

# Unit 1

## Earth Science

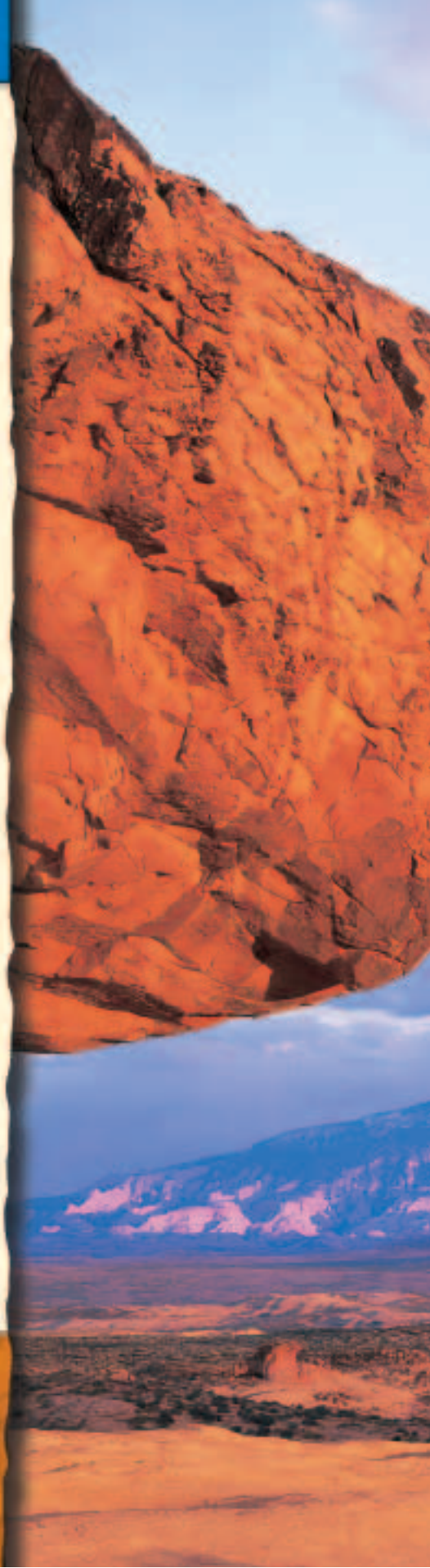
**E**arth science is a blend of many different sciences, including geology, meteorology, oceanography, and astronomy. Earth scientists in these different specialties study and model the processes that change our planet. Some of these changes take place in a matter of seconds; others take millions of years to occur. The rocks and structures shown here formed millions of years ago as a result of many interactions among some of Earth's systems. In this unit, you'll learn about some of the methods used by Earth scientists, how various parts of Earth interact to produce changes, and how our planet can be represented by models known as maps.

### Unit Contents

- 1 The Nature of Science
- 2 Mapping Our World



Go to the [National Geographic Expedition](#) on page 864 to learn more about topics that are connected to this unit.





Sunset Arch, Grand Staircase—  
Escalante Wilderness, Utah



# Chapter 1

## What You'll Learn

- How Earth science is a blend of sciences.
- How Earth's four major systems interact.
- What is involved in carrying out scientific experiments.
- Why it is important to communicate scientific methods and results accurately.

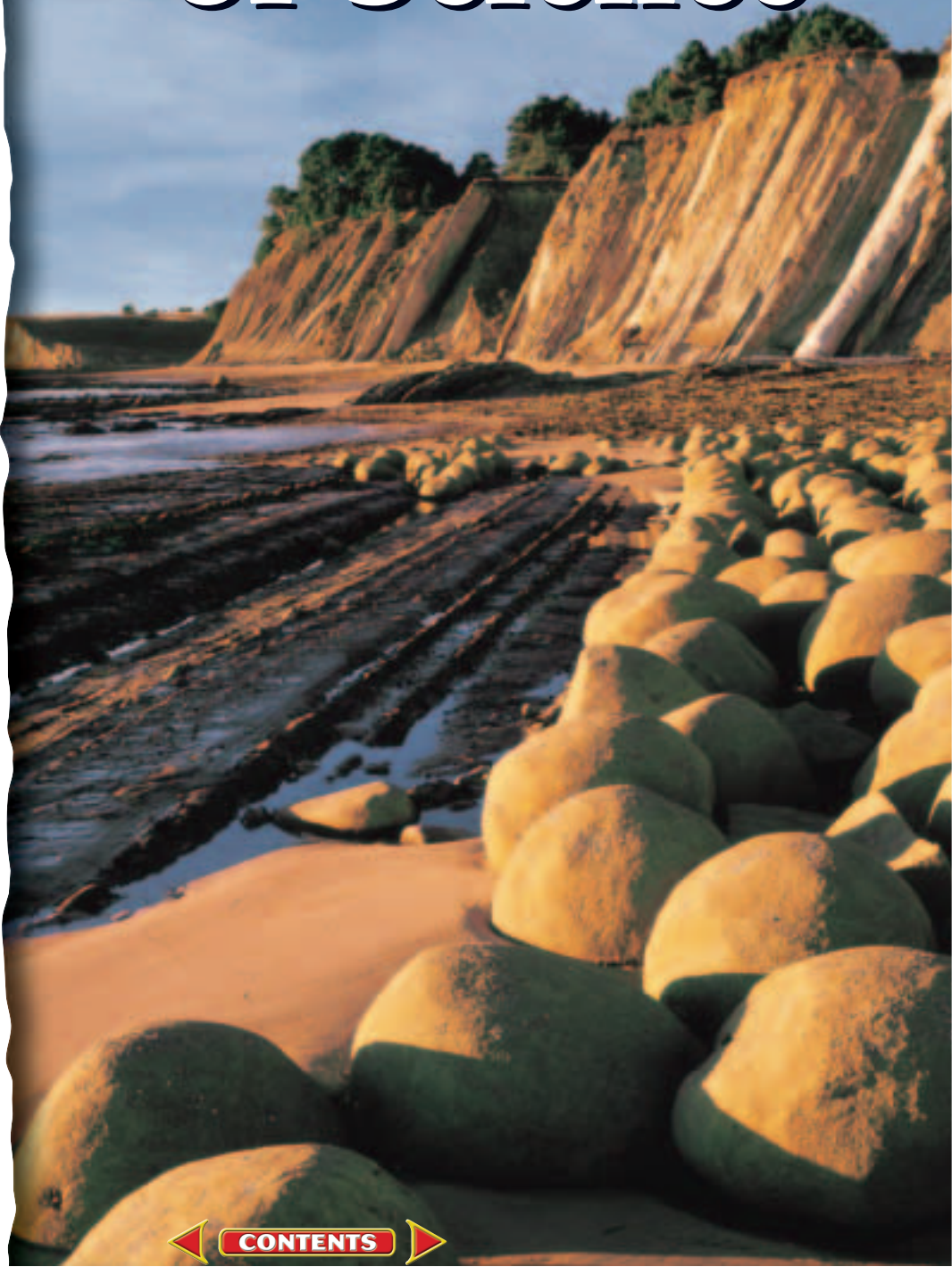
## Why It's Important

In order to better understand Earth and how its processes affect our lives and the environment, it is necessary to learn about its major systems, the methods used by Earth scientists, and how scientific work is done.



To find out more about the planet on which you live, visit the Earth Science Web Site at [earthgeu.com](http://earthgeu.com)

# The Nature of Science



## Discovery Lab

Have you ever explained something to someone only to later find out that what you thought was a crystal-clear explanation was confusing, misleading, or even incorrect? Communication is a very important skill both in everyday life and in science. In this activity, you will work with a partner to describe objects provided by your teacher.

1. Obtain an object from your teacher. Don't show it to your partner.
2. Write only one sentence that accurately describes the object in detail without actually saying what the object is.

## Scientific Communication

3. Give your partner the description and allow him or her a few minutes to try to determine what your object is.
4. Now use your partner's description to determine what his or her object is.

**Communicate** Work together to rewrite each description in your science journals to make them as succinct as possible. Trade the new descriptions with another pair of students. Did this pair of students have an easier time at determining the objects than you and your partner did? Why or why not?



### SECTION

## 1.1

## Earth Science

### OBJECTIVES

- **Differentiate** among the four major branches of Earth science.
- **Contrast** the four systems of Earth.
- **Discuss** how Earth science affects your daily life.

### VOCABULARY

astronomy    asthenosphere  
meteorology    hydrosphere  
geology    atmosphere  
oceanography    biosphere  
lithosphere

It is easy to see from the photograph on page 4 why this strip of the California coast is called Bowling Ball Beach. These round structures are concretions—masses of rock that form as the result of processes at work on Earth's surface. In this book, you'll learn about Earth and the processes and forces that change it, the materials from which it is made, its long history, and its place in the universe.

### THE SCOPE OF EARTH SCIENCE

The scope of Earth science is vast. Dinosaur bones on display at museums were once embedded in the rocks that make up some of Earth's cliffs and canyons. Mining certain rocks produces some of the gold used by jewelers and dentists. Computer models simulate the flow of the blanket of air that surrounds Earth so that scientists better understand stormy weather. Ocean-floor exploration has led to the discovery of bizarre creatures that never see the light of day, while the study of objects in space has revealed much about our own planet.



**Figure 1-1** Astronomy includes the study of Earth, its neighbors, and distant stars. The Keck Telescope in Hawaii, shown here, is used to study stars trillions of kilometers from Earth.



As you can see, there are many different areas of Earth science. This broad field can be broken into four major areas of specialization: astronomy, meteorology, geology, and oceanography.

**Astronomy** **Astronomy** is the study of objects beyond Earth’s atmosphere. Prior to the invention of sophisticated instruments, such as the telescope shown in *Figure 1-1*, many astronomers merely described the locations of objects in space in relation to one another. Today, these Earth scientists study the universe and everything in it, including Earth, its neighbors, and other bodies in the universe.

**Meteorology** The branch of Earth science that studies the air that surrounds our planet is called **meteorology**. Meteorologists study the forces and processes that cause the atmosphere to change to produce weather. These Earth scientists also try to predict the weather and how changes in weather might affect Earth’s climate.

**Geology** The study of the materials that make up Earth and the processes that form and change these materials is the branch of Earth science known as **geology**. Geologists identify rocks, study glacial movements, interpret clues to Earth’s 4.6 billion-year history, and determine how forces change our planet, among many other things.

**Oceanography** The study of Earth’s oceans, which cover nearly three-fourths of the planet, is called **oceanography**. Oceanographers study the creatures that inhabit salty water, measure different physical and chemical properties of the oceans, and observe various processes in these bodies of water. Some oceanographers study the effects of human activities on Earth’s saltwater bodies. The oil shown in *Figure 1-2* is just a very small portion of the 70 000 tonnes that were spilled off the coast of Wales in 1996.

**Figure 1-2** Some oceanographers study how human activities affect Earth’s oceans. This oil spill occurred off the coast of Wales in 1996.






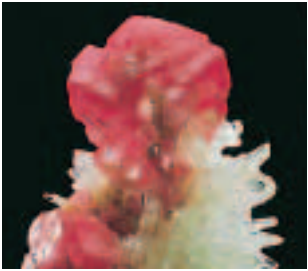




The study of our planet is a broad endeavor, and thus it requires a variety of subspecialties of the four major areas of Earth science. Some of these subspecialties are listed in **Table 1-1**. What kinds of things does a paleontologist study? Which subspecialty is concerned with the environment? What types of things are studied by scientists specializing in tectonics? What might a hydrologist study?

## EARTH'S SYSTEMS

Scientists who study Earth have identified four main Earth systems: the lithosphere, the hydrosphere, the atmosphere, and the biosphere. Each system is unique, yet each interacts with the others. None of Earth's systems is independent of the others, nor of the global system of Earth itself.

**Table 1-1** Some Subspecialties of Earth Science

Subspecialty	Subjects Studied	Subspecialty	Subjects Studied
Climatology 	Patterns of weather over a long period of time; effects of human activities on weather and climate	Ecology 	Habitats of organisms and how organisms interact with each other and their environments
Paleontology 	Remains of organisms that once lived on Earth; ancient environments	Geochemistry 	Earth's composition and the processes that change it
Hydrology 	Water flow on and below Earth's surface; sources of and solutions to water pollution	Tectonics 	Effects of internal processes on Earth's surface, including earthquakes and mountain building



**Topic: Earth's Systems**

To learn more about Earth's four major systems, visit the Earth Science Web Site at [earthgeu.com](http://earthgeu.com)

**Activity:** Write a study question for each of the Earth's four major systems based on your new knowledge.

**The Lithosphere** Earth's **lithosphere** is the rigid outer shell of the planet and includes the crust and the solid, uppermost part of the layer below the crust, the mantle. There are two kinds of crust: continental crust and oceanic crust. Earth's continental crust is made mostly of a rock called granite. Oceanic crust is mainly basalt, a rock that is denser than granite. Earth's mantle is mainly composed of a rock called peridotite. Some of Earth's upper mantle behaves like a rigid solid while other parts of this layer are partially molten and flow like a soft plastic. This partially molten layer is the **asthenosphere**.

Beneath Earth's mantle is the core, which can be divided into two parts: an outer, liquid part and a solid, inner part. Earth's core is thought to be made of iron and nickel. While Earth's core and asthenosphere are not parts of the lithosphere, they do interact with this system of Earth to produce many of the features at the planet's surface. You'll learn how the lithosphere and asthenosphere interact to produce volcanoes, mountains, and earthquakes in Unit 5.

**The Hydrosphere** The water in Earth's oceans, seas, lakes, rivers, and glaciers, as well as the water in the atmosphere, makes up the **hydrosphere**. About 97 percent of Earth's water exists as salt water; the remaining 3 percent is freshwater contained in glaciers, in lakes and rivers, and beneath Earth's surface as groundwater. About three fourths of all freshwater is contained in glaciers and icebergs, such as the one shown in *Figure 1-3*; most of the rest of this freshwater is groundwater. On a fraction of Earth's total amount of freshwater is in lakes and rivers. You'll find out more about Earth's hydrosphere in Units 3, 4, and 7.

**Figure 1-3** Most of Earth's freshwater is contained in glaciers. The iceberg shown here broke off of one of the glaciers that covers nearly all of the continent of Antarctica.





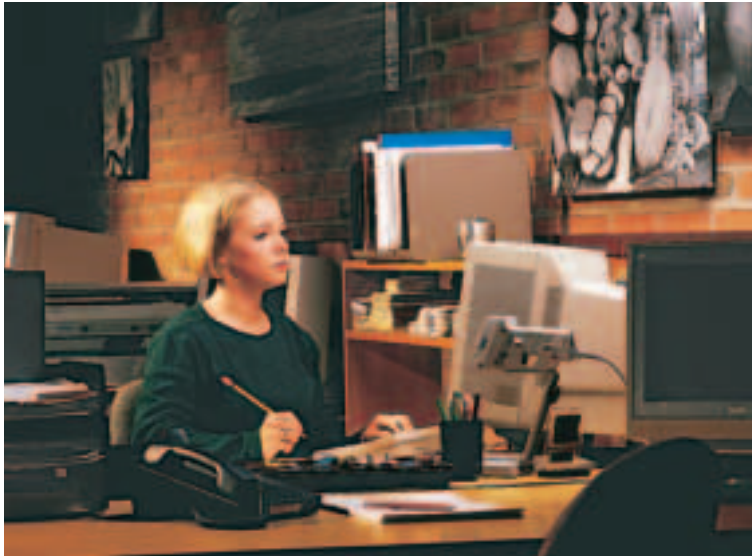
**Figure 1-4** The biosphere, hydrosphere, atmosphere, and lithosphere are interdependent systems of Earth.

**The Atmosphere** The blanket of gases that surrounds our planet is called the **atmosphere**. Among other things, Earth’s atmosphere is necessary for respiration by most living things, protects Earth’s inhabitants from harmful radiation from the Sun, and helps to keep the planet at a temperature suitable for life. Earth’s atmosphere contains about 78 percent nitrogen and 21 percent oxygen. The remaining 1 percent of gases in the atmosphere include water vapor, argon, carbon dioxide, and other trace gases. You will learn more about Earth’s atmosphere and how parts of this system interact to produce weather in Unit 4.

**The Biosphere** The **biosphere** includes all organisms on Earth as well as the environments in which they live. Most organisms exist within a few meters of Earth’s surface, but some live deep beneath the ocean’s surface, and others live high atop Earth’s mountains. Earth’s biosphere appears to be unique in that scientists have not yet found any confirmed evidence of life on other planets in our solar system or elsewhere in the galaxy.

As you can see in **Figure 1-4**, Earth’s biosphere, lithosphere, hydrosphere, and atmosphere are interdependent systems. Earth’s present atmosphere, for example, formed millions of years ago as a result of volcanic activity, respiration and transpiration by ancient organisms, and photosynthesis. Today’s organisms, including humans, continue to change the atmosphere through their life processes and activities. You’ll explore interactions among Earth’s biosphere and other systems, both past and present, in Units 3, 4, 6, and 7.





**Figure 1-5** Computers, calculators, telephones, and electricity are technological advances used by many people in their daily lives.

## EARTH SCIENCE IN YOUR EVERYDAY LIFE

You and the billions of other life-forms that live on Earth are part of the biosphere. Together with many of these creatures, you live on Earth's crust, which is part of the lithosphere, and breathe the gases in Earth's atmosphere. You also depend in many ways on the substance that covers nearly three-fourths of Earth—water, which makes up the hydrosphere. In what other ways is Earth science a part of your everyday life?

**Technology** While you might not realize it, the study of science, including Earth science, has led to the discovery of many things that you use every day. This application of scientific discoveries is called technology. Freeze-dried foods, ski goggles, micro-fabrics, and the ultra-light materials used to make many pieces of sports equipment are just a few examples of technological advances developed as a result of scientific study. Today, these items, along with those shown in *Figure 1-5*, are common.

Technology is transferable, which means that it can be applied to new situations. The technological developments just described were first developed for use in space. Later, they were modified for use here on Earth. In the *Science & Technology* feature at the end of this chapter, you'll find out how medical technology has been used to study dinosaurs!

### SECTION ASSESSMENT

1. Name and briefly describe the four branches of Earth science.
2. What does a geologist study?
3. What does a geochemist study?
4. Compare and contrast Earth's lithosphere and asthenosphere.
5. Describe the subdivisions of Earth's hydrosphere.
6. **Thinking Critically** What kinds of interactions do you think occur between Earth's hydrosphere and atmosphere?

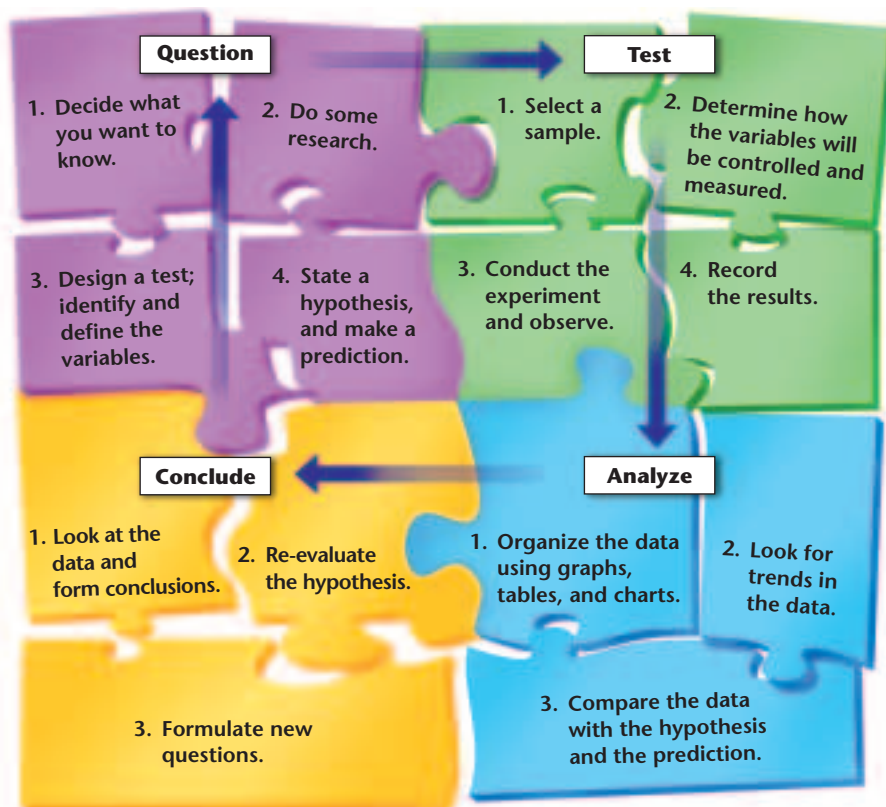
#### SKILL REVIEW

7. **Outlining** Outline the main ideas of this section. For more help, refer to the *Skill Handbook*.

Are you a scientist? Have you ever picked up a rock and peered at it for clues about its origin? Have you ever made a decision about what to wear after having observed the clouds in the sky? Have you wondered where soil comes from, or where it goes during a heavy rain? While you might not be a scientist, if you answered *yes* to any of these or similar questions, you have thought like a scientist. What makes scientific methods different from other methods of problem solving?

### THE NATURE OF SCIENTIFIC INVESTIGATIONS

A scientific method is a planned, organized approach to solving a problem. While the steps taken to solve the problem can vary, the first step involved in scientific problem solving, as shown in **Figure 1-6**, is usually identifying the problem, or determining what it is you want to know. Often, scientific problem solving involves researching the problem. Once the problem is defined and research is complete, a **hypothesis**, or suggested explanation for an observation, is made. Often, a hypothesis is stated in the form of a question that can be answered by the results of a test or an experiment.



### OBJECTIVES

- **List** the steps used in a scientific method.
- **Compare and contrast** experimental variables and controls.
- **Identify** basic SI units.
- **Explain** how to write numbers using scientific notation.

### VOCABULARY

*hypothesis*  
*independent variable*  
*dependent variable*  
*control*  
*Le Système International d'Unités (SI)*  
*scientific notation*

**Figure 1-6** Various steps and processes are involved in a scientific approach to problem solving.

## MiniLab

### How do soil and water absorb and release heat?

**Experiment** to determine the relationship between variables.

#### Procedure

1. Obtain the materials for this lab from your teacher.
2. Put soil into one container until it is half full. Put water into other container until it is half full.
3. Place one thermometer in the soil so that the bulb is barely covered. Use masking tape to secure another thermometer about 1 cm from the top of the soil.
4. Repeat step 3 with the container of water.
5. Put the containers on a very sunny windowsill. Record the temperature shown on each thermometer. Write these values in a table. Then record temperature readings every 5 minutes for half an hour.
6. Remove the containers from the windowsill and immediately record the temperature on each thermometer every 5 minutes for half an hour.

#### Analyze and Conclude

1. Which substance absorbed heat faster?
2. Which substance lost heat faster?
3. What was your independent variable?  
Your dependent variable?

**Experimentation** A hypothesis is tested by conducting an experiment, which is an organized procedure that involves making measurements and observations. A good scientific experiment tests only one variable, or changeable factor, at a time. The **independent variable** in an experiment is the factor that is manipulated by the experimenter. A **dependent variable** is a factor that can change if the independent variable is changed. Constants are factors that do not change during an experiment. A **control** is used in an experiment to show that the results of an experiment are actually a result of the condition being tested. Refer to the *Skill Handbook* for more information on variables. You will experiment with variables in the *MiniLab* on this page and in many other activities throughout this book.

**Safety in the Science Classroom** Some of the labs and activities in this book will require that you handle various materials and equipment, including those shown in *Figure 1-7*. When conducting any scientific investigation, it is important to use all materials and equipment only as instructed. Follow the safety rules listed in *Table 1-2* to



**Figure 1-7** Safety goggles and a lab apron should be worn during any activity or experiment in the science lab.



**Table 1-2 Some Important Safety Rules  
for the Science Lab**

1. Before beginning any investigation, understand the safety symbols noted by referring to the symbols and their meanings in *Appendix B*.
2. Wear safety goggles and a safety apron during all investigations that involve heating, pouring, or using chemicals.
3. Tie back long hair and loose clothing before you begin any investigation.
4. Always slant test tubes away from yourself and others when heating the tubes. Keep all materials away from open flames.
5. Never eat or drink in the lab and never use laboratory glassware as food or drink containers.
6. Never inhale chemicals, and never taste any substance used in the lab. Also, don't draw any material into a tube with your mouth.
7. Know what to do in case of fire. Also, know the location and proper use of the fire extinguisher, safety shower, fire blanket, first-aid kit, and fire alarm.
8. Report any spill, accident, or injury to your teacher immediately.
9. When cleaning up, dispose of chemicals and other materials only as directed by your teacher.
10. Always wash your hands thoroughly with soap after working in the lab.

help prevent injury to you and others in the lab as well as make you aware of possible hazards in a science lab. Refer to *Appendix B* for additional safety information and a table of symbols that will alert you to potential hazards.

**Analysis and Conclusions** During a scientific experiment, all data, including measurements and observations, are carefully recorded. Once an experiment is complete, the data must be formatted so that they can be studied, or analyzed. Graphs, tables, and charts are commonly used to format and display scientific data, which are then analyzed so that a conclusion can be drawn. Sometimes, a conclusion is contrary to the original hypothesis. In such a case, because the conclusion is supported by the data, the hypothesis, *not* the conclusion or the data, must be re-evaluated.

It is important to note, as shown in *Figure 1-6*, that scientific methods are not rigid, step-by-step outlines to solve problems. Scientists can take many different approaches to solving a scientific problem. In many scientific investigations, for example, scientists form new ideas after observing unexpected results. Sometimes, during the process of investigating one problem, an experimenter might encounter a different problem and choose to pursue the new problem rather than the original hypothesis.



**Topic: SI Measurements**

To learn more about SI, visit the Earth Science Web Site at [earthgeu.com](http://earthgeu.com)

**Activity:** List three facts about the history of SI.



**Using Math**

**Measuring** Use a metric ruler to measure the length of the following objects in both millimeters and centimeters: this book, a small paper clip, and your pencil. Would you use these same units to measure the length of your classroom? Why or why not?

## MEASUREMENT

Scientific experiments often involve making measurements. A measurement, as you already know, includes both a number that identifies how many units there are and a unit of measure. Most scientific studies and experiments use a standard system of units called **Le Système International d'Unités**, or **SI** for short. This system is a modern version of the metric system. SI is based on a decimal system that uses the number 10 as the base unit. You will make various measurements in SI in the *GeoLab* at the end of this chapter.

**Length** The standard SI unit to measure length is the meter (m). The distance from a doorknob to the floor is about 1 m. A guitar is also about 1 m long. The meter is divided into 100 equal parts called centimeters (cm). Thus, 1 cm is 1/100 of 1 m. One millimeter (mm) is smaller than 1 cm. There are 10 mm in 1 cm. How many millimeters are in 1 m? Long distances are measured in kilometers (km). There are 1000 m in 1 km. How many centimeters are in 1 km?

**Weight and Mass** Weight is a measure of the gravitational force on an object. Weight is typically measured with some type of scale. Unlike mass, weight varies with location. For example, the weight of the astronaut shown in **Figure 1-8** while on the Moon is about one-sixth the astronaut's weight on Earth. This is because the gravitational force exerted by the Moon on the astronaut is one-sixth the force exerted by Earth on the astronaut. Weight is a force, and the SI unit for force is the newton (N). The SI unit of mass is the kilogram (kg). A half-cup of water with a mass of 4 ounces weighs about 1 N, and a person with a mass of 60 kg weighs about 600 N.

Mass is the amount of matter in an object and depends on the number and kinds of atoms that make up the object. The mass of an

**Figure 1-8** The gravitational force exerted by the Moon is less than the gravitational force exerted by Earth. Thus, when this astronaut visited the Moon in 1969, he weighed less than he did on Earth.



object, unlike weight, does not change with an object's position. Mass can be measured with a balance like the one shown in *Figure 1-9*.

**Area and Volume** Some measurements, such as area, require a combination of SI units. Area is the amount of surface included within a set of boundaries and is expressed in square units of length, such as square meters ( $m^2$ ) or square centimeters ( $cm^2$ ). Determine the area, in square centimeters, of this book by multiplying the length of the book by its width.

The amount of space occupied by an object is the object's volume. The SI units for volume, like those of area, are derived from the SI units used to measure length. The basic SI unit of volume for a regularly shaped, solid object is the cubic meter ( $m^3$ ). SI measurements for liquid volumes are usually made in milliliters (mL) or liters (L). Volume can also be expressed in cubic centimeters ( $cm^3$ );  $1\text{ cm}^3$  equals 1 mL.

**Density** Density is a measure of the amount of matter that occupies a given space. Density is calculated by dividing the mass of the matter by its volume. Density is often expressed in grams per cubic centimeter ( $g/cm^3$ ), grams per milliliter ( $g/mL$ ), or kilograms per cubic meter ( $kg/m^3$ ).

**Time** Time is the interval between two events and is usually measured with a watch or clock. The clock shown in *Figure 1-10* is an atomic clock, which provides the most precise measure of time. The SI unit of time is the second (s). In the activities in this book, you will generally measure time in seconds or minutes.

**Temperature** Temperature is a measure of the average vibrations of the particles that make up a material. A mass made up of particles that vibrate quickly has a higher temperature than a mass whose particles vibrate more slowly. Temperature is measured in degrees with a thermometer. In science, temperature is often measured on the Celsius (C) scale. On the Celsius scale, a comfortable room temperature is about  $25^\circ\text{C}$ , and the normal temperature of the human body is about  $37^\circ\text{C}$ . In SI, temperature is measured on the Kelvin scale. On this scale, the coldest possible temperature is absolute zero, or 0 K, which is equal to  $-273^\circ\text{C}$ .



**Figure 1-9** Mass is measured with a balance.

**Figure 1-10** Atomic clocks provide much more precise measures of time than ordinary clocks.







**Figure 1-11** The Sombrero Galaxy, shown here, is just one of many groups of stars in the universe.

## SCIENTIFIC NOTATION

In many branches of science, some numbers are very small, while others are quite large. To conveniently express these numbers, scientists use a type of shorthand called **scientific notation** to express the number as a multiplier and a power of 10.

In scientific notation, a number is expressed as a value between 1 and 10 multiplied by a power of 10. The power of 10 is the number of places the decimal point must be shifted so that only a single digit remains either to the left or right of the decimal point. If the decimal point must be shifted to the left, the exponent of 10 is positive. For example, the approximate number of stars in the Sombrero Galaxy, some of which are shown in **Figure 1-11**, is 90 000 000 000. In scientific notation, this number is written as  $9 \times 10^{10}$ . The mass of Earth, which is 5 974 200 000 000 000 000 000 kg, is written as  $5.9742 \times 10^{24}$  kg in scientific notation. If the decimal point in a number must be shifted to the right, then the exponent of 10 is negative. The diameter of an atom in meters, for example, which is approximately 0.0000000001 m, is written as  $1 \times 10^{-10}$  m.

All of the quantities discussed in this section and the units used to measure them are summarized in *Appendix A*. You can also refer to *Appendix A* for explanations of how to convert between the units you are familiar with, such as feet and pounds, and SI units. In the next section, you will learn about other ways in which scientific information is communicated.

## SECTION ASSESSMENT

1. Describe the steps used in a scientific method.
2. Contrast dependent and independent variables.
3. What is the purpose of a control in a scientific experiment?
4. Explain how to write a large number using scientific notation.
5. **Thinking Critically** An increase in the temperature of matter generally results in a decrease in its density. Water is an exception to this rule. What do you think happens to water when it freezes?

### SKILL REVIEW

6. **Concept Mapping** Use the terms below to make a concept map that summarizes the units used to measure each quantity discussed in this section. For help, refer to the *Skill Handbook*.

time

density

temperature

volume

mass

weight

length

area

$^{\circ}\text{C}$

g/mL

km

s

$\text{cm}^3$

$\text{m}^2$

kg

N



There are many ways to communicate the same information, as you found out in the *Discovery Lab* at the beginning of this chapter. Scientists generally communicate through laboratory reports and research papers. Often, scientists propose models to try to explain ideas or systems. When an explanation withstands the test of repeated experiments, a theory might be proposed. Scientific models and theories can be modified when new observations and data are collected.

### COMMUNICATING RESULTS

One important goal of science is to make results available to others. Communicating scientific data and results allows others to learn of new discoveries, to possibly verify what has been reported, and to conduct new experiments using the information. From the laboratory reports that you will generate as you use this book to scientific papers published in professional journals, scientific results are communicated in many ways.

**Lab Reports** Throughout this book, you will conduct many Earth science experiments and activities. During and after each activity or experiment, you will be asked to record and analyze the information that you collected and to draw conclusions based on your data. Your resulting lab report, similar to the one shown in *Figure 1-12*, will be used by your teacher to assess your understanding of the activity or experiment. You might also be asked to compare your results with the results of other students to help you find both similarities and differences among the results.

**Graphs** You will be asked to graph the results of many experiments and activities in this book. As you will find out in the *Problem-Solving Lab* on page 18, a line graph is a visual display that shows how two variables are related. On a line graph, the independent variable is plotted on the horizontal ( $x$ ) axis, and the dependent

### OBJECTIVES

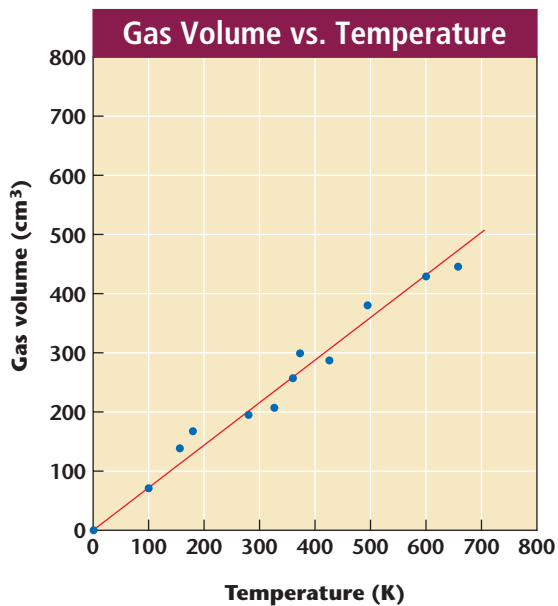
- **List** several ways in which scientific information is communicated.
- **Differentiate** between a scientific theory and a scientific law.

### VOCABULARY

theory  
law

**Figure 1-12** The results of laboratory experiments and the answers to questions posed in the experiment should be recorded neatly in your science journal.





**Figure 1-13** A line graph shows the relationship between two variables. Refer to the *Skill Handbook* for other types of graphs.

variable is plotted on the vertical ( $y$ ) axis. Refer to the line graph in *Figure 1-13*. What is the independent variable? The dependent variable?

## MODELS

In some of the activities and experiments in this book, you will be making and using models. A scientific model is an idea, a system, or a mathematical expression that is similar to the idea being explained. While a model might not have all of the components of a given idea, it should be a fairly accurate representation. Models can change when more data are gathered. Early astronomers, for example, thought that Earth was the center of the solar system, as shown in *Figure 1-14A*. This model was changed as the result of careful observations of the motions of the Sun and the planets in the night sky that showed that the planets in our solar system orbit the Sun, as shown in *Figure 1-14B*.

## Problem-Solving Lab

### Making and Using Graphs

**Make and use a graph** that shows how the annual, average surface temperature of Earth has varied over the past 500 years. The data in the table are global, average surface temperatures, in Kelvins, starting in the year 1500.

#### Procedure

1. Convert each temperature from kelvins to degrees Celsius by subtracting 273 from each value.
2. Determine appropriate scales for your graph. Plot the year on the  $x$ -axis and temperature, in degrees Celsius, on the  $y$ -axis.

#### Analysis

3. Describe the general trend shown by the data.

#### Average Surface Temperatures

Year	Average Surface Temperature (K)
1500	285.8
1600	285.9
1700	286.0
1800	286.2
1900	286.5
2000	286.9

4. How has Earth's average surface temperature changed with time?

#### Thinking Critically

5. Use the graph to determine the average surface temperature for 1980.
6. Extrapolate the data to predict what the average surface temperature will be in the year 2100.





**Figure 1-14** Some early astronomers thought that the Sun and other planets orbited Earth (A). It is now known that Earth and its eight neighbors orbit a star we call the Sun (B).

## THEORIES AND LAWS

A scientific **theory** is an explanation based on many observations during repeated experiments. A scientific theory is valid only if it is consistent with observations, makes predictions that can be tested, and is the simplest explanation of observations. Like a scientific model, a theory can be changed or modified with the discovery of new data.

A scientific **law** is a basic fact that describes the behavior of a natural phenomenon. A scientific law can be thought of as a “rule of nature,” even though the cause of the law may not be known. The events described by a law are observed to be the same every time. An example of a scientific law is Sir Isaac Newton’s first law of motion, which states that an object at rest or in motion stays at rest or in motion unless it is acted upon by an outside force. This law explains why Earth and eight other planets remain in orbit around the Sun. Theories are often used to explain scientific laws.

In this book, you will communicate your observations and draw conclusions based on scientific data. You will also find out about many of the models, theories, and laws used by Earth scientists to explain the various processes and phenomena that make Earth unique among its celestial neighbors.

### SECTION ASSESSMENT

1. What is the purpose of communicating scientific information?
2. What is the purpose of writing lab reports for experiments and activities in this book?
3. How are data plotted on a line graph?
4. What is a scientific model?
5. Contrast scientific theories and laws.
6. **Critical Thinking** When ice is heated, it melts. Is this a theory or a law? Explain.

#### SKILL REVIEW

7. **Recognizing Cause and Effect** Refer to *Figure 1-13*. Explain the relationship between the independent and dependent variables. For more help, refer to the *Skill Handbook*.

# Measuring in SI

**S**uppose someone asked you to measure the area of your classroom in square cubits. What would you use? A cubit is an ancient unit of length equal to the distance from the elbow to the tip of the middle finger. Since this length varies among individuals, the cubit is not a standard unit of measure. SI units are standard units, which means that they are exact quantities that have been agreed upon to use for comparison. In this GeoLab, you will use SI units to measure various properties of rock samples.

## Preparation

### Problem

Measure various properties of rocks and use the measurements to explain the relationships among the properties.

### Materials

water  
250-mL beaker  
graph paper  
balance  
pieces of string  
spring scale  
rock samples



### Objectives

*In this GeoLab, you will:*

- **Measure** the area, volume, mass, and weight of several rock samples.
- **Calculate** the density of each sample.
- **Explain** the relationships among the quantities.



## Procedure

1. Use the information in the *Skill Handbook* to design a data table in which to record the following measurements for each sample: area, volume, mass, weight, and density.
2. Obtain rock samples from your teacher. Carefully trace the outline of each rock onto the graph paper. Determine the area of each sample and record the values in your data table.
3. Pour water into the beaker until it is half full. Record this volume in the table. Tie a piece of string securely around one rock sample. Slowly lower the sample into the beaker. Record the volume of the water. Subtract the two values to determine the volume of the rock sample.
4. Repeat step 3 for the other rocks. Make sure the original volume of water is the same as when you measured your first sample.
5. Follow your teacher's instructions about how to use the balance to determine the mass of each rock. Record the measurements in your table.
6. Again, secure each rock with a piece of dry string. Make a small loop in the other end of the string. Place the loop over the hook of the spring scale to determine the weight of each rock sample. Record the values in your data table.

## Analyze

1. Compare the area of each of your samples with the areas determined by other students for the same samples. Explain any differences.
2. Compare the volume of each of your samples with the volumes determined by other students for the same samples. Explain any differences.
3. Compare the weight and mass of each of your samples with the values for these quantities determined by other students. Again, explain any differences.
4. Use your measurements to calculate the density of each sample using this formula:  $density = mass/volume$ . Record these values in your data table.

## Conclude & Apply

1. How accurate do you think your measurement of the area of each sample is? Explain.
2. What were the variables you used to determine the volume of each sample?
3. How could you find the volume of a rock such as pumice, which floats in water?
4. Does mass depend on the size or shape of a rock? Explain.



# Science & Technology



## Willo, Sue, and Technology, Too

**P**aleontology, the area of Earth science that studies ancient life forms, has long been associated with hands-on work—digging, cleaning, and handling fossils. However, technology is playing an increasing role in this area. Technologies borrowed from medicine, manufacturing, and the aerospace industry are leading to new discoveries about dinosaurs—especially Willo and Sue.

Willo, the fossil remains of a 66-million year old *Thescelosaurus*, and Sue, the nearly complete skeleton of a 66-million year old *Tyrannosaurus rex*, were both studied using computerized tomographic scanning, or CT scans. A CT scan is a type of scan in which X rays move through a specimen at different rates depending on the density of the tissues encountered. A CT scan produces a picture of a very thin slice of a portion of a specimen. A computer is used to record and process the rates to produce an image on the screen. Multiple CT slices can be stacked to generate a three-dimensional image of the complete specimen.

### A Dinosaur with Heart

Willo was found by paleontologist Michael Hammer in Harding County, South Dakota, in 1993. Willo was a plant-eater about the size of a pony. A CT scan of a dark mass of rock found in Willo's chest cavity revealed a structure that appears to be a heart—a four-chambered heart. A four-chambered heart would strongly support a relatively new hypothesis that dinosaurs were warm-blooded rather than cold-blooded animals.

### Sue's Sniffer

Sue, the most complete skeleton of a *T. rex* ever recovered, was put on display at the Field Museum in Chicago, Illinois, in May 2000. Sue was found and excavated by amateur paleontolo-

gist Sue Hendrickson in the South Dakota Badlands in 1990. The skull of Sue was sent for CT scanning to a company that makes jet airplane engines because medical scanners couldn't accommodate the skull's 1.6-meter length! The scan, which is shown above and is on display with a cast of the skull, revealed that the ferocious carnivore had a much more acute sense of smell than had been expected. The scan of Sue's skull showed olfactory bulbs the size of grapefruits! The discovery of these scent-sensing organs would never have been made without the use of CT technology.

Technology is changing how discoveries are made in Earth science, but also how they are shared. The images from CT scans are digital. They can be e-mailed and downloaded by scientists and students all over the world. The ease of access to important data will, in turn, lead to more exciting discoveries.

### Internet

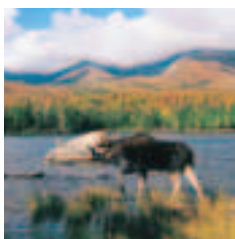
For more information on the use of CT scans in the area of paleontology, visit the Earth Science Web Site at [earthgeu.com](http://earthgeu.com). Compare and contrast scanned skulls of meat-eating dinosaurs with those of plant-eating dinosaurs. Present your findings in a table.

# CHAPTER 1 Study Guide

## Summary

### SECTION 1.1

#### Earth Science



#### Main Ideas

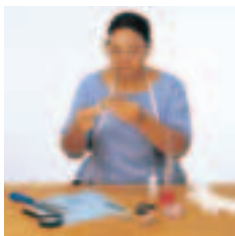
- There are four major areas in Earth science. Astronomy is the study of objects beyond Earth's atmosphere. Meteorology is the branch of Earth science that deals with Earth's atmosphere. The study of the materials that make up Earth and the processes that form and change these materials is known as geology. The study of Earth's oceans is called oceanography.
- Earth can be divided into four main systems. The lithosphere includes the rocks that make up the crust and rigid, upper mantle. The atmosphere is the blanket of gases that surrounds Earth. Earth's hydrosphere is the system of all of the water on the planet. The biosphere is Earth's inhabitants and their environments.
- All of Earth's systems interact. You are part of the biosphere and you live on the crust, which is part of the lithosphere. You breathe the gases in that atmosphere and depend in many ways on the water in the hydrosphere.

#### Vocabulary

asthenosphere (p. 8)  
astronomy (p. 6)  
atmosphere (p. 9)  
biosphere (p. 9)  
geology (p. 6)  
hydrosphere (p. 8)  
lithosphere (p. 8)  
meteorology (p. 6)  
oceanography (p. 6)

### SECTION 1.2

#### Methods of Scientists



#### Main Ideas

- The order of steps in a scientific method can vary. Most scientific methods to solving a problem, however, include defining the problem, stating a hypothesis, testing the hypothesis, analyzing the results of the test, and drawing conclusions.
- Variables are factors that change in an experiment. A dependent variable can change in response to changes in the independent variable. A control is a standard for comparison.
- Basic units used in SI include the liter, the meter, the second, the kilogram, the Newton, and degrees Celsius.
- In scientific notation, a number is expressed as a multiplier and a power of 10.

#### Vocabulary

control (p. 12)  
dependent variable (p. 12)  
hypothesis (p. 11)  
independent variable (p. 12)  
Le Système International d'Unités (SI) (p. 14)  
scientific notation (p. 16)

### SECTION 1.3

#### Communicating in Science



#### Main Ideas

- Scientific information is communicated through lab reports, professional papers, tables and graphs, and models.
- A scientific theory is an explanation based on many observations during repeated experiments. A scientific theory is valid only if it is consistent with observations, makes predictions that can be tested, and is the simplest explanation of observations. A theory can be changed or modified if it is found to be incorrect.
- A scientific law is a basic fact that describes the behavior of a natural phenomenon. A scientific law can be thought of as a "rule of nature," even though the cause of the law may not be known.

#### Vocabulary

law (p. 19)  
theory (p. 19)



# CHAPTER 1 Assessment

## Understanding Main Ideas

- Which area of Earth science includes the study of ancient organisms?
  - astronomy
  - meteorology
  - paleontology
  - geology
- Which area of Earth science includes the study of stars?
  - meteorology
  - hydrology
  - geology
  - astronomy
- What is geology?
  - the study of the processes that form and change Earth
  - the study of Earth's oceans
  - the study of objects beyond Earth's atmosphere
  - the systematic study of weather and climate
- Which of the following is NOT a part of Earth's lithosphere?
  - the inner core
  - the crust
  - the upper mantle
  - rocks on the surface
- What is Earth's hydrosphere?
  - the gases in the air
  - the solid, rocky part of Earth
  - all of the water on the planet
  - the study of Earth's atmosphere
- What are the two most common gases in the atmosphere?
  - hydrogen and oxygen
  - nitrogen and water vapor
  - oxygen and nitrogen
  - hydrogen and nitrogen
- Which of the following scientists would most likely study Earth's past biosphere?
  - hydrologist
  - geochemist
  - meteorologist
  - paleontologist

- What is technology, and how is it different from science?
- List the steps involved in a scientific approach to solving a problem.
- What is a hypothesis, and how is it different from a scientific theory?
- What is a dependent variable in a scientific investigation? How does it differ from an independent variable?
- List the SI units that would be used to measure the following quantities: the mass of an apple, the length of a beetle, the weight of the planet Jupiter, the volume of a medium-sized soft drink, and the volume of a cube of sugar.
- How are area and volume alike? How do they differ?
- Complete the table below. Once you have made the conversions, express each answer in scientific notation.

Some SI Conversions

1 m	_____ mm	_____ km
1 g	_____ mg	_____ kg
1 cm <sup>3</sup>	_____ m <sup>3</sup>	_____ mL
3.5 km	_____ m	_____ cm
18.6 cm	_____ km	_____ m

- Refer to *Appendix B*. What are the safety symbols for a biological hazard, an electrical hazard, an open flame, and the need to wear safety goggles?

## Test-Taking Tip

**PREPARING FOR A TEST** As soon as you find out about an upcoming test, ask which concepts and topics will be tested. When you study for the test, make sure you cover all of the material on which you may be tested.



# CHAPTER 1 Assessment

16. Compare and contrast scientific theories and laws. Give an example of each.
17. Explain how variables are plotted on a line graph.
18. What is a scientific model?

## Applying Main Ideas

19. Which of the safety symbols in *Appendix B* would be shown in an activity in which you were asked to test the acidity of several liquids?
20. Explain how you might test which of three paper towels is most absorbent.
21. Suppose you were testing the effects of the amount of fertilizer needed to produce tall grass. What would be your independent variable? Your dependent variable? Your control?
22. A doctor is testing a new cancer drug. She chooses 50 patients who have the particular cancer to take part in the study. She gives 25 patients the new drug and the other 25 patients a placebo, which is a substance that contains no active ingredients. What is the purpose of this second group in the doctor's study?

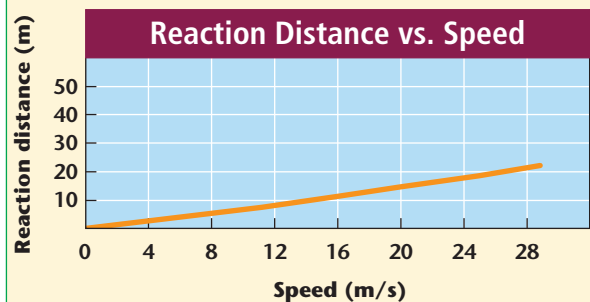
## Thinking Critically

23. Suppose you want to find out whether doubling the amount of potassium in a soil will increase the yield of tomato plants. Describe how you would test this hypothesis. What would be your variables? What would you use as a control?
24. How might elements in Earth's hydrosphere interact with Earth's lithosphere?
25. Explain your dependence on each of Earth's four systems.
26. When air or helium is added to a balloon, the balloon expands. Suggest a model that could be used to explain why this happens.

## Standardized Test Practice

1. Which of the following lists Earth's layers from the inside out?
  - a. inner core, outer core, mantle, crust
  - b. crust, mantle, outer core, inner core
  - c. crust, inner core, outer core, mantle
  - d. mantle, outer core, inner core, crust
2. A block is 2 cm wide, 5.4 cm deep, and 3.1 cm long. The density of the block is  $8.5 \text{ g/cm}^3$ . What is the mass of the block?
  - a. 33.48 g
  - b. 85.10 g
  - c. 399.3 g
  - d. 284.58 g

**USING GRAPHS** Use the graph below to answer questions 3 and 4.



3. The distance a car travels between the time the driver decides to stop the car and the time the driver puts on the brakes is called the reaction distance. How does the reaction distance change with speed?
  - a. Reaction distance decreases with speed.
  - b. Reaction distance is the same as speed.
  - c. Reaction distance increases with speed.
  - d. You cannot tell from this graph.
4. What is the reaction distance of a driver traveling 20 m/s?
  - a. 3 m
  - b. 15 m
  - c. 20 m
  - d. 28 m