LESSON

1 Earth's Interior

Guiding Questions

- How do geologists study Earth's layered interior?
- What roles do heat and pressure in Earth's interior play in the cycling of matter?
- What are the patterns and effects of convection in Earth's mantle?

Connections

Literacy Translate Information

Math Construct Graphs

MS-ESS2-1

Vocabulary

seismic wave
crust
mantle
outer core
inner core

Academic Vocabulary

evidence
elements

VOCABULARY APP

Practice vocabulary on a mobile device.

Quest CONNECTION

Think about how understanding the structure of Earth's interior can help you to evaluate Earth processes depicted in a movie script.

Connect It!

What do you observe about the rock shown in Figure 1?

Determine Differences How do the xenoliths compare to the surrounding rock?

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Apply Scientific Reasoning How might xenoliths help geologists understand Earth's interior?

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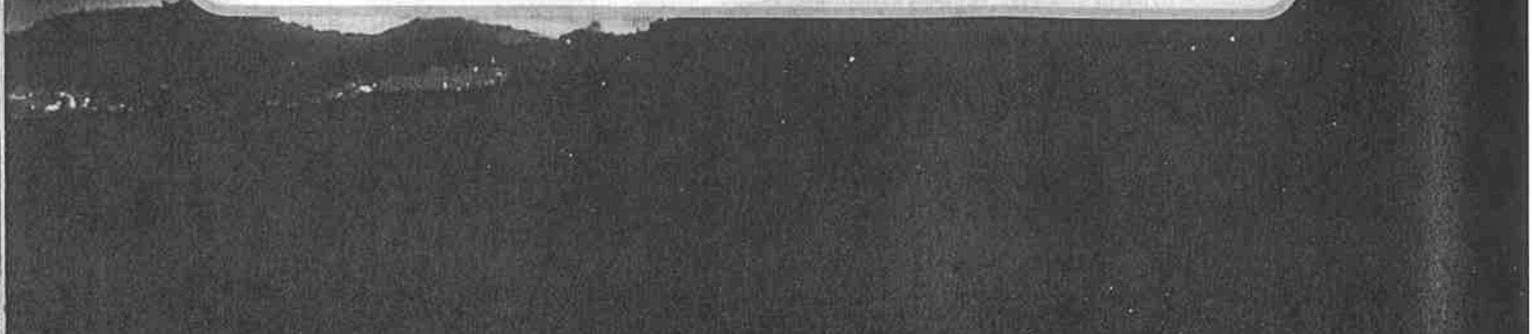

Learning About Earth's Interior

How do we study Earth's interior and connect those interior processes to things we see or experience on Earth's surface? This question is difficult to answer because geologists are unable to see deep inside Earth. However, geologists have found other ways to study the unseen interior of Earth. Their methods focus on two main types of **evidence**: direct evidence from rock samples and indirect evidence from seismic waves.

Academic Vocabulary

Suppose you think the air temperature is getting colder. Give two examples of evidence you could use to support your idea.

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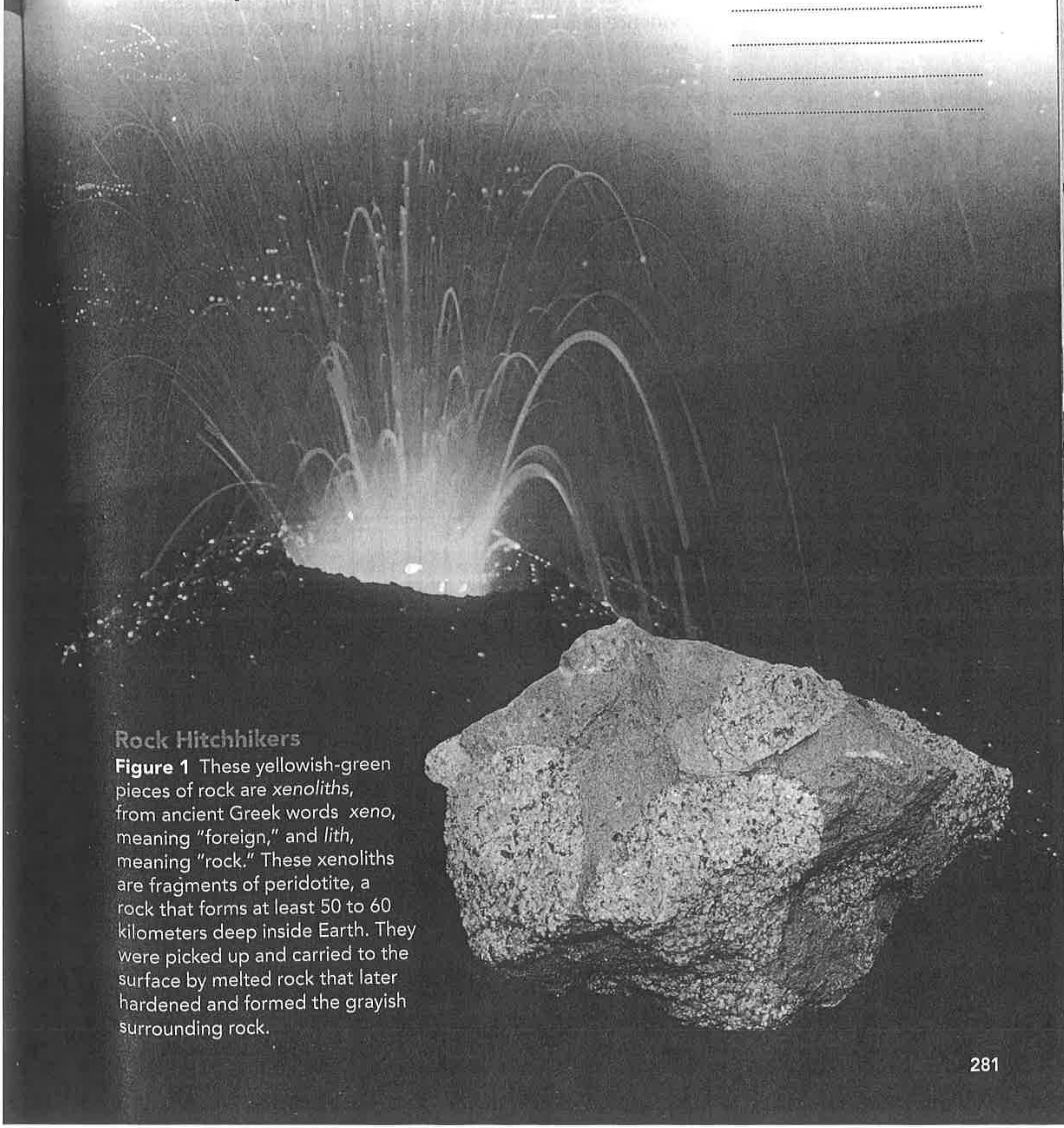

Rock Hitchhikers

Figure 1 These yellowish-green pieces of rock are *xenoliths*, from ancient Greek words *xeno*, meaning "foreign," and *lith*, meaning "rock." These xenoliths are fragments of peridotite, a rock that forms at least 50 to 60 kilometers deep inside Earth. They were picked up and carried to the surface by melted rock that later hardened and formed the grayish surrounding rock.

INTERACTIVITY

Explore how to investigate something you cannot directly observe.

Evidence From Rock Samples Geologists have drilled holes as deep as 12.3 kilometers into Earth. Drilling brings up many samples of rock and gives geologists many clues. They learn about Earth's structure and conditions deep inside Earth where the rocks are formed. In addition, volcanoes sometimes carry rocks to the surface from depths of more than 100 kilometers. These rocks provide more information about Earth's interior, including clues about how matter and energy flow there. Some rocks from mountain ranges show evidence that they formed deep within Earth's crust and later were elevated as mountains formed. Also, in laboratories, geologists have used models to recreate conditions similar to those inside Earth to see how those conditions affect rock.

Evidence From Seismic Waves To study Earth's interior, geologists also use an indirect method. When earthquakes occur, they produce **seismic waves** (SIZE mik). Geologists record the seismic waves and study how they travel through Earth. The paths of seismic waves reveal where the makeup or form of the rocks change, as shown in **Figure 2**.

Waves

Figure 2 Earthquakes produce different types of seismic waves that travel through Earth. The speed of these waves and the paths they take give geologists clues about the structure of the planet's interior.

Make Observations Compare and contrast the paths that P-waves and S-waves take through Earth. How do you think this information helps geologists understand Earth's interior?

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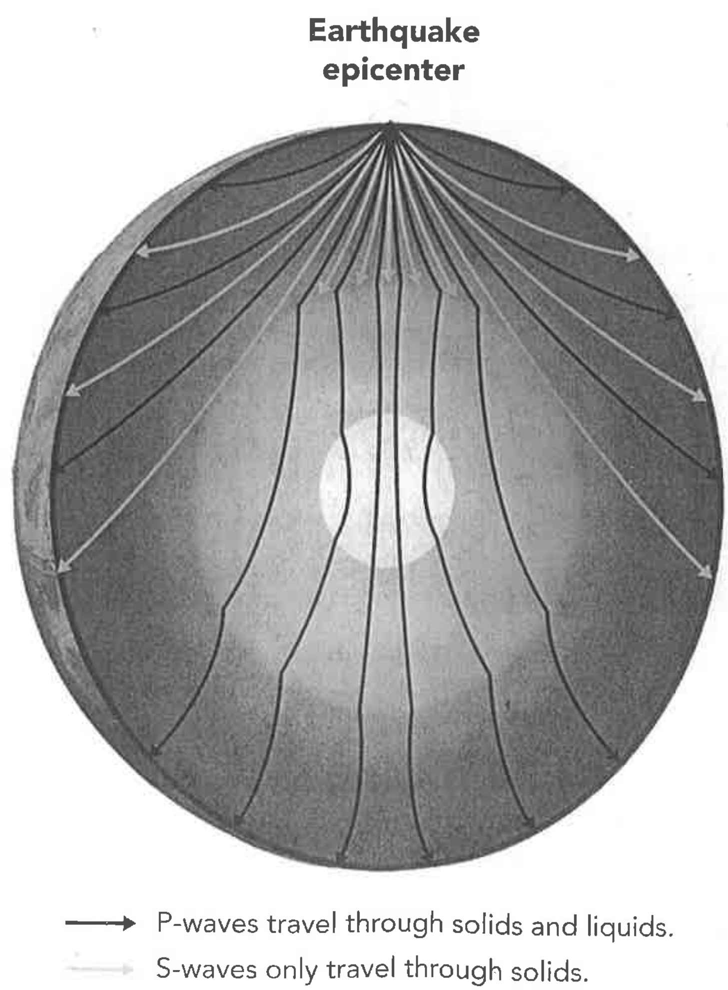
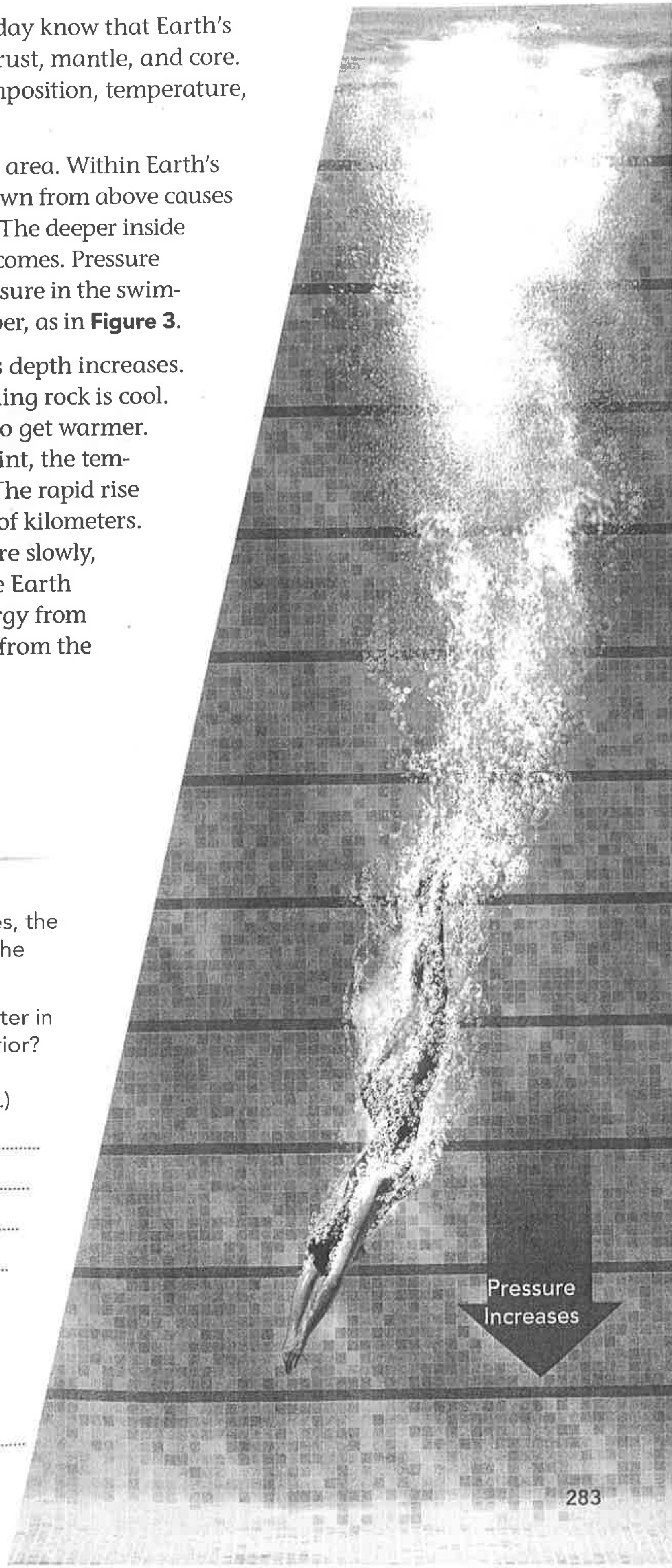


Earth's Layers

After many years of research, scientists today know that Earth's interior is made up of three main layers: crust, mantle, and core. These layers vary greatly in thickness, composition, temperature, and pressure.

Pressure results from a force pressing on an area. Within Earth's interior, the mass of rock that is pressing down from above causes an increase of pressure on the rocks below. The deeper inside Earth's interior, the greater the pressure becomes. Pressure inside Earth increases much like water pressure in the swimming pool increases as you dive down deeper, as in **Figure 3**.

The temperature inside Earth increases as depth increases. Just beneath Earth's surface, the surrounding rock is cool. At about 20 meters down, the rock starts to get warmer. For every 40 meters of depth from that point, the temperature typically rises 1 degree Celsius. The rapid rise in temperature continues for several tens of kilometers. Eventually, the temperature increases more slowly, but steadily. The high temperatures inside Earth are mostly the result of the release of energy from radioactive substances and heat left over from the formation of Earth 4.6 billion years ago.



Pressure and Depth

Figure 3 The deeper that the swimmer goes, the greater the pressure on the swimmer from the surrounding water.

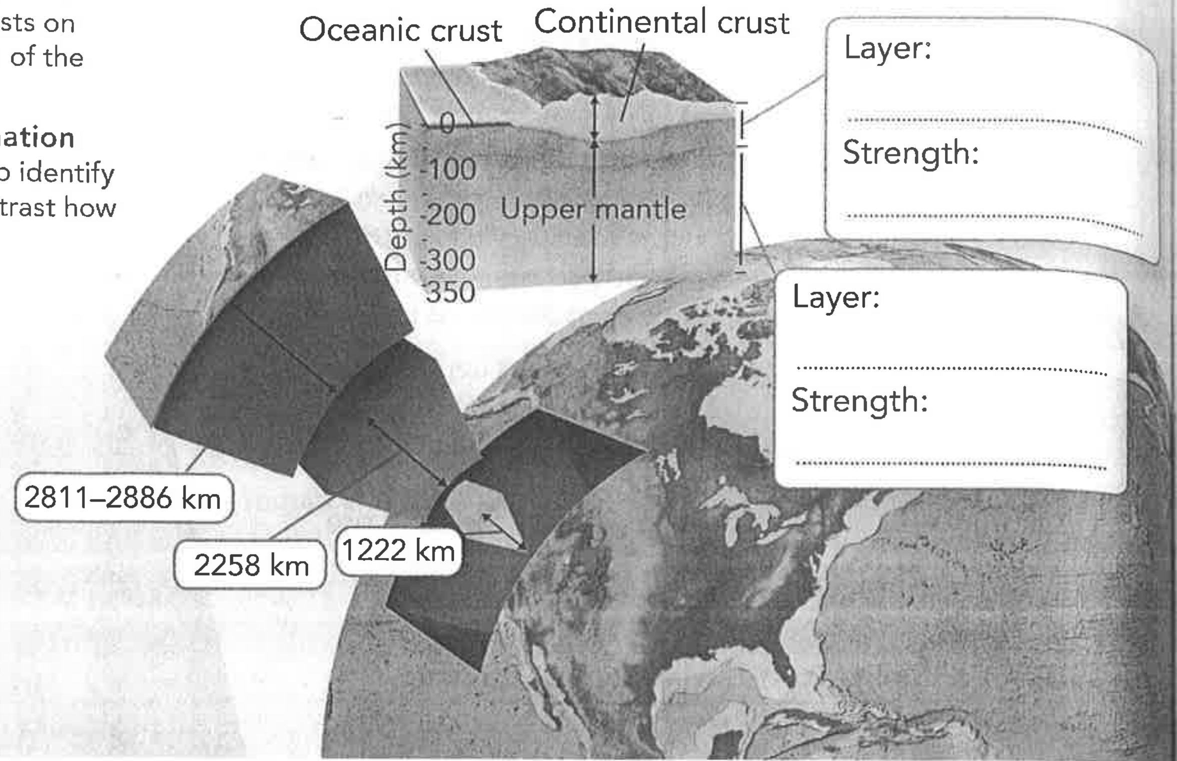
1. Compare and Contrast How is the water in the swimming pool similar to Earth's interior? How is it different? (*Hint:* Consider both temperature and pressure in your answer.)

2. Use Proportional Relationships At what location in the pool would the water pressure be greatest?

Earth's Layers

Figure 4 The crust and uppermost mantle make up the rigid lithosphere. The lithosphere rests on the softer material of the asthenosphere.

Translate Information Use the diagram to identify the layers and contrast how rigid they are.



Academic Vocabulary

Oxygen and silicon are two of the chemical elements that make up the crust. *Elements* can also refer to the smallest or most basic parts of something, such as machine. Describe the elements of something, such as parts of a machine, that you used today.

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The Crust Have you ever hiked up a mountain, toured a mine, or explored a cave? During each of these activities people interact with Earth's **crust**, the rock that forms Earth's outer layer. The crust is a layer of solid rock that includes both dry land and the ocean floor. The main **elements** of the rocks in the crust are oxygen and silicon.

The crust is much thinner than the layers beneath it. In most places, the crust is between 5 and 40 kilometers thick. It is thickest under high mountains, where it can be as thick as 80 kilometers, and it is thinnest beneath the ocean floor. There are two types of crust: oceanic crust and continental crust.

The crust that lies beneath the ocean is called oceanic crust. The composition of all oceanic crust is nearly the same. Its overall composition is much like basalt, with small amounts of ocean sediment on top. Basalt (buh SAWLT) is a dark, fine-grained rock.

Continental crust forms the continents. It contains many types of rocks. But overall the composition of continental crust is much like granite. Granite is a rock that usually is a light color and has coarse grains.

The Mantle Directly below the crust, the rock in Earth's interior changes. Rock here contains more magnesium and iron than does the rock above it. The rock below the crust is the solid material of the **mantle**, a layer of hot rock. Overall, the mantle is nearly 3,000 kilometers thick.

The uppermost part of the mantle is brittle rock, like the rock of the crust. Both the crust and the uppermost part of the mantle are strong, hard, and rigid. Geologists often group the crust and uppermost mantle into a single layer called the lithosphere. As shown in **Figure 4**, Earth's lithosphere is about 100 kilometers thick.

Below the lithosphere, the material is increasingly hotter. As a result, the part of the mantle just beneath the lithosphere is less rigid than the lithosphere itself. Over thousands of years, this part of the mantle may bend like a metal spoon, but it is still solid. This solid yet bendable layer is called the asthenosphere.

Beneath the asthenosphere is the lower mantle, which is hot, rigid, and under intense pressure. The lower mantle extends down to Earth's core.

INTERACTIVITY

Examine the different layers of Earth.

Math Toolbox

Temperature in Earth's Layers

1. **Construct Graphs** Use the data in the table to complete the line graph.
2. **Interpret Graphs** How does temperature change with depth in Earth's mantle?

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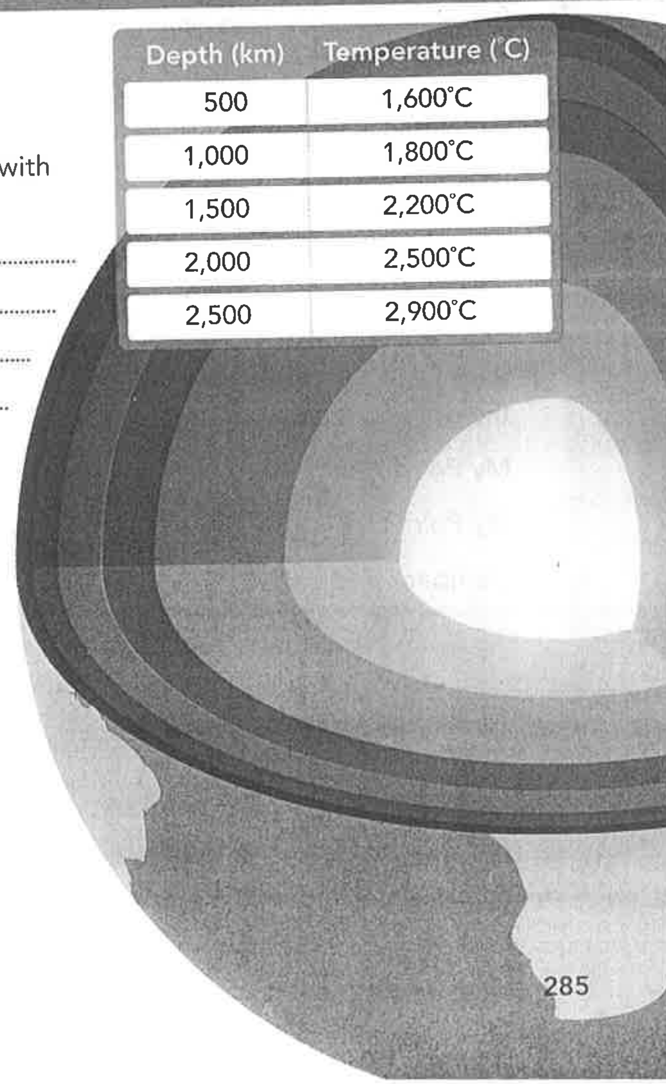
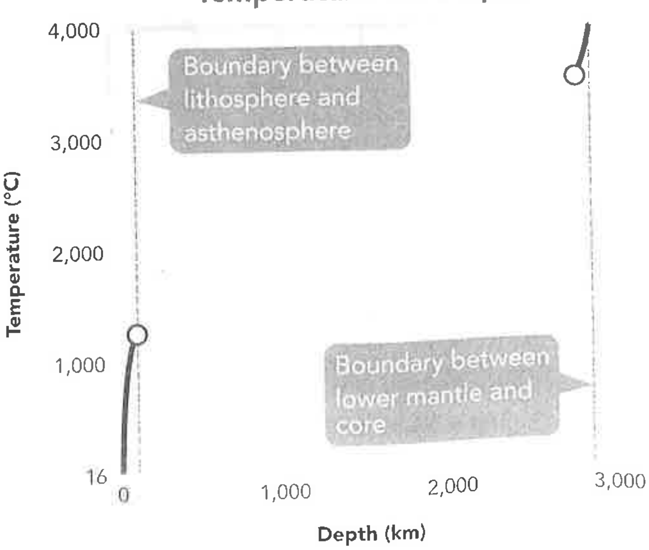
Depth (km)	Temperature (°C)
500	1,600°C
1,000	1,800°C
1,500	2,200°C
2,000	2,500°C
2,500	2,900°C



Temperature and Depth



INTERACTIVITY

Analyze the heat of Earth's interior.

The Core Below the mantle is Earth's dense core. Earth's core occupies the center of the planet. It consists of two parts, a liquid outer core and a solid inner core. The outer core is 2,260 kilometers thick. The inner core is a solid ball with a radius of about 1,220 kilometers. Therefore, total radius of the entire core is approximately 3,480 kilometers.

The **outer core** is a layer of molten metal surrounding the inner core. Despite enormous pressure, the outer core is liquid. The **inner core** is a dense ball of solid metal. In the inner core, extreme pressure squeezes the atoms of iron and nickel so much that they cannot spread out to become liquid despite the extremely high temperatures.

Currently, most evidence suggests that both parts of the core are mostly made of iron and nickel. Scientists have found data suggesting that the core also contains smaller amounts oxygen, sulfur, and silicon.

Model It!

1. Develop Models Label Earth's layers and use the text on the page to fill in the table with details about the layers.

	Thickness	Composition	Solid/Liquid
Crust:			
Mantle:			
Outer core:			
Inner core:			
Total:	6,370 km		

2. Compare and Contrast Pick any two points inside Earth and label them A and B. Record their locations.

My Point A is in the ....

My Point B is in the ....

Compare and contrast Earth at those two points.

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The Core and Earth's Magnetic Field Scientists think that movements in the liquid outer core produce Earth's magnetic field. Earth's magnetic field affects the whole planet.

To understand how a magnetic field affects an object, think about a bar magnet. If you place the magnet on a piece of paper and sprinkle iron filings on the paper, the iron filings automatically line up in a pattern matching the bar's magnetic field. If you could surround Earth with iron filings, they would form a similar pattern. This is also what happens when you use a compass. The compass needle aligns with Earth's magnetic field.

READING CHECK **Identify Evidence** How can iron filings provide evidence that a bar magnet has a magnetic field?

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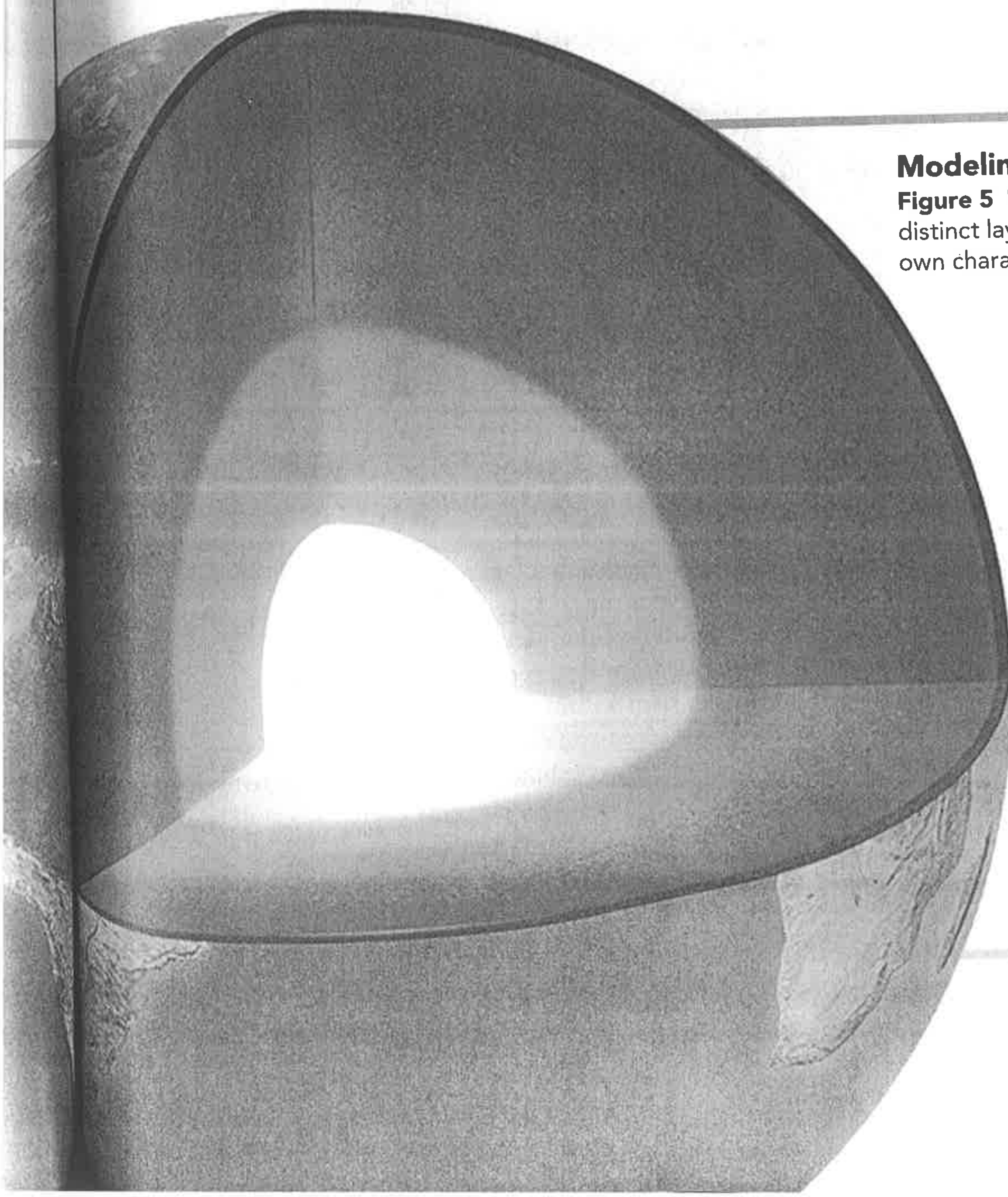

Modeling Earth's Interior
Figure 5 Earth is divided into distinct layers. Each layer has its own characteristics.

Movement in Earth's Mantle

HANDS-ON LAB

Investigate Explore how convection works.

Recall that Earth's mantle and core are extremely hot. Heat is a form of energy that flows. It transfers from matter at a higher temperature to matter at a lower temperature. The transfer of heat in the mantle drives a process called convection. This process is how matter and energy cycle through Earth's interior as well as its surface.

Convection Currents When you heat water on a stove, the water at the bottom of the pot gets hot and expands. As the heated water expands, its density decreases. Less-dense fluids flow up through denser fluids.

Convection Currents in Hot Springs

Figure 6 Hot springs are common in Yellowstone National Park. Here, melted snow and rainwater seep far below the crust into the mantle, where a shallow magma chamber heats the rock of Earth's crust. The rock heats the water to more than 200°C and puts it under very high pressure. This superheated groundwater rises to the surface and forms pools of hot water.

1. **Compare and Contrast** The heated water is (more/less) dense than the melted snow and rainwater.
2. **Apply Concepts** What process causes convection currents to form in a hot spring?

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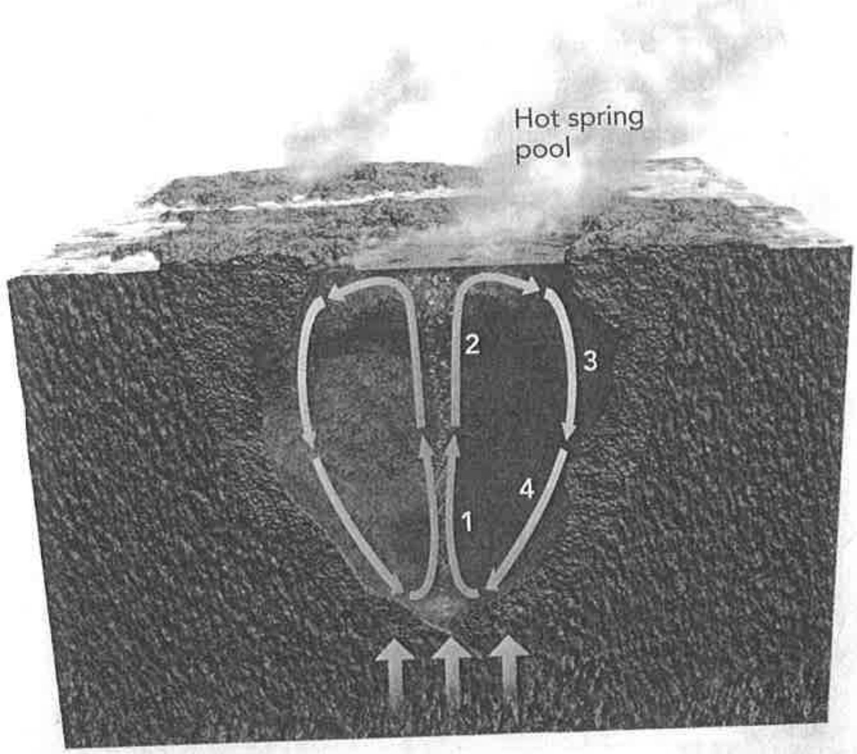

The warm, less dense water moves upward and floats over the cooler, denser water. Near the surface, the warm water cools, becoming denser again. It sinks back down to the bottom of the pot. Here, the water heats and rises again. The flows shown in **Figure 6** that transfer heat within matter are called convection currents. Heating and cooling of matter, changes in matter's density, and the force of gravity combine and set convection currents in motion. Without heat, convection currents eventually stop.

READING CHECK **Cause and Effect** What three processes or forces combine to set convection currents in motion?

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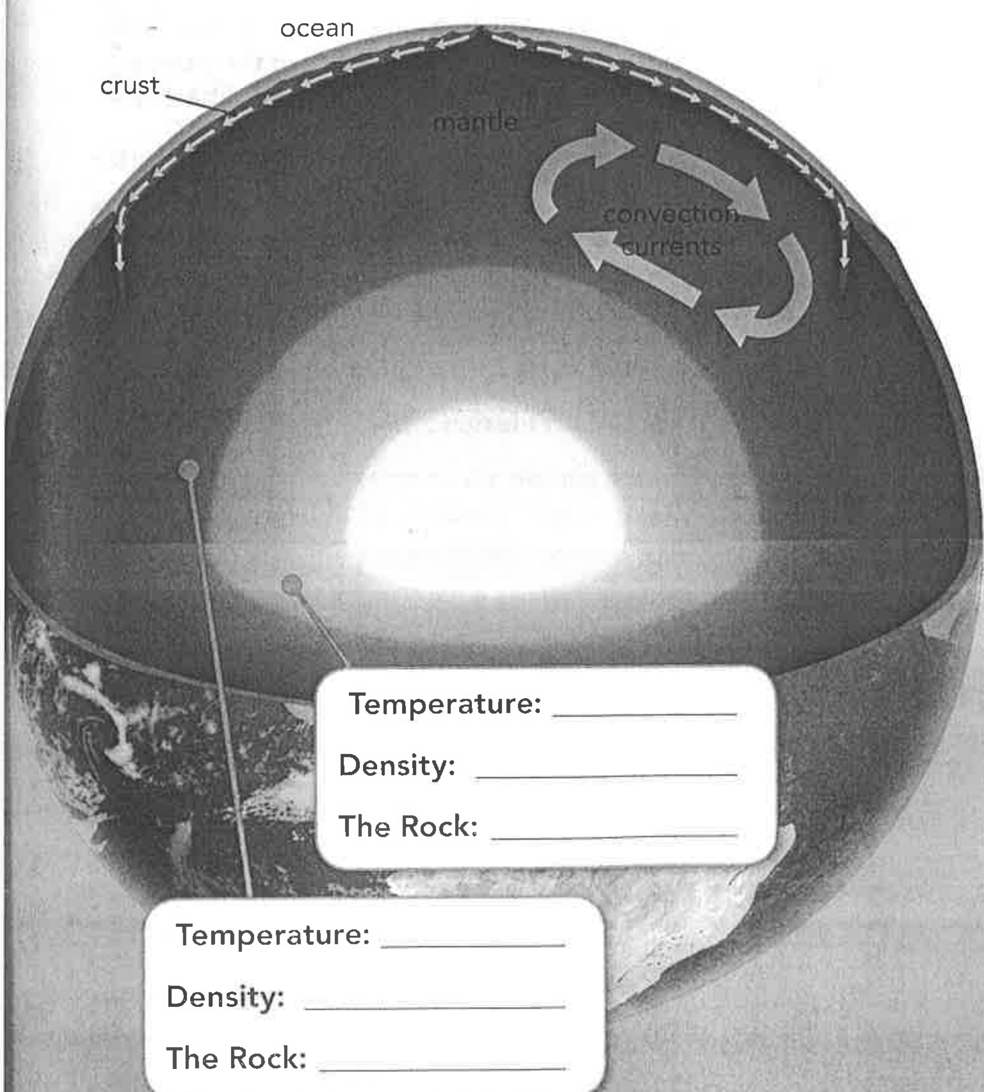
Convection Currents in Earth Heat from the core and from the mantle itself drives convection currents. These currents carry hot, solid rock of the mantle outward and cooled, solid rock inward in a never-ending cycle.

As the oceanic lithosphere cools and sinks, it drives a pattern of mantle convection. The cold lithosphere moves down into the mantle, where it is heated. An upward return flow of hot rock completes the cycle, as shown in **Figure 7**. Over and over, the cycle of sinking and rising takes place. One full cycle takes millions of years. Convection currents are involved in the production of new rock at Earth's surface. There are also convection currents in the outer core.



Literacy Connection

Translate Information As you look at the visuals depicting convection, come up with an explanation for how the directions of two side-by-side convection currents determine whether material in the mantle rises or descends.

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Mantle Convection

Figure 7 Complete the model by drawing the missing convection currents.

Use Models Then complete the figure labels by using the terms in the box.

hotter
colder
less dense
more dense
sinks
rises

Make Meaning How can a solid such as mantle rock flow? Think about candle wax. In your science notebook, describe how you can make candle wax flow. What other solids have you observed that can flow?

LESSON 1 Check

MS-ESS2-1

1. **Identify** Name each layer of Earth, starting from Earth's center.

2. **Apply Concepts** Give examples of direct evidence and indirect evidence that geologists use to learn about Earth's interior.

3. **Predict** What would happen to the convection currents in the mantle if Earth's interior cooled down? Why?

4. **Explain** How does convection cause movement of material and energy in Earth's interior?

5. **Evaluate** How is the rock in the deep mantle similar to the rock in the parts of the mantle nearest the surface? How are they different?

Quest CHECK-IN

In this lesson, you learned about Earth's interior and also how energy and material move between Earth's interior and its surface.

Engage in Argument Explain why you think it is or isn't important for science fiction films to depict natural processes and geological events as accurately as possible.

INTERACTIVITY

The Deep Drill

Go online to find out more about Earth's interior structure. Then evaluate science facts in a movie script.