Section 3 Magnetic Earth

Objectives

After this lesson, students will be able to

N.1.3.1 Explain how Earth is like a bar magnet.

N.1.3.2 Describe the effects of Earth's magnetic field.

Target Reading Skill

Building Vocabulary Explain that using vocabulary strategies such as writing a meaningful sentence helps students define key-concept words.

Answers

Sample answers:

Christopher Columbus used a **compass** to navigate in 1492. **Magnetic declination** is that angle between two imaginary lines from geographic North Pole and magnetic north pole. The **Van Allen belts** are doughnut-shaped regions above Earth's surface. The sun sends out a stream of electrically charged particles called the **solar wind**. The **magnetosphere** is shaped by the solar wind. An example of an **aurora** is the Northern Lights.

Preteach

Build Background Knowledge L2

Using a Compass

Have students recall their experiences using a compass. Ask: **Has anyone ever used a compass while camping or taking a hike?** *(Sample answer: We used a compass at scout camp.)* **What is a compass used for?** *(Sample answer: To tell you which way is north. To help you navigate.)* **Which direction does a compass needle always point?** *(To the north)* **Why?** *(Some students may suggest that the North Pole is magnetic.)* Explain that in this section students will learn why a compass needle points north.

Section 3

Integrating Earth Science

Magnetic Earth

Reading Preview

Key Concepts

- How is Earth like a bar magnet?
- What are the effects of Earth's magnetic field?

Key Terms

- compass
- magnetic declination
- Van Allen belts
- solar wind
- magnetosphere
- aurora

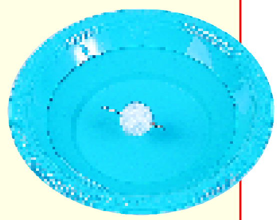
Target Reading Skill

Building Vocabulary Using a word in a sentence helps you think about how best to explain the word. After you read the section, reread the paragraphs that contain definitions of Key Terms. Use all the information you have learned to write a meaningful sentence using the Key Term.

Lab zone Discover Activity

Can You Use a Needle to Make a Compass?

1. Magnetize a large needle by rubbing it several times in the same direction with one end of a strong bar magnet. Push the needle through a ball of foam or tape it to a small piece of cork.
2. Place a drop of dishwashing soap in a bowl of water. Then float the foam or cork in the water. Adjust the needle until it floats horizontally.
3. Allow the needle to stop moving. Note the direction it points.
4. Use a local map to determine the direction in which it points.

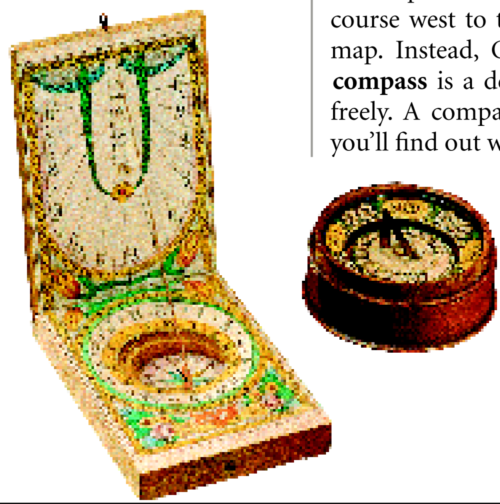


Think It Over

Observing In what direction did the needle point? If you repeat the activity, will it still point in the same direction? What does this tell you about Earth?

When Christopher Columbus sighted land in 1492, he didn't know what he had found. He was trying to find a shortcut from Europe to India. Where he landed, however, was on an island in the Caribbean Sea just south of the present-day United States. He had no idea that such an island even existed.

In spite of his error, Columbus had successfully followed a course west to the Americas without the help of an accurate map. Instead, Columbus used a compass for navigation. A **compass** is a device that has a magnetized needle that spins freely. A compass needle usually points north. As you read, you'll find out why.



◄ Columbus navigated across the Atlantic Ocean using a compass similar to one of these.

Lab zone Discover Activity

Skills Focus Observing L2

Materials large needle, strong bar magnet, dish, water, dishwashing soap, cork or foam ball

Time 15 minutes

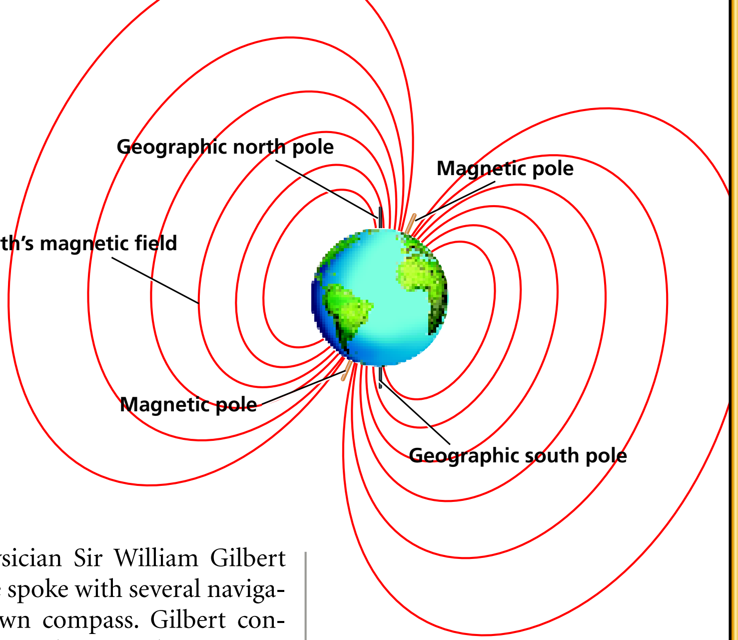
Tips Caution students to handle the needle carefully. Students should rub the needle in only one direction. Magnetized objects in the room may attract the needle.

Use a compass to verify that the needle points north.

Expected Outcome The needle will point north.

Think It Over Sample answer: The needle pointed north. Yes. The needle will always point north because Earth has a magnetic field.

FIGURE 12
Earth's Magnetic Field
The magnetic field lines show the shape of Earth's magnetic field.
Observing *What magnetic properties does Earth have?*



Earth as a Magnet

In the late 1500s, the English physician Sir William Gilbert became interested in compasses. He spoke with several navigators and experimented with his own compass. Gilbert confirmed that a compass always points in the same direction, no matter where it is. But no one knew why.

Gilbert hypothesized that a compass behaves as it does because Earth acts as a giant magnet. Although many educated people of his time laughed at this idea, Gilbert turned out to be correct. **Just like a bar magnet, Earth has a magnetic field surrounding it and two magnetic poles.**

The fact that Earth has a magnetic field explains why a compass works as it does. The poles of the magnetized needle on the compass align themselves with Earth's magnetic field.

Earth's Core Gilbert thought that Earth's center, or core, contains magnetic rock. Scientists now think that this is not the case, since the material inside Earth's core is too hot to be solid. Also, the temperature is too high for the material to be magnetic. Earth's magnetism is still not completely understood. But scientists do know that the circulation of molten material in Earth's core is related to Earth's magnetism.

Earth's Magnetic Poles You know that Earth rotates on its axis, around the geographic poles. But Earth also has magnetic poles. These magnetic poles are located on Earth's surface where the magnetic force is strongest. As you can see in Figure 12, the magnetic poles are not in the same place as the geographic poles. For example, the magnetic pole in the Northern Hemisphere is located in northern Canada about 1,250 kilometers from the geographic North Pole.

Discovery Channel School
Magnetism
Video Preview
▶ Video Field Trip
Video Assessment

Instruct

Earth as a Magnet

Teach Key Concepts L2

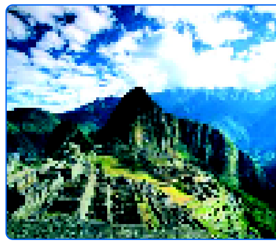
Earth Has a Magnetic Field

Focus Tell students that Earth itself has magnetic properties.

Teach Ask: **How is Earth like a bar magnet?** *(Earth has a magnetic field surrounding it and two magnetic poles.)* **Are Earth's magnetic poles in the same place as its geographic poles?** *(No.)* **To which pole does a compass needle point?** *(The magnetic pole in the north)*

Apply Have students observe a compass. Ask: **Why does a compass needle point north?** *(It is magnetized; it points north because it aligns with Earth's magnetic field.)* **learning modality: verbal**

All in One Teaching Resources
- Transparency N8



Discovery Channel School Video Field Trip

Magnetism

Show the Video Field Trip to help students better understand Earth's magnetic field. Discussion question: **How far does Earth's magnetic field extend into space?** *(It extends thousands of kilometers into space.)*

Independent Practice L2

All in One Teaching Resources
- *Guided Reading and Study Worksheet: Earth as a Magnet*

Student Edition on Audio CD

Monitor Progress L2

Oral Presentation Have students explain why a compass needle always points north.

Answer
Figure 12 Earth has a magnetic field surrounding it and two magnetic poles.

Differentiated Instruction

Less Proficient Readers L1

Answering Questions Select a passage from the text, such as the subsection Earth's Magnetic Field. Read the passage aloud to students as they follow along in their books. After reading, ask some questions about the passage. If they don't know the answers, challenge them to find the answers in the passage. **learning modality: verbal**

Gifted Students L3

Communicating Have interested students research what Earth scientists understand about how Earth's core creates Earth's magnetic field as well as what causes the magnetic field to reverse directions. Ask students to make a presentation to the class of their findings. **learning modality: verbal**

Math Analyzing Data

Math Skill Interpreting data

Focus Tell students that a data table is useful for organizing data so that the data can be interpreted or graphed.

Teach Ask: **What is the subject of the data table?** *(The movement of the magnetic north pole)* **What period of time does the data represent?** *(1948 through 2001, or 53 years)* **Is the time between the years of reading the same in each case?** *(No. The years between readings are different in every case.)*

Answers

1. The average speed of the pole's movement is increasing.
2. Between 1948 and 2001, the pole has moved 857 km *(150 km + 120 km + 120 km + 180 km + 287 km = 857 km)*.
3. Sample answer: The average speed increased by 23.0 km/yr from 1994 to 2001 *(41.0 km/yr – 18.0 km/yr = 23.0 km/yr)*. That is an increase of 3.3 km/yr per year *(23.0 km/yr ÷ 7yr = 3.3 km/yr/yr)*. There are 9 years between 2001 and 2010. Therefore, a good prediction is that the average speed of the pole's movement in 2010 will be 29.7 km/yr *(3.3 km/yr/yr × 9yr = 29.7 km/yr)*.

Earth's Magnetic Field

Teach Key Concepts L2

Earth Magnetizes Materials

Focus Explain that Earth's magnetic field is strong, and Earth can make magnets just as other strong magnets do.

Teach Ask: **How can a magnetic field make a magnet?** *(A magnet can be made by placing an unmagnetized ferromagnetic material in a strong magnetic field.)*

Apply Ask: **When molten material from underground rises to the surface, how is the iron in the material affected by Earth's magnetic field?** *(The iron in the molten material lines up in the direction of Earth's magnetic field.)* **What have scientists learned by studying the rock that has hardened from molten material?** *(Scientists have learned that Earth's magnetic field has completely reversed direction every million years or so.)* **learning modality: verbal**

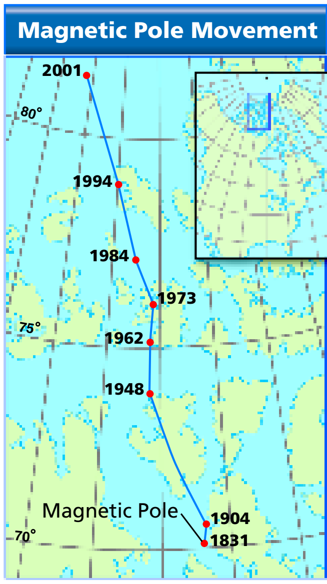


FIGURE 13
The location of Earth's magnetic poles does not stay the same.

Magnetic Declination If you use a compass, you have to account for the fact that Earth's geographic and magnetic poles are different. Suppose you could draw a line between you and the geographic North Pole. The direction of this line is geographic north. Then imagine a second line drawn between you and the magnetic pole in the Northern Hemisphere. The angle between these two lines is the angle between geographic north and the north to which a compass needle points. This angle is known as **magnetic declination**. So, magnetic declination differs depending on your location on Earth.

The magnetic declination of a location on Earth today is not the same as it was 10 years ago. The magnetic declination of a location changes. Earth's magnetic poles do not stay in one place as the geographic poles do. Figure 13 shows how the location of Earth's magnetic pole in the Northern Hemisphere has drifted over time.

Earth's Magnetic Field

You learned that a material such as iron can be made into a magnet by a strong magnetic field. **Since Earth produces a strong magnetic field, Earth itself can make magnets out of ferromagnetic materials.**

Earth as a Magnet Maker Suppose you leave an iron bar lying in a north-south direction for many years. Earth's magnetic field may attract the domains strongly enough to cause them to line up in the same direction. When the domains in the iron bar align, the bar becomes a magnet. This can happen to some everyday objects. So even though no one has tried to make metal objects such as file cabinets in your school into magnets, Earth might have done so anyway!

Math Analyzing Data

Movement of Earth's Magnetic Poles

Earth's magnetic poles move slowly over time. The data in the table show the position of Earth's magnetic north pole in specific years.

1. **Interpreting Data** What is the trend in the speed of the pole's movement?
2. **Calculating** What is the total distance the pole has traveled over the time shown?
3. **Predicting** Using this data, predict the average speed of the pole's movement between 2001 and 2010. Explain.

Magnetic North Pole Movement

Year of Reading	Distance Moved Since Previous Reading (km)	Average Speed (km/yr)
1948	420	9.5
1962	150	10.7
1973	120	10.9
1984	120	10.9
1994	180	18.0
2001	287	41.0

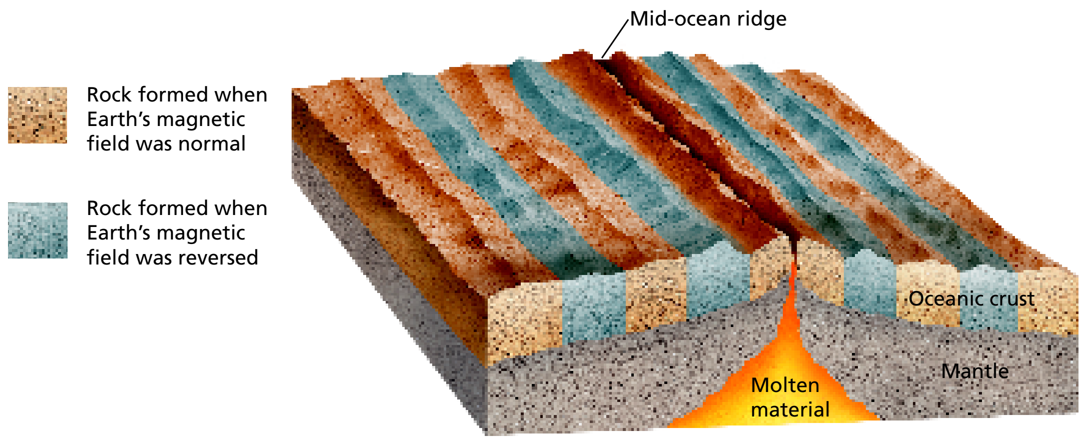


FIGURE 14
Earth's Magnetic Stripes
When molten material hardens into the rock of the ocean floor, the direction of Earth's magnetic field at that time is permanently recorded. **Applying Concepts** *How can scientists use this rock record to study changes in Earth's magnetic field?*

Earth Leaves a Record Earth's magnetic field also acts on rocks that contain magnetic material, such as rock on the ocean floor. Rock is produced on the ocean floor from molten material that seeps up through a long crack in the ocean floor known as a mid-ocean ridge. When the rock is molten, the iron it contains lines up in the direction of Earth's magnetic field. As the rock cools and hardens, the iron is locked in place. This creates a permanent record of the magnetic field.

As scientists studied such rock, they discovered that the direction and strength of Earth's magnetic field have changed over time. Earth's magnetic field has completely reversed direction every million years or so.

The different colored layers in Figure 14 indicate the directions of Earth's magnetic field over time. Notice that the patterns of bands on either side of the ridge are mirror images. This is because the sea floor spreads apart from the mid-ocean ridge. So rocks farther from the ridge are older than rocks near the ridge. Scientists can determine when the rock was formed by looking at the rock's magnetic record.

Why does Earth's magnetic field change direction? No one knows. Scientists hypothesize that changes in the motion of molten material in Earth's core may cause changes in Earth's magnetic field. But scientists cannot explain why changes in the molten material take place.

Reading Checkpoint **What evidence shows that Earth's magnetic field changes?**

Lab zone **Skills Activity**

Measuring

1. Use a local map to locate geographic north relative to your school. Mark the direction on the floor with tape or chalk.
2. Use a compass to find magnetic north. Again mark the direction.
3. Use a protractor to measure the number of degrees between the two marks.

Compare the directions of magnetic and geographic north. Is magnetic north to the east or west of geographic north?

Lab zone **Skills Activity**

Skills Focus Measuring L2

Materials Local map, tape or chalk, compass, protractor

Time 10 minutes

Tips If possible, do this activity outdoors, away from power lines or other magnetic materials.

Expected Outcome Students should find that the compass needle points at an angle to the left, or west, of geographic north.

Extend Have students identify the direction the compass illustration points on a map of the local area and compare it to magnetic north. Encourage students to identify landmarks in each direction. **learning modality: logical/mathematical**

Lab zone **Teacher Demo**

Earth Magnetizes Iron L2

Materials metal filing cabinet or other large object that has been in one place for a long time, such as a metal locker; compass

Time 5 minutes

Focus Tell students that Earth's magnetic field magnetizes everyday objects.

Teach Hold the compass parallel to the ground and move it slowly from the top of the filing cabinet or metal locker down to the bottom. If the needle turns and points in a different direction than north, then the filing cabinet or locker is magnetized. Allow students to move the compass around the cabinet or locker and watch for deflection of the needle.

Apply Ask: **What is the process by which this filing cabinet become magnetized?** *(Earth's magnetic field caused the domains to line up in the same direction).* **learning modality: visual**

All in One **Teaching Resources**

- Transparency N9

Monitor Progress L2

Drawing Have students make captioned sketches to explain why a compass does not point to geographic north.

Students can keep their drawings in their portfolios. Portfolio

Answers

Figure 14 By studying the direction of the iron in a rock, scientists can determine the direction of Earth's magnetic field at the time the rock solidified from molten material.

Reading Checkpoint The magnetic record in rock on the ocean floor shows that Earth's magnetic field has completely reversed direction every million years or so.

Integrating Earth Science L2

Evidence of Movements of Earth's Plates

Focus Tell students that the surface of Earth is composed of huge plates that move very slowly.

Teach Ask: **How is a permanent record of Earth's magnetic field made in rocks?** *(Before rocks harden, the iron in the rocks lines up in the direction of Earth's magnetic field.)* Explain that Earth scientists have studied rocks from all over the world, and the record in rocks of Earth's magnetic field is evidence that these plates have moved greatly over time.

Apply Ask: **Once a rock hardens, can the iron in the rock change directions?** *(Not easily. The rock's domains are very rigid and difficult to move.)* **If the iron in a rock is lined up in a different direction than the direction of Earth's magnetic field, what might that show about the rock?** *(The rock has moved from the position where the molten material originally hardened.)* **learning modality: verbal**

The Magnetosphere

Teach Key Concepts L2

Solar Wind and Auroras

Focus Tell students that Earth's magnetic field affects both atoms in materials on Earth and atomic particles in Earth's atmosphere.

Teach Ask: **What are the Van Allen belts?** *(They are doughnut-shaped regions above Earth's surface that contain electrons and protons traveling at very high speeds.)* **How do these charged particles reach the Van Allen belts?** *(They come from the stream of charged particles flowing from the sun, or the solar wind.)* **What is the magnetosphere?** *(The region of Earth's magnetic field shaped by the solar wind)*

Apply Ask: **Where do particles in the solar wind dip down toward Earth's surface?** *(Near the poles)* Refer to Figure 16, and emphasize that auroras occur near the magnetic poles. Ask: **What caused this aurora to occur?** *(Electrically charged particles in solar wind dipped down towards Earth's surface. When they got close to the surface, they interacted with atoms in the atmosphere and caused a glowing region, or an aurora.)* **learning modality: verbal**

All in One Teaching Resources

- Transparency N10

Lab zone Try This Activity

Spinning in Circles

Which way will a compass point?

1. Place a bar magnet in the center of a sheet of paper.
2. Place a compass about 2 cm beyond the north pole of the magnet. Draw a small arrow showing the direction of the compass needle.
3. Repeat Step 2, placing the compass at 20 to 30 different positions around the magnet.
4. Remove the magnet and observe the pattern of arrows you drew.

Drawing Conclusions What does your pattern of arrows represent? Do compasses respond only to Earth's magnetic field?

The Magnetosphere

Earth's magnetic field extends into space. Space is not empty. It contains electrically charged particles. **Earth's magnetic field affects the movements of electrically charged particles in space.** Those charged particles also affect Earth's magnetic field.

Between 1,000 and 25,000 kilometers above Earth's surface are two doughnut-shaped regions called the **Van Allen belts.** They are named after their discoverer, J. A. Van Allen. These regions contain electrons and protons traveling at very high speeds. At one time it was feared that these particles would be dangerous for spacecraft passing through them, but this has not been the case.

Solar Wind Other electrically charged particles in space come from the sun. Earth and the other objects in our solar system experience a solar wind. The **solar wind** is a stream of electrically charged particles flowing at high speeds from the sun. The solar wind pushes against Earth's magnetic field and surrounds the field, as shown in Figure 15. The region of Earth's magnetic field shaped by the solar wind is called the **magnetosphere.** The solar wind constantly reshapes the magnetosphere as Earth rotates on its axis.

Although most particles in the solar wind cannot penetrate Earth's magnetic field, some particles do. They follow Earth's magnetic field lines to the magnetic poles. At the poles, the magnetic field lines dip down to Earth's surface.

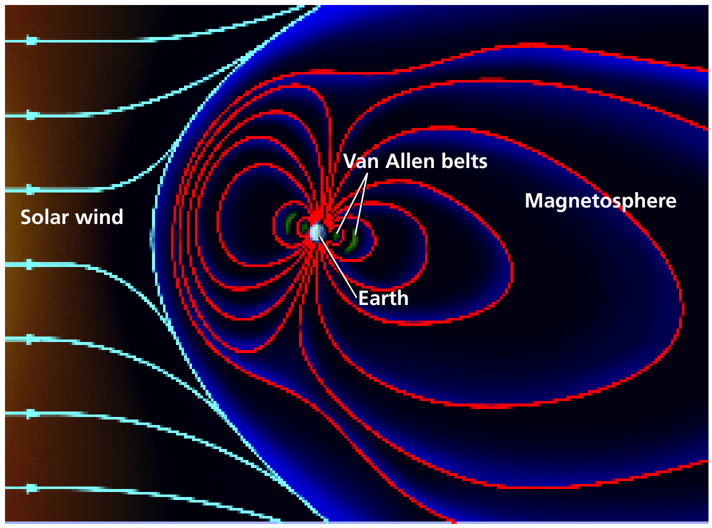


FIGURE 15
Earth's Magnetosphere
The solar wind causes Earth's magnetic field to stretch out on the side of Earth not facing the sun.
Relating Cause and Effect *What shapes the magnetosphere?*

Lab zone Try This Activity

Skills Focus Drawing conclusions L2

Materials bar magnet, sheet of paper, compass

Time 10 minutes

Tips Use a bar magnet that is much larger than the compass to give the most accurate results.

Expected Outcome Students will draw 20–30 small arrows, the pattern of which represents the bar magnet's magnetic field. Compasses respond both to Earth's magnetic field and to magnetic material near them.

Extend Students can repeat the activity using a horseshoe magnet. **learning modality: visual**

FIGURE 16
Aurora
A band of colored light called an aurora occasionally appears in the night sky near the magnetic poles.

Auroras When high-speed, charged particles get close to Earth's surface, they interact with atoms in the atmosphere. This causes some of the atoms to give off light. The result is one of Earth's most spectacular displays—a curtain of shimmering bright light in the atmosphere. A glowing region in the atmosphere caused by charged particles from the sun is called an **aurora**. In the Northern Hemisphere, an aurora is called the Northern Lights, or aurora borealis. In the Southern Hemisphere, it is called the Southern Lights, or aurora australis.

Reading Checkpoint **What causes an aurora?**

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For: More on Earth's magnetic field
Visit: PHSchool.com
Web Code: cgd-4013

Section 3 Assessment

Target Reading Skill Building Vocabulary Use your sentences to help answer the questions.

Reviewing Key Concepts

1. a. **Reviewing** How are Earth and a bar magnet similar?
   b. **Describing** How do Earth's magnetic properties explain how a compass works?
   c. **Interpreting Diagrams** Look at Figure 12. How do the positions of the geographic and magnetic poles compare?
2. a. **Identifying** What are two effects of Earth's magnetic field?
   b. **Explaining** How can scientists use rocks to learn about Earth's magnetic field?
   c. **Relating Cause and Effect** What causes the part of Earth's magnetic field called the magnetosphere to exist?

Lab zone At-Home Activity

House Compass With a family member, explore your home with a compass. Use the compass to discover magnetic fields in your house. Try metal objects that have been in the same position over a long period of time. Explain to your family member why the compass needle moves away from north near some objects.

Lab zone At-Home Activity

House Compass L1 Students should explain to the family member that Earth's magnetic field can magnetize a ferromagnetic material left in a certain position for many years. Some students may find that the top and bottom of a filing cabinet are opposite poles. This is due to magnetic lines that are not parallel to Earth's surface but are at an angle to Earth's surface.

Lab zone Chapter Project

Keep Students on Track A few days before presentations are to begin, ask a volunteer group to "exhibit" its sculpture for the rest of the class. This may give groups having trouble with the project a concrete idea about how to proceed. Ask groups still working on their sculptures what help they need to complete the project.

Go Online PHSchool.com
For: More on Earth's magnetic field
Visit: PHSchool.com
Web Code: cdg-4013

Download a worksheet that will guide students' review of Internet resources on Earth's magnetic field.

Monitor Progress L2

Answers

Figure 15 The solar wind shapes the magnetosphere.

Reading Checkpoint An aurora is caused by charged particles from the sun entering Earth's magnetic field and interacting with atoms in the atmosphere.

Assess

Reviewing Key Concepts

1. a. Like a bar magnet, Earth has a magnetic field surrounding it and two magnetic poles. **b.** A compass has a magnetized needle that aligns with Earth's magnetic field. **c.** The magnetic poles are not in the same place as the geographic poles.

2. a. Earth's magnetic field can magnetize a ferromagnetic material left in a certain position for many years. Earth's magnetic field lines up iron in molten rocks. **b.** By examining the pattern of magnetic material, scientists can study the magnetic history of Earth. When rock is molten, the iron it contains lines up in the direction of Earth's magnetic field. When the rock hardens, the iron is locked in place. This creates a permanent record of the magnetic field. **c.** The solar wind creates the magnetosphere as it pushes against and shapes Earth's magnetic field.

Reteach L1

Call on students to define the key terms *magnetic declination, magnetosphere*, and *aurora* and explain what causes each.

Performance Assessment L2

Drawing Have each student make a drawing of Earth and its magnetic field. Drawings should include magnetic field lines and the approximate locations of Earth's geographic and magnetic poles.

All in One **Teaching Resources**

- Section Summary: *Magnetic Earth*
- Review and Reinforcement: *Magnetic Earth*
- Enrich: *Magnetic Earth*