1 FOCUS

Section Objectives

9.10 **Relate** the unequal distribution of heat in Earth and the mechanism of mantle convection to the movement of tectonic plates.

9.11 **Compare** the mechanisms of slab-pull and ridge-push as contributing to plate motion.

Reading Focus

Build Vocabulary L2

Paraphrase Have students explain, in their own words, the meaning of the new vocabulary terms in this section. Since each term contains an "action-type" word (*pull*, *push*, *plume*, *convection*), students should be able to form mental images to help with their explanations.

Reading Strategy L2

a. mechanism of plate motion in which the descending slab pulls on the plate
b. mechanism of plate motion in which the force of new crust formed at the high ridges pushes on the plate
c. the major mechanism of plate motion as the upward flow of hot, less dense mantle material and the downward flow of cold, dense material drives plate tectonics

2 INSTRUCT

Causes of Plate Motion

Build Science Skills L2

Using Models Challenge students to use their hands, phone books, or other objects to model slab-pull and ridge-push. Have them explain the processes as they manipulate the model.
Verbal, Kinesthetic

9.4 Mechanisms of Plate Motion

Reading Focus

Key Concepts

- What causes plate motions?
- What are the mechanisms of plate motions?

Vocabulary

- convection current
- slab-pull
- ridge-push
- mantle plume

Reading Strategy

Identifying Main Ideas Copy the table. As you read, write the main ideas for each topic.

Topic	Main Idea
Mantle convection	a. ?
Slab pull	b. ?
Ridge push	c. ?

You may have watched bits of vegetables rising and sinking in a pot of soup on the stove. This rising and sinking is an example of a convection current. A **convection current** is the continuous flow that occurs in a fluid because of differences in density. Warm material is less dense, so it rises. Cooler material is denser, so it sinks.

What Causes Plate Motions?

The convection currents in a pot of soup can serve as a model for the causes of plate motion. **Convection currents in the mantle provide the basic driving forces for plate motions.** The hot, but solid, rock of the mantle behaves in a plastic way over geologic times—that is, it can flow slowly. The main heat source for mantle convection is energy released by radioactive isotopes in the mantle, such as uranium, thorium, and potassium. Another source is heat from the core. Since most of the heat comes from within the mantle, a bowl of soup in a microwave oven is a better analogy for this process than a pot on a stove.

But how does mantle convection produce plate motions? The plates are simply the top part of mantle convection currents. The weakness of the asthenosphere allows the stiff lithosphere above to slide across it. At the "top" of these convection currents, ocean plates cool and become denser than the mantle rock beneath them. As a result, an ocean plate will begin to subduct beneath another plate. The greater density of the cold ocean plate causes it to sink all the way down to the base of the mantle. Rock from the lower mantle rises into the upper mantle and reaches the surface at mid-ocean ridges, where new ocean floor is formed. This cyclic flow of mantle rock, which may take a half-billion years, is called whole-mantle convection, shown in Figure 23.

Facts and Figures

Starting Subduction We have a good sense of how subduction ends, with the collision of two continents. But how subduction begins is less understood. A leading hypothesis is that the accumulation of sediments from rivers at the edge of a passive continental margin (like the eastern coast of North America) pushes the edge of the ocean crust down until the ocean crust breaks off from the continent and begins to subduct. This process is made easier by all of the faults and fractures at the edge of the continent that were formed the last time a supercontinent broke apart. For instance, the crust beneath New Jersey is filled with faults that formed when Africa rifted away 200 million years ago. Those faults may eventually help the Atlantic Ocean floor to break off from the continent and begin to sink beneath North America. Then, once again, there will be large volcanoes and earthquakes beneath New Jersey.

Plate Motion Mechanisms

The sinking of cold ocean lithosphere directly drives the motions of mantle convection through slab-pull and ridge-push. Some scientists think mantle plumes are involved in the upward flow of rock in the mantle. In **slab-pull,** the force of gravity pulls old ocean lithosphere, which is relatively cold and dense, down into the deep mantle. In **ridge-push,** the stiff ocean lithosphere slides down the asthenosphere that is elevated near mid-ocean ridges. This downward slide is the result of gravity acting on the cool and dense ocean lithosphere. Acting together, ridge-push and slab-pull move ocean lithosphere from mid-ocean ridges toward subduction zones and then down into the mantle.

Because Earth is not growing or shrinking in size, the downward flow of subducted ocean lithosphere must equal the upward flow of rock back toward the surface. Scientists are debating how this happens. Some scientists think that most upwelling of mantle rock occurs in the form of hot-spot mantle plumes. A **mantle plume** is a rising column of hot, solid mantle rock. Other scientists do not think that large mantle plumes exist. They think that rock replaces sinking ocean lithosphere through a slow, broad rise of rock throughout the mantle. Most scientists think both processes are involved.

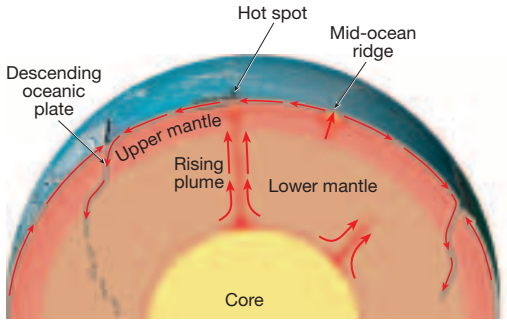

Figure 23 Whole Mantle Convection In the whole-mantle convection model, cold oceanic lithosphere descends into the mantle. Hot mantle plumes transfer heat toward the surface.

Reading Checkpoint *What is a mantle plume?*

Section 9.4 Assessment

Reviewing Concepts

1. How are plate motions connected with motions within the rest of Earth's mantle?
2. How are the forces of slab-pull and ridge-push related to plate motions?
3. What is the ultimate source of heat that moves the plates?

Critical Thinking

4. **Predicting** If Earth did not form with very much uranium, thorium, or potassium, how might it have been different than it is today?
5. **Inferring** What characteristic of old, oceanic lithosphere in a subduction zone contributes to slab-pull? Explain.

Connecting Concepts

Convection Currents Review Section 9.2. Use what you learned about sea-floor spreading and about the role of convection currents in plate tectonics to write the "life story" of a plate made up of oceanic lithosphere.

Use Visuals L1

Figure 23 Have students study the figure. Ask: **At what type of boundary does upward convective movement occur?** *(divergent)* **At what type of boundary does downward convective movement occur?** *(convergent)*

3 ASSESS

Evaluate Understanding L2

To assess students' knowledge of section content, have them write a short paragraph explaining convection. Paragraphs should include the cause of convection currents and the movements that occur.

Reteach L1

Demonstrate convection as follows: Heat a beaker of water on a hot plate. When the water is hot, add an ice cube to the water near the edge of the beaker. Drop a few drops of food coloring next to the ice cube. Students will be able to watch the food coloring move through the water by convection.

Connecting Concepts

It would provide the missing mechanism that causes the continents to move.

Answers to . . .

Reading Checkpoint *A column of hot rock rising through the mantle*

Section 9.4 Assessment

1. Convection currents in the mantle provide the forces that drive plate motions in the lithosphere.
2. In slab pull, gravity pulls cool, dense oceanic lithosphere down into the mantle. In ridge push, gravity causes stiff oceanic lithosphere to slide down the asthenosphere, which is elevated near mid-ocean ridges. Both slab pull and ridge push contribute to the movement of oceanic lithosphere.
3. Heat left over from the formation of Earth and heat from radioactive isotopes such as uranium, thorium, and potassium
4. Without radioactive elements, Earth's interior would be cooler. This would slow or perhaps stop the convection currents that cause plate motions. As a result, Earth might lack many of the geologic features, such as mountains and volcanoes, produced by plate tectonics.
5. Old oceanic lithosphere in a subduction zone is cooler and denser than oceanic lithosphere near a mid-ocean ridge. As a result, it can more easily be subducted beneath continental lithosphere or younger, less dense oceanic lithosphere.