SECTION 1
READING WARM-UP

Inside the Earth

Terms to Learn

crust
mantle
core
lithosphere
asthenosphere
mesosphere
outer core
inner core
tectonic plate

What You'll Do

- Identify and describe the layers of the Earth by what they are made of.
- Identify and describe the layers of the Earth by their physical properties.
- Define *tectonic plate.*
- Explain how scientists know about the structure of Earth's interior.

The Earth is not just a ball of solid rock. It is made of several layers with different physical properties and compositions. As you will discover, scientists think about the Earth's layers in two ways—by their *composition* and by their *physical properties.*

Earth's layers are made of different mixtures of elements. This is what is meant by differences in composition. Many of the Earth's layers also have different physical properties. Physical properties include temperature, density, and ability to flow. Let's first take a look at the composition of the Earth.

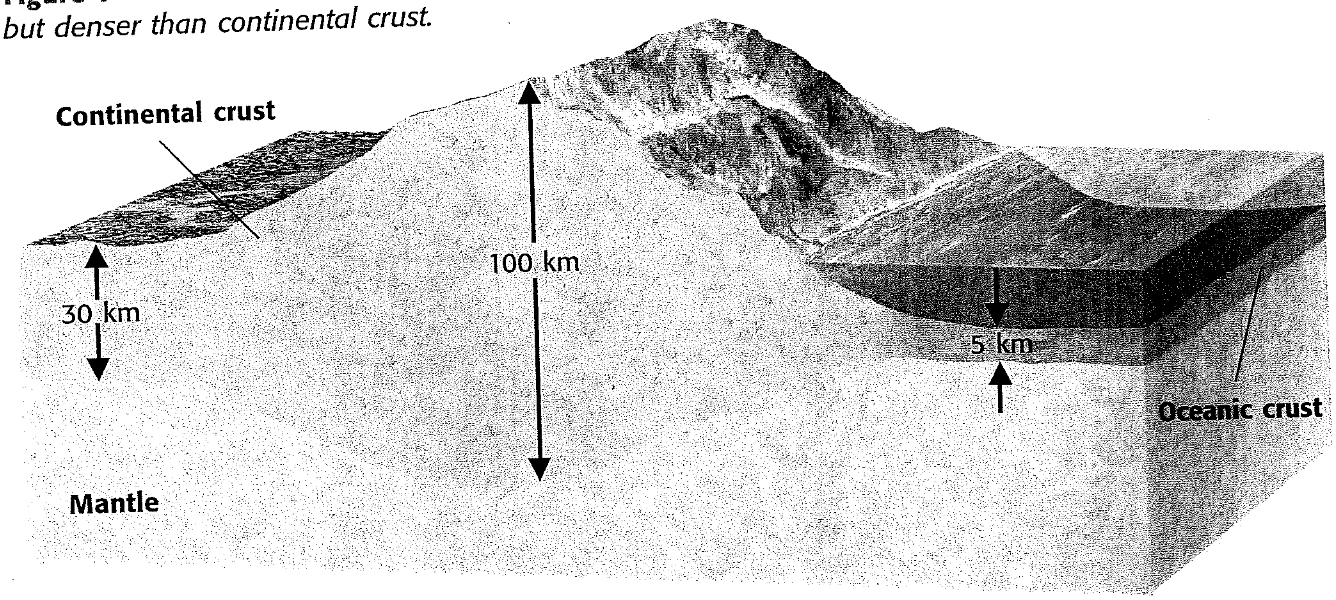
The Composition of the Earth

The Earth is divided into three layers—the *crust, mantle,* and *core*—based on what each one is made of. The lightest materials make up the outermost layer, and the densest materials make up the inner layers. This is because lighter materials tend to float up, while heavier materials sink.

The Crust The **crust** is the outermost layer of the Earth. Ranging from 5 to 100 km thick, it is also the thinnest layer of the Earth. And because it is the layer we live on, we know more about this layer than we know about the other two.

There are two types of crust—continental and oceanic. *Continental crust* has a composition similar to granite. It has an average thickness of 30 km. *Oceanic crust* has a composition similar to basalt. It is generally between 5 and 8 km thick. Because basalt is denser than granite, oceanic crust is denser than continental crust.

Figure 1 *Oceanic crust is thinner but denser than continental crust.*



The Mantle The **mantle** is the layer of the Earth between the crust and the core. Compared with the crust, the mantle is extremely thick and contains most of the Earth's mass.

No one has ever seen what the mantle really looks like. It is just too far down to drill for a sample. Scientists must infer what the composition and other characteristics of the mantle are from observations they make on the Earth's surface. In some places mantle rock has been pushed up to the surface by tectonic forces, allowing scientists to observe the rock directly.

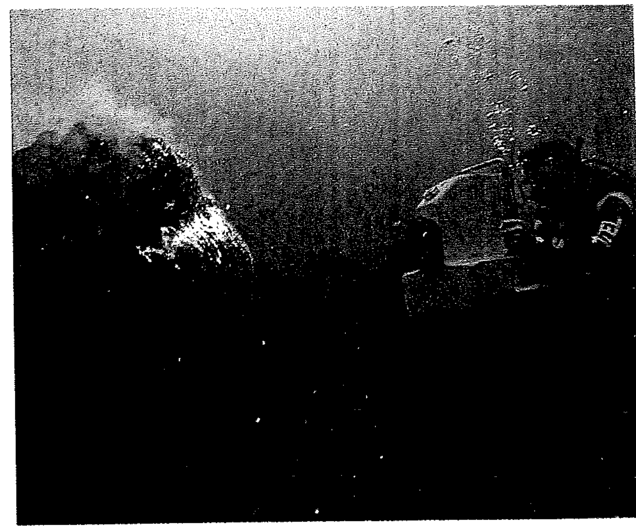


Figure 2 *Volcanic vents on the ocean floor, such as this one off the coast of Hawaii, allow magma to escape from the mantle beneath oceanic crust.*

As you can see in **Figure 2,** another place scientists look is on the ocean floor, where molten rock from the mantle flows out of active volcanoes. These underwater volcanoes are like windows through the crust into the mantle. The "windows" have given us strong clues about the composition of the mantle. Scientists have learned that the mantle's composition is similar to that of the mineral olivine, which has large amounts of iron and magnesium compared with other common minerals.

The Core By studying the different layers that make up the Earth, geologists can get an idea of which elements each is made of. They think that the Earth's *core* is made mostly of iron, with smaller amounts of nickel and possibly some sulfur and oxygen. The **core** extends from the bottom of the mantle to the center of the Earth. As you can see in **Figure 3,** the diameter of the planet Mars is slightly smaller than that of the Earth's core.

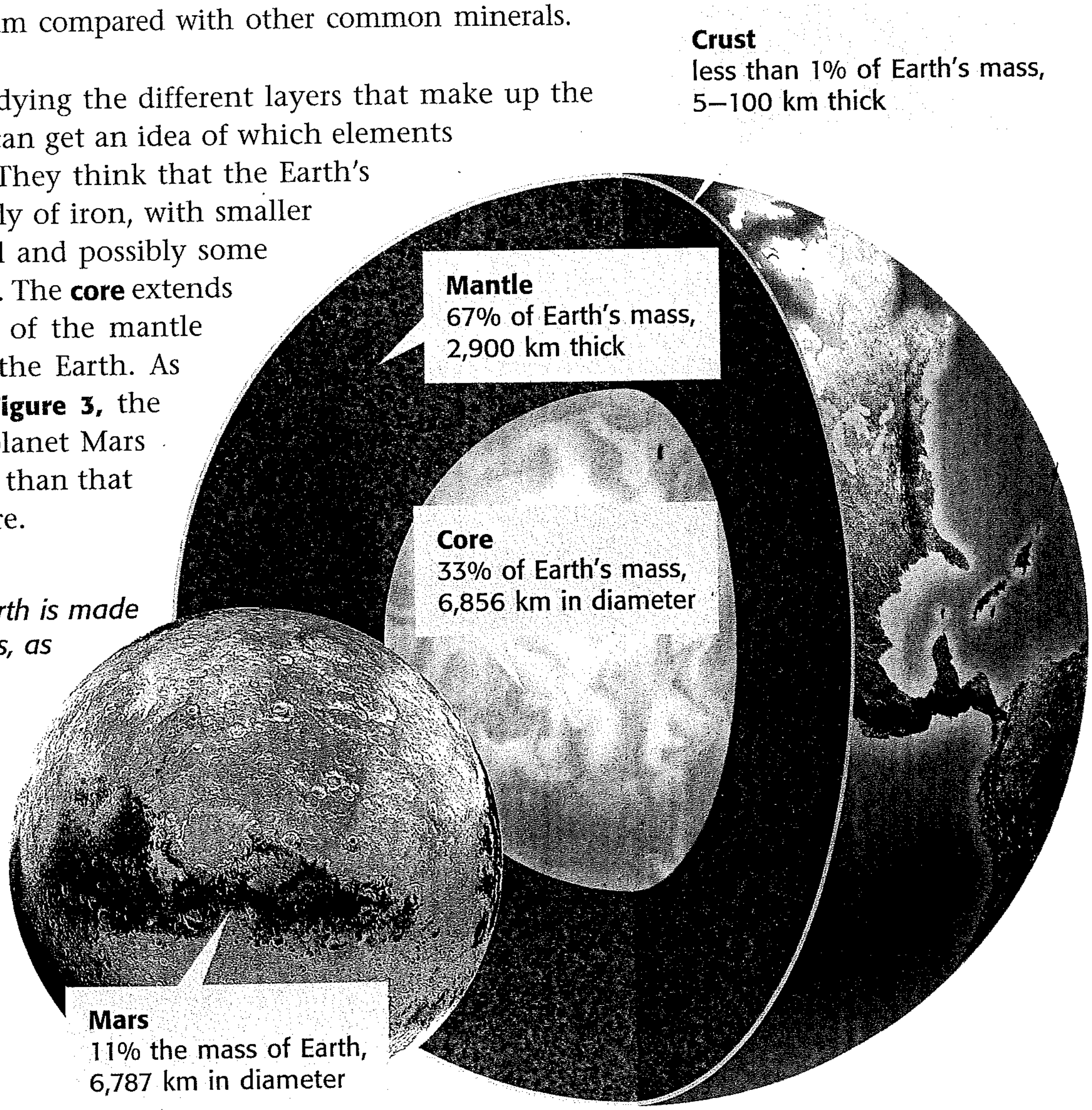


Figure 3 *The Earth is made up of three layers, as shown here.*

MATH BREAK

Using Models

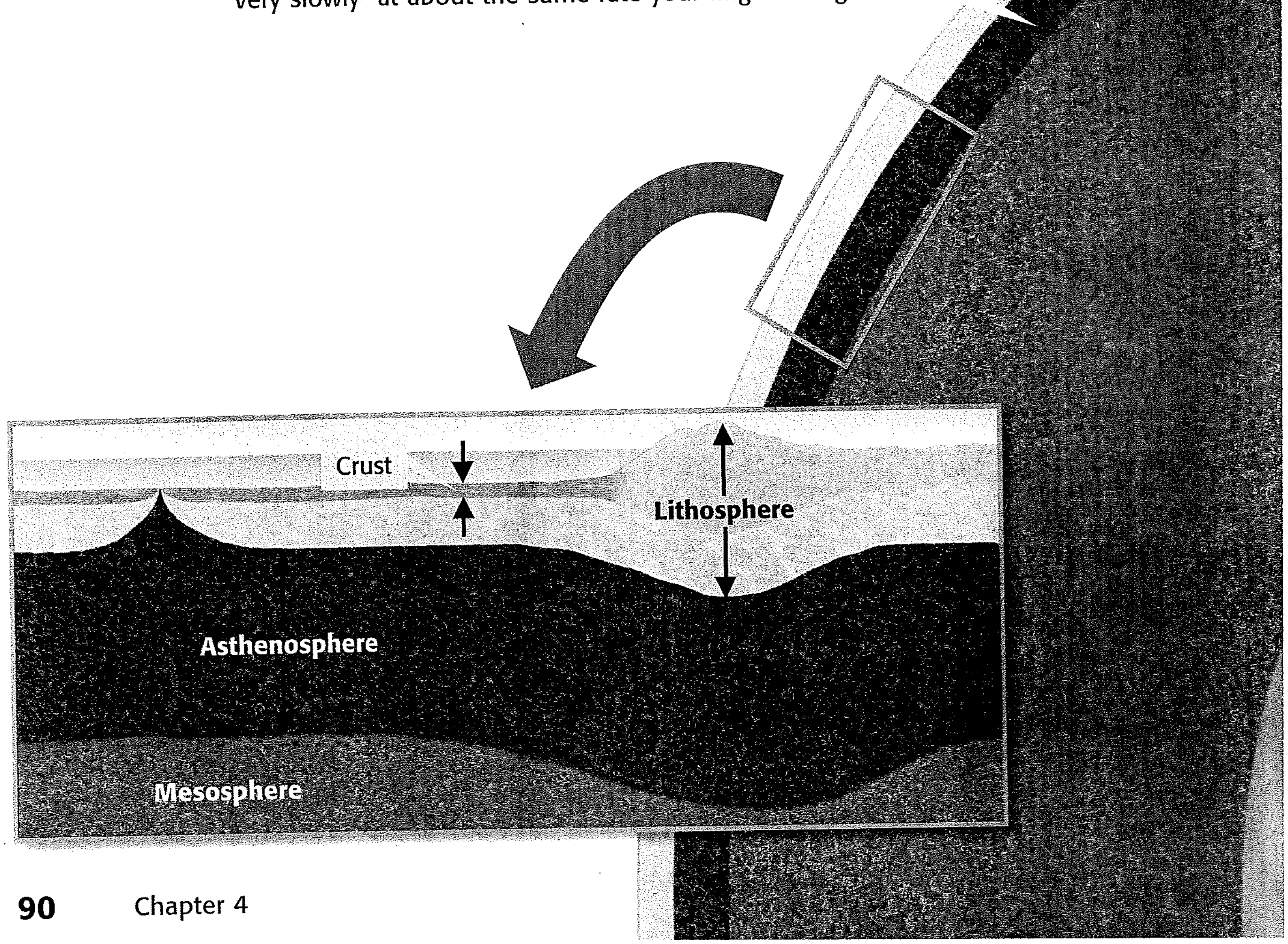
Imagine that you are building a model of the Earth that is going to have a radius of 1 m. You find out that the average radius of the Earth is 6,378 km and that the thickness of the lithosphere is about 150 km. What percentage of the Earth's radius is the lithosphere? How thick (in centimeters) would you make the lithosphere in your model?

The Structure of the Earth

So far we have talked about the composition of the Earth. Another way to look at how the Earth is made is to examine the physical properties of its layers. The Earth is divided into five main physical layers—the *lithosphere, asthenosphere, mesosphere, outer core,* and *inner core.* As shown below, each layer has its own set of physical properties.

Lithosphere The outermost, rigid layer of the Earth is called the **lithosphere** ("rock sphere"). The lithosphere is made of two parts—the crust and the rigid upper part of the mantle. The lithosphere is divided into pieces called *tectonic plates.*

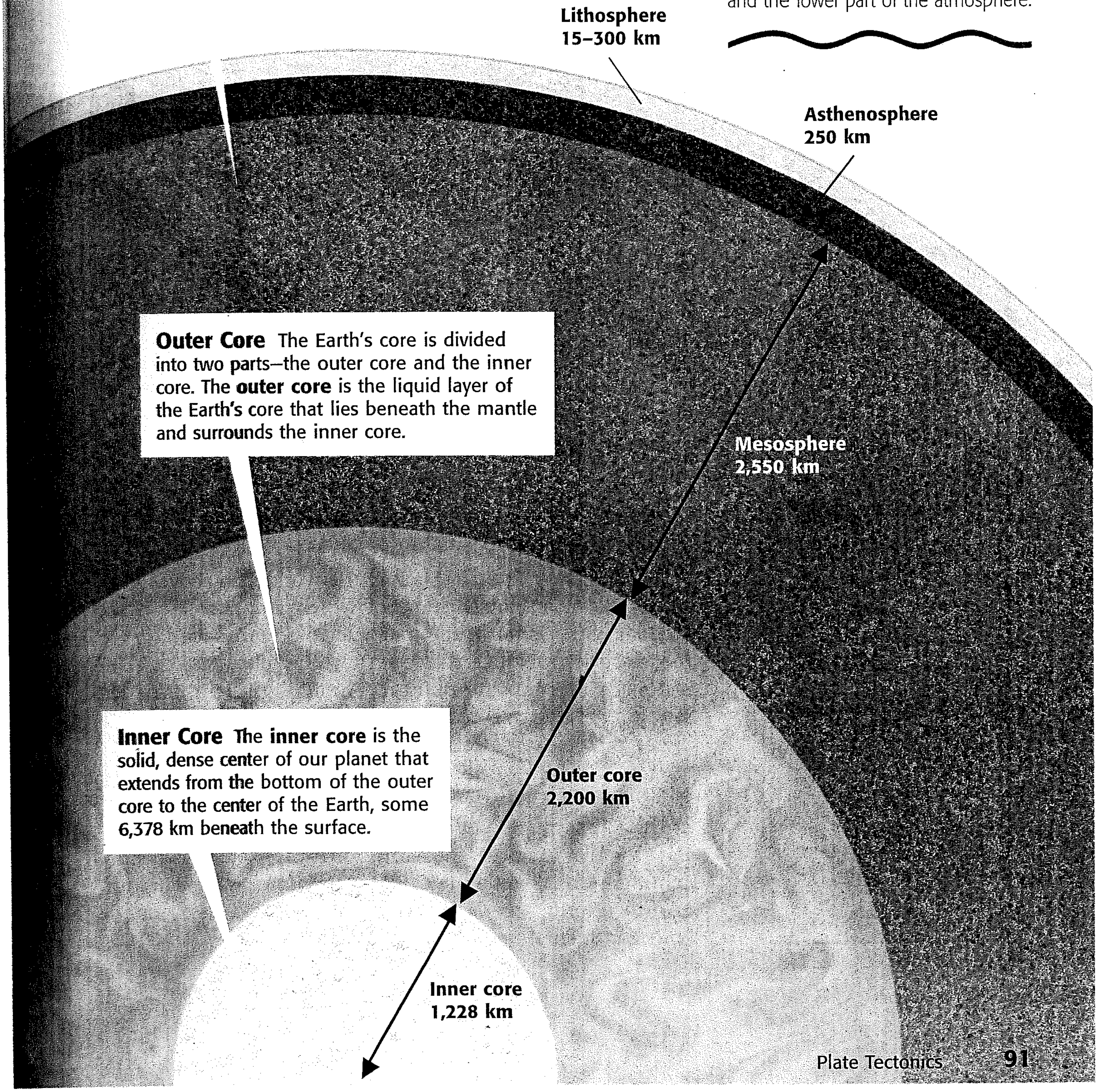
Asthenosphere The **asthenosphere** ("weak sphere") is a soft layer of the mantle on which pieces of the lithosphere move. It is made of solid rock that, like putty, flows very slowly—at about the same rate your fingernails grow.



Mesosphere Beneath the asthenosphere is the strong, lower part of the mantle called the **mesosphere** ("middle sphere"). The mesosphere extends from the bottom of the asthenosphere down to the Earth's core.

Biology CONNECTION

Scientists call the part of the Earth where life is possible the *biosphere.* The biosphere is the layer of the Earth above the crust and below the uppermost part of the atmosphere. It includes the oceans, the land surface, and the lower part of the atmosphere.



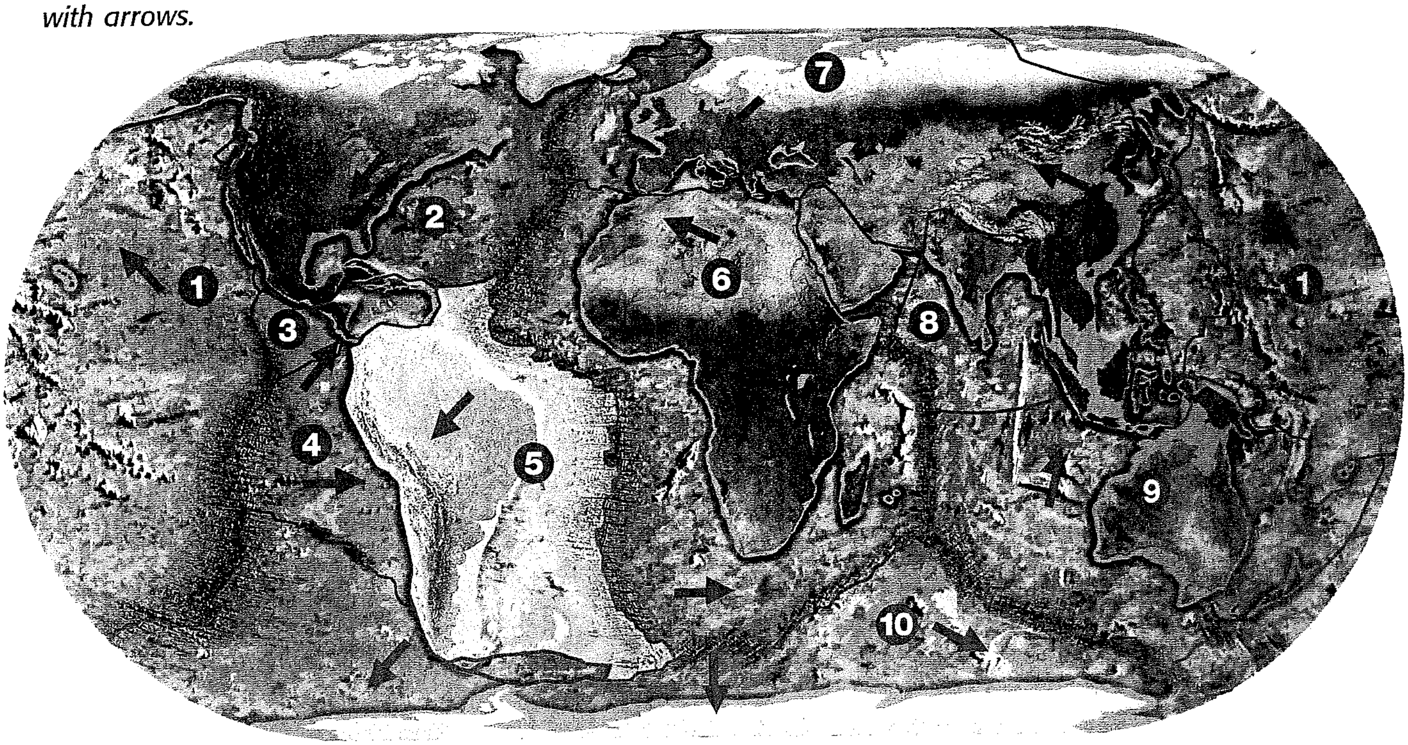
Outer Core The Earth's core is divided into two parts—the outer core and the inner core. The **outer core** is the liquid layer of the Earth's core that lies beneath the mantle and surrounds the inner core.

Inner Core The **inner core** is the solid, dense center of our planet that extends from the bottom of the outer core to the center of the Earth, some 6,378 km beneath the surface.

Tectonic Plates

Tectonic plates are pieces of the lithosphere that move around on top of the asthenosphere. But what exactly does a tectonic plate look like? How big are tectonic plates? How and why do they move around? To answer these questions, start by thinking of the lithosphere as a giant jigsaw puzzle.

Figure 4 *Tectonic plates fit together like the pieces of a jigsaw puzzle. On this map, the relative motions of some of the major tectonic plates are shown with arrows.*



Major Tectonic Plates

1. Pacific plate
2. North American plate
3. Cocos plate
4. Nazca plate
5. South American plate
6. African plate
7. Eurasian plate
8. Indian plate
9. Australian plate
10. Antarctic plate

A Giant Jigsaw Puzzle Look at the world map above. All of the plates have names, some of which you may already be familiar with. Some of the major tectonic plates are listed in the key at left. Notice that each tectonic plate fits the other tectonic plates that surround it. The lithosphere is like a jigsaw puzzle, and the tectonic plates are like the pieces of a jigsaw puzzle.

You will also notice that not all tectonic plates are the same. Compare the size of the North American plate with that of the Cocos plate. But tectonic plates are different in other ways too. For example, the North American plate has an entire continent on it, while the Cocos plate only has oceanic crust. Like the North American plate, some tectonic plates include both continental *and* oceanic crust.

A Tectonic Plate Close-up What would a tectonic plate look like if you could lift it out of its place? **Figure 5** shows what the South American plate might look like if you could. Notice that this tectonic plate consists of both oceanic and continental crust, just like the North American plate.

The thickest part of this tectonic plate is on the South American continent, under the Andes mountain range. The thinnest part of the South American plate is at the Mid-Atlantic Ridge.

South American Plate

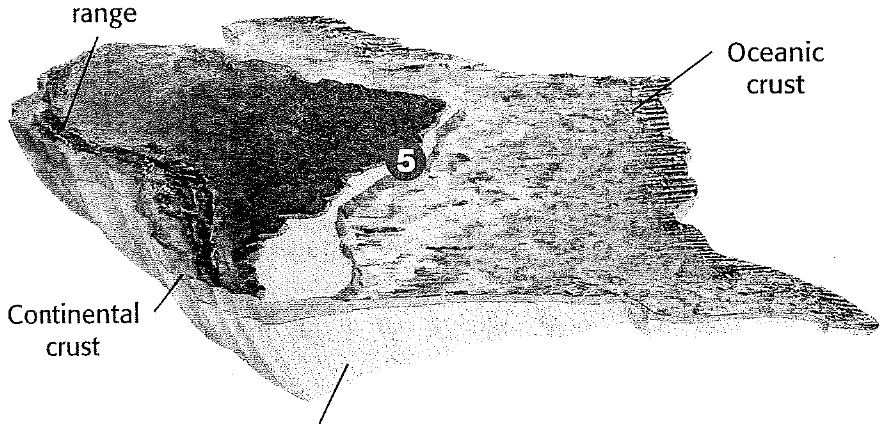


Figure 5 *The South American plate is one of the many pieces of the spherical "jigsaw puzzle" we call the lithosphere.*

Tip of the Iceberg If you could look at a tectonic plate from the side, you would see that mountain ranges are like the tips of icebergs—there is much more material below the surface than above. Mountain ranges that occur in continental crust have very deep roots relative to their height. For example, the Rocky Mountains rise less than 5 km above sea level, but their roots go down to about 60 km *below* sea level.

But if continental crust is so much thicker than oceanic crust, why doesn't it sink down below the oceanic crust? Think back to the difference between continental and oceanic crust. Continental crust stands much higher than oceanic crust because it is both thicker and less dense. Both kinds of crust are less dense than the mantle and "float" on top of the asthenosphere, similar to the way ice floats on top of water.

QuickLab

Floating Mountains

1. Take a large **block** of wood and place it in a clear plastic **container.** The block of wood represents the mantle part of the lithosphere.
2. Fill the container with **water** at least 10 cm deep. The water represents the asthenosphere. Use a ruler to measure how far the top of the wood block sits above the surface of the water.
3. Now try loading the block of wood with several different **wooden objects,** each with a different weight. These objects represent different amounts of crustal material loaded onto the lithosphere during mountain building. Measure how far the block sinks under each different weight.
4. What can you conclude about how the tectonic plate reacts to increasing weight of crustal material?
5. What happens to a tectonic plate when the crustal material is removed?

TRY at HOME

Mapping the Earth's Interior

How do we know all these things about the deepest parts of the Earth, where no one has ever been? Scientists have never even drilled through the crust, which is only a thin skin on the surface of the Earth. So how do we know so much about the mantle and the core?

Would you be surprised to know that the answers come from earthquakes? When an earthquake occurs, vibrations called seismic waves are produced. *Seismic waves* are vibrations that travel through the Earth. Depending on the density and strength of material they pass through, seismic waves travel at different speeds. For example, a seismic wave traveling through solid rock will go faster than a seismic wave traveling through a liquid.

When an earthquake occurs, *seismographs* measure the difference in the arrival times of seismic waves and record them. Seismologists can then use these measurements to calculate the density and thickness of each physical layer of the Earth. **Figure 6** shows how one kind of seismic wave travels through the Earth.

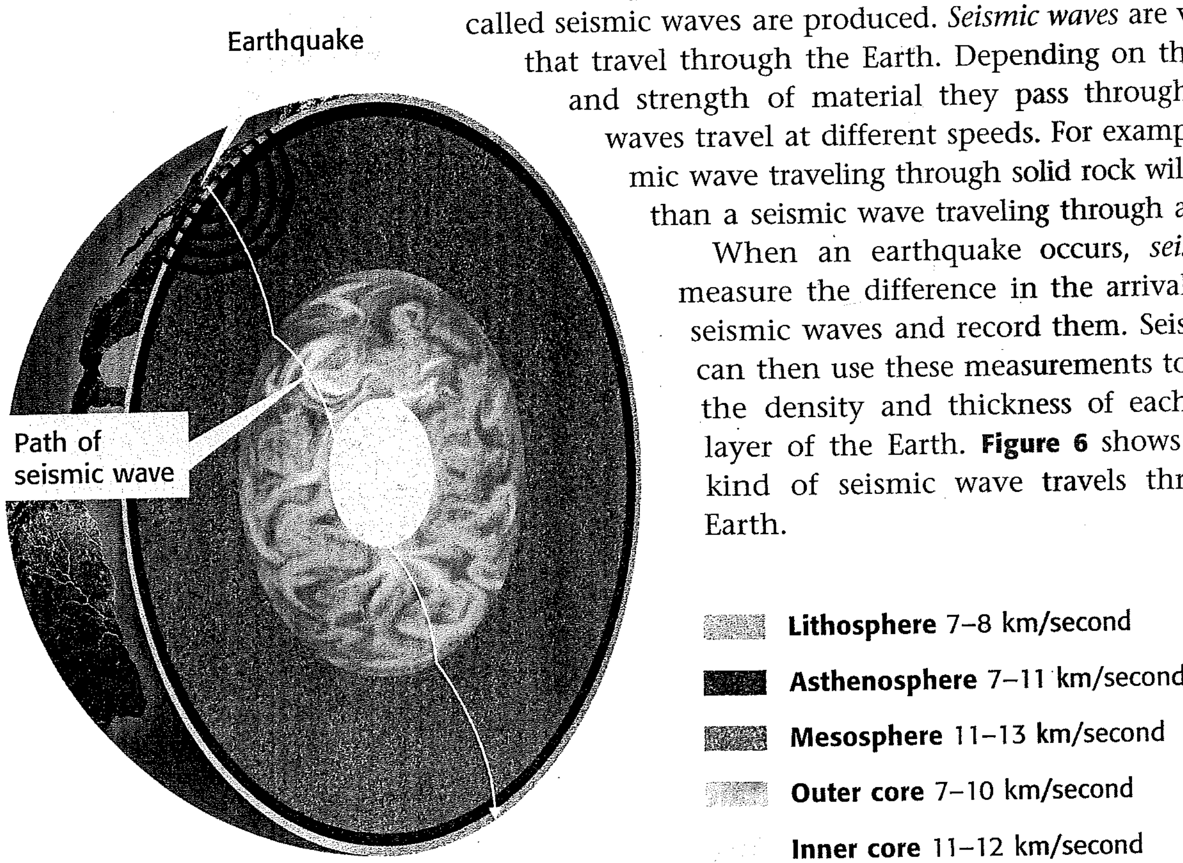


Figure 6 *The speed of seismic waves depends on the density of the material they travel through. The denser the material, the faster seismic waves move.*

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SECTION REVIEW

1. What is the difference between continental and oceanic crust?
2. How is the lithosphere different from the asthenosphere?
3. How do scientists know about the structure of the Earth's interior? Explain.
4. **Analyzing Relationships** Explain the difference between the crust and the lithosphere.