Section 1

Terms to Learn

atmosphere
air pressure
altitude
troposphere
stratosphere
ozone
mesosphere
thermosphere

What You'll Do

- Discuss the composition of the Earth's atmosphere.
- Explain why pressure changes with altitude.
- Explain how temperature changes with altitude.
- Describe the layers of the atmosphere.

Characteristics of the Atmosphere

If you were lost in the desert, you could survive for a few days without food and water. But you wouldn't last more than 5 minutes without the *atmosphere*. The **atmosphere** is a mixture of gases that surrounds the Earth. In addition to containing the oxygen we need to breathe, it protects us from the sun's harmful rays. But the atmosphere is always changing. Every breath we take, every tree we plant, and every motor vehicle we ride in affects the composition of our atmosphere. Later you will find out how the atmosphere is changing. But first you need to learn about the atmosphere's composition and structure.

Composition of the Atmosphere

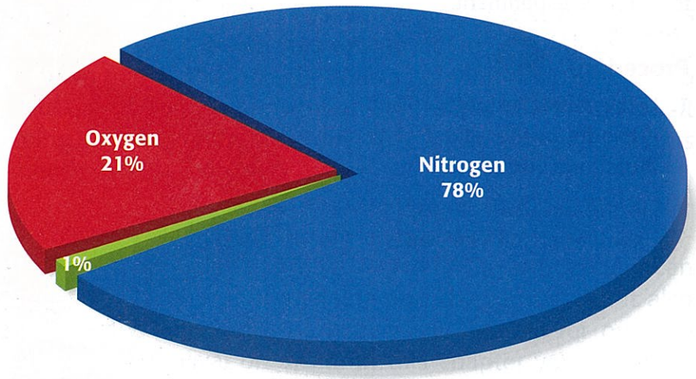
Figure 1 shows the relative amounts of the gases that make up the atmosphere. Besides gases, the atmosphere also contains small amounts of solids and liquids. Tiny solid particles, such as dust, volcanic ash, sea salt, dirt, and smoke, are carried in the air. Next time you turn off the lights at night, shine a flashlight and you will see some of these tiny particles floating in the air. The most common liquid in the atmosphere is water. Liquid water is found as water droplets in clouds. Water vapor, which is also found in the atmosphere, is a gas and is not visible.

Figure 1 *Two gases—nitrogen and oxygen—make up 99 percent of the air we breathe.*

Nitrogen is the most abundant gas in the atmosphere. It is released into the atmosphere by volcanic eruptions and when dead plants and dead animals decay.

Oxygen, the second most common gas in the atmosphere, is produced by plant-like protists and plants.

The **remaining 1 percent** of the atmosphere is made up of argon, carbon dioxide, water vapor, and other gases.



Atmospheric Pressure and Temperature

Have you ever been in an elevator in a tall building? If you have, you probably remember the "popping" in your ears as you went up or down. As you move up or down in an elevator, the air pressure outside your ears changes, while the air pressure inside your ears stays the same. **Air pressure** is the measure of the force with which the air molecules push on a surface. Your ears pop when the pressure inside and outside of your ears suddenly becomes equal. Air pressure changes throughout the atmosphere. Temperature and the kinds of gases present also change. Why do these changes occur? Read on to find out.

Chemistry CONNECTION

Water is the only substance that exists as a liquid, a solid, and a gas in the Earth's atmosphere.

Pressure Think of air pressure as a human pyramid, as shown in **Figure 2.** The people at the bottom of the pyramid can feel all the weight and pressure of the people on top. The person on top doesn't feel any weight because there isn't anyone above. The atmosphere works in a similar way.

The Earth's atmosphere is held around the planet by gravity. Gravity pulls the gas molecules in the atmosphere toward the Earth's surface, giving them weight. This weight causes the air to push against the Earth's surface. As you move farther away from the Earth's surface, air pressure decreases because fewer gas molecules are pushing on you. **Altitude** is the height of an object above the Earth's surface. As altitude increases, air pressure decreases.

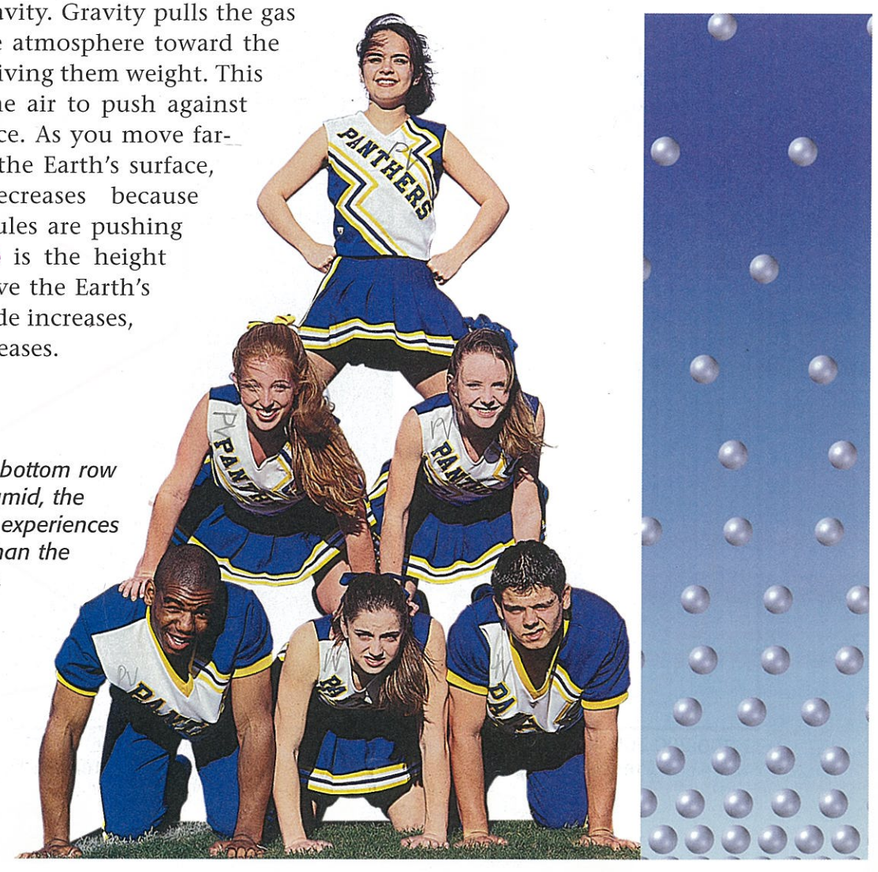


Figure 2 *Like the bottom row of the human pyramid, the lower atmosphere experiences greater pressure than the upper atmosphere.*

Self-Check

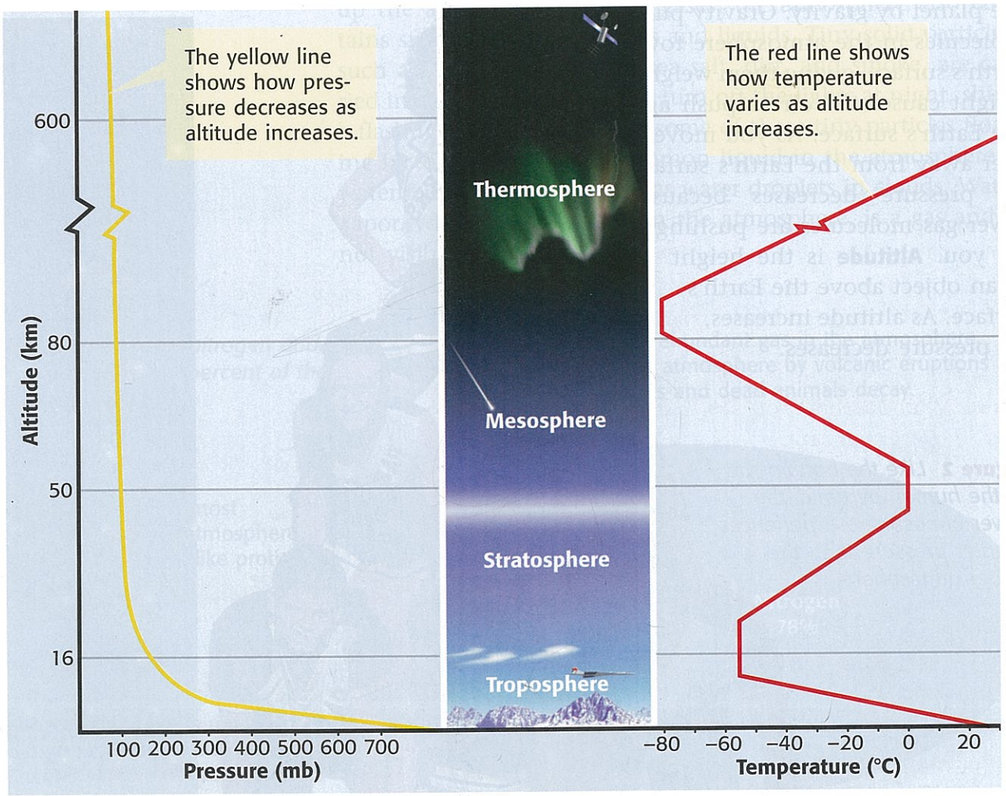
Does air become more or less dense as you climb a mountain? Why? *(See page 726 to check your answer.)*

Air Temperature Air temperature also changes as you increase altitude. As you pass through the atmosphere, air temperature changes between warmer and colder conditions. The temperature differences result mainly from the way solar energy is absorbed as it moves downward through the atmosphere. Some parts of the atmosphere are warmer because they contain gases that absorb solar energy. Other parts do not contain these gases and are therefore cooler.

Layers of the Atmosphere

Based on temperature changes, the Earth's atmosphere is divided into four layers—the troposphere, stratosphere, mesosphere, and thermosphere. **Figure 3** illustrates the four atmospheric layers, showing their altitude and temperature. As you can see, each layer has unique characteristics.

Figure 3 **Profile of the Earth's Atmosphere**



Troposphere The **troposphere,** which lies next to the Earth's surface, is the lowest layer of the atmosphere. The troposphere is also the densest atmospheric layer, containing almost 90 percent of the atmosphere's total mass. Almost all of Earth's carbon dioxide, water vapor, clouds, air pollution, weather, and life-forms are found in the troposphere. In fact, the troposphere is the layer in which you live. **Figure 4** shows the effects of altitude on temperature in the troposphere.

Stratosphere The atmospheric layer above the troposphere is called the **stratosphere.** In the stratosphere, the air is very thin and contains little moisture. The lower stratosphere is extremely cold, measuring about –60°C. In the stratosphere, the temperature rises with increasing altitude. This occurs because of ozone. **Ozone** is a molecule that is made up of three oxygen atoms, as shown in **Figure 5.** Almost all of the ozone in the atmosphere is contained in the *ozone layer* of the stratosphere. Ozone absorbs solar energy in the form of ultraviolet radiation, warming the air. By absorbing the ultraviolet radiation, the ozone layer also protects life at the Earth's surface.

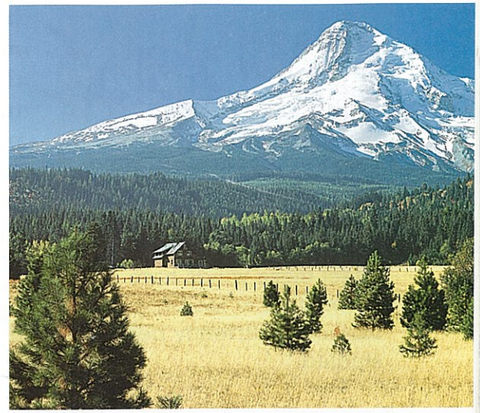


Figure 4 *Snow can remain year-round on a mountain top. That is because as altitude increases, the atmosphere thins, losing its ability to absorb and transfer thermal energy.*

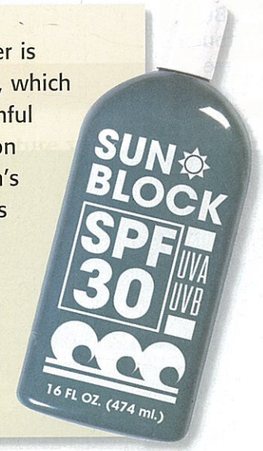
Oxygen gas (O_2) Ozone (O_3)

Figure 5 *While ozone is made up of three oxygen atoms, the oxygen in the air you breathe is made up of two oxygen atoms.*

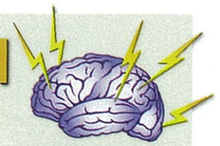
APPLY

UV and SPFs

People protect themselves from the sun's damaging rays by applying sunblock. Exposure of unprotected skin to the sun's ultraviolet rays over a long period of time can cause skin cancer. The breakdown of the Earth's ozone layer is thinning the layer, which allows some harmful ultraviolet radiation to reach the Earth's surface. Sunblocks contain different ratings of SPFs, or skin protection factors. What do the SPF ratings mean?



BRAIN FOOD



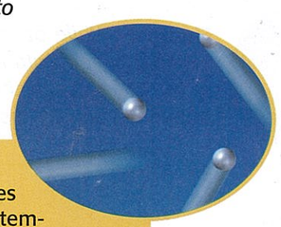
Large continent-sized windstorms were detected by the *Upper Atmosphere Research Satellite.* The effect these winds have on weather at the Earth's surface is currently being studied.

Mesosphere Above the stratosphere is the mesosphere. The **mesosphere** is the coldest layer of the atmosphere. As in the troposphere, the temperature drops with increasing altitude. Temperatures can be as low as –93°C at the top of the mesosphere. Scientists have recently discovered large wind storms in the mesosphere with winds reaching speeds of more than 320 km/h.

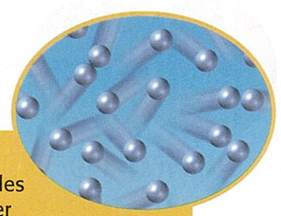
Thermosphere The uppermost atmospheric layer is the **thermosphere.** Here temperature again increases with altitude because many of the gases are absorbing solar radiation. Temperatures in this layer can reach 1,700°C.

When you think of an area with high temperatures, you probably think of a place that is very hot. While the thermosphere has very high temperatures, it would not feel hot. Temperature and heat are not the same thing. Temperature is a measure of the average energy of particles in motion. A high temperature means that the particles are moving very fast. Heat, on the other hand, is the transfer of energy between objects at different temperatures. But in order to transfer energy, particles must touch one another. **Figure 6** illustrates how the density of particles affects the heating of the atmosphere.

Figure 6 *Temperatures in the thermosphere are higher than those in the troposphere, but the air particles are too far apart for energy to be transferred.*



The **thermosphere** contains few particles that move fast. The temperature of this layer is high due to the speed of its particles. But because the particles rarely touch one another, the thermosphere does not transfer much energy.



The **troposphere** contains more particles that travel at a slower speed. The temperature of this layer is lower than that of the thermosphere. But because the particles are bumping into one another, the troposphere transfers much more energy.

Ionosphere In the upper mesosphere and the lower thermosphere, nitrogen and oxygen atoms absorb harmful solar energy, such as X rays and gamma rays. This absorption not only contributes to the thermosphere's high temperatures but also causes the gas particles to become electrically charged. Electrically charged particles are called ions; therefore, this part of the thermosphere is referred to as the *ionosphere*. Sometimes these ions radiate energy as light of different colors, as shown in **Figure 7.**

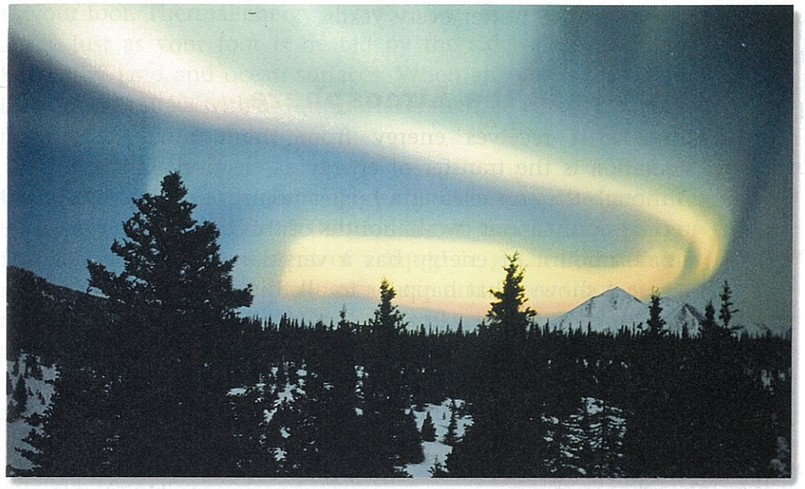


Figure 7 *Aurora borealis (northern lights) and aurora australis (southern lights) occur in the ionosphere.*

The ionosphere also reflects certain radio waves, such as AM radio waves. If you have ever listened to an AM radio station, you can be sure that the ionosphere had something to do with how clear it sounded. When conditions are right, an AM radio wave can travel around the world after being reflected off the ionosphere. These radio signals bounce off the ionosphere and are sent back to Earth.

REVIEW

1. Explain why pressure decreases but temperature varies as altitude increases.
2. What causes air pressure?
3. How can the thermosphere have high temperatures but not feel hot?
4. **Analyzing Relationships** Identify one characteristic of each layer of the atmosphere, and explain how that characteristic affects life on Earth.

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Section 2

Terms to Learn

radiation
conduction
convection
greenhouse effect
global warming

What You'll Do

- Describe what happens to radiation that reaches the Earth.
- Summarize the processes of radiation, conduction, and convection.
- Explain how the greenhouse effect could contribute to global warming.

Heating of the Atmosphere

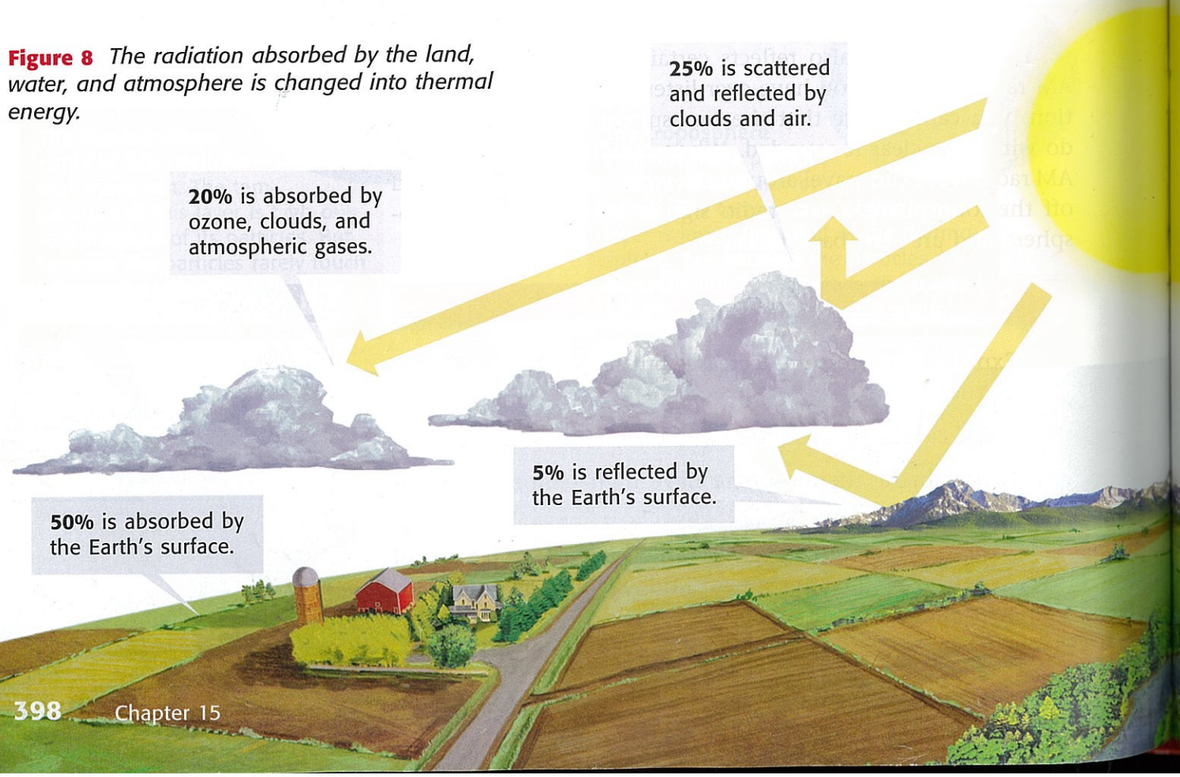
Have you ever walked barefoot across a sidewalk on a sunny day? If so, your foot felt the warmth of the hot pavement. How did the sidewalk become so warm? The sidewalk was heated as it absorbed the sun's energy. The Earth's atmosphere is also heated in several ways by the transfer of energy from the sun. In this section you will find out what happens to the solar energy as it enters the Earth's atmosphere, how the energy is transferred through the atmosphere, and why it seems to be getting hotter every year.

Energy in the Atmosphere

The Earth receives energy from the sun by radiation. **Radiation** is the transfer of energy as electromagnetic waves. Although the sun releases a huge amount of energy, the Earth receives only about two-billionths of this energy. Yet even this small amount of energy has a very large impact on Earth. **Figure 8** shows what happens to all this energy once it enters the atmosphere.

When energy is absorbed by a surface, it heats that surface. For example, when you stand in the sun on a cool day, you can feel the sun's rays warming your body. Your skin absorbs the radiation, causing your skin's molecules to move faster. You feel this as an increase in temperature. The same thing happens when energy is absorbed by the Earth's surface. The energy from the Earth's surface can then be transferred to the atmosphere, which heats it.

Figure 8 *The radiation absorbed by the land, water, and atmosphere is changed into thermal energy.*



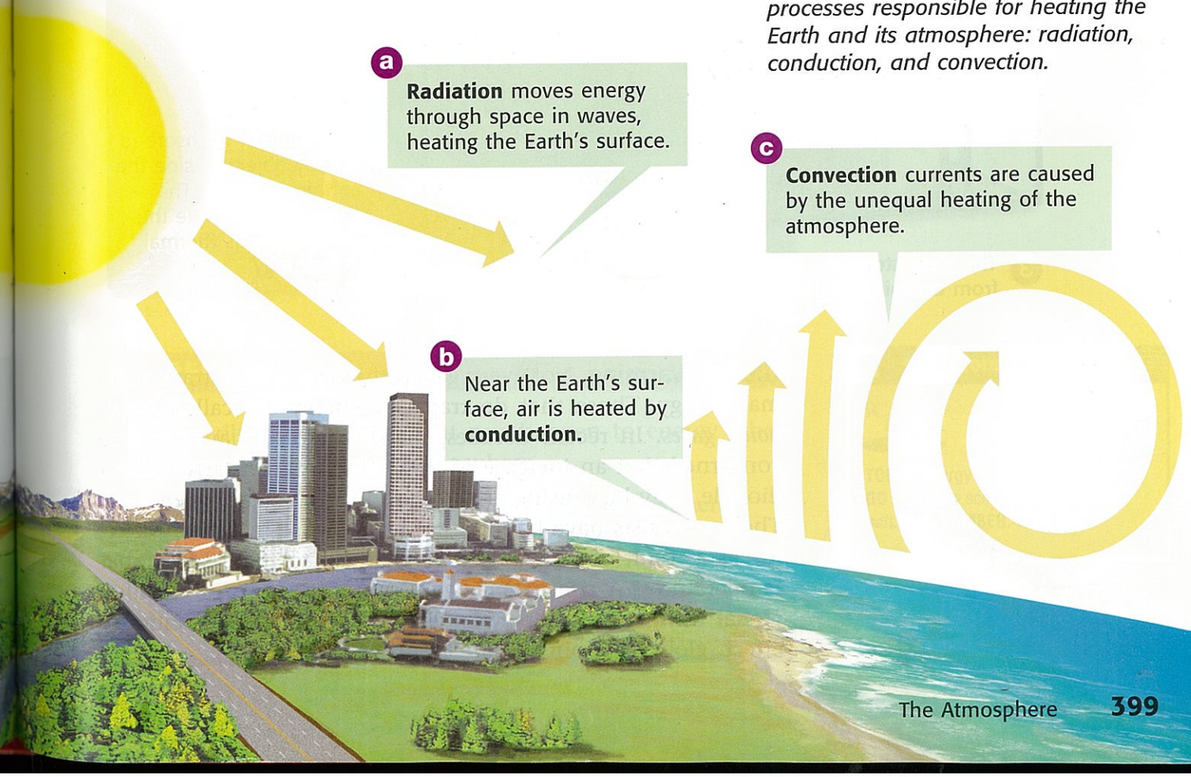
Conduction **Conduction** is the transfer of thermal energy from one material to another by direct contact. Think back to the example about walking barefoot on a hot sidewalk. Conduction occurs when thermal energy is transferred from the sidewalk to your foot. Thermal energy always moves from warm to cold areas. Just as your foot is heated by the sidewalk, the air is heated by land and ocean surfaces. When air molecules come into direct contact with a warm surface, thermal energy is transferred to the atmosphere.

Convection Most thermal energy in the atmosphere moves by *convection*. **Convection** is the transfer of thermal energy by the circulation or movement of a liquid or gas. For instance, as air is heated, it becomes less dense and rises. Cool air is more dense and sinks. As the cool air sinks, it pushes the warm air up. The cool air is eventually heated by the ground and again begins to rise. This continual process of warm air rising and cool air sinking creates a circular movement of air, called a *convection current,* as shown in **Figure 9.**

BRAIN FOOD

If the Earth is continually absorbing solar energy and changing it to thermal energy, why doesn't the Earth get hotter and hotter? The reason is that much of this energy is lost to space. This is especially true on cloudless nights.

Figure 9 *There are three important processes responsible for heating the Earth and its atmosphere: radiation, conduction, and convection.*



The Greenhouse Effect

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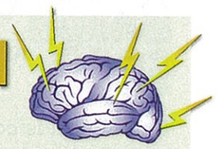

Annual average surface temperatures in the Northern Hemisphere have been higher in the 1990s than at any other time in the past 600 years.

As you have already learned, 50 percent of the radiation that enters the Earth's atmosphere is absorbed by the Earth's surface. This energy is then reradiated to the Earth's atmosphere as thermal energy. Gases, such as carbon dioxide and water vapor, can stop this energy from escaping into space by absorbing it and then radiating it back to the Earth. As a result, the Earth's atmosphere stays warm. This is similar to how a blanket keeps you warm at night. The Earth's heating process, in which the gases in the atmosphere trap thermal energy, is known as the **greenhouse effect.** This term is used because the Earth's atmosphere works much like a greenhouse, as shown in **Figure 10.**

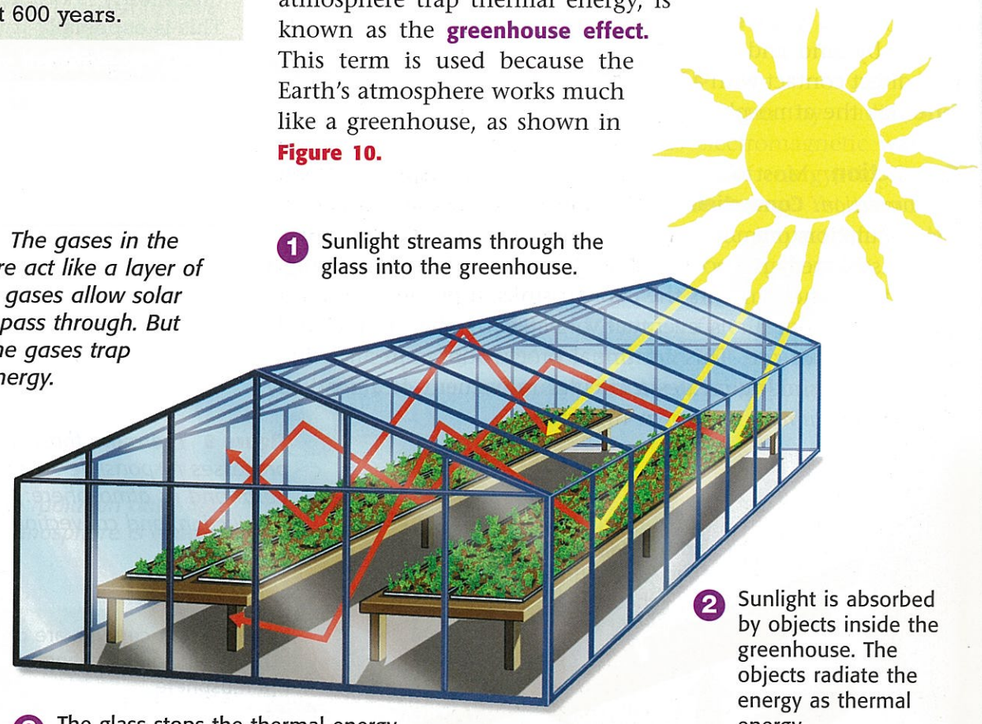

Figure 10 *The gases in the atmosphere act like a layer of glass. The gases allow solar energy to pass through. But some of the gases trap thermal energy.*

Global Warming Not every gas in the atmosphere traps thermal energy. Those that do trap this energy are called *greenhouse gases*. In recent decades, many scientists have become concerned that an increase of these gases, particularly carbon dioxide, may be causing an increase in the greenhouse effect. These scientists have hypothesized that a rise in carbon dioxide as a result of human activity has led to increased global temperatures. A rise in average global temperatures is called **global warming.** If there were an increase in the greenhouse effect, global warming would result.

The Radiation Balance For the Earth to remain livable, the amount of energy received from the sun and the amount of energy returned to space must be equal. As you saw in Figure 8, about 30 percent of the incoming energy is reflected back into space. Most of the 70 percent that is absorbed by the Earth and its atmosphere is also sent back into space. The balance between incoming energy and outgoing energy is known as the *radiation balance*. If greenhouse gases, such as carbon dioxide, continue to increase in the atmosphere, the radiation balance may be affected. Some of the energy that once escaped into space could be trapped. The Earth's temperatures would continue to rise, causing major changes in plant and animal communities.

Keeping the Earth Livable Some scientists argue that the Earth had warmer periods before humans ever walked the planet, so global warming may be a natural process. Nevertheless, many of the world's nations have signed a treaty to reduce activities that increase greenhouse gases in the atmosphere. Another step that is being taken to reduce high carbon dioxide levels in the atmosphere is the planting of millions of trees by volunteers, as shown in **Figure 11.**

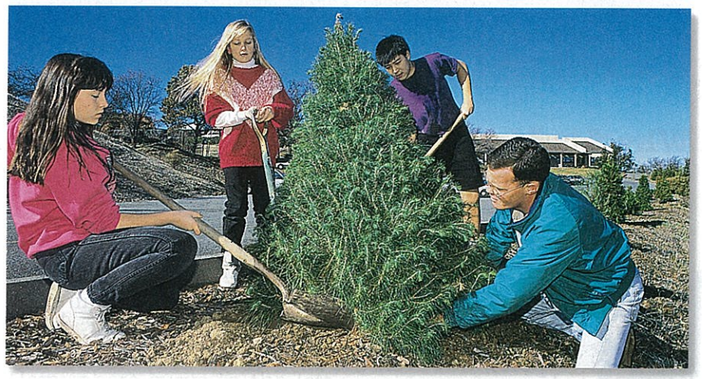

Figure 11 *Plants take in harmful carbon dioxide and give off oxygen, which we need to breathe.*

REVIEW

1. Describe three things that can happen to energy when it reaches the Earth's atmosphere.
2. How is energy transferred through the atmosphere?
3. What is the greenhouse effect?
4. **Inferring Relationships** How does the process of convection rely on conduction?

Biology CONNECTION

Did you know that if you lived in Florida, your fingernails and toenails would grow faster than if you lived in Minnesota? Studies by scientists at Oxford University, in England, showed that warm weather helps tissue growth, while cold weather slightly slows it.

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