Lesson 1

How is thermal energy transferred?

Thermal energy is the total kinetic and potential energy of the particles in a substance. Heat is thermal energy that moves from one substance to another. Heat can move by conduction, convection, and radiation.

Thermal Energy

When you look at the molten glass, it is easy to see that its particles are moving. The molten glass flows. But a solid object, such as a glass pitcher, seems to be perfectly still. Are you surprised to find out that it's not?

All matter is made of particles that are always moving. The particles have kinetic energy, or energy due to motion. The particles in a substance always pull on each other. This means the particles have potential energy, or energy due to position. Particles in a gas can move freely. They do not pull strongly on each other. Particles in a liquid can only flow around each other. They pull more strongly on each other than gas particles do. The particles in a solid pull strongly on each other. They vibrate, but they cannot move from their fixed position.

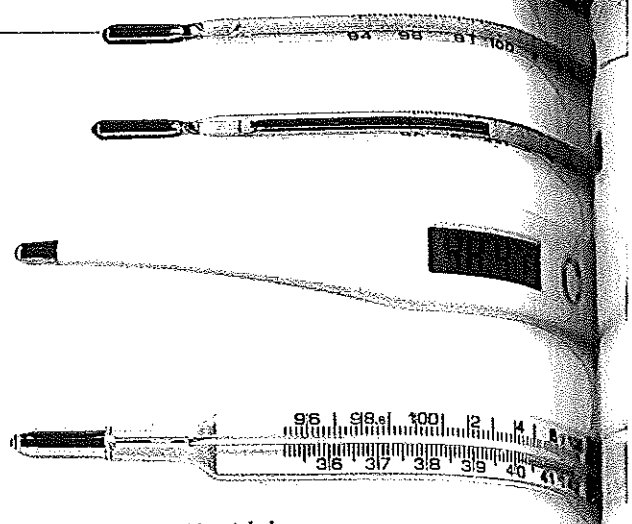
The total kinetic and potential energy of the particles in a substance is **thermal energy.** The amount of thermal energy depends on the amount of the substance. If you have a cup of water and you pour half of it out, the part that is left has half the number of particles. It therefore has half the thermal energy that the full cup of water had.

Thermal energy determines how warm a substance feels. A warm cup of water has more thermal energy than a cool cup of water. The warm and cool water have about the same number of particles, but the particles in the warm water are moving faster. They have more kinetic energy. Therefore, they have more thermal energy and feel warmer.

1. ✓**Checkpoint** What is the difference between kinetic energy and potential energy?
2. Writing in Science **Expository** You place a cup of water in a freezer and it changes to ice. Explain what happens to the thermal energy of the water.

Heat

You've probably measured your kinetic energy many times, but you may not have known it. Temperature is a measure of the average kinetic energy of an object's particles. When you take your temperature with a thermometer, your body heat increases the kinetic energy of particles of a liquid in the thermometer. The thermometer then shows the average kinetic energy of particles in your body.

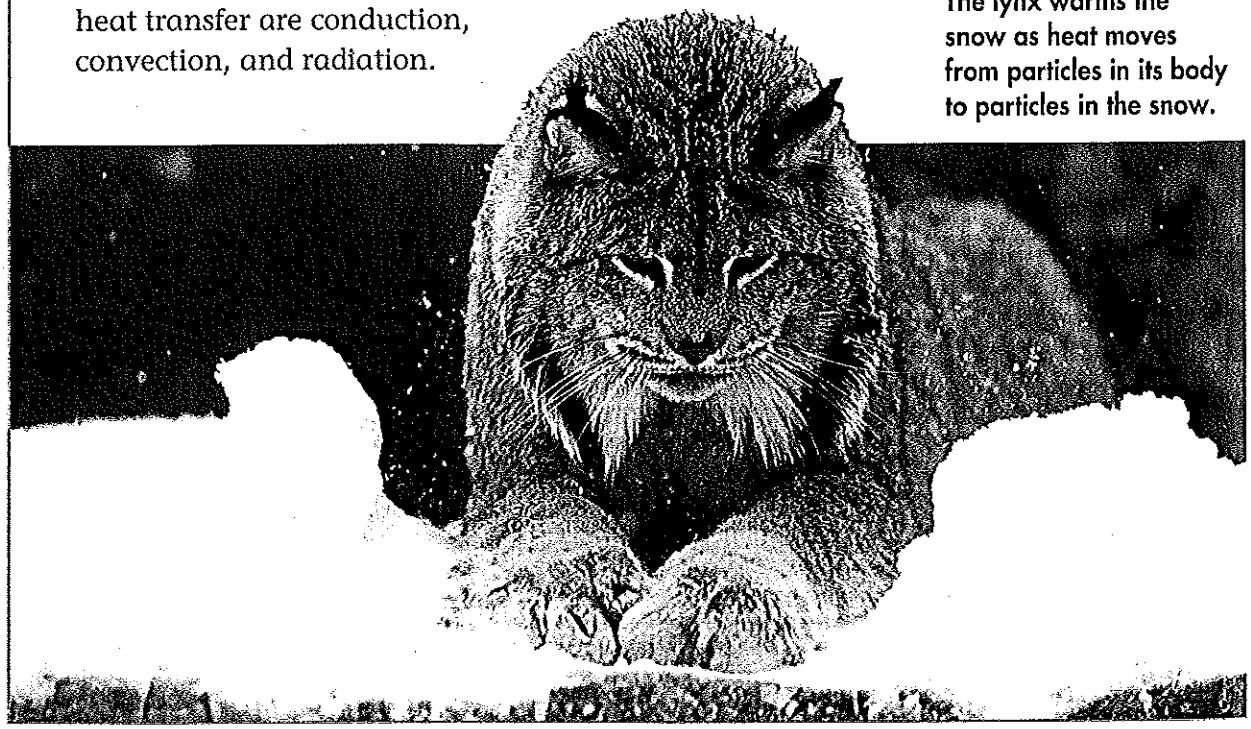


Liquid thermometers measure temperature change when increased kinetic energy causes a liquid to expand. Digital thermometers measure temperature change when increased kinetic energy causes a metal to expand.

Temperature is not the same as thermal energy. Temperature depends only on the average kinetic energy. Thermal energy is the sum of kinetic and potential energy. Unlike thermal energy, temperature does not depend on the amount of a substance. If you split an object in half, each part has half as many particles. But the temperature does not change. The average kinetic energy is the same.

Thermal energy that can move from one substance to another is called **heat.** Heat always moves from a warmer substance to a cooler one. An increase in temperature means that heat moves into a substance. When heat moves into a substance, the average kinetic energy of the particles rises. The extra kinetic energy increases the particles' vibrations. Particles vibrate faster when a substance is heated.

The movement of heat from one substance to another can occur between objects that touch and objects that don't touch. The three types of heat transfer are conduction, convection, and radiation.



The lynx warms the snow as heat moves from particles in its body to particles in the snow.

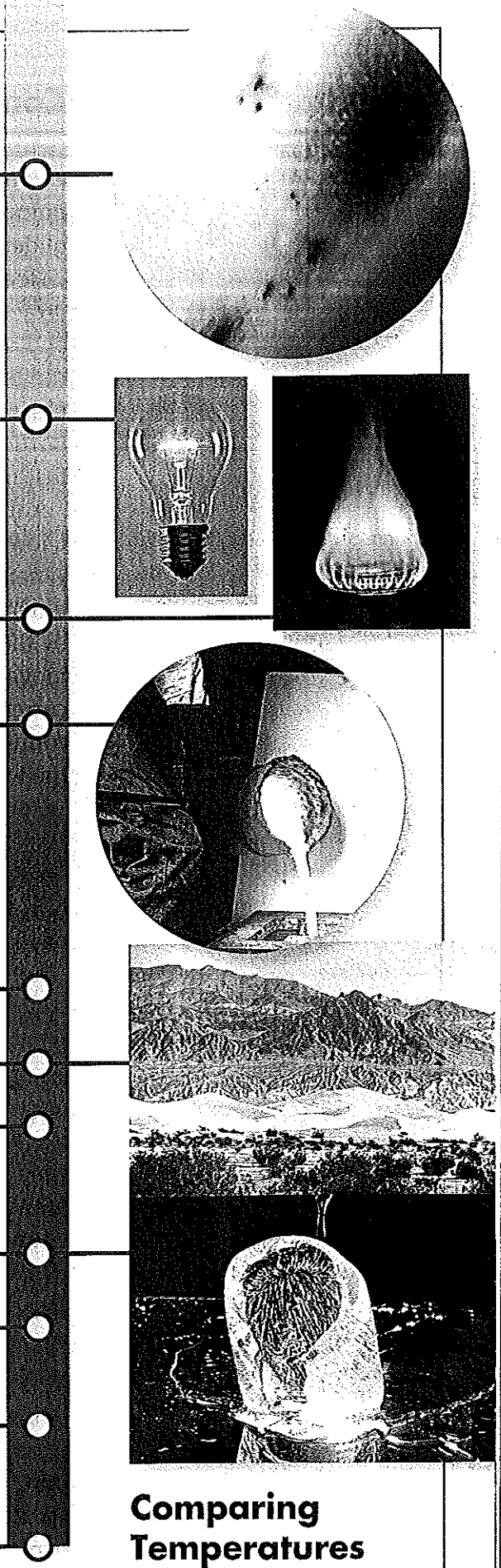
Conduction

Heat transfer between two objects that touch is called **conduction.** Think about what happens if you place ice cubes in a glass of warm lemonade. Do the ice cubes cool the lemonade, or does the lemonade warm the ice cubes?

The temperature of the ice cubes is lower than the temperature of the lemonade. The particles that make up the lemonade are vibrating faster than the particles of the ice. When the ice touches the lemonade, the particles in the lemonade bump against the ice particles. This causes the ice particles to move faster and faster. Heat flows from the warmer lemonade to the cooler ice. The lemonade particles slow down. Conduction of heat has warmed the ice and cooled the lemonade.

When heat moves by conduction, the particles in the substances do not change their location. Energy is passed from particle to particle as the particles vibrate and bump against other particles. This movement of energy may occur between a warmer substance and a cooler one. It may also occur between the warm part of an object and a cooler part of the same object.

1. **Checkpoint** Why doesn't the temperature of an object change if you break the object in half?
2. **Technology** in Science Heat naturally moves from warm to cool objects, but refrigerators reverse this movement. Research and write a paragraph that explains this process.



Comparing Temperatures

Convection

A hang glider soars through the air, swooping up and circling again and again. The wings of the glider provide balance, but how is the glider able to move upward? Hang gliders depend on the movement of thermal energy in the air.

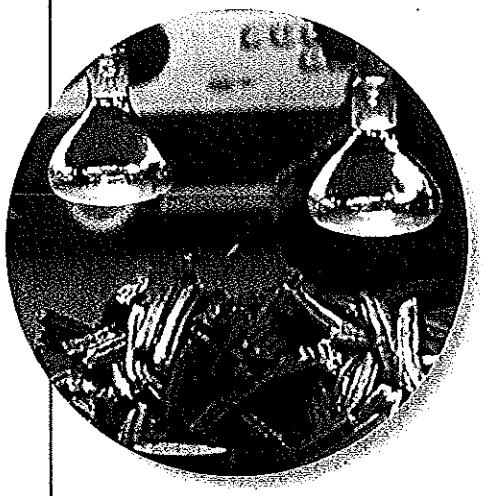
Heat moves from the warm ground to the air just above it by conduction. As with solids, the kinetic and potential energy of particles in a fluid—a liquid or gas—increases if the fluid touches a warmer object. Energy from the warmer object moves into the fluid. As the fluid becomes warmer, its particles move faster. The density of a fluid decreases as the fast-moving particles spread apart.

A fluid with a higher density sinks below a fluid with a lower density. This causes the lower-density fluid to rise. When this happens, the rising fluid carries thermal energy along with it. **Convection** is the transfer of thermal energy by the movement of the particles of a liquid or a gas. This movement results in a stream of fluid called a convection current. Hang gliders can fly great distances as they are continually pushed upward by convection currents along the way.

Hang gliders can stay in the air longer because of convection. They are pushed upward as they fly through rising currents of warm air called thermals.

Convection currents in the air cause winds to form. As warm air rises, cooler air rushes in to fill its place near the ground. The rising warm air becomes cooler and begins to fall. The cooler air near the ground becomes warmer and begins to rise.

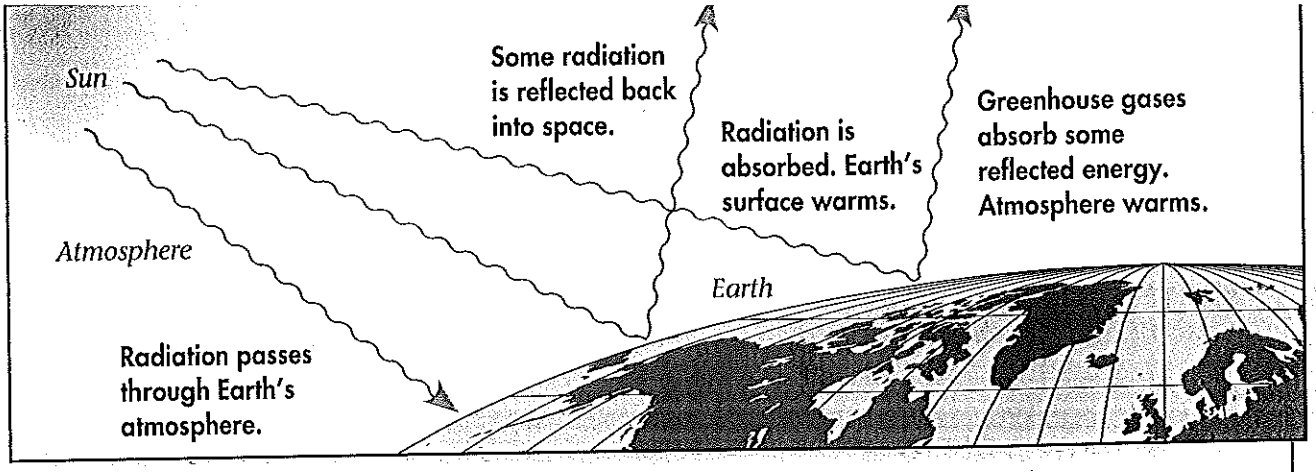
A pot of boiling water is another example of convection. If you place a pot of water on a stove, the temperature of the pot rises by conduction. Heat moves from the stove to the pot. The pot then warms the water that touches it by conduction as heat moves from the pot to the water. The warm water is less dense than the cooler water above it. The cool water then sinks, causing the warm water to rise. The rising and falling of warmer and cooler water increases the temperature of the entire pot of water.



Energy from these lamps moves by radiation to keep the food warm.

Radiation

For the chameleon, a good way to spend a sunny afternoon is sitting on a rock. Like all reptiles, chameleons warm their bodies with energy from the Sun. This energy must travel from the Sun to Earth through space that has almost no matter. **Radiation** is the transfer of thermal energy as waves. It can involve energy transfer through matter or across empty space.



When solar radiation reaches Earth's atmosphere, some of the energy is reflected back toward space. The rest of the radiation reaches Earth. Like the atmosphere, Earth's surface reflects some radiation and absorbs the rest. The absorbed radiation heats Earth's surface, which releases some of this heat back into the atmosphere. There gases, such as carbon dioxide and water vapor, absorb the energy and become warmer. These gases surround Earth and act like a blanket to hold heat. This process by which the atmosphere holds heat is called the greenhouse effect.

The greenhouse effect is a natural process. Without it, Earth would be a cold, lifeless planet. But some scientists are concerned that the increase in some atmospheric gases, such as carbon dioxide, will cause the atmosphere to become too warm. Increased temperatures can have a harmful effect on Earth's ecosystems.

Energy from the Sun warms a chameleon by radiation. The chameleon is also warmed by conduction. Heat moves from the rock into the chameleon's body.

1. **Checkpoint** Why is radiation the only type of heat transfer by which the Sun's energy can move to Earth?
2. **Art in Science** Draw an illustration that explains convection currents.