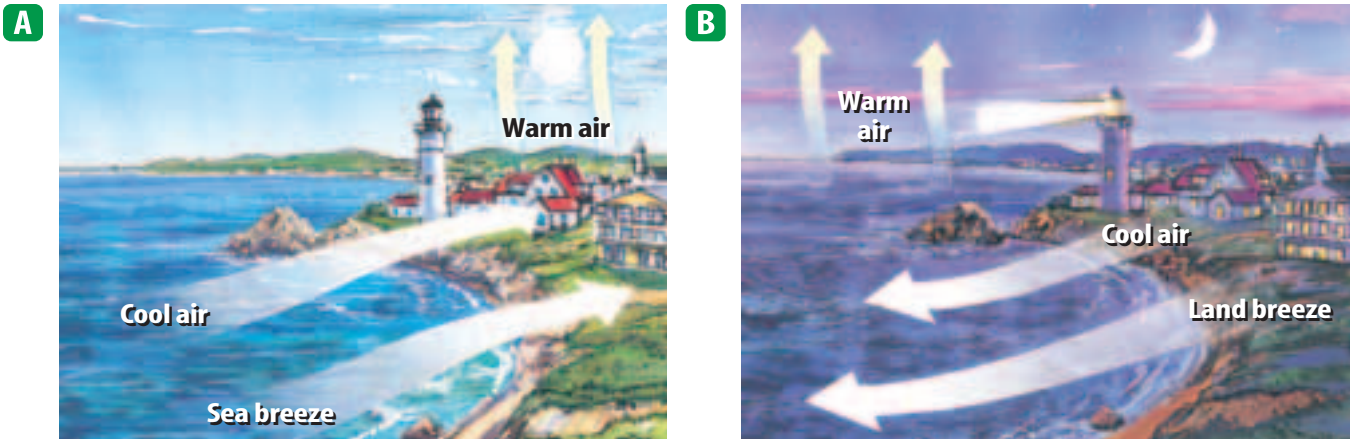



**Figure 19** These daily winds occur because land heats up and cools off faster than water does. A During the day, cool air from the water moves over the land, creating a sea breeze. B At night, cool air over the land moves toward the warmer air over the water, creating a land breeze.

**Sea and Land Breezes** Convection currents over areas where the land meets the sea can cause wind. A **sea breeze,** shown in **Figure 19,** is created during the day because solar radiation warms the land more than the water. Air over the land is heated by conduction. This heated air is less dense and has lower pressure. Cooler, denser air over the water has higher pressure and flows toward the warmer, less dense air. A convection current results, and wind blows from the sea toward the land. The reverse occurs at night, when land cools much more rapidly than ocean water. Air over the land becomes cooler than air over the ocean. Cooler, denser air above the land moves over the water, as the warm air over the water rises. Movement of air toward the water from the land is called a **land breeze.**

**Reading Check** *How does a sea breeze form?*

## section 3 review

### Summary

**Forming Wind**

- Warm air is less dense than cool air.
- Differences in density and pressure cause air movement and wind.
- The Coriolis effect causes moving air to appear to turn right north of the equator and left south of the equator.

**Wind Systems**

- Wind patterns are affected by latitude.
- High-altitude belts of wind, called jet streams, can be found near the top of the troposphere.
- Sea breezes blow from large bodies of water toward land, while land breezes blow from land toward water.

### Self Check

1. **Conclude** why some parts of Earth's surface, such as the equator, receive more of the Sun's heat than other regions.
2. **Explain** how the Coriolis effect influences winds.
3. **Analyze** why little wind and much afternoon rain occur in the doldrums.
4. **Infer** which wind system helped early sailors navigate Earth's oceans.
5. **Think Critically** How does the jet stream help move storms across North America?

**Applying Skills**

6. **Compare and contrast** sea breezes and land breezes.

LAB

Design Your Own

# The Heat Is On

## Goals

- **Design** an experiment to compare heat absorption and release for soil and water.
- **Observe** how heat release affects the air above soil and above water.

## Possible Materials

ring stand
soil
metric ruler
water
masking tape
clear-plastic boxes (2)
overhead light with reflector
thermometers (4)
colored pencils (4)

## Safety Precautions

**WARNING:** *Be careful when handling the hot overhead light. Do not let the light or its cord make contact with water.*

## Real-World Question

Sometimes, a plunge in a pool or lake on a hot summer day feels cool and refreshing. Why does the beach sand get so hot when the water remains cool? A few hours later, the water feels warmer than the land does. How do soil and water compare in their abilities to absorb and emit heat?

## Form a Hypothesis

Form a hypothesis about how soil and water compare in their abilities to absorb and release heat. Write another hypothesis about how air temperatures above soil and above water differ during the day and night.

David Young-Wolff/PhotoEdit, Inc.

## Test Your Hypothesis

### Make a Plan

1. As a group, agree upon and write your hypothesis.
2. **List** the steps that you need to take to test your hypothesis. Include in your plan a description of how you will use your equipment to compare heat absorption and release for water and soil.
3. **Design** a data table in your Science Journal for both parts of your experiment—when the light is on and energy can be absorbed and when the light is off and energy is released to the environment.

### Follow Your Plan

1. Make sure your teacher approves your plan and your data table before you start.
2. Carry out the experiment as planned.
3. During the experiment, record your observations and complete the data table in your Science Journal.
4. Include the temperatures of the soil and the water in your measurements. Also compare heat release for water and soil. Include the temperatures of the air immediately above both of the substances. Allow 15 min for each test.

## Analyze Your Data

1. Use your colored pencils and the information in your data tables to make line graphs. Show the rate of temperature increase for soil and water. Graph the rate of temperature decrease for soil and water after you turn the light off.
2. **Analyze** your graphs. When the light was on, which heated up faster—the soil or the water?
3. **Compare** how fast the air temperature over the water changed with how fast the temperature over the land changed after the light was turned off.

## Conclude and Apply

1. Were your hypotheses supported or not? Explain.
2. **Infer** from your graphs which cooled faster—the water or the soil.
3. **Compare** the temperatures of the air above the water and above the soil 15 minutes after the light was turned off. How do water and soil compare in their abilities to absorb and release heat?

### Communicating Your Data

Make a poster showing the steps you followed for your experiment. Include graphs of your data. Display your poster in the classroom.



David Young-Wolff/PhotoEdit, Inc.

# Song of the Sky Loom[1]

**Brian Swann, ed.**

*This Native American prayer probably comes from the Tewa-speaking Pueblo village of San Juan, New Mexico. The poem is actually a chanted prayer used in ceremonial rituals.*

Mother Earth Father Sky

we are your children
With tired backs we bring you gifts you love
Then weave for us a garment of brightness
its warp[2] the white light of morning,
weft[3] the red light of evening,
fringes the falling rain,
its border the standing rainbow.
Thus weave for us a garment of brightness
So we may walk fittingly where birds sing,
So we may walk fittingly where grass is green.

Mother Earth Father Sky

1 a machine or device from which cloth is produced

2 threads that run lengthwise in a piece of cloth

3 horizontal threads interlaced through the warp in a piece of cloth

## Understanding Literature

**Metaphor** A metaphor is a figure of speech that compares seemingly unlike things. Unlike a simile, a metaphor does not use the connecting words *like* or *as*. Why does the song use the image of a garment to describe Earth's atmosphere?

### Respond to Reading

1. What metaphor does the song use to describe Earth's atmosphere?
2. Why do the words *Mother Earth* and *Father Sky* appear on either side and above and below the rest of the words?
3. **Linking Science and Writing** Write a four-line poem that uses a metaphor to describe rain.

INTEGRATE Earth Science

In this chapter, you learned about the composition of Earth's atmosphere. The atmosphere maintains the proper balance between the amount of heat absorbed from the Sun and the amount of heat that escapes back into space. The water cycle explains how water evaporates from Earth's surface back into the atmosphere. Using metaphor instead of scientific facts, the Tewa song conveys to the reader how the relationship between Earth and its atmosphere is important to all living things.

## Reviewing Main Ideas

### Section 1 Earth's Atmosphere

1. Earth's atmosphere is made up mostly of gases, with some suspended solids and liquids. The unique atmosphere allows life on Earth to exist.
2. The atmosphere is divided into five layers with different characteristics.
3. The ozone layer protects Earth from too much ultraviolet radiation, which can be harmful.

### Section 2 Energy Transfer in the Atmosphere

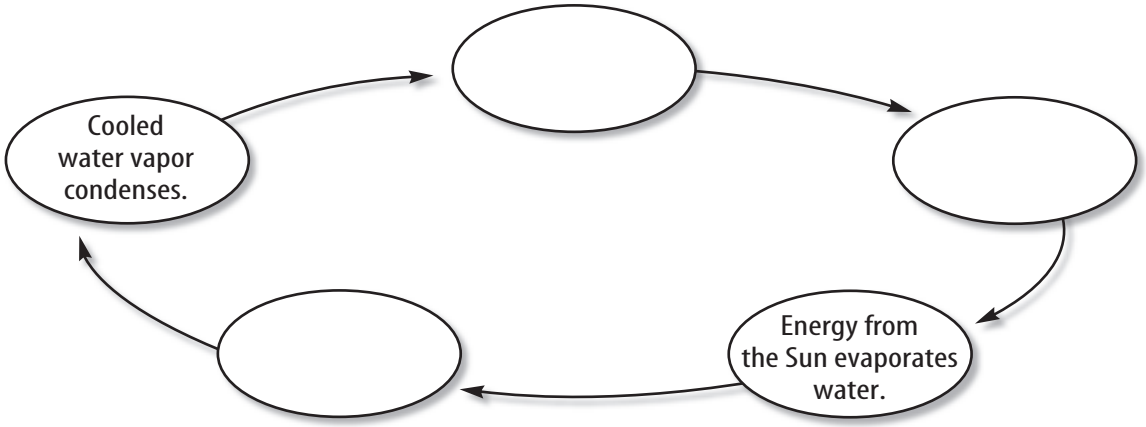
1. Earth receives its energy from the Sun. Some of this energy is reflected back into space, and some is absorbed.
2. Heat is distributed in Earth's atmosphere by radiation, conduction, and convection.
3. Energy from the Sun powers the water cycle between the atmosphere and Earth's surface.
4. Unlike the atmosphere on Mars or Venus, Earth's unique atmosphere maintains a balance between energy received and energy lost that keeps temperatures mild. This delicate balance allows life on Earth to exist.

### Section 3 Air Movement

1. Because Earth's surface is curved, not all areas receive the same amount of solar radiation. This uneven heating causes temperature differences at Earth's surface.
2. Convection currents modified by the Coriolis effect produce Earth's global winds.
3. The polar jet stream is a strong current of wind found in the upper troposphere. It forms at the boundary between cold, polar air and warm, tropical air.
4. Land breezes and sea breezes occur near the ocean.

## Visualizing Main Ideas

*Copy and complete the following cycle map on the water cycle.*



# chapter 4 Review

## Using Vocabulary

atmosphere p. 90
chlorofluorocarbon p. 96
condensation p. 101
conduction p. 100
convection p. 100
Coriolis effect p. 104
hydrosphere p. 101
ionosphere p. 93
jet stream p. 106
land breeze p. 107
ozone layer p. 96
radiation p. 100
sea breeze p. 107
troposphere p. 92
ultraviolet radiation p. 96

*Fill in the blanks below with the correct vocabulary word or words.*

**1.** Chlorofluorocarbons are dangerous because they destroy the _____.

**2.** Narrow belts of strong winds called _____ blow near the top of the troposphere.

**3.** The thin layer of air that surrounds Earth is called the _____.

**4.** Heat energy transferred in the form of waves is called _____.

**5.** The ozone layer helps protect us from _____.

## Checking Concepts

*Choose the word or phrase that best answers the question.*

**6.** Nitrogen makes up what percentage of the atmosphere?
**A)** 21% **C)** 78%
**B)** 1% **D)** 90%

**7.** What causes a brown haze near cities?
**A)** conduction
**B)** mud
**C)** car exhaust
**D)** wind

**8.** Which is the uppermost layer of the atmosphere?
**A)** troposphere **C)** exosphere
**B)** stratosphere **D)** thermosphere

**9.** What layer of the atmosphere has the most water?
**A)** troposphere **C)** mesosphere
**B)** stratosphere **D)** exosphere

**10.** What protects living things from too much ultraviolet radiation?
**A)** the ozone layer **C)** nitrogen
**B)** oxygen **D)** argon

**11.** Where is air pressure least?
**A)** troposphere **C)** exosphere
**B)** stratosphere **D)** thermosphere

**12.** How is energy transferred when objects are in contact?
**A)** trade winds **C)** radiation
**B)** convection **D)** conduction

**13.** Which surface winds are responsible for most of the weather movement across the United States?
**A)** polar easterlies
**B)** sea breeze
**C)** prevailing westerlies
**D)** trade winds

**14.** What type of wind is a movement of air toward water?
**A)** sea breeze
**B)** polar easterlies
**C)** land breeze
**D)** trade winds

**15.** What are narrow belts of strong winds near the top of the troposphere called?
**A)** doldrums
**B)** jet streams
**C)** polar easterlies
**D)** trade winds


Science Online green.msscience.com/vocabulary_puzzlemaker

## Thinking Critically

16. **Explain** why there are few or no clouds in the stratosphere.

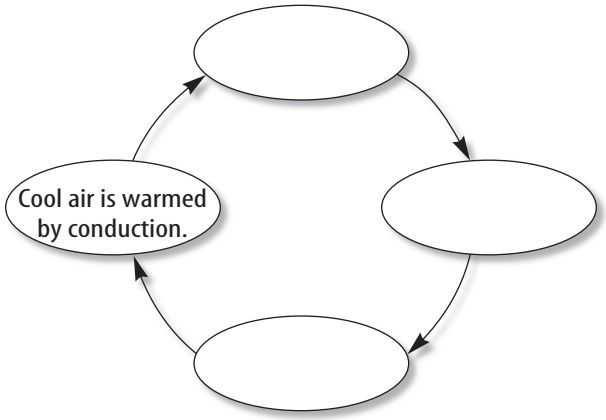
17. **Describe** It is thought that life could not have existed on land until the ozone layer formed about 2 billion years ago. Why does life on land require an ozone layer?

18. **Diagram** Why do sea breezes occur during the day but not at night?

19. **Describe** what happens when water vapor rises and cools.

20. **Explain** why air pressure decreases with an increase in altitude.

21. **Concept Map** Copy and complete the cycle concept map below using the following phrases to explain how air moves to form a convection current: *Cool air moves toward warm air, warm air is lifted and cools, and cool air sinks.*




22. **Form Hypotheses** Carbon dioxide in the atmosphere prevents some radiation from Earth's surface from escaping to space. Hypothesize how the temperature on Earth might change if more carbon dioxide were released from burning fossil fuels.

23. **Identify and Manipulate Variables and Controls** Design an experiment to find out how plants are affected by differing amounts of ultraviolet radiation. In the design, use filtering film made for car windows. What is the variable you are testing? What are your constants? Your controls?

24. **Recognize Cause and Effect** Why is the inside of a car hotter than the outdoor temperature on a sunny summer day?

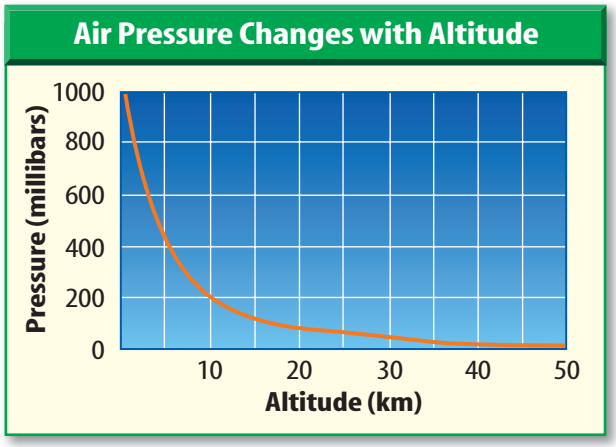
## Performance Activities

25. **Make a Poster** Find newspaper and magazine photos that illustrate how the water cycle affects weather patterns and climate around the world.

26. **Experiment** Design and conduct an experiment to find out how different surfaces such as asphalt, soil, sand, and grass absorb and reflect solar energy. Share the results with your class.

## Applying Math

**Use the graph below to answer questions 27–28.**



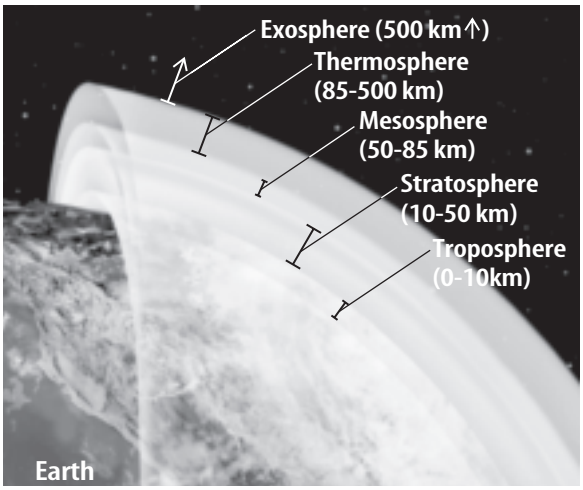

27. **Altitude and Air Pressure** What is the altitude at which air pressure is about 1,000 millibars? What is it at 200 millibars?

28. **Mt. Everest** Assume the altitude on Mt. Everest is about 10 km high. How many times greater is air pressure at sea level than on top of Mt. Everest?

## Part 1 Multiple Choice

*Record your answers on the answer sheet provided by your teacher or on a sheet of paper.*

**Use the illustration below to answer questions 1–3.**




**1.** Which layer of the atmosphere contains the ozone layer?
- **A.** exosphere
- **B.** mesosphere
- **C.** stratosphere
- **D.** troposphere

**2.** Which atmospheric layer contains weather?
- **A.** mesosphere
- **B.** stratosphere
- **C.** thermosphere
- **D.** troposphere

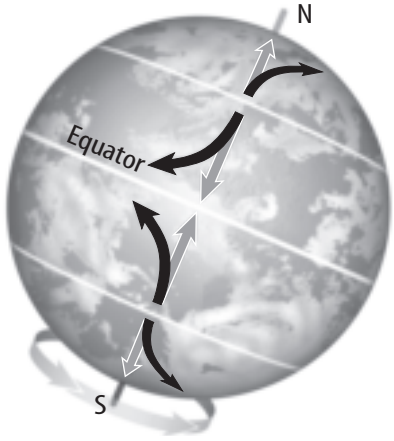
**3.** Which atmospheric layer contains electrically charged particles?
- **A.** stratosphere
- **B.** ionosphere
- **C.** exosphere
- **D.** troposphere

**4.** What process changes water vapor to a liquid?
- **A.** condensation
- **B.** evaporation
- **C.** infiltration
- **D.** precipitation

**5.** Which process transfers heat by contact?
- **A.** conduction
- **B.** convection
- **C.** evaporation
- **D.** radiation

**6.** Which global wind affects weather in the U.S.?
- **A.** doldrums
- **B.** easterlies
- **C.** trade winds
- **D.** westerlies

**Use the illustration below to answer question 7.**




**7.** Which deflects winds to the west or east?
- **A.** convection
- **B.** Coriolis effect
- **C.** jet stream
- **D.** radiation

**8.** Which forms during the day because water heats slower than land?
- **A.** easterlies
- **B.** westerlies
- **C.** land breeze
- **D.** sea breeze

**9.** Which is the most abundant gas in Earth's atmosphere?
- **A.** carbon dioxide
- **B.** nitrogen
- **C.** oxygen
- **D.** water vapor

## Part 2 Short Response/Grid In

*Record your answers on the answer sheet provided by your teacher or on a sheet of paper.*

**10.** Why does pressure drop as you travel upward from Earth's surface?

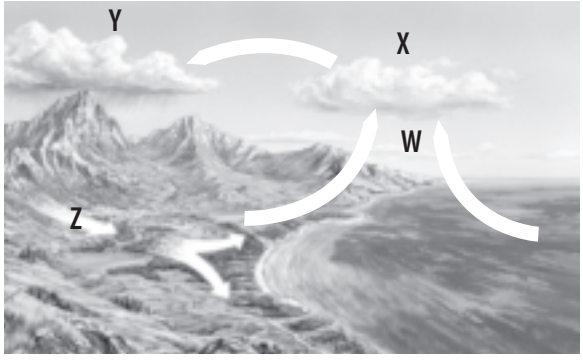
**11.** Why does the equator receive more radiation than areas to the north or south?

**12.** Why does a land breeze form at night?

**13.** Why does the jet stream move faster in the winter?

**14.** Why is one global wind pattern known as the trade winds?

**Use the illustration below to answer questions 15–17.**




**15.** What process is illustrated?

**16.** Explain how this cycle affects weather patterns and climate.

**17.** What happens to water that falls as precipitation and does not runoff and flow into streams?

**18.** How do solid particles become part of Earth's atmosphere?

**19.** Why can flying from Seattle to Boston take less time than flying from Boston to Seattle in the same aircraft?

## Part 3 Open Ended

*Record your answers on a sheet of paper.*

**20.** Explain how ozone is destroyed by chlorofluorocarbons.

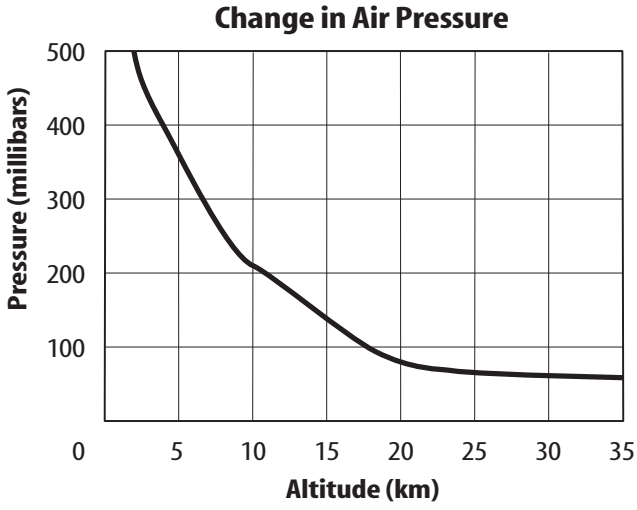
**21.** Explain how Earth can heat the air by conduction.

**22.** Explain how humans influence the composition of Earth's atmosphere.

**23.** Draw three diagrams to demonstrate radiation, convection, and conduction.

**24.** Explain why the doldrums form over the equator.

## Part 2 Constructed Response




**25.** As you increase in altitude what happens to the air pressure? How might this affect people who move to the mountains?

**Test-Taking Tip**

**Trends in Graphs** When analyzing data in a table or graph, look for a trend. Questions about the pattern may use words like *increase, decrease, hypothesis,* or *summary.*

**Question 25** The word "increase" indicates that you should look for the trend in air pressure as altitude increases.