Section 2
Atmospheric Heating

Key Concept Heat in Earth's atmosphere is transferred by radiation, conduction, and convection.

What You Will Learn
- Solar energy travels through space as radiation and passes through the atmosphere to Earth's surface.
- Energy is carried through the atmosphere by radiation, conduction, and convection.

Why It Matters
Energy from the sun maintains Earth's global temperature so that plants and animals can survive.

You are lying in a park. You feel the warmth of the sun on your face. The sun is nearly 150,000,000 km from Earth! Have you ever wondered how the sun's warmth reaches you?

Radiation: Energy Transfer by Waves
Energy from the sun, or solar energy, takes a little more than eight minutes to travel from the sun to Earth. Solar energy reaches Earth by radiation. **Radiation** is the transfer of energy as waves through space or matter.

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 many processes at Earth's surface. For example, the sun provides the energy that drives winds, the water cycle, ocean currents, and changes in the weather. **Figure 1** shows what happens to solar energy that enters Earth's atmosphere.

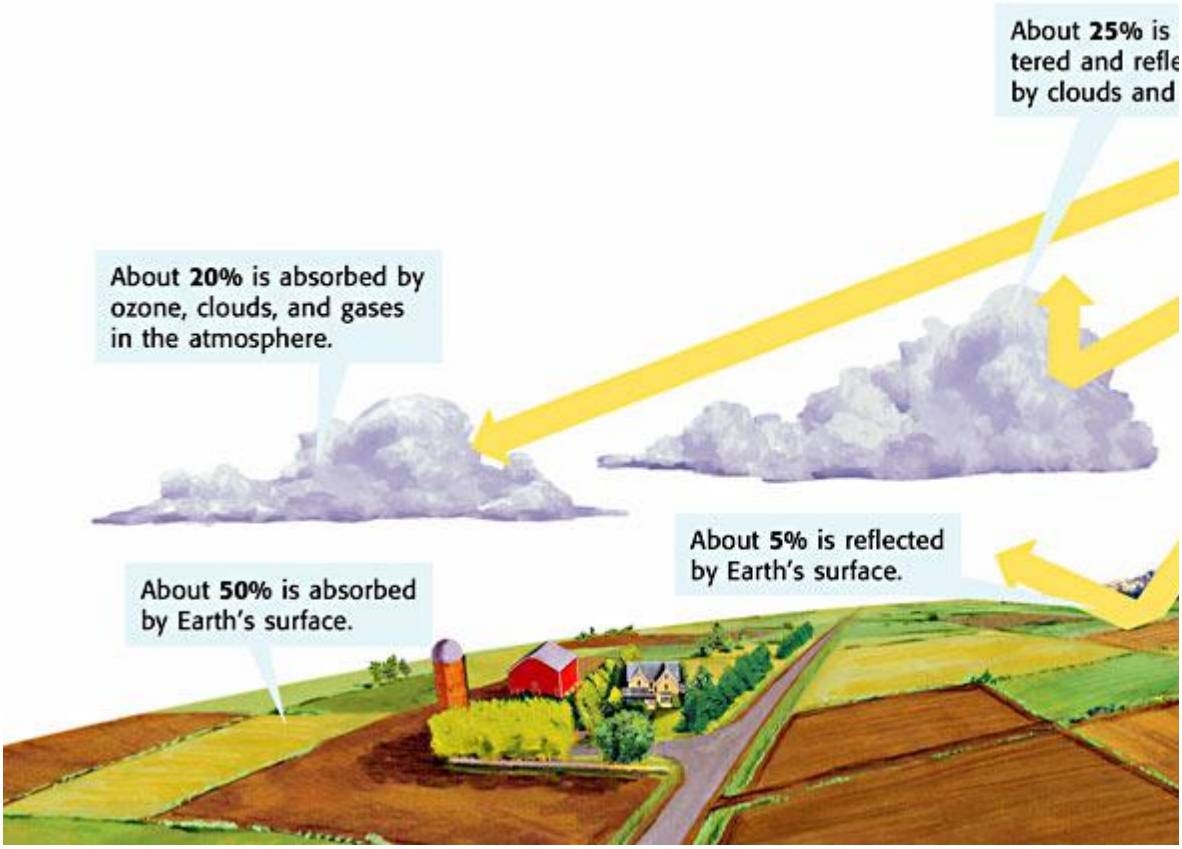


Figure 1 Different amounts of energy from the sun are absorbed, scattered, or reflected by the atmosphere and Earth's surface. **Is more energy absorbed or reflected by Earth's surface?**

Standards Check What is the source of energy that drives most processes at Earth's surface, and how does that energy reach Earth?

The Electromagnetic Spectrum

Radiation travels through space in the form of waves at a very high speed—about 300,000 km/s. These waves are called *electromagnetic waves.* Almost all of the energy that reaches Earth from the sun is in the form of electromagnetic waves. The **electromagnetic spectrum,** shown in **Figure 2,** contains all of the kinds of electromagnetic waves.

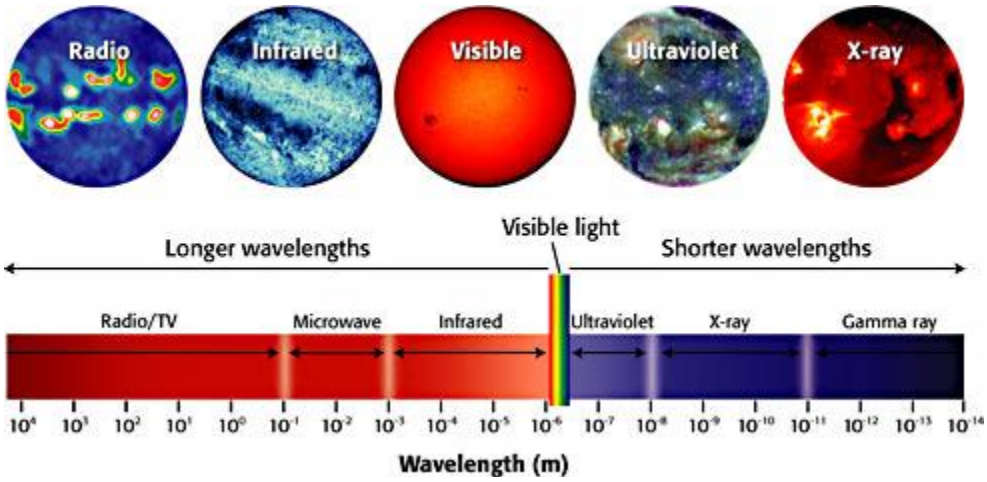


Figure 2 Radiation from the sun includes the entire electromagnetic spectrum. Each image of the sun above the spectrum shows different wavelengths of radiation.

The kinds of electromagnetic radiation differ in the length of their waves. The distance from any point on a wave to the identical point on the next wave is called the *wavelength.* Visible light consists of waves that have wavelengths that humans can see as different colors. The wavelengths of ultraviolet rays, X rays, and gamma rays are shorter than the wavelengths of visible light. Infared waves and radio waves have wavelengths that are longer than those of visible light.

The Atmosphere and Solar Radiation

Earth's atmosphere affects incoming solar radiation in many ways. The upper atmosphere absorbs almost all radiation that has wavelengths shorter than those of visible light. Nitrogen and oxygen in the thermosphere and mesosphere absorb the X rays, gamma rays, and some ultraviolet rays. In the stratosphere, ultraviolet rays are absorbed by and act upon oxygen molecules to form ozone.

Most incoming infared radiation is absorbed by gases in the troposphere. But some of this longer-wavelength energy reaches Earth's surface. Only a small amount of visible light is absorbed by the atmosphere. As a

result, most of the solar rays that reach Earth's surface are visible light.

Standards Check What form of energy is most solar energy that reaches Earth's surface?

Conduction: Energy Transfer by Contact

If you have ever touched something hot, you have experienced the process of conduction. **Conduction** is the transfer of energy, as heat, through a material by direct physical contact between particles. Heat is always transferred from warmer areas to colder areas. When air molecules come into direct contact with the warm surface of Earth, heat is transferred to the atmosphere by conduction, as shown in **Figure 3.**

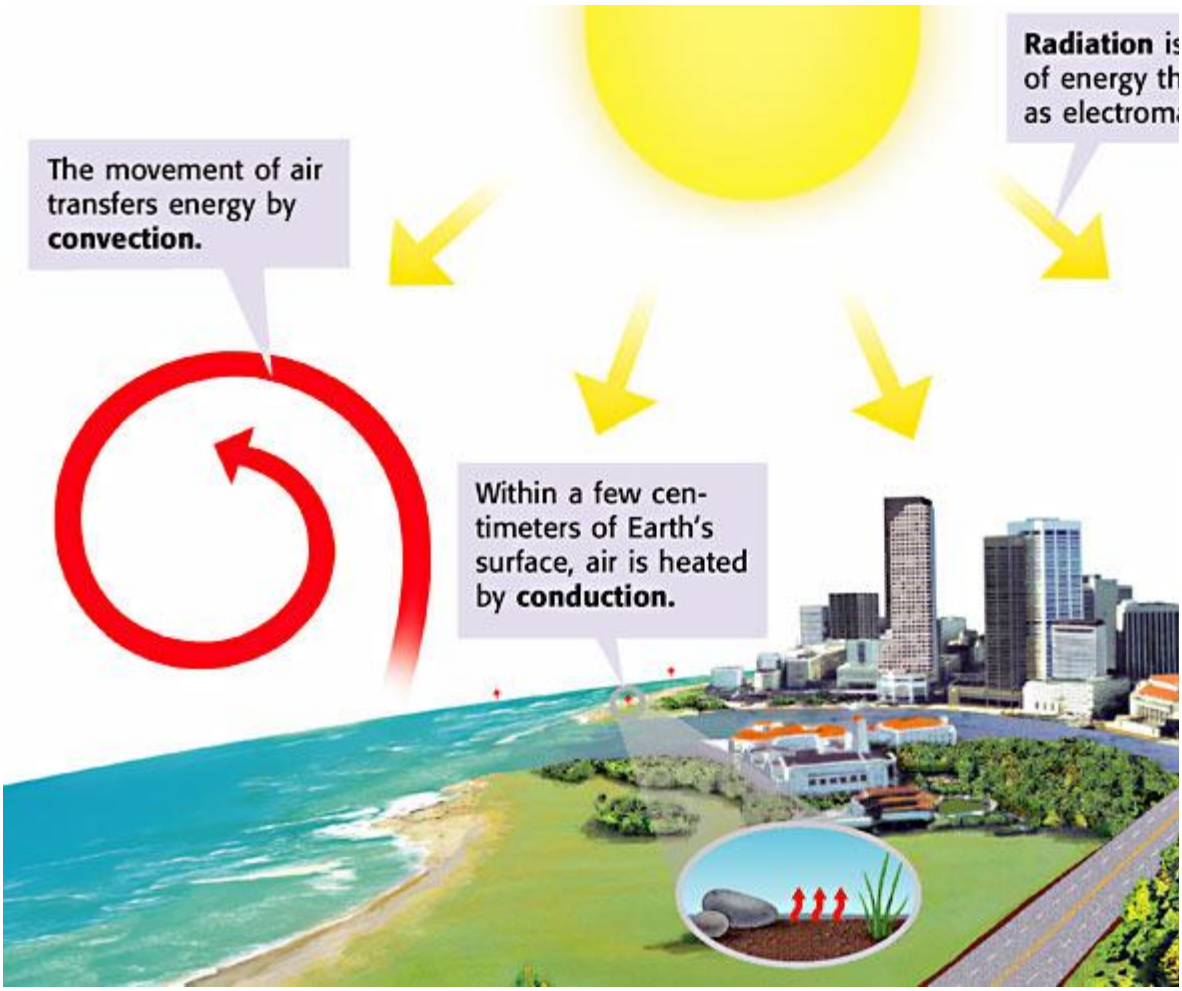


Figure 3 The processes of radiation, conduction, and convection heat Earth and its atmosphere.

Conduction happens when atoms or molecules that have different amounts of average kinetic energy collide. Atoms or molecules that have more kinetic energy transfer energy to atoms or molecules that have less kinetic energy. Hot objects have atoms that have greater average kinetic energy than the atoms of cold objects do. Therefore, the kinetic energy of the atoms in the hot object is transferred to the atoms of the cold object. In a solid, the atoms vibrate in place, but energy may still be transferred from atom to atom. This process happens when a pan is placed on a stove and the pan's handle becomes hot. The same mechanism happens in liquids and gases. In liquids and gases, the atoms collide as they slip past one another.

Standards Check How does heat flow by conduction in solids?

Convection: Energy Transfer by Motion

If you have ever watched a pot of water boil, you have observed convection. **Convection** is the transfer of heat by the circulation or movement of a liquid or gas. Convection occurs because most fluids, such as liquids and gases, become less dense when they are heated. Because the hot fluid is less dense, it is more buoyant than surrounding cool fluid. Therefore, the hot fluid rises. As hot fluid rises away from a heat source, it may cool, become denser, and sink back to the source to be warmed again. This cycle of warm fluid rising and cool fluid sinking may cause a circular movement called a **convection current.**

Most heat in the atmosphere is transferred by convection, as shown in **Figure 3.** For example, as air is heated by conduction from the ground, the air becomes less dense. The surrounding cool air is denser than the warm air, so the cool air sinks. As the cool air sinks, it pushes the warm air up. The cool air is eventually heated by conduction from the ground, and the process repeats.

Standards Check Describe the flow of heat by convection in fluids.

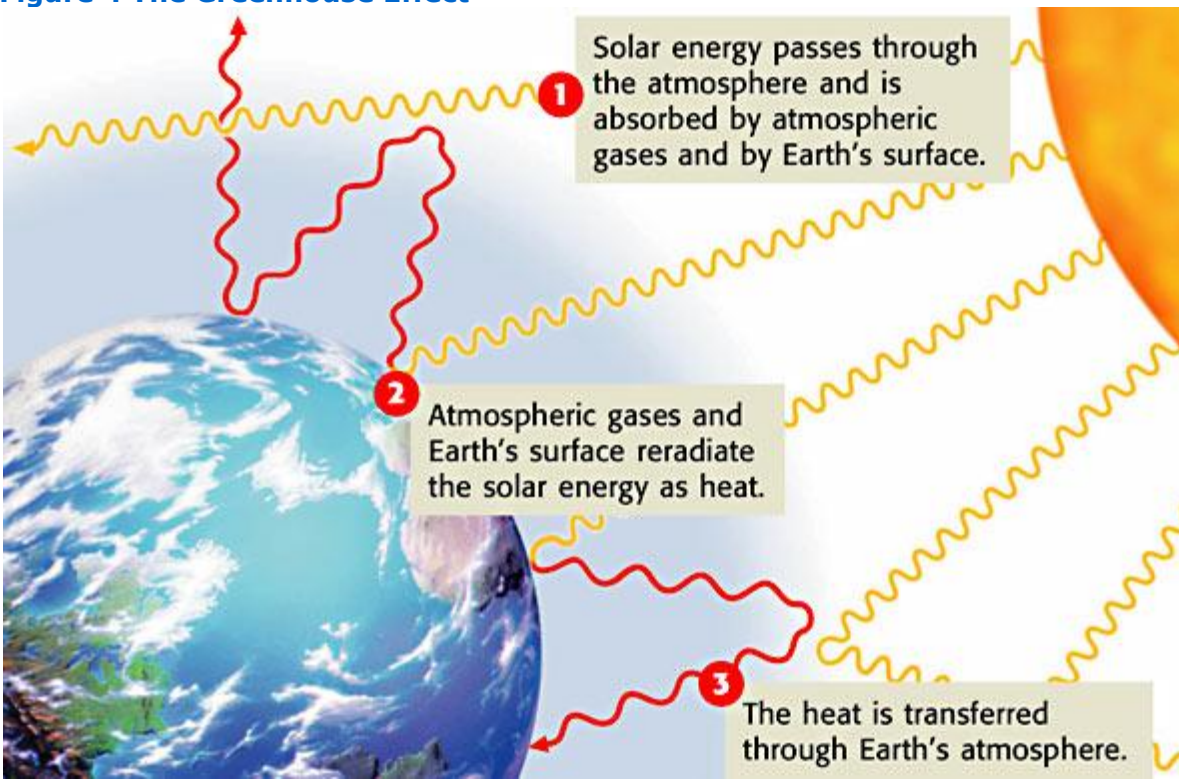
The Greenhouse Effect

About 70% of the radiation that enters Earth's atmosphere is absorbed by atmospheric gases and by Earth's surface. This energy is changed into heat that warms the planet.

In other words, visible light is absorbed and then is reradiated into the atmosphere as heat.

So, why doesn't this heat escape back into space? Most of it does. But the atmosphere is like a warm blanket that absorbs enough energy to make Earth livable. This process, shown in **Figure 4,** 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 and reradiate heat.

Figure 4 The Greenhouse Effect



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 Earth's surface and atmosphere is reradiated into space as heat. Every day, Earth receives more energy from the sun. And every day, Earth releases energy back into space. The balance between incoming energy and outgoing energy is known as the *radiation balance.*

Standards Check How does the sun's radiation make Earth livable?

Global Warming

Many scientists are concerned that average global temperatures have increased in the past 100 years. This increase in average global temperatures is called *global warming.* Human activity, such as the burning of fossil fuels, as shown in **Figure 5,** may lead to global warming. Burning fossil fuels releases greenhouse gases, such as carbon dioxide, into the atmosphere. An increase in the amount of greenhouse gases may cause global warming because the gases absorb more heat. If the amount of greenhouse gases in the atmosphere continues to rise, global temperatures may continue to rise. If global warming con tinues, global climate patterns could be disrupted. However, the causes of global warming are still being debated.

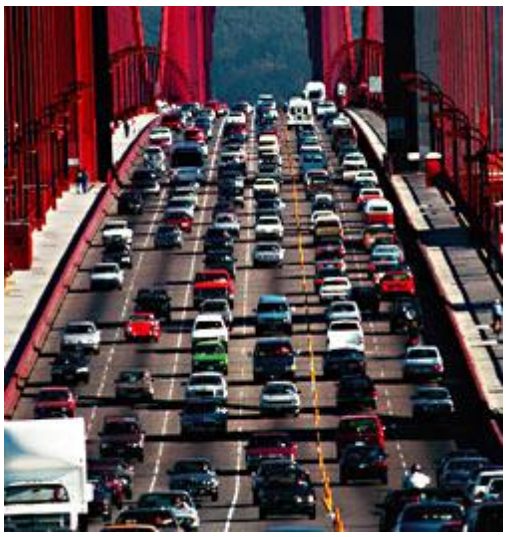


Figure 5 While in traffic on the Golden Gate Bridge, vehicles burn fossil fuels, which may lead to global warming.

Section Summary

- Energy travels from the sun to Earth by

radiation. This energy drives many processes at Earth's surface.

- Energy in Earth's atmosphere is transferred by radiation, conduction, and convection.
- Radiation is the transfer of energy through space or matter by waves.
- Conduction is the transfer of energy by direct contact.
- Convection is energy transfer by the movement of matter.