SECTION 2

The Atmosphere

Earth is surrounded by a mixture of gases known as the **atmosphere.** Nitrogen, oxygen, carbon dioxide, and other gases are all parts of this mixture. Earth's atmosphere changes constantly as these gases are added and removed. For example, animals remove oxygen when they breathe in and add carbon dioxide when they breathe out. Plants take in carbon dioxide and add oxygen to the atmosphere when they produce food. Gases can be added to and removed from the atmosphere in ways other than through living organisms. A volcanic eruption adds gases. A vehicle both adds and removes gases.

The atmosphere also insulates Earth's surface. This insulation slows the rate at which heat from the sun is lost. The atmosphere keeps Earth at temperatures at which living things can survive.

Objectives

- Describe the composition of the Earth's atmosphere.
- Describe the layers of the Earth's atmosphere.
- Explain three mechanisms of heat transfer in Earth's atmosphere.
- Explain the greenhouse effect.

Key Terms

atmosphere
troposphere
stratosphere
ozone
radiation
conduction
convection
greenhouse effect

Composition of the Atmosphere

Figure 10 shows the percentages of gases that make up Earth's atmosphere. Nitrogen makes up 78 percent of the Earth's atmosphere. It enters the atmosphere when volcanoes erupt and when dead plants and animals decay. Oxygen, the second most abundant gas in Earth's atmosphere, is primarily produced by plants. Gases including argon, carbon dioxide, methane, and water vapor make up the rest of the atmosphere.

In addition to gases, the atmosphere contains many types of tiny, solid particles, or atmospheric dust. Atmospheric dust is mainly soil but includes salt, ash from fires, volcanic ash, particulate matter from combustion, skin, hair, bits of clothing, pollen, bacteria and viruses, and tiny, liquid droplets called *aerosols*.

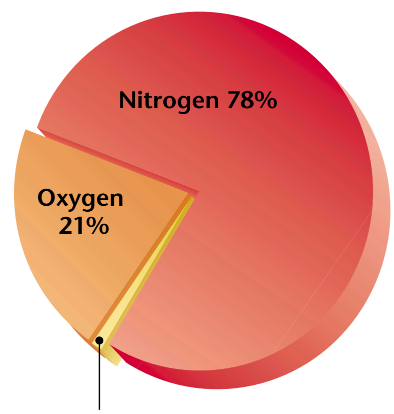

Figure 10 ▶ Ninety-nine percent of the air we breathe is made up of nitrogen and oxygen.

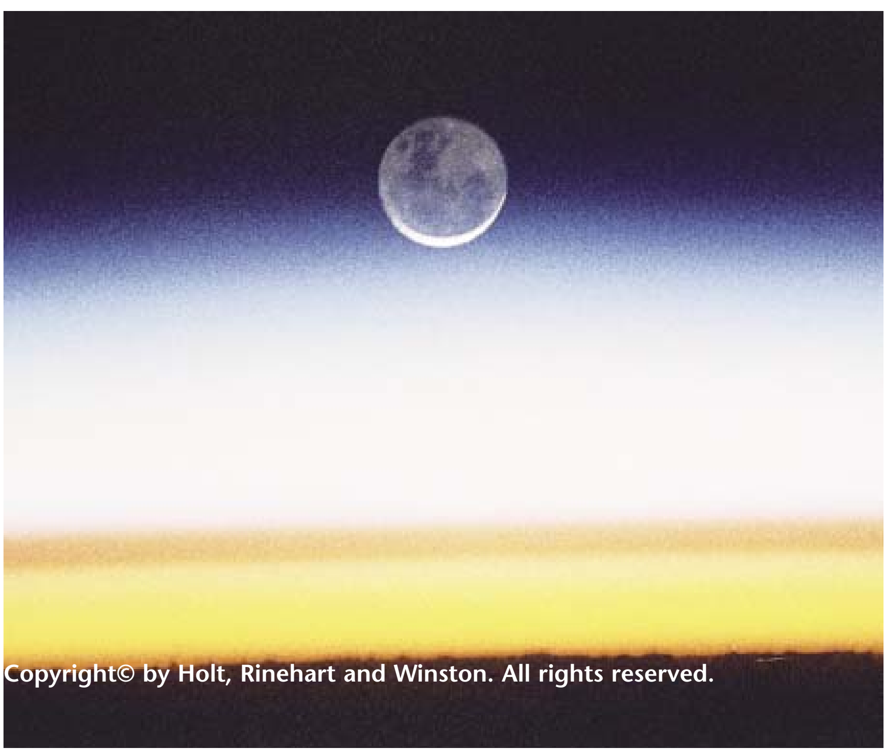

Figure 11 ▶ This sunrise scene that was taken from space captures the tropopause, the transitional zone that separates the troposphere (yellow layer) from the stratosphere (white layer). The tropopause is the illuminated brown layer.

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Air Pressure Earth's atmosphere is pulled toward Earth's surface by gravity. As a result of the pull of gravity, the atmosphere is denser near Earth's surface. Almost the entire mass of Earth's atmospheric gases is located within 30 km of our planet's surface. Fewer gas molecules are found at altitudes above 30 km; therefore, less pressure at these altitudes pushes downward on atmospheric gases. The air also becomes less dense as elevation increases, so breathing at higher elevations is more difficult.

Layers of the Atmosphere

The atmosphere is divided into four layers based on temperature changes that occur at different distances above the Earth's surface. **Figure 12** shows the four layers of Earth's atmosphere.

The Troposphere The atmospheric layer nearest Earth's surface is the troposphere. The **troposphere** extends to 18 km above Earth's surface. Almost all of the weather occurs in this layer, as shown in **Figure 13.** The troposphere is Earth's densest atmospheric layer. Temperature decreases as altitude increases in the troposphere.

Geofact

The Mesosphere In geology, the term *mesosphere,* which means "middle sphere," refers to the 2,550 km thick compositional layer of the Earth that lies below the asthenosphere. The mesosphere is also the name of the atmospheric layer that extends from 50 to 80 km above Earth's surface.

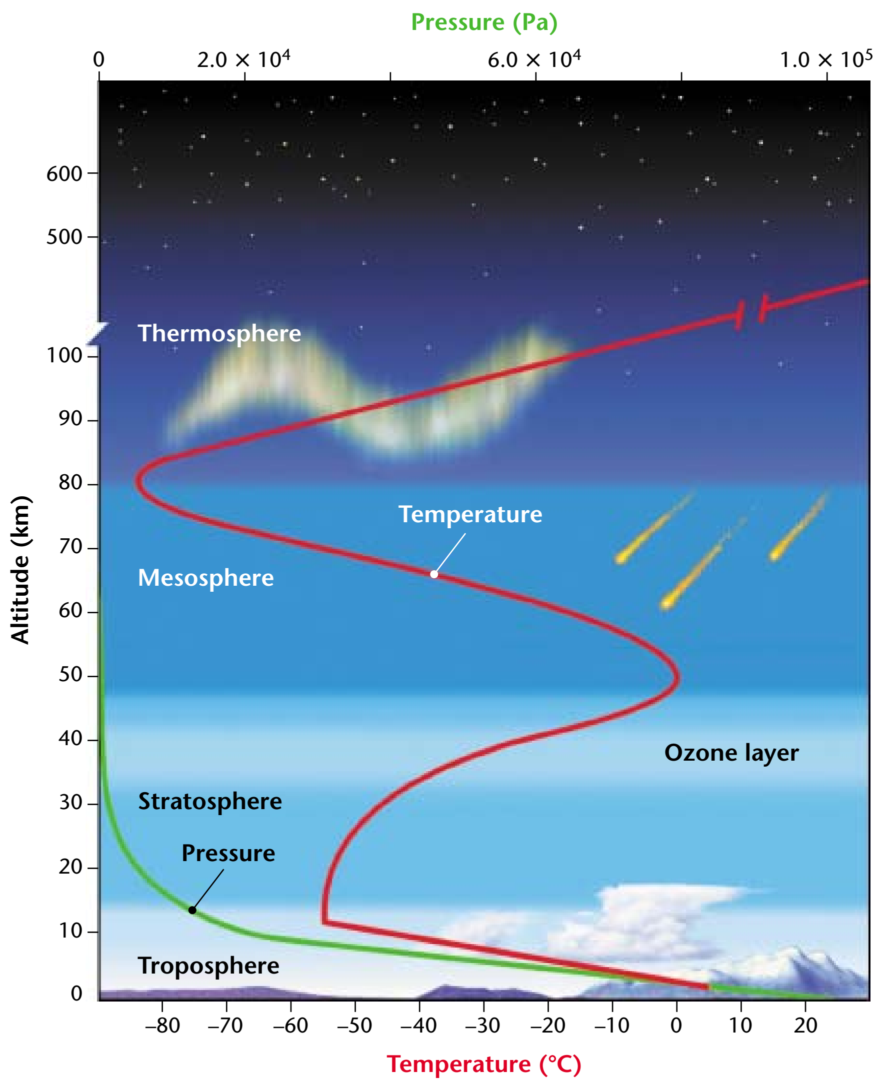


Figure 12 ▶ The layers of the atmosphere are defined by changes in temperature and pressure. The red line indicates temperature, and the green line indicates pressure in pascals.

Figure 13 ▶ Scientists on board a research plane from the National Oceanic and Atmospheric Administration (NOAA) are making measurements of temperature, humidity, barometric pressure, and wind speed as they fly over the eye of a hurricane.

The Stratosphere Above the troposphere is the stratosphere. The **stratosphere** extends from 18 km to an altitude of about 50 km. Temperatures rise as altitude increases in the stratosphere. This change happens because ozone in the stratosphere absorbs the sun's ultraviolet (UV) energy and warms the air. **Ozone,** O_3, is a molecule that is made up of three oxygen atoms. Almost all the ozone in the atmosphere is concentrated in the ozone layer in the stratosphere. Because ozone absorbs UV radiation, it reduces the amount of UV radiation that reaches the Earth. UV radiation that reaches Earth can damage living cells.

The Mesosphere The layer above the stratosphere is the *mesosphere*. This layer extends to an altitude of about 80 km. The mesosphere is the coldest layer of the atmosphere, and its temperatures have been measured as low as –93°C.

The Thermosphere The atmospheric layer located farthest from Earth's surface is the *thermosphere*. In the thermosphere, nitrogen and oxygen absorb solar radiation, which results in temperatures that have been measured above 2,000°C. Even though air temperatures in this layer are very high, the thermosphere would not feel hot to us. Air particles that strike one another transfer heat. The air in the thermosphere is so thin that air particles rarely collide, so little heat is transferred.

Nitrogen and oxygen atoms in the lower region of the thermosphere (about 80 km to 550 km above Earth's surface) absorb harmful solar radiation, such as X rays and gamma rays. This absorption causes atoms to become electrically charged. Electrically charged atoms are called *ions*. The lower thermosphere is called the *ionosphere*. Sometimes ions radiate energy as light. These lights often glow in spectacular colors in the night skies near the Earth's North and South Poles, as shown in **Figure 14.**

Figure 14 ▶ The *aurora borealis,* or Northern Lights, can be seen in the skies around Earth's North Pole.

QuickLAB

The Heat Is On!

Procedure

1. Fill two **250 mL beakers** with **water.** Use a **thermometer** to record the initial temperature of the water in both beakers. The temperature of the water should be the same for both beakers.
2. Wrap one beaker with **white paper**, and wrap one with **black paper.** Secure the paper with a piece of **tape.**
3. Place a **150 W floodlight** 50 cm away from the beakers, and turn the light on.
4. Record the temperature of the water in both beakers at 1 min, 5 min, and 10 min.

Analysis

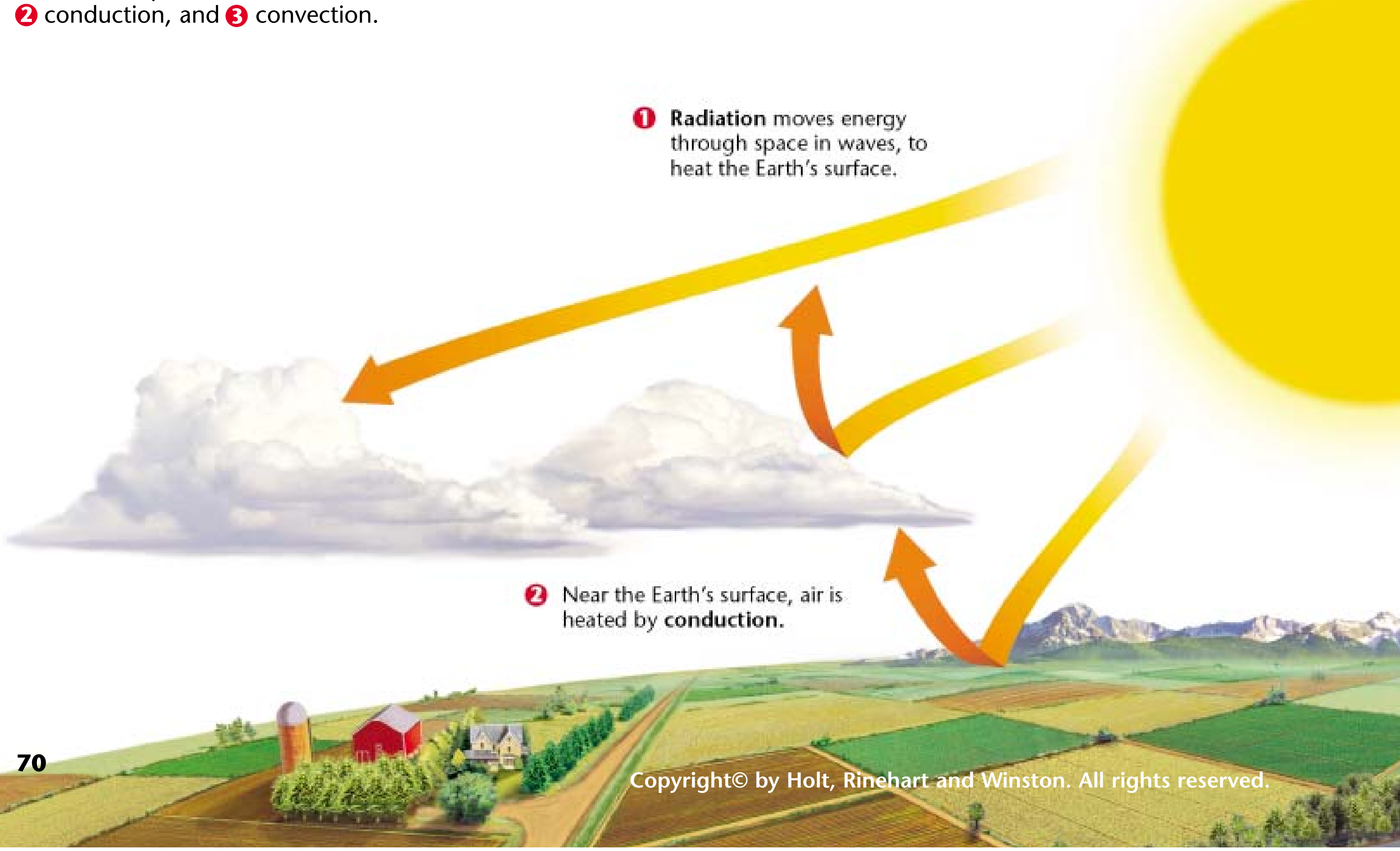
1. By what mechanism is energy being transferred to the beakers? Explain your answer.

Energy in the Atmosphere

As shown in **Figure 15,** energy from the sun is transferred in Earth's atmosphere by three mechanisms: radiation, convection, and conduction. **Radiation** is the transfer of energy across space and in the atmosphere. When you stand before a fire or a bed of coals, the heat you feel has reached you by radiation. **Conduction** is the flow of heat from a warmer object to a colder object when the objects are placed in direct physical contact. **Convection** is the transfer of heat by air currents. Hot air rises and cold air sinks. Thus, if you hold your hand above a hot iron, you will feel the heat because a current of hot air rises up to your hand.

Heating of the Atmosphere Solar energy reaches the Earth as electromagnetic radiation, which includes visible light, infrared radiation, and ultraviolet light. The sun releases a vast amount of radiation, but our planet only receives about two-billionths of this energy. This seemingly small amount of radiation contains a tremendous amount of energy, however. As shown in **Figure 15,** about half of the solar energy that enters the atmosphere passes through the atmosphere and reaches Earth's surface. The rest of the energy is absorbed or reflected in the atmosphere by clouds, gases, and dust, or it is reflected by the Earth's surface. On a sunny day, rocks may become too hot to touch. If the Earth's

Figure 15 ▶ Thermal Radiation Three important mechanisms responsible for transferring heat in the atmosphere are ❶ radiation, ❷ conduction, and ❸ convection.



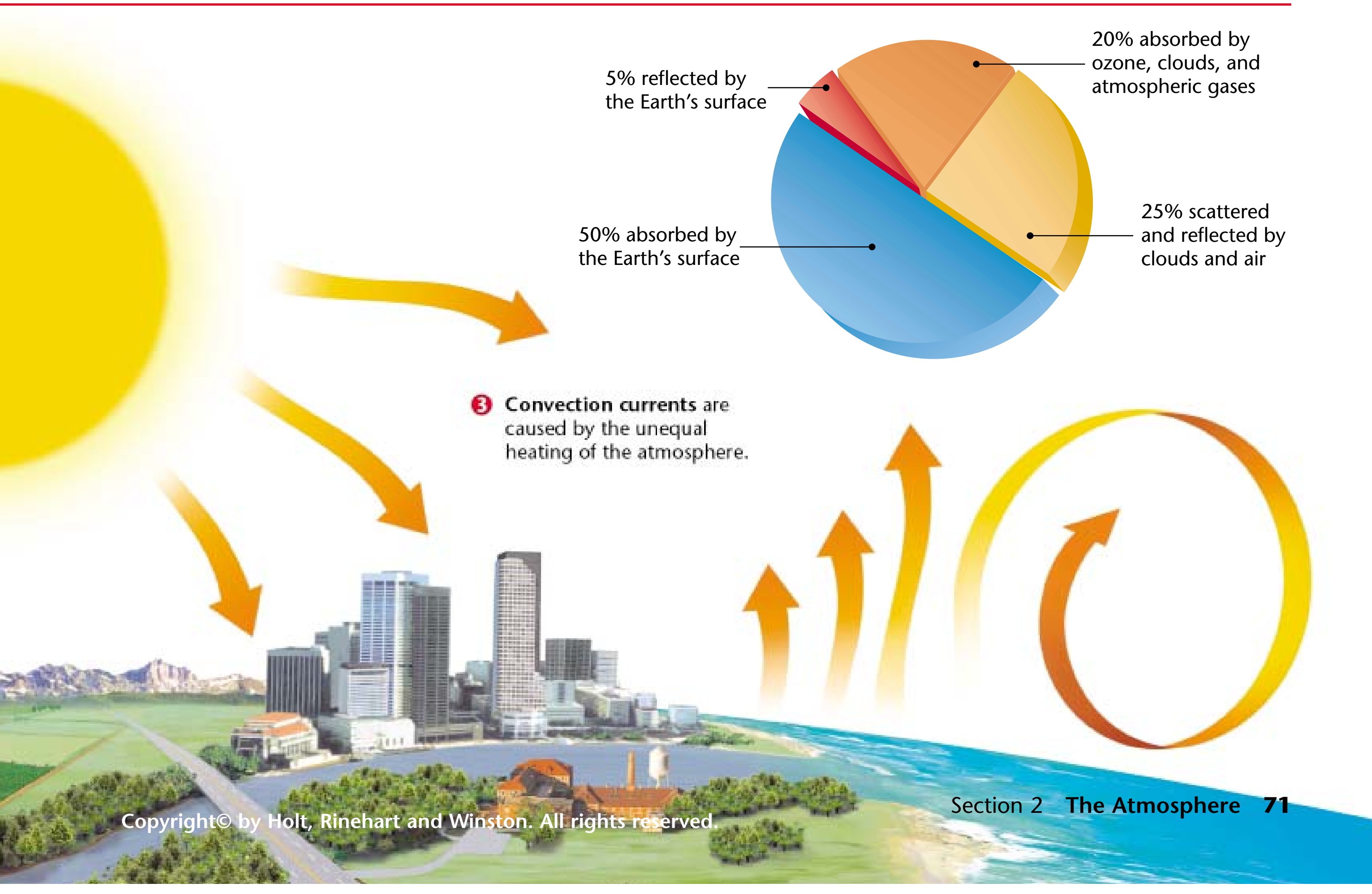
surface continually absorbed energy, the Earth would get hotter and hotter. The Earth does not continue to get warmer, because the oceans and the land radiate the energy they have absorbed back into the atmosphere.

You may have noticed that dark-colored objects become much hotter in the sun than light-colored objects. Dark-colored objects absorb more solar radiation than light-colored objects, so dark-colored objects have more energy to release as heat. This is one reason the temperature in cities is higher than the temperature in the surrounding countryside.

The Movement of Energy in the Atmosphere Air that is constantly moving upward, downward, or sideways causes Earth's weather. In the troposphere, currents of less dense air, warmed by the Earth's surface, rise into the atmosphere and currents of denser cold air sink toward the ground. As a current of air rises into the atmosphere, it begins to cool. Eventually, the air current becomes more dense than the air around it and sinks instead of continuing to rise. So, the air current moves back toward Earth's surface until it is heated by the Earth and becomes less dense. Then, the air current begins to rise again. The continual process of warm air rising and cool air sinking moves air in a circular motion, called a *convection current.* A convection current is shown in **Figure 15.**

Ecofact

Lost Weekend Have you ever complained about how it always seems to rain on the weekends? If you live on the East Coast, you might actually have a point. Researchers recently found that the mid-Atlantic states have a 30 to 40 percent greater chance of rain on the weekends. Why? Researchers suggest that the automobile exhaust that accumulates in the atmosphere over the course of the work week has actually caused weather patterns in this area to shift. By Friday, the exhaust levels are high enough to trigger rain over the weekend, which cleanses the atmosphere for another week.



FIELD ACTIVITY

Exploring the Greenhouse Effect Some of your classmates and teachers probably drive to school. Given what you know about the reflection and absorption of heat, go to the parking lot on a sunny day and hypothesize which cars will have the hottest interiors. Base your hypothesis on such variables as the color of car interiors and whether the windows are tinted or untinted. Record your observations in your ***Ecolog.***

The Greenhouse Effect

The gases in Earth's atmosphere act like the glass in the car shown in **Figure 16.** Sunlight that penetrates Earth's atmosphere heats the surface of the Earth. The Earth's surface radiates heat back to the atmosphere, where some of the heat escapes into space. The remainder of the heat is absorbed by greenhouse gases, which warms the air. Heat is then radiated back toward the surface of the Earth. This process, in which gases trap heat near the Earth, is known as the **greenhouse effect.** Without the greenhouse effect, the Earth would be too cold for life to exist.

The gases in our atmosphere that trap and radiate heat are called *greenhouse gases*. None of the greenhouse gases have a high concentration in Earth's atmosphere. The most abundant greenhouse gases are water vapor, carbon dioxide, methane, and nitrous oxide. The quantities of carbon dioxide and methane in the atmosphere vary considerably as a result of natural and industrial processes, and the amount of water varies because of natural processes.

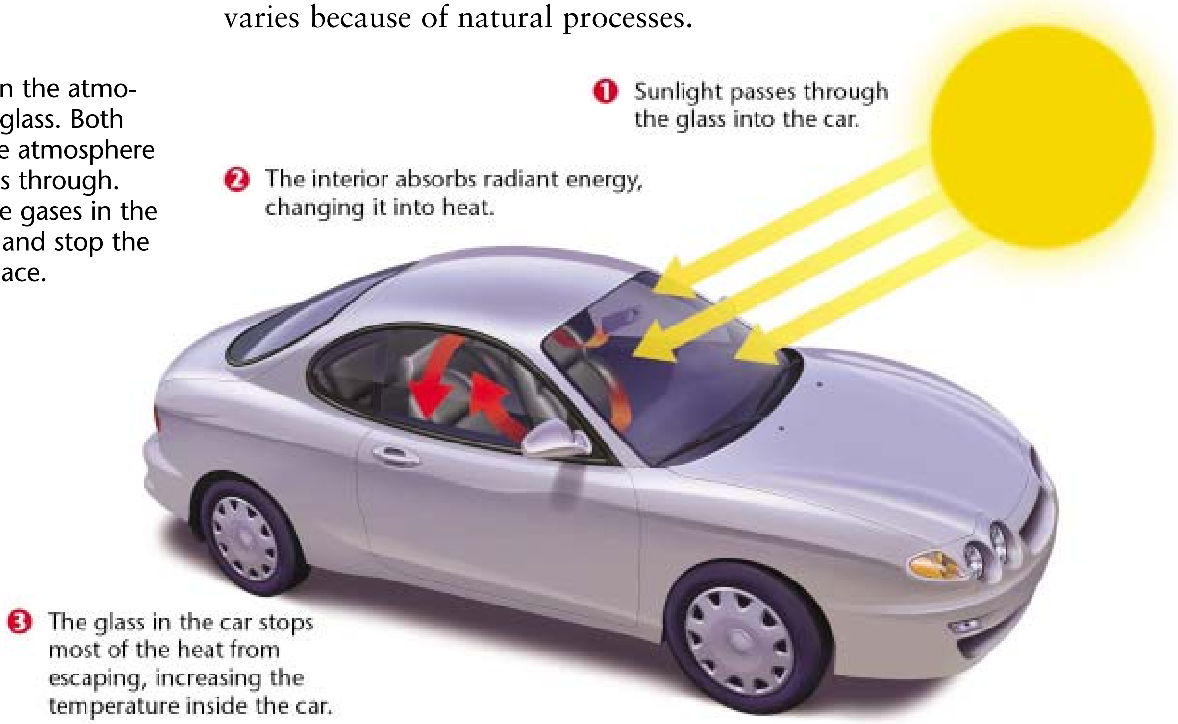


Figure 16 ▶ The gases in the atmosphere act like a layer of glass. Both glass and the gases in the atmosphere allow solar energy to pass through. But glass and some of the gases in the atmosphere absorb heat and stop the heat from escaping to space.

SECTION 2 Review

1. **Describe** the composition of Earth's atmosphere.
2. **Describe** a characteristic of each layer of the atmosphere.
3. **Explain** the three mechanisms of heat transfer in Earth's atmosphere.
4. **Describe** the role of greenhouse gases in Earth's atmosphere.

CRITICAL THINKING

5. **Analyzing Processes** Read about the density of Earth's atmosphere under the heading "Air Pressure." Write a paragraph that explains why Earth's atmosphere becomes less dense with increasing altitude above Earth. WRITING SKILLS
6. **Analyzing Processes** How does human activity change some greenhouse-gas levels?