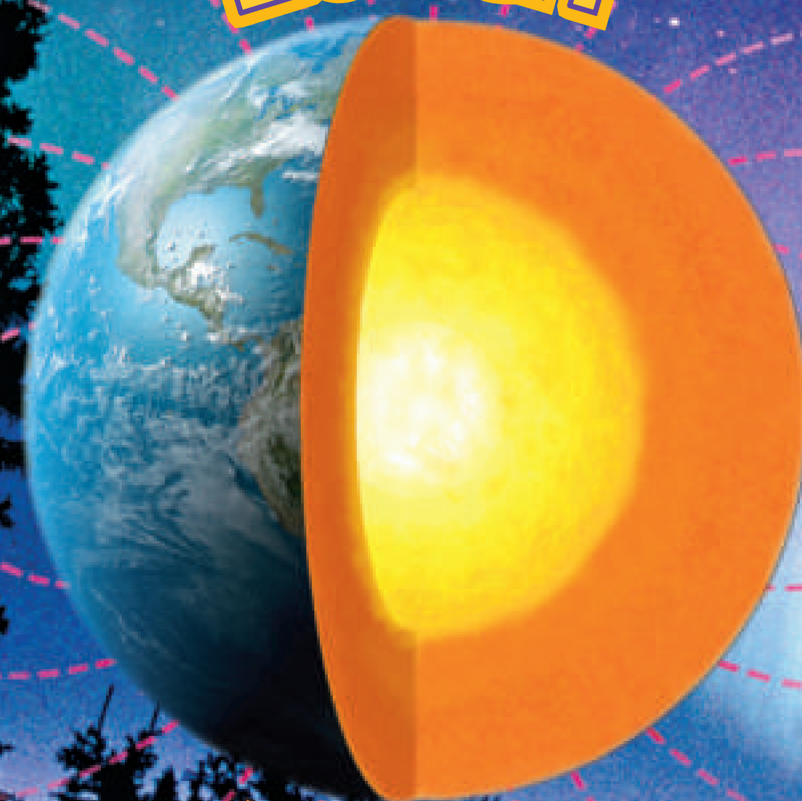
California Science

Physical Sciences

Our Magnetic Earth



by Mary Beth Spann

Genre	Comprehension Skill	Text Features	Science Content
Nonfiction	Main Idea and Details	• Captions • Diagrams • Maps • Glossary	Magnetism

Scott Foresman Science 4.2

PEARSON
Scott Foresman
scottforesman.com

ISBN 0-328-23545-8
9 780328 235452 90000

Vocabulary	Extended Vocabulary
electromagnet	aurora
generator	dynamo theory
magnetic field	ionosphere
magnetic poles	magnetometer
magnetism	magnetosphere
	Main Field
	solar wind
	Van Allen belts

Picture Credits
Illustrations
22 Adam Benton.

Photographs
Every effort has been made to secure permission and provide appropriate credit for photographic material. The publisher deeply regrets any omission and pledges to correct errors called to its attention in subsequent editions.

Unless otherwise acknowledged, all photographs are the copyright of Dorling Kindersley, a division of Pearson.

2 Erich Schrempp /Photo Researchers, Inc.; 6 NASA; 8 ©DK Images; 9 Photo Researchers, Inc.; 11 ©Kennan Ward/Corbis; 16 Geoff Lane/CSIRO/Photo Researchers, Inc.; 19 Luciano Corbella/DK Images.

ISBN: 0-328-23545-8

1 2 3 4 5 6 7 8 9 10 V010 13 12 11 10 09 08 07 06

Our Magnetic Earth

by Mary Beth Spann

PEARSON
Scott Foresman

What You Already Know

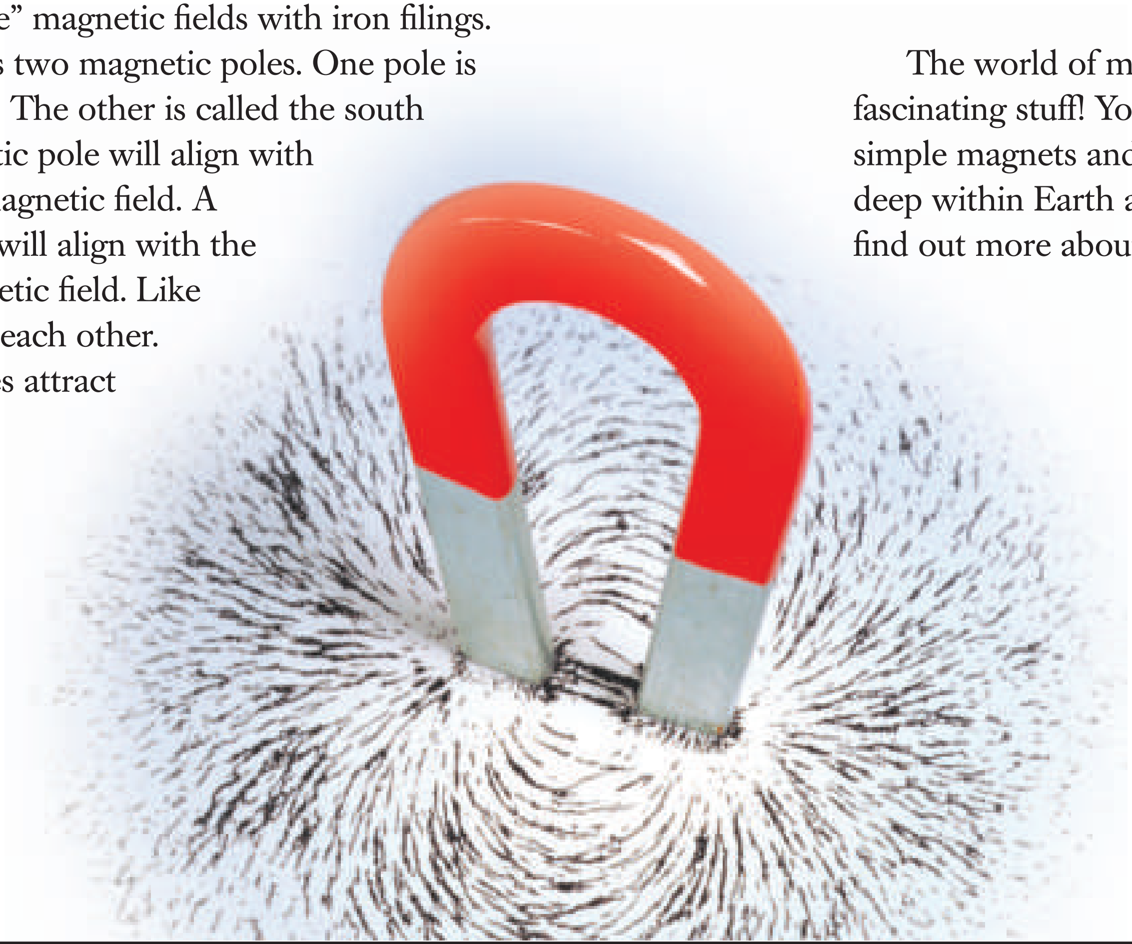
Magnetism is a force. It acts on a moving electric charge and nearby magnetic materials. A magnetic field is the space around a magnet in which magnetic forces act. A magnet's strength and shape determine its magnetic field. A magnet's poles are where its magnetic force is greatest.

Magnetic fields are invisible. They are made by electric currents. You can "see" magnetic fields with iron filings.

Every magnet has two magnetic poles. One pole is called the north pole. The other is called the south pole. A south magnetic pole will align with the north pole of a magnetic field. A north magnetic pole will align with the south pole of a magnetic field. Like magnetic poles repel each other. Unlike magnetic poles attract each other.

An electromagnet is a coil of wire wrapped around an iron bar, or something else that can be given a magnetic field. As the current passes through the wire, it creates a magnetic field around the bar. A generator is a machine made from wires coiled around powerful magnets. Generators turn motion into electrical energy.

The world of magnets and magnetism is filled with fascinating stuff! You have learned about the magnetism of simple magnets and compasses. But magnetism also exists deep within Earth and in Earth's atmosphere. Keep reading to find out more about this magnetism.



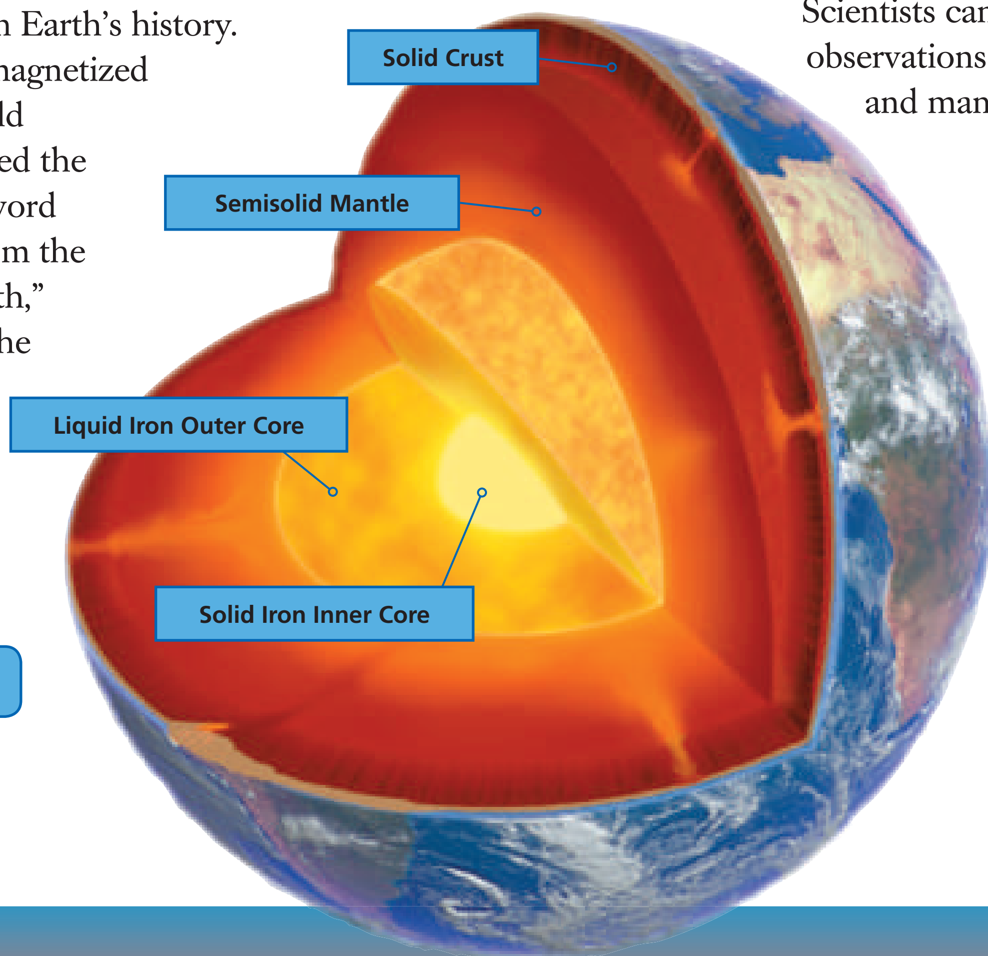
The iron filings scattered around this horseshoe magnet have aligned with its magnetic field.

Geomagnetism

Earth is made up of several layers. The top layer is a solid crust. The continents and ocean floors sit on the top of this crust. Below the solid crust is a semisolid mantle. Then comes an outer core. Scientists think it is made up of hot liquid iron, also called molten iron. Finally, there is a solid inner core. Scientists think it is also made up of iron.

Most of Earth's magnetism comes from its outer core. Scientists think the outer core is about 3.5 billion years old. Scientists think Earth itself is 4.5 billion years old. So magnetism began early in Earth's history.

Earth is like a giant magnetized sphere. The magnetic field surrounding Earth is called the geomagnetic field. The word "geomagnetic" comes from the Greek *geo*, meaning "Earth," and *magnetic*, meaning "the force of magnetism."



Earth

The geomagnetic field is huge. It is created by electric currents moving deep below and high above Earth's surface.

Scientists still have a lot to learn about the geomagnetic field. But the field can be hard to study. For one thing, scientists will never be able to travel into Earth's core. It is too hot and has too much pressure for people to survive there. But scientists have learned a lot about geomagnetism by looking at and studying things from Earth's surface.

For example, scientists have observed that the geomagnetic field is constantly changing. These changes are probably caused by changes within Earth's crust and mantle. Scientists cannot go into the crust and mantle. But their observations make sense based on ideas about the crust | and mantle.

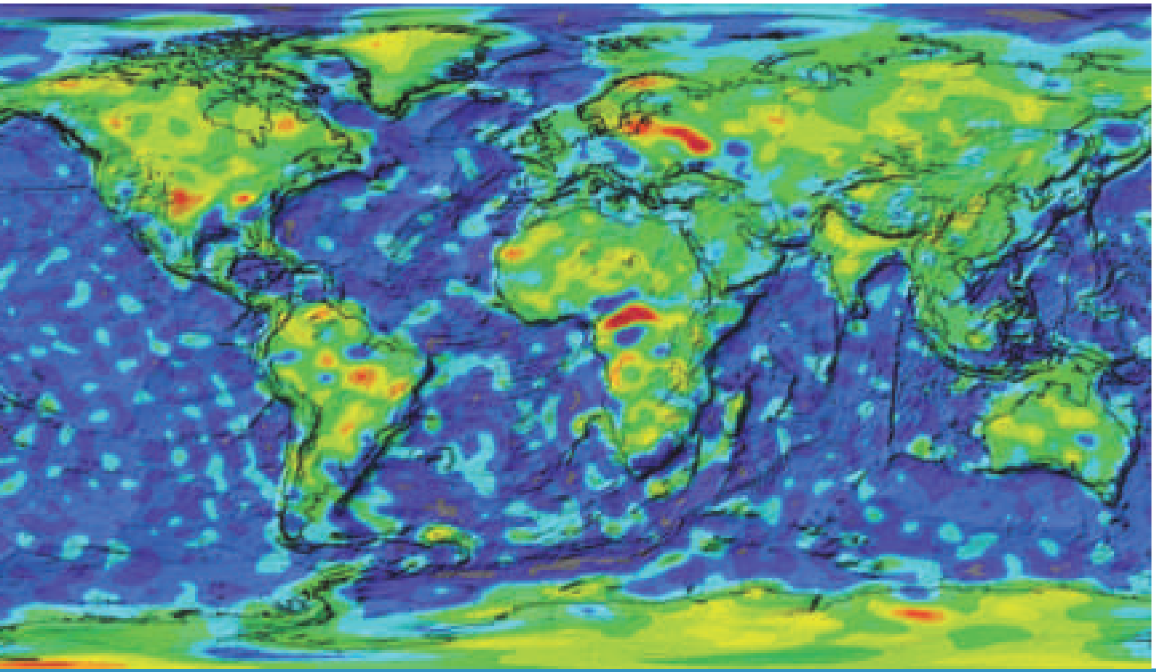
This diagram shows the lines of force that make up Earth's geomagnetic field.

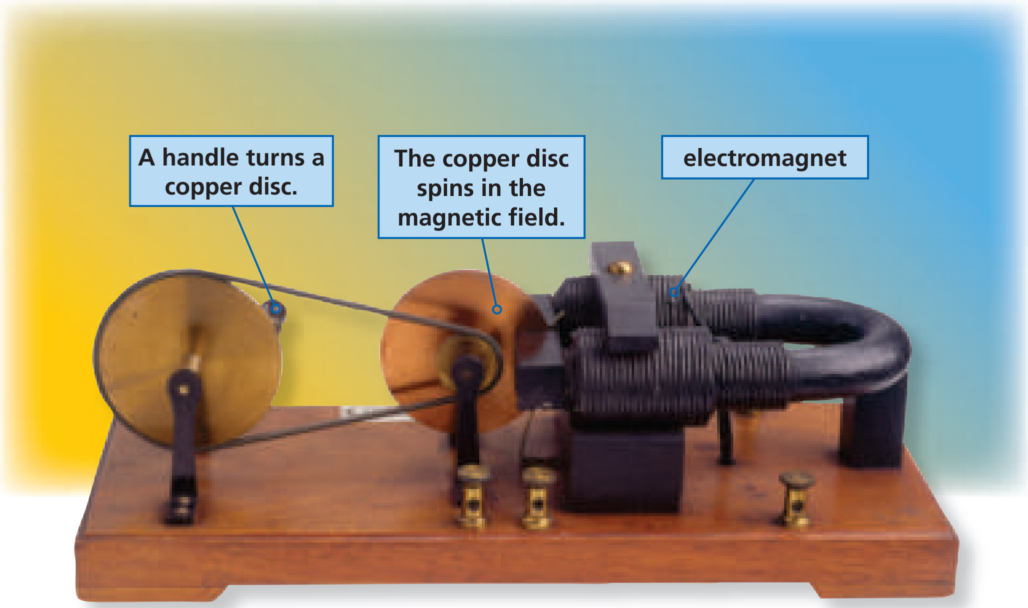
The Main Field and Dynamo Theory

The Main Field makes up about nine-tenths of the geomagnetic field. It is made by Earth's outer core. The outer core is made up mostly of iron. This iron is not like the iron on Earth's surface. The heat of the iron in Earth's outer core stops the iron in the core from being magnetic.

This leads to a mystery. The outer core's iron is too hot to be magnetic. So how can the outer core create geomagnetism? And how has geomagnetism been able to last for millions of years without weakening? Scientists have come up with a theory called "dynamo theory" in an attempt to solve this mystery.

The red areas of this model show where Earth's crust is most magnetized. The blue areas show where it is least magnetized.





Dynamo theory was named for the dynamo, which the British scientist Michael Faraday invented in 1831. The parts that make up a simple dynamo are labeled.

Here is how dynamo theory works: heat currents cause the molten iron in Earth's outer core to flow. The flow is kept moving by the Earth's spinning. Molten iron is very different from solid iron. But it still conducts electricity.

When molten iron flows across a weak magnetic field, it makes an electric current. The electric current makes a new magnetic field. The new magnetic field combines with the old magnetic field. Together they form a stronger magnetic field. This is the Main Field.

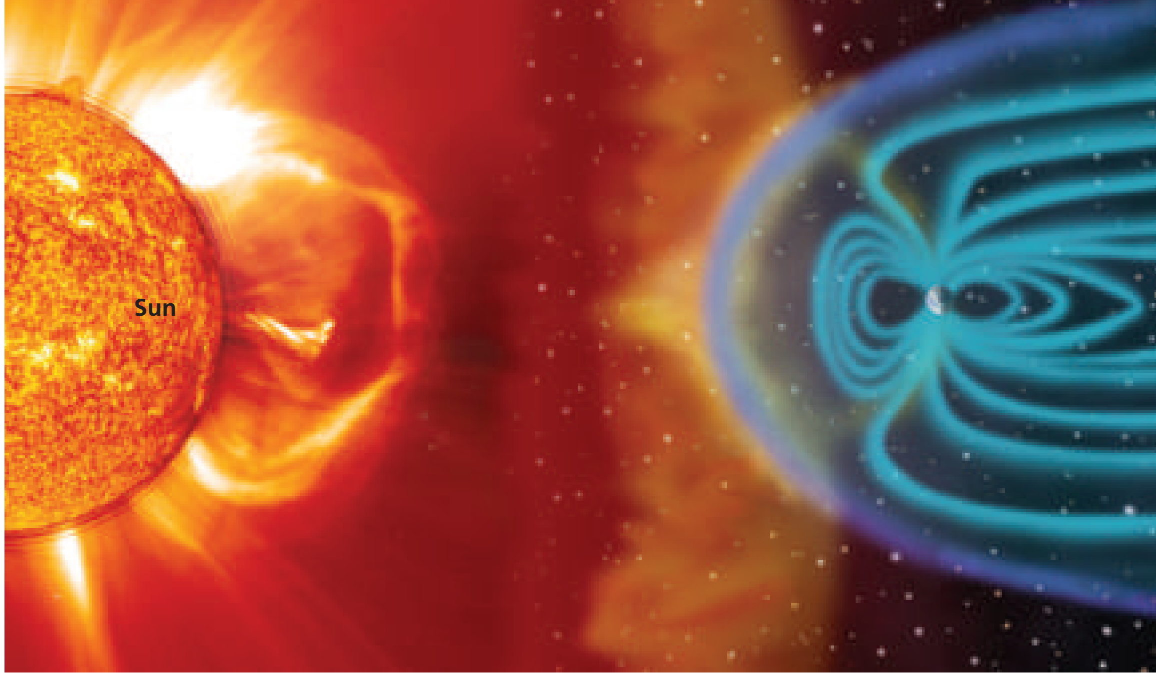
Dynamo theory explains why the Main Field has lasted and stayed at about the same strength. It has lasted because the outer core's molten iron has kept flowing. It has stayed at the same strength because two magnetic fields are constantly mixing to create it.

Sources of the Geomagnetic Field

Earth's geomagnetic field comes from several sources. Electric currents flowing through space make up part of it. So do electric currents flowing through Earth's crust and oceans. Magnetic rocks on Earth's surface contribute to geomagnetism. So does the ionosphere.

The ionosphere is a part of the upper atmosphere. The flow of electricity in the ionosphere is strong enough to influence Earth's magnetic field. This flow of electricity is caused mainly by radiation from the Sun hitting the atmosphere. The electrical current made by the Sun's radiation creates magnetic fields. These fields contribute to the overall geomagnetic field. They also cause changes to the geomagnetic field.

These metal nails were attracted to this rock's magnetic field. Magnetic rocks contribute to geomagnetism.



This illustration, which is not to scale, shows Earth's magnetosphere being hit by the Sun's solar winds.

The part of the geomagnetic field that reaches into space is called the magnetosphere. The magnetosphere protects Earth from the Sun's solar winds. These winds carry an electric charge. Their electric charge makes them magnetic.

Solar winds from the Sun travel millions of miles from the Sun toward Earth. When they hit Earth's magnetic field, the side of the magnetosphere facing the Sun is pushed inward. The side facing away from the Sun streams outward. This makes the magnetosphere quite lopsided.

The magnetosphere is important to life on Earth. Without it, solar winds would hit our planet. This could result in a loss of Earth's water and atmosphere. Scientists think such an event may have happened on Mars.

Auroras and Van Allen Belts

Even with the magnetosphere, Earth is still affected by solar wind. If enough solar wind gets through, it can cause auroras. Auroras are colorful lights in the upper atmosphere. Usually auroras are seen only near the geographic poles. However, in periods of heavy solar winds, they can be seen over much wider areas.

For years, people have enjoyed looking at auroras. But the auroras actually warn us of the danger of solar radiation. The solar wind that creates auroras contains radiation. When that radiation hits the magnetosphere, it becomes trapped. In 1958, James Van Allen proved that this trapped radiation existed. Since then it has been called the Van Allen belts. The radiation can damage satellites and spacecraft. If astronauts spend too much time in space, it can hurt them.

It was once claimed that the Van Allen belts were a result of nuclear testing! Scientists now know that nuclear testing did not make them. Instead, natural forces created the Van Allen belts.

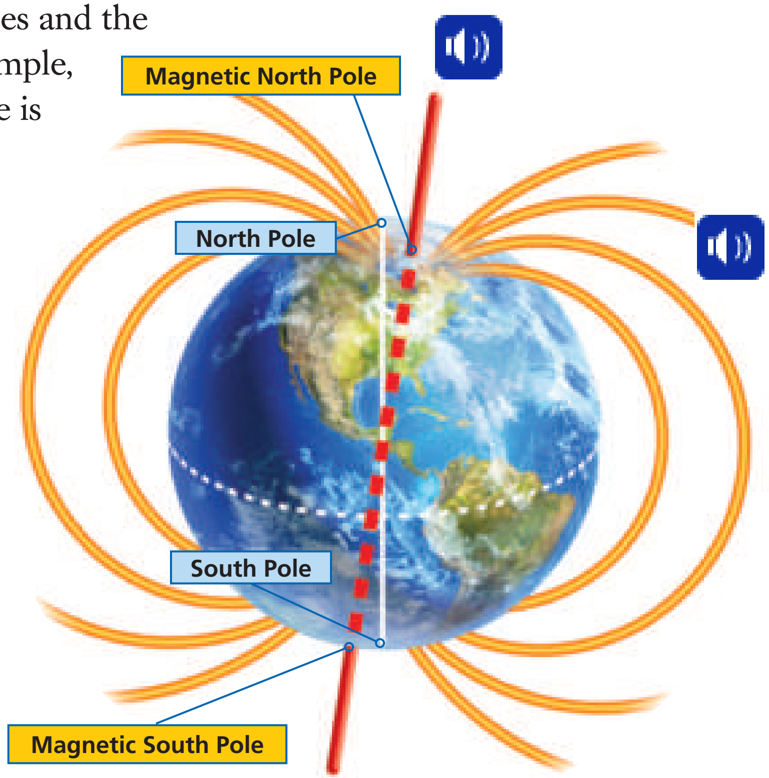
Auroras such as the one shown here are created when solar winds hit Earth's atmosphere.

The Geomagnetic Poles

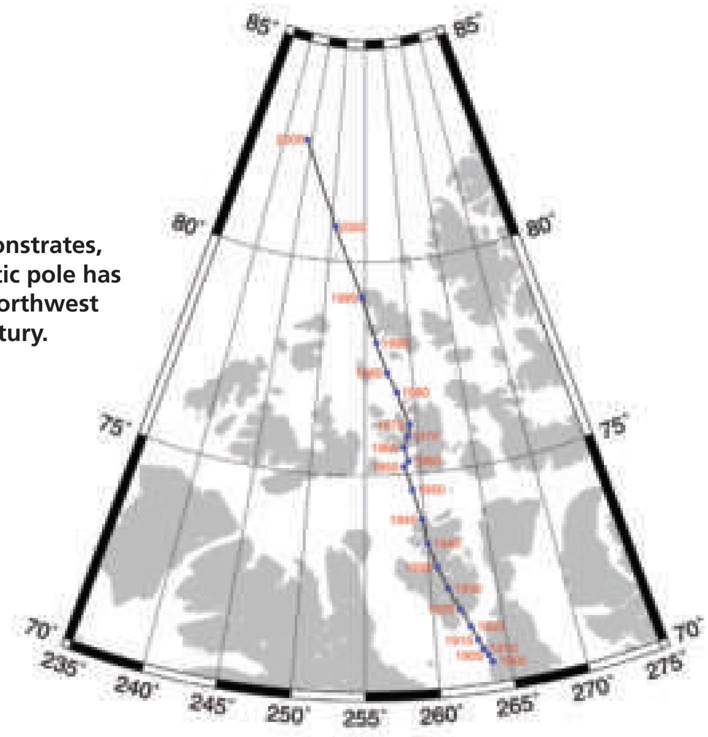
In some ways, Earth's magnetism is like that of a bar magnet. Like a bar magnet, Earth has two magnetic poles. These poles occur where the magnetic lines of force bunch together. But unlike a bar magnet, the location of these poles is continually changing. This is because Earth's overall magnetic field is continually changing.

The magnetic north pole is located in the Canadian Arctic. The magnetic south pole is located in the Antarctic Ocean, south of Australia.

There are important differences between the magnetic poles and the geographic poles. For example, the geographic North Pole is located directly opposite from the geographic South Pole. The two geomagnetic poles are not directly opposite from each other.



This diagram illustrates the locations of the geographic poles compared to the magnetic poles.



As this map demonstrates, the north magnetic pole has drifted steadily northwest over the past century.

Earth's magnetic poles can move as much as 80 kilometers in a day. They move so fast that scientists avoid talking about where they are at any one moment. Instead scientists talk about the magnetic poles' average position.

The Geological Survey of Canada (GSC) keeps track of the north magnetic pole's drift. Their records show that the pole has moved over 1,100 kilometers in the past century.

The pole does not move at the same constant rate. From 1831 to 1904, the pole barely moved. But starting around 1970, the pole began moving quite rapidly. At the time, the pole was moving at about 10 kilometers a year. The latest GSC studies show that the north magnetic pole is moving northwest at about 40 kilometers a year.

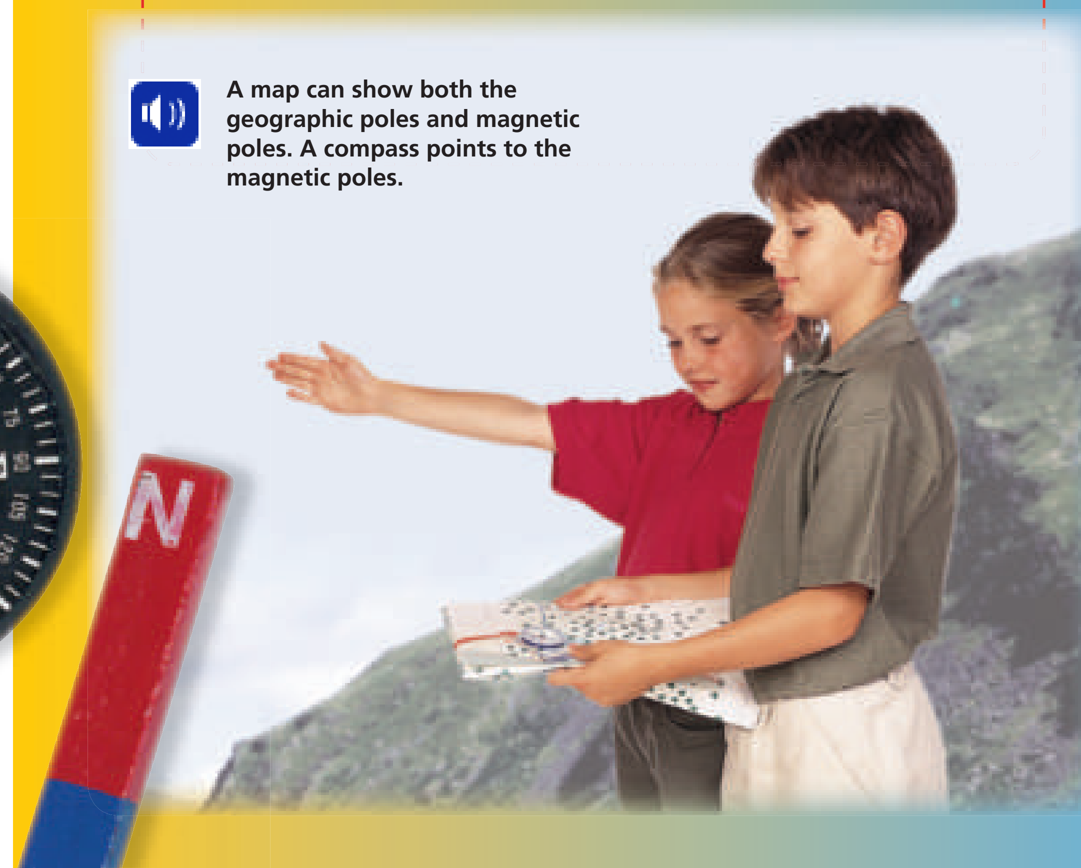
Compasses and the Magnetic Poles

The magnetic poles are constantly moving. So how can people rely on compasses? They can rely on them because of Earth's magnetic lines of force. These lines run north and south between the magnetic poles. Compass needles line up with the lines of force to point north and south. They tell a compass user where north and south are.

However, compasses become unreliable when they are used near the magnetic poles. Why? Compass needles line up with magnetic lines of force. But the lines of force bunch up near the magnetic poles. They are no longer straight, like normal lines. This makes compass needles swing away from pointing north and south. Fortunately, scientists have figured out the zones around the magnetic poles in which compasses become unreliable.

Which Way Is North?

Most travelers want to know where they are compared to the geographic poles. But compass needles point toward the magnetic poles instead. Fortunately, there is math we can use to relate the magnetic poles to the geographic poles. The numbers used to do the math change depending on your location and the position of the magnetic poles.



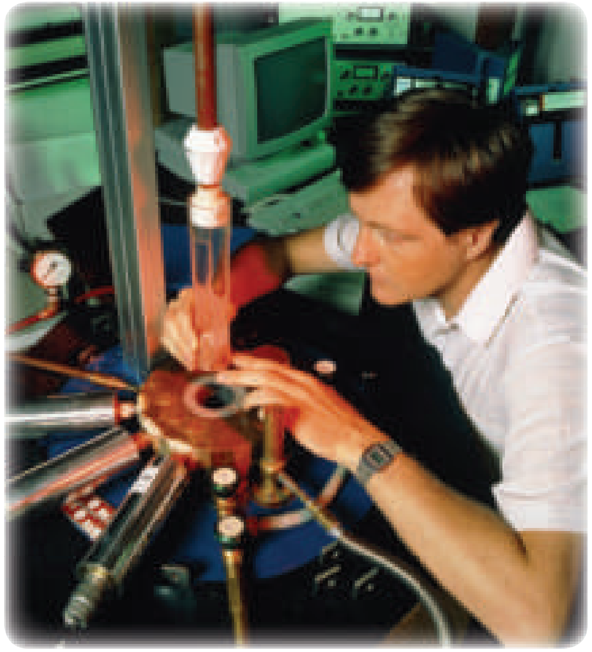
A map can show both the geographic poles and magnetic poles. A compass points to the magnetic poles.

Scientists and Magnetism

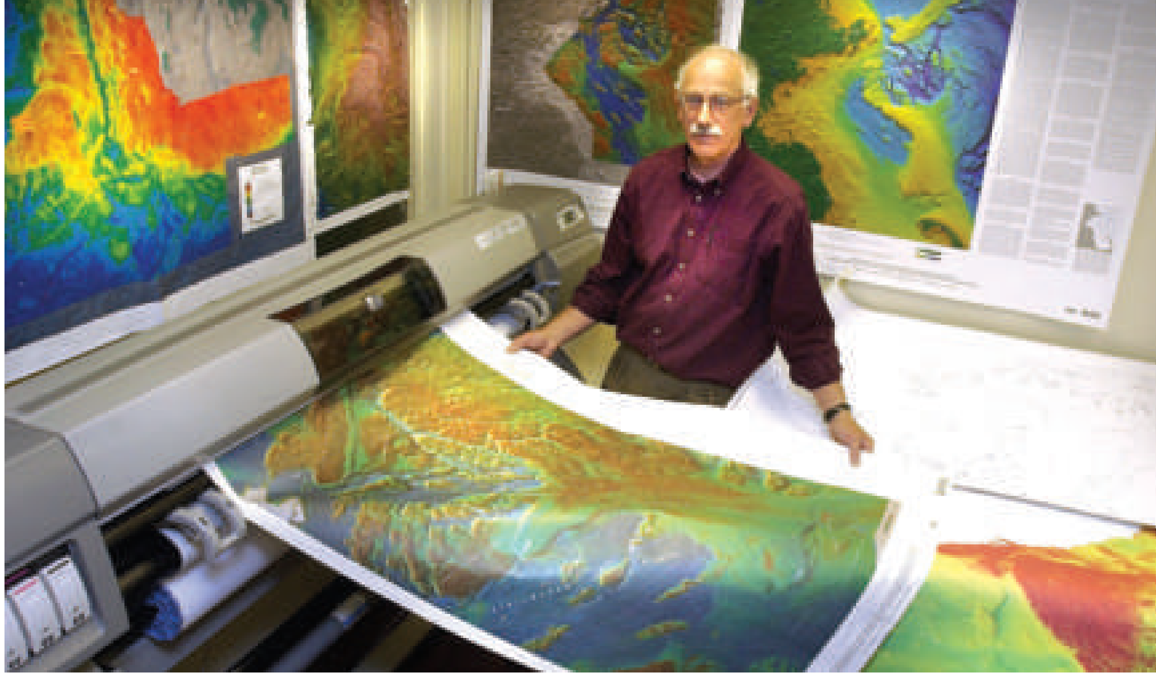
Scientists think that Earth's magnetic field has always been changing. This makes it impossible to predict accurately what the field will look like, or how it will act, in the future.

However, there are many things about Earth's magnetic field that scientists can measure. For example, scientists can measure the direction of the geomagnetic field at any one point. Scientists can also measure its strength.

Such measurements allows scientists to "see" into Earth and learn about rocks buried deep below the surface. The measurements of Earth's magnetic field can describe buried rock formations, including the faults that create earthquakes. The measurements also help scientists make predictions about changes to Earth's surface.



This scientist is researching magnetic reversals. You will read about magnetic reversals later in the book.



Here you see an oceanographer with a map of the ocean floor. The ocean floor shows evidence of Earth's past magnetic field.

Scientists who measure Earth's magnetic fields are called physicists. These physicists work with oceanographers, geologists, and seismologists. Oceanographers study the oceans. Geologists study soil and rocks. Seismologists study Earth's crust. Seismologists and geologists watch for any relationship between Earth's shifting geomagnetic field and increased earthquake activity. So far, no link has been proven.

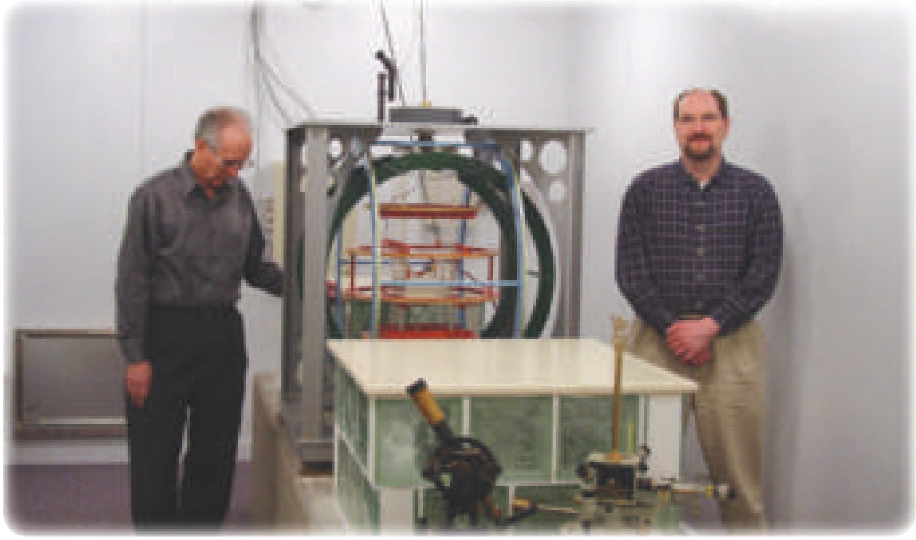
The electrical charge carried in the atmosphere and oceans affects Earth's magnetism. So meteorologists, who study climate and weather, also study geomagnetism. People who work with devices that send electronic signals understand how changes in electromagnetic fields can affect electronic communications. They can also play an important role in studying geomagnetism.

Measuring and Monitoring Magnetism

Magnetometers measure the strength of a magnetic field. Magnetic observatories use ground-based magnetometers to measure the strength of Earth's magnetic field. They also note any changes in the field's location.

There are approximately 440 magnetic observatories operating worldwide. About 100 of them have been collecting records for 50 years. Ground-based magnetometers help scientists study geomagnetism in several ways. These instruments collect minute-by-minute information about the location, range, and stability of the geomagnetic field.

These scientists work at the magnetic observatory shown below. The observatory is in Fairbanks, Alaska.



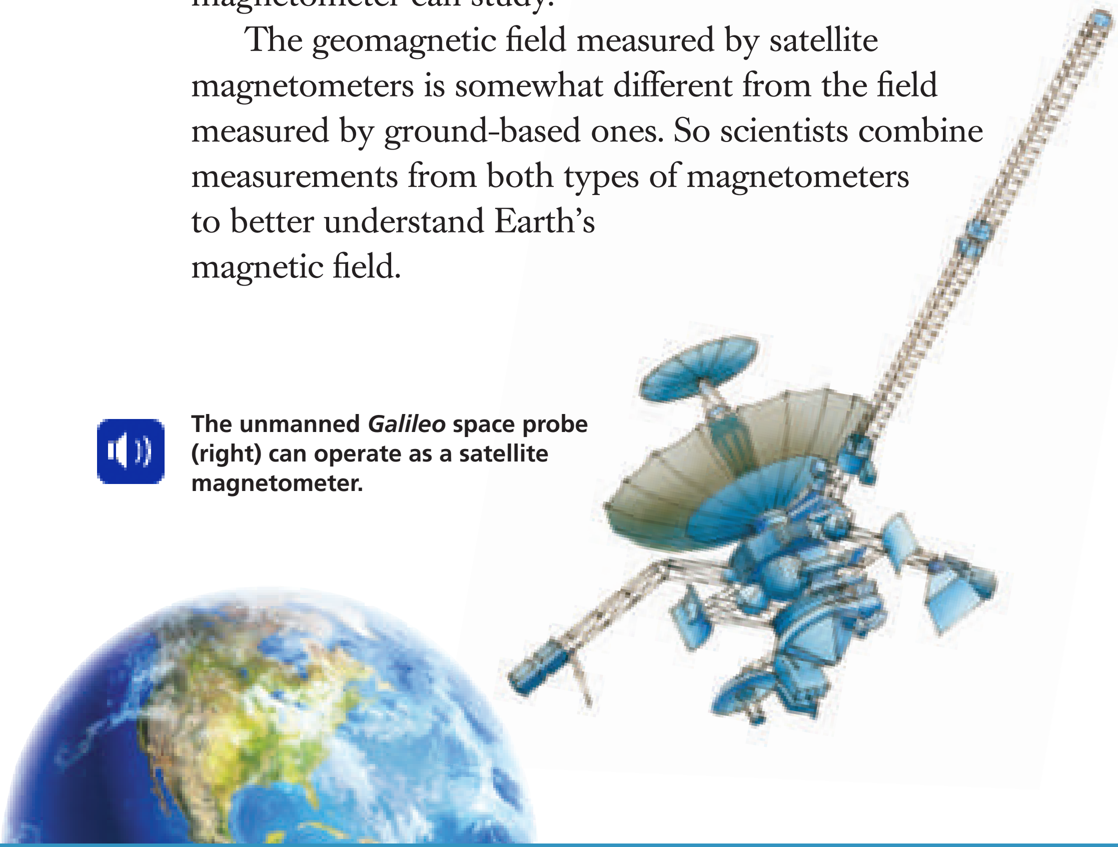
Scientists study magnetism with satellite magnetometers as well as ground-based magnetometers. *Galileo* is one kind of satellite magnetometer. It orbits Earth collecting data. The data are later used for geomagnetism studies.

There are reasons for and against using each type of magnetometer. Ground-based magnetometers are much less expensive. They are easier to set up and control. They also give us many different sets of data, all at the same time, about different parts of Earth's magnetic fields.

Satellite magnetometers have one big advantage: they cover a much wider area. Many ground-based magnetometers are needed to cover the same area that just one satellite magnetometer can study.

The geomagnetic field measured by satellite magnetometers is somewhat different from the field measured by ground-based ones. So scientists combine measurements from both types of magnetometers to better understand Earth's magnetic field.

The unmanned *Galileo* space probe (right) can operate as a satellite magnetometer.



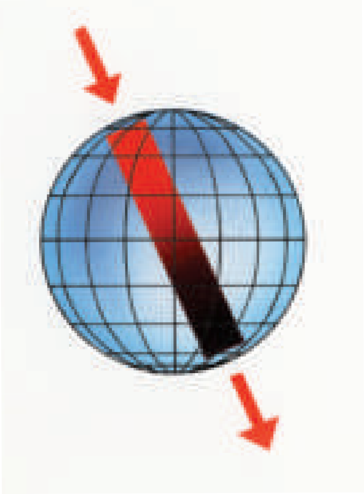
Heading for a Reverse?

Some scientists think Earth's magnetic field is getting ready to reverse. Studies of the rocks on the ocean floor show that Earth's magnetic field has strengthened, weakened, and reversed itself throughout Earth's history.

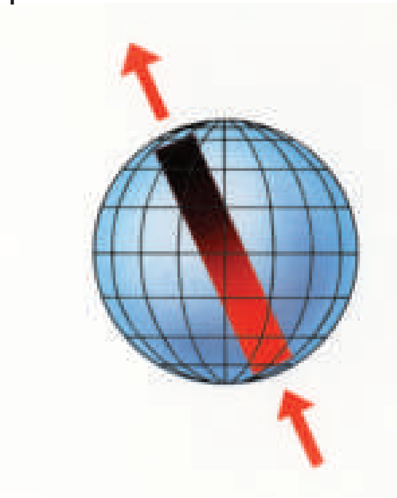
Even if Earth's magnetic field is beginning to reverse, it would still take several thousand years to complete the process. During a reversal, Earth's magnetic field would be weaker than it is now. This weaker magnetic field would also have many magnetic poles. The last time the magnetic field reversed was between about 750,000 and 780,000 years ago.

If a magnetic reversal were to occur right now, radio communications might break down. Although compasses would still work, their needles would point south.

Below are Earth's magnetic poles today, prior to a magnetic reversal.



Below are Earth's magnetic poles after a magnetic reversal. The poles have reversed themselves.



The magnetite in this sea turtle's brain might help it migrate.

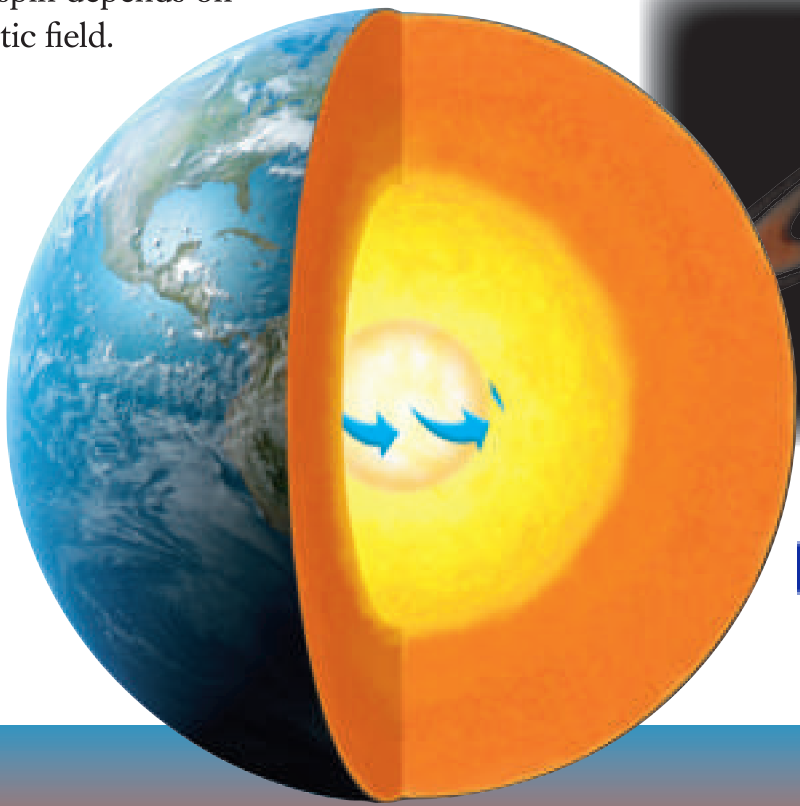
Animals might also have problems during a magnetic reversal. Many animals seem to use Earth's magnetic fields as a guide. Sea turtles, for example, are able to return and lay their eggs on the same beach where they were born. Scientists think that magnetite, a mineral found in an animal's brain, may have something to do with this ability. Animals could have problems migrating if the magnetic field were to reverse.

However, some scientists think that animals would be able to adjust to a change in the magnetic field. They have performed experiments that show animals can learn to use weaker magnetic fields similar to those that Earth might have during a reversal. Also, there is no evidence that animals have become extinct because of a reversal.

New Discoveries and Other Planets

Scientists are continually learning more about the Earth through their observations. In 2005, scientists announced that Earth's solid inner core is probably spinning faster than the rest of the planet. They learned this by studying the way earthquakes traveled through the center of Earth.

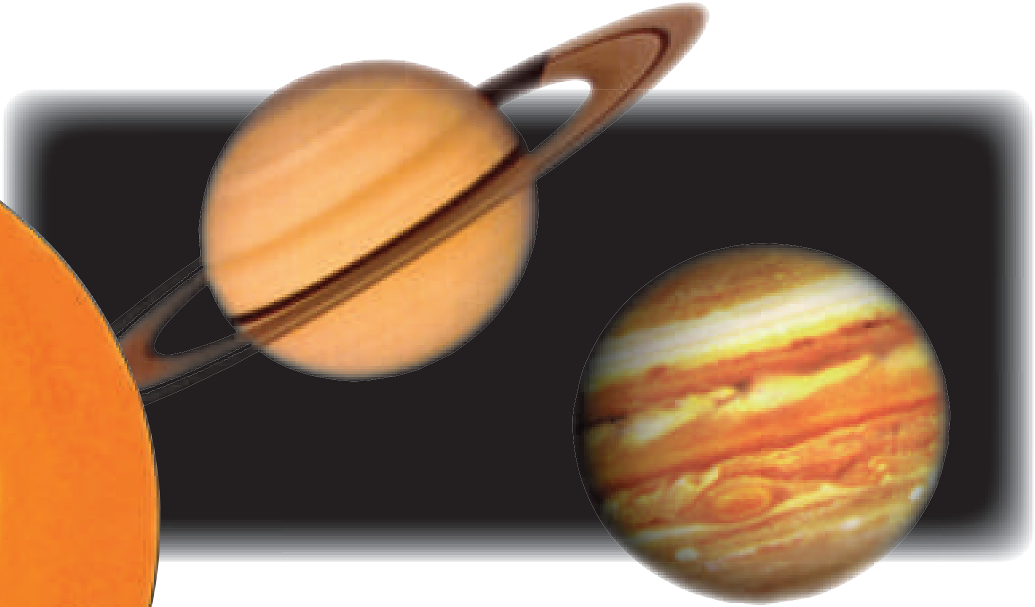
What does this have to do with magnetism? Scientists believe that the faster spin of the inner core is a result of the magnetism generated in the center of the planet. They think the core's spinning might help support dynamo theory and further explain how the Main Field is formed. They also think the rate of the inner core's spin depends on variations in Earth's magnetic field.



This cutaway illustration of Earth shows the direction of the solid inner core's spin.

Space probes have provided scientists with data that seem to show that Jupiter, Saturn, Uranus, and Neptune are magnetized. In fact, these planets have magnetic fields that are much stronger than Earth's. Mars and Venus show little magnetic activity. This might be because there is not enough pressure in their cores to produce magnetic fields.

We have now finished our tour of Earth's magnetism. Who would have thought there was so much going on with magnetism on our planet? And as it turns out, there's a lot of magnetism on other planets! One thing is for sure: scientists will continue to study magnetism on Earth, and in the universe beyond, until they've unlocked all of its mysteries.



Scientists have discovered that the magnetic fields of Saturn (left) and Jupiter (right) are stronger than Earth's.

Glossary

aurora	colorful lights caused by solar wind hitting the upper atmosphere
dynamo theory	the theory that describes how Earth's magnetic field is generated
ionosphere	the part of the upper atmosphere where electromagnetic currents flow
magnetometer	an instrument for measuring the strength of a magnetic field
magnetosphere	the space around Earth into which the geomagnetic field extends
Main Field	the part of the geomagnetic field that originates in Earth's outer core
solar wind	electrically charged matter released from the Sun
Van Allen belts	bands of harmful solar radiation trapped by Earth's magnetosphere

What did you learn?

1. For about how long has Earth's magnetic field existed?
2. How does dynamo theory explain Earth's magnetic field?
3. How does the magnetosphere protect Earth?
4. **Writing** in Science Write a paragraph about Earth's north magnetic pole. Then read the paragraph over, and revise it by adding, deleting, and moving words around.
5. **Main Idea and Details** What is the main idea of page 20? What are some details that support it?