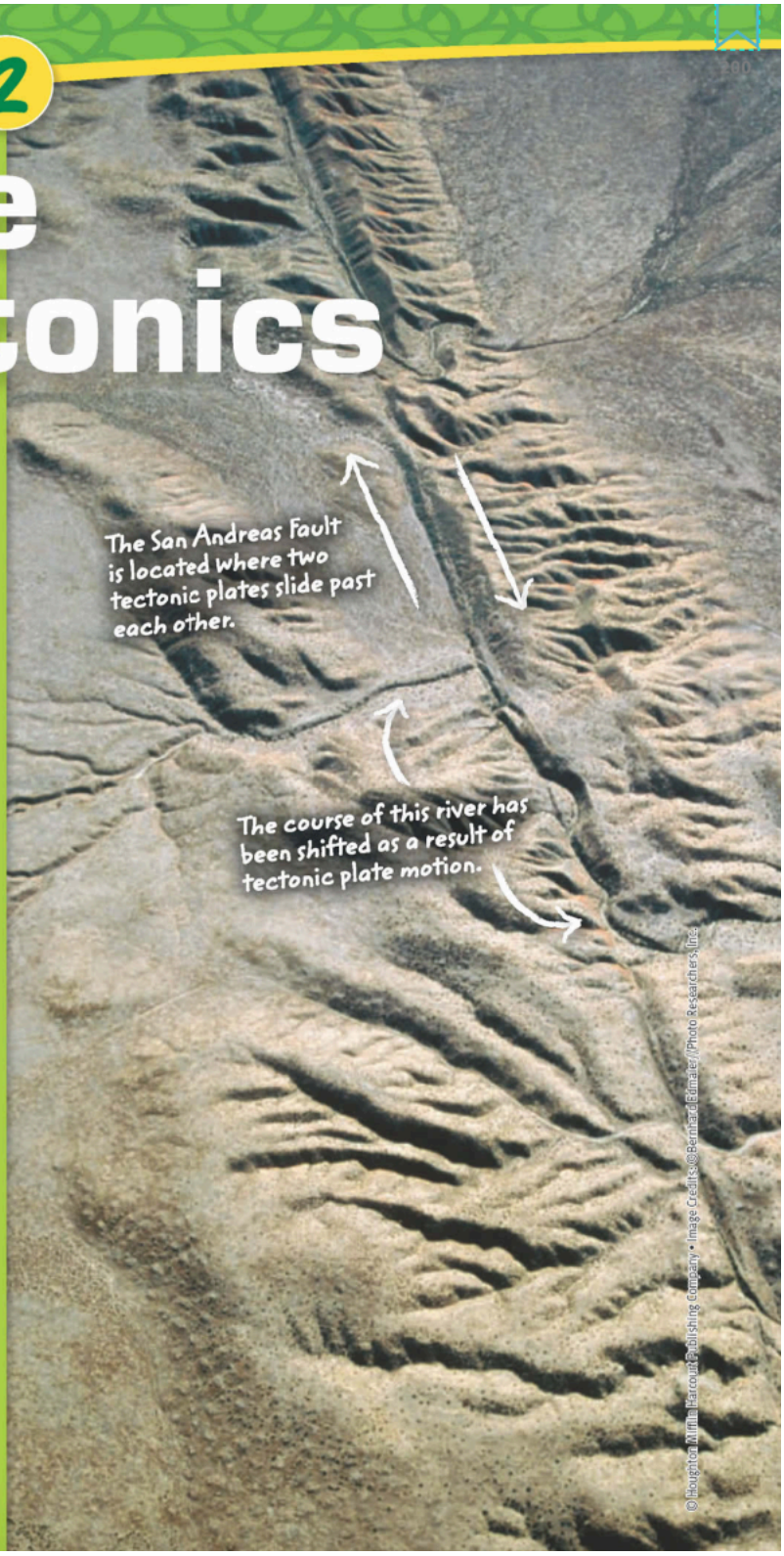
Lesson 2

Plate Tectonics



ESSENTIAL QUESTION

What is plate tectonics?

By the end of this lesson, you should be able to explain the theory of plate tectonics, to describe how tectonic plates move, and to identify geologic events that occur because of tectonic plate movement.

Lesson Labs

Quick Labs
- Tectonic Ice Cubes
- Mantle Convection
- Reconstructing Land Masses

Exploration Lab
- Seafloor Spreading

Engage Your Brain

1 Identify Check T or F to show whether you think each statement is true or false.

T	F	
☐	☐	Earth's surface is all one piece.
☐	☐	Scientists think the continents once formed a single landmass.
☐	☐	The sea floor is smooth and level.
☐	☐	All tectonic plates are the same.

2 Predict Imagine that ice cubes are floating in a large bowl of punch. If there are enough cubes, they will cover the surface of the punch and bump into one another. Parts of the cubes will be below the surface of the punch and will displace the punch. Will some cubes displace more punch than others? Explain your answer.

Active Reading

3 Apply Many scientific words, such as *divergent,* also have everyday meanings or are related to words with everyday meanings. Use context clues to write your own definition for each underlined word.

Example sentence
They argued about the issue because their opinions about it were <u>divergent</u>.

divergent:

Example sentence

The two rivers <u>converged</u> near the town.

convergent:

Vocabulary Terms

- **Pangaea**
- **sea-floor spreading**
- **plate tectonics**
- **tectonic plates**
- **convergent boundary**
- **divergent boundary**
- **transform boundary**
- **convection**

4 Identify This list contains key terms you'll learn in this lesson. As you read, underline the definition of each term.

Puzzling Evidence

What evidence suggests that continents move?

Have you ever looked at a map and noticed that the continents look like they could fit together like puzzle pieces? In the late 1800s, Alfred Wegener proposed his hypothesis of continental drift. He proposed that the continents once formed a single landmass, broke up, and drifted. This idea is supported by several lines of evidence. For example, fossils of the same species are found on continents on different sides of the Atlantic Ocean. These species could not have crossed the ocean. The hypothesis is also supported by the locations of mountain ranges and rock formations and by evidence of the same ancient climatic conditions on several continents.

Geologic evidence supports the hypothesis of continental drift.

Visualize It! **5 Summarize** Using the map and its key, complete the table to describe evidence that indicates each continent pair was once joined.

	Fossil evidence	Mountain evidence
South America and Africa		
North America and Europe		

What is Pangaea?

Active Reading **6 Identify** As you read, underline the description of how North America formed from Pangaea.

Using evidence from many scientific fields, scientists can construct a picture of continental change throughout time. Scientists think that about 245 million years ago, the continents were joined in a single large landmass they call **Pangaea** (pan•JEE•uh). As the continents collided to form Pangaea, mountains formed. A single, large ocean called Panthalassa surrounded Pangaea.

About 200 million years ago, a large rift formed and Pangaea began to break into two continents—*Laurasia* and *Gondwana*. Then, Laurasia began to drift northward and rotate slowly, and a new rift formed. This rift separated Laurasia into the continents of North America and Eurasia. The rift eventually formed the North Atlantic Ocean. At the same time, Gondwana also broke into two continents. One continent contained land that is now the continents of South America and Africa. The other continent contained land that is now Antarctica, Australia, and India.

About 150 million years ago, a rift between Africa and South America opened to form the South Atlantic Ocean. India, Australia, and Antarctica also began to separate from each other. As India broke away from Australia and Antarctica, it started moving northward, toward Eurasia.

As India and the other continents moved into their present positions, new oceans formed while others disappeared. In some cases, continents collided with other continents. About 50 million years ago, India collided with Eurasia, and the Himalaya Mountains began to form. Mountain ranges form as a result of these collisions, because a collision welds new crust onto the continents and uplifts some of the land.

The Breakup of Pangaea

245 million years ago

200 million years ago

65 million years ago

3 million years ago

What discoveries support the idea of continental drift?

Wegener's ideas of continental drift were pushed aside for many years because scientists could not determine how continents moved. Then, in the mid-1900s, scientists began mapping the sea floor. They expected the floor to be smooth and level. Instead, they found huge under-water mountain ranges called *mid-ocean ridges*. The discovery of mid-ocean ridges eventually led to the theory of plate tectonics, which built on some of Wegener's ideas.

7 **Summarize** Why would many scientists not accept the hypothesis of continental drift?

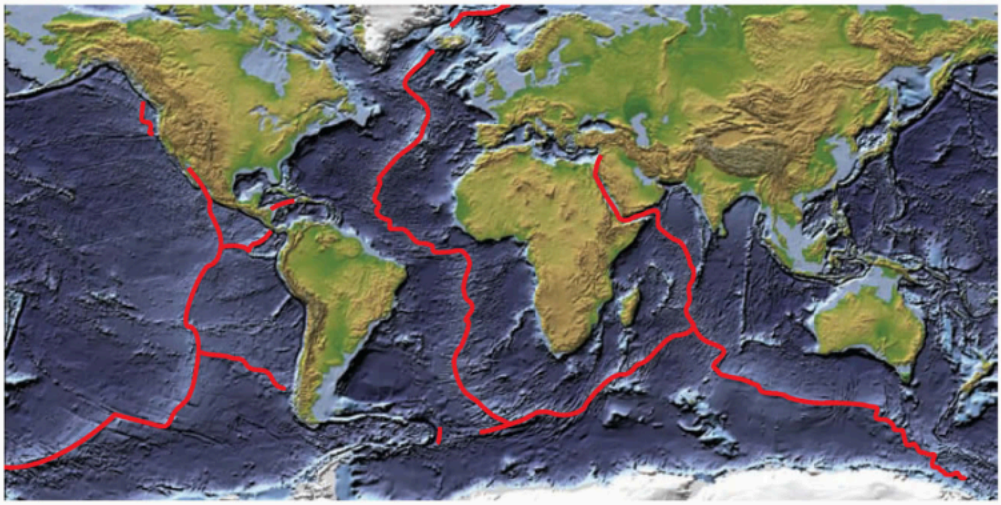
Age and Magnetic Properties of the Sea Floor

Scientists learned that the mid-ocean ridges form along cracks in the crust. Rock samples from the sea floor revealed that the youngest rock is closest to the ridge, while the oldest rock is farthest away. The samples also showed that even the oldest ocean crust is young compared to continental crust. Scientists also discovered that sea-floor rock contains magnetic patterns. These patterns form mirror images on either side of a mid-ocean ridge.

Sea-Floor Spreading

To explain the age and magnetic patterns of sea-floor rocks, scientists proposed a process called **sea-floor spreading**. In this process, molten rock from inside Earth rises through the cracks in the ridges, cools, and forms new oceanic crust. The old crust breaks along the mid-point of the ridge and the two pieces of crust move away in opposite directions from each other. In this way, the sea floor slowly spreads apart. As the sea floor moves, so do the continents on the same piece of crust.

This map shows where mid-ocean ridges are located.



Ocean Trenches

If the sea floor has been spreading for millions of years, why is Earth not getting larger? Scientists discovered the answer when they found huge trenches, like deep canyons, in the sea floor. At these sites, dense oceanic crust is sinking into the asthenosphere as shown in the diagram below. Older crust is being destroyed at the same rate new crust is forming. Thus, Earth remains the same size.

With this new information about the sea floor, sea-floor spreading, and ocean trenches, scientists could begin to understand how continents were able to move.

Active Reading

8 Identify Why is Earth not getting larger if the sea floor is spreading?

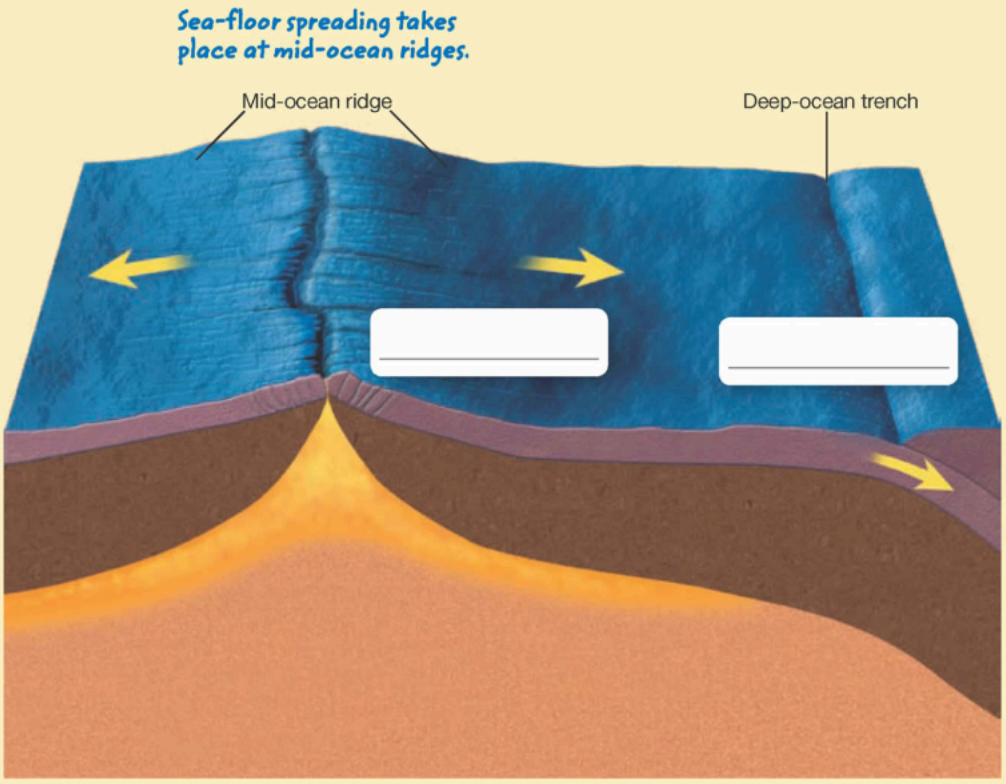
_____

_____

_____

Visualize It!

9 Provide Label the youngest rock and the oldest rock on this diagram of sea-floor spreading.



A Giant Jigsaw

What is the theory of plate tectonics?

Think Outside the Book

10 Apply Imagine that the theory of plate tectonics has just been proposed. Design a magazine ad for the theory.

As scientists' understanding of continental drift, mid-ocean ridges, and sea-floor spreading grew, scientists formed a theory to explain these processes and features. **Plate tectonics** describes large-scale movements of Earth's lithosphere, which is made up of the crust and the rigid, upper part of the mantle. Plate tectonics explains how and why features in Earth's crust form and continents move.

What is a tectonic plate?

Active Reading

11 Identify As you read, underline the definition of *tectonic plates*.

The lithosphere is divided into pieces called **tectonic plates.** These plates move around on top of the asthenosphere. The plates are moving in different directions and at different speeds. Each tectonic plate fits together with the plates that surround it. The continents are located on tectonic plates and move around with them. The major tectonic plates include the Pacific, North American, Nazca, South American, African, Australian, Eurasian, Indian, and Antarctic plates. Not all tectonic plates are the same. The South American plate has an entire continent on it and has oceanic crust. The Nazca plate has only oceanic crust.

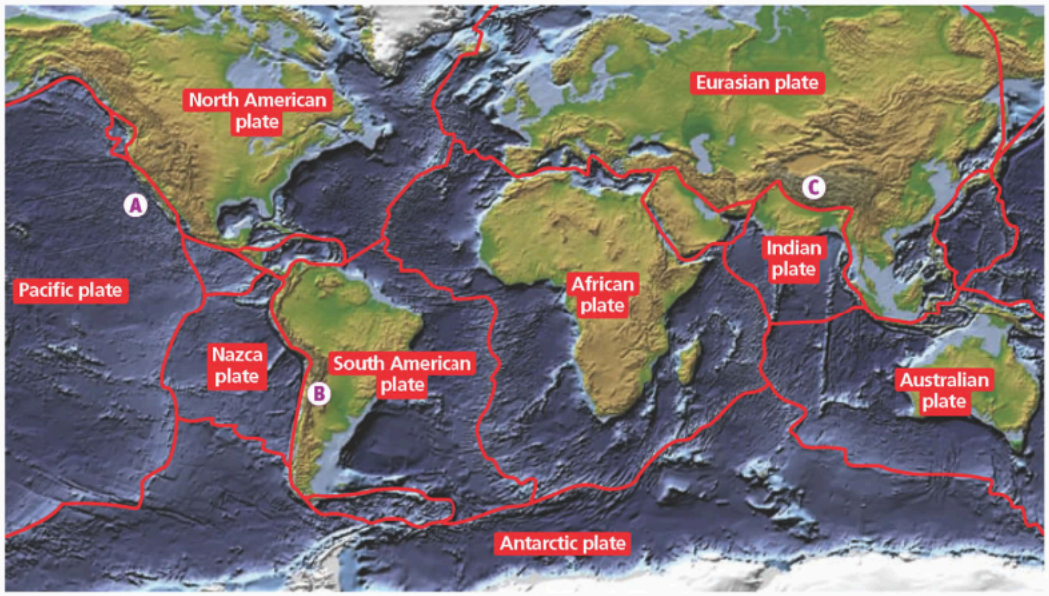
Tectonic plates cover the surface of the asthenosphere. They vary in size, shape, and thickness. Thick tectonic plates, such as those with continents, displace more asthenosphere than thin oceanic plates do. But, oceanic plates are much more dense than continental plates are.

The Andes Mountains formed where the South American plate and Nazca plate meet.

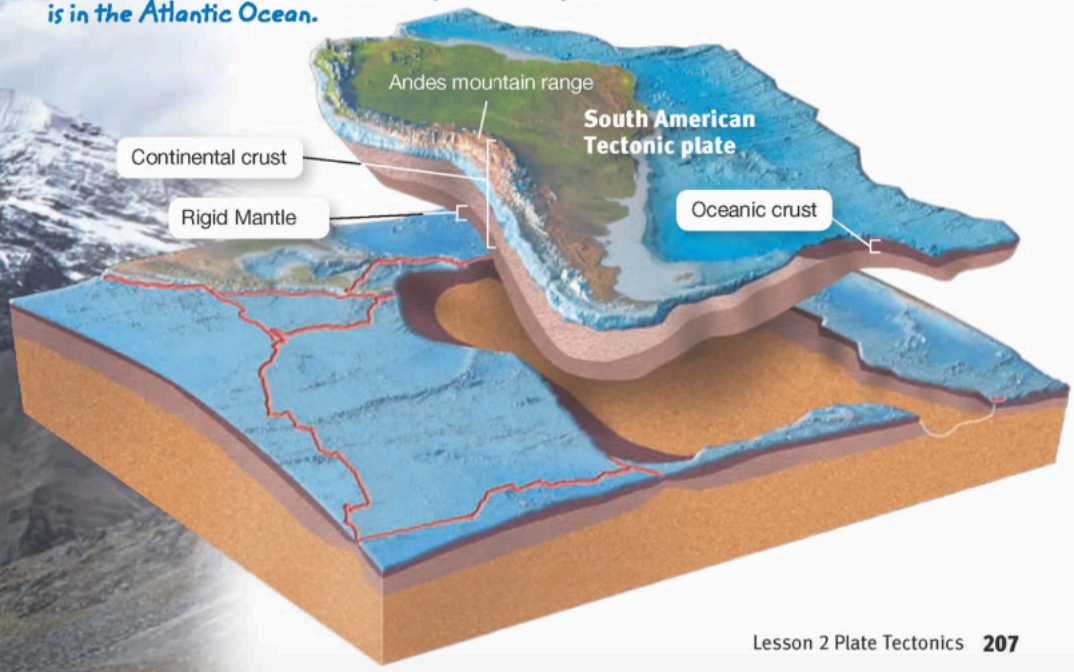
Visualize It!

12 Locate Which letter marks where the Andes Mountains are located on the map of tectonic plates, A, B, or C? _____

The tectonic plates fit together like the pieces of a jigsaw puzzle.



The thickest part of the South American plate is the continental crust. The thinnest part of this plate is in the Atlantic Ocean.



Boundaries

What are the three types of plate boundaries?

The most dramatic changes in Earth's crust occur along plate boundaries. Plate boundaries may be on the ocean floor, around the edges of continents, or even within continents. There are three types of plate boundaries: divergent boundaries, convergent boundaries, and transform boundaries. Each type of plate boundary is associated with characteristic landforms.

Active Reading

13 Identify As you read, underline the locations where plate boundaries may be found.

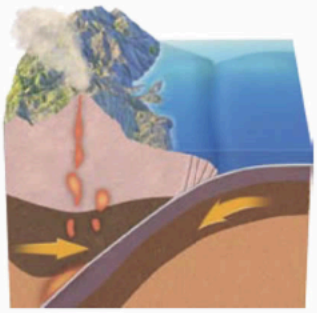
Convergent Boundaries

Convergent boundaries form where two plates collide. Three types of collisions can happen at convergent boundaries. When two tectonic plates of continental lithosphere collide, they buckle and thicken, which pushes some of the continental crust upward. When a plate of oceanic lithosphere collides with a plate of continental lithosphere, the denser oceanic lithosphere sinks into the asthenosphere. Boundaries where one plate sinks beneath another plate are called subduction zones. When two tectonic plates of oceanic lithosphere collide, one of the plates subducts, or sinks, under the other plate.

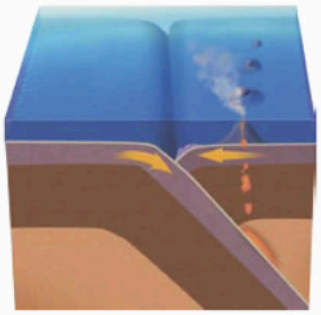
Inquiry

14 Infer Why do you think the denser plate subducts in a collision?

Continent-Continent Collisions
When two plates of continental lithosphere collide, they buckle and thicken. This causes mountains to form.



Continent-Ocean Collisions
When a plate of oceanic lithosphere collides with a plate of continental lithosphere, the oceanic lithosphere subducts because it is denser.

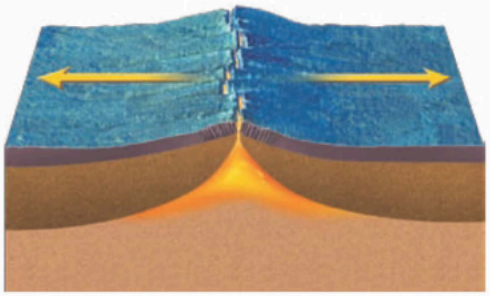


Ocean-Ocean Collisions
When two plates of oceanic lithosphere collide, the older, denser plate subducts under the other plate.

Divergent Boundaries

At a **divergent boundary**, two plates move away from each other. This separation allows the asthenosphere to rise toward the surface and partially melt. This melting creates magma, which erupts as lava. The lava cools and hardens to form new rock on the ocean floor.

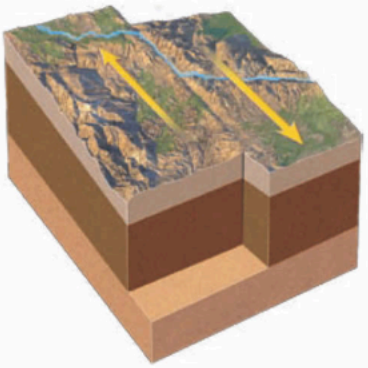
As the crust and the upper part of the asthenosphere cool and become rigid, they form new lithosphere. This lithosphere is thin, warm, and light. This warm, light rock sits higher than the surrounding sea floor because it is less dense. It forms mid-ocean ridges. Most divergent boundaries are located on the ocean floor. However, rift valleys may also form where continents are separated by plate movement.



At divergent boundaries, plates separate.

Transform Boundaries

A boundary at which two plates move past each other horizontally is called a **transform boundary**. However, the plate edges do not slide along smoothly. Instead, they scrape against each other in a series of sudden slippages of crustal rock that are felt as earthquakes. Unlike other types of boundaries, transform boundaries generally do not produce magma. The San Andreas Fault in California is a major transform boundary between the North American plate and the Pacific plate. Transform motion also occurs at divergent boundaries. Short segments of mid-ocean ridges are connected by transform faults called fracture zones.



At transform boundaries, plates slide past each other horizontally.

Active Reading

15 Contrast How are transform boundaries different from convergent and divergent boundaries?

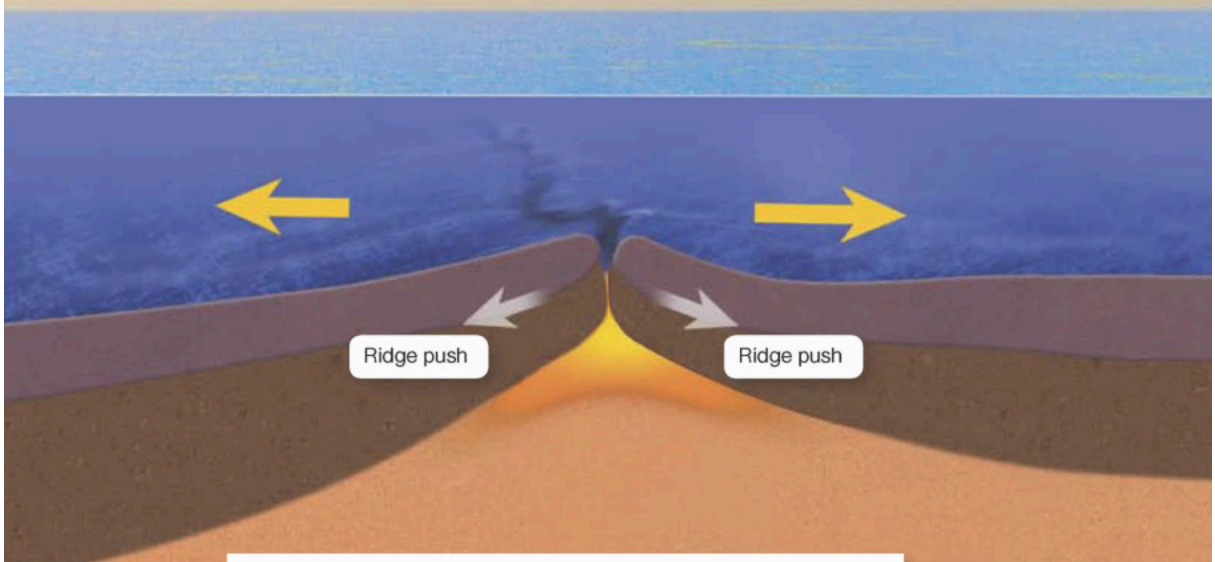
Hot Plates

What causes tectonic plates to move?

Scientists have proposed three mechanisms to explain how tectonic plates move over Earth's surface. Mantle convection drags plates along as mantle material moves beneath tectonic plates. Ridge push moves plates away from mid-ocean ridges as rock cools and becomes more dense. Slab pull tugs plates along as the dense edge of a plate sinks beneath Earth's surface.

Active Reading

16 Identify As you read, underline three mechanisms scientists have proposed to explain plate motion.



Mantle Convection

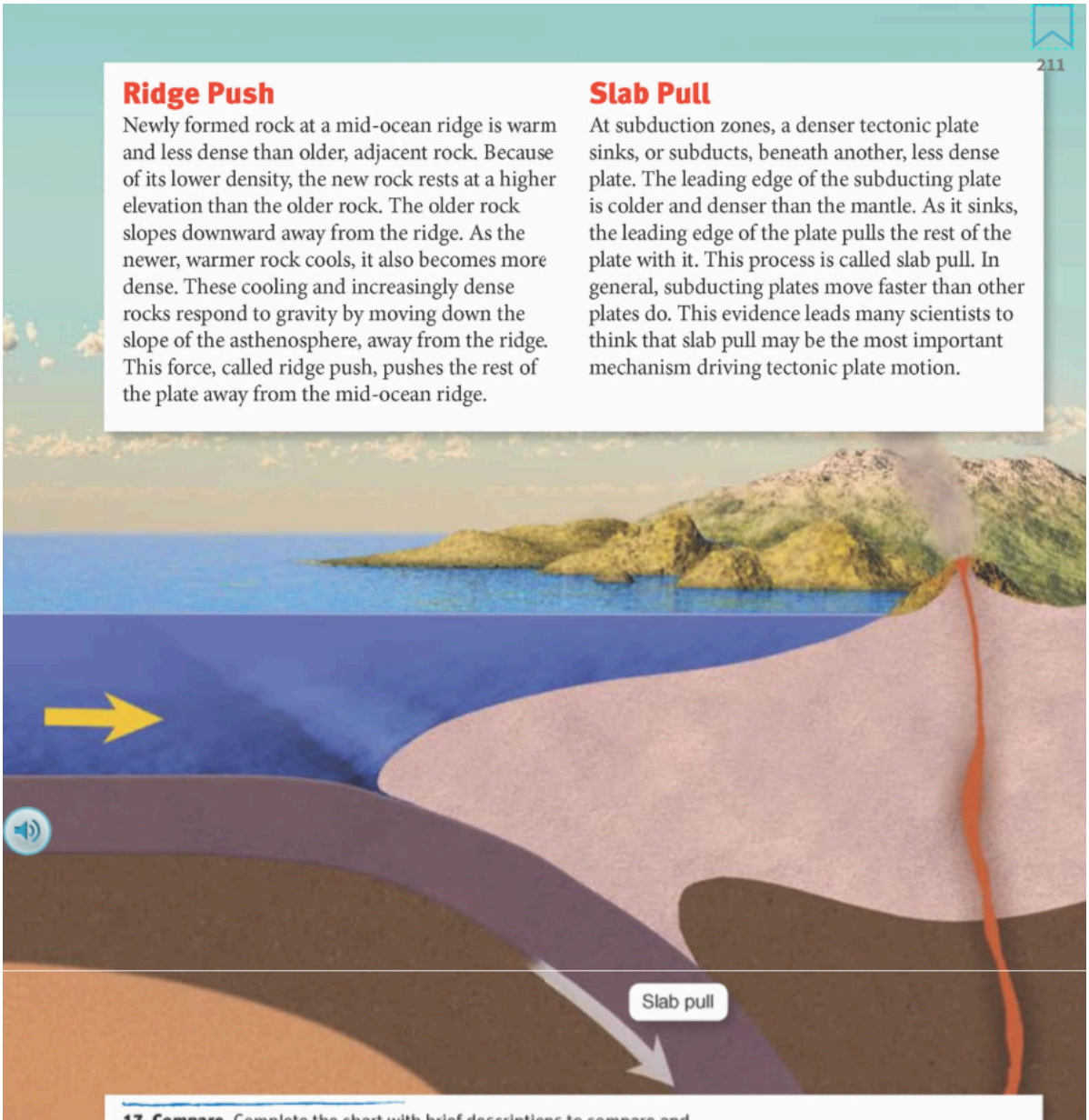
As atoms in Earth's core and mantle undergo radioactive decay, energy is released as heat. Some parts of the mantle become hotter than others parts. The hot parts rise as the sinking of cooler, denser material pushes the heated material up. This kind of movement of material due to differences in density is called **convection**. It was thought that as the mantle convects, or moves, it would drag the overlying tectonic plates along with it. However, this hypothesis has been criticized by many scientists because it does not explain the huge amount of force that would be needed to move plates.

Ridge Push

Newly formed rock at a mid-ocean ridge is warm and less dense than older, adjacent rock. Because of its lower density, the new rock rests at a higher elevation than the older rock. The older rock slopes downward away from the ridge. As the newer, warmer rock cools, it also becomes more dense. These cooling and increasingly dense rocks respond to gravity by moving down the slope of the asthenosphere, away from the ridge. This force, called ridge push, pushes the rest of the plate away from the mid-ocean ridge.

Slab Pull

At subduction zones, a denser tectonic plate sinks, or subducts, beneath another, less dense plate. The leading edge of the subducting plate is colder and denser than the mantle. As it sinks, the leading edge of the plate pulls the rest of the plate with it. This process is called slab pull. In general, subducting plates move faster than other plates do. This evidence leads many scientists to think that slab pull may be the most important mechanism driving tectonic plate motion.



17 Compare Complete the chart with brief descriptions to compare and contrast mantle convection, ridge push, and slab pull.

Mechanisms		
Mantle convection	Ridge push	Slab pull

Visual Summary

To complete this summary, fill in the blanks to complete the label or caption. Then use the key below to check your answers. You can use this page to review the main concepts of the lesson.

Plate Tectonics

The continents were joined in a single landmass.

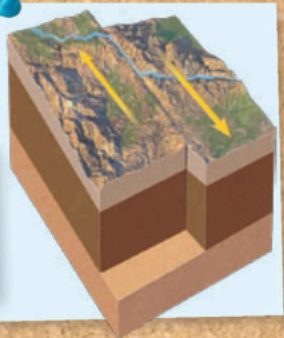
18 Scientists call the landmass _____

Tectonic plates differ in size and composition.

19 The United States lies on the _____ plate.

There are three types of plate boundaries: convergent, divergent, and transform.

20 This image shows a _____ boundary.



Three mechanisms may drive plate motion. These are mantle convection, slab pull, and ridge push.

21 The mechanism that scientists think is most important is _____

Answers: 18 Pangaea; 19 North American; 20 transform; 21 slab pull

22 Synthesize How does the flow of energy as heat in Earth's interior contribute to the movement of tectonic plates? Explain what would happen if Earth were not a convecting system.

Lesson Review

Vocabulary

Fill in the blanks with the term that best completes the following sentences.

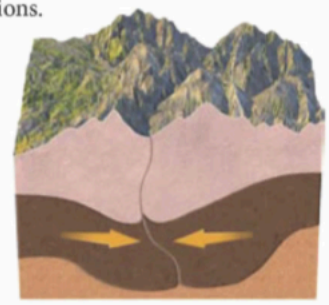
1 The lithosphere is divided into pieces called _____.

2 The theory that describes large-scale movements of Earth's lithosphere is called _____.

3 The movement of material due to differences in density that are caused by differences in temperature is called _____.

Key Concepts

Use this diagram to answer the following questions.



4 Identify What type of plate boundary is shown?

5 Identify Which types of lithosphere are colliding at this boundary?

6 Identify What landforms are likely to form at this boundary?

7 Describe How is continental lithosphere different from oceanic lithosphere?

8 Compare How are convergent boundaries different from divergent boundaries?

Critical Thinking

9 Analyze Explain why cool rock material sinks when convection takes place in the mantle.

10 Defend A classmate states that continental drift could not be possible because it would take far too much force to move tectonic plates. Describe the hypotheses scientists use to explain the movement of tectonic plates. Which hypothesis do many scientists think may explain the great force needed to move plates?