SECTION 2

Atmospheric Heating

You are lying in a park. Your eyes are closed, and you feel the warmth of the sun on your face. You may have done this before, but have you ever stopped to think that it takes a little more than eight minutes for the energy that warms your face to travel from a star that is 149,000,000 km away?

What You Will Learn

- Describe what happens to solar energy that reaches Earth.
- Summarize the processes of radiation, thermal conduction, and convection.
- Explain the relationship between the greenhouse effect and global warming.

Vocabulary

radiation
thermal conduction
convection
global warming
greenhouse effect

READING STRATEGY

Reading Organizer As you read this section, make a table comparing radiation, conduction, and convection.

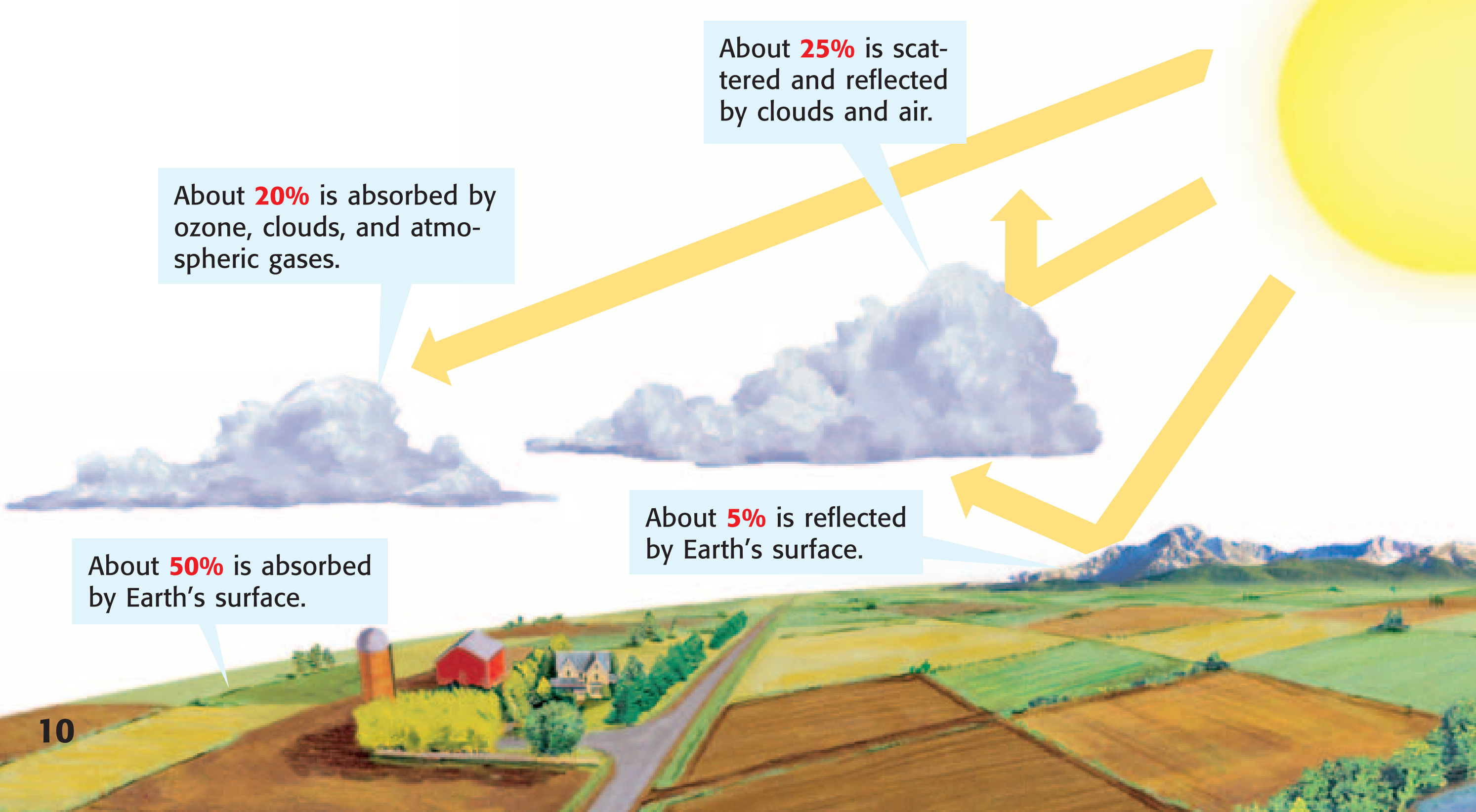
Energy in the Atmosphere

In the scenario above, your face was warmed by energy from the sun. Earth and its atmosphere are also warmed by energy from the sun. In this section, you will find out what happens to solar energy as it enters the atmosphere.

Radiation: Energy Transfer by Waves

The Earth receives energy from the sun by radiation. **Radiation** is the transfer of energy as electromagnetic waves. Although the sun radiates a huge amount of energy, Earth receives only about two-billionths of this energy. But this small fraction of energy is enough to drive the weather cycle and make Earth habitable. **Figure 1** shows what happens to solar energy once it enters the atmosphere.

Figure 1 *Energy from the sun is absorbed by the atmosphere, land, and water and is changed into thermal energy.*



Conduction: Energy Transfer by Contact

If you have ever touched something hot, you have experienced the process of conduction. **Thermal conduction** is the transfer of thermal energy through a material. Thermal energy is always transferred from warm to cold areas. When air molecules come into direct contact with the warm surface of Earth, thermal energy is transferred to the atmosphere.

radiation the transfer of energy as electromagnetic waves

thermal conduction the transfer of energy as heat through a material

convection the transfer of thermal energy by the circulation or movement of a liquid or gas

Convection: Energy Transfer by Circulation

If you have ever watched a pot of water boil, you have observed convection. **Convection** is the transfer of thermal energy by the circulation or movement of a liquid or gas. Most thermal energy in the atmosphere is transferred by convection. For example, as air is heated, it becomes less dense and rises. Cool air is denser, so it sinks. As the cool air sinks, it pushes the warm air up. The cool air is eventually heated by the Earth's surface and begins to rise again. This cycle of warm air rising and cool air sinking causes a circular movement of air, called a *convection current,* as shown in **Figure 2.**

Reading Check **How do differences in air density cause convection currents? (*See the Appendix for answers to Reading Checks.*)**

Figure 2 *The processes of radiation, thermal conduction, and convection heat Earth and its atmosphere.*

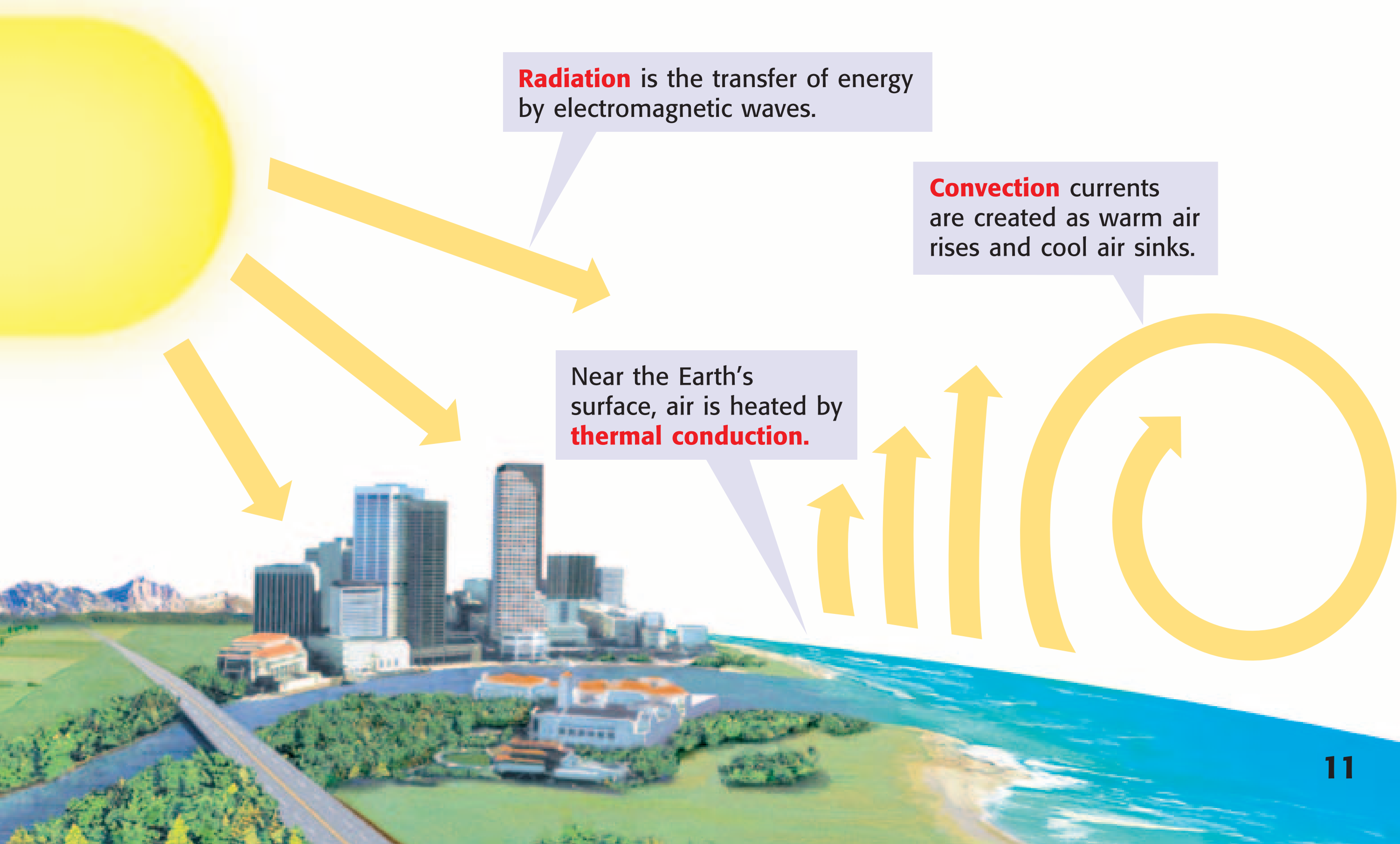
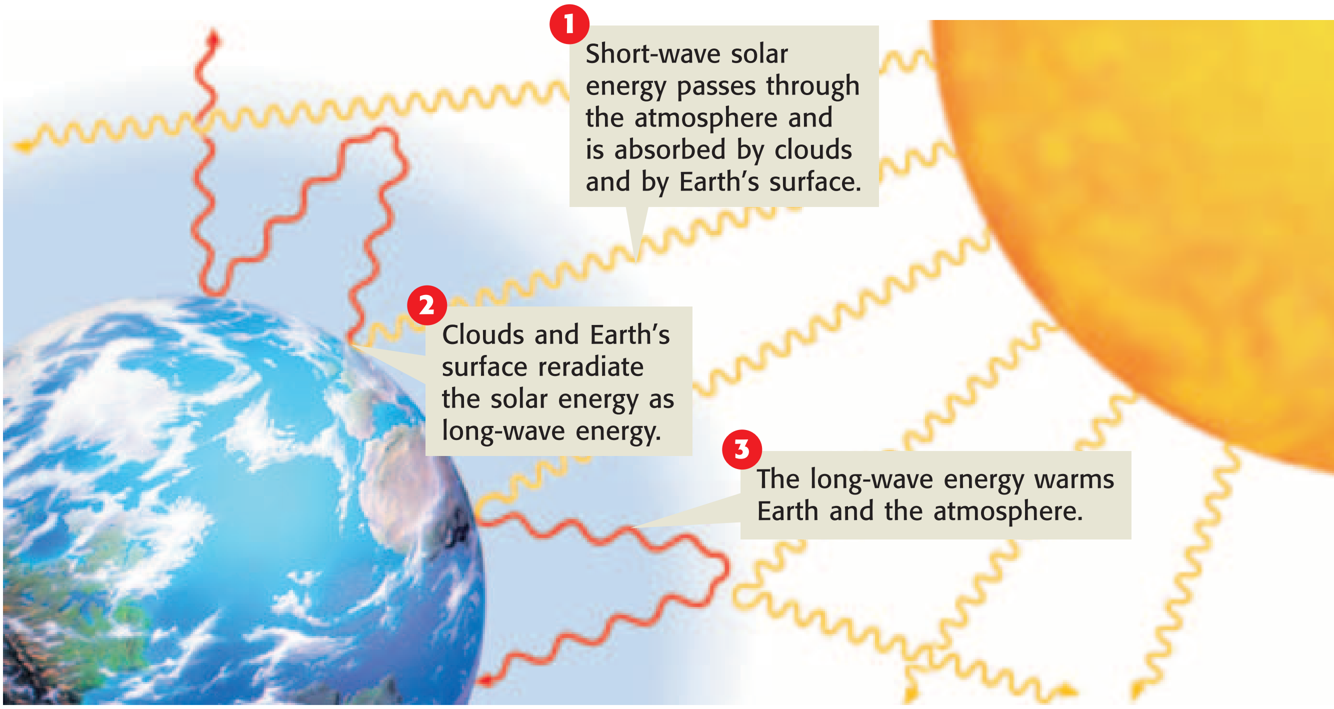


Figure 3 **The Greenhouse Effect**



The Greenhouse Effect and Life on Earth

As you have learned, about 70% of the radiation that enters Earth's atmosphere is absorbed by clouds and by the Earth's surface. This energy is converted into thermal energy that warms the planet. In other words, short-wave visible light is absorbed and reradiated into the atmosphere as long-wave thermal energy. So, why doesn't this thermal energy escape back into space? Most of it does, but the atmosphere is like a warm blanket that traps enough energy to make Earth livable. This process, shown in **Figure 3,** is called the greenhouse effect. The **greenhouse effect** is the process by which gases in the atmosphere, such as water vapor and carbon dioxide, absorb thermal energy and radiate it back to Earth. This process is called the greenhouse effect because the gases function like the glass walls and roof of a greenhouse, which allow solar energy to enter but prevent thermal energy from escaping.

greenhouse effect the warming of the surface and lower atmosphere of Earth that occurs when water vapor, carbon dioxide, and other gases absorb and reradiate thermal energy

The Radiation Balance: Energy In, Energy Out

For Earth to remain livable, the amount of energy received from the sun and the amount of energy returned to space must be approximately equal. Solar energy that is absorbed by the Earth and its atmosphere is eventually reradiated into space as thermal energy. Every day, the Earth receives more energy from the sun. The balance between incoming energy and outgoing energy is known as the *radiation balance*.

Greenhouse Gases and Global Warming

Many scientists have become concerned about data that show that average global temperatures have increased in the past 100 years. Such an increase in average global temperatures is called **global warming.** Some scientists have hypothesized that an increase of greenhouse gases in the atmosphere may be the cause of this warming trend. Greenhouse gases are gases that absorb thermal energy in the atmosphere.

global warming a gradual increase in average global temperature

Human activity, such as the burning of fossil fuels and deforestation, may be increasing levels of greenhouse gases, such as carbon dioxide, in the atmosphere. If this hypothesis is correct, increasing levels of greenhouse gases may cause average global temperatures to continue to rise. If global warming continues, global climate patterns could be disrupted. Plants and animals that are adapted to live in specific climates would be affected. However, climate models are extremely complex, and scientists continue to debate whether the global warming trend is the result of an increase in greenhouse gases.

Reading Check **What is a greenhouse gas?**

SECTION Review

Summary

- Energy from the sun is transferred through the atmosphere by radiation, thermal conduction, and convection.
- Radiation is energy transfer by electromagnetic waves. Thermal conduction is energy transfer by direct contact. Convection is energy transfer by circulation.
- The greenhouse effect is Earth's natural heating process. Increasing levels of greenhouse gases could cause global warming.

Using Key Terms

1. Use each of the following terms in a separate sentence: *thermal conduction, radiation, convection, greenhouse effect,* and *global warming.*

Understanding Key Ideas

2. Which of the following is the best example of thermal conduction?
   - a. a light bulb warming a lampshade
   - b. an egg cooking in a frying pan
   - c. water boiling in a pot
   - d. gases circulating in the atmosphere
3. Describe three ways that energy is transferred in the atmosphere.
4. What is the difference between the greenhouse effect and global warming?
5. What is the radiation balance?

Math Skills

6. Find the average of the following temperatures: 73.2°F, 71.1°F, 54.6°F, 65.5°F, 78.2°F, 81.9°F, and 82.1°F.

Critical Thinking

7. **Identifying Relationships** How does the process of convection rely on radiation?
8. **Applying Concepts** Describe global warming in terms of the radiation balance.

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For a variety of links related to this chapter, go to www.scilinks.org

Topic: Energy in the Atmosphere
SciLinks code: HSM0512

SECTION 3

Global Winds and Local Winds

If you open the valve on a bicycle tube, the air rushes out. Why? The air inside the tube is at a higher pressure than the air is outside the tube. In effect, letting air out of the tube created a wind.

What You Will Learn

- Explain the relationship between air pressure and wind direction.
- Describe global wind patterns.
- Explain the causes of local wind patterns.

Vocabulary

wind
Coriolis effect
polar easterlies
westerlies
trade winds
jet stream

READING STRATEGY

Prediction Guide Before reading this section, write the title of each heading in this section. Next, under each heading, write what you think you will learn.

wind the movement of air caused by differences in air pressure

Why Air Moves

The movement of air caused by differences in air pressure is called **wind.** The greater the pressure difference, the faster the wind moves. The devastation shown in **Figure 1** was caused by winds that resulted from extreme differences in air pressure.

Air Rises at the Equator and Sinks at the Poles

Differences in air pressure are generally caused by the unequal heating of the Earth. The equator receives more direct solar energy than other latitudes, so air at the equator is warmer and less dense than the surrounding air. Warm, less dense air rises and creates an area of low pressure. This warm, rising air flows toward the poles. At the poles, the air is colder and denser than the surrounding air, so it sinks. As the cold air sinks, it creates areas of high pressure around the poles. This cold polar air then flows toward the equator.

Figure 1 *In 1992, Hurricane Andrew became the most destructive hurricane in U.S. history. The winds from the hurricane reached 264 km/h.*

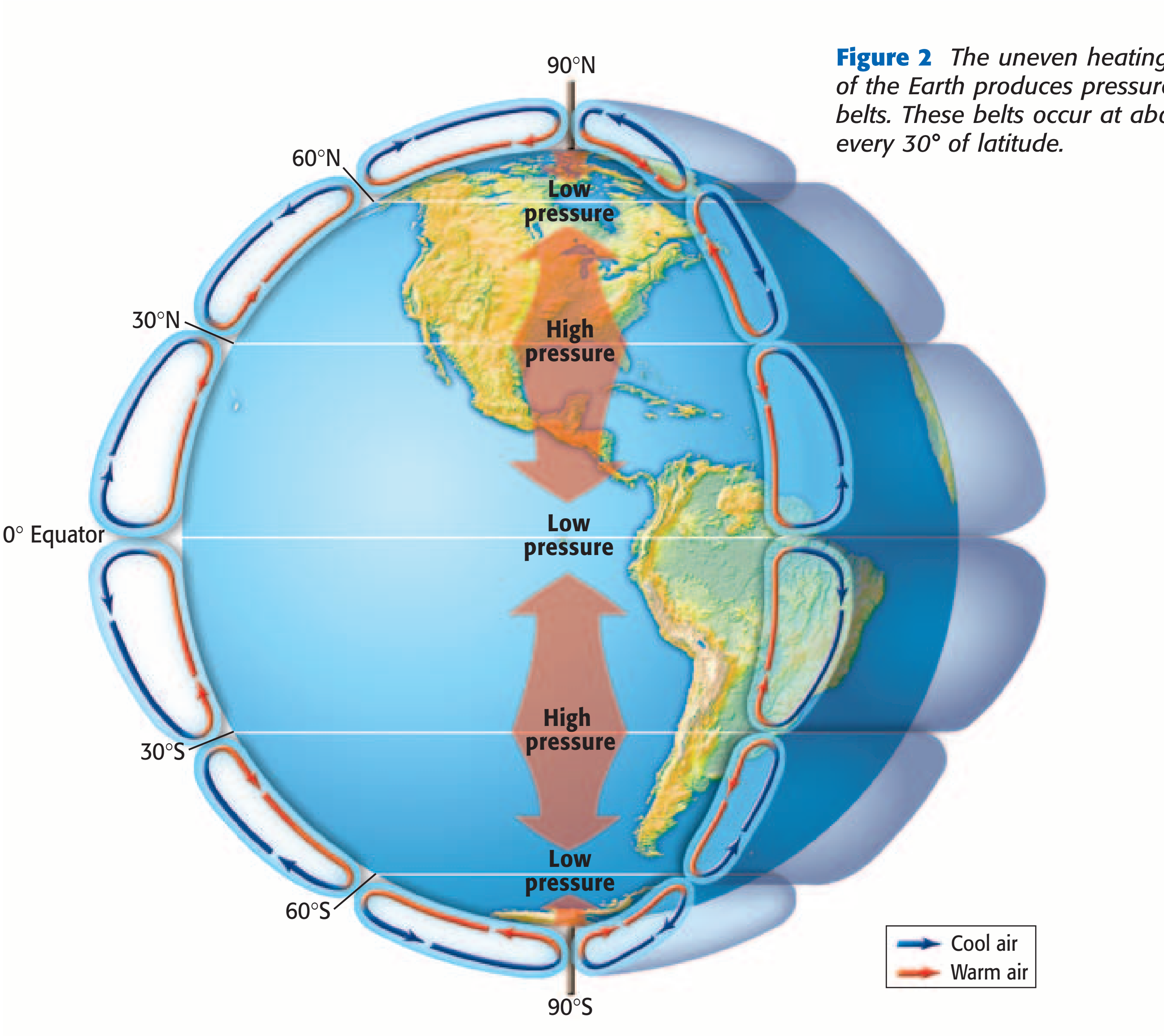


Figure 2 *The uneven heating of the Earth produces pressure belts. These belts occur at about every 30° of latitude.*

Pressure Belts Are Found Every 30°

You may imagine that wind moves in one huge, circular pattern from the poles to the equator. In fact, air travels in many large, circular patterns called *convection cells*. Convection cells are separated by *pressure belts,* bands of high pressure and low pressure found about every 30° of latitude, as shown in **Figure 2.** As warm air rises over the equator and moves toward the poles, the air begins to cool. At about 30° north and 30° south latitude, some of the cool air begins to sink. Cool, sinking air causes high pressure belts near 30° north and 30° south latitude. This cool air flows back to the equator, where it warms and rises again. At the poles, cold air sinks and moves toward the equator. Air warms as it moves away from the poles. Around 60° north and 60° south latitude, the warmer air rises, which creates a low pressure belt. This air flows back to the poles.

Reading Check **Why does sinking air cause areas of high pressure?** (*See the Appendix for answers to Reading Checks*.)

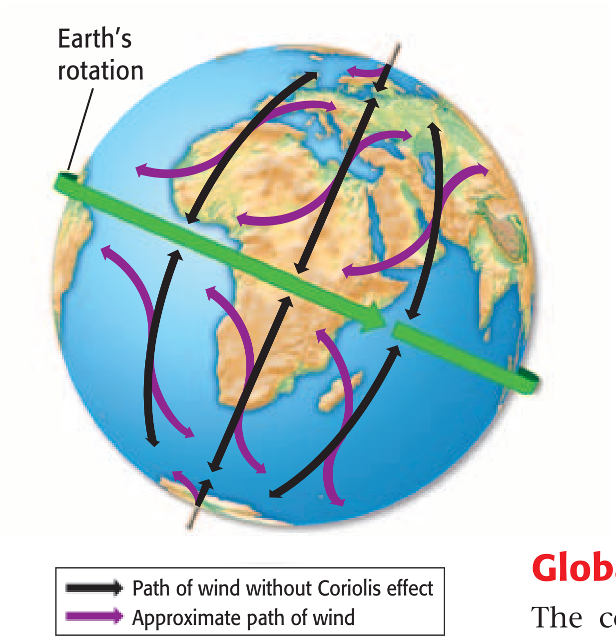


Figure 3 *The Coriolis effect in the Northern Hemisphere causes winds traveling north to appear to curve to the east and winds traveling south to appear to curve to the west.*

The Coriolis Effect

As you have learned, pressure differences cause air to move between the equator and the poles. But try spinning a globe and using a piece of chalk to trace a straight line from the equator to the North Pole. The chalk line curves because the globe was spinning. Like the chalk line, winds do not travel directly north or south, because the Earth is rotating. The apparent curving of the path of winds and ocean currents due to the Earth's rotation is called the **Coriolis effect.** Because of the Coriolis effect in the Northern Hemisphere, winds traveling north curve to the east, and winds traveling south curve to the west, as shown in **Figure 3.**

Global Winds

The combination of convection cells found at every 30° of latitude and the Coriolis effect produces patterns of air circulation called *global winds*. **Figure 4** shows the major global wind systems: polar easterlies, westerlies, and trade winds. Winds such as easterlies and westerlies are named for the direction from which they blow.

Polar Easterlies

The wind belts that extend from the poles to 60° latitude in both hemispheres are called the **polar easterlies.** The polar easterlies are formed as cold, sinking air moves from the poles toward 60° north and 60° south latitude. In the Northern Hemisphere, polar easterlies can carry cold arctic air over the United States, producing snow and freezing weather.

Westerlies

The wind belts found between 30° and 60° latitude in both hemispheres are called the **westerlies.** The westerlies flow toward the poles from west to east. The westerlies can carry moist air over the United States, producing rain and snow.

Trade Winds

In both hemispheres, the winds that blow from 30° latitude almost to the equator are called **trade winds.** The Coriolis effect causes the trade winds to curve to the west in the Northern Hemisphere and to the east in the Southern Hemisphere. Early traders used the trade winds to sail from Europe to the Americas. As a result, the winds became known as "trade winds."

Reading Check **If the trade winds carried traders from Europe to the Americas, what wind system carried traders back to Europe?**

Coriolis effect the apparent curving of the path of a moving object from an otherwise straight path due to the Earth's rotation

polar easterlies prevailing winds that blow from east to west between 60° and 90° latitude in both hemispheres

westerlies prevailing winds that blow from west to east between 30° and 60° latitude in both hemispheres

trade winds prevailing winds that blow northeast from 30° north latitude to the equator and that blow southeast from 30° south latitude to the equator

The Doldrums

The trade winds of the Northern and Southern Hemispheres meet in an area around the equator called the *doldrums*. In the doldrums, there is very little wind because the warm, rising air creates an area of low pressure. The name *doldrums* means "dull" or "sluggish."

The Horse Latitudes

At about 30° north and 30° south latitude, sinking air creates an area of high pressure. The winds at these locations are weak. These areas are called the *horse latitudes*. According to legend, this name was given to these areas when sailing ships carried horses from Europe to the Americas. When the ships were stuck in this windless area, horses were sometimes thrown overboard to save drinking water for the sailors. Most of the world's deserts are located in the horse latitudes because the sinking air is very dry.

INTERNET ACTIVITY

For another activity related to this chapter, go to **go.hrw.com** and type in the keyword **HZ5ATMW.**

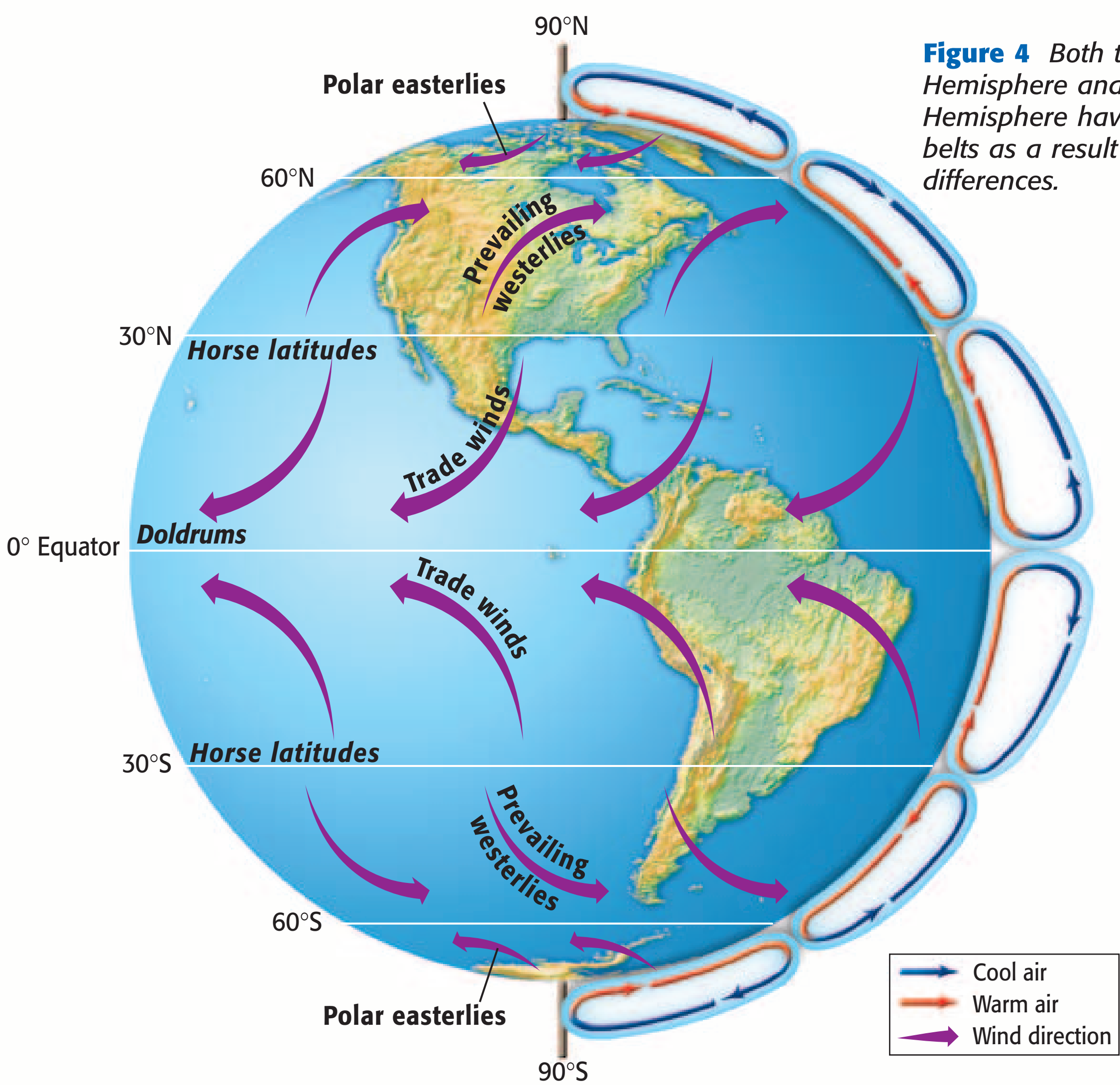


Figure 4 *Both the Northern Hemisphere and the Southern Hemisphere have three wind belts as a result of pressure differences.*

Figure 5 *The jet stream forms this band of clouds as it flows above the Earth.*

Jet Streams: Atmospheric Conveyor Belts

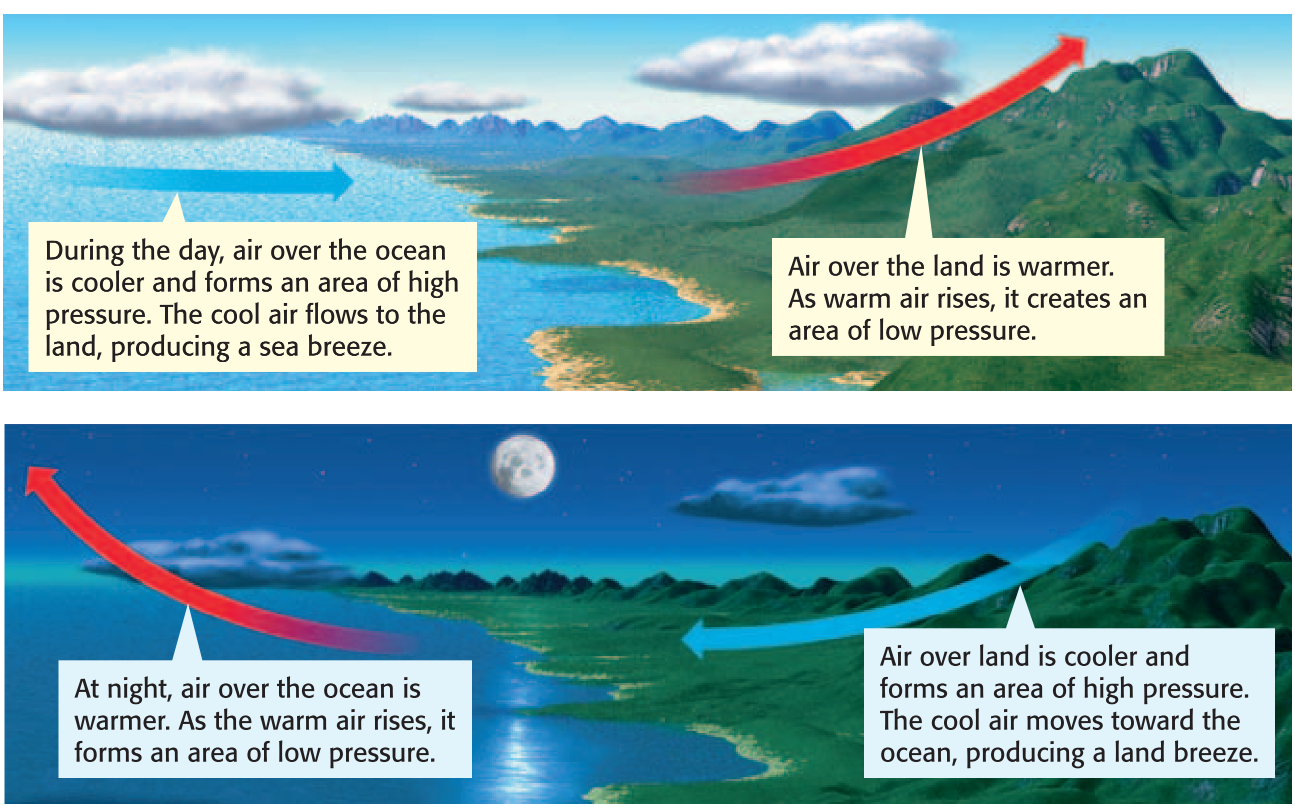
The flight from Seattle to Boston can be 30 minutes faster than the flight from Boston to Seattle. Why? Pilots take advantage of a jet stream similar to the one shown in **Figure 5.** The **jet streams** are narrow belts of high-speed winds that blow in the upper troposphere and lower stratosphere. These winds can reach maximum speeds of 400 km/h. Unlike other global winds, the jet streams do not follow regular paths around the Earth. Knowing the path of a jet stream is important not only to pilots but also to meteorologists. Because jet streams affect the movement of storms, meteorologists can track a storm if they know the location of a jet stream.

jet stream a narrow belt of strong winds that blow in the upper troposphere

Local Winds

Local winds generally move short distances and can blow from any direction. Local geographic features, such as a shoreline or a mountain, can produce temperature differences that cause local winds. For example, the formation of sea and land breezes is shown in **Figure 6.** During the day, the land heats up faster than the water, so the air above the land becomes warmer than the air above the ocean. The warm land air rises, and the cold ocean air flows in to replace it. At night, the land cools faster than water, so the wind blows toward the ocean.

Figure 6 **Sea and Land Breezes**



Mountain Breezes and Valley Breezes

Mountain and valley breezes are other examples of local winds caused by an area's geography. Campers in mountainous areas may feel a warm afternoon quickly change into a cold night soon after the sun sets. During the day, the sun warms the air along the mountain slopes. This warm air rises up the mountain slopes, creating a valley breeze. At nightfall, the air along the mountain slopes cools. This cool air moves down the slopes into the valley, producing a mountain breeze.

Reading Check **Why does the wind tend to blow down from mountains at night?**

CONNECTION TO Social Studies

Local Breezes The chinook, the shamal, the sirocco, and the Santa Ana are all local winds. Find out about an interesting local wind, and create a poster-board display that shows how the wind forms and how it affects human cultures.

ACTIVITY

SECTION Review

Summary

- Winds blow from areas of high pressure to areas of low pressure.
- Pressure belts are found approximately every 30° of latitude.
- The Coriolis effect causes wind to appear to curve as it moves across the Earth's surface.
- Global winds include the polar easterlies, the westerlies, and the trade winds.
- Local winds include sea and land breezes and mountain and valley breezes.

Using Key Terms

1. In your own words, write a definition for each of the following terms: *wind, Coriolis effect, jet stream, polar easterlies, westerlies,* and *trade winds.*

Understanding Key Ideas

2. Why does warm air rise and cold air sink?
   a. because warm air is less dense than cold air
   b. because warm air is denser than cold air
   c. because cold air is less dense than warm air
   d. because warm air has less pressure than cold air does
3. What are pressure belts?
4. What causes winds?
5. How does the Coriolis effect affect wind movement?
6. How are sea and land breezes similar to mountain and valley breezes?
7. Would there be winds if the Earth's surface were the same temperature everywhere? Explain your answer.

Math Skills

8. Flying an airplane at 500 km/h, a pilot plans to reach her destination in 5 h. But she finds a jet stream moving 250 km/h in the direction she is traveling. If she gets a boost from the jet stream for 2 h, how long will the flight last?

Critical Thinking

9. **Making Inferences** In the Northern Hemisphere, why do westerlies flow from the west but trade winds flow from the east?
10. **Applying Concepts** Imagine you are near an ocean in the daytime. You want to go to the ocean, but you don't know how to get there. How might a local wind help you find the ocean?

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