How Are Waffles & Running Shoes Connected?
For centuries, shoes were made mostly of leather, cloth, or wood. These shoes helped protect feet, but they didn’t provide much traction on slippery surfaces. In the early twentieth century, manufacturers began putting rubber on the bottom of canvas shoes, creating the first “sneakers.” Sneakers provided good traction, but the rubber soles could be heavy—especially for athletes. One morning in the 1970s, an athletic coach stared at the waffles on the breakfast table and had an idea for a rubber sole that would be lighter in weight but would still provide traction. That’s how the first waffle soles were born. Waffle soles soon became a world standard for running shoes.
Science is a method of learning and communicating information about the natural world.

1.1 The Methods of Science
   Scientific investigations don’t always proceed with identical steps but do contain similar methods.

1.2 Standards of Measurement
   Standard measurement units, such as centimeters and seconds, are exact quantities used to compare measurements.

1.3 Communicating with Graphs
   Graphs are a visual representation of numerical data.

Out of This World
The space program was developed in response to many unanswered questions. Scientists have worked together to develop ways in which to answer those questions. In this chapter, you will learn how scientists learn about the natural world.

Science Journal
Look at the picture above. Write in your Science Journal why scientists study space.
Understanding Measurements

During a track meet, one athlete ran 1 mile in 5 min and another athlete ran 5,000 m in 280 s. The two runners used different units to describe their races, so how can you compare them? Do the following lab to explore how using different units can make it difficult to compare measurements.

1. Measure the distance across your classroom using your foot as a measuring device.
2. Record your measurement and name your measuring unit.
3. Now, have your partner measure the same distance using his or her foot as the measuring device. Record this measurement and make up a different name for the unit.
4. Think Critically Explain why you think it might be important to have standard, well-defined units to make measurements.

Identify Questions Before you read the chapter, write what you already know about science under the left tab of your Foldable, and write questions about what you’d like to know under the center tab. After you read the chapter, list what you learned under the right tab.

Scientific Processes Make the following Foldable to help identify what you already know, what you want to know, and what you learned about science.

**STEP 1** Fold a vertical sheet of paper from side to side. Make the front edge about 1.25 cm shorter than the back edge.

**STEP 2** Turn lengthwise and fold into thirds.

**STEP 3** Unfold and cut only the top layer along both folds to make three tabs. Label each tab.

Know? | Like to know? | Learned?
What is science?

Science is not just a subject in school. It is a method for studying the natural world. After all, science comes from the Latin word *scientia*, which means “knowledge.” Science is a process that uses observation and investigation to gain knowledge about events in nature.

Nature follows a set of rules. Many rules, such as those concerning how the human body works, are complex. Other rules, such as the fact that Earth rotates about once every 24 h, are much simpler. Scientists ask questions to learn about the natural world.

Major Categories of Science  Science covers many different topics that can be classified according to three main categories. (1) Life science deals with living things. (2) Earth science investigates Earth and space. (3) Physical science deals with matter and energy. In this textbook, you will study mainly physical science. Sometimes, though, a scientific study will overlap the categories. One scientist, for example, might study the motions of the human body to understand how to build better artificial limbs. Is this scientist studying energy and matter or how muscles operate? She is studying both life science and physical science. It is not always clear what kind of science you are using, as shown in Figure 1.
Science Explains Nature  Scientific explanations help you understand the natural world. Sometimes these explanations must be modified. As more is learned about the natural world, some of the earlier explanations might be found to be incomplete or new technology might provide more accurate answers.

For example, look at Figure 2. In the late eighteenth century, most scientists thought that heat was an invisible fluid with no mass. Scientists observed that heat seemed to flow like a fluid. It also moves away from a warm body in all directions, just as a fluid moves outward when you spill it on the floor.

However, the heat fluid idea did not explain everything. If heat were an actual fluid, an iron bar that had a temperature of 1,000°C should have more mass than it did at 100°C because it would have more of the heat fluid in it. The eighteenth-century scientists thought they just were not able to measure the small mass of the heat fluid on the balances they had. When additional investigations showed no difference in mass, scientists had to change the explanation.

Investigations  Scientists learn new information about the natural world by performing investigations, which can be done many different ways. Some investigations involve simply observing something that occurs and recording the observations, perhaps in a journal. Other investigations involve setting up experiments that test the effect of one thing on another. Some investigations involve building a model that resembles something in the natural world and then testing the model to see how it acts. Often, a scientist will use something from all three types of investigation when attempting to learn about the natural world.

Why do scientific explanations change?

Scientific Methods  Although scientists do not always follow a rigid set of steps, investigations often follow a general pattern. An organized set of investigation procedures is called a scientific method. Six common steps found in scientific methods are shown in Figure 3. A scientist might add new steps, repeat some steps many times, or skip steps altogether when doing an investigation.
Stating a Problem Many scientific investigations begin when someone observes an event in nature and wonders why or how it occurs. Then the question of “why” or “how” is the problem. Sometimes a statement of a problem arises from an activity that is not working. Some early work on guided missiles showed that the instruments in the nose of the missiles did not always work. The problem statement involved finding a material to protect the instruments from the harsh conditions of flight.

Later, National Aeronautics and Space Administration (NASA) scientists made a similar problem statement. They wanted to build a new vehicle—the space shuttle—that could carry people to outer space and back again. Guided missiles did not have this capability. NASA needed to find a material for the outer skin of the space shuttle that could withstand the heat and forces of reentry into Earth’s atmosphere.

Researching and Gathering Information Before testing a hypothesis, it is useful to learn as much as possible about the background of the problem. Have others found information that will help determine what tests to do and what tests will not be helpful? The NASA scientists gathered information about melting points and other properties of the various materials that might be used. In many cases, tests had to be performed to learn the properties of new, recently created materials.

Forming a Hypothesis A hypothesis is a possible explanation for a problem using what you know and what you observe. NASA scientists knew that a ceramic coating had been found to solve the guided missile problem. They hypothesized that a ceramic material also might work on the space shuttle.

Testing a Hypothesis Some hypotheses can be tested by making observations. Others can be tested by building a model and relating it to real-life situations. One common way to test a hypothesis is to perform an experiment. An experiment tests the effect of one thing on another using controlled conditions.
Variables  An experiment usually contains at least two variables. A variable is a quantity that can have more than a single value. You might set up an experiment to determine which of three fertilizers helps plants to grow the biggest. Before you begin your tests, you would need to think of all the factors that might cause the plants to grow bigger. Possible factors include plant type, amount of sunlight, amount of water, room temperature, type of soil, and type of fertilizer.

In this experiment, the amount of growth is the dependent variable because its value changes according to the changes in the other variables. The variable you change to see how it will affect the dependent variable is called the independent variable.

Constants and Controls  To be sure you are testing to see how fertilizer affects growth, you must keep the other possible factors the same. A factor that does not change when other variables change is called a constant. You might set up one trial, using the same soil and type of plant. Each plant is given the same amount of sunlight and water and is kept at the same temperature. These are constants. Three of the plants receive a different amount of fertilizer, which is the independent variable.

The fourth plant is not fertilized. This plant is a control. A control is the standard by which the test results can be compared. Suppose that after several days, the three fertilized plants grow between 2 and 3 cm. If the unfertilized plant grows 1.5 cm, you might infer that the growth of the fertilized plants was due to the fertilizers.

How might the NASA scientists set up an experiment to solve the problem of the damaged tiles shown in Figure 4? What are possible variables, constants, and controls?

**Why is a control used in an experiment?**

**Classification Systems**

Through observations of living organisms, Aristotle designed a classification system. Systems used today group organisms according to variables such as habits and physical and chemical features. Research to learn recent recategorizations of organisms. Share your findings with your class.

**Figure 4** NASA has had an ongoing mission to improve the space shuttle. A technician is replacing tiles damaged upon reentry into Earth’s atmosphere.
Analyzing the Data  An important part of every experiment includes recording observations and organizing the test data into easy-to-read tables and graphs. Later in this chapter you will study ways to display data. When you are making and recording observations, you should include all results, even unexpected ones. Many important discoveries have been made from unexpected occurrences.

Interpreting the data and analyzing the observations is an important step. If the data are not organized in a logical manner, wrong conclusions can be drawn. No matter how well a scientist communicates and shares that data, someone else might not agree with the data. Scientists share their data through reports and conferences. In Figure 5 a student is displaying her data.

Drawing Conclusions  Based on the analysis of your data, you decide whether or not your hypothesis is supported. When lives are at stake, such as with the space shuttle, you must be very sure of your results. For the hypothesis to be considered valid and widely accepted, the experiment must result in the exact same data every time it is repeated. If your experiment does not support your hypothesis, you must reconsider the hypothesis. Perhaps it needs to be revised or your experiment needs to be conducted differently.

Being Objective  Scientists also should be careful to reduce bias in their experiments. A bias occurs when what the scientist expects changes how the results are viewed. This expectation might cause a scientist to select a result from one trial over those from other trials. Bias also might be found if the advantages of a product being tested are used in a promotion and the drawbacks are not presented.

Scientists can lessen bias by running as many trials as possible and by keeping accurate notes of each observation made. Valid experiments also must have data that are measurable. For example, a scientist performing a global warming study must base his or her data on accurate measures of global temperature. This allows others to compare the results to data they obtain from a similar experiment. Most importantly, the experiment must be repeatable. Findings are supportable when other scientists perform the same experiment and get the same results.

Figure 5  An exciting and important part of investigating something is sharing your ideas with others, as this student is doing at a science fair.
Visualizing with Models

Scientists cannot see everything that they are testing. They might be observing something that is too large, too small, or takes too much time to see completely. In these cases, scientists use models. A model represents an idea, event, or object to help people better understand it.

Models in History Models have been used throughout history. One scientist, Lord Kelvin, who lived in England in the 1800s, was famous for making models. To model his idea of how light moves through space, he put balls into a bowl of jelly and encouraged people to move the balls around with their hands. Kelvin’s work to explain the nature of temperature and heat still is used today.

High-Tech Models Scientific models don’t always have to be something you can touch. Today, many scientists use computers to build models. NASA experiments involving space flight would not be practical without computers. The complex equations would take far too long to calculate by hand, and errors could be introduced much too easily.

Another type of model is a simulator, like the one shown in Figure 6. An airplane simulator enables pilots to practice problem solving with various situations and conditions they might encounter when in the air. This model will react the way a plane does when it flies. It gives pilots a safe way to test different reactions and to practice certain procedures before they fly a real plane.
**Scientific Theories and Laws**

A scientific **theory** is an explanation of things or events based on knowledge gained from many observations and investigations. It is not a guess. If scientists repeat an investigation and the results always support the hypothesis, the hypothesis can be called a theory. Just because a scientific theory has data supporting it does not mean it will never change. Recall that the theory about heat being a fluid was discarded after further experiments. As new information becomes available, theories can be modified. A theory accepted today might at some time in the future also be discarded.

A **scientific law** is a statement about what happens in nature and that seems to be true all the time. Laws tell you what will happen under certain conditions, but they don’t explain why or how something happens. Gravity is an example of a scientific law. The law of gravity says that any one mass will attract another mass. To date, no experiments have been performed that disprove the law of gravity.

A theory can be used to explain a law. For example, many theories have been proposed to explain how the law of gravity works. Even so, there are few theories in science and even fewer laws.

**The Limitations of Science**

Science can help you explain many things about the world, but science cannot explain or solve everything. Although it’s the scientist’s job to make guesses, the scientist also has to make sure his or her guesses can be tested and verified. But how do you prove that people will like a play or a piece of music? You cannot and science cannot.

Most questions about emotions and values are not scientific questions. They cannot be tested. You might take a survey to get people’s opinions about such questions, but that would not prove that the opinions are true for everyone. A survey might predict that you will like the art in **Figure 7**, but science cannot prove that you or others will.

**Figure 7** Science can’t answer all questions.

**Analyze** Can anyone prove that you like artwork? Explain.

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**Topic: Archimedes’ Principle**

Visit [gpscience.com](http://gpscience.com) for Web links to information about Archimedes’ principle.

**Activity** Place a full soft-drink bottle, water bottle, or container of milk in a tub of water. What happens to the pop bottle or milk container? Would you classify Archimedes’ principle as a scientific theory or scientific law?

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**What is the difference between a scientific theory and a scientific law?**
**Using Science—Technology**

Many people use the terms *science* and *technology* interchangeably, but they are not the same. **Technology** is the application of science to help people. For example, when a chemist develops a new, lightweight material that can withstand great amounts of heat, science is used. When that material is used on the space shuttle, technology is applied. **Figure 8** shows other examples of technology.

Technology doesn’t always follow science, however. Sometimes the process of discovery can be reversed. One important historic example of science following technology is the development of the steam engine. The inventors of the steam engine had little idea of how it worked. They just knew that steam from boiling water could move the engine. Because the steam engine became so important to industry, scientists began analyzing how it worked. Lord Kelvin, James Prescott Joule and Sadi Carnot, who lived in the 1800s, learned so much from the steam engine that they developed revolutionary ideas about the nature of heat.

Science and technology do not always produce positive results. The benefits of some technological advances, such as nuclear technology and genetic engineering, are subjects of debate. Being more knowledgeable about science can help society address these issues as they arise.

**Summary**

**What is science?**
- Scientists ask questions and perform investigations to learn more about the natural world.

**Scientific Methods**
- Scientists perform the six-step scientific method to test their hypotheses.

**Visualizing with Models**
- Models help scientists visualize concepts.

**Scientific Theories and Laws**
- A theory is a possible explanation for observations while a scientific law describes a pattern but does not explain why things happen.

**Using Science—Technology**
- Technology is the application of science into our everyday lives.

**Self-Check**

1. **Define** the first step a scientist usually takes to solve a problem.
2. **Explain** why a control is needed in a valid experiment.
3. **Think Critically** What is the dependent variable in an experiment that shows how the volume of gas changes with changes in temperature?

**Applying Math**

4. **Find the Average** You perform an experiment to determine how many breaths a fish takes per minute. Your experiment yields the following data: minute 1: 65 breaths; minute 2: 73 breaths; minute 3: 67 breaths; minute 4: 71 breaths; minute 5: 62 breaths. Calculate the average number of breaths that a fish takes per minute.
Standard is an exact quantity that people agree to use to compare measurements. Look at Figure 9. Suppose you and a friend want to make some measurements to find out whether a desk will fit through a doorway. You have no ruler, so you decide to use your hands as measuring tools. Using the width of his hands, your friend measures the doorway and says it is 8 hands wide. Using the width of your hands, you measure the desk and find it is $7\frac{3}{4}$ hands wide. Will the desk fit through the doorway? You can’t be sure. What went wrong? Even though you both used hands to measure, you didn’t check to see whether your hands were the same width as your friend’s. In other words, you didn’t use a measurement standard, so you can’t compare the measurements.

**Measurement Systems**

Suppose the label on a ball of string indicates that the length of the string is 150. Is the length 150 feet, 150 m, or 150 cm? For a measurement to make sense, it must include a number and a unit.

Your family might buy lumber by the foot, milk by the gallon, and potatoes by the pound. These measurement units are part of the English system of measurement, which is commonly used in the United States. Most other nations use the metric system—a system of measurement based on multiples of ten.
International System of Units  In 1960, an improved version of the metric system was devised. Known as the International System of Units, this system is often abbreviated SI, from the French Le Systeme Internationale d’Unites. All SI standards are universally accepted and understood by scientists throughout the world. The standard kilogram, which is kept in Sèvres, France, is shown in Figure 10. All kilograms used throughout the world must be exactly the same as the kilogram kept in France.

Each type of SI measurement has a base unit. The meter is the base unit of length. Every type of quantity measured in SI has a symbol for that unit. These names and symbols for the seven base units are shown in Table 1. All other SI units are obtained from these seven units.

SI Prefixes  The SI system is easy to use because it is based on multiples of ten. Prefixes are used with the names of the units to indicate what multiple of ten should be used with the units. For example, the prefix kilo- means “1,000.” That means that one kilometer equals 1,000 meters. Likewise, one kilogram equals 1,000 grams. Because deci- means “one-tenth,” one decimeter equals one tenth of a meter. A decigram equals one tenth of a gram. The most frequently used prefixes are shown in Table 2.

---

**Table 1  SI Base Units**

<table>
<thead>
<tr>
<th>Quantity Measured</th>
<th>Unit</th>
<th>Symbol</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length</td>
<td>meter</td>
<td>m</td>
</tr>
<tr>
<td>Mass</td>
<td>kilogram</td>
<td>kg</td>
</tr>
<tr>
<td>Time</td>
<td>second</td>
<td>s</td>
</tr>
<tr>
<td>Electric current</td>
<td>ampere</td>
<td>A</td>
</tr>
<tr>
<td>Temperature</td>
<td>kelvin</td>
<td>K</td>
</tr>
<tr>
<td>Amount of substance</td>
<td>mole</td>
<td>mol</td>
</tr>
<tr>
<td>Intensity of light</td>
<td>candela</td>
<td>cd</td>
</tr>
</tbody>
</table>

**Table 2  Common SI Prefixes**

<table>
<thead>
<tr>
<th>Prefix</th>
<th>Symbol</th>
<th>Multiplying Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kilo-</td>
<td>k</td>
<td>1,000</td>
</tr>
<tr>
<td>Deci-</td>
<td>d</td>
<td>0.1</td>
</tr>
<tr>
<td>Centi-</td>
<td>c</td>
<td>0.01</td>
</tr>
<tr>
<td>Milli-</td>
<td>m</td>
<td>0.001</td>
</tr>
<tr>
<td>Micro-</td>
<td>µ</td>
<td>0.000 001</td>
</tr>
<tr>
<td>Nano-</td>
<td>n</td>
<td>0.000 000 001</td>
</tr>
</tbody>
</table>

---

*Figure 10  The standard for mass, the kilogram, and other standards are kept at the International Bureau of Weights and Measures in Sèvres, France. Explain the purpose of a standard.*

*Reading Check  How many meters is 1 km? How many grams is 1 dg?*
Converting Between SI Units Sometimes quantities are measured using different units as shown in Figure 11. A conversion factor is a ratio that is equal to one and is used to change one unit to another. For example, there are 1,000 mL in 1 L, so $1,000 \text{ mL} = 1 \text{ L}$. If both sides in this equation are divided by 1 L, the equation becomes:

$$\frac{1,000 \text{ mL}}{1 \text{ L}} = 1$$

To convert units, you multiply by the appropriate conversion factor. For example, to convert 1.255 L to mL, multiply 1.255 L by a conversion factor. Use the conversion factor with new units (mL) in the numerator and the old units (L) in the denominator.

$$1.255 \text{ L} \times \frac{1,000 \text{ mL}}{1 \text{ L}} = 1,255 \text{ mL}$$

Figure 11 One centimeter contains 10 mm. Determine the length of the paper clip in centimeters and millimeters.

**Conversion Equations**

**Convert Units** How long, in centimeters, is a 3,075-mm rope?

1. **This is what you know:**
   - rope length in mm = 3,075 mm
   - 1 m = 100 cm = 1,000 mm

2. **This is what you need to find:** rope length in cm

3. **Use this formula:**
   $$\text{length in cm} = \text{length in mm} \times \frac{100 \text{ cm}}{1,000 \text{ mm}}$$

4. **Substitute:**
   $$\text{length in cm} = 3,075 \text{ mm} \times \frac{100 \text{ cm}}{1,000 \text{ mm}} = 307.5 \text{ cm}$$

5. **Determine the units:** cm = mm $\times$ cm/mm

**Answer:** The rope is 307.5 cm long

**Practice Problems**

1. Your pencil is 11 cm long. How long is it in millimeters?

2. **Challenge** The Bering Land Bridge National Preserve is a summer home to birdlife. Some birds migrate 20,000 miles. If 1 mile equals 1.6 kilometers, calculate the distance birds fly in kilometers.

For more practice problems, go to page 834, and visit gpscience.com/extra_problems.
Measuring Distance

The word *length* is used in many different ways. For example, the length of a novel is the number of pages or words it contains. In scientific measurement, however, length is the distance between two points. That distance might be the diameter of a hair or the distance from Earth to the Moon. The SI base unit of length is the meter, m. A baseball bat is about 1 m long. Metric rulers and metersticks are used to measure length. Figure 12 compares a meter and a yard.

Choosing a Unit of Length As shown in Figure 13, the size of the unit you measure with will depend on the size of the object being measured. For example, the diameter of a shirt button is about 1 cm. You probably also would use the centimeter to measure the length of your pencil and the meter to measure the length of your classroom. What unit would you use to measure the distance from your home to school? You probably would want to use a unit larger than a meter. The kilometer, km, which is 1,000 m, is used to measure these kinds of distances.

By choosing an appropriate unit, you avoid large-digit numbers and numbers with many decimal places. Twenty-one kilometers is easier to deal with than 21,000 m. And 13 mm is easier to use than 0.013 m.

Astronomical Units The standard measurement for the distance from Earth to the Sun is called the astronomical unit, AU. The distance is about 150 billion (1.5 \times 10^{11}) m. In your Science Journal, calculate what 1 AU would equal in km.

Predict whether your time for a 100-m dash would be slightly more or less than your time for a 100-yard dash.
The amount of space occupied by an object is called its **volume**. If you want to know the volume of a solid rectangle, such as a brick, you measure its length, width, and height and multiply the three numbers and their units together \( V = l \times w \times h \). For a brick, your measurements probably would be in centimeters. The volume would then be expressed in cubic centimeters, \( \text{cm}^3 \). To find out how much a moving van can carry, your measurements probably would be in meters, and the volume would be expressed in cubic meters, \( \text{m}^3 \), because when you multiply you add exponents.

### Measuring Liquid Volume

How do you measure the volume of a liquid? A liquid has no sides to measure. In measuring a liquid’s volume, you are indicating the capacity of the container that holds that amount of liquid. The most common units for expressing liquid volumes are liters and milliliters. These are measurements used in canned and bottled foods. A liter occupies the same volume as a cubic decimeter, \( \text{dm}^3 \). A cubic decimeter is a cube that is 1 dm, or 10 cm, on each side, as in Figure 14.

Look at Figure 14. One liter is equal to 1,000 mL. A cubic decimeter, \( \text{dm}^3 \), is equal to 1,000 cm\(^3\). Because 1 L = 1 dm\(^3\), it follows that:

\[
1 \text{ mL} = 1 \text{ cm}^3
\]

Sometimes, liquid volumes such as doses of medicine are expressed in cubic centimeters.

Suppose you wanted to convert a measurement in liters to cubic centimeters. You use conversion factors to convert L to mL and then mL to cm\(^3\).

\[
1.5 \text{ L} \times \frac{1,000 \text{ mL}}{1 \text{ L}} \times \frac{1 \text{ cm}^3}{1 \text{ mL}} = 1,500 \text{ cm}^3
\]

**Figure 14** The large cube has a volume of 1 dm\(^3\), which is equivalent to 1 L. **Calculate** the cubic centimeters (cm\(^3\)) in the large cube.
Measuring Matter

A table-tennis ball and a golf ball have about the same volume. But if you pick them up, you notice a difference. The golf ball has more mass. **Mass** is a measurement of the quantity of matter in an object. The mass of the golf ball, which is about 45 g, is almost 18 times the mass of the table-tennis ball, which is about 2.5 g. A bowling ball has a mass of about 5,000 g. This makes its mass roughly 100 times greater than the mass of the golf ball and 2,000 times greater than the table-tennis ball’s mass. To visualize SI units, see Figure 15 on the following page.

**Density** A cube of polished aluminum and a cube of silver that are the same size not only look similar but also have the same volume. The mass and volume of an object can be used to find the density of the material the object is made of. **Density** is the mass per unit volume of a material. You find density by dividing an object’s mass by the object’s volume. For example, the density of an object having a mass of 10 g and a volume of 2 cm³ is 5 g/cm³. Table 3 lists the densities of some familiar materials.

**Derived Units** The measurement unit for density, g/cm³, is a combination of SI units. A unit obtained by combining different SI units is called a derived unit. An SI unit multiplied by itself also is a derived unit. Thus the liter, which is based on the cubic decimeter, is a derived unit. A meter cubed, expressed with an exponent—m³—is a derived unit.

### Measuring Time and Temperature

It is often necessary to keep track of how long it takes for something to happen, or whether something heats up or cools down. These measurements involve time and temperature.

Time is the interval between two events. The SI unit for time is the second. In the laboratory, you will use a stopwatch or a clock with a second hand to measure time.

### Table 3 Densities of Some Materials at 20°C

<table>
<thead>
<tr>
<th>Material</th>
<th>Density (g/cm³)</th>
<th>Material</th>
<th>Density (g/cm³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>hydrogen</td>
<td>0.000 09</td>
<td>aluminum</td>
<td>2.7</td>
</tr>
<tr>
<td>oxygen</td>
<td>0.001 4</td>
<td>iron</td>
<td>7.9</td>
</tr>
<tr>
<td>water</td>
<td>1.0</td>
<td>gold</td>
<td>19.3</td>
</tr>
</tbody>
</table>

### Determining the Density of a Pencil

**Procedure**

1. Find a pencil that will fit in a 100-mL graduated cylinder below the 90-mL mark.
2. Measure the mass of the pencil in grams.
3. Put 90 mL of water (initial volume) into a 100-mL graduated cylinder. Lower the pencil, eraser first, into the cylinder. Push the pencil down until it is just submerged. Hold it there and record the final volume to the nearest tenth of a milliliter.

**Analysis**

1. Determine the water displaced by the pencil by subtracting the initial volume from the final volume.
2. Calculate the pencil’s density by dividing its mass by the volume of water displaced.
3. Is the density of the pencil greater than or less than the density of water? How do you know?
The characteristics of most of these everyday objects are measured using an international system known as SI dimensions. These dimensions measure length, volume, mass, density, and time. Celsius is not an SI unit but is widely used in scientific work.

**MILLIMETERS** A dime is about 1 mm thick.

**METERS** A football field is about 91 m long.

**KILOMETERS** The distance from your house to a store can be measured in kilometers.

**LITERS** This carton holds 1.98 L of frozen yogurt.

**MILLILITERS** A teaspoonful of medicine is about 5 mL.

**GRAMS/METER** This stone sinks because it is denser—has more grams per cubic meter—than water.

**GRAMS** The mass of a thumbtack and the mass of a textbook can be expressed in grams.

**METERS/SECOND** The speed of a roller-coaster car can be measured in meters per second.

**CELSIUS** Water boils at 100°C and freezes at 0°C.
What’s Hot and What’s Not  You will learn the scientific meaning of the word temperature in a later chapter. For now, think of temperature as a measure of how hot or how cold something is.

Look at Figure 16. For most scientific work, temperature is measured on the Celsius (°C) scale. On this scale, the freezing point of water is 0°C, and the boiling point of water is 100°C. Between these points, the scale is divided into 100 equal divisions. Each one represents 1°C. On the Celsius scale, average human body temperature is 37°C, and a typical room temperature is between 20°C and 25°C.

Kelvin and Fahrenheit  The SI unit of temperature is the kelvin (K). Zero on the Kelvin scale (0 K) is the coldest possible temperature, also known as absolute zero. Absolute zero is equal to −273°C, which is 273° below the freezing point of water.

Most laboratory thermometers are marked only with the Celsius scale. Because the divisions on the two scales are the same size, the Kelvin temperature can be found by adding 273 to the Celsius reading. So, on the Kelvin scale, water freezes at 273 K and boils at 373 K. Notice that degree symbols are not used with the Kelvin scale.

The temperature measurement you are probably most familiar with is the Fahrenheit scale, which was based roughly on the temperature of the human body, 98.6°F.

What is the relationship between the Celsius scale and the Kelvin scale?

Figure 16  These three thermometers illustrate the scales of temperature between the freezing and boiling points of water.

Compare the boiling points of the three scales.
Scientists often graph the results of their experiments because they can detect patterns in the data easier in a graph than in a table. A graph is a visual display of information or data. Figure 17 is a graph that shows a girl walking her dog. The horizontal axis, or the x-axis, measures time. Time is the independent variable because as it changes, it affects the measure of another variable. The distance from home that the girl and the dog walk is the other variable. It is the dependent variable and is measured on the vertical axis, or y-axis.

Graphs are useful for displaying numerical information in business, science, sports, advertising, and many everyday situations. Different kinds of graphs—line, bar, and circle—are appropriate for displaying different types of information.

What are three common types of graphs?

Business people, as well as scientists, need an organized method to display data. Graphs make it easier to understand patterns by displaying data in a visual manner. Scientists often graph their data to detect patterns that would not have been evident in a table. Business people may graph sales dollars to determine trends. Different graphs use different methods for displaying information. The conclusions drawn from graphs must be based on accurate information.
Line Graphs

A line graph can show any relationship where the dependent variable changes due to a change in the independent variable. Line graphs often show how a relationship between variables changes over time. You can use a line graph to track many things, such as how certain stocks perform or how the population changes over any period of time—a month, a week, or a year.

You can show more than one event on the same graph as long as the relationship between the variables is identical. Suppose a builder had three choices of thermostats for a new school. He wanted to test them to know which was the best brand to install throughout the building. He installed a different thermostat in classrooms A, B, and C. He set each thermostat at 20°C. He turned the furnace on and checked the temperatures in the three rooms every 5 min for 25 min. He recorded his data in Table 4.

The builder then plotted the data on a graph. He could see from the table that the data did not vary much for the three classrooms. So he chose small intervals for the $y$-axis and left part of the scale out (the part between 0° and 15°). See Figure 18. This allowed him to spread out the area on the graph where the data points lie. You can see easily the contrast in the colors of the three lines and their relationship to the black horizontal line. The black line represents the thermostat setting and is the control. The control is what the resulting room temperature of the classrooms should be if the thermostats are working efficiently.

### Table 4  Room Temperature

<table>
<thead>
<tr>
<th>Time* (min)</th>
<th>Classroom Temperature (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A</td>
</tr>
<tr>
<td>0</td>
<td>16</td>
</tr>
<tr>
<td>5</td>
<td>17</td>
</tr>
<tr>
<td>10</td>
<td>19</td>
</tr>
<tr>
<td>15</td>
<td>20</td>
</tr>
<tr>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>25</td>
<td>20</td>
</tr>
</tbody>
</table>

*minutes after turning on heat

**Figure 18** The room temperatures of classrooms A, B, and C are shown in contrast to the thermostat setting of 20°C. **Identify** the thermostat that achieved its temperature setting the quickest.
Constructing Line Graphs  Besides choosing a scale that makes a graph readable, as illustrated in Figure 18, other factors are involved in constructing useful graphs. The most important factor in making a line graph is always using the \( x \)-axis for the independent variable. The \( y \)-axis always is used for the dependent variable. Because the points in a line graph are related, you connect the points.

Another factor in constructing a graph involves units of measurement. For example, you might use a Celsius thermometer for one part of your experiment and a Fahrenheit thermometer for another. But you must first convert your temperature readings to the same unit of measurement before you make your graph.

In the past, graphs had to be made by hand, with each point plotted individually. Today, scientists use a variety of tools, such as computers and graphing calculators like the one shown in Figure 19, to help them draw graphs.

### Applying Science

**GRAPHING TEMPERATURE**  In an experiment, you checked the air temperature at certain hours of the day. At 8 A.M., the temperature is 27°C; at noon, the temperature is 32°C; and at 4 P.M., the temperature is 30°C. Graph the results of your experiment.

**IDENTIFY known values**

- time = independent variable which is the \( x \)-axis
- temperature = dependent variable which is the \( y \)-axis

**GRAPH the problem**

Graph time on the \( x \)-axis and temperature on the \( y \)-axis. Mark the equal increments on the graph to include all measurements. Plot each point on the graph by finding the time on the \( x \)-axis and moving up until you find the recorded temperature on the \( y \)-axis. Place a point there. Continue placing points on the graph. Then connect the points from left to right.

**Practice Problems**

As you train for a marathon, you compare your previous times. In year one, you ran it in 5.2 h; in year two, you ran it in 5 h; in year three, you ran it in 4.8 h; in year four, you ran it in 4.3 h; and in year five, you ran it in 4 h.

1. Make a table of your data.
2. Graph the results of your marathon races.
3. Calculate your percentage of improvement from year 1 to year 5.

For more practice problems, go to page 834, and visit [gpscience.com/extra_problems](http://gpscience.com/extra_problems).
Bar Graphs

A bar graph is useful for comparing information collected by counting. For example, suppose you counted the number of students in every classroom in your school on a particular day and organized your data as in Table 5. You could show these data in a bar graph like the one shown in Figure 20. Uses for bar graphs include comparisons of oil, or crop productions, costs, or as data in promotional materials. Each bar represents a quantity counted at a particular time, which should be stated on the graph. As on a line graph, the independent variable is plotted on the x-axis and the dependent variable is plotted on the y-axis.

Recall that you might need to place a break in the scale of the graph to better illustrate your results. For example, if your data were 1,002, 1,010, 1,030, and 1,040 and the intervals on the scale were every 100 units, you might not be able to see the difference from one bar to another. If you had a break in the scale and started your data range at 1,000 with intervals of ten units, you could make a more accurate comparison.

Describe possible data where using a bar graph would be better than using a line graph.

Table 5 Classroom Size

<table>
<thead>
<tr>
<th>Number of Students</th>
<th>Number of Classrooms</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>1</td>
</tr>
<tr>
<td>21</td>
<td>3</td>
</tr>
<tr>
<td>22</td>
<td>3</td>
</tr>
<tr>
<td>23</td>
<td>2</td>
</tr>
<tr>
<td>24</td>
<td>3</td>
</tr>
<tr>
<td>25</td>
<td>5</td>
</tr>
<tr>
<td>26</td>
<td>5</td>
</tr>
<tr>
<td>27</td>
<td>3</td>
</tr>
</tbody>
</table>

Figure 20 The height of each bar corresponds to the number of classrooms having a particular number of students.
**Circle Graphs**

A circle graph, or pie graph, is used to show how some fixed quantity is broken down into parts. The circular pie represents the total. The slices represent the parts and usually are represented as percentages of the total.

**Figure 21** illustrates how a circle graph could be used to show the percentage of buildings in a neighborhood using each of a variety of heating fuels. You easily can see that more buildings use gas heat than any other kind of system. What else does the graph tell you?

To create a circle graph, you start with the total of what you are analyzing. **Figure 21** starts with 72 buildings in the neighborhood. For each type of heating fuel, you divide the number of buildings using each type of fuel by the total (72). You then multiply that decimal by 360° to determine the angle that the decimal makes in the circle. Eighteen buildings use steam. Therefore, \(18 \div 72 \times 360° = 90°\) on the circle graph. You then would measure 90° on the circle with your protractor to show 25 percent.

When you use graphs, think carefully about the conclusions you can draw from them. You want to make sure your conclusions are based on accurate information and that you use scales that help make your graph easy to read.

---

**Heating Fuel Usage**

- **Gas**: 50%
- **Steam**: 25%
- **Coal**: 10%
- **Electric**: 10%
- **Other**: 5%

---

**Summary**

**A Visual Display**

- Graphs are a visual representation of data.
- Scientists often graph their data to detect patterns.
- The type of graph used is based on the conclusions you want to identify.

**Line Graphs**

- A line graph shows how a relationship between two variables changes over time.

**Bar Graphs**

- Bar graphs are best used to compare information collected by counting.

**Circle Graphs**

- A circle graph shows how a fixed quantity is broken down into parts.

---

**Self Check**

1. **Identify** the kind of graph that would best show the results of a survey of 144 people where 75 ride a bus, 45 drive cars, 15 carpool, and 9 walk to work.

2. **State** which type of variable is plotted on the \(x\)-axis and which type is plotted on the \(y\)-axis.

3. **Explain** why the points in a line graph are connected.

4. **Think Critically** How are line, bar, and circle graphs similar? How are they different?

---

**Applying Math**

5. **Percentage** In a survey, it was reported that 56 out of 245 people would rather drink orange juice in the morning than coffee. Calculate what percentage of a circle graph this data would occupy.
Look through a recipe book. Are any of the ingredient amounts stated in SI? How can you convert English measurements to SI measurements?

**Real-World Question**

How do kitchen measurements compare with SI measurements?

**Goals**

- Determine a relationship between two systems of measurements.
- Calculate the conversion factors for converting English units to SI units.

**Materials**

- balance
- 100-mL graduated cylinder
- measuring cup
- measuring teaspoon
- measuring tablespoon
- cornmeal
dried beans
dried rice
potato flakes
water
vinegar
cornmeal

**Safety Precautions**

- 

**Procedure**

1. Copy the data table into your Science Journal and record each SI measurement.
2. Use the appropriate English measuring cup or spoon to measure the amounts of each ingredient shown in the table.
3. Use a balance to measure each dry ingredient. Use a graduated cylinder to measure each liquid ingredient.

**Conclude and Apply**

1. **Calculate** the number of grams in one cup of each dry ingredient. Calculate the number of milliliters in one cup, one teaspoon, and one tablespoon of each liquid ingredient.
2. **Write** conversion factors that will convert each English unit to an SI unit for each ingredient.
3. **Calculate** how many milliliters you would measure if a recipe called for three tablespoons of salad oil.
4. **Compare and contrast** your conversion factors for the dry ingredients and your conversion factors for the liquid ingredients.

**English to SI Conversions**

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>English Measure</th>
<th>SI Measure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>1/2 cup</td>
<td></td>
</tr>
<tr>
<td>Cornmeal</td>
<td>2 cups</td>
<td></td>
</tr>
<tr>
<td>Salad oil</td>
<td>4 tablespoons</td>
<td></td>
</tr>
<tr>
<td>Dried rice</td>
<td>1/2 cup</td>
<td></td>
</tr>
<tr>
<td>Potato flakes</td>
<td>3 cups</td>
<td></td>
</tr>
<tr>
<td>Vinegar</td>
<td>1 teaspoon</td>
<td></td>
</tr>
<tr>
<td>Dried beans</td>
<td>3 cups</td>
<td></td>
</tr>
</tbody>
</table>

Do not write in this book.

**Communicating Your Data**

Write a recipe used in your home converting all the English units to SI units.
To develop the International System of Units, people had to agree on set standards and basic definitions of scale. If you had to develop a new measurement system, people would have to agree with your new standards and definitions. In this activity, your team will use string to devise and test its own SI (String International) system for measuring length. What are the requirements for designing a new measurement system using string?

**Form a Hypothesis**

Based on your knowledge of measurement standards and systems, form a hypothesis that explains how exact units help keep measuring consistent.

**Test Your Hypothesis**

**Make a Plan**

1. As a group, agree upon and write out the hypothesis statement.
2. As a group, list the steps that you need to take to test your hypothesis. Be specific, describing exactly what you will do at each step.
3. Make a list of the materials that you will need.

**Possible Materials**

- string
- scissors
- marking pen
- masking tape
- miscellaneous objects for standards

**Goals**

- **Design** an experiment that involves devising and testing your own measurement system for length.
- **Measure** various objects with the string measurement system.

**Safety Precautions**

- Be careful when using scissors and marking pens.
4. **Design** a data table in your Science Journal so it is ready to use as your group collects data.

5. As you read over your plan, be sure you have chosen an object in your classroom to serve as a standard. It should be in the same size range as what you will measure.

6. Consider how you will mark scale divisions on your string. Plan to use different pieces of string to try different-sized scale divisions.

7. What is your new unit of measurement called? Come up with an abbreviation for your unit. Will you name the smaller scale divisions?

8. What objects will you measure with your new unit? Be sure to include objects longer and shorter than your string. Will you measure each object more than once to test consistency? Will you measure the same object as another group and compare your findings?

**Follow Your Plan**

1. Make sure your teacher approves your plan before you start.
2. Carry out the experiment as it has been planned.
3. **Record** observations that you make and complete the data table in your Science Journal.

**Analyze Your Data**

1. Which of your string scale systems will provide the most accurate measurement of small objects? Explain.
2. How did you record measurements that were between two whole numbers of your units?

**Conclude and Apply**

1. When sharing your results with other groups, why is it important for them to know what you used as a standard?
2. **Infer** how it is possible for different numbers to represent the same length of an object.

**Communicating Your Data**

Compare your conclusions with other students’ conclusions. Are there differences? Explain how these may have occurred.
Temple Grandin is an animal scientist and writer who also happens to be autistic. People with autism are said to think in pictures. I think in pictures. Words are like a second language to me. I translate both spoken and written words into full-color movies, complete with sound, which run like a VCR tape in my head. When somebody speaks to me, his words are instantly translated into pictures. Language-based thinkers often find this phenomenon difficult to understand, but in my job as equipment designer for the livestock industry, visual thinking is a tremendous advantage.

...I credit my visualization abilities with helping me understand the animals I work with. Early in my career I used a camera to help give me the animals’ perspective as they walked through a chute for their veterinary treatment. I would kneel down and take pictures through the chute from the cow’s eye level. Using the photos, I was able to figure out which things scared the cattle.

Every design problem I’ve ever solved started with my ability to visualize and see the world in pictures. I started designing things as a child, when I was always experimenting with new kinds of kites and model airplanes.

1 Autism is a complex developmental disability that usually appears during the first three years of life. Children and adults with autism typically have difficulties in communicating with others and relating to the outside world.
Section 1  The Methods of Science

1. Science is a way of learning about the natural world, such as the hurricane shown below, through investigation.

![Hurricane Image]

2. Scientific investigations can involve making observations, testing models, or conducting experiments.

3. Scientific experiments investigate the effect of one variable on another. All other variables are kept constant.

4. Scientific laws are repeated patterns in nature. Theories attempt to explain how and why these patterns develop.

Section 2  Standards of Measurement

1. A standard of measurement is an exact quantity that people agree to use as a basis of comparison. The International System of Units, or SI, was established to provide a standard and reduce confusion.

2. When a standard of measurement is established, all measurements are compared to the same exact quantity—the standard. Therefore, all measurements can be compared with one another.

3. The most commonly used SI units include: length—meter, volume—liter, mass—kilogram, and time—second.

4. In SI, prefixes are used to make the base units larger or smaller by multiples of ten.

5. Any SI unit can be converted to any other related SI unit by multiplying by the appropriate conversion factor. These towers are 45,190 cm in height, which is equal to 451.9 m.

Section 3  Communicating With Graphs

1. Graphs are a visual representation of data that make it easier for scientists to detect patterns.

2. Line graphs show continuous changes among related variables. Bar graphs are used to show data collected by counting. Circle graphs show how a fixed quantity can be broken into parts.

3. To create a circle graph, you have to determine the angles for your data.

4. In a line graph, the independent variable is always plotted on the horizontal x-axis. The dependent variable is always plotted on the vertical y-axis.

Foldables Use the Foldable that you made at the beginning of this chapter to help you review scientific processes.
Using Vocabulary

<table>
<thead>
<tr>
<th>Phrase</th>
<th>Term</th>
</tr>
</thead>
<tbody>
<tr>
<td>bias</td>
<td>p. 10</td>
</tr>
<tr>
<td>constant</td>
<td>p. 9</td>
</tr>
<tr>
<td>control</td>
<td>p. 9</td>
</tr>
<tr>
<td>density</td>
<td>p. 19</td>
</tr>
<tr>
<td>dependent variable</td>
<td>p. 9</td>
</tr>
<tr>
<td>experiment</td>
<td>p. 8</td>
</tr>
<tr>
<td>graph</td>
<td>p. 22</td>
</tr>
<tr>
<td>hypothesis</td>
<td>p. 8</td>
</tr>
<tr>
<td>independent variable</td>
<td>p. 9</td>
</tr>
<tr>
<td>mass</td>
<td>p. 19</td>
</tr>
<tr>
<td>model</td>
<td>p. 11</td>
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<td>scientific law</td>
<td>p. 12</td>
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<td>scientific method</td>
<td>p. 7</td>
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<td>SI</td>
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<td>standard</td>
<td>p. 14</td>
</tr>
<tr>
<td>technology</td>
<td>p. 13</td>
</tr>
<tr>
<td>theory</td>
<td>p. 12</td>
</tr>
<tr>
<td>variable</td>
<td>p. 9</td>
</tr>
<tr>
<td>volume</td>
<td>p. 18</td>
</tr>
</tbody>
</table>

1. the modern version of the metric system
2. the amount of space occupied by an object
3. an agreed-upon quantity used for comparison
4. the amount of matter in an object
5. a variable that changes as another variable changes
6. a visual display of data
7. a test set up under controlled conditions
8. a variable that does NOT change as another variable changes
9. mass per unit volume
10. an educated guess using what you know and observe

12. Which of the following is an example of an SI unit?
   A) foot                      C) pound
   B) second                   D) gallon

13. One one-thousandth is expressed by which prefix?
   A) kilo-                     C) centi-
   B) nano-                    D) milli-

14. Which of the following is an example of an SI unit?
   A) inches                   C) English units
   B) powers of five           D) powers of ten

15. What is the symbol for deciliter?
   A) dL                        C) dKL
   B) dcL                      D) Ld

16. Which of the following is NOT a derived unit?
   A) dm³                      C) cm³
   B) m                        D) g/ml

17. Which of the following is NOT equal to 1,000 mL?
   A) 1 L                      C) 1 dm³
   B) 100 cL                   D) 1 cm³

18. The illustrations above show the items needed for an investigation. Which item is the independent variable? Which items are the constants? What might a dependent variable be?
19. Copy and complete this concept map on scientific methods.

20. Communicate Standards of measurement used during the Middle Ages often were based on such things as the length of the king’s arm. How would you go about convincing people to use a different system of standard units?

21. Analyze What are some advantages and disadvantages of adopting SI in the United States?

22. Identify when bias occurs in scientific experimentation. Describe steps scientists can take to reduce bias and validate experimental data.

23. Demonstrate Not all objects have a volume that is measured easily. If you were to determine the mass, volume, and density of your textbook, a container of milk, and an air-filled balloon, how would you do it?

24. Apply Suppose you set a glass of water in direct sunlight for 2 h and measure its temperature every 10 min. What type of graph would you use to display your data? What would the dependent variable be? What would the independent variable be?

25. Form a Hypothesis A metal sphere is found to have a density of 5.2 g/cm³ at 25°C and a density of 5.1 g/cm³ at 50°C. Form a hypothesis to explain this observation. How could you test your hypothesis?

26. List the SI units of length you would use to express the following.
   a. diameter of a hair
   b. width of your classroom
   c. width of a pencil lead
   d. length of a sheet of paper

27. Compare and contrast the ease with which conversions can be made among SI units versus conversions among units in the English system.

28. Convert Units Make the following conversions.
   A) 1,500 mL to L
   B) 2 km to cm
   C) 5.8 dg to mg
   D) 22°C to K

29. Calculate the density of an object having a mass of 17 g and a volume of 3 cm³.

30. Solve A block of wood is 0.4 m by 0.2 m by 0.7 m. Find its dimensions in centimeters. Then find its volume in cubic centimeters.
Record your answers on the answer sheet provided by your teacher or on a sheet of paper.

Use the graph below to answer questions 1 and 2.

1. Students drop objects from a height and measure the time it takes each to reach the ground. What is the dependent variable in this experiment?
   A. falling time       C. drop height
   B. shoe              D. paper

2. What is a constant in this experiment?
   A. throwing some objects and dropping others
   B. measuring different falling times for each object
   C. dropping each object from the same height
   D. dropping a variety of objects

3. Which of the following is a statement about something that happens in nature which seems to be true all the time?
   A. theory            C. hypothesis
   B. scientific law    D. conclusion

4. What does the symbol ns represent?
   A. millisecond        C. microsecond
   B. nanosecond         D. kelvin

5. Which of these best defines mass?
   A. the amount of space occupied by an object
   B. the distance between two points
   C. the quantity of matter in an object
   D. the interval between two events

6. Which two liquids have the highest and the lowest densities?
   A. oil and water
   B. oil and corn syrup
   C. orange juice and water
   D. corn syrup and orange juice

7. What is the density of oil in units of mg/cm³?
   A. 850 mg/cm³
   B. 85 mg/cm³
   C. 0.085 mg/cm³
   D. 8500 mg/cm³

8. Which type of graph is most useful for showing how the relationship between independent and dependent variables changes over time?
   A. circle graph
   B. bar graph
   C. pictograph
   D. line graph

Test-Taking Tip: Recheck Your Answers  Double check your answers before turning in the test.

34  STANDARDIZED TEST PRACTICE
9. Describe several ways scientists use investigations to learn about the natural world.

10. Define the term technology. Identify three ways that technology makes your life easier, safer, or more enjoyable.

11. Describe the three major categories into which science is classified. Which branches of science would be most important to an environmental engineer? Why?

12. Make the following conversions:
   - a. 615 mg to g
   - b. 75 dL to mL
   - c. 0.95 km to cm

13. Define the term volume. Calculate the volume of the cube shown above. Give your answer in cm³ and mL.

14. Define the term density. If the mass of the cube is 96 g, what is the density of the cube material?

15. Why do scientists use graphs when analyzing data?

16. A friend frequently misses the morning school bus. Use the scientific method to address this problem.

Use the illustration below to answer questions 17 and 18.

17. What is the standard unit shown in this picture? Why is it kept under cover, in a vacuum-sealed container?

18. Why is this standard important to anyone who makes measurements? Explain why valid experimental results must be based on standards.

19. You must decide what items to pack for a hiking and camping trip. Space is limited, and you must carry all items during hikes. What measurements are important in your preparation?

Use the table below to answer question 20.

<table>
<thead>
<tr>
<th>Animal Life Span</th>
<th>Cow</th>
<th>Dog</th>
<th>Horse</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resting Heart Rate</td>
<td>52 beats per min</td>
<td>95 beats per min</td>
<td>48 beats per min</td>
</tr>
<tr>
<td>Average Life Span</td>
<td>18 years</td>
<td>16 years</td>
<td>27 years</td>
</tr>
</tbody>
</table>

20. Create a graph to display the data shown above.