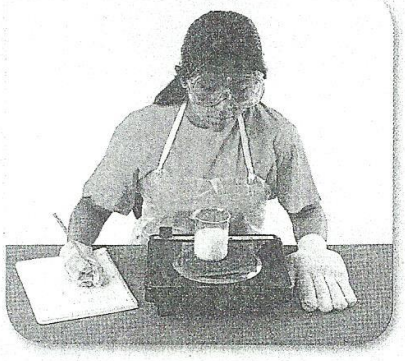
Launch Lab

15 minutes

How can movement deep within Earth change its surface?

Have you ever warmed a pot of soup on a stove ? If so, you probably noticed that the noodles and vegetables moved around the pot. How is this movement similar to movement within Earth?



1. Read and complete a lab safety form.
2. Pour the **fluid** into a **250-mL glass beaker** until the beaker is about half full.
3. Place the beaker in the center of a **hot plate.**
4. Turn the hot plate on low, and slowly warm the fluid.
5. When the fluid starts to move, observe the beaker from the top and the side. Record your observations in your Science Journal.

Think About This

1. Describe, in detail, how the fluid moves as it warms.
2. **Key Concept** Based on your observations, how do you think this relates to movement within Earth?

Plate Tectonics

Have you ever looked at a map like the one shown in Figure 1? Did you notice that the surface is not the same everywhere? Some regions have tall, rugged mountains. Some regions have flat plains. What causes different landforms? What processes shape and change Earth's surface?

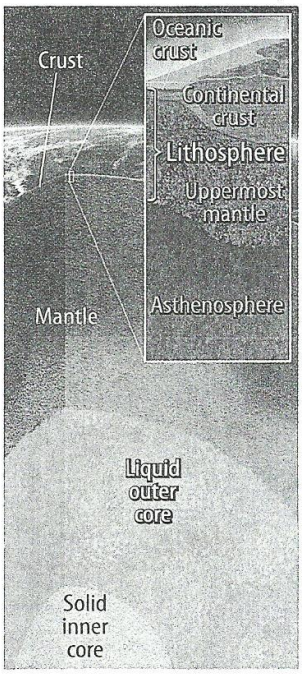
During the 1960s, scientists developed a theory to explain many of the features on Earth's surface. The theory is called **plate tectonics** (tek TAH nihks) and states that *Earth's surface is broken into large, rigid pieces that move with respect to each other.* These pieces, or tectonic plates, move slowly over Earth's surface. You will read how tectonic plate motion forms volcanoes and mountains and causes earthquakes. The theory of plate tectonics was revolutionary because it explained much about how Earth changes.

Key Concept Check What is the theory of plate tectonics?

Figure 1 Tectonic plate motion and other processes have affected North America. The western United States has tall mountains, while the central region is flat.

Word Origin

tectonic
from Greek *tekton*, means "builder"



▲ **Figure 2** The lithosphere consists of the crust and the upper part of the mantle. The lithosphere is above the hotter asthenosphere.

What is a tectonic plate?

You might know that Earth is not a solid ball of rock but is made of layers of material. The outermost layer is called the crust. As shown in **Figure 2**, *the crust and uppermost part of the mantle, make up the* **lithosphere** (LIH thuh sfihr). The lithosphere forms a rigid shell on the outside of Earth. However, it is broken into large pieces—tectonic plates.

The rocks in the lithosphere are strong and do not bend easily. However, *the partially melted portion of the mantle below the lithosphere is the* **asthenosphere** (as THEN uh sfihr), also shown in **Figure 2**. The asthenosphere is hotter than the lithosphere and can bend more easily. As you will read, the ability of the asthenosphere to bend is related to tectonic plate movement.

Major Tectonic Plates

Scientists have identified 15 large tectonic plates, as shown in **Figure 3**. Some plates are so large they support entire continents. Other plates are so small that they cannot be represented on a map of this scale.

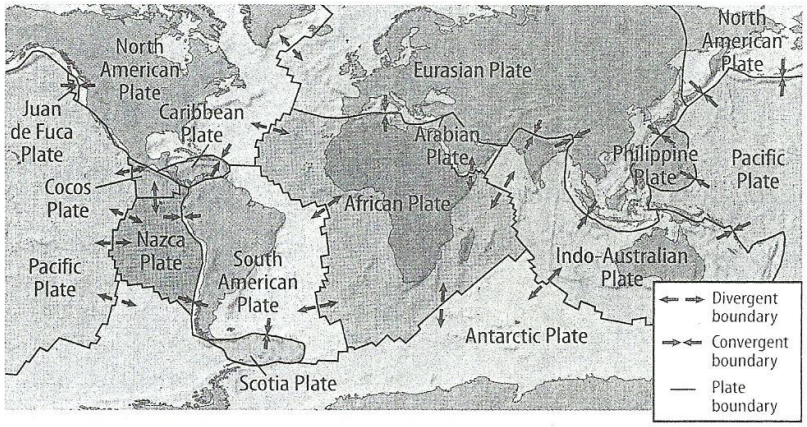
Many of you live on the North American Plate. To the east of it is the Eurasian Plate. To the west are two plates—a small plate called the Juan de Fuca Plate and the largest plate, the Pacific Plate. Oceans completely cover some plates, such as the Juan de Fuca Plate. Other plates, such as the North American Plate, are made of both oceanic crust and continental crust.

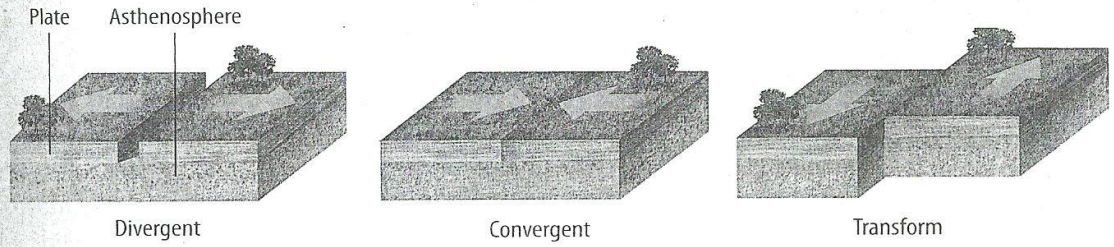
Reading Check What is a tectonic plate?

Earth's Tectonic Plates

Figure 3 Earth's tectonic plates fit together like puzzle pieces. They are in constant motion across the surface.

Visual Check How many large plates have continents on them?





▲ **Figure 4** The relative movement of tectonic plates creates three types of plate boundaries.

Concepts in Motion
Animation

Plate Boundaries

How do scientists describe the movement of a tectonic plate? They describe a plate's relative motion—how it moves in relation to another plate. For example, the North American Plate is moving away from the Eurasian Plate, but it is also moving toward the Pacific Plate.

Place two pieces of paper side by side on your desk. How can you make one sheet move relative to the other? You can push the sheets together so one goes over or under the other. Or you might move them apart or slide them by each other. Tectonic plates move in a similar way, as illustrated in **Figure 4.** As plates move relative to each other, they form different types of boundaries. The type of boundary depends on the relative motion of the plates.

Divergent Boundaries

A boundary where two plates move away from each other is called a **divergent boundary.** The boundary between the North American Plate and the Eurasian Plate is a divergent boundary. As plates move apart, new crust forms between them.

Convergent Boundaries

A boundary where two plates move toward each other is a **convergent boundary.** In some locations, one plate is pushed under the other plate and down into the mantle. That plate melts and becomes part of the mantle. **Subduction** *is the process that occurs when one tectonic plate moves under another tectonic plate,* as shown in **Figure 5.** The Pacific Plate is being subducted under the North American Plate at the convergent plate boundary adjacent to Alaska.

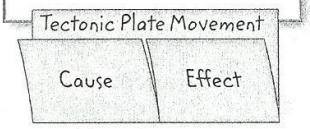
Transform Boundaries

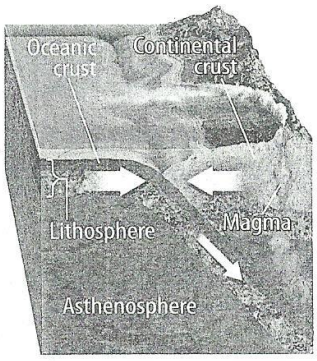
Two plates slide past each other at a **transform boundary.** The boundary between the Pacific Plate and the North American Plate in California is an example of a transform boundary.

Key Concept Check What are the differences between divergent, convergent, and transform plate boundaries?

FOLDABLES®

Make a horizontal two-tab book with an extended tab. Label it as shown. Use it to summarize the causes and effects of tectonic plate movement.





▲ **Figure 5** At a convergent boundary, the process of subduction forces one plate into the mantle.

Figure 6 Over time, tectonic plate motion broke apart the supercontinent Pangaea.

Visual Check Where were North America and Europe joined as part of Pangea?

Concepts in Motion

Animation

Measuring Plate Movement

Tectonic plates move horizontally over Earth's surface. They move so slowly that before the mid-twentieth century, geologists could not measure their movement. However, during the 1970s, scientists and engineers developed new technologies that enabled them to measure how fast tectonic plates move. This technology has determined that North America is separating from Europe at an average rate of just 2.5 cm/y.

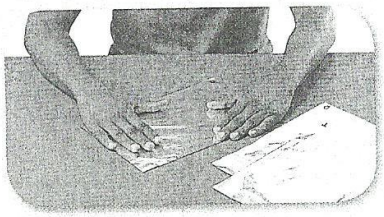
The position of any point on Earth's surface can be accurately measured using the network of satellites known as the Global Positioning System (GPS). GPS is a set of 24 satellites in orbit around Earth that send signals to help locate and track various moving objects. By tracking tectonic plate positions over several years, scientists can measure the speed and the direction of plate movement.

Even though plate movement is slow, dramatic changes occur over long periods of time. North America and Europe once were part of a large continent called Pangaea (pan GEE uh), illustrated in **Figure 6.** A divergent boundary formed between North America and Europe about 200 million years ago. The plates moved apart, and the Atlantic Ocean formed.

Inquiry **MiniLab** 15 minutes

What happens at plate boundaries?

Most rocks seem hard and unchangeable. But, under the right conditions, they can bend or break. Can you model how rocks change along plate boundaries?



1. Read and complete a lab safety form.
2. Obtain three pieces of **foil,** each 20 cm long. Use a **marker** to mark the pieces with a *C,* a *D,* and a *T.*
3. Place foil C flat on your desktop. Place the palms of your hands on the foil as shown. Slowly move your hands toward each other. Observe and record the results in your Science Journal.
4. Place foil piece D flat on your desktop. Place your palms along the edges of the foil. Slowly pull outward on the foil. Observe and then record the results.
5. Place foil piece T on your desktop. Place your palms flat against each end of the foil. At the same time, slowly move your right hand toward you and your left hand away from you. Observe and then record the results.

Analyze and Conclude

1. **Compare and Contrast** How did each piece of foil change? How does the motion of the foil model the movement of plate boundaries?
2. **Key Concept** What are the differences between divergent, convergent, and transform plate boundaries?

Why do tectonic plates move?

You have read that tectonic plates move over Earth's surface. As the plates move and interact with each other, they form convergent, divergent, and transform boundaries. But what causes plates to move?

Convection

Recall that density is the amount of matter per unit of volume. When a fluid is heated, its molecules spread out. It has less matter in the same amount of volume. So, it becomes less dense. However, fluids do not heat evenly. Some of a fluid can be warmer and less dense, while some is cooler and more dense. The warmer, less dense fluid rises, and the cooler, denser fluid sinks, as shown in **Figure 7**. *The circulation within fluids caused by differences in density and thermal energy is called* **convection.**

Convection also occurs in Earth's asthenosphere, just below the lithosphere. Recall that rocks in the mantle are hot enough to bend easily. They can flow in a way similar to fluids. Convection in the mantle can drag plates over Earth's surface, as illustrated in **Figure 7.**

Another process that causes plate movement is subduction. A plate at Earth's surface is colder and denser than the mantle below it. When two plates collide, one can subduct or sink into the hotter, less-dense mantle. When this happens, the rest of plate is pulled along behind the sinking part of the plate.

Key Concept Check What causes tectonic plates to move?

Convection Currents

Review
Personal Tutor

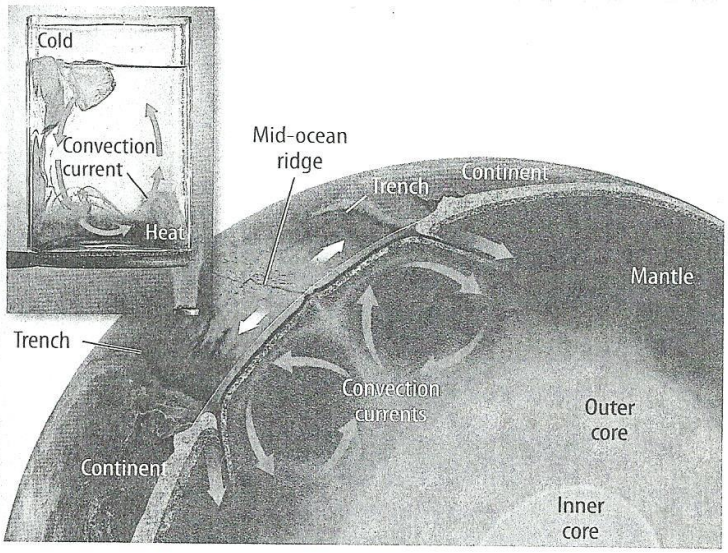


Figure 7 The left image shows convection in water—heated water rises to the surface, cools, and sinks back down. As shown on the right, heated rock in the mantle does the same. As the mantle convects, it pulls and pushes the tectonic plates above.

Math Skills

Use Proportions

The plates along the Mid-Atlantic Ridge spread at an average rate of 2.5 cm/y. How long will it take the plates to spread 100 m? Use proportions to find the answer.

1. Convert the distances to the same unit.
   100 cm = 1 m so
   2.5 cm = 0.025 m
2. Set up a proportion.
   $\frac{0.025\text{m}}{1\text{ y}} = \frac{100\text{ m}}{x\text{ y}}$
3. Cross multiply and solve for x.
   $0.025\text{m} \times x\text{ y} = 100\text{m} \times 1\text{ y}$
4. Divide both sides by 0.025 m.
   $x\text{ y} = \frac{100\text{ m/y}}{0.025\text{ m}}$
   $x = 4{,}000\text{ y}$

Practice

The Eurasian Plate travels at about 0.7 cm/y. How long would it take the plate to travel 1 km?

(1 km = 100,000 cm)

Review
- Math Practice
- Personal Tutor