All matter is made of moving particles.

You have read that any object in motion has kinetic energy. All the moving objects you see around you—from cars to planes to butterflies—have kinetic energy. Even objects so small that you cannot see them, such as atoms, are in motion and have kinetic energy.

You might think that a large unmoving object, such as a house or a wooden chair, does not have any kinetic energy. However, all matter is made of atoms, and atoms are always in motion, even if the objects themselves do not change their position. The motion of these tiny particles gives the object energy. The chair you are sitting on has some amount of energy. You also have energy, even when you are not moving.
**The Kinetic Theory of Matter**

Physical properties and physical changes are the result of how particles of matter behave. The **kinetic theory of matter** states that all of the particles that make up matter are constantly in motion. As a result, all particles in matter have kinetic energy. The kinetic theory of matter helps explain the different states of matter—solid, liquid, and gas.

1. The particles in a solid, such as concrete, are not free to move around very much. They vibrate back and forth in the same position and are held tightly together by forces of attraction.

2. The particles in a liquid, such as water in a pool, move much more freely than particles in a solid. They are constantly sliding around and tumbling over each other as they move.

3. In a gas, such as the air around you or in a bubble in water, particles are far apart and move around at high speeds. Particles might collide with one another, but otherwise they do not interact much.

Particles do not always move at the same speed. Within any group of particles, some are moving faster than others. A fast-moving particle might collide with another particle and lose some of its speed. A slow-moving particle might be struck by a faster one and start moving faster. Particles have a wide range of speeds and often change speeds.

What is the kinetic theory of matter?
**Temperature and Kinetic Energy**

Particles of matter moving at different speeds have different kinetic energies because kinetic energy depends on speed. It is not possible to know the kinetic energy of each particle in an object. However, the average kinetic energy of all the particles in an object can be determined.

**Temperature** is a measure of the average kinetic energy of all the particles in an object. If a liquid, such as hot cocoa, has a high temperature, the particles in the liquid are moving very fast and have a high average kinetic energy. The cocoa feels hot. If a drink, such as a fruit smoothie, has a low temperature, the particles in the liquid are moving more slowly and have a lower average kinetic energy. The smoothie feels cold.

You experience the connection between temperature and the kinetic energy of particles every day. For example, to raise the temperature of your hands on a cold day—to warm your hands—you have to add energy, perhaps by putting your hands near a fire or a hot stove. The added energy makes the particles in your hands move faster. If you let a hot bowl sit on a table for a while, the particles in the bowl slow down due to collisions with particles in the air and in the table. The temperature of the bowl decreases, and it becomes cooler.

Temperature is the measurement of the average kinetic energy of particles, not just their speed. Recall that kinetic energy depends on mass as well as speed. Particles in a metal doorknob do not move as fast as particles in air. However, the particles in a doorknob have more mass and they can have the same amount of kinetic energy as particles in air. As a result, the doorknob and the air can have equal temperatures.

How does temperature change when kinetic energy increases?
Temperature can be measured.

You have read that a warmer temperature means a greater average kinetic energy. How is temperature measured and what does that measurement mean? Suppose you hear on the radio that the temperature outside is 30 degrees. Do you need to wear a warm coat to spend the day outside? The answer depends on the temperature scale being used. There are two common temperature scales, both of which measure the average kinetic energy of particles. However, 30 degrees on one scale is quite different from 30 degrees on the other scale.

Temperature Scales

To establish a temperature scale, two known values and the number of units between the values are needed. The freezing and boiling points of pure water are often used as the standard values. These points are always the same under the same conditions and they are easy to reproduce. In the two common scales, temperature is measured in units called degrees (°), which are equally spaced units between two points.

The scale used most commonly in the United States for measuring temperature—in uses ranging from cooking directions to weather reports—is the Fahrenheit (FAR-uhn-HYT) scale (°F). It was developed in the early 1700s by Gabriel Fahrenheit. On the Fahrenheit scale, pure water freezes at 32°F and boils at 212°F. Thus, there are 180 degrees—180 equal units—between the freezing point and the boiling point of water.

The temperature scale most commonly used in the rest of the world, and also used more often in science, is the Celsius (SEHL-see-uhhs) scale (°C). This scale was developed in the 1740s by Anders Celsius. On the Celsius scale, pure water freezes at 0°C and boils at 100°C, so there are 100 degrees—100 equal units—between these two temperatures.

Recall the question asked in the first paragraph of this page. If the outside temperature is 30 degrees, do you need to wear a warm coat? If the temperature is 30°F, the answer is yes, because that temperature is colder than the freezing point of water. If the temperature is 30°C, the answer is no—it is a nice warm day (86°F).

How are the Fahrenheit and Celsius temperature scales different? How are they similar?
**Thermometers**

Temperature is measured by using a device called a thermometer. A thermometer measures temperature through the regular variation of some physical property of the material inside the thermometer. A mercury or alcohol thermometer, for example, can measure temperature because the liquid inside the thermometer always expands or contracts by a certain amount in response to a change in temperature.

Liquid-filled thermometers measure how much the liquid expands in a narrow tube as the temperature increases. The distances along the tube are marked so that the temperature can be read. At one time, thermometers were filled with liquid mercury because it expands or contracts evenly at both high and low temperatures. This means that mercury expands or contracts by the same amount in response to a given change in temperature. However, mercury is dangerous to handle, so many thermometers today are filled with alcohol instead.

Some thermometers work in a different way—they use a material whose electrical properties change when the temperature changes. These thermometers can be read by computers. Some show the temperature on a display panel and are often used in cars and in homes.

**INVESTIGATE Temperature Measurements**

**How does a thermometer work?**

**PROCEDURE**

1. To make your own thermometer, fill the bottle halfway with the alcohol solution. Add a small amount of food coloring and mix thoroughly.
2. Place the straw into the bottle. Use clay to suspend the straw above the bottom of the bottle and to seal the bottle’s mouth completely.
3. Pour ice water into the bowl and place the bottle into the ice water. Record your observations, and then empty the bowl.
4. Pour hot water into the bowl and place the bottle into the hot water. Record your observations.

**WHAT DO YOU THINK?**

- What happened to the level of the alcohol solution in the straw when the bottle was put into the ice water? into the hot water?
- Why do you think these changes happened?

**CHALLENGE** How could you modify your thermometer so that you could use it to measure a temperature?
During construction of the Gateway Arch in St. Louis, engineers had to account for thermal expansion.

Thermal Expansion

The property that makes liquid-filled thermometers work is called thermal expansion. Thermal expansion affects many substances, not just alcohol and liquid mercury. All gases, many liquids, and most solids expand when their temperature increases.

Construction engineers often have to take thermal expansion into account because steel and concrete both expand with increasing temperature. An interesting example involves the construction of the Gateway Arch in St. Louis, which is built mostly of steel.

The final piece of the Arch to be put into place was the top segment joining the two legs. The Arch was scheduled to be completed in the middle of the day for its opening ceremony. However, engineers knew that the side of the Arch facing the Sun would get hot and expand due to thermal expansion.

This expansion would narrow the gap between the legs and prevent the last piece from fitting into place. In order to complete the Arch, workers sprayed water on the side facing the Sun. The water helped cool the Arch and decreased the amount of thermal expansion. Once the final segment was in place, engineers made the connection strong enough to withstand the force of the expanding material.

Thermal expansion occurs in solids because the particles of solids vibrate more at higher temperatures. Solids expand as the particles move ever so slightly farther apart. This is why bridges and highways are built in short segments with slight breaks in them, called expansion joints. These joints allow the material to expand safely.

Why do objects expand when their temperatures increase?

**KEY CONCEPTS**

1. Describe the relationship between temperature and kinetic energy.
2. Describe the way in which thermometers measure temperature.
3. How can you explain thermal expansion in terms of kinetic energy?

**CRITICAL THINKING**

4. **Synthesize** Suppose a mercury thermometer shows that the air temperature is 22°C (72°F). Do particles in the air have more average kinetic energy than particles in the mercury? Explain.

5. **Infer** If a puddle of water is frozen, do particles in the ice have kinetic energy? Explain.

**CHALLENGE**

6. **Apply** Why might a sidewalk be built with periodic breaks in it?