Chapter 7

Heat Inside Earth

People often travel to tropical areas to get warm in the winter time. What would you think if you saw an advertisement that said, "Warm up this winter in the hot center of Earth"? The center of Earth is hot, but could you actually get to the center of Earth and take a vacation there? On the next page, you will read about a science-fiction story that was based on this idea. However, in the chapter, as you learn what Earth looks like inside, you will also learn that traveling to the center of Earth is not possible!

Key Questions

1. *Is it possible to travel to Earth's core through a volcano?*
2. *What is Earth's core made of?*
3. *How is a continent like a boat?*

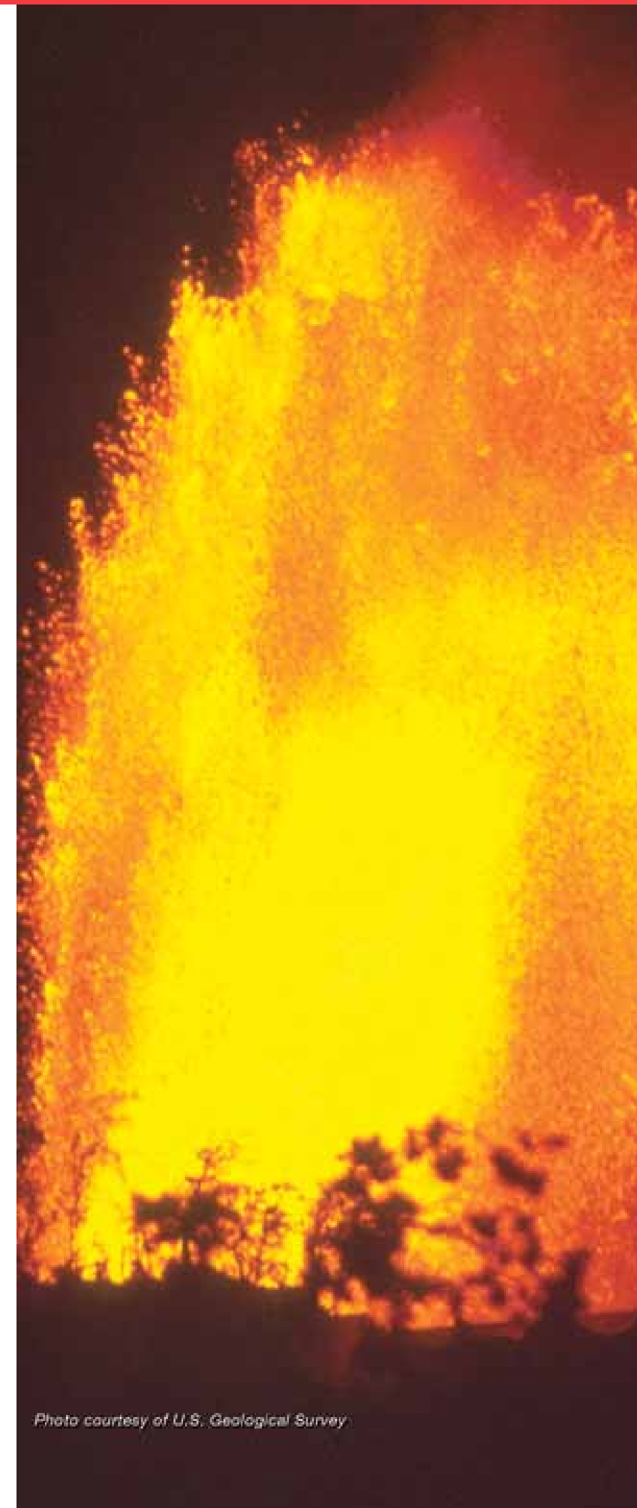


Photo courtesy of U.S. Geological Survey

7.1 Sensing the Interior of Earth

No one has seen the center of our planet because it's impossibly deep. The distance from Earth's surface to its center is about 6,400 kilometers. The deepest we have drilled into Earth is about 13 kilometers—not even close! For a long time our knowledge of the center of Earth could be drawn only from studying its surface. In this section, you will learn how we study Earth's interior and what it looks like.

VOCABULARY

seismic waves - vibrations that travel through Earth and are caused by events like earthquakes or human-made blasts.

seismologist - a scientist who detects and interprets seismic waves.

Ideas from the past

Science fiction Jules Verne wrote popular science-fiction books in the mid-1800s (Figure 7.1). Verne was popular among readers because he researched his topics and wrote stories that could have been true. In 1864, he wrote *A Journey to the Center of the Earth*. The main characters were three adventurers who explored a hollow Earth and lived to tell their tale. Along the way, they:

- entered Earth through an opening in a volcano in Iceland;
- climbed down through many strange chambers;
- crossed an ocean at the center of Earth; and
- escaped to the surface by riding a volcanic eruption.

Today scientists know that this adventure story is purely fictional and could never happen. But, how do they know this? What has changed in our view of the interior of Earth since the 1800s?

Special vibrations Scientists began to study special vibrations that travel through Earth shortly after Verne's book was written. These vibrations, called **seismic waves**, have revealed the structure of Earth's interior. Seismic waves are caused by events like earthquakes and human-made blasts. The waves pass along the surface and through Earth. A **seismologist** is a scientist who detects and interprets these vibrations at different locations on Earth's surface.

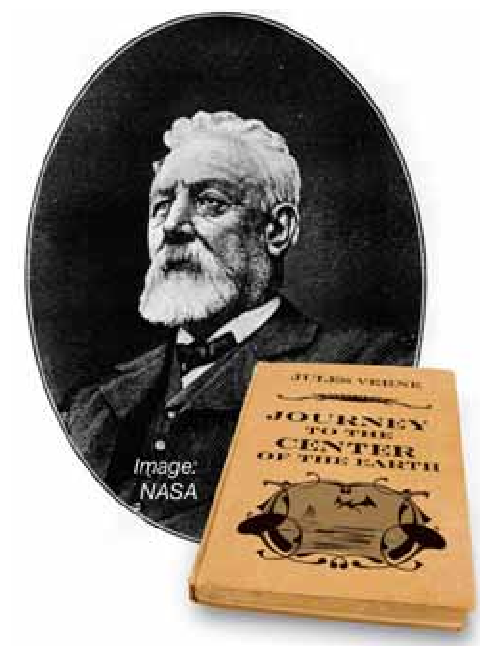


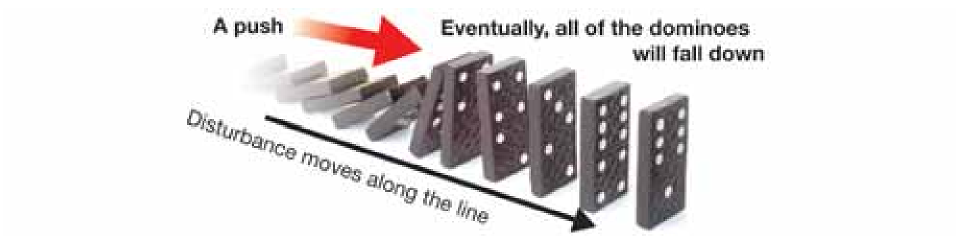
Figure 7.1: *Jules Verne wrote popular science-fiction books—like* A Journey to the Center of the Earth*—in the mid-1800s.*

Wave motion

A push moves along a line Imagine a line of students waiting for a bus. A student at the end of the line falls forward and bumps into the student in front of him before righting himself again. This causes that student to bump into the next student. The bumped student bumps another student and so on along the line. Each student in the line falls forward, bumps the next student, then rights himself. Eventually, the student at the head of the line feels the push that began at the end of the line.

Forward-and-backward motion The "push" or **disturbance** that traveled down the line of students is an example of forward-and-backward wave motion. The student at the end of the line was still at the end of the line when the student at the front of the line felt the push. The disturbance traveled down the line while the students kept their places.

A domino "wave" A line of dominoes also illustrates how a disturbance can travel. The first domino is pushed and soon the last domino falls over, even though it is far from the first one! However, a line of dominoes falls in one direction without any forward-and-backward motion.



Up-and-down and side-to-side motion Other kinds of wave motion are up-and-down and side-to-side motion (Figure 7.2). You are probably familiar with the up-and-down motion of water waves in a pool. You can demonstrate side-to-side wave motion by wiggling a rope.

VOCABULARY

disturbance - a movement that begins in one location and sets things in motion farther away.

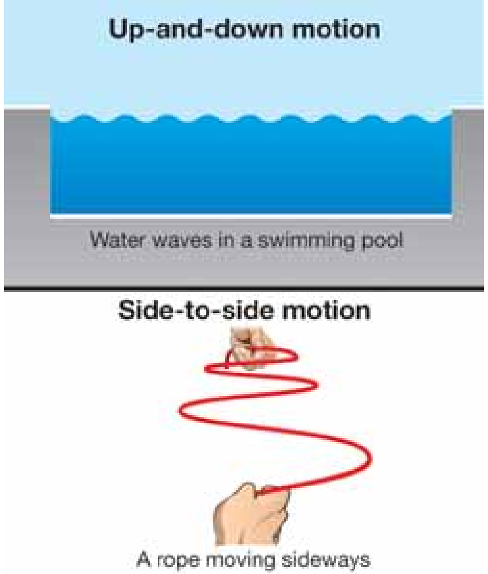


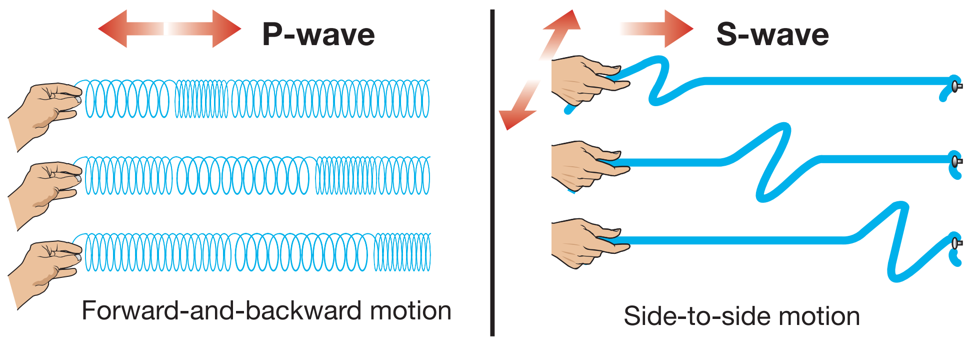
Figure 7.2: *Up-and-down and side-to-side motion.*

MY JOURNAL

What kinds of disturbances can create water waves? Make a list of these disturbances and draw sketches to illustrate your list.

Kinds of seismic waves

P-waves and S-waves There are several kinds of seismic waves. Two that are important for studying Earth's interior are primary and secondary waves. These waves are usually called by their first letter, P-waves and S-waves. **P-waves** travel faster than S-waves and move with a forward-and-backward motion. Slower **S-waves** travel with a side-to-side motion. S-waves do not pass through liquids, unlike P-waves which pass through solids, liquids, and gases.



Waves tell us about Earth's interior As P-waves and S-waves travel through Earth, they might be bent, bounced, sped up, or slowed down depending on the nature of the material they encounter. By studying what happens to the waves on their path through Earth, scientists are able to make detailed maps of Earth's interior.

A clue from S-waves Here is a simple example of how scientists use seismic waves. Scientists observed that when S-waves are produced on one side of Earth due to an earthquake, there is a large area on the other side where the waves can't be detected (Figure 7.3). They called this area the *S-shadow*. Something was blocking the S-waves as they tried to pass through! Scientists know that secondary waves do not pass through liquid. With this fact and these observations, they realized that the outer core of Earth must be liquid.

VOCABULARY

P-waves - seismic waves that move with a forward-and-backward motion; these waves are faster than S-waves.

S-waves - seismic waves that move with a side-to-side motion and are slower than P-waves.

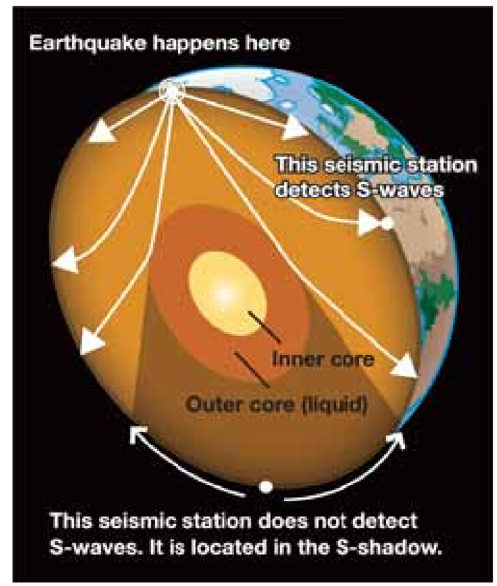


Figure 7.3: *In the graphic above, S-waves deflect off the liquid outer core of Earth. Since S-waves cannot pass through the outer core, an S-shadow is created on the side of Earth opposite the earthquake.*

7.1 Section Review

1. What is Earth's radius in kilometers? What is Earth's radius in miles (1 kilometer = 0.62 miles)?
2. Answer these questions about the vibrations that travel through Earth:
   a. What are these vibrations called?
   b. What causes them?
   c. What have these vibrations revealed about Earth's interior?
3. What is a seismologist?
4. During wave motion, what moves from one place to another?
5. What are the two general types of wave motion described in this section?
6. List the two most important seismic waves used for studying Earth's interior. Give three facts about each type of wave.
7. After an earthquake, P-waves travel at an average speed of 5 kilometers per second and S-waves travel at an average speed of 3 kilometers per second. A seismic station is located 30 kilometers from where the earthquake occurred (Figure 7.4).
   a. How many seconds would it take for the P-waves to reach the seismic station?
   b. How many seconds would it take for the S-waves to reach the station?
8. What can happen to seismic waves as they travel through Earth?
9. What are S-shadows? You may use a diagram to help you answer this question.
10. What do S-shadows tell us about the interior of Earth?

MY JOURNAL

Is it possible to travel to Earth's core through a volcano?

Write a paragraph that answers this question based on what you knew about Earth *before* you read Section 7.1.

Then, write a paragraph that answers this question based on what you know about Earth *now that you have finished* reading Section 7.1.

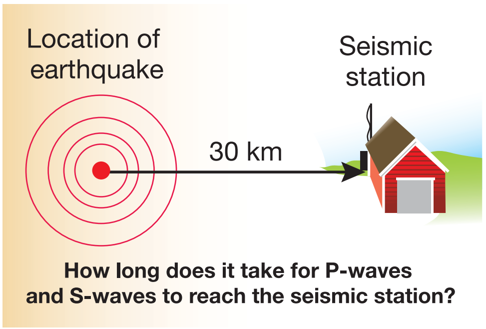
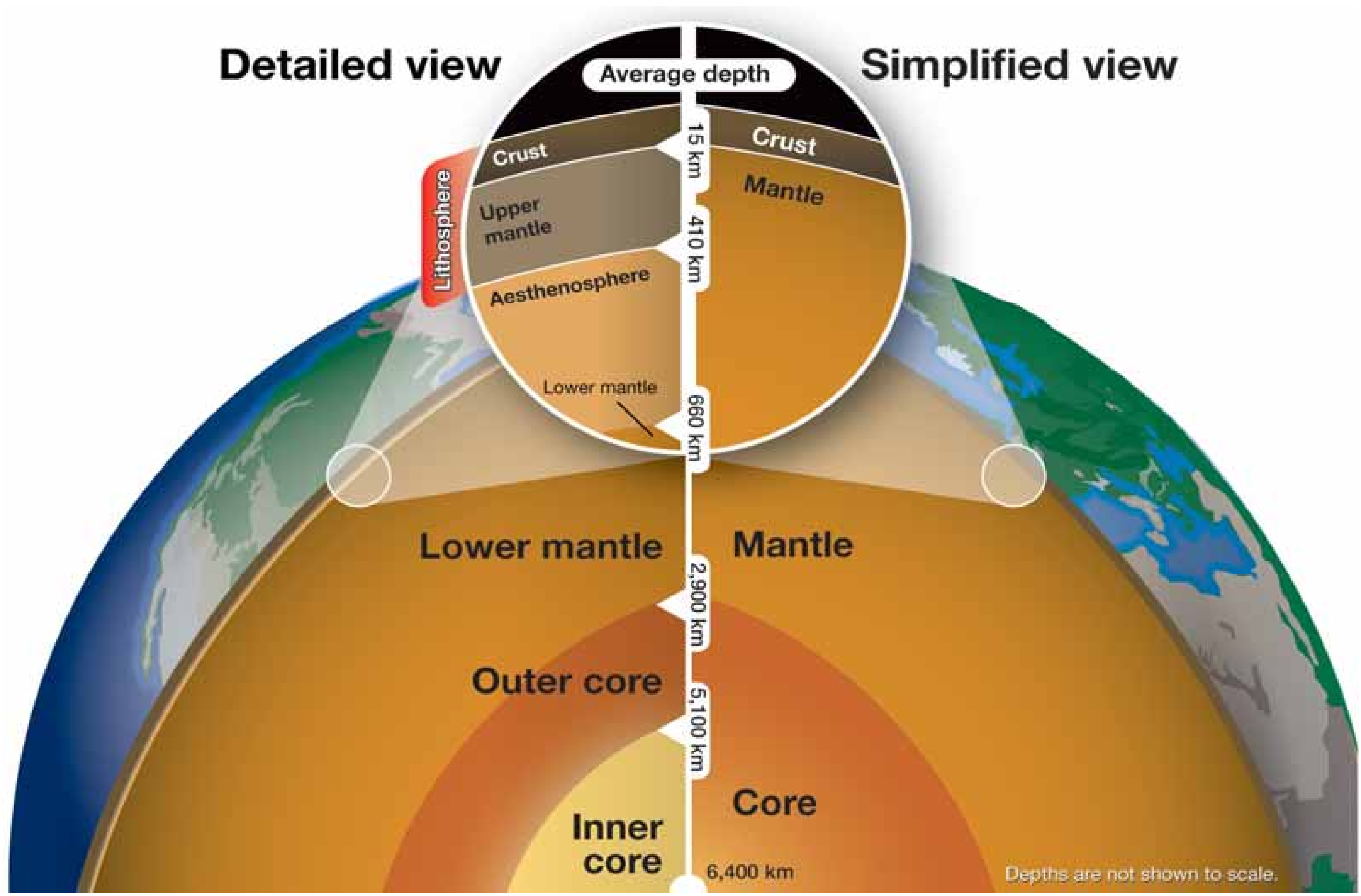


Figure 7.4: *An earthquake occurs 30 kilometers away from a seismic station. How long does it take for P-waves and S-waves to reach the station?*

7.2 Earth's Interior

Simple diagrams of Earth's interior show it as having three layers—an outer crust, a mantle, and a core. Modern science has revealed much more detail in these layers. The graphic below shows some of this detail.



The crust and the mantle

What is Earth's crust? The **crust** is the outermost surface of Earth. Oceanic crust lies under the oceans and is thin. Its average thickness is about 5 kilometers. Continental crust forms continents and is thicker. Its average thickness is 30 kilometers (Figure 7.5). Because rock in the crust is cool, the crust is brittle (cracks and breaks easily). Shallow earthquakes occur in the crust.

What is Earth's mantle? In the simplified view of Earth, the **mantle** is the layer between the crust and the core. The simplified mantle includes the upper and lower mantle of the detailed view, and is about 2,900 kilometers thick. Mantle material is warm and soft enough to flow. The less-dense crust floats on the mantle!

Lithosphere The **lithosphere** includes the crust and a thin part of the mantle. This thin, outer-most mantle is called the *upper mantle*. The plates that move about Earth's surface are pieces of lithosphere.

Aesthenosphere The aesthenosphere lies just under the lithosphere and is the outermost part of the lower mantle. The aesthenosphere is a slushy zone of hot rock with a small amount of melted rock. This part of the lower mantle is important because the lithospheric plates slide on it. The aesthenosphere is 100 or more kilometers thick under oceans, and much less under continents.

Lower mantle In the simplified view of Earth, the mantle includes everything below the crust and above the core. The detailed view of Earth separates the mantle into the upper and lower mantle. The lower mantle includes the aesthenosphere. The lower mantle is the largest part of Earth's interior. Although the lower mantle is made of rock, it is warm. Because it is warm, it is *plastic*. Plastic here means that the lower mantle flows slowly rather than breaking.

VOCABULARY

crust - the outermost surface of Earth.

mantle - the warm, flowing, solid layer of Earth between the crust and the core.

lithosphere - a layer of Earth that includes the crust and upper mantle.

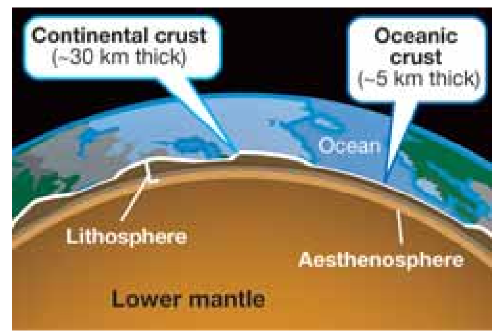


Figure 7.5: *The continental crust is about 30 kilometers thick. The oceanic crust is about 5 kilometers thick.*

The core

What is Earth's core? The **core** is the name for the center of Earth. In the simplified, traditional view of Earth, the core is a single central ball. The detailed view divides the core into two layers, the inner and outer core. The material that makes up the core is denser than the material in the mantle. The core is also an extremely hot place! Earth's temperature increases from the crust to the core.

Outer core Seismic S-waves show that the outer core is liquid. The outer core is made mostly of iron, and is so hot the iron is melted. Powerful electric currents are formed as the liquid outer core moves. These electric currents create Earth's magnetic field. This magnetic field protects the planet from harmful solar radiation (Figure 7.6). It also protects the atmosphere. Life on Earth would be in danger if the outer core cooled and stopped moving.

Inner core The inner core is also made mostly of iron, but it is solid. The inner core is also hot enough to melt iron, so why is it solid? Melting depends on pressure as well as temperature. The pressure at the inner core is so enormous that iron, and the rest of the inner core, remains a solid.

Summary Information about the layers of Earth is summarized below.

Layers of Earth		Average depth (km)	Relative temperature (°C)	Description
Lithosphere	Crust	15	0	The uppermost layer
	Upper mantle	410	870	
	Aesthenosphere	660		The surface of the lower mantle on which lithospheric plates slide.
	Lower mantle	2900	3700	Largest part of Earth's interior
Core	Outer core	5100	4300	Liquid
	Inner core	6400	7200	Solid (hotter than the surface of the Sun)

Temperature increases with depth

VOCABULARY

core - the center of Earth; it is divided into the inner core and the outer core.

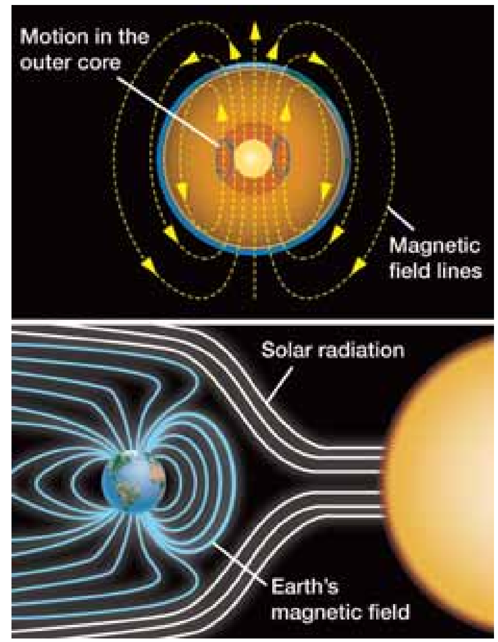


Figure 7.6: *Earth's magnetic field is created by powerful electric currents formed by the motion of liquid iron in Earth's outer core. Earth's magnetic field protects the planet from harmful radiation from the Sun.*

7.2 Section Review

1. Simplified diagrams of Earth's interior show three layers. What are these layers?
2. Use Figure 7.7 to help you answer the following questions.
   a. What layers compose Earth's core?
   b. The upper mantle and crust make up which layer of Earth's interior?
   c. What is the name of the thickest layer of Earth's interior?
3. How thick is the outer core in kilometers?
4. Which is thicker—oceanic crust or continental crust?
5. Is the crust brittle? Why is this? Do earthquakes occur in the crust?
6. The plates that move about Earth's surface are pieces of the ______________.
7. What is the aesthenosphere and why is it important?
8. What material makes up most of the outer core? Is it solid or liquid? Why?
9. What material makes up most of the inner core? Is it solid or liquid? Why?
10. What very important process happens in the outer core? Why is it important?

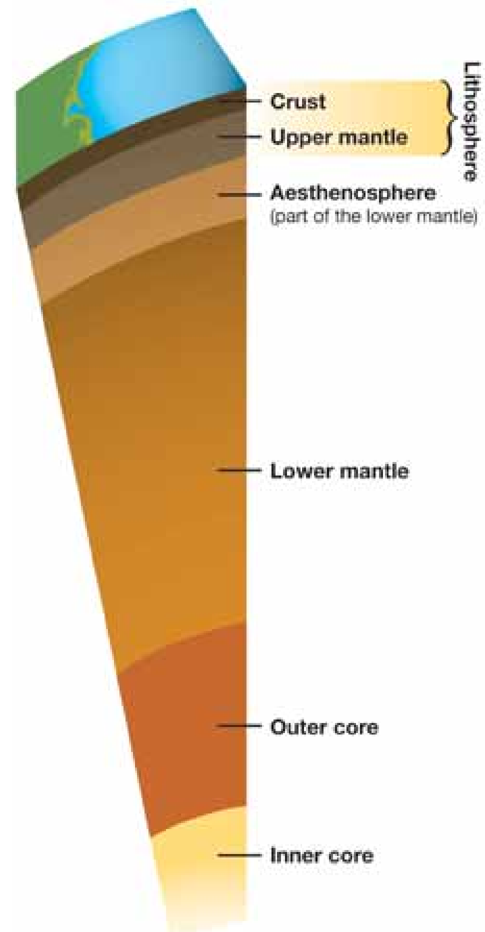


Figure 7.7: *A detailed view of the layers of Earth's interior.*

7.3 Density and Buoyancy Inside Earth

Scientists believe that Earth formed from the gas and dust that surrounded our young sun. At first, Earth's surface was made of the same materials as its center. At some point, the material melted and became fluid.

Earth's materials sorted by density

Earth's layers You learned in Chapter 5 that less dense objects will float in more dense fluids. Once Earth became fluid, materials began to sort out by their densities. Less buoyant, denser materials settled toward the center. More buoyant and less dense materials rose toward the surface. Today aluminum and silicon are common within Earth's crust. These elements have low densities. The inner and outer cores are composed mostly of dense iron (Figure 7.8).

	Density (g/cm^3)
aluminum	2.7
silicon	2.3
iron	7.9
water	1.0

Figure 7.8: *Density values for substances that make up Earth.*

Earth's crust floats on the mantle Earth's crust is made of different types of rock that are less dense than the mantle. Oceanic crust is made of *basalt* and is slightly denser than continental crust. Continental crust is made of mostly *andesite* and *granite* (Figure 7.9). Oceanic crust is thinner than continental crust, but both kinds of crust float on the mantle.

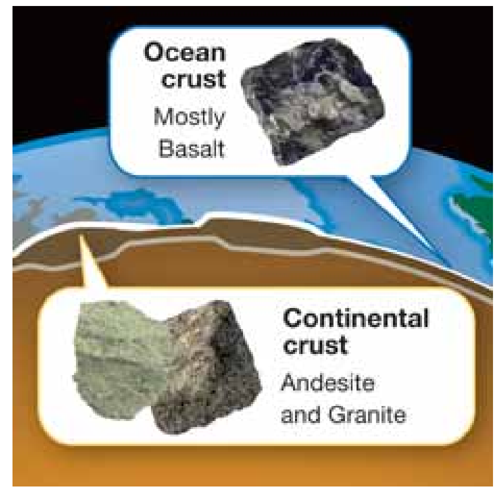
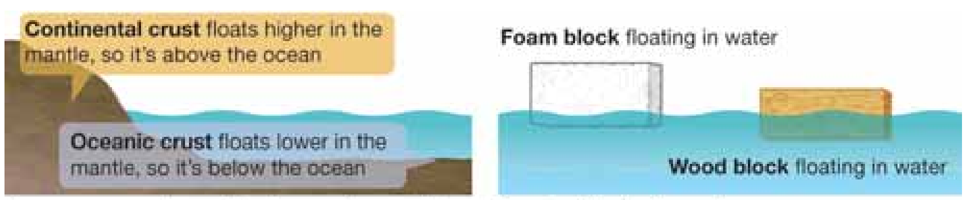


Figure 7.9: *The oceanic crust is made mostly of basalt. The continental crust is made mostly of andesite and granite.*

Rocks float on rocks! We tend to think that rocks are all the same. It's hard to imagine rocks floating on other rocks, but this is what happens inside Earth! The cold brittle rocks of the crust float on the hot, soft, and denser rock below.

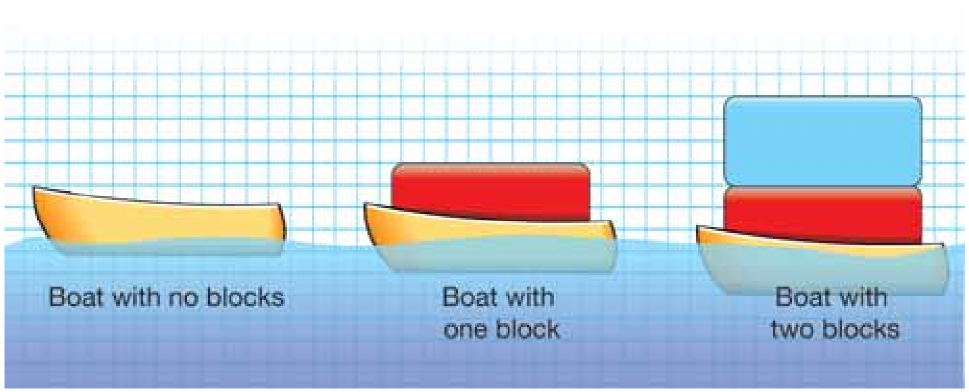


Because oceanic crust is denser than continental crust, it floats lower in Earth's mantle. Blocks of foam and wood floating in water demonstrate this phenomenon.

Floating continents

How is a continent like a boat?

Imagine stacking blocks on a toy boat floating in a pool. As you add blocks, the stack gets higher and heavier. The extra weight presses more of the boat into the water to support the stack. The finished stack stands taller than the original boat, but the boat is also deeper in the water.



Mountains on continents

Earth's crust floats on the mantle just like the boat. A mountain on land is just like the stack of blocks (Figure 7.10). Like the boat, the crust with a mountain sticks down into the mantle. The average thickness of continental crust is 30 kilometers, but the combination of a mountain and its bulge underneath may make the crust as thick as 70 kilometers.

Glaciers on continents

During an ice age, the weight of glacial ice presses down the crust just like a mountain. After the ice age ends and the glacier melts, the crust springs back up again (Figure 7.11). Scientists studying shorelines have detected these up-and-down movements.

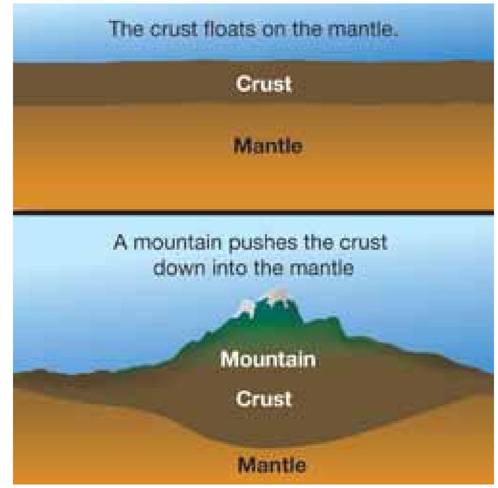


Figure 7.10: *How a mountain affects the crust.*

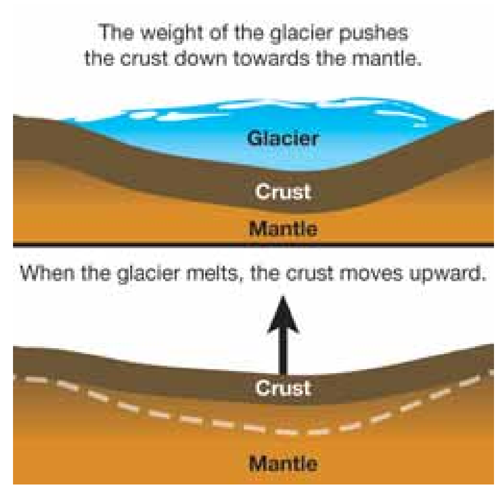


Figure 7.11: *How a glacier affects the crust. The effects have been exaggerated to show the changes.*

Convection

Convection in the lower mantle

Most of the remaining heat from the formation of our planet lies in the core. The hot core heats the lower mantle where the two layers come together. Can you predict what happens next? Heating the lower mantle causes the material to expand. The mass doesn't change, but the volume increases. This makes the heated material less dense. You know that less dense objects will float in more dense fluids. The result is a plume of hot lower mantle material rising up from near the core toward the lithosphere.

As the convection current nears the lithosphere, it turns and runs along underneath. Eventually the convection current loses its heat and sinks back toward the core. You will recognize this as a convection cell (Figure 7.12). Convection in the lower mantle is identical to convection in a heated room and in our atmosphere. In the next chapter on plate tectonics, you will see how lower mantle convection drives the lithospheric plates across Earth's surface.

Seismic tomography

In the early days of seismology, scientists detected seismic waves with mechanical detectors. All studies of arriving waves were done with paper and pencil. Today the tools are much better. Electronic detectors provide much more information about seismic waves. But the real improvement is in the use of computers and the invention of *seismic tomography* by Dr. Adam Dziewonski of Harvard University. Seismic tomography uses seismic waves collected from all over the world to create a three-dimensional image of Earth's interior (Figure 7.13). This process is similar to using many x-ray sensors to create a CAT scan of someone's head. CAT stands for computer-assisted tomography. A computer combines the signals from these x-ray detectors to produce a three-dimensional image of the inside of the patient's head.

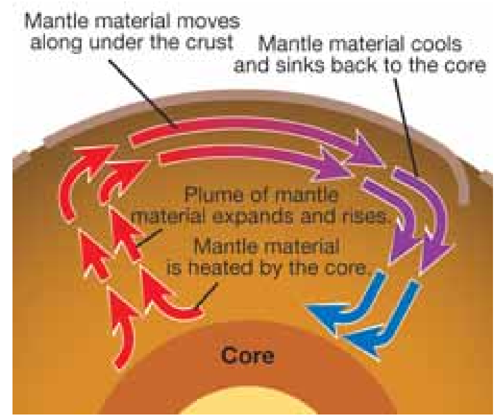


Figure 7.12: *How convection in the mantle occurs.*

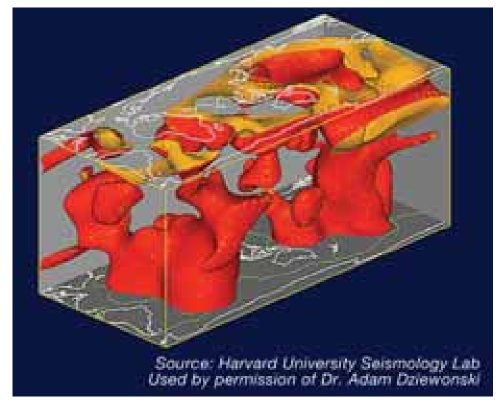


Figure 7.13: *The red blobs in the graphic are warmer, less dense convection currents of mantle rising toward Earth's surface from the core.*

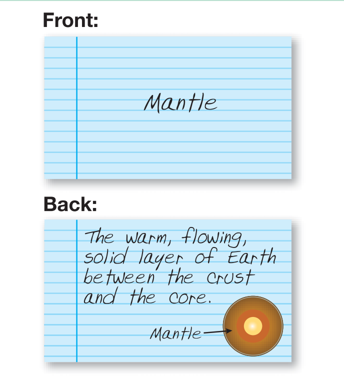
7.3 Section Review

1. Explain how the young Earth separated into layers. Use the term *density* in your answer.
2. Draw a simplified diagram of Earth's interior.
   a. Indicate on the diagram where you would find aluminum and silicon.
   b. Then, indicate on the diagram where you would most likely find iron.
   c. Using the density values in Figure 7.8, explain why water floats on Earth's surface.
   d. How do you think the density of the mantle compares to the densities of the crust and the core? Explain your answer.
3. What kind of rock makes up the ocean floor?
4. What kind of rock makes up the continents?
5. Can rocks float? Explain.
6. What might happen to a mountain that would cause the crust to float higher in the mantle?
7. What might happen to a glacier that would cause the crust to float higher in the mantle?
8. What process drives the lithospheric plates across the surface of Earth? Draw a diagram of this process.
9. What is seismic tomography?
10. How is a CAT scan like seismic tomography?

STUDY SKILLS

You have learned many new terms in Units 1 and 2. To help you better understand and remember these terms, make a flash card for each vocabulary word using index cards.

A flash card has the term on one side and the definition on the other side. It looks like this:



Flash cards are useful because they are small enough to take anywhere. Study one or two flash cards whenever you have a break during the day.

If you have read all of Unit 1 and Unit 2, you have learned more than 60 new vocabulary terms!

Good job!

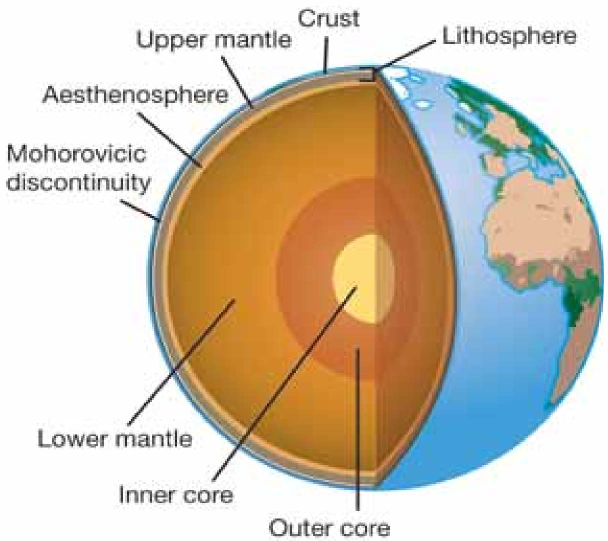
RESEARCH CONNECTION

Drilling to Earth's Core

How do you get to the heart of the matter on this planet? It's deep down there, nearly 4,000 miles (about 6,500 kilometers) beneath your feet. If we could somehow reach Earth's core, from there every direction would be "up."

We may never reach that center core, but scientists are always getting closer. For the first time, people have drilled into the lower section of Earth's crust. Just getting through the planet's outer layer was a huge job: eight 0weeks of drilling a hole in the ocean floor.

Scientists will not stop there. They hope to break into the upper mantle, the layer just beneath the crust, some time in the coming years. That is one of the goals of the Integrated Ocean Drilling Program (IODP).



Scientists are looking for a boundary they call the "Moho," short for the Mohorovicic discontinuity. This boundary between Earth's crust and the upper mantle below is named for Andrija Mohorovicic, the Croatian seismologist who first identified it in 1909.

The planet's outer crust is thin and hard. The mantle lies just below the crust, and it is hot and soft and a more flexible layer. The three layers of the mantle (the upper mantle, the aesthenosphere, and the lower mantle) make up nearly 80 percent of Earth's total volume. Beneath the mantle is the liquid outer core and the solid inner core.

Digging for clues

By drilling deep into the crust, scientists hope to learn more about how it forms. They also hope to learn more about the movement of the upper mantle.


Ocean drilling platform

Why drill in the oceans? The simple reason is that the oceanic crust is thinner, about 5 kilometers (3 miles) thick in the ocean trenches. The continental crust is about 30 kilometers thick (about 18 or 19 miles).

If the drill can reach the Moho, we may learn how the mantle and the crust interact, or, more importantly, how the crust forms. All of this information will help scientists understand the differences between the mantle and the crust.

The complex inner Earth

Drilling has allowed scientists to learn more about Earth's structure. It shows how complex the structure is and how Earth evolved. The IODP scientists for the first time have collected data from the lower crust. Mantle material, however, has yet to be recovered.

Finding the Moho isn't easy because it isn't at the same depth everywhere. The latest IODP hole—that took almost 8 weeks to drill—went about 4,644 feet (1,415 meters) below the floor of the Atlantic Ocean.

Drilling into the rock

Even at that depth, the Moho was not reached. Still, the rock that was drilled out taught us new things about the complexity of the planet's structure.

Another glimpse deep down

Another way we learn about Earth's interior is from earthquakes. An earthquake's seismic waves travel through the layers of the mantle and through the core.

The study of seismic waves has already convinced scientists that Earth's core is rotating faster than its surface. This was confirmed by comparing the travel times of waves passing through the core.

Researchers did this by comparing two earthquakes that had happened in almost the exact same place but on different dates. Then they compared the time it took each quake's shockwaves to pass through the core. Some parts of the core are denser than others, which can speed up or slow the shock waves as they pass through the core.

Scientists studied two almost identical earthquakes that happened at the same place near South America. If the core was moving at the same speed as the surface, the time it took for the seismic waves to be recorded would be the same for each earthquake. But the times and shapes of the waves were different. This meant that the seismic waves passed through a different part of the core in each earthquake.

Based on this, scientists believe Earth's core is spinning faster than the planet's surface. It actually “laps” the surface about every 400 years!

Why does this matter? Differences in the core's rotation may affect the whole planet's rotation. Understanding Earth's past and present will influence how we move forward into the future. By looking inside it, we may see much farther outside Earth as we evolve along with it.

Questions:

1. What is the IODP and what is one of its goals?
2. Has the IODP succeeded in reaching its goal? Why or why not?
3. What is the Moho?
4. Which layer of Earth makes up nearly 80 percent of its total volume?
5. What has convinced researchers that Earth's core is spinning faster than the planet's surface?

CHAPTER ACTIVITY Modeling Wave Motion Through Different Materials

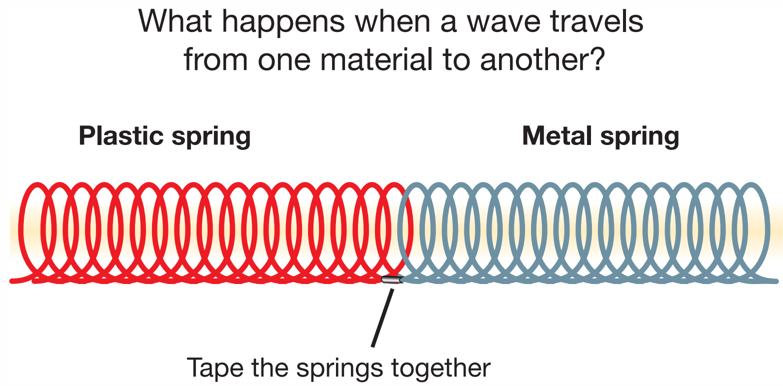
In this activity, you will be observing wave motion, the movement of primary and secondary waves, and the change in behavior of a wave as it passes from one material to another. As you have learned, seismic waves have given humans a great amount of information about our Earth. You have also learned that there is more than one kind of seismic wave and that even though all of them produce wave motions, the individual disturbances along the wave move very differently through the planet. Let's look and see if we can demonstrate how this energy travels.

Materials

- Large springs (both metal and plastic)
- Electrical tape
- Meter stick
- Water
- Shallow rectangular bin for water
- Small stone

What you will do

1. Modeling wave motion: Fill the bin with an inch or two of water. Drop the stone into the water and watch the waves. Try this several times and then answer questions a-c. You have just modeled wave motion!
2. With a partner take the metal spring and stretch it about 3 meters and lay it on a flat surface such as the floor or a long table.
3. To demonstrate P-wave motion, one person will hold the spring at one end. The other person will move their hand holding the spring forward and backward. Answer question d.
4. To demonstrate S-wave motion, one person will hold the spring on one end firmly and the other person will move his or hand quickly side-to-side. Answer question e.
5. Now take the plastic spring and tape one end to one end of the metal spring. The two springs represent two different materials. This demonstration will show what happens when wave energy passes through a boundary of two different materials, like different layers in Earth. Generate both P- and S-waves as you did before using the metal spring. Watch as the wave motion travels through to the plastic spring. Answer question f.



Applying your knowledge

a. Draw or describe how the waves looked in the water.
b. Did the waves in the water tend to move over the surface or down through the water to the bottom of the bin?
c. How is this different from how P- and S-waves move?
d. Describe or draw what happens with the P-wave motion.
e. Describe or draw what happens with the S wave motion.
f. Describe what happens at the boundary of the two springs.
g. A P-wave from an earthquake goes through the mantle and then through the core of Earth. Based on what you have observed in this lab, what would you expect about the path of this wave?

Chapter 7 Assessment

Vocabulary

Select the correct term to complete the sentences.

seismologist	crust	seismic waves
lithosphere	core	P-waves
mantle	S-waves	disturbance

Section 7.1

1. _____ are seismic waves that do not pass through liquids.
2. A scientist that detects and interprets seismic waves at different locations on Earth is called a _____.
3. Vibrations that travel through Earth are called _____.
4. _____ are seismic waves that move in a forward-and-backward motion.
5. During wave motion, a _____ moves from one place to another.

Section 7.2

6. The largest part of Earth's interior that is made of rock, but is flexible, is the _____.
7. The _____ is the inner iron-containing layer of Earth.
8. Made of the crust and upper mantle, the _____ makes up the plates that move about Earth's surface.
9. The outermost surface of Earth is called the _____.

Concepts

Section 7.1

1. Jules Verne described Earth and its interior in his book *A Journey to the Center of the Earth*. Was he a scientist? Why or why not?
2. People cannot travel to the center of Earth in person. How then do scientists study what Earth looks like inside?
3. You can create an up-and-down wave by wiggling a jump rope. What travels from one place to another during the wave motion? What stays in place?
4. For each of these statements write either P-wave or S-wave:
    a. Travels through all material.
    b. Does not travel through liquids
    c. Forward-and-backward motion
    d. Side-to-side motion
    e. Slower
    f. Faster

Section 7.2

5. How is Earth's crust different from the mantle? List three ways.
6. The _____ is the slippery surface on which the lithospheric plates move around Earth's surface.
7. What causes Earth's magnetic field? Why is Earth's magnetic field important?
8. The inner core is really hot but solid. Why isn't the inner core a liquid like the outer core?

Section 7.3

9. With all the layers that make up Earth, which layer is the densest and which is the least dense? Why?
10. List the differences between the continental crust and the oceanic crust.
11. How would studying a shoreline help a scientist figure out that there had been up and down movement of the crust?
12. What do you think would happen if there was no convection in Earth's mantle?
13. The up-and-down movement of the crust due to the weight of overlying objects, such as mountains or melting of glaciers is a result of _____.

    (a) convection in the mantle
    (b) buoyancy of the crust floating on the mantle
    (c) magnetic fields
    (d) mantle plumes

14. The rock of the ocean floor, basalt, is slightly _____ than granite, the rock of the continents.

    (a) denser
    (b) less dense
    (c) more magnetic
    (d) more flexible

Math and Writing Skills

Section 7.1

1. In the box below is a list of four events that happen in *A Journey to the Center of the Earth*. Write a paragraph that explains whether each is a realistic event or not.

> In *A Journey to the Center of the Earth*, the main characters were three adventurers who explored a hollow Earth and lived to tell their tale. Along the way, they:
>
> - entered Earth through an opening in a volcano in Iceland;
> - climbed down through many strange chambers;
> - crossed an ocean at the center of Earth; and
> - escaped to the surface by riding a volcanic eruption.

2. Reading about the way scientists learned about the outer core being liquid, do you have a personal experience where you learned something new in an indirect way? Explain your experience in a paragraph.
3. After an earthquake, P-waves travel at an average speed of 5 kilometers per second and S-waves travel at an average speed of 3 kilometers per second. A seismic station is located 15 kilometers from where the earthquake occurred. How many seconds would it take:
    a. the P-waves to reach the station?
    b. the S-waves to reach the station?

Section 7.2

4. What is the radius of Earth in kilometers? What is the diameter of Earth in kilometers?
5. Scientists have only been able to drill into the lower part of Earth's crust. What percentage of the radius have scientists drilled into?

   (a) 100% (c) less than 1%

   (b) 50% (d) 25%

6. The continental crust averages about 30 kilometers thick. You learned that the continental crust is thickest at mountains. Where would it be thinnest?
7. Where would the oceanic crust (which averages about 5 kilometers thick) be thinnest?
8. How thick is the lower mantle?

Section 7.3

9. Why does water float on Earth's surface? Refer to the table below to help you answer this question.

	Density (g/cm^3)
aluminum	2.7
silicon	2.3
iron	7.9
water	1.0

10. Imagine you are a lithospheric plate on Earth's surface. Describe yourself. Explain how you move around on Earth.

Chapter Project—Earth Model Flash Cards

1. Make a 3-dimensional model of the detailed view of Earth's interior (see Figure 7.7). Include all the layers and label them. For your materials, you will need to be creative. Some ideas—use modelling clay or place layers of colored sand in a transparent container.
2. In Section 5.1, you learned a good study skill—making flash cards to help you learn concepts and vocabulary. Make flash cards of the vocabulary you have learned so far in chapters 1 through 7. Add colorful diagrams to your flash cards!