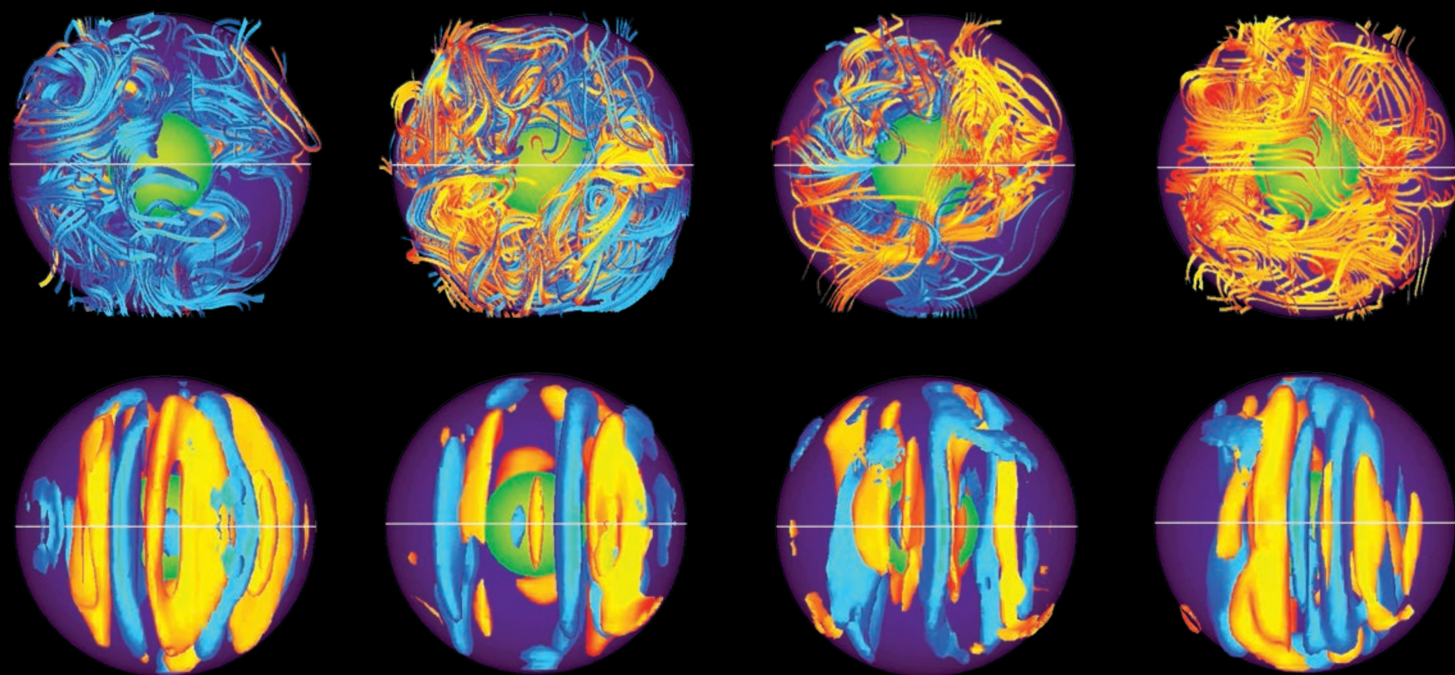
Science News

IN HIGH SCHOOLS | EDUCATOR GUIDE



Mystery at the Center of the Earth

SOCIETY FOR SCIENCE & THE PUBLIC

SN EDUCATOR GUIDE

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About the article

The *Science News* feature article, "Mystery at the Center of the Earth," focuses on the inner workings and history of Earth's magnetic field. Recent studies have offered conflicting predictions of how well iron in Earth's core conducts heat, and therefore how much heat flow is left over to drive the swirling convection that generates the planet's magnetic field. Some of these computer simulations predict that the early Earth had only a very weak magnetic field, while ancient rocks reveal that a strong magnetic field protected the planet billions of years ago. This paradox, as one scientist calls it, has scientists using both experimental and theoretical approaches to study the problem.

"Mystery at the Center of the Earth" can be used across a wide range of curricula, including **chemistry**, **earth science, physics** and **language arts**, and can be used to support the following education standards:

Next Generation Science	Common Core
ESS2.A Earth's Systems HS-ESS2-3.	ELA Standards Reading Informational Text for 9–12
PS3.A Energy HS-PS3-1, HS-PS3-2.	ELA Standards Reading for Literacy in Science and Technical Subjects 9–12
PS1.A Structure and Properties of Matter HS-PS1-1, HS-PS1-3, HS-PS2-6.	ELA Standards in Writing for 9–12 (includes using and creating graphs and charts)
	ELA Standards for Literacy in History and Social Studies for 9-12 (includes integrating graphs and charts)

Prior to reading

Guide student reading by first outlining a theme. Point out connections between this article and what students are learning in class. Here, find ideas for a few standard-aligned paths to follow while reading:

- "Mystery at the Center of the Earth" explores Earth's magnetic field and the processes by which that field is formed. With that in mind, ask students to share what they know about Earth's **magnetic field**. *(Also called the geomagnetic field, Earth's magnetic field protects the planet from damaging solar storms. A magnetic field can be produced by an electric charge under certain conditions.)* Have students fill in the provided K-W-H-L chart (Blackline Master #1) before, during and after reading.
- The different layers of the Earth *(inner core, outer core, mantle, crust)* are key to the generation of the magnetic field. Ask students which elements make up the core. *(Primarily iron, but traces of other elements such as oxygen, sulfur and nickel are also present.)* Ask if students know or remember how Earth's magnetic field is produced. Remind them that it requires an electric charge. Where might a charge that powerful come from? *(Heat left over from cosmic collisions early in the solar system heated up a young Earth. As the core of the Earth cools, it releases heat into the molten iron of the outer core.)*
- Ask students to share what they know about how heat can be transported by way of **conduction** and **convection**. *(Conduction: Heat flows from hotter to cooler regions without moving the material itself. Convection: Hotter patches of material rise and cooler regions fall. This creates a circular motion of material. Convection, but not conduction, within the liquid iron that makes up Earth's outer core helps generate the planet's magnetic field. Note that radiation is a third way heat can be transferred, but is not covered in this article. Learn more basic information about heat transfer from Columbia University by clicking here.)*
- Ask students to take note of the **elements** mentioned throughout the article. What, if anything, do they know about the properties for each of those elements or what their placement on the periodic table means? *(Elements from article include: iron, oxygen, sulfur, uranium, thorium and gold. Not mentioned, but present in the core, primarily with iron, are nickel and cobalt. More information on the properties of elements can be found here.)* Which of these are radioactive? *(Uranium, thorium)*

After reading: Comprehension

You can adapt and print this assessment (see Blackline Master #2) to check for comprehension before or after discussion.

1. **What is the main topic of the article?** *New studies have created a paradox, or conflicting predictions, for scientists with regard to what they know and have recently learned about Earth's magnetic field, including how iron conducts heat in Earth's core and the processes by which that field is formed.*
2. **Why does life on Earth need a magnetic field?** *To protect all living things on Earth and its atmosphere from destruction by solar storms.*

3. **Investigations of Earth's magnetic field have created what the author considers a riddle of sorts. Explain what he means.** *From the article: In 2012, scientists proposed that iron in the planet's core conducts heat more readily than previously thought. That would imply less mixing in the outer core and a young Earth with only a meager magnetic field, if any at all. Yet ancient rocks reveal magnetic records of an early, powerful magnetic field protecting the planet billions of years ago*

4. **Define both conduction and convection based on information found within the article and your own background knowledge of the two concepts.** *The first paragraph of the section "Freezing over hell" from the article and the graphic on Page 19 illustrate these two concepts. If students have any background knowledge, they should be able to define these concepts as they apply to the transfer of energy.*

5. **What does convection of molten iron in Earth's outer core produce?** *Magnetization or a magnetic field.*

6. **What is a dynamo?** *A dynamo is an electric generator that helps produce a magnetic field. The movement of a conductive material, such as the molten iron in the outer core, within an existing magnetic field induces an electrical current. This current produces its own magnetic field that strengthens and sustains the original field.*

7. **What processes, other than thermal convection, might keep the Earth's dynamo running?** *Buoyancy. The solid inner core currently grows by as much as 6,000 metric tons every second. Lighter elements such as oxygen and sulfur mixed in with the solidifying iron are expelled into the outer core. The buoyancy of the ousted elements helps churn the outer core and keep the dynamo running. Also: the additional heat provided by the decay of radioactive elements may also contribute.*

Analyze

Offer students other ways to explore the content of the article, as it ties to your curriculum, such as:

1. **Why is it important to understand how Earth's magnetic field is produced and its history?** *Answers will vary, but could include: It protects Earth from solar storms that would incinerate all life; it is important for the protection of the atmosphere; it provides an understanding of Earth's layers and their properties, specifically the core; it helps us understand the history of Earth and how it has changed over time; it has implications for the history of life.*

2. **Why are scientists excited about the "new core paradox"?** *Answers will vary, but could include: It will inspire scientists to look at the problem from many different angles; it will lead to more studies and the more studies conducted, the greater likelihood that scientists will solve the paradox; as Peter Driscoll, a geophysicist at the Carnegie Institution for Science in Washington, D.C., is quoted in the article: "The community is never going to converge toward a solution until people start pushing from both directions."*

3. **Think about how hot the Earth's core is. (Scientists estimate it to be 6,000° Celsius — that's roughly 11,000° Fahrenheit! It is similar to the temperature of the surface of the sun.) The core is also buried under thousands of kilometers of rock, with a pressure greater than 3 million times the air pressure at sea level. It is so hot and deep that it is impossible to physically get a core sample. So how do scientists explore the Earth's core? How do they know what the core is made of or how hot it gets? And what role does the enormous pressure at Earth's core play?** *Answers will vary based on background knowledge, but may include: Scientists run computer simulations that mimic the conditions of the core, allowing them to predict how materials will behave under such intense conditions; scientists run experiments to mimic less intense conditions and then extrapolate to core conditions; scientists make predictions about the planet's composition and structure based on what they have learned from studies of earthquakes (earthquakes send seismic waves through the planet that can be measured and analyzed); the presence of Earth's powerful magnetic field, ancient rocks and their magnetism also provide hints about the planet's interior; studies of chemical elements and how each reacts under high heat and high pressure allow scientists to predict conditions at the core. Also, see section "Electron pinball" on Page 20 of the article.*

Discuss and Assess

After students read the article independently, return as a group to the questions posed prior to reading. Invite students to share their answers and observations from the article and lead a class discussion that further underscores your current curriculum. The discussion can serve as an informal assessment. Ideas for further reading discussion or writing prompts include:

- **What is the paradox presented in the article?** *In 2012, scientists proposed that iron in the planet's core more readily conducts heat than previously thought. That work suggested that when the Earth was young, it had only a meager magnetic field. Yet ancient rocks reveal magnetic records of an early, powerful magnetic field protecting the planet billions of years ago.*

- **Scientists are trying to reckon evidence of Earth's magnetic history with new computer simulations of processes within the planet, what's called the "new core paradox." Give an example of things that don't "match up." Why is it important?** *Recent simulations have suggested that convection processes within the planet might have been too weak to power up a strong magnetic field on a young Earth. Yet, at the same time, ancient rocks reveal magnetic records of an early, powerful magnetic field protecting the planet billions of years ago. Scientists are striving to more accurately predict the conditions inside Earth's core, both now and in the distant past, so that they may better understand how Earth generates its magnetic field, its history and future.*

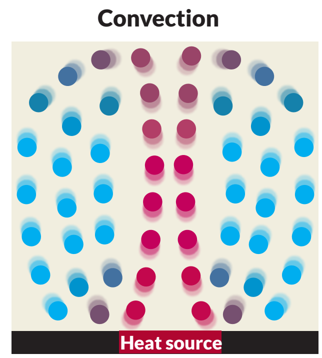
- **Remind students that they noted different elements mentioned throughout the article. Take this opportunity for a discussion about the periodic table. Using iron as an example, ask what they remember or learned from the article about the conductivity and properties of iron when heated and under pressure. What role do iron's electrons play in how the metal behaves under these extreme conditions?** *Understanding the conductivity of iron requires a deep knowledge of how electrons zip and whiz around iron atoms. In metals such as iron, free-moving electrons ferry electric charge and thermal energy. How readily iron conducts electricity and heat depends on how easily these electrons can travel. Electrons in a superconductor move unhindered while electrons in insulators are tightly confined.* You can use this interactive table to learn more about the other elements mentioned in the article.

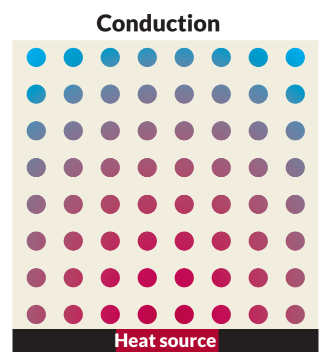
Engage

Offer students other ways to explore the content of the article, as it ties to your curriculum, such as:

- **Conduction and Convection Experiment:** Help students visualize the concepts of conduction and convection with a couple of simple experiments. Boiling a pot of water can illustrate both concepts. As the water heats, heat moves up through the water molecules, warming them. As the water gets warmer, so does the once-cool pot. If you put a metal spoon in the water, it, too, will grow increasingly warm as the water gets warmer. (Try a wooden spoon for comparison to show a poor conductor.) This is conduction. Right before the water boils, you'll see a circular motion in the water as hot water rises and displaces cooler water at the top. This circular motion becomes faster and more frenzied as the water boils, distributing the heat and also creating steam bubbles that rise to the top (note that the steam bubbles represent a different phenomenon). This illustrates convection as the heat is transferred through the liquid.

  You can also demonstrate these two concepts as follows:

  - To demonstrate *convection* you'll need a large beaker (or clear tub/tank), an ice-cube tray, a small water bottle, some pennies (or rocks), some food coloring, ice and hot water/cold water.
  - In an ice-cube tray, mix water and food coloring and then freeze.
  - Fill your beaker partway with lukewarm water and carefully lower a colored ice cube into the water. The cold food coloring will fall to the bottom of the container as the ice melts.
  - Empty out the beaker and fill it back up partway with cold water. Fill your small bottle with hot water and a bit of food coloring and drop in some weights, such as pennies or rocks. Screw the cap on the bottle and carefully lower it into the beaker, then twist off the cap. The food coloring will float to the top of the container.
  - The rising hot water and the sinking cold water both demonstrate convection, the same process that mixes Earth's liquid outer core and helps generate our planet's magnetic field.
  - You can demonstrate *conduction* using a metal rod immersed in hot water, which will warm up as you tightly hold one end. Heat passes through the rod via conduction, while heat moved through the water primarily through convection.

- **Heavy Metal:** Ask students to dive into the properties of at least two of the metals on the periodic table (excluding iron). Use the compare/contrast chart provided (Blackline Master #3) for your comparisons and then analyze the information (students may need two copies). Questions they could answer include: How are the metals similar? How are they different? What is their atomic number? What is the melting point for each on Earth's surface? Now compare one of those metals to iron. Explain that the melting point of iron on Earth's surface is approximately 2,800° F (1,538° C), yet the solid iron core at the center of the planet is roughly 11,000° F (about 6,000° C). Why? (The high pressures in the planet's core raise the melting point of iron.) Encourage students to investigate the effect of pressure on the melting points of their chosen metals.

- **Making Waves:** Explain that scientists are able to study Earth's core as a result of what they've learned from earthquakes. By measuring these seismic waves as they ricochet through the planet, scientists know a lot about the makeup of our planet, as seismic waves behave differently when traveling through different materials. Try making your own energy waves using a slinky so that students can visibly see the waves. You can find more information about this simple experiment here. Or learn earthquake basics and try any of these experiment ideas from the U.S. Geological Survey here.

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Reading Strategy — K-W-H-L Chart

Students can use this chart to help them comprehend the magnetic field or other topics from the article, “Mystery at the Center of the Earth.” Note that the ‘H’ column encourages students to think about information sources besides the article they can use to answer their questions.

K **What I know**	W **What I want to know**	H **How I’ll learn it**	L **What I learned**

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Reading Comprehension

After reading the article, "Mystery at the Center of the Earth," answer these questions:

1. **What is the main topic of the article?**

2. **Why does life on Earth need a magnetic field?**

3. **Investigations of Earth's magnetic field have created what the author considers a riddle of sorts. Explain what he means.**

4. **Define both conduction and convection based on information found within the article and your own background knowledge of the two concepts.**

5. **What does convection of molten iron in Earth's outer core produce?**

6. **What is a dynamo?**

7. **What processes, other than thermal convection, might keep the dynamo running?**

Analyze

Use what you already know about the topic, as well as what you learned in the article "Mystery at the Center of the Earth," and answer these questions:

1. **Why is it important to understand how Earth's magnetic field is produced?**

2. **Why are scientists excited about the "new core paradox"?**

3. **Think about how hot the Earth's core is. (Scientists estimate it to be 6,000° Celsius — that's roughly 11,000° Fahrenheit! It is similar to the temperature of the surface of the sun.) The core is also buried under thousands of kilometers of rock, with a pressure greater than 3 million times the air pressure at sea level. It is so hot and deep that it is impossible to physically get a core sample. So how do scientists explore the Earth's core? How do they know what the core is made of or how hot it gets? And what role does the enormous pressure at Earth's core play?**

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Reading Strategy — Compare and Contrast

Students can use this chart to explore how metals are similar and how they differ. Then they can compare one or both metals with iron.

Metal 1

Metal 2

Similarities

Differences	Differences with respect to...	Differences