Section 4

# Uses of Heat

## Reading Preview

### Key Concepts

- How do heat engines use thermal energy?
- How do refrigerators keep things cold?

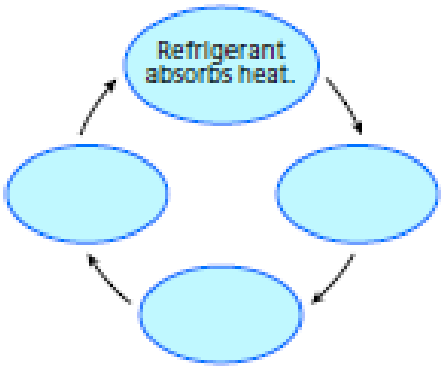
### Key Terms

- heat engine
- external combustion engine
- internal combustion engine
- refrigerant

### Target Reading Skill

**Sequencing** A sequence is the order in which the steps in a process occur. As you read, make a cycle diagram that shows how refrigerators work. Write each phase of the cooling system's cycle in a separate circle.

**How Refrigerators Work**




Lab ZONE **Discover Activity**

### What Happens at the Pump?

1. Obtain a bicycle pump and a deflated basketball or soccer ball.
2. Feel the pump with your hand. Note whether it feels cool or warm to the touch.
3. Use the pump to inflate the ball to the recommended pressure.
4. As soon as you stop pumping, feel the pump again. Observe any changes in temperature.

**Think It Over**

**Developing Hypotheses** Propose an explanation for any changes that you observed.

For more than 100 years, the steam locomotive was a symbol of power and speed. It first came into use in the 1830s, and was soon hauling hundreds of tons of freight faster than a horse could gallop. Today, many trains are pulled by diesel locomotives that are far more efficient than steam locomotives.

## Heat Engines

To power a coal-burning steam locomotive, coal is shoveled into a roaring fire. Heat is then transferred from the fire to water in the boiler. But how can heat move a train?

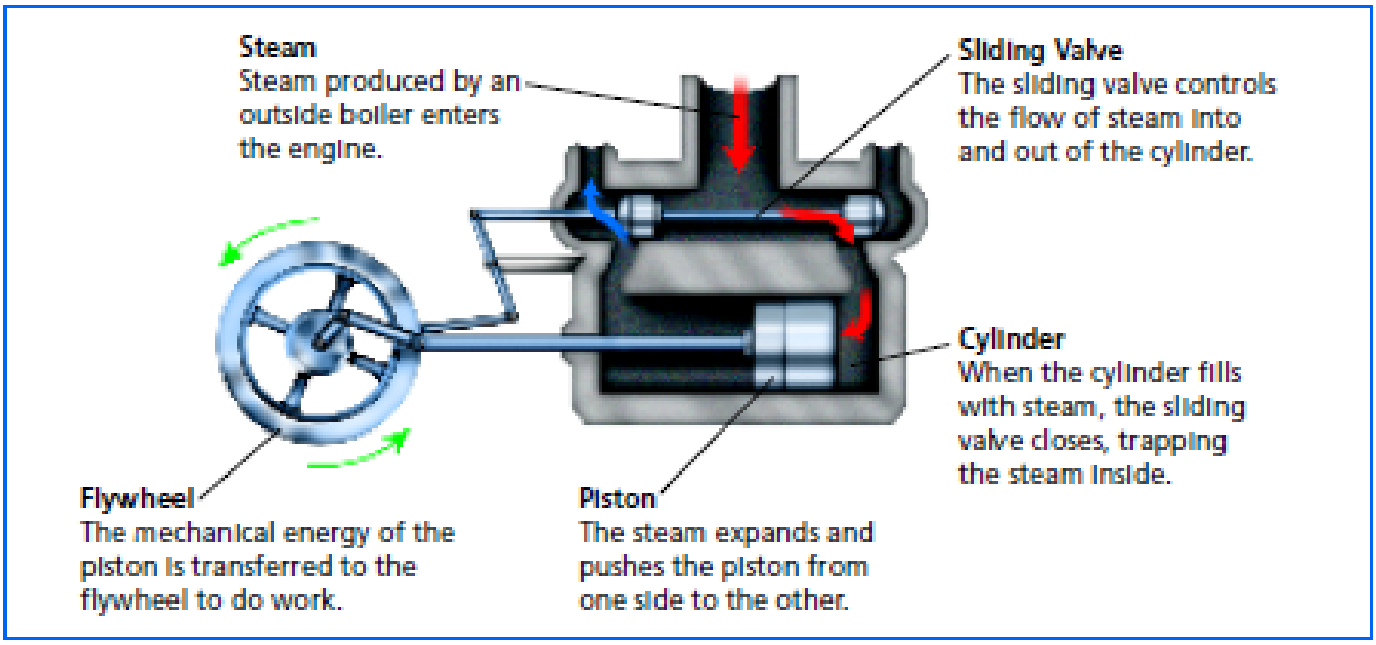
The thermal energy of the coal fire must be transformed to the mechanical energy, or energy of motion, of the moving train. You already know about the reverse process, the transformation of mechanical energy to thermal energy. It happens when you rub your hands together to make them warm.

The transformation of thermal energy to mechanical energy requires a device called a **heat engine.** Heat engines usually make use of combustion. Recall from Chapter 5 that combustion is the process of burning a fuel, such as coal or gasoline. During combustion, chemical energy that is stored in fuel is transformed to thermal energy. **Heat engines transform thermal energy to mechanical energy.** Heat engines are classified according to whether combustion takes place outside the engine or inside the engine.

FIGURE 15

## External Combustion Engine

In a steam-powered external combustion engine, expanding steam pushes a piston back and forth inside a cylinder. The steam's thermal energy is transformed to mechanical energy.




Lab zone **Try This Activity**

### Shake It Up

How does work relate to temperature?

1. Place a handful of dry sand in a metal container that has a cover.
2. Measure the temperature of the sand with a thermometer.
3. Cover the can and shake it vigorously for a minute or two.
4. Predict any change in the temperature of the sand. Was your prediction correct?

**Classifying** Identify any energy transformations and use them to explain your observations.

**External Combustion Engines** Engines that burn fuel outside the engine in a boiler are called **external combustion engines.** A steam engine, like the one shown in Figure 15, is an example of an external combustion engine. The combustion of wood, coal, or oil heats water in a boiler. As its thermal energy increases, the liquid water turns to water vapor, or steam. The steam is then passed through a sliding valve into the engine, where it pushes against a metal plunger called a piston. Work is done on the piston as it moves back and forth in a tube called a cylinder. The piston's motion turns a flywheel.

**Internal Combustion Engines** Engines that burn fuel in cylinders inside the engine are called **internal combustion engines.** Diesel and gasoline engines, which power most automobiles, are internal combustion engines. A piston inside a cylinder moves up and down, turning a crankshaft. The motion of the crankshaft is transferred to the wheels of the car.

Each up or down movement by a piston is called a stroke. Most diesel and gasoline engines are four-stroke engines, as shown in Figure 16. Automobile engines usually have four, six, or eight cylinders. The four-stroke process occurs in each cylinder, and is repeated many times each second.

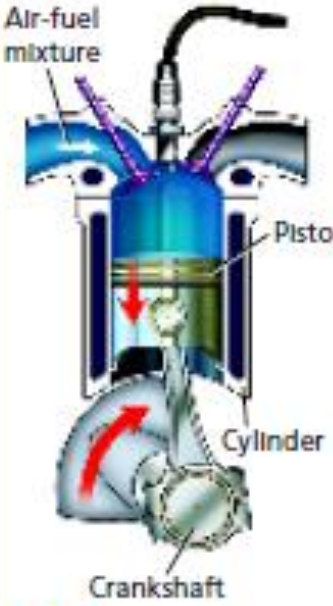
Reading Checkpoint **How many cylinders do automobiles usually have?**

FIGURE 16

## Four-Stroke Engine

Most automobiles use four-stroke engines. These four strokes occur repeatedly in each of the engine's cylinders.

**Interpreting Diagrams** *During which stroke is thermal energy transformed to mechanical energy?*

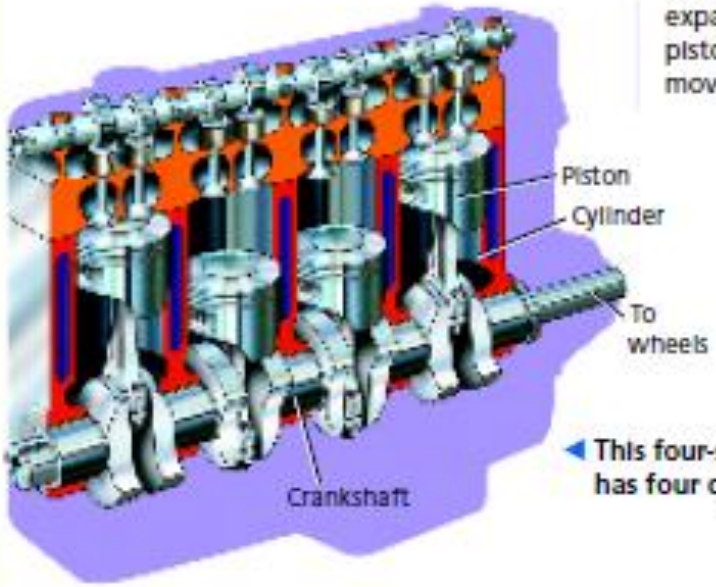



**1 Intake Stroke**
A mixture of fuel and air is drawn into the cylinder as the piston moves down.


**2 Compression Stroke**
The mixture is compressed into a smaller space as the piston moves back up.


**3 Power Stroke**
A spark plug ignites the mixture. The heated gas expands and pushes the piston down. The piston moves the crankshaft.


**4 Exhaust Stroke**
The piston moves back up, pushing the heated gas out. This makes room for new fuel and air, so that the cycle can be repeated.




◀ **This four-stroke engine has four cylinders.**

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## Cooling Systems

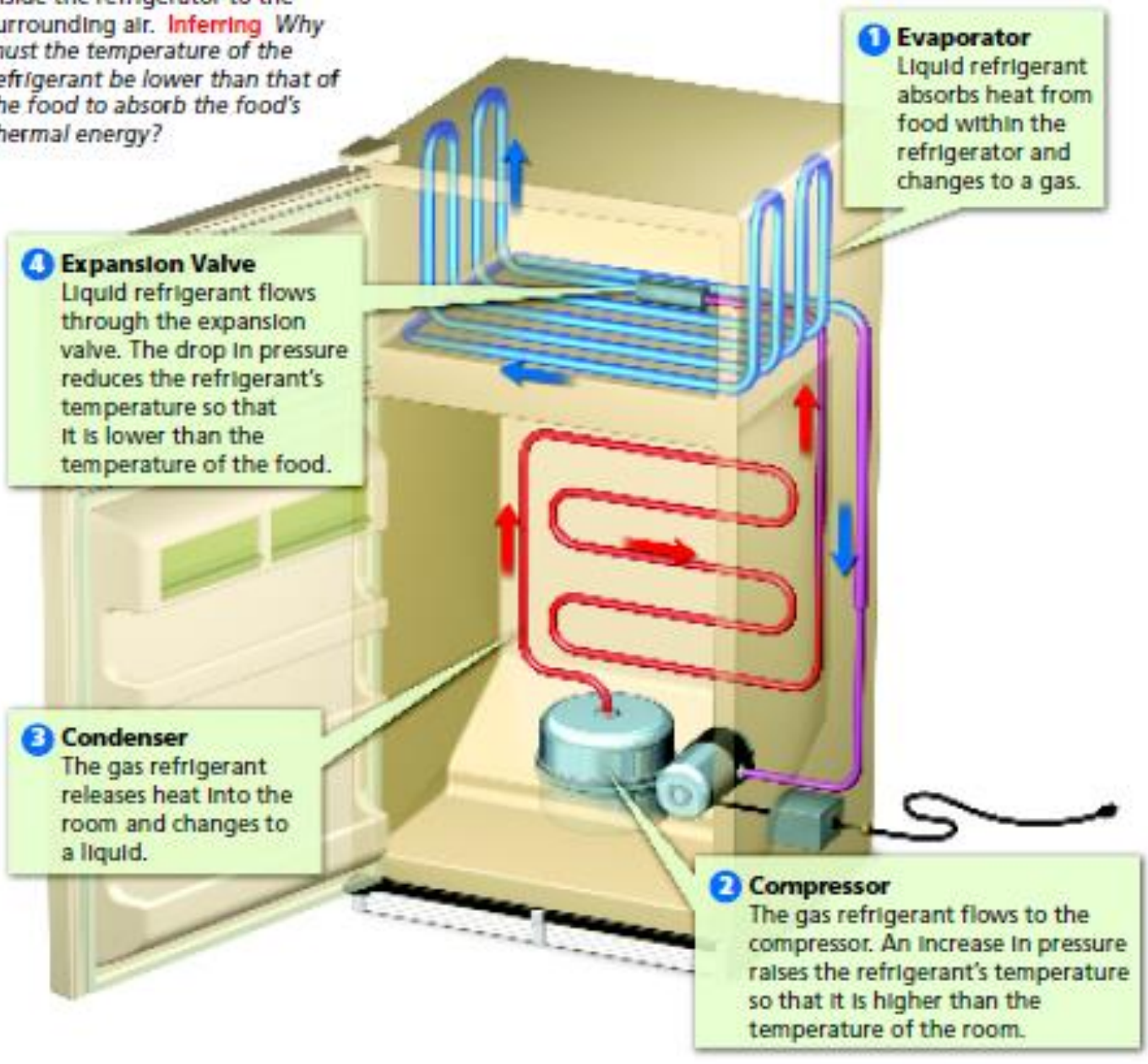
The transfer of heat can sometimes be used to keep things cool. Are you surprised? After all, heat naturally flows from a warm area to a cold area—not the other way around. But some devices, such as refrigerators, can transfer heat from cold areas to warm areas.

**Refrigerators** A refrigerator is cold inside. So where does the heat in the warm air rising from the back of a refrigerator come from? You may be surprised to learn that part of the heat actually comes from food in the refrigerator! **A refrigerator is a device that transfers thermal energy from inside the refrigerator to the room outside.** In doing so, the refrigerator transfers thermal energy from a cool area to a warm area.

FIGURE 17

### Refrigerator

Inside a refrigerator, refrigerant moves through a system of pipes, transferring thermal energy from inside the refrigerator to the surrounding air. Inferring *Why must the temperature of the refrigerant be lower than that of the food to absorb the food's thermal energy?*



A substance called a **refrigerant** absorbs and releases heat in a refrigerator. As shown in Figure 17, the refrigerant moves through a closed system of pipes. These pipes run along the back of the refrigerator and inside where food is stored. The coiled pipes inside make up the evaporator. As the refrigerant enters the evaporator, it is a liquid. Because it is colder than the food, it absorbs the thermal energy of the food. The food's thermal energy raises the refrigerant's temperature, causing it to evaporate. Then, the gas refrigerant enters an electric pump called a compressor. The compressor increases the refrigerant's pressure, further raising its temperature.

From the compressor, the gas refrigerant flows to the coiled pipes at the back of the refrigerator that make up the condenser. When it enters the condenser, the refrigerant is warmer than the air in the room. It releases heat into the air and its temperature drops, causing the refrigerant to condense. The pressure of the liquid refrigerant is decreased as it flows into a narrow opening called an expansion valve. The decreased pressure lowers the refrigerant's temperature further. The refrigerant recycles as it flows back to the evaporator.

**Air Conditioners** The air conditioners used in homes, schools, and cars cool air in the same way that a refrigerator cools food. Refrigerant in a system of pipes changes from a liquid to a gas and back again to transfer heat. Unlike a refrigerator, however, an air conditioner absorbs heat from the air inside a room or car and transfers it to the outdoors.

Reading Checkpoint **How are air conditioners and refrigerators similar?**

## Section 4 Assessment

**Target Reading Skill** Sequencing Refer to your cycle diagram about cooling systems as you answer Question 2.

### Reviewing Key Concepts

1. a. Describing What does a heat engine do?
   b. Comparing and Contrasting How are internal combustion engines different from external combustion engines? How are they similar?
   c. Making Generalizations Why do you think modern cars use internal rather than external combustion engines?
2. a. Identifying What changes of state occur in the refrigerant of a refrigerator?
   b. Explaining Where do the changes of state occur?
   c. Predicting If the compressor in a refrigerator stopped working, how would its failure affect the heat transfer cycle?

### Writing in Science

**Cause-and-Effect Paragraph** The invention of the heat engine and refrigerator both had a great impact on society. Write about how daily life might be different if either system had not been invented.