Chapter 1

Introduction to Earth Science

Chapter Outline

Why It Matters

Scientists who study Earth explore the relationships among human society and the air, water, and soil of Earth. They also solve mysteries, such as how this heavy boulder moves on its own across a flat plain in Death Valley, California.

Inquiry Lab

15 min

How Observant Are You?

Working in groups, make and record as many observations about your classroom as you can in 10 min. Use a **magnifying glass**, a **thermometer**, and a **meterstick** to help you. Compare your observations with the observations made by other students.

Questions to Get You Started

1. Which of your observations were qualitative? Which were quantitative?
2. Think of a question about your classroom that could be answered by making more observations. What observations would you make to answer your question?

READING TOOLBOX

These reading tools will help you learn the material in this chapter.

Word Parts

Suffixes When you add the suffix *-logy* to a root word or a prefix, you form a word that means "the science of." For example, when you combine *-logy* with the prefix *bio-* (which means "life"), you form the word *biology*. Biology is the study of life.

Your Turn Two key terms in Section 1 use the suffix *-logy.* (Key terms in sections are indicated by bold text with yellow highlights.) Copy the table below and add the second key term.

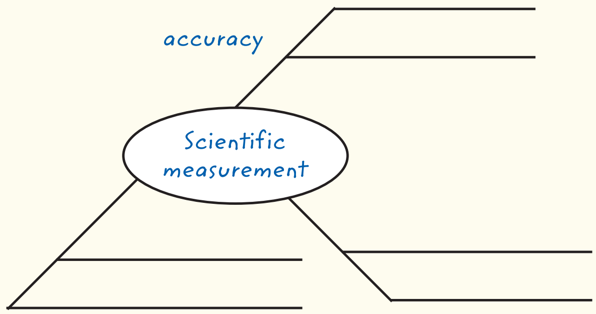
Key term	Root and its meaning	Suffix	Definition
geology	geo-, means "Earth"	-logy	the study of the origin, history, processes, and structure of the solid Earth

Graphic Organizers

Spider Maps Spider maps show how details are organized into categories that, in turn, are related to a main idea. To make a spider map, follow these steps.

1. For your title, write the main topic. Draw an oval around it.
2. From the oval, draw legs. Each leg represents a category of the main topic.
3. From each leg, draw horizontal lines. Write details about each category on these lines.

Your Turn As you read Section 2, complete a spider map like the one started here to organize the ideas you learn about scientific measurement.



Finding Examples

Words That Signal Examples As you are reading, certain words or phrases can serve as signals that an example is about to be introduced. Two of these signal phrases are "for example" and "such as."

Your Turn In Chapter 1, there are ten sentences with examples that are signaled by "for example" and ten sentences with examples that are signaled by "such as." Search the chapter to find and record three sentences that use "for example" and four sentences that use "such as."

For more information on how to use these and other tools, see **Appendix A.**

SECTION 1 What Is Earth Science?

Key Ideas	Key Terms	Why It Matters
❯ Describe two cultures that contributed to modern scientific study. ❯ Name the four main branches of Earth science. ❯ Discuss how Earth scientists help us understand the world around us.	**Earth science** **geology** **oceanography** **meteorology** **astronomy**	Earth scientists help us understand our place in Earth's history and in the universe. They can also help us gain access to Earth's resources and use these resources wisely.

For thousands of years, people have looked at the world around them and wondered what forces shaped it. Throughout history, many cultures have been terrified and fascinated by seeing volcanoes erupt, feeling the ground shake during an earthquake, or watching the sky darken during an eclipse.

Some cultures developed myths or stories to explain these events. Modern science searches for natural causes and uses careful observations to explain these same events and to understand Earth and its changing landscape.

The Scientific Study of Earth

Scientific study of Earth began with careful observations. Scientists in China began keeping records of earthquakes as early as 780 BCE. The ancient Greeks compiled a catalog of rocks and minerals around 200 BCE. Other ancient peoples, including the Maya, tracked the movements of the sun, the moon, and the planets at observatories like the one shown in **Figure 1.** The Maya used these observations to create accurate calendars.

Earth science the scientific study of Earth and the universe around it

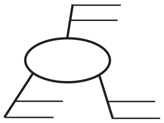
For many centuries, scientific discoveries were limited to observations of phenomena that could be seen with the unaided eye. Then, in the 16th and 17th centuries, the inventions of the microscope and the telescope made seeing previously hidden worlds possible. Eventually, the body of knowledge about Earth became known as Earth science. **Earth science** is the study of Earth and of the universe around it. Earth science, like other sciences, assumes that natural events, or phenomena, can be explained through careful observation and experimentation.

Figure 1 El Caracol, an observatory built by the ancient Maya of Central America, is one of the oldest known observatories in the Americas. Mayan calendars include the celestial movements that the Maya tracked by using observatories.

READING TOOLBOX

Spider Map

Create a spider map that summarizes the branches of Earth science. Use the green heads in this section as the legs of your spider map, and add one or two branches to each leg.



geology the scientific study of the origin, history, and structure of Earth and the processes that shape Earth

oceanography the scientific study of the ocean, including the properties and movements of ocean water, the characteristics of the ocean floor, and the organisms that live in the ocean

Academic Vocabulary

technology (tek NAHL uh jee) tools, including electronic devices

Branches of Earth Science

The ability to make observations improves when technology, such as new processes or equipment, is developed. Technology has allowed scientists to explore the ocean depths, Earth's unseen interior, and the vastness of space. Earth scientists have used technology and hard work to build an immense body of knowledge about Earth.

Most Earth scientists specialize in one of four major areas of study: the solid Earth, the oceans, the atmosphere, and the universe beyond Earth. Examples of Earth scientists working in these areas are shown in **Figure 2.**

Geology

The study of the origin, history, processes, and structure of the solid Earth is called **geology.** Geology includes many specialized areas of study. Some geologists explore Earth's crust for deposits of coal, oil, gas, and other resources. Other geologists study the forces within Earth to predict earthquakes and volcanic eruptions. Some geologists study fossils to learn more about Earth's past. Often, new knowledge forms new areas of study.

Oceanography

Oceans cover nearly three-fourths of Earth's surface. The study of Earth's oceans is called **oceanography.** Some oceanographers work on research ships that are equipped with special instruments for studying the sea. Other oceanographers study waves, tides, and ocean currents. Some oceanographers explore the ocean floor to obtain clues to Earth's history or to locate mineral deposits.

Figure 2 Fields of Study in Earth Science

Geologists who study volcanoes are called volcanologists. This volcanologist is measuring the properties of moving lava.

This astronomer is linking a telescope with a specialized instrument called a spectrograph. Information gathered will help her catalog the composition of more than 100 galaxies.

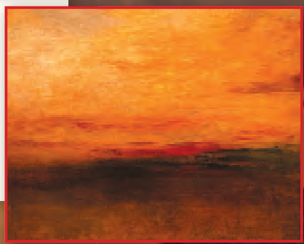
This meteorologist is studying ice samples to learn about past climate. Studying past climate patterns gives scientists information about possible future changes in climate.

Why It Matters

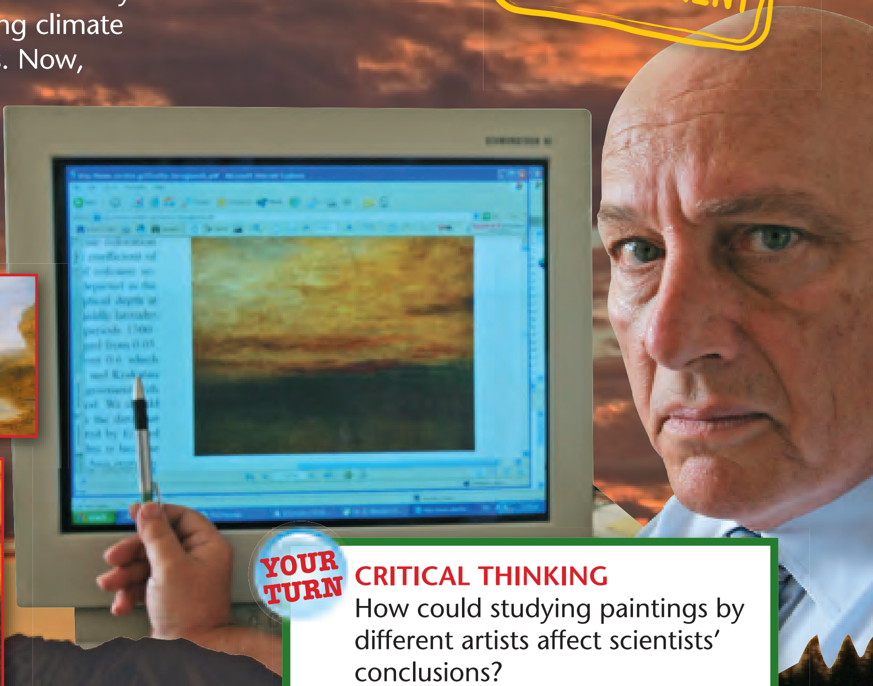
More than a Pretty Picture

EYE ON THE ENVIRONMENT

Scientists use a variety of instruments and methods to study Earth. For example, common methods for studying climate change include analyzing ice cores and tree rings. Now, one innovative scientist has turned instead to art. Scientists know that volcanic ash in the atmosphere blocks sunlight, which causes temperatures to drop. Could painting shed light on past temperatures?



J.M.W. Turner made the top painting three years before a volcanic eruption in the Philippines in 1831. He made the bottom painting in 1833. The redder sunset in the bottom painting was caused by volcanic ash.



YOUR TURN

CRITICAL THINKING
How could studying paintings by different artists affect scientists' conclusions?

Meteorology

The study of Earth's atmosphere is called **meteorology**. Using satellites, radar, and other technologies, meteorologists study the atmospheric conditions that produce weather. Many meteorologists work as weather observers and measure factors such as wind speed, temperature, and rainfall. This weather information is then used to prepare detailed weather maps. Other meteorologists use weather maps, satellite images, and computer models to make weather forecasts. Some meteorologists study *climate*, the patterns of weather that occur over long periods of time.

meteorology the scientific study of Earth's atmosphere, especially in relation to weather and climate

astronomy the scientific study of the universe

Astronomy

The study of the universe beyond Earth is called **astronomy.** Astronomy is one of the oldest branches of Earth science. In fact, the ancient Babylonians charted the positions of planets and stars nearly 4,000 years ago. Modern astronomers use Earth-based and space-based telescopes as well as other instruments to study the sun, the moon, the planets, and the universe. Technologies such as rovers and space probes have also provided astronomers with new information about the universe.

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Topic: Branches of Earth Science
Code: **HQX0191**

Reading Check **What information is used for weather maps?** (See Appendix G for answers to Reading Checks.)

Figure 3 These meteorologists are risking their lives to gather information about tornadoes. If scientists can better predict when tornadoes will occur, many lives may be saved each year.

Environmental Science and Earth Science

Some Earth scientists study the ways in which humans interact with their environment in a relatively new field of science called *environmental science*. Many fields of study, such as Earth science, biology, and the social sciences, contribute to environmental science. The goal of environmental science is to understand and solve problems that result from how we use natural resources and how our actions affect the environment.

The Importance of Earth Science

Natural forces not only shape Earth but also affect life on Earth. For example, a volcanic eruption may bury a town under ash. And an earthquake may produce huge ocean waves that destroy shorelines. By understanding how natural forces shape our environment, Earth scientists, such as those in **Figure 3,** can better predict potential disasters and help save lives and property.

The work of Earth scientists also helps us understand our place in the universe. Astronomers studying distant galaxies have come up with new ideas about the origins of our universe. Geologists studying rock layers have found clues to Earth's past environments and to the evolution of life on this planet.

Earth provides the resources that make life as we know it possible. Earth also provides the materials to enrich the quality of people's lives. The fuel that powers a jet, the metal used in surgical instruments, and the paper and ink in this book all come from Earth's resources. The study of Earth science can help people gain access to Earth's resources, but Earth scientists also strive to help people use those resources wisely.

Section 1 Review

Key Ideas

1. **Discuss** how one culture contributed to modern science.
2. **Name** the four major branches of Earth science.
3. **Describe** two specialized fields of geology.
4. **Describe** the work of oceanographers and meteorologists.
5. **Explain** how the work of astronomers has been affected by technology.

Critical Thinking

6. **Analyzing Ideas** How have Earth scientists improved our understanding of the environment?
7. **Analyzing Concepts** Give two examples of how exploring space and exploring the ocean depths are similar.

Concept Mapping

8. Use the following terms to create a concept map: *Earth science, geology, meteorology, climate, environmental science, astronomy,* and *oceanography.*

SECTION 2

Science as a Process

Key Ideas	Key Terms	Why It Matters
❯ Explain how science is different from other forms of human endeavor. ❯ Identify the steps that make up scientific methods. ❯ Analyze how scientific thought changes as new information is collected. ❯ Explain how science affects society.	**observation** **hypothesis** **independent variable** **dependent variable** **peer review** **theory**	Science helps us understand Earth, nature, and the universe. Science also helps us apply our knowledge to develop technologies which, in turn, help us solve problems and improve the condition of human society.

Art, architecture, philosophy, and science are all forms of human endeavor. Although artists, architects, and philosophers may use science in their work, science does not have the same goals as other human endeavors do.

The goal of science is to explain natural phenomena. Scientists ask questions about natural events and then work to answer those questions through experiments and examination. Scientific understanding moves forward through the work of many scientists, who build on the research of the generations of scientists before them.

Behavior of Natural Systems

Scientists start with the assumption that nature is understandable, and they expect that similar forces in a similar situation will cause similar results. But the forces involved in natural events are complex. For example, changes in temperature and humidity can cause rain in one city, but the same changes in temperature and humidity may cause fog in another city. These different results might be due to differences in the two cities or due to complex issues, such as differences in climate.

Scientists also expect that nature is predictable, which means that the future behavior of natural forces can be anticipated. So, if scientists understand the forces and materials involved in a process, they can predict how that process will evolve. The scientists in **Figure 1,** for example, are studying ice cores in Antarctica. Ice cores can provide clues to Earth's past climate changes. Because natural systems are complex, however, a high level of understanding and predictability can be difficult to achieve. To increase their understanding, scientists follow the same basic processes of studying and describing natural events.

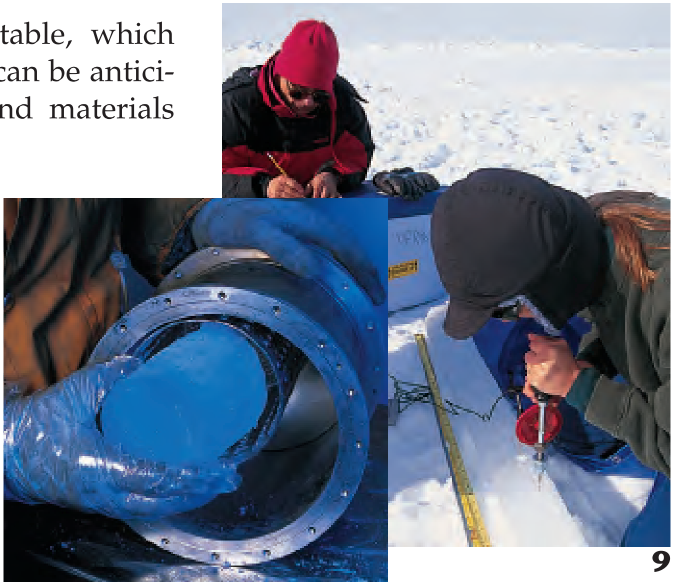

Figure 1 Scientists use ice cores to study past compositions of Earth's atmosphere. This information can help scientists learn about past climate changes.

Scientific Methods

Over time, the scientific community has developed organized and logical approaches to scientific research. These approaches are known as *scientific methods*. Scientific methods are not a set of sequential steps that scientists always follow. Rather, these methods are guidelines to scientific problem solving. **Figure 2** shows a basic flowchart of scientific methods.

Ask a Question

observation the process of obtaining information by using the senses; the information obtained by using the senses

hypothesis a testable idea or explanation that leads to scientific investigation

Scientific methods often begin with observations. **Observation** is the process of using the senses of sight, touch, taste, hearing, and smell to gather information about the world. When you see thunderclouds form in the summer sky, you are making an observation. And when you feel cool, smooth, polished marble or hear the roar of river rapids, you are making observations.

Observations can often lead to questions. What causes tornadoes to form? Why is oil discovered only in certain locations? What causes a river to change its course? What causes some plants to grow faster than others? Simple questions such as these have fueled years of scientific research and have been investigated through scientific methods.

Form a Hypothesis

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Topic: Scientific Methods
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Once a question has been asked and basic information has been gathered, a scientist may propose a tentative answer, which is also known as a hypothesis (hie PAHTH uh sis). A **hypothesis** (plural, *hypotheses*) is a possible explanation or solution to a problem. Hypotheses can be developed through close and careful observation. Most hypotheses are based on known facts about similar events. One example of a hypothesis is that plants that are given a large amount of sunlight will grow faster than plants given a smaller amount of sunlight. This hypothesis could be made from observing how and where other plants grow.

Reading Check **Name two ways scientific methods depend on careful observations.**

Figure 2 **Scientific Method Flowchart**

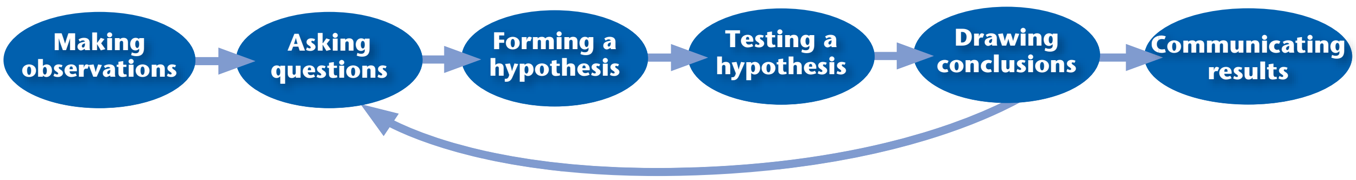

Figure 3 Astronaut Shannon Lucid observes wheat plants as a part of a controlled experiment in orbit around Earth.

independent variable in an experiment, the factor that is deliberately manipulated

dependent variable in an experiment, the factor that changes as a result of manipulation of one or more other factors (the independent variables)

Test the Hypothesis

After a hypothesis is proposed, it is often tested by performing experiments. An *experiment* is a procedure that is carried out according to certain guidelines. Factors that can be changed in an experiment are variables. **Independent variables** are factors that are changed by the person performing the experiment. **Dependent variables** are variables that change as a result of a change in independent variables.

In most experiments, only one independent variable is tested. For example, to test how sunlight affects plants, a scientist would grow identical plants. The plants would receive the same amount of water and fertilizer but different amounts of sunlight. Thus, sunlight would be the independent variable. How the plants respond to the different amounts of sunlight would be the dependent variable. Most experiments include a control group. A *control* group is a group that serves as a standard of comparison with another group to which the control group is identical except for one factor. In this experiment, the plants that receive a natural amount of sunlight would be the control group. An experiment that contains a control is called a *controlled experiment*. Most scientific experiments are controlled experiments. The "zero gravity" experiment shown in **Figure 3** is a controlled experiment.

Draw Conclusions

After many experiments and observations, a scientist may reach conclusions about his or her hypothesis. If the hypothesis fits the known facts, it may be accepted as true. If the experimental results differ from what was expected, the hypothesis may be changed or discarded. Expected and unexpected results lead to new questions and further study. The results of scientific inquiry may also lead to new knowledge and new methods of inquiry that further scientific aims.

Quick **Lab**

5 min

Making Observations

Procedure

1. Get an ordinary **candle** of any shape and color.
2. Record all the observations you can make about the candle.
3. Light the candle with a **match,** and watch it burn for 1 min.
4. Record as many observations about the burning candle as you can. When you are finished, extinguish the flame. Record any observations.

Analysis

1. Share your results with your class. How many things that your classmates observed did you not observe? Explain this phenomenon.

Good accuracy and good precision

Poor accuracy but good precision

Good overall accuracy but poor precision

Figure 4 Accuracy and Precision

THINK central
INTERACT ONLINE
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Scientific Measurements and Analysis

During an experiment, scientists must gather information. An important method of gathering information is measurement. Measurement is the comparison of some aspect of an object or event with a standard unit. Scientists around the world can compare and analyze each other's measurements because scientists use a common system of measurement called the *International System of Units*, or SI. This system includes standard measurements for length, mass, temperature, and volume. All SI units are based on intervals of 10. The Reference Tables section of the Appendix contains a chart of SI units.

Accuracy and Precision

Accuracy and precision are important in scientific measurements. *Accuracy* refers to how close a measurement is to the true value of the thing being measured. *Precision* is the exactness of the measurement. For example, a distance that is measured in millimeters is more precise than a distance that is measured in centimeters. Measurements can be precise and yet inaccurate. The relationship between accuracy and precision is shown in **Figure 4.**

Quick Lab — Sample Size and Accuracy

15 min

Procedure

1. Shuffle a **deck of 52 playing cards** eight times.
2. Lay out 10 cards. Record the number of red cards.
3. Reshuffle, and repeat step 2 four more times.
4. Which trials showed the highest number and lowest number of red cards? Calculate the total range of red cards by finding the difference between the highest number and lowest number.
5. Determine the mean number of red cards per trial by adding the number of red cards in the five trials and then dividing by 5.

Analysis

1. A deck of cards has 50% red cards. How close is your average to the percentage of red cards in the deck?
2. Pool the results of your classmates. How close is the new average to the percentage of red cards in the deck?
3. How does changing the sample size affect accuracy?

Error

Error is an expression of the amount of imprecision or variation in a set of measurements. Error is commonly expressed as percentage error or as a confidence interval. Percentage error is the percentage of deviation of an experimental value from an accepted value. A *confidence interval* describes the range of values for a set percentage of measurements. For example, imagine that the average length of all of the ears of corn in a field is 23 cm, and 90% of the ears are within 3 cm of the average length. A scientist may report that the average length of all of the ears of corn in a field is 23 ± 3 cm with 90% confidence.

Math Skills

Percentage Error

Percentage error is calculated by using the following equation:

$$\text{percent error} = \left[\frac{(\text{accepted value} - \text{experimental value})}{\text{accepted value}}\right] \times 100$$

If the accepted value for the weight of a gallon of water is 3.78 kg and the measured value is 3.72 kg, what is the percentage error for the measurement? Show your work.

Observations and Models

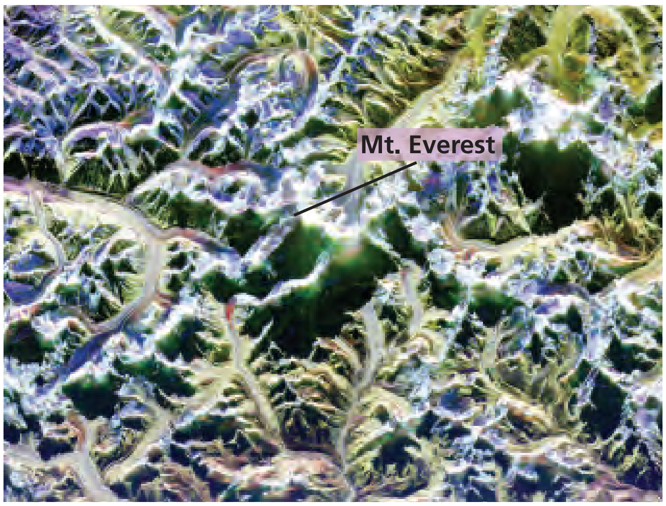
In Earth science, using controlled experiments to test a hypothesis is often impossible. When experiments are impossible, scientists make additional observations to gather evidence. The hypothesis is then tested by examining how well the hypothesis fits or explains all of the known evidence.

Scientists also use models to simulate conditions in the natural world. A *model* is a description, representation, or imitation of an object, system, process, or concept. Scientists use several types of models, two of which are shown in **Figure 5.** Physical models are three-dimensional models that can be touched. Maps and charts are examples of graphical models.

Conceptual models are verbal or graphical models that represent how a system works or is organized. Mathematical models are mathematical equations that represent the way a system or process works. Computer models are a kind of mathematical model that use the high speed and efficiency of a computer to make calculations and display results. After a good computer model has been created, scientists can perform experiments by manipulating variables much as they would when performing a physical experiment.

Reading Check **Name three types of models.**

Figure 5 Two models of Mount Everest are shown below. The computer model on the right is used to track erosion along the Tibetan Plateau. The model on the left is a physical model.



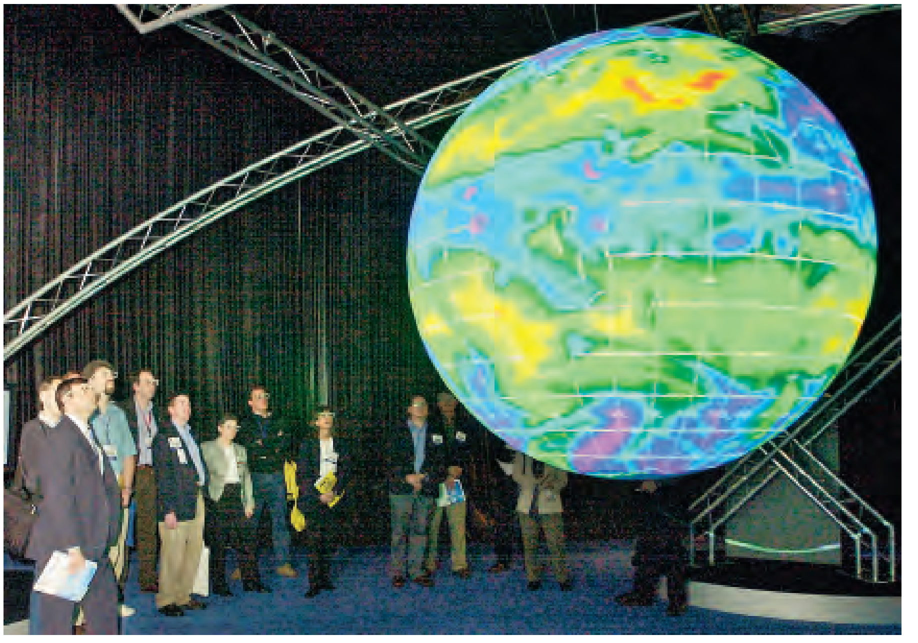


Figure 6 Meteorologists at a conference in California are watching the "Science On a Sphere™" exhibit. They are wearing 3-D glasses to better see the complex and changing three-dimensional display of global temperatures.

Acceptance of Scientific Ideas

When scientists reach a conclusion, they introduce their findings to the scientific community. New scientific ideas undergo review and testing by other scientists before the ideas are accepted.

Publication of Results and Conclusions

Scientists commonly present the results of their work in scientific journals or at professional meetings, such as the one shown in **Figure 6.** Results published in journals are usually written in a standard scientific format. Many journals are now being published online to allow scientists quicker access to the results of other scientists and to reduce the costs of printing journals.

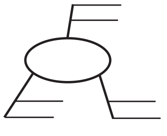
Peer Review

Scientists in any one research group tend to view scientific ideas similarly. Therefore, they may be biased in their experimental design or data analysis. To reduce bias, scientists submit their ideas to other scientists for peer review. **Peer review** is the process in which several experts on a given topic review another expert's work on that topic before the work gets published. These experts determine if the results and conclusions of the study merit publication. Peer reviewers commonly suggest improvements to the study, or they may determine that the results or conclusions are flawed and recommend that the study not be published. Scientists follow an ethical code that states that only valid experimental results should be published. The peer review process serves as a filter that allows only well-supported ideas to be published.

Reading Check **Name two places scientists present the results of their work.**

READING TOOLBOX

Spider Map
Create a spider map that outlines the process that new scientific ideas go through before they are accepted by the scientific community. Label the center of your spider map "Acceptance of a new scientific idea," and create a leg for each part of the process. Add details about each part of the process to its corresponding leg.



peer review the process in which experts in a given field examine the results and conclusions of a scientist's study before that study is accepted for publication

Formulating a Theory

After results are published, they usually lead to more experiments, which are designed to test and expand the original idea. This process may continue for years until the original idea is disproved, is modified, or becomes generally accepted. Sometimes, elements of different ideas are combined to form concepts that are more complete.

When an idea has undergone much testing and reaches general acceptance, that idea may help form a theory. A **theory** is an explanation that is consistent with all existing tests and observations. Theories are often based on scientific laws. A *scientific law* is a general statement that describes how the natural world behaves under certain conditions and for which no exceptions have been found. Like theories, laws are discovered through scientific research. Theories and scientific laws can be changed if conflicting information is discovered in the future.

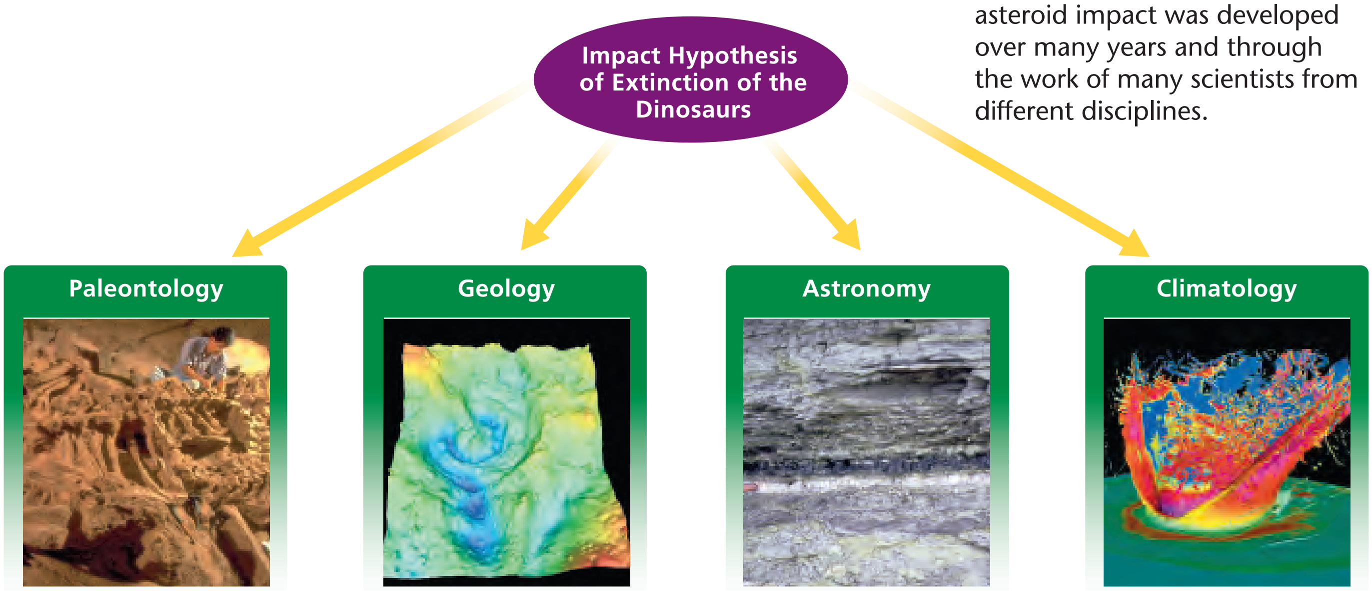
Academic Vocabulary

concept (KAHN sept) an idea or a thought

theory a system of ideas that explains many related observations and is supported by a large body of evidence acquired through scientific investigation

The Importance of Interdisciplinary Science

Scientists from many disciplines commonly contribute the information necessary to support an idea. The free exchange of ideas between fields of science allows scientists to identify explanations that fit a wide range of scientific evidence. When an explanation is supported by evidence from a variety of fields, the explanation is more likely to be accurate. New disciplines of science sometimes emerge as a result of new connections that are found between more than one branch of science. An example of the development of a widely accepted hypothesis that is based on interdisciplinary evidence is shown in **Figure 7.**



No dinosaur fossils exist in rock layers younger than 65 million years old.

A large impact crater about 65 million years old exists in the ocean near the Yucatan Peninsula.

A layer of iridium occurs in rocks about 65 million years old all around Earth. Iridium is rare on Earth, but is common in asteroids.

Climate models predict that a large impact would change Earth's climate and affect life on Earth.

Figure 7 The hypothesis that the dinosaurs were killed by an asteroid impact was developed over many years and through the work of many scientists from different disciplines.

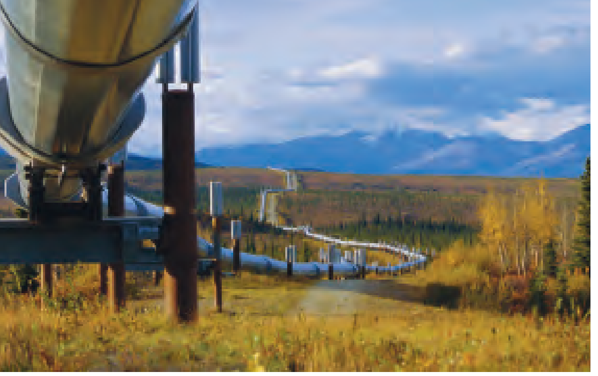


Figure 8 The Alaskan pipeline has carried more than 15 billion barrels of oil since it was built in 1977. The pipeline has also sparked controversy about the potential dangers to nearby Alaskan wildlife.

Science and Society

Scientific knowledge helps us understand our world. The work of people, including scientists, is influenced by their cultural and personal beliefs. Science is a part of society, and advances in science can have important and long-lasting effects on both science and society. Examples of these far-reaching advances include the theory of plate tectonics, quantum mechanics, and the theory of evolution.

Science is also used to develop new technology, including new tools, machines, materials, and processes. Sometimes, technologies are designed to address a specific human need. In other cases, technology is an indirect result of science that was directed at another goal. For example, technology that was designed for space exploration has been used to improve computers, cars, medical equipment, and airplanes.

However, new technology may also create new problems. Scientists involved in research that leads to new technologies may or may not consider the possible negative effects of their work. Before making decisions about the technology they adopt, people should consider alternatives, risks, and costs and benefits to humans, to other life, and to Earth. Even after decisions are made, society often continues to debate them. For example, the Alaskan pipeline, part of which is shown in **Figure 8,** transports oil. But the transport of oil in the United States is part of an ongoing debate about how we use oil resources and how these uses affect our natural world.

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Topic: Careers in Earth Science
Code: HQX0222

Section 2 Review

Key Ideas

1. **Describe** one reason that a scientist might conduct research.
2. **Identify** the steps that make up scientific methods.
3. **Compare** a hypothesis with a theory.
4. **Describe** how scientists test hypotheses.
5. **Describe** the difference between a dependent variable and an independent variable.
6. **Describe** the conditions under which scientific laws and theories can be changed.
7. **Summarize** how scientific methods contribute to the development of modern science.
8. **Explain** how technology can affect scientific research.

Critical Thinking

9. **Analyzing Ideas** An observation can be precise but inaccurate. Do you think it is possible for an observation to be accurate but not precise? Explain.
10. **Making Comparisons** When an artist paints a picture of a natural scene, what aspects of his or her work are similar to the methods of a scientist? What aspects are different?
11. **Demonstrating Reasoned Judgment** A new technology is known to be harmful to a small group of people. How does this knowledge affect whether you would use this new technology? Explain.

Concept Mapping

12. Use the following terms to create a concept map: *independent variable, observation, experiment, dependent variable, hypothesis, scientific methods,* and *conclusion.*

Why It Matters

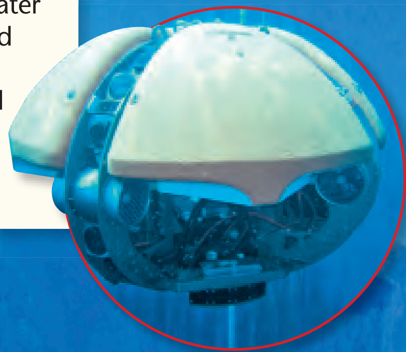
How Do Robots Go to Extremes?

REAL WORLD

Scientific observation is not always easy. Earth scientists often need to go to extreme places to make observations and gather data. But some places are too extreme, even for the most daring scientists. How can scientists gather data in places that are too cold, too hot, too deep, or too far away?

The answer, more and more often, is robots. Robots can be designed to withstand extreme conditions, such as intense cold. They also can be outfitted with special tools and abilities for their missions. For example, one robot, which was designed for research in Antarctica, hovers like a helicopter and flies at speeds up to 100 km/h. It uses a camera and infrared sensor to observe the ice below. Another robot is designed to glide across snowy slopes and icy crevasses.

Robovolc explores volcanoes and collects samples to analyze. Its six rugged wheels keep it stable on jagged volcanic terrain. Its gripper is engineered to pick up rock samples.



DEPTHX, an underwater rover, can be lowered hundreds of meters into deep, uncharted sinkholes such as El Zacatón cenote in central Mexico.

Mars Science Laboratory (MSL) is the next-generation Mars rover. Its lab equipment will help scientists study Mars's geology, and possible biology, in greater detail than ever before.

Micro-scale nanobots are so small that their components can be single molecules! As shown in this artwork, this technology may one day produce devices that can enter the human bloodstream and target specific cells or viruses.

YOUR TURN **ONLINE RESEARCH**

How is the Mars Science Laboratory rover similar to the current Mars rovers, *Spirit* and *Opportunity*? How is it different?

Inquiry Lab

90 min

What You'll Do

- **Observe** natural phenomena.
- **Propose** hypotheses to explain natural phenomena.
- **Evaluate** hypotheses.

What You'll Need

hand lens
meterstick

Scientific Methods

Not all scientists think alike, and scientists don't always agree about various concepts. However, all scientists use scientific methods, part of which are the skills of observing, inferring, and predicting. In this lab, you will apply scientific methods as you examine a place where puddles often form after rainstorms. You can study the puddle area even when the ground is dry, but it would be best to observe the area again when it is wet. Because water is one of the most effective agents of change in our environment, you should be able to make many observations.

Make Observations

1. Examine the area of the puddle and the surrounding area carefully. Make a numbered list of what can be seen, heard, smelled, or felt. Sample observations are as follows: "The ground where the puddle forms is lower than the surrounding area, and there are cracks in the soil." Remember to avoid making any suggestions of causes.

Form a Hypothesis

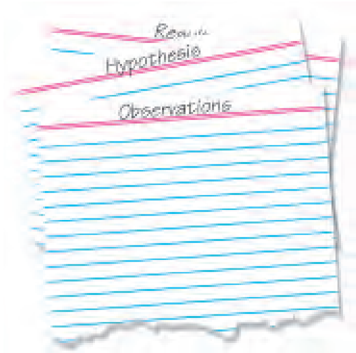
2. Review your observations, and write possible hypotheses for those observations. A sample hypothesis might be "Cracks in the soil (Observation 2) may have been caused by a lack of rain (Observation 5)."
3. Review your observations and possible hypotheses, and place them into similar groups, if possible. Can one hypothesis or set of hypotheses explain several observations? Is each hypothesis reasonable when compared with the others? Does any hypothesis contradict any of the other observations?

Step 1

Test the Hypothesis

4. Based only on your hypotheses, make some predictions about what will happen at the puddle as conditions change. Describe the changes you expect and your reasoning. A sample prediction is the following: "If the puddle dries out, the crack will grow wider because of the loss of water."

5. Revisit the puddle several times to see if the changes that you observe match your predictions.



Step 2

Analyze the Results

1. **Evaluating Results** Which of your predictions were correct, and which predictions were incorrect?

2. **Analyzing Methods** Which of your senses did you use most to make your observations? How could you improve your observations by using this sense? by using other senses?

3. **Evaluating Methods** What could you have used to measure, or quantify, many of your observations? Is quantitative observation better than qualitative observation? Explain your answer.

Draw Conclusions

4. **Drawing Conclusions** Examine your incorrect predictions. What new knowledge have you gained from them?

5. **Analyzing Results** Reexamine your hypotheses. What can you say now about the ones that were correct?

6. **Drawing Conclusions** When knowledge is derived from observation and prediction, this process uses *scientific methods*. After reporting the results of a prediction, how might a scientist continue his or her research?

Extension

Designing Experiments Choose another small area to examine, but look for changes caused by a different factor, such as wind. Follow the steps outlined in this lab to predict changes that will occur in the area. Use scientific methods to design an experiment. Briefly describe your experiment, including how you would perform it.

MAPS in Action

Geologic Features and Political Boundaries in Europe

Map Skills Activity

This map shows the political boundaries of a part of Europe. The map also shows some surface features. Use the map to answer the questions below.

1. **Using a Key** What do the blue lines represent?
2. **Analyzing Data** How many countries are represented on the map?
3. **Examining Data** What country has two smaller countries within its borders?
4. **Applying Ideas** What type of surface features define the political boundary between Romania and Moldova and the political boundary between Switzerland and Germany?
5. **Applying Ideas** What type of surface feature defines the political boundary between Poland and Slovakia?
6. **Making Inferences** Why do you think that political boundaries commonly correspond with surface features?

Chapter 1 Summary

THINK central SUPER SUMMARY Keyword: HQXIESS

Section 1

Key Ideas

What Is Earth Science?

- Many cultures, including the ancient Greeks and Maya, contributed to the development of modern scientific study.
- The four main branches of Earth science are geology, oceanography, meteorology, and astronomy.
- Earth scientists help us understand how Earth formed and the natural forces that affect human society.

Key Terms

Earth science, p. 5
geology, p. 6
oceanography, p. 6
meteorology, p. 7
astronomy, p. 7

Section 2

Science as a Process

- Science differs from other human endeavors by following a procedure of testing to help understand natural phenomena.
- The steps that make up scientific methods include asking questions, forming hypotheses, testing hypotheses, and drawing conclusions.
- New scientific thought undergoes review and testing by other scientists before new ideas are accepted.
- Science affects society by helping us understand our world. Science is also used to develop new technology that can help solve existing problems as well as create new problems that require solutions.

Key Terms

observation, p. 10
hypothesis, p. 10
independent variable, p. 11
dependent variable, p. 11
peer review, p. 14
theory, p. 15

Chapter 1 Review

1. **Word Parts** Write the word *astronomy* and its definition. Then use a dictionary to look up the meanings of *astro-* and *-nomy*. Do this for two more words that have the suffix *-nomy*.

READING TOOLBOX

USING KEY TERMS

Use each of the following terms in a separate sentence.

2. *observation*
3. *peer review*
4. *theory*

For each pair of terms, explain how the meanings of the terms differ.

5. *hypothesis* and *theory*
6. *geology* and *astronomy*
7. *oceanography* and *meteorology*
8. *dependent variable* and *independent variable*
9. *Earth science* and *geology*

UNDERSTANDING KEY IDEAS

10. The study of solid Earth is called
    a. geology. **c.** oceanography.
    b. meteorology. **d.** astronomy.
11. The Earth scientist most likely to study storms is a(n)
    a. geologist.
    b. meteorologist.
    c. oceanographer.
    d. astronomer.
12. The study of the origin of the solar system and the universe in general is
    a. geology.
    b. ecology.
    c. meteorology.
    d. astronomy.
13. How long ago were the first scientific observations about Earth made?
    a. a few years ago
    b. a few decades ago
    c. hundreds of years ago
    d. several thousand years ago
14. The Earth scientist most likely to study volcanoes is a(n)
    a. geologist.
    b. meteorologist.
    c. oceanographer.
    d. astronomer.
15. One possible first step in scientific problem solving is to
    a. form a hypothesis.
    b. ask a question.
    c. test a hypothesis.
    d. state a conclusion.
16. A possible explanation for a scientific problem is called a(n)
    a. experiment. **c.** observation.
    b. theory. **d.** hypothesis.
17. A statement that consistently and correctly explains a natural phenomenon is
    a. a hypothesis. **c.** an observation.
    b. a theory. **d.** a control.
18. When scientists pose questions about how nature operates and attempt to answer those questions through testing and observation, they are conducting
    a. research. **c.** examinations.
    b. predictions. **d.** peer reviews.

SHORT ANSWER

19. How does accuracy differ from precision in a scientific measurement?
20. Why do scientists use control groups in experiments?
21. A meteorite lands in your backyard. What two branches of Earth science would help you explain that natural event?
22. Write a short paragraph about the relationship between science and technology.
23. Give two reasons why interdisciplinary science is important to society.
24. Explain how peer review affects scientific knowledge.
25. How did some ancient cultures explain natural phenomena?

CRITICAL THINKING

26. Making Connections How could knowing how our solar system formed affect our understanding of the universe?

27. Evaluating Hypotheses Some scientists have hypothesized that meteorites have periodically bombarded Earth and caused mass extinctions every 26 million years. How might this hypothesis be tested?

28. Determining Cause and Effect Name some possible negative effects of a new technology that uses nuclear fuel to power cars.

29. Analyzing Ideas A scientist observes that each eruption of a volcano is preceded by a series of small earthquakes. The scientist then makes the following statement: "Earthquakes cause volcanic eruptions." Is the scientist's statement a hypothesis or a theory? Why?

30. Forming a Hypothesis You find a yellow rock and wonder if it is gold. How could you apply scientific methods to this problem?

CONCEPT MAPPING

31. Use the following terms to create a concept map: *control group, accuracy, precision, variable, technology, Earth science, experiment,* and *error*.

MATH SKILLS

Math Skills

32. Making Calculations One kilogram is equal to 2.205 lb at sea level. At the same location, how many kilograms are in 100 lb?

33. Making Calculations One meter is equal to 3.281 ft. How many meters are in 5 ft?

34. Making Calculations The accepted value of the average distance between Earth and the moon is 384,467 km. If a scientist measures that the moon is 384,476 km from Earth, what is the measurement's percentage error?

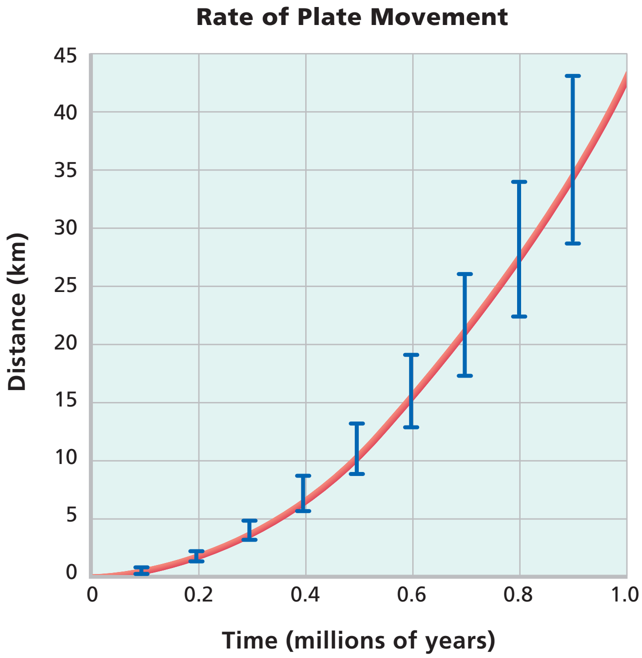
WRITING SKILLS

35. Expressing Original Ideas Imagine that you must live in a place that has all the benefits of only one of the Earth sciences. Which branch would you choose? Defend your choice in an essay.

36. Outlining Topics Explain the sequence of events that happens as a scientific hypothesis becomes a theory.

INTERPRETING GRAPHICS

The graph below shows error in measuring tectonic plate movements. The blue bars represent confidence intervals. Use this graph to answer the questions that follow.



37. How much error is there in the smallest measurement of plate movement?

38. How much error is there in the largest measurement of plate movement?

39. How would you explain the difference between the error in the smallest measurement and the error in the largest measurement?

Standardized Test Prep

Understanding Concepts

Directions (1–5): For each question, write on a separate sheet of paper the letter of the correct answer.

1. A tested explanation of a natural phenomenon that has become widely adopted is a scientific
   - **A.** hypothesis.
   - **B.** law.
   - **C.** theory.
   - **D.** observation.
2. If experimental results do not match their predictions, scientists generally will
   - **F.** repeat the experiment until they do match.
   - **G.** make the measurements more precise.
   - **H.** revise their working hypothesis.
   - **I.** change their experimental results.
3. Scientists who study weather charts to analyze trends and to predict future weather events are
   - **A.** astronomers.
   - **B.** environmental scientists.
   - **C.** geologists.
   - **D.** meteorologists.
4. What type of model uses molded clay, soil, and chemicals to simulate a volcanic eruption?
   - **F.** conceptual model
   - **G.** physical model
   - **H.** mathematical model
   - **I.** computer model
5. Which of the following is an example of a new technology?
   - **A.** a tool that is designed to help a doctor better diagnose patients
   - **B.** a previously unknown element that is discovered in nature
   - **C.** a law that is passed to fund scientists conducting new experiments
   - **D.** scientists that record observations on the movement of a star

Directions (6–7): For each question, write a short response.

6. What is the term for the factors that change as a result of a scientific experiment?
7. Why do scientists often review one another's work before it is published?

Reading Skills

Directions (8–10): Read the passage below. Then, answer the questions.

Scientific Investigation

Scientists look for answers by asking questions. These questions are often answered through experimentation and observation. For example, scientists have wondered if there is some relationship between Earth's core and Earth's magnetic field.

To form their hypothesis, scientists started with what they knew: Earth has a dense, solid inner core and a molten outer core. They then created a computer model to simulate how Earth's magnetic field is generated. The model predicted that Earth's inner core spins in the same direction as the rest of Earth does but slightly faster than the surface does. If the hypothesis is correct, it might explain how Earth's magnetic field is generated. But how could the researchers test the hypothesis? Because scientists do not have the technology to drill to the core, they had to get their information indirectly. To do this, they decided to track the seismic waves that are created by earthquakes. These waves travel through Earth, and scientists can use them to infer information about the core.

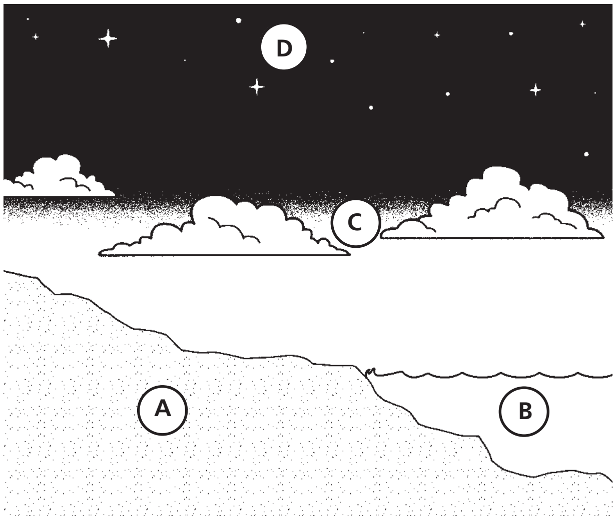
8. The possibility of a connection between Earth's core and Earth's magnetic field formed the basis of the scientist's what?
   - **F.** theory
   - **G.** law
   - **H.** hypothesis
   - **I.** fact
9. To begin their investigation, the scientists first built a model. What did this model predict?
   - **A.** Earth's outer core is molten, and the inner core is solid.
   - **B.** Earth's inner core is molten, and the outer core is solid.
   - **C.** Earth's inner core spins in the same direction as the rest of Earth does.
   - **D.** Earth's outer core spins in the same direction as the rest of Earth does.
10. Why might the scientists have chosen to build a computer model of Earth, instead of a physical model of Earth?

Interpreting Graphics

Directions (11–12): For each question below, record the correct answer on a separate sheet of paper.

The diagram below shows the four major areas studied by Earth scientists. Use this diagram to answer question 11.

Branches of Earth Science

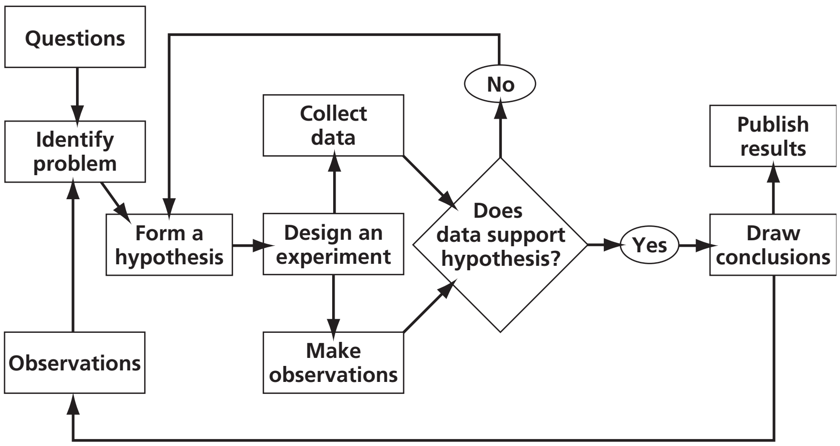


11. A scientist studying the events that take place in area C would be primarily concerned with which of the following?

F. Earth's age
G. Earth's weather
H. movement of waves and tides
I. movement of the stars across the sky

Use the flowchart below to answer question 12.

Using a Scientific Method



12. What are two possible outcomes of the experimental process? What would a scientist do with the information gathered during the experimental process?

Test Tip

If you are unsure of an answer, eliminate the answers that you know are wrong before choosing your response.