1 FOCUS

Section Objectives

9.1 **Describe** the hypothesis of continental drift.
9.2 **Evaluate** the evidence in support of continental drift.
9.3 **Identify** the main objections to Wegener's hypothesis of continental drift.

Reading Focus

Build Vocabulary L2

Word Forms Before students read this section, ask them to write a sentence or two describing the meaning of the word *drift*. Then have them write a prediction for what they think continental drift means. After students read the section, have them examine their predictions and discuss whether their predictions must be changed.

Reading Strategy L2

a. continental puzzle
b. matching fossils
c. matching rocks and structures
d. ancient climates

2 INSTRUCT

An Idea Before Its Time

Use Visuals L1

Figure 1 Point out the small areas of brown and light blue between Africa and South America. Ask: **What could cause the brown-shaded regions of overlap?** *(accumulation of sediments deposited by rivers and stretching of the plates)* **What do you think the light blue areas represent?** *(the continental shelf)*
Visual

9.1 Continental Drift

Reading Focus

Key Concepts

- What is the hypothesis of continental drift?
- What evidence supported continental drift?
- Why was Wegener's hypothesis rejected?

Vocabulary

- continental drift
- Pangaea

Reading Strategy

Summarizing Copy the table. Fill it in as you read to summarize the evidence of continental drift.

Hypothesis	Evidence
Continental Drift	a. continental puzzle
	b. ?
	c. ?
	d. ?

More than 300 years ago, mapmakers produced world maps that accurately showed the shapes of the continents. Looking at these maps, people noticed that some continents fit together like pieces of a jigsaw puzzle. Few people thought much about this observation until the early twentieth century. Then, scientists began to look again at the fit of the continents and think about what it might mean.

Figure 1 A Curious Fit This map shows the best fit of South America and Africa at a depth of about 900 meters. Areas of overlap appear in brown.

The Continental Puzzle

A German scientist, Alfred Wegener, also noticed the similarity between the coastlines on opposite sides of the South Atlantic Ocean. As you can see in Figure 1, the shapes of South America and Africa are an approximate fit. In 1915, Wegener proposed his radical hypothesis of **continental drift.** **According to Wegener's hypothesis of continental drift, the continents had once been joined to form a single supercontinent.** He called this supercontinent **Pangaea,** meaning *all land*.

Wegener also hypothesized that about 200 million years ago Pangaea began breaking into smaller continents. The continents then drifted slowly to their present positions.

Facts and Figures

Origins of the Idea of Continental Drift
Scientists rarely come up with ideas entirely on their own. They always draw upon the works of previous scientists. Even Sir Isaac Newton, the father of physics, said "If I have seen farther than others it is because I have stood on the shoulders of giants." The hypothesis of continental drift was no exception. Many people, including Francis Bacon and mapmaker Antonio Snider-Pellegrini, had commented upon the fit of continents around the Atlantic Ocean. Benjamin Franklin, in 1782, proposed something similar to continental drift: "The crust of the Earth must be a shell floating on a fluid interior. . . . Thus the surface of the globe would be capable of being broken and distorted by the violent movements of the fluids on which it rested." Frank Taylor proposed the idea in 1908 that the continents had moved, and he published it in 1910. Alfred Wegener's ideas combined and built upon the research of many other geoscientists.

Evidence for Continental Drift

Wegener presented a variety of evidence to support the hypothesis of continental drift. His evidence included similar fossils, types of rock, and traces of glaciation on widely separated landmasses.

Matching Fossils

Fossil evidence for continental drift includes several fossil organisms found on different landmasses. Wegener reasoned that these organisms could not have crossed the vast oceans presently separating the continents. An example is *Mesosaurus*, a reptile whose fossil remains are limited to eastern South America and southern Africa, as shown in Figure 2. Scientists think that *Mesosaurus* lived in freshwater lakes and shallow bays. It could not have swum across the vast, salty Atlantic Ocean. Therefore, Wegener argued, South America and Africa must have been joined.

The distribution of other types of fossils also supported Wegener's hypothesis. For example, fossils of *Glossopteris*, a small plant, are found today in South America, southern Africa, and India. Yet the characteristics of *Glossopteris* seeds make it very unlikely that the seeds could have blown or floated long distances across the oceans. Fossils of the land reptile *Lystrosaurus* show a similar pattern of distribution.

In Wegener's time, the idea of land bridges was the accepted explanation for similar fossils being found on different landmasses. However, if land bridges did exist between South America and Africa, their remnants should still lie below sea level. But no signs of such land bridges have ever been found in the Atlantic Ocean.

Reading Checkpoint

How does the distribution of Mesosaurus fossils provide evidence for continental drift?

Q & A

Q *If all the continents were once joined as Pangaea, what did the rest of Earth look like?*

A When all the continents were together, there must also have been one huge ocean surrounding them. This ocean is called *Panthalassa* (*pan* = all, *thalassa* = sea). Today all that remains of Panthalassa is the Pacific Ocean, which has been decreasing in size since the breakup of Pangaea.

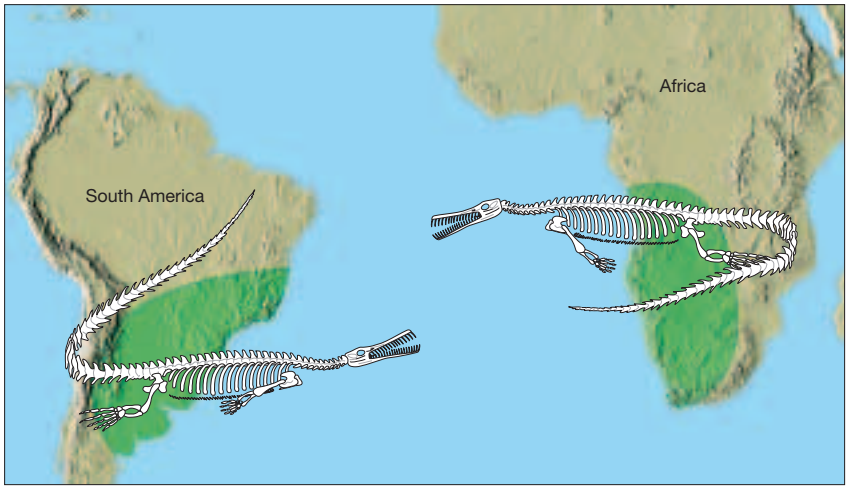


Figure 2 Fossil Evidence Fossils of *Mesosaurus* have been found on both sides of the South Atlantic and nowhere else in the world. Fossil remains of this and other organisms on the continents of Africa and South America appear to link these landmasses at some time in Earth's history.

Teacher Demo

Evidence: Matching Fossils

L2

Purpose Students compare two groups of fossils from two continents to identify those fossils that are common to both continents.

Materials 2 groups of photographs or samples of fossils, including at least one type of fossil found in both groups

Procedure Have students examine the two groups of fossils. Tell them that the two groups were found on different continents. Ask them to identify any fossils that were found on both continents. Have students infer the implications of this observation.

Expected Outcome Students should infer that the two continents had to be connected at some point in the past when the organism in the fossil lived.

Visual, Logical

Customize for Inclusion Students

Visually Impaired Puzzle pieces of continents can be made out of sandpaper by gluing a map onto the back of a piece of sandpaper and cutting out the continents. This learning tool can be used by both visually impaired students and students who learn tactilely. Remind students who use these pieces that the piece must be held with the rough side down for correct geographical orientation of the continent.

Answer to . . .

Reading Checkpoint Mesosaurus *occurs only in eastern South America and southern Africa.*

Build Science Skills

L2

Using Models Have students use a child's jigsaw puzzle with several large pieces to demonstrate matching rock types and mountain belts as follows. Students should put the puzzle together on a piece of cardboard. After putting it together, the puzzle should be covered with another piece of cardboard and flipped over. On the back of the puzzle, students should draw lines representing a mountain belt that extends across several puzzle pieces. Students will understand when the puzzle is put together how mountain chains form continuous belts across land masses.
Kinesthetic, Visual

Build Reading Literacy

L1

Refer to **p. 246D** which provides the guidelines for relating cause and effect.

Relate Cause and Effect Have students read the section on pp. 250–251 about ancient climates as evidence for continental drift. Ask: **Why did Wegener believe that the existence of glaciers in tropical regions of the Southern Hemisphere was evidence of continental drift rather than climatic change?** *(The Northern Hemisphere was once tropical, as evidenced by coal deposits that were formed from tropical plants. If the Northern Hemisphere had once been closer to the equator, the Southern Hemisphere probably had also been further south, closer to the South Pole. It was not likely that such a large change in climate could have taken place without continental drift.)*
Logical

Go Online NSTA SCILINKS

Download a worksheet on continental drift for students to complete, and find additional teacher support from NSTA SciLinks.

Matching Mountain Ranges

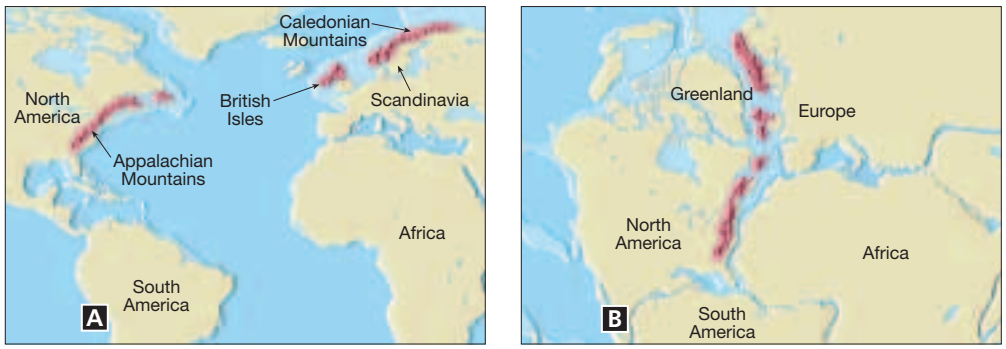


Figure 3 **A** The Appalachian Mountains run along the eastern side of North America and end off the coast of Newfoundland. Mountains that are similar in age and structure are found in the British Isles and Scandinavia. **B** When these landmasses were united as Pangaea, these ancient mountain chains formed a nearly continuous belt.

Go Online NSTA SCILINKS

For: Links on continental drift
Visit: www.SciLinks.org
Web Code: cjn-3091

Rock Types

Anyone who has worked a jigsaw puzzle knows that the pieces must fit together to form a complete picture. The picture in the continental drift puzzle is one of matching rock types and mountain belts. If the continents were once part of Pangaea, the rocks found in a particular region on one continent should closely match in age and type those in adjacent positions on the adjoining continent.

Matching types of rock in several mountain belts that today are separated by oceans provide evidence for continental drift. For example, the Appalachian mountain belt in eastern North America ends off the coast of Newfoundland, as shown in Figure 3A. Mountains of the same age with similar rocks and structures are found in the British Isles and Scandinavia. When these landmasses are fitted together as in Figure 3B, the mountain chains form a nearly continuous belt.

Ancient Climates

Wegener found evidence for dramatic global climate changes that supported his hypothesis. **Wegener found glacial deposits showing that between 220 million and 300 million years ago, ice sheets covered large areas of the Southern Hemisphere. Deposits of glacial till occurred at latitudes that today have temperate or even tropical climates: southern Africa, South America, India, and Australia.** Below these beds of glacial debris lay scratched and grooved bedrock carved by the ice. In some locations, the scratches and grooves showed that the ice had moved from what is now the sea onto land. It is unusual for large continental glaciers to move from the sea onto land. It is also interesting that much of the land area that shows evidence of this glaciation now lies near the equator in a subtropical or tropical climate.

Facts and Figures

Scientists think that 200 million years ago, what is now Pennsylvania was located farther south, near the equator. Fossils from coal fields in Pennsylvania show that the plants from which the coal formed had large leaf-like structures that are typical of tropical plants. The trunks of the plants had no growth rings, also typical of tropical plants because there is little seasonal temperature fluctuation to produce the rings. Scientists believe that these fossils are evidence that Pennsylvania once had a tropical climate and was located closer to the equator.

Could Earth have been cold enough to allow the formation of continental glaciers in what is now a tropical region? Wegener rejected this idea because, during this same time period, large tropical swamps existed in the Northern Hemisphere. The lush vegetation of these swamps eventually became the major coal fields of the eastern United States, Europe, and Siberia.

Wegener thought there was a better explanation for the ancient climate evidence he observed. Thinking of the landmasses as a supercontinent, with South Africa centered over the South Pole, would create the conditions necessary to form large areas of glacial ice over much of the Southern Hemisphere. The supercontinent idea would also place the northern landmasses nearer the tropics and account for their vast coal deposits, as shown in Figure 4.

Reading Checkpoint *Summarize the climate evidence for continental drift.*

Glacier Evidence

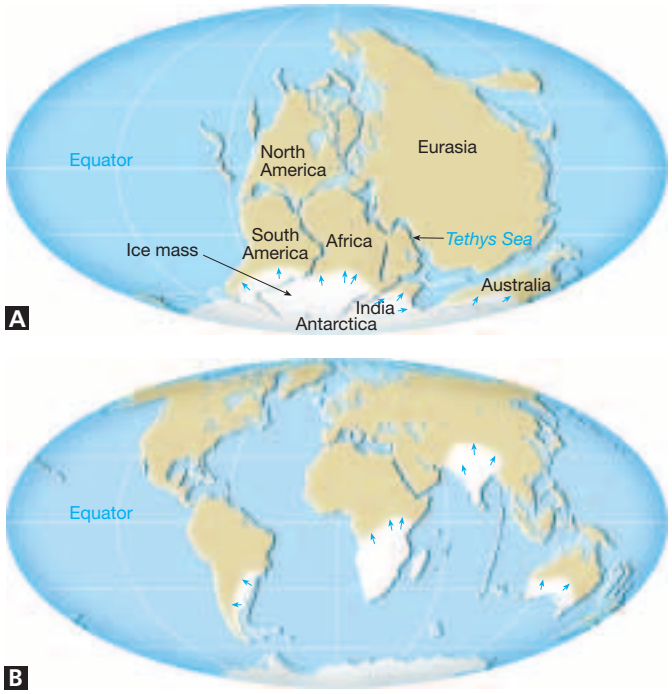


Figure 4 **A** The area of Pangaea covered by glacial ice 300 million years ago. **B** The continents as they are today. The white areas indicate where evidence of the old ice sheets exists. **Interpreting Diagrams** ***Where were the continents located when the glaciers formed?***

Quick Lab

Charting the Age of the Atlantic Ocean

Procedure

1. The distance between two locations across the Atlantic Ocean, one in South America and one in Africa, is approximately 4300 km.
2. Assume that these two locations were once joined as part of Pangaea.

Analyze and Conclude

1. **Calculating** If the two landmasses moved away from each other at a rate of 3.3 cm per year, how long did it take these two locations to move to their current positions?

Quick Lab

Charting the Age of the Atlantic Ocean L2

Objective
After completing this activity, students will be able to calculate the length of time it takes two land masses to separate, given the rate of spreading.

Skills Focus **Calculating, Inferring**

Prep Time none

Class Time 10 minutes

Teaching Tips You might want to review conversion factors with students.

Expected Outcome The two continents took more than 130 million years to separate.

Analyze and Conclude
1. 130.3 million years
2. The rate would probably have varied over time because the driving mechanism was most likely not uniform. Few Earth processes are uniform over time.
Logical

For Enrichment L3

Have students research the following question: Pangaea began to break up and South America and Africa began to separate 200 million years ago. What types of living organisms were found on Earth when the two continents reached their current positions?

Answer to . . .

Figure 4 *The continents were near the South Pole when the glaciers formed.*

Reading Checkpoint *Glaciers in southern South America, southern Africa, India, and Australia are found in areas that now have tropical climates. There is also evidence for tropical climates and coal swamps in areas that are now at higher latitudes, such as northern Europe and the northeastern United States.*

Rejecting a Hypothesis

Build Science Skills

L2

Using Tables and Graphs Have students make a table listing the reasons why Wegener's hypothesis was criticized by some people and accepted by others. **Intrapersonal, Verbal**

3 ASSESS

Evaluate Understanding

L2

To assess students' knowledge of section content, have them write two or three sentences describing each of the four lines of evidence for Wegener's continental drift hypothesis.

Reteach

L1

Have students explain in their own words why Figure 2 shows evidence for continental drift.

Writing in Science

Pangaea was a supercontinent made up of all the major continents joined together. It began breaking into smaller continents about 200 million years ago. Pangaea was located near the South Pole. The southern part of Pangaea, made up of South America, Africa, India, Australia, and Antarctica, had a cold climate with large continental glaciers.

Figure 5 Today, scientists know that plate movements helped to push up mountain ranges such as the Canadian Rockies in Banff National Park, Alberta, Canada.

Rejection of Wegener's Hypothesis

Wegener's hypothesis faced a great deal of criticism from other scientists. **The main objection to Wegener's hypothesis was that he could not describe a mechanism capable of moving the continents.** Wegener proposed that the tidal influence of the Moon was strong enough to give the continents a westward motion. However, physicists quickly responded that tidal friction great enough to move the continents would stop Earth's rotation.

Wegener also proposed that the larger and sturdier continents broke through the oceanic crust, much like ice-breakers cut through ice. However, there was no evidence to suggest that the ocean floor was weak enough to permit passage of the continents without the ocean floors being broken and deformed in the process.

Most scientists in Wegener's day rejected his hypothesis. However, a few geologists continued to search for evidence of continental drift.

During the years that followed Wegener's hypothesis, major strides in technology enabled scientists to map the ocean floor. Extensive data on earthquake activity and Earth's magnetic field also became available. By 1967, these findings led to a new theory, known as plate tectonics. The theory of plate tectonics proved that Wegener was correct—the continents move. The theory also provided the framework for understanding many other geologic processes, such as the formation of the mountains shown in Figure 5.

Reading Checkpoint *How did Wegener try to explain continental drift?*

Section 9.1 Assessment

Reviewing Concepts

1. What is the hypothesis of continental drift?
2. List the evidence that supported the hypothesis of continental drift.
3. Why did scientists reject Wegener's continental drift hypothesis?
4. What was Pangaea?

Critical Thinking

5. **Applying Concepts** How does the occurrence of the same plant fossils in South America and Africa support continental drift? Explain.
6. **Drawing Conclusions** How did Wegener explain the existence of glaciers in the southern landmasses, and the lush tropical swamps in North America, Europe, and Siberia?

Writing in Science

Descriptive Paragraph Write a paragraph describing Pangaea. Include the location and climate of Pangaea. Use the equator as your reference for position.

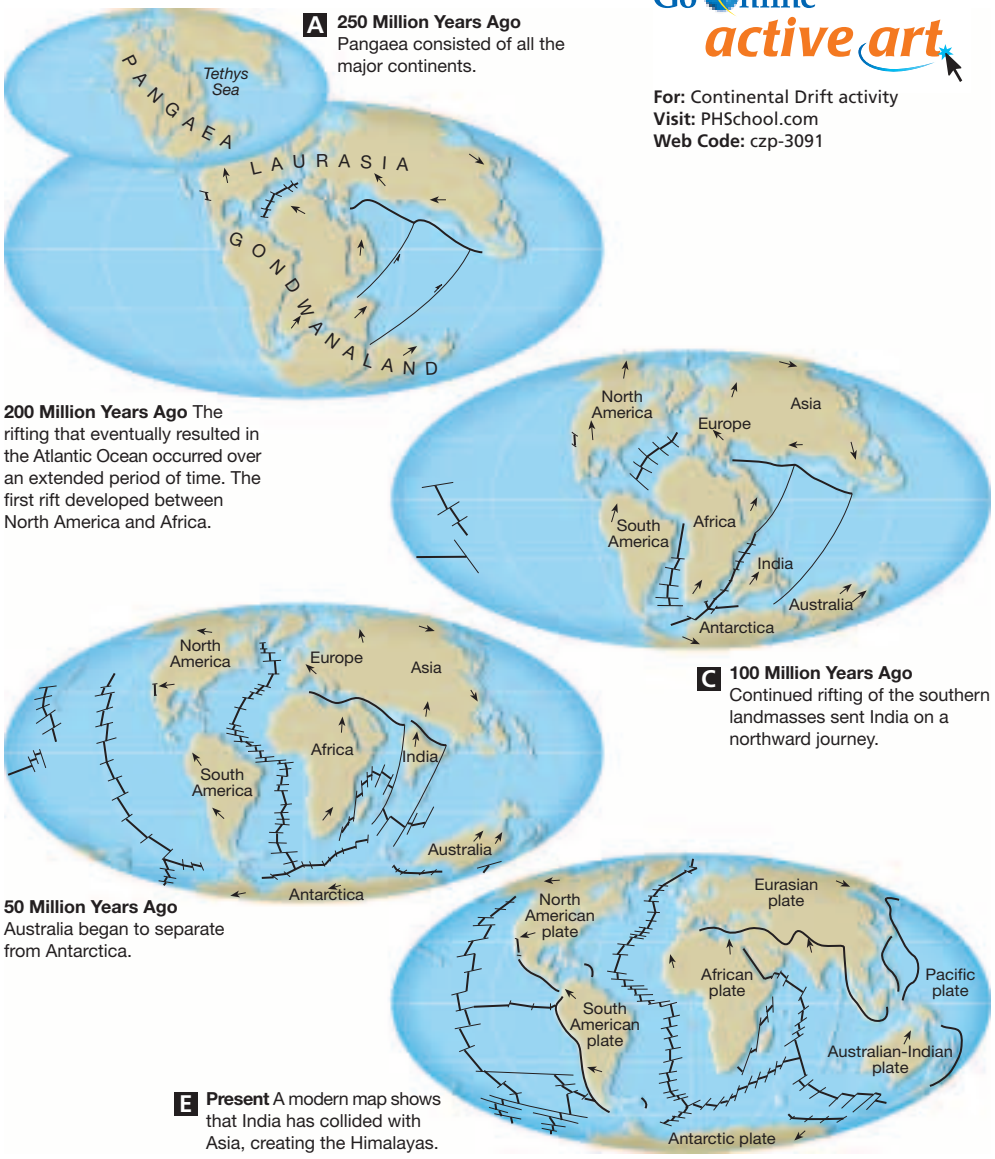
Answer to . . .

Reading Checkpoint *Wegener proposed that tidal forces due to the moon might give the continents a westward motion and that the continents somehow pushed their way across the ocean floor.*

Section 9.1 Assessment

1. a hypothesis that proposes that the continents where once joined to form one supercontinent
2. matching continental outlines, matching fossils, matching rocks and structures, ancient climates
3. He could not provide a mechanism to explain the movement of the continents.
4. the supercontinent proposed by Wegener's hypothesis of continental drift
5. A land plant most likely could not travel across a large ocean such as the Atlantic. If the plant is found in both Africa and South America, those areas had to have been joined when the plant was growing.
6. It is difficult to imagine that Earth had cooled enough to form glaciers in tropical latitudes, so in order to explain the glaciers, those areas had to have been closer to the poles than in the present day. Also, the glacial grooves indicate the ice was coming from an area that at present is ocean. Large continental glaciers form only on land, so that area had to be land.

Breakup of Pangaea



A **250 Million Years Ago** Pangaea consisted of all the major continents.

B **200 Million Years Ago** The rifting that eventually resulted in the Atlantic Ocean occurred over an extended period of time. The first rift developed between North America and Africa.

C **100 Million Years Ago** Continued rifting of the southern landmasses sent India on a northward journey.

D **50 Million Years Ago** Australia began to separate from Antarctica.

E **Present** A modern map shows that India has collided with Asia, creating the Himalayas.

Go Online active art

For: Continental Drift activity
Visit: PHSchool.com
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Figure 6 Pangaea broke up gradually over a period of 200 million years.

Use Visuals

L1

Figure 3 Have students study the maps showing the breakup of Pangaea. Ask: **In the breakup of Pangaea, what continents appear to have separated first?** *(North America and Africa)* **What ocean began to form when North America and Africa separated?** *(Atlantic Ocean)* **How was India formed?** *(India broke away from Gondwanaland. It moved north and eventually collided with Asia.)*
Visual, Logical

Address Misconceptions

L2

Some students may think that the continents have remained in approximately the same positions since the breakup of Pangaea. Make transparencies of the five parts of Figure 3. Superimpose the transparencies two at a time to show students the changes. Ask students to come up to the projection to point out changes in the location of continents from one transparency to another. Ask which continent has moved the farthest. *(Asia)*
Visual, Logical

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Visit: PHSchool.com
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Students interact with maps showing continental drift online.