Chapter 9

Plate Tectonics

North Carolina Essential Standards

6.P.2.3 Compare the physical properties of pure substances that are independent of the amount of matter present including density, melting point, boiling point, and solubility to properties that are dependent on the amount of matter present to include volume, mass and weight.

6.E.2.2 Explain how crustal plates and ocean basins are formed, move and interact using earthquakes, heat flow and volcanoes to reflect forces within the earth.

Plate Tectonics

The Continental Drift Hypothesis

Key Concepts
- What evidence supports continental drift?
- Why did scientists question the continental drift hypothesis?

Before You Read

What do you think? Read the two statements below and decide whether you agree or disagree with them. Place an A in the Before column if you agree with the statement or a D if you disagree. After you've read this lesson, reread the statements to see if you have changed your mind.

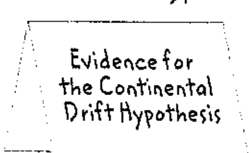
Before	Statement	After
	1. India has always been north of the equator.	
	2. All the continents once formed one supercontinent.	

Mark the Text

Identify the Main Ideas Highlight two or three phrases in each paragraph that summarize the information presented. After you have finished the lesson, review the highlighted text.

FOLDABLES

Make a half-book. Use it to organize your notes on the continental drift hypothesis.

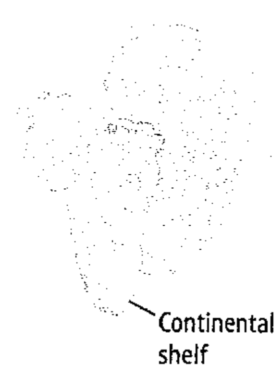


Read to Learn

Pangaea

Nearly 100 years ago, a scientist named Alfred Wegener (VAY guh nuhr) began an investigation. He wanted to know if Earth's continents had always been in the same place, or if they had moved. Wegener proposed that *all the continents were once part of a supercontinent called* **Pangaea** (pan JEE uh). Over time, Pangaea broke apart, and the continents slowly drifted to their present locations. Wegener proposed the hypothesis of continental drift. *The* **continental drift** *hypothesis suggested that continents are in constant motion on the surface of Earth.*

Wegener looked at the coastlines of continents that are now separated by oceans. He saw similarities in their shapes. For instance, Africa and South America seemed to fit together like the pieces of a puzzle, as shown below.



Visual Check

1. Identify With a pen or pencil, trace the area where Africa and South America match up.

Evidence That Continents Move

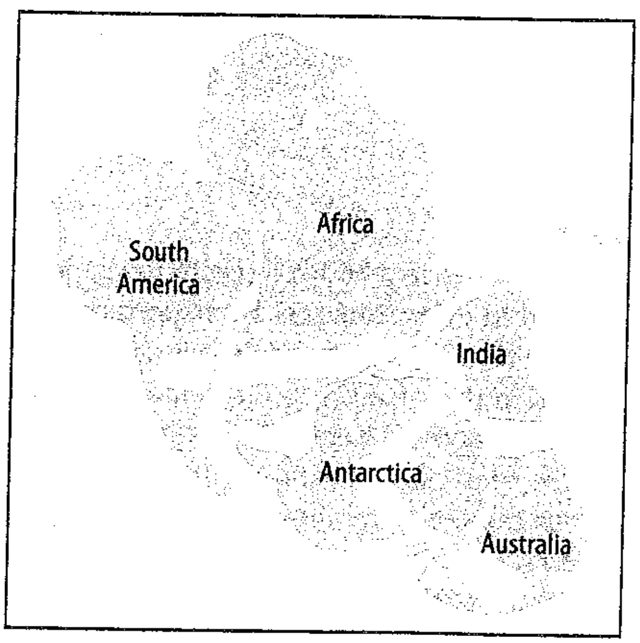
Wegener knew that he needed evidence to support his hypothesis of continental drift. The most obvious evidence was how the continents fit together like pieces of a puzzle. But other scientists were doubtful of his hypothesis. Wegener needed more evidence.

Fossil Clues

There are many animals and plants that live only on one continent. For example, lions live in Africa but not in South America. Because oceans separate the continents, animals cannot travel from one continent to another by natural means. However, fossils of similar organisms have been discovered on several continents that are now separated by oceans.

Fossils of a plant called *Glossopteris* (glahs AHP tur us) have been discovered in rocks from South America, Africa, India, Antarctica, and Australia. Today these continents are far apart and separated by oceans. The plant's seeds could not have traveled across the oceans.

The figure below shows how some of the continents were joined as part of Pangaea 250 million years ago. The lighter area on the map shows where *Glossopteris* fossils have been found. Notice that the plant once grew in parts of five continents—South America, Africa, India, Antarctica, and Australia. Because these plants grew in a swampy environment, this region, including Antarctica, was different from how it is today. Most of Antarctica is covered in ice sheets. No swampy environments are found there now.



REVIEW VOCABULARY
fossil
the naturally preserved remains, imprints, or traces of organisms that lived long ago

Think it Over

2. Specify Where did *Glossopteris* probably grow?

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Visual Check

3. Consider Which of the continents would not support *Glossopteris* growth today?

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Climate Clues

Other fossil evidence supported continental drift. Coal beds are in Antarctica, a polar climate today. Yet coal formed from fossilized plants that lived long ago in warm, wet climates. This meant that Antarctica must have been warmer and wetter when these plants were alive. Is it possible that Antarctica was at one time closer to the equator? Did Antarctica move to a colder climate near the South Pole?

Another climate clue used by Wegener to support continental drift came from glaciers. When Wegener pieced Pangaea together, he proposed that South America, Africa, India, and Australia were located closer to the South Pole 250 million years ago. He suggested that a large ice sheet covered much of the continents, as shown below. When the ice sheet melted as Pangaea spread apart, it left rock and sediment behind. Wegener studied the similarities of these sediments.

Wegener also studied glacial grooves. Glacial grooves are deep scratches in rocks made as ice sheets move across the land. Wegener found glacial grooves on many different continents. By studying these grooves, he was able to determine the direction that the ice sheet moved across the joined continents.

Reading Check

4. State Why did Wegener suggest that continents in the southern hemisphere had a colder climate long ago?

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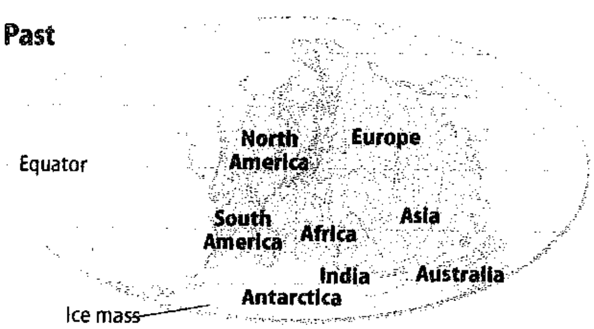

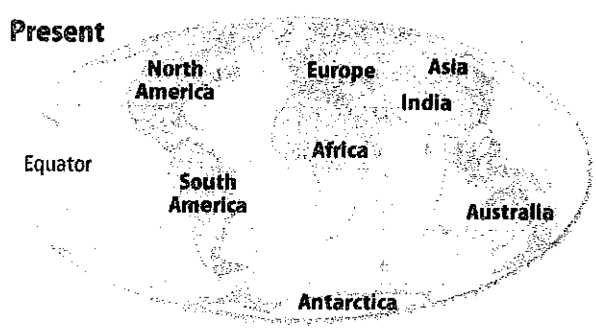

Visual Check

5. Name the areas on Earth where there is evidence of ancient glaciers.

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Rock Clues

Some of the evidence used by Wegener to support his idea of continental drift came from rock formations on different continents. The rock formations and mountain ranges seemed to have formed in the same way at the same time. Today geologists know that there were large-scale volcanic eruptions on the western coast of Africa and on the eastern coast of South America hundreds of millions of years ago. Geologists have studied rocks from these eruptions. They found that the volcanic rocks from both continents were identical in chemistry and age.

Mountain Chains More evidence came from the rocks that make up two mountain chains in Europe and North America. Locate the caledonian mountain range and the Appalachian Mountains in the figure below on the left. The caledonian mountain range is in northern Europe, and the Appalachian Mountains are in eastern North America.

Visual Check
6. Name Which mountain range is in Europe?

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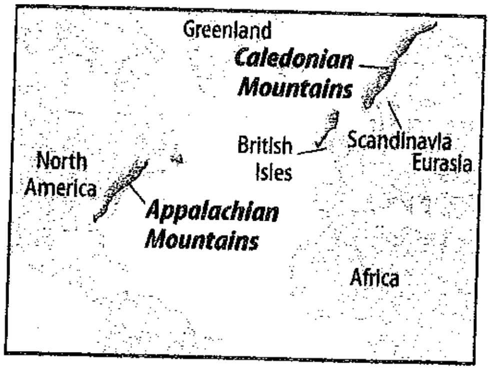
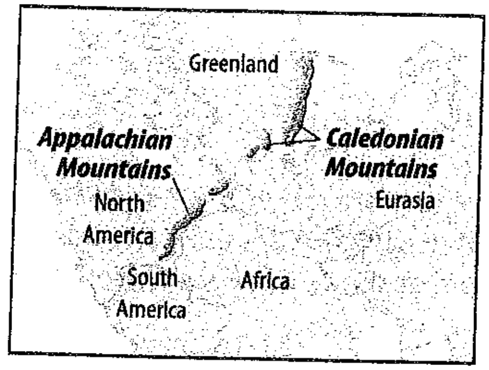
Mountain Ranges





Rock Types Rocks in these two mountain chains are similar in age and structure. Both are also composed of the same rock types. If you could place North America and Europe next to each other, these mountain chains would meet. They would form one long, continuous mountain belt, shown in the figure above on the right.

Key Concept Check
7. Specify How were similar rock types used to support the continental drift hypothesis?

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What was missing?

Wegener supported his continental drift hypothesis until his death in 1930. Wegener's ideas were not widely accepted until nearly 40 years later. Why were scientists skeptical of Wegener's hypothesis?

Continental drift is a slow process. Wegener could not measure how fast the continents moved. Wegener also could not explain what forces caused the continents to move. The mantle under the continents and seafloor was made of solid rock. How could continents push their way through solid rock? Wegener needed more scientific evidence to prove his hypothesis.

The evidence for drifting continents was hidden on the seafloor. During Wegener's lifetime, scientists did not have the tools to determine what happened beneath the oceans. Wegener also could not have known what the seafloor looked like. The evidence needed to prove continental drift was not discovered until long after Wegener's death.

Key Concept Check
8. Explain Why did scientists argue against Wegener's continental drift hypothesis?

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Mini Glossary

continental drift: a hypothesis suggesting that continents are in constant motion on the surface of Earth

Pangaea (pan JEE uh): one supercontinent that all the continents were once part of

1. Review the terms and their definitions in the Mini Glossary. Write two sentences that explain how Pangaea and continental drift are related.

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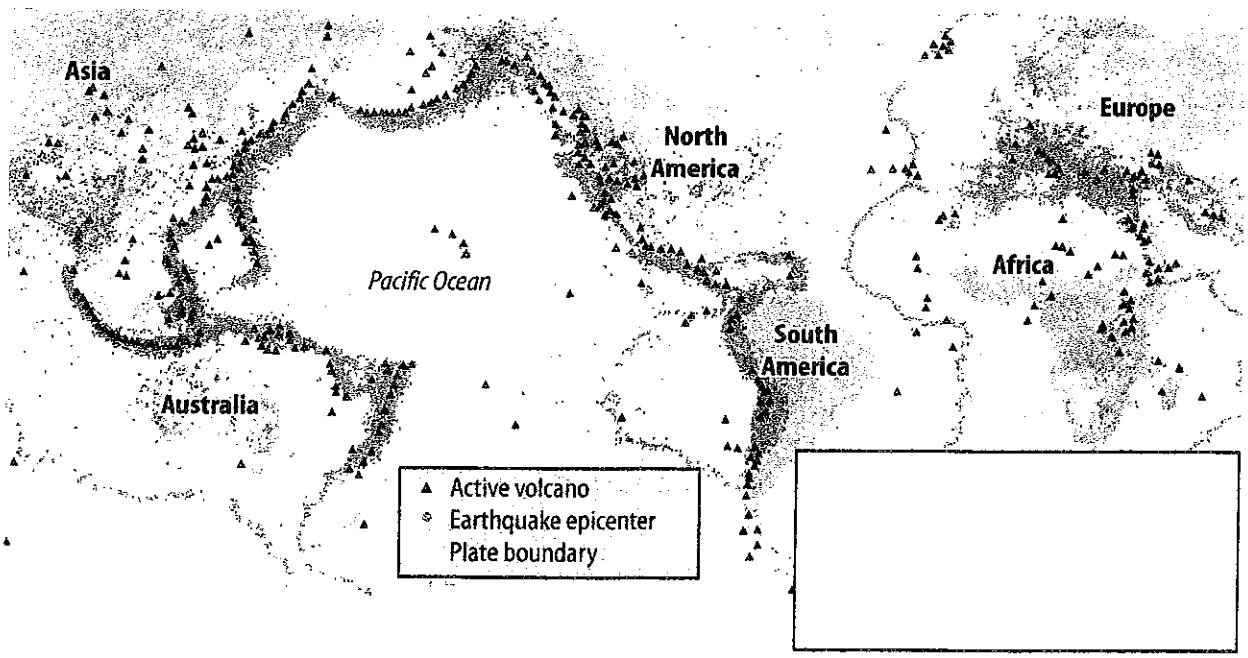
2. Draw three types of evidence on the map that support Wegener's hypothesis of continental drift. Highlight each drawing with a different-colored marker. Make a key next to the map that shows what each color means.



3. How did highlighting one or two phrases in each paragraph help you understand the hypothesis of continental drift?

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What do you think NOW?

Reread the statements at the beginning of the lesson. Fill in the After column with an A if you agree with the statement or a D if you disagree. Did you change your mind?

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Name ______________________________ Date ____________

Plate Tectonics

THE BIG IDEA **What is the theory of plate tectonics?**

Before You Read

Before you read the chapter, think about what you know about plate tectonics. Record your thoughts in the first column. Pair with a partner, and discuss his or her thoughts. Write those thoughts in the second column. Then record what you both would like to share with the class in the third column.

Think	Pair	Share

Chapter Vocabulary

Lesson 1	Lesson 2	Lesson 3
NEW Pangaea continental drift **REVIEW** fossil	**NEW** mid-ocean ridge seafloor spreading normal polarity magnetic reversal reversed polarity **ACADEMIC** normal	**NEW** plate tectonics lithosphere divergent plate boundary transform plate boundary convergent plate boundary subduction convection ridge push slab pull

Lesson 1 The Continental Drift Hypothesis

Scan *Lesson 1. Then write three questions that you have about continental drift in your Science Journal. Try to answer your questions as you read.*

Main Idea	Details
Pangaea *I found this on page ______.*	**Define** Pangaea. *Include in your definition the name of the scientist who proposed the idea.* ______ ______ ______
I found this on page ______.	**Summarize** *the effect of* continental drift *on* Pangaea. ______ ______ ______ ______
Evidence That Continents Move *I found this on page ______.*	**Model** *the stages of the breakup of* Pangaea. *Draw or describe each stage.* Beginning Early in the Process Much Later

Main Idea

Details

Classify *two examples of evidence that continents have moved during Earth's history. Write an explanation and give two examples for each kind of clue.*

Clue	Explanation	Examples
Climate clues		
Rock clues		

I found this on page ______.

I found this on page ______.

What was missing?
I found this on page ______.

Identify *two reasons why scientists doubted Wegener's ideas.*

1. ______________________________
____

2. ______________________________
____

Analyze It Many natural resources are mined from the rock beneath Earth's surface. Use what you have learned to explain how evidence found on one continent could be useful on another.

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Plate Tectonics

Development of a Theory

Key Concepts
- What is seafloor spreading?
- What evidence is used to support seafloor spreading?

Before You Read

What do you think? Read the two statements below and decide whether you agree or disagree with them. Place an A in the Before column if you agree with the statement or a D if you disagree. After you've read this lesson, reread the statements to see if you have changed your mind.

Before	Statement	After
	3. The seafloor is flat.	
	4. Volcanic activity occurs only on the seafloor.	

Study Coach

Two-Column Notes As you read, organize your notes in two columns. In the left column, write the main idea of each paragraph. In the right column, write details that support each main idea. Review your notes to help you remember the details of the lesson.

Read to Learn

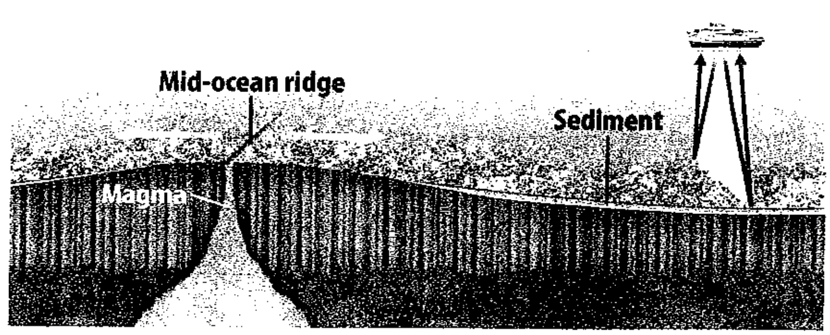
Mapping the Ocean Floor

Scientists began exploring the seafloor in greater detail during the late 1940s. They used a device called an echo sounder to measure the depths of the ocean floor. An echo sounder produces sound waves that travel from a ship to the seafloor. The waves echo, or bounce, off the seafloor and back to the ship. The echo sounder records the time it takes the echo to return. When the ocean is deeper, the time it takes for the sound waves to bounce back is longer. Scientists calculated ocean depths and used these data to create topographic maps of the seafloor.

These new topographic maps showed large mountain ranges that stretched for many miles along the seafloor. *The mountain ranges in the middle of the oceans are called* **mid-ocean ridges.** Mid-ocean ridges, shown in the figure below, are much longer than any mountain range on land.

Visual Check

1. Identify Circle the area on the map that shows the mid-ocean ridge.



Seafloor Spreading

By the 1960s, scientists had discovered a new process to help explain continental drift. This process is called seafloor spreading. **Seafloor spreading** *is the process by which new oceanic crust forms along a mid-ocean ridge and older oceanic crust moves away from the ridge.*

When the seafloor spreads, Earth's mantle melts and forms magma. The liquid magma is less dense than the solid mantle. The magma rises through cracks in the crust along the mid-ocean ridge. When magma reaches Earth's surface, it is called lava.

As the lava cools and crystallizes on the seafloor, it forms a type of rock called basalt. Oceanic crust is mostly basalt. Because the lava erupts into water, it cools rapidly. The rapidly cooling lava forms rounded structures called pillow lava.

As the seafloor spreads apart, new crust that is forming pushes the older crust away from the mid-ocean ridge. The mid-ocean ridge, at the center of this formation, is shown below. The closer the crust is to a mid-ocean ridge, the younger the oceanic crust is. Scientists concluded that as the seafloor spreads, the continents must be moving. Seafloor spreading is the mechanism that explains Wegener's hypothesis of continental drift.

FOLDABLES

Make a layered book to record your notes and illustrate seafloor spreading.

Key Concept Check

2. Identify What is seafloor spreading?

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Visual Check

3. Interpret Propose a pattern that exists in rocks on either side of the mid-ocean ridge.

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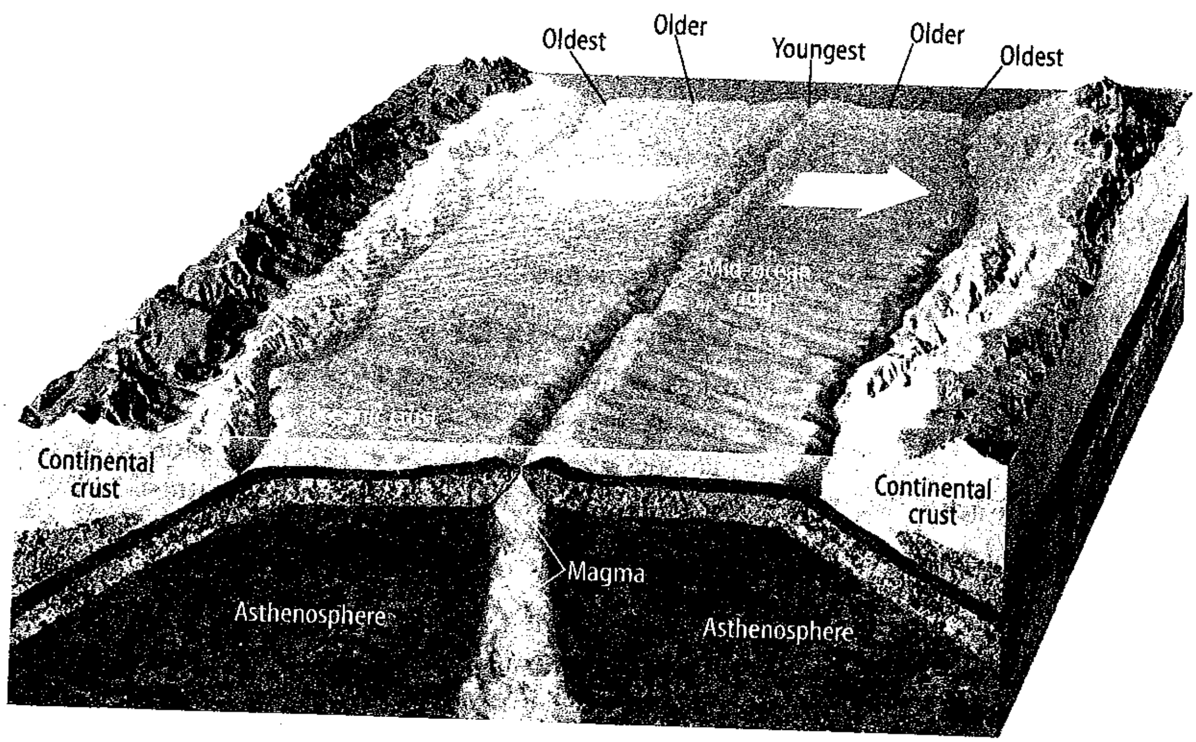

Topography of the Seafloor

What determines the topography of the ocean floor? One factor is seafloor spreading. The rugged mountains that make up the mid-ocean ridge system can form in two different ways. Some form as large amounts of lava erupt from the center of the ridge. That lava cools and builds up around the ridge. Others form as the lava cools and forms new crust that cracks. The rocks move up or down along these cracks and form jagged mountains.

Reading Check
4. Describe How do mountains form along a mid-ocean ridge?

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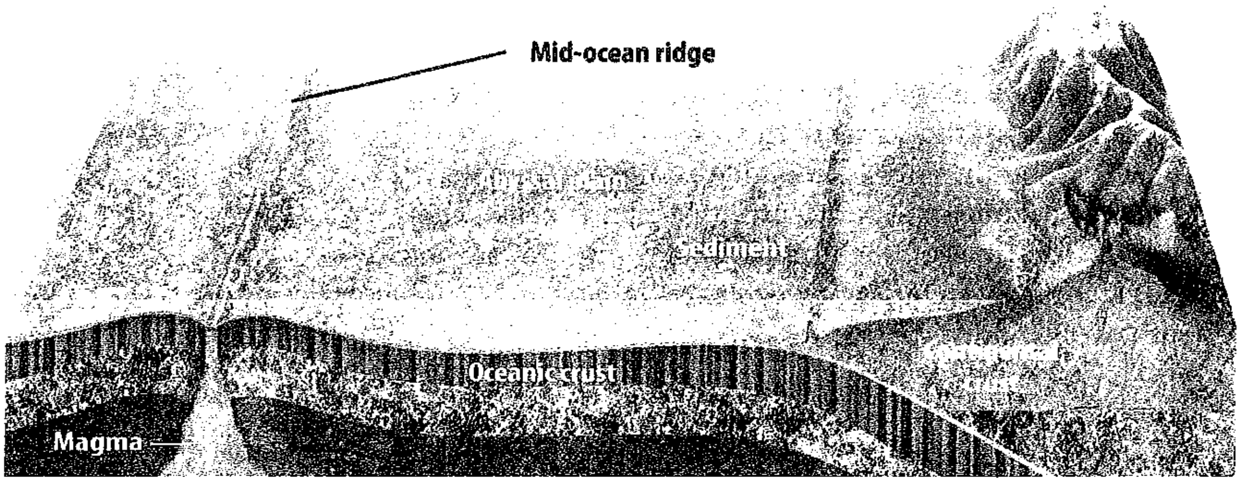
Sediment also determines the topography of the ocean floor. Close to a mid-ocean ridge, the crust is young, and there is not much sediment. However, farther from the ridge, sediment becomes thick enough to make the seafloor smooth. This deep, smooth part of the ocean floor, shown below, is called the abyssal (uh BIH sul) plain.



Visual Check
5. Compare the topography of a mid-ocean ridge to an abyssal plain.

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Moving Continents Around

The theory of seafloor spreading provides a way to explain how continents move. Continents do not move through the solid mantle or the seafloor. However, seafloor spreading suggests that continents move as the seafloor spreads along a mid-ocean ridge.

Development of a Theory

Just as evidence was needed to support continental drift, evidence was needed to support seafloor spreading. Some of the evidence to support seafloor spreading came from rocks on the ocean floor that were not covered with sediment. Scientists studied the magnetic signatures of minerals in these rocks. They discovered two important things. First, Earth's magnetic field changes. Second, these changes appear in rocks that make up the ocean floor.

Reading Check
6. Identify What evidence supports seafloor spreading?

____

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Magnetic Reversals

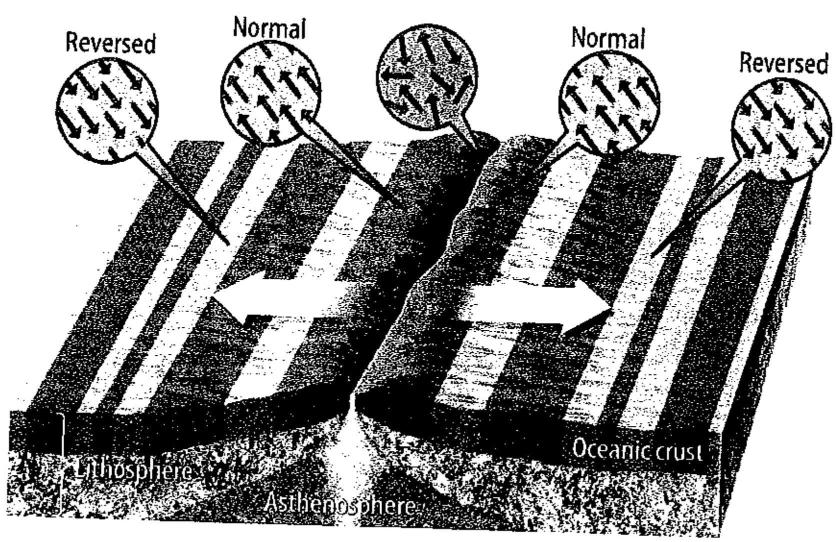
Earth's iron-rich, liquid outer core is like a giant magnet that creates Earth's magnetic field. The direction of this magnetic field is not always the same. Today's magnetic field is described as having normal polarity. **Normal polarity** *is a state in which magnetized objects, such as compass needles, will orient themselves to point north.*

Sometimes a **magnetic reversal** *occurs and the magnetic field reverses direction.* The opposite of normal polarity is reversed polarity. **Reversed polarity** *is a state in which magnetized objects reverse direction and orient themselves to point south.*

Magnetic reversals have occurred hundreds of times in Earth's past. They occur every few hundred thousand to every few million years.

Rocks Reveal Magnetic Signature

Ocean crust contains large amounts of basalt. Basalt contains iron-rich minerals that are magnetic. Each mineral acts like a small magnet. The figure below shows how magnetic minerals align themselves with Earth's magnetic field. When lava erupts along a mid-ocean ridge, it cools, crystallizes, and permanently records the direction of Earth's magnetic field at the time of the eruption. Scientists have discovered parallel patterns in the magnetic signature of rocks on either side of mid-ocean ridges. For example, in the figure below, notice the normal pattern exists closest to either side of the mid-ocean ridge. Likewise, the reversed polarity pattern exists at about the same distance on either side of the mid-ocean ridge.



Reading Check

7. Identify Does Earth's magnetic field currently have normal or reversed polarity?

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Visual Check

8. Describe the pattern in the magnetic stripes shown in the image to the left.

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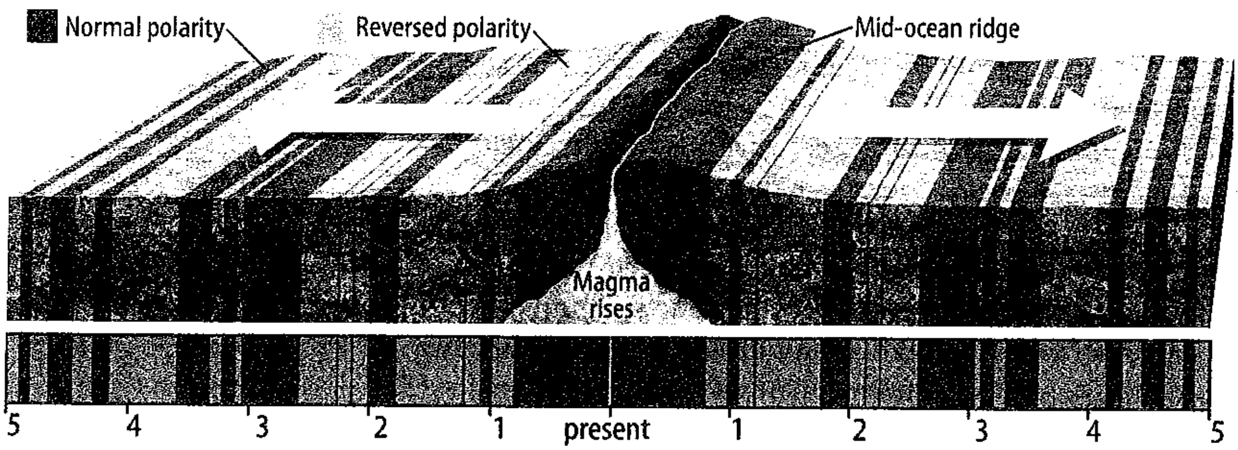
Evidence to Support the Theory

To support the theory of seafloor spreading, scientists collected data about the magnetic minerals in rocks from the seafloor. They used a magnetometer (mag nuh TAH muh tur) to measure and record the magnetic signature of these rocks. The data collected showed parallel magnetic stripes on either side of the mid-ocean ridge, as shown below. What do these stripes mean?

Reading Check
9. Discuss How do magnetic minerals help support the theory of seafloor spreading?

Each pair of magnetic stripes is similar in composition, age, and magnetic character. Each stripe also records whether Earth's magnetic field was in a period of normal or reversed polarity when the crust formed. Notice that the stripes on either side of the ridge are the same. This pattern supports the idea that ocean crust forms along mid-ocean ridges and is carried away from the center of the ridges.



Visual Check
10. Determine What was the polarity of Earth's magnetic field 4 million years ago?

Other measurements made on the seafloor confirm seafloor spreading. Scientists drilled holes in the seafloor and measured the temperature below the surface. These temperatures show how much thermal energy leaves Earth. Scientists discovered that more thermal energy leaves Earth near mid-ocean ridges than is released from beneath abyssal plains. In addition, studies of sediment show that sediment closest to a mid-ocean ridge is younger and thinner than sediment farther away from the ridge.

Reading Check
11. Locate Where does more thermal energy leave Earth—near mid-ocean ridges or beneath abyssal plains?

Mini Glossary

magnetic reversal: when a magnetic field reverses direction

mid-ocean ridge: a mountain range in the middle of the ocean

normal polarity: a state in which magnetized objects, such as compass needles, will orient themselves to point north

reversed polarity: a state in which magnetized objects reverse direction and orient themselves to point south

seafloor spreading: the process by which new oceanic crust forms along a mid-ocean ridge and older oceanic crust moves away from the ridge

1. Review the terms and their definitions in the Mini Glossary. Write one or two original sentences to explain seafloor spreading.

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____

2. Use words from the word bank to complete the events chain. Use each word only once.

crust **lava** **mid-ocean ridge** **new** **oceanic** **old** **vents**

Magma rises through cracks in the ______________ along a ______________.

↓

______________ erupts from volcanic ______________ in the ridge.

↓

Lava cools and hardens to form new ______________ crust.

↓

______________ ocean crust pushes ______________ crust away from the ridge.

3. What is the difference between normal polarity and reversed polarity?

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What do you think NOW?

Reread the statements at the beginning of the lesson. Fill in the After column with an A if you agree with the statement or a D if you disagree. Did you change your mind?

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Log on to ConnectED.mcgraw-hill.com and access your textbook to find this lesson's resources.

Development of a Theory

Predict *three facts that will be discussed in Lesson 2 after reading the headings. Write your predictions in your Science Journal.*

Main Idea / Details

Mapping the Ocean Floor

I found this on page ________.

Assess *information about the ocean floor. Read the statements below. If the statement is true, write* true *on the line. If it is false, write* false *on the line and rewrite the underlined portion of the statement so that it is true.*

A device called an echo-sounder can determine the depth of the ocean.

____

Topographic maps of the seafloor made from ocean depth data reveal that the seafloor is almost completely flat.

____

Mid-ocean ridges are shorter than mountain ranges found on land.

____

Seafloor Spreading

I found this on page ________.

Sequence *the process of* seafloor spreading.

The seafloor spreads at a mid-ocean ridge. Solid mantle material begins to ________. This material is ________ dense than the surrounding solid rock.

↓

The liquid ________ rises through ________ in the crust and erupts from volcanic vents along the ________.

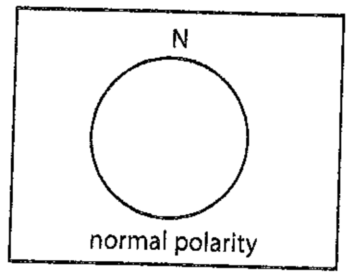
↓

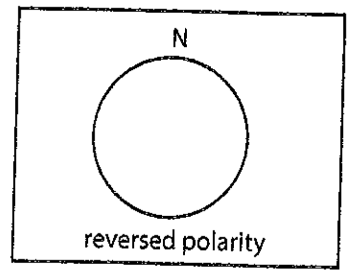
The magma, now called ________, cools, solidifies, and forms a rock called ________.

↓

Magma continues to rise and solidify. It pushes the newly-formed ________ away from the ________. Younger, less dense, warmer rocks are found ________ the ridge. Older, denser, cooler rocks are found ________ the ridge.

Main Idea	Details
I found this on page ______.	**Summarize** *the importance of the idea of* seafloor spreading.
Development of a Theory *I found this on page* ______.	**Model** normal polarity *and* reversed polarity *by drawing arrows in the diagrams below.*





Main Idea	Details
I found this on page ______.	**Draw** *the seafloor on either side of a* mid-ocean ridge. *Show the rocks that formed during times of* normal polarity *in blue. Show those that formed during times of* reversed polarity *in red. Then write a sentence to explain how* magnetic reversal *confirms the idea of* seafloor spreading.

Connect It Recall the questions that scientists had about Wegener's continental drift theory. Explain how seafloor spreading answers one or more of those questions.

Plate Tectonics

The Theory of Plate Tectonics

Key Concepts
- What is the theory of plate tectonics?
- What are the three types of plate boundaries?
- Why do tectonic plates move?

Before You Read

What do you think? Read the two statements below and decide whether you agree or disagree with them. Place an A in the Before column if you agree with the statement or a D if you disagree. After you've read this lesson, reread the statements to see if you have changed your mind.

Before	Statement	After
	5. Continents drift across a molten mantle.	
	6. Mountain ranges can form when continents collide.	

Study Coach

Make an Outline Use the main heads in this lesson as the main points of your outline. Complete the outline with details found in the lesson. Study the lesson by reviewing your outline.

Read to Learn

The Plate Tectonics Theory

When you blow into a balloon, the balloon expands. Its surface area also increases. As more air is added to the balloon, the balloon gets larger. Similarly, if ocean crust continually forms at mid-ocean ridges and is never destroyed, Earth's surface should be expanding. But measurements of the planet show that Earth is not getting larger. How can this be explained?

Geologists proposed a more complete theory in the late 1960s. It was called plate tectonics theory. The theory of **plate tectonics** states that *Earth's surface is made of rigid slabs of rock, or plates, that move with respect to each other,* or in relation to each other. This new theory suggested that Earth's surface, the lithosphere, is divided into large pieces of rock. These pieces are called plates. Each plate moves slowly over Earth's hot and semiplastic mantle.

Key Concept Check
1. State What is plate tectonics?

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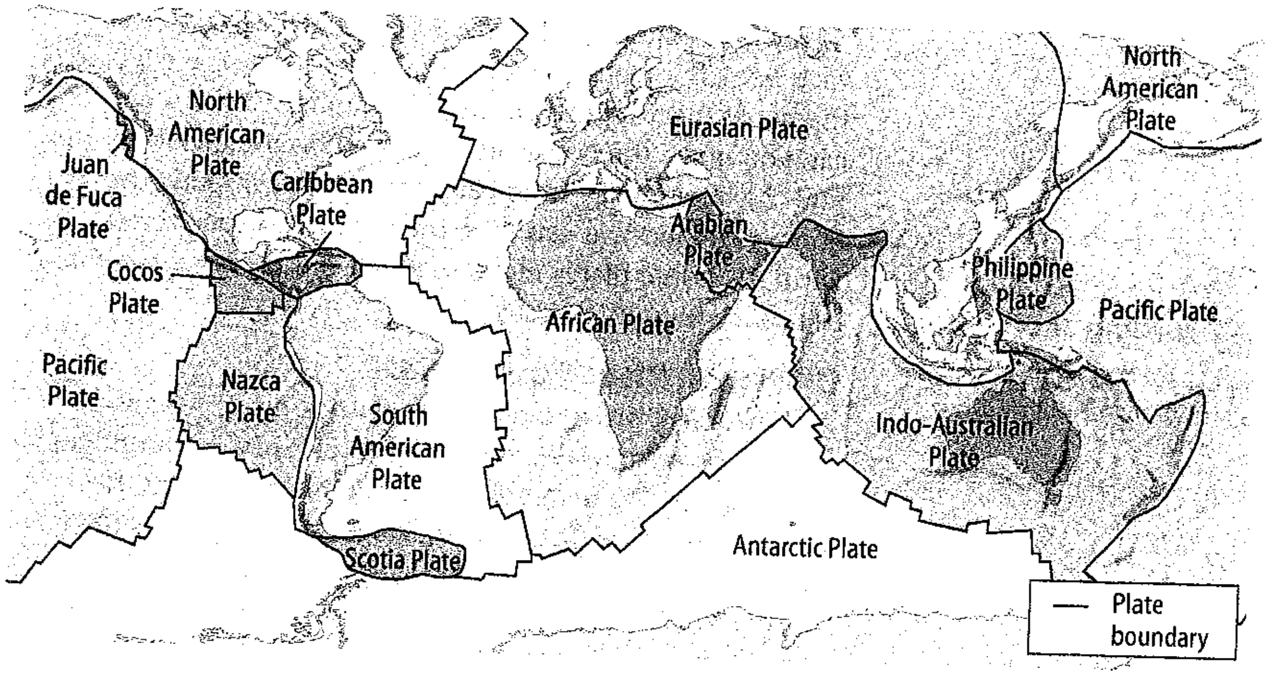
The word *tectonic* describes the forces that shape Earth's surface and the rock structures that form as a result. Plate tectonics explains why earthquakes occur and volcanoes erupt. When plates separate on the seafloor, earthquakes result and a mid-ocean ridge forms. When plates come together, one plate can move under the other. This causes earthquakes and creates a chain of volcanoes. When plates slide past each other, earthquakes can result.

Earth's Tectonic Plates



Tectonic Plates

Earth's surface is divided into rigid plates that move relative to one another. Look at the map above. It shows Earth's major plates and their boundaries. Notice how some boundaries are in the middle of the oceans. Many of these boundaries are located at mid-ocean ridges. The Pacific Plate is the largest plate. The Juan de Fuca is one of the smallest plates.

Earth's outermost layers are cold and rigid compared to the layers within Earth's interior. *The cold and rigid outermost rock layer is called the* **lithosphere.** The crust and the solid, uppermost mantle form the lithosphere.

The lithosphere varies in thickness. It is thin below mid-ocean ridges. It is thick below continents. Earth's tectonic plates are large pieces of lithosphere. These plates fit together like the pieces of a giant jigsaw puzzle.

Directly below the lithosphere is a very hot part of the mantle. This layer of Earth is called the asthenosphere (as THEE nuh sfihr). Even though it is solid, the asthenosphere behaves like a plastic material because it is so hot.

The asthenosphere flows below Earth's plates and enables the plates to move. The ways in which the lithosphere and asthenosphere interact help explain plate tectonics.

Visual Check

2. Locate Circle the Nazca Plate.

Science Use v. Common Use

plastic

Science Use capable of being molded or changing shape without breaking

Common Use any of numerous organic, synthetic, or processed materials made into objects

Reading Check

3. Identify What are Earth's outermost layers called?

____

____

Plate Boundaries

Imagine placing two books side by side. Imagine that each book is a tectonic plate. The place where the edges of the books meet represents a plate boundary. How many ways can you move the books along a set of boundaries? You can pull the books away from each other. You can push the books together. You can slide the books past each other. Earth's tectonic plates move in much the same way as you can move these books.

Reading Check

4. Describe three ways in which tectonic plates move.

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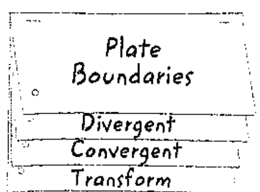
Divergent Plate Boundaries

A **divergent plate boundary** *forms where two tectonic plates separate. Divergent* means "moving apart." Mid-ocean ridges are located along divergent plate boundaries. When the seafloor spreads at a mid-ocean ridge, lava erupts. As the lava cools and hardens, it forms new oceanic crust. As this process continues, the plates move away from each other.

Divergent plate boundaries can also exist in the middle of a continent. At these boundaries, continents pull apart and a rift valley forms. The East African Rift is one example of a continental rift.

FOLDABLES

Make a layered book to organize your notes on the three types of plate boundaries.



Transform Plate Boundaries

The San Andreas Fault in California is a transform plate boundary. *A* **transform plate boundary** *forms where two tectonic plates slide past each other.* As they move past each other, the plates might get stuck and stop moving. Stress builds up where the plates are stuck. When this stress is too great, the rocks break and suddenly move apart. The result is a rapid release of energy in the form of an earthquake.

Convergent Plate Boundaries

A **convergent plate boundary** *forms where two plates collide. The denser plate sinks below the more buoyant plate in a process* called **subduction.** A subduction zone is the area where a denser plate descends into Earth along a convergent plate boundary. The two types of convergent plate boundaries are ocean-to-continent and continent-to-continent.

Key Concept Check

5. Name What are the three types of plate boundaries?

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Ocean-to-Continent Boundary When a dense oceanic plate and a less-dense continental plate collide, the oceanic plate subducts, or sinks, under the edge of the continental plate. This creates a deep ocean trench and a line of volcanoes forms on the edge of the continent. This process can also occur when two oceanic plates collide. An older and denser oceanic plate will subduct beneath a younger oceanic plate. A deep ocean trench forms, along with a line of volcanoes.

Continent-to-Continent Boundary Convergent plate boundaries also form when two continental plates collide. When this happens, neither plate is subducted. The less-dense plate folds and deforms, forming mountains such as the Himalayas in India.

Evidence for Plate Tectonics

When Wegener proposed the continental drift hypothesis, technology was not available to measure how fast the continents moved. Remember that continents move apart or come together at speeds of only a few centimeters per year. This is about the length of a small paper clip.

Today, scientists can measure how fast continents move. A network of satellites orbiting Earth is used to monitor plate motion. By keeping track of the distance between satellites and Earth, it is possible to determine how fast a tectonic plate moves. This network of satellites is called the Global Positioning System (GPS).

The theory of plate tectonics explains why earthquakes and volcanoes are more common in some places than in others. Recall that when plates separate, collide, or slide past each other, stress builds. When this stress suddenly releases, earthquakes can result.

Volcanoes can also form along a mid-ocean ridge or continental rifts. They also form where plates collide along a subduction zone. Mountains can form where two continents collide. The map below shows that most earthquakes and volcanoes occur along tectonic plate boundaries.

Reading Check

6. Identify Along what type of convergent plate boundary did the Himalayas form? (Circle the correct answer.)

a. ocean-to-ocean

b. continent-to-continent

c. ocean-to-continent

Key Concept Check

7. Explain How are earthquakes and volcanoes related to the theory of plate tectonics?

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Visual Check

8. Interpret Do earthquakes and volcanoes occur anywhere away from plate boundaries? If so, where?

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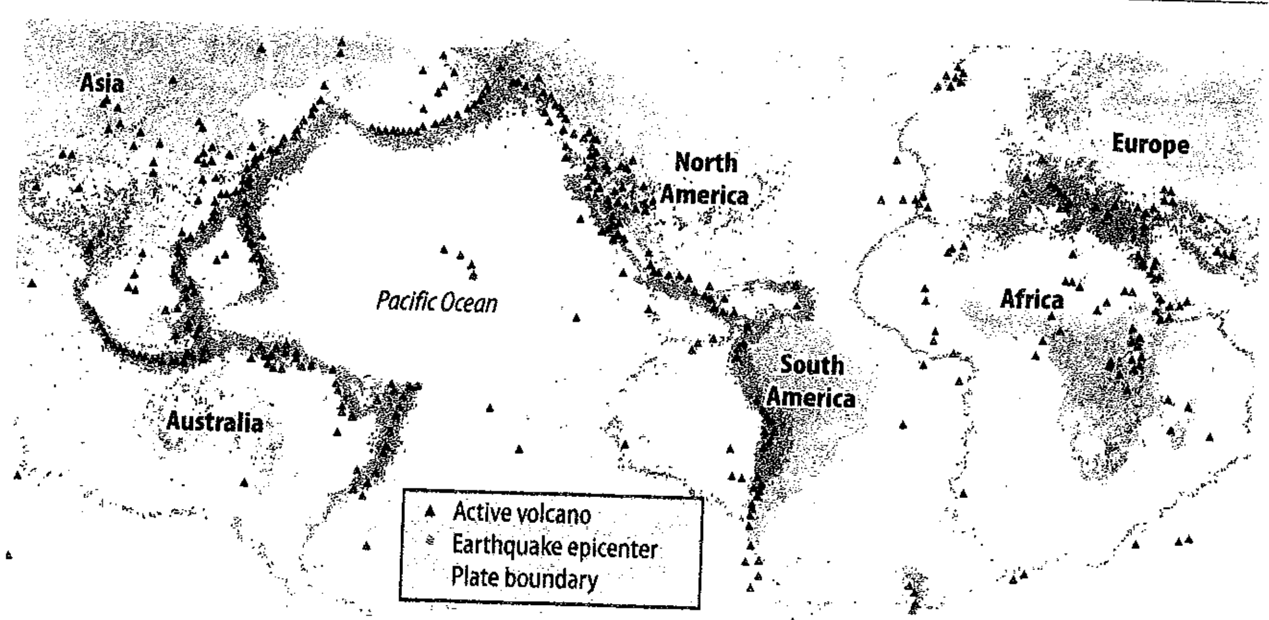

Plate Motion

You learned that the main objection to Wegener's continental drift hypothesis was that he could not explain how or why Earth's continents move. Scientists now understand that continents move because the asthenosphere moves underneath the rigid lithosphere.

Convection Currents

The circulation of material caused by differences in temperature and density is called **convection.** For example, the upstairs floors of homes are often warmer because hot air rises. Hot air is less dense than cold air. As the cold air sinks, the hot air rises.

Convection in the mantle is related to plate tectonic activity. The warmth for convection comes from radioactive elements inside Earth, such as uranium, thorium, and potassium. When materials such as solid rock are heated, they expand and become less dense. Heated mantle material rises and comes in contact with Earth's crust. Thermal energy is transferred from hot mantle material to the colder surface above. As the mantle cools, it becomes denser and sinks, forming a convection current. These currents in the asthenosphere act like a conveyor belt moving the lithosphere above it. Therefore, tectonic plates move in response to the heating and cooling of mantle material.

Forces Causing Plate Motion

How can something as large as the Pacific Plate move? Convection currents in the mantle produce enormous forces that can move Earth's massive plates. These forces are basal drag, ridge push, and slab pull. Scientists' opinions differ on which force is strongest.

Basal Drag Convection currents in the mantle produce a force on plates that causes motion called basal drag. Convection currents in the asthenosphere can drag the lithosphere. This is similar to how a conveyor belt moves items at a supermarket.

Ridge Push Recall that mid-ocean ridges are higher than the surrounding seafloor. Because mid-ocean ridges are elevated, gravity pulls the surrounding rocks down and away from the ridge. *Rising mantle material at mid-ocean ridges creates the potential for plates to move away from the ridge with a force called* **ridge push.** Ridge push moves the lithosphere in opposite directions away from the mid-ocean ridge.

Reading Check

9. Explain What causes convection?

Key Concept Check

10. Cause and Effect Why do tectonic plates move?

Reading Check

11. Explain What causes ridge push? (Circle the correct answer.)

a. a plate going into the mantle

b. force on the bottom of a plate

c. movement along a mid-ocean ridge

Slab Pull You learned that when tectonic plates collide, the denser plate will sink into the mantle along a subduction zone. This sinking plate is called a slab. Because the slab is old and cold, it is denser than the surrounding mantle. Therefore, it sinks. *As a slab sinks, it pulls on the rest of the plate with a force called* **slab pull.** This is similar to pushing a tablecloth over the edge of a table. When enough of the cloth slides over the edge, it will pull the rest of the cloth off the table.

A Theory in Progress

Plate tectonics is often said to be the unifying theory in geology. It explains the connection between continental drift and the formation and destruction of crust along plate boundaries. It also helps explain why earthquakes and volcanoes occur and why mountains form.

The investigation that Wegener began nearly a century ago is still being updated. Several questions remain.

- Why is Earth the only planet in the solar system that has plate tectonic activity? No other planet in our solar system is known to have active tectonic plates.
- Why do some earthquakes and volcanoes occur far from plate boundaries? Perhaps it is because plates are not perfectly rigid. Different thicknesses and weaknesses exist within plates. Also, the mantle is much more active than scientists originally understood.
- What forces actually dominate plate motions? Currently accepted models suggest that convection currents occur in the mantle. However, there is no way to measure or observe them.
- How will scientists answer these questions? One topic of interest is creating 3-D images of seismic wave velocities in a subduction zone. This technology is called anisotropy. It might help scientists better understand the processes that occur within the mantle and along plate boundaries.

Math Skills

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 1 m? Use proportions to find the answer.

a. Convert the distance to the same unit.

$$1 \text{ m} = 100 \text{ cm}$$

b. Set up a proportion:

$$\frac{2.5 \text{ cm}}{1 \text{ y}} = \frac{100 \text{ cm}}{x \text{ y}}$$

c. Cross-multiply and solve for x as follows:

$$2.5 \text{ cm} \times x\text{y} = 100 \text{ cm} \times 1\text{y}$$

d. Divide both sides by 2.5 cm.

$$x\text{y} = \frac{100 \text{ cm y}}{2.5 \text{ cm}}$$

$$x = 40 \text{ y}$$

12. Use Proportions The Eurasian Plate travels the slowest, at about 0.7 cm/y. How long would it take the plate to travel 3 m?

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Reading Check

13. Explain Why does the theory of plate tectonics continue to change?

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Mini Glossary

convection: the circulation of material caused by differences in temperature and density

convergent plate boundary: forms where two plates collide

divergent plate boundary: forms where two tectonic plates separate

lithosphere: the cold and rigid outermost rock layer of Earth

plate tectonics: the theory that states that Earth's surface is made of rigid slabs of rocks, or plates, that move with respect to each other

ridge push: when the rising mantle material at mid-ocean ridges creates the potential for plates to move away from the ridge with a force

slab pull: when a slab sinks and pulls on the rest of the plate with a force

subduction: the process by which the denser plate sinks below the more buoyant plate when two plates collide

transform plate boundary: forms where two tectonic plates slide past each other

1. Review the terms and their definitions in the Mini Glossary. Choose one term and explain what it means in your own words.

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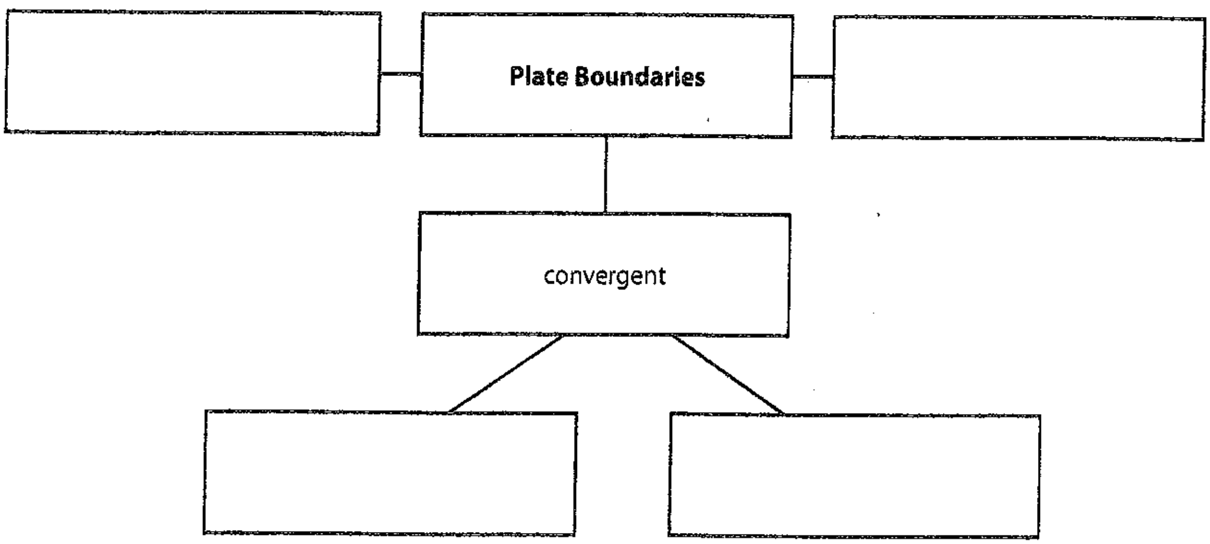
2. Use what you have learned about plate tectonics to complete the concept map.



What do you think NOW?

Reread the statements at the beginning of the lesson. Fill in the After column with an A if you agree with the statement or a D if you disagree. Did you change your mind?

ConnectED

Log on to ConnectED.mcgraw-hill.com and access your textbook to find this lesson's resources.

Lesson 3 **The Theory of Plate Tectonics**

Predict *three ideas that will be discussed in Lesson 3 after reading the headings. Write your predictions in your Science Journal.*

Main Idea / Details

The Plate Tectonics Theory

I found this on page ______.

State *the problem that scientists had with seafloor spreading.*

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I found this on page ______.

Define plate tectonics. *Explain what the word* tectonic *means as part of your definition.*

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I found this on page ______.

Identify *the layers of Earth involved in plate movements. Describe how these layers interact.*

Layer	Description
______________	consists of the crust and the solid, uppermost mantle
Asthenosphere	

Plate Boundaries

I found this on page ______.

Organize *information about* divergent plate boundaries. *Use arrows to show how plates move relative to one another at this type of boundary.*

Type of Boundary	Description	Movement
Divergent		

Main Idea	Details
I found this on page ______.	**Model** transform plate boundaries. *Either write a description or illustrate this type of plate interaction. Include arrows to show the direction of movement. Label the plates and the structures that result from the collisions.*
	Transform Plate Boundaries
I found this on page ______.	**Continent-to-Continent Collision**

Main Idea	Details
Evidence for Plate Tectonics *I found this on page* ______.	**Identify** *evidence for plate motion provided by* plate tectonics. 1. ______ 2. ______ 3. ______ 4. ______
Plate Motion *I found this on page* ______.	**Define** convection, *and give an example of* convection *you have experienced in your everyday life.* Definition: ______ ______ Example: ______ ______ ______ ______
I found this on page ______.	**Explain** *how* convection *occurs in the mantle by completing the sequence diagram.* ______ elements heat the inside of Earth. ↓ The ______ is transferred from the ______ to the ______. ______ currents form. ↓ These currents in the asthenosphere move the ______ above it. ↓ In this way, ______ move in response to ______.

Main Idea	Details
I found this on page ______.	**Describe** *the forces that cause plate motion.*

Force	Description
Basal drag	
Ridge push	
Slab pull	

A Theory in Progress

I found this on page ______.

Identify *four questions scientists have about* plate tectonics.

1. ____________________

2. ____________________

3. ____________________

4. ____________________

Synthesize It What explanation can you offer for several volcanoes located in a line on the seafloor erupting over time to form islands?

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Review

Plate Tectonics

Chapter Wrap-Up

Now that you have read the chapter, think about what you have learned.

Use this checklist to help you study.

- ❑ Complete your Foldables® Chapter Project.
- ❑ Study your *Science Notebook* on this chapter.
- ❑ Study the definitions of vocabulary words.
- ❑ Reread the chapter, and review the charts, graphs, and illustrations.
- ❑ Review the Understanding Key Concepts at the end of each lesson.
- ❑ Look over the Chapter Review at the end of the chapter.

THE BIG IDEA

Summarize It Reread the chapter Big Idea and the lesson Key Concepts. Draw a world map showing how the continents might be arranged 100 million years from now. Label the landmasses on your map, and explain why you positioned them in the way that you did.

Challenge *Suppose that you are designing a new scientific instrument to record or measure some geological data that previously could not be observed. Describe what your new super-technology could detect and how those discoveries might solve remaining mysteries of plate tectonics.*