Reflect

Have you ever cut an apple in half and looked at the layers inside? When you cut something in half, the resulting view is called a cross section. When you look at the cross section of an apple, you see several layers: the skin, the pulp, the core, and the seeds. Much like the apple, Earth is made up of layers, too. If you could look at a cross section of our planet, you would see the crust, the mantle, the outer core, and the inner core. If Earth were an apple, the crust would be the apple's skin. The mantle would be the apple's pulp, making up most of the inside. Earth also has a central core, similar to an apple's core, though Earth's core does not contain any seeds! Of course, scientists cannot cut the whole planet in half to see a cross section the way you can with an apple. How do you think scientists know about Earth's internal layers?

crust – the thin, solid, outermost layer of Earth

mantle – the solid layer of Earth, between the crust and the core

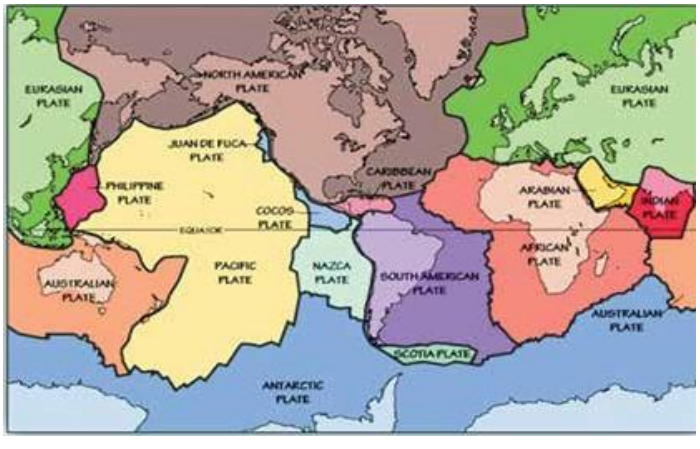
outer core – the liquid, outer shell of Earth's core

inner core – the sphere of solid nickel and iron at Earth's center

Scientists divide Earth's interior into distinct layers.
Scientists can distinguish different layers in Earth depending on the properties used to identify each layer. For example, scientists identify the crust, mantle, and core based on each layer's basic chemical composition. In other words, the crust, mantle, and core are each made up of different chemical elements. The crust and mantle are composed primarily of the elements oxygen and silicon. These are known as *silicates.* Silicates of the mantle contain heavier elements.

This makes them denser than those found in the crust. The core is composed of the densest materials, primarily iron and nickel. Earth's layers can also be identified by using each layer's physical state of matter. The crust and the uppermost part of the mantle, together, make up a layer called the *lithosphere*. The lithosphere is the cool, rigid, outermost layer of Earth. The lithosphere is in the solid state of matter.

This solid rock is broken into large pieces called *lithospheric plates.* Lithospheric plates are also called tectonic plates.



This map shows Earth's main lithospheric plates. Over time, the plates drift slowly across the planet's surface. Millions of years ago, the continents were in very different locations than they are today.

Just below the lithosphere is a layer called the asthenosphere. The asthenosphere is a shallow layer of the upper mantle. The asthenosphere, which lies directly below the lithosphere, is also solid. However, the asthenosphere is less rocky and rigid than the lithosphere above. The asthenosphere has plasticity. Plasticity is the condition of a material in a solid state that gives it the ability to flow. Think of putty, clay, or dough, all of which have plasticity. The lithospheric plates "float" on top of the asthenosphere. As the material in the asthenosphere slowly flows, it moves the lithospheric plates in different directions.

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Dough is a solid with plasticity.

The rest of the mantle beneath the asthenosphere is also in the solid state of matter. The asthenosphere and the rest of the mantle can be distinguished from each other by differences in density. Deeper sections of mantle also have greater plasticity.

At the very center of Earth, surrounded by the mantle, is the planet’s core. The core is separated into two layers: the outer core and the inner core. The outer core is in the liquid state of matter. The inner core is in the solid state of matter.

What Do You Think?

How does the lithosphere get its name? The prefix *lith-* comes from the ancient Greek word *lithos*, meaning “stone.” The lithosphere gets its name because it is made of solid rock. How does the asthenosphere get its name? The prefix *astheno-* comes from the Greek word *asthenes*. *Asthenes* means “weak” or “lacking strength.” The asthenosphere gets its name because it has plasticity. The asthenosphere is soft and weak compared to the strong, rigid rock of the lithosphere above it.

Identify each layer in the model of Earth to the right. Now that you know about Earth’s layers, how do you think these layers formed?

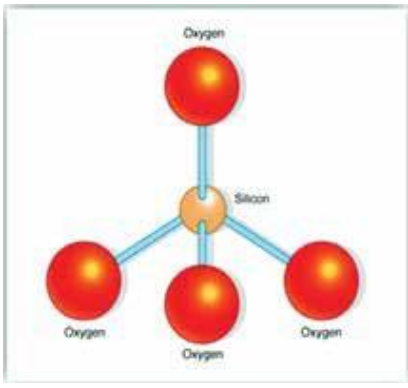
By investigating Earth’s layers, scientists learn about the history of Earth’s formation.
Earth formed about 4.6 billion years ago. The early Earth was a very different place than the planet is today. When Earth first formed, it was in a molten state. This means that it was in the liquid state of matter.

You have learned that some things float in certain liquids and some things sink. When Earth was still a liquid, the different chemical elements began to float or sink in the molten Earth, according to their different densities. As Earth cooled and formed a planet, the less dense elements of the crust and mantle separated, forming layers around the denser core. The least dense silicates floated to the very top to form the crust. The medium-density silicates floated up to form the mantle. The heaviest elements, iron and nickel, sank to the center of Earth to form the core.

Look Out!

Density is a very important concept to understand when discussing Earth's layers. Remember that Earth's layers result from the different densities of the planet's materials, not their different weights. If you have seen a huge ship floating in the ocean or a pebble at the bottom of a stream, you know that some heavy objects float in water and some light objects sink. It all depends on how tightly the materials that make up an object are packed together.

For example, a boat is made of metal, but it contains a lot of empty space inside. Although it is very heavy, it has a very low density, so it floats on the water. If you could crush that boat into a big ball of metal, it would be much denser, so it would sink. Similarly, the rocks that make up most of Earth's crust and mantle are silicates. Silicates are all made of silicon and oxygen atoms. However, the silicon and oxygen can create molecules and crystals of different shapes. In the mantle, the silicon and oxygen atoms are tightly packed together, and other elements are packed in with them. This makes mantle rock denser. In the crust, the atoms are spread farther apart. This makes crust rock less dense.



In a typical silicate molecule, a silicon atom is bonded to four oxygen atoms. The atoms form a crystal structure.

Scientists use models to represent the different layers of Earth's interior.
When constructing a model of the layers of Earth, scientists need to consider the chemical composition, state of matter, and thickness of each layer. Just like the skin of an apple, Earth's crust is very thin compared to the other layers. It is about 25–70 km thick beneath the continents. Under the oceans, the crust is only about 5–7 km thick; however, it is much denser. The mantle is much thicker than the crust is, taking up most of Earth's volume. The mantle begins directly beneath Earth's crust. It reaches all the way to the outer core, about 2,900 km below the planet's surface. In other words, Earth is about 1% crust, 83% mantle, and 16% core.

The crust and uppermost mantle are solid. The rest of the mantle is solid with plasticity. The core is made of very dense iron and nickel. The outer core is liquid, because it is hot enough to melt the iron and nickel. The inner core is solid. Even though it is as hot as the outer core, there is so much pressure at the very center of Earth that the iron and nickel stay in a solid state.

Looking to the Future: Exploring Earth's Interior
Despite what you may have read in stories or seen in movies, scientists have never journeyed to the center of Earth. In fact, scientists have never made it through Earth's crust! However, this has not stopped them from trying. The crust at the bottom of the oceans is much thinner than the crust of the continents. Therefore, drilling through the oceanic crust is the best chance that scientists have to make it to the mantle.

Several programs have been developed since the 1960s to attempt to drill through the ocean crust to the mantle, but none have been successful yet. The latest program is called the Integrated Ocean Drilling Program (IODP). This program began in 2003.

The JOIDES Resolution can drill more than 2,000 m through the ocean's crust. It can drill in water as deep as 8,000 m!

As part of the IODP, the United States and 26 other nations are planning a program that began in 2013. According to the plan for this new program, scientists will attempt to drill through 5–6 kilometers of oceanic crust. They will attempt to take rock samples and data directly from the mantle. They will do this using several separate drilling platforms.

If this new program is successful, scientists could gain valuable insights about the crust and the mantle as well as a wealth of other scientific information. For now, however, scientists have to make do with indirect observations about Earth's internal layers. For example, scientists study the way that vibrations from earthquakes—called seismic waves—travel through Earth. These waves change speed and bend as they travel through different densities and different states of matter. By carefully studying the way these waves travel and bend through Earth, scientists can learn about each of Earth's layers. This allows them to construct a model of Earth's interior, even though they have never actually seen most of it.

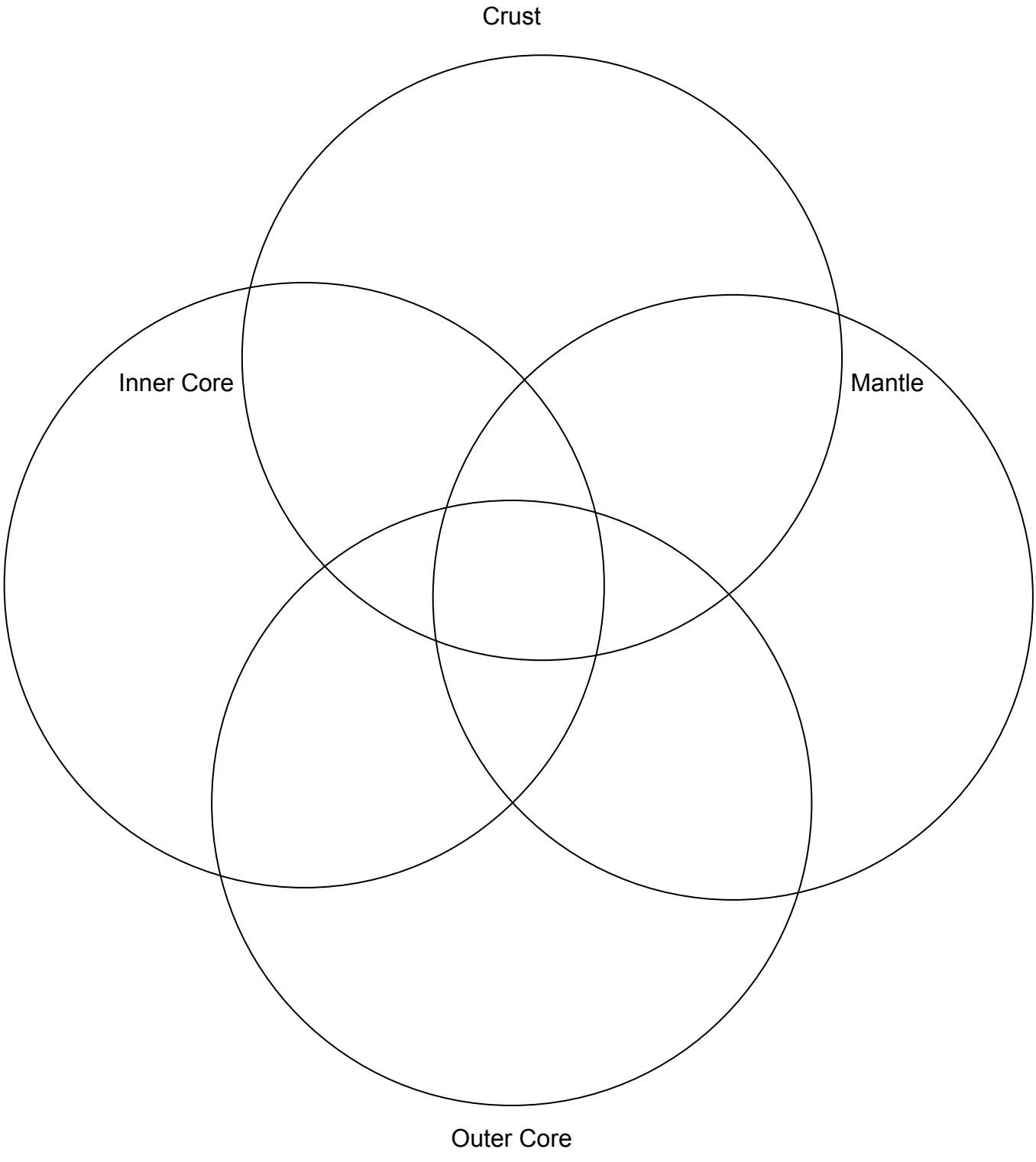
What Do You Think?

Earth is made up of the crust, mantle, outer core, and inner core. Read the characteristics of Earth's layers below. Decide whether each characteristic describes the crust, mantle, outer core, or inner core. Some of Earth's layers have overlapping characteristics. Write each characteristic in the correct section of the Venn diagram on the next page.

Characteristics of Earth's Layers

- In the solid state of matter
- Included in the lithosphere
- Includes the asthenosphere
- In the liquid state of matter
- Has plasticity
- Made mostly of silicate minerals
- Made mostly of iron and nickel
- Earth's thinnest layer
- Earth's thickest layer

Layers of Earth



Try Now

Fill in the blanks of the paragraph below using the word bank. Hint: Words can be used more than once.

Word Bank

Inner core	Mantle	Lithosphere	Outer core	Solid
Crust	Matter	Oxygen	Silicates	Core

Earth's layers are the _____, _____, _____, and _____. The _____ and _____ are composed primarily of the elements _____ and silicon. These are known as _____. Silicates of the mantle contain heavier elements. This makes them denser than those found in the crust. The _____ is composed of the densest materials, primarily iron and nickel. Earth's layers can also be identified using each layer's physical state of _____. The crust and the uppermost part of the mantle together make up a layer called the _____. The lithosphere is the cool, rigid, outermost layer of Earth. The lithosphere is in the _____ state of matter.