Length

Length is defined as the distance between two points. Lengths measured with different tools can describe a range of things from the distance from Earth to Mars to the thickness of a human hair. In your laboratory activities, you usually will measure length with a metric ruler or meterstick.

The **meter** (m) is the SI unit of length. One meter is about the length of a baseball bat. The size of a room or the dimensions of a building would be measured in meters. For example, the height of the Washington Monument in Washington, D.C. is 169 m.

Smaller objects can be measured in centimeters (cm) or millimeters (mm). The length of your textbook or pencil would be measured in centimeters. A twenty-dollar bill is 15.5 cm long. You would use millimeters to measure the width of the words on this page. To measure the length of small things such as blood cells, bacteria, or viruses, scientists use micrometers (millionths of a meter) and nanometers (billionths of a meter).

Figure 8 These runners have just completed a 10-kilometer race—known as a 10K. **Estimate** *how many kilometers is the distance between your home and your school.*

A Long Way Sometimes people need to measure long distances, such as the distance a migrating bird travels or the distance from Earth to the Moon. To measure such lengths, you use kilometers. Kilometers might be most familiar to you as the distance traveled in a car or the measure of a long-distance race, as shown in **Figure 8.** The course of a marathon is measured carefully so that the competitors run 42.2 km. When you drive from New York to Los Angeles, you cover 4,501 km.

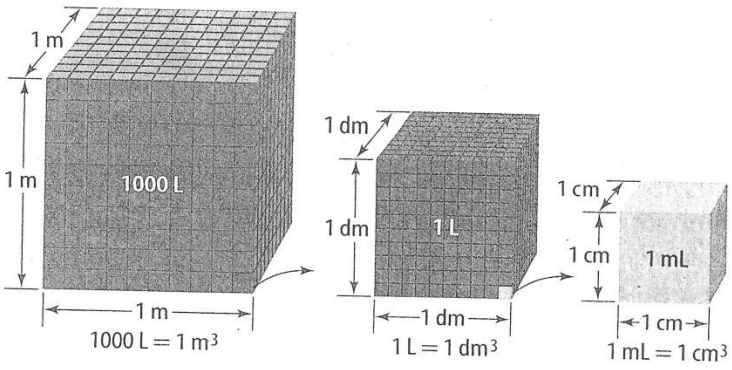
Table 3 Common Objects in SI Measurements

Object	Type of Measurement	Measurement
can of soft drink	volume	355 mL
bag of potatoes	mass	4.5 kg
fluorescent tube	length	1.2 m
refrigerator	temperature	276 K

INTEGRATE Astronomy

Measurement Accuracy How important are accurate measurements? In 1999, the *Mars Climate Orbiter* disappeared as it was to begin orbiting Mars. NASA later discovered that a unit system error caused the flight path to be incorrect and the orbiter to be lost. Research the error and determine what systems of units were involved. How can using two systems of units cause errors?

Figure 9 A cubic meter equals the volume of a cube 1 m by 1 m by 1 m.
Infer *how many cubic centimeters are in a cubic meter.*



Volume

The amount of space an object occupies is its **volume.** Units of volume are created by multiplying units of length. Therefore, they are not base units and are not listed in **Table 1.** The cubic meter (m^3), shown in **Figure 9,** is the SI unit of volume. You can measure smaller volumes with the cubic centimeter (cm^3 or cc). To find the volume of a square or rectangular object, such as a brick or your textbook, measure its length, width, and height and multiply them together. What is the volume of a compact disc case?

You are probably familiar with a 2-L bottle. A liter is a measurement of liquid volume. A cube 10 cm by 10 cm by 10 cm holds 1 L (1,000 cm^3) of water. A cube 1 cm on each side holds 1 mL (1 cm^3) of water.

Volume by Immersion Not all objects have an even, regular shape. How can you find the volume of something irregular like a rock or a piece of metal?

Have you ever added ice cubes to a nearly full glass of water only to have the water overflow? Why did the water overflow? Did you suddenly have more water? The volume of water did not increase at all, but the water was displaced when the ice cubes were added. Each ice cube takes up space or has volume. The difference in the volume of water before and after the addition of the ice cubes equals the volume of the ice cubes that are under the surface of the water.

The ice cubes took up space and caused the total volume in the glass to increase. The volume of an irregular object can be measured the same way. Start with a known volume of water and drop in, or immerse, the object. The increase in the volume of water is equal to the volume of the object.

Mini LAB

Measuring Volume

Procedure

1. Fill a plastic or glass **liquid measuring cup** until half full with **water.** Measure the volume.
2. Find an **object,** such as a rock, that will fit in your measuring cup.
3. Carefully lower the object into the water. If it floats, push it just under the surface with a **pencil.**
4. Record in your **Science Journal** the new volume of the water.

Analysis

1. How much space does the object occupy?
2. If 1 mL of water occupies exactly 1 cm^3 of space, what is the volume of the object in cm^3?

Try at Home

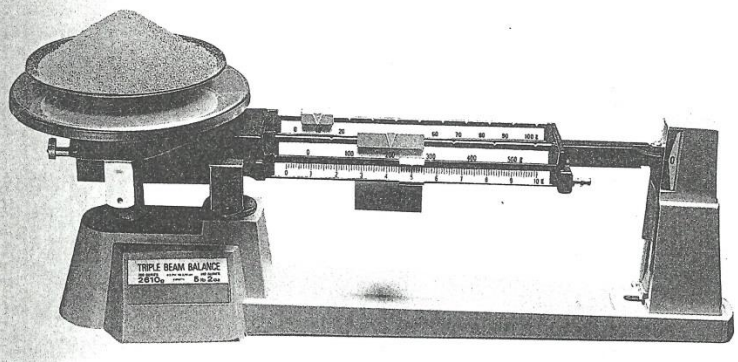


Figure 10 A triple beam balance compares an unknown mass to known masses.

Mass

The **mass** of an object measures the amount of matter in the object. The **kilogram** (kg) is the SI unit for mass. One liter of water has a mass of about 1 kg. Smaller masses are measured in grams (g). One gram is about the mass of a large paper clip.

You can determine mass with a triple-beam balance, shown in **Figure 10.** The balance compares an object to a known mass. It is balanced when the known standard mass of the slides on the balance is equal to the object on the pan.

Why use the word *mass* instead of *weight?* Weight and mass are not the same. Mass depends only on the amount of matter in an object. If you ride in an elevator in the morning and then ride in the space shuttle later that afternoon, your mass is the same. Mass does not change when only your location changes.

Weight

Weight is a measurement of force. The SI unit for weight is the newton (N). Weight depends on gravity, which can change depending on where the object is located. A spring scale measures how a planet's gravitational force pulls on objects. Several spring scales are shown in **Figure 11.**

If you were to travel to other planets, your weight would change, even though you would still be the same size and have the same mass. This is because gravitational force is different on each planet. If you could take your bathroom scale, which uses a spring, to each of the planets in this solar system, you would find that you weigh much less on Mars and much more on Jupiter. A mass of 75 pounds, or 34 kg, on Earth is a weight of 332 N. On Mars, the same mass is 126 N, and on Jupiter it is 782 N.

Reading Check *What does weight measure?*

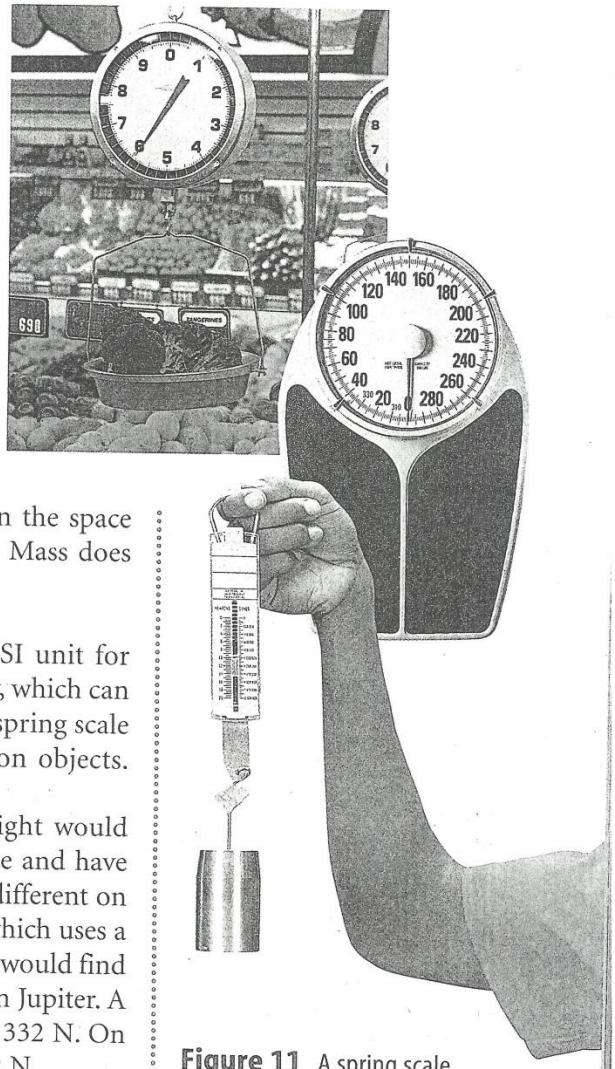
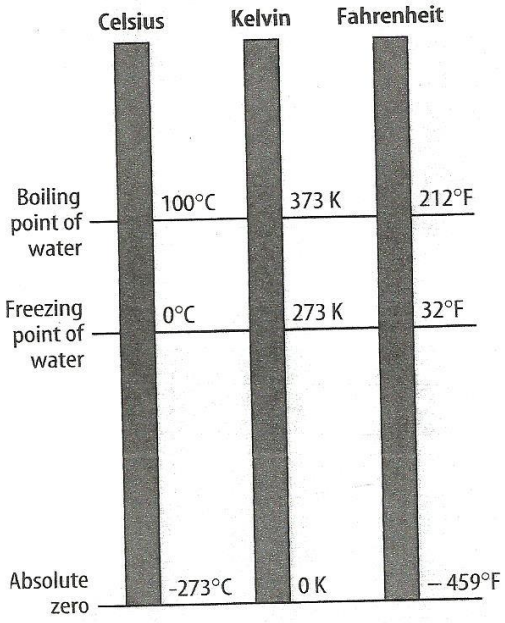


Figure 11 A spring scale measures an object's weight by how much it stretches a spring.

Figure 12 The kelvin scale starts at 0 K. In theory, 0 K is the coldest temperature possible in nature.



Temperature

The physical property of temperature is related to how hot or cold an object is. Temperature is a measure of the kinetic energy, or energy of motion, of the particles that make up matter.

Temperature is measured in SI with the **kelvin** (K) scale. The Fahrenheit and Celsius temperature scales are the two most common scales used on thermometers and in classroom laboratories. These two scales do not start at zero, as shown in **Figure 12.** A 1 K difference in temperature is the same as a 1°C difference in temperature.

Time and Rates

Time is the interval between two events. The SI unit of time is the second (s). Time also is measured in hours (h). Can you imagine hearing that a marathon was run in 7,620 s instead of 2 h and 7 min?

A **rate** is the amount of change of one measurement in a given amount of time. One rate you are familiar with is speed, which is the distance traveled in a given time. Speeds often are measured in kilometers per hour (km/h).

The unit that is changing does not necessarily have to be an SI unit. For example, you can measure the number of cars that pass through an intersection per hour in cars/h.

SECTION 2 REVIEW

Summary

The International System

- The International System of Units, SI, was established to provide a standard of physical measurement and to reduce international confusion when comparing measurements.

Measurement

- Length is the distance between two points.
- Volume is the amount of space an object occupies.
- To calculate volume, multiply length by width by height.
- The amount of matter in an object is its mass.
- Weight is determined by gravitational pull.
- Celsius temperature scales are more common in laboratories than kelvin scales.

Self Check

1. **Describe** a situation in which different units of measure could cause confusion.
2. **Define** what type of quantity the cubic meter measures.
3. **Explain** how you would change a measurement in centimeters to kilometers.
4. **Identify** what SI unit replaces the pound. What does this measure?
5. **Think Critically** How would you find the mass of a metal cube?

Applying Math

6. **Measure** A block of wood is 0.2 m by 0.1 m by 0.5 m. Find its dimensions in centimeters. Then find its volume in cubic centimeters.

Science online red.msscience.com/self_check_quiz

Section 3

Drawings, Tables, and Graphs

as you read

What You'll Learn

- **Describe** how to use pictures and tables to give information.
- **Identify** and use three types of graphs.
- **Distinguish** the correct use of each type of graph.

Why It's Important

Illustrations, tables, and graphs help you communicate data about the world around you in an organized and efficient way.

Review Vocabulary

model: a representation of an object or event used as a tool for understanding the natural world

New Vocabulary

- table
- graph
- line graph
- bar graph
- circle graph

Scientific Illustrations

Most science books include pictures. Photographs and drawings model and illustrate ideas and sometimes make new information clearer than written text can. For example, a drawing of an airplane engine shows how all the parts fit together much better than several pages of text could describe it.

Drawings A drawing is sometimes the best choice to show details. For example, a canyon cut through red rock reveals many rock layers. If the layers are all shades of red, a drawing can show exactly where the lines between the layers are. A drawing can emphasize only the things that are necessary to show.

A drawing also can show things you can't see. You can't see the entire solar system, but drawings show you what it looks like. Also, you can make quick sketches to help model problems. For example, you could draw the outline of two continents to show how they might have fit together at one time.

Drawings can show hidden things, as well. A drawing can show the details of the water cycle, as in **Figure 13.** Architects use drawings to show what the inside of a building will look like. Biologists use drawings to show where the nerves in your arm are found.

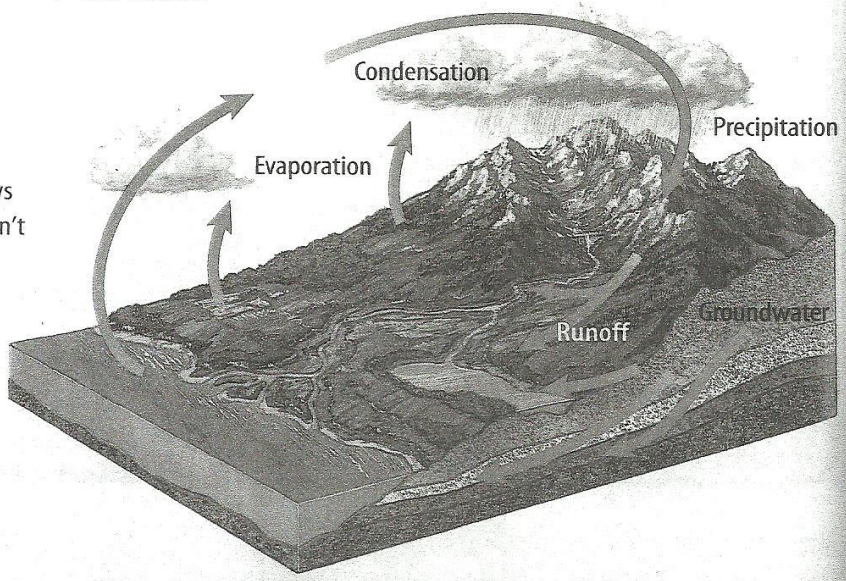


Figure 13 This drawing shows details of the water cycle that can't be seen in a photograph.

Photographs A still photograph shows an object exactly as it is at a single moment in time. Movies show how an object moves and can be slowed down or sped up to show interesting features. In your schoolwork, you might use photographs in a report. For example, you could show the different types of trees in your neighborhood for a report on ecology.

Tables and Graphs

Everyone who deals with numbers and compares measurements needs an organized way to collect and display data. A **table** displays information in rows and columns so that it is easier to read and understand, as seen in **Table 4.** The data in the table could be presented in a paragraph, but it would be harder to pick out the facts or make comparisons.

A **graph** is used to collect, organize, and summarize data in a visual way. The relationships between the data often are seen more clearly when shown in a graph. Three common types of graphs are line, bar, and circle graphs.

Line Graph A **line graph** shows the relationship between two variables. A variable is something that can change, or vary, such as the temperature of a liquid or the number of people in a race. Both variables in a line graph must be numbers. An example of a line graph is shown in **Figure 14.** One variable is shown on the horizontal axis, or *x*-axis, of the graph. The other variable is placed along the vertical axis, or *y*-axis. A line on the graph shows the relationship between the two variables.

Table 4 Endangered Animal Species in the United States

Year	Number of Endangered Animal Species
1984	192
1986	213
1988	245
1990	263
1992	284
1994	321
1996	324
1998	357
2000	379
2002	389

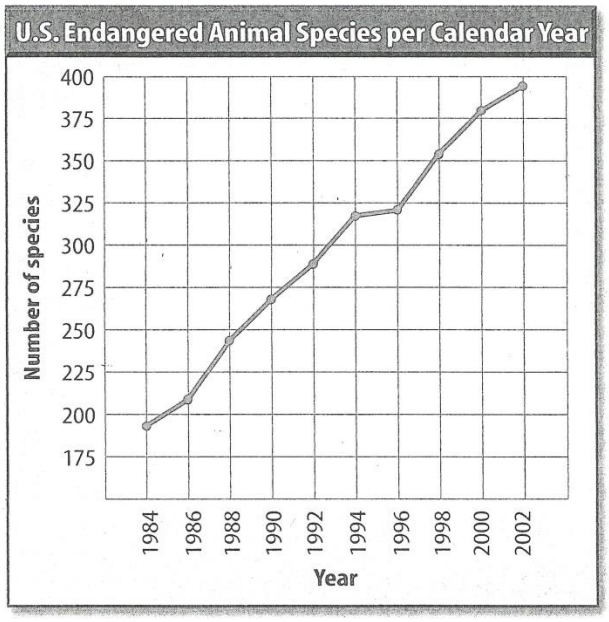


Figure 14 To find the number of endangered animal species in 1992, find that year on the *x*-axis and see what number corresponds to it on the *y*-axis.
Interpret Data *How many species were endangered in 1998?*

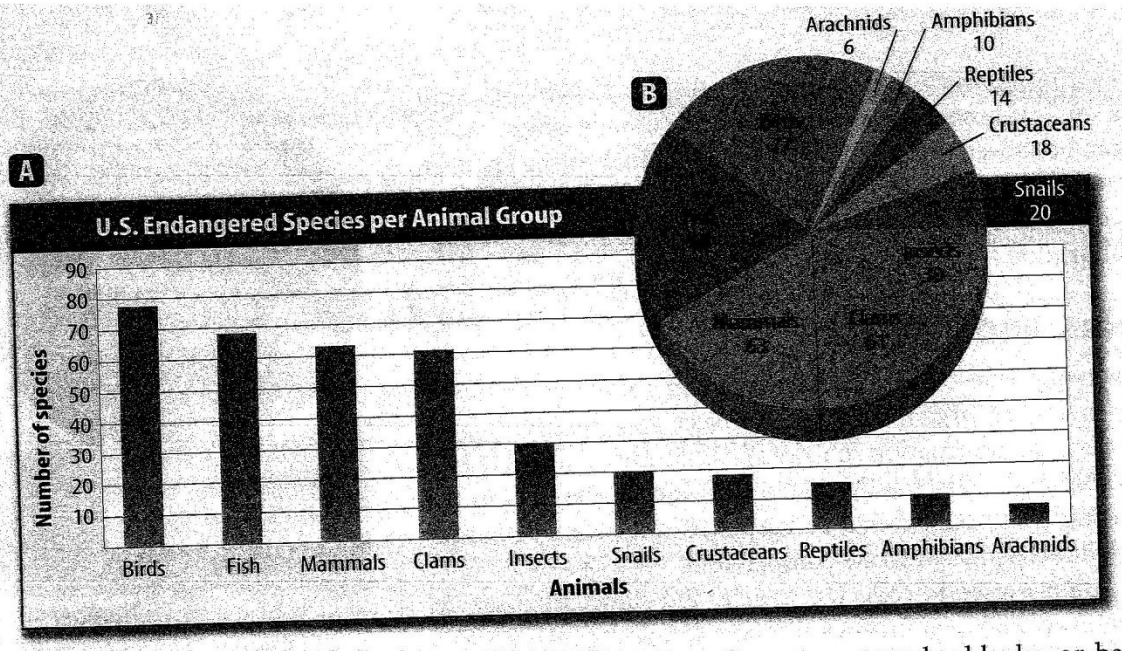


Figure 15 **A** Bar graphs allow you to picture the results easily. **B** On this circle graph, you can see what part of the whole each animal represents.
Infer *Which category of animals has the most endangered species?*

Bar Graph A **bar graph** uses rectangular blocks, or bars, of varying sizes to show the relationships among variables. One variable is divided into parts. It can be numbers, such as the time of day, or a category, such as an animal. The second variable must be a number. The bars show the size of the second variable. For example, if you made a bar graph of the endangered species data from **Figure 14,** the bar for 1990 would represent 263 species. An example of a bar graph is shown in **Figure 15A.**

Circle Graph Suppose you want to show the relationship among the types of endangered species. A **circle graph** shows the parts of a whole. Circle graphs are sometimes called pie graphs. Each piece of pie visually represents a fraction of the total. Looking at the circle graph in **Figure 15B,** you see quickly which animals have the highest number of endangered species by comparing the sizes of the pieces of pie.

A circle has a total of 360°. To make a circle graph, you need to determine what fraction of 360 each part should be. First, determine the total of the parts. In **Figure 15B,** the total of the parts, or endangered species, is 367. One fraction of the total, *Mammals,* is 63 of 367 species. What fraction of 360 is this? To determine this, set up a ratio and solve for x:

$$\frac{63}{367} = \frac{x}{360°} \qquad x = 61.8°$$

Mammals will have an angle of 61.8° in the graph. The other angles in the circle are determined the same way.

Reading Check ***What is another name for a circle graph?***

Science Online
Topic: Scientific Data
Visit red.msscience.com for Web links to information about scientific illustrations, tables, and graphs and their importance in the scientific community.
Activity Create a table or graph using data collected from a classroom observation.

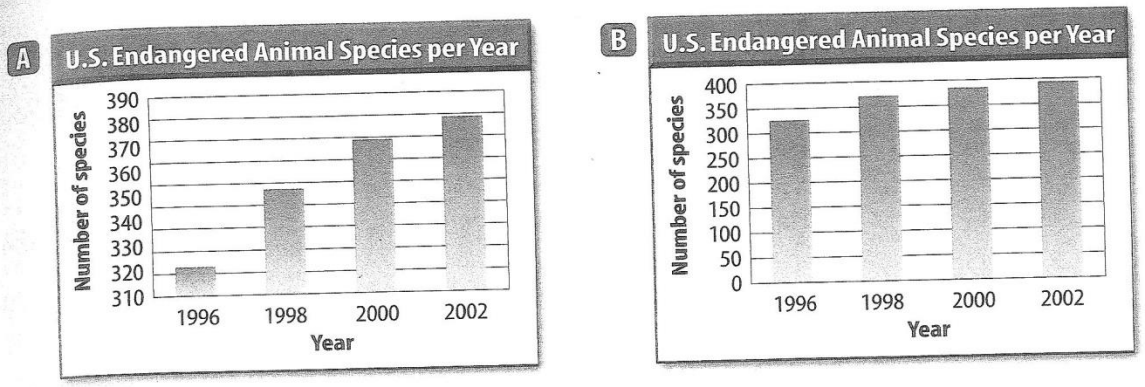


Figure 16 Careful reading of graphs is important. **A** This graph does not start at zero, which makes it appear that the number of species has more than quadrupled from 1996–2002. **B** The actual increase is about 20 percent, as you can see from this full graph. The broken scale must be noted in order to interpret the results correctly.

Reading Graphs When you are using or making graphs to display data, be careful—the scale of a graph can be misleading. The way the scale on a graph is marked can create the wrong impression, as seen in **Figure 16A.** Until you see that the *y*-axis doesn't start at zero, it appears that the number of endangered species has quadrupled in just six years.

This is called a broken scale and is used to highlight small but significant changes, just as an inset on a map draws attention to a small area of a larger map. **Figure 16B** shows the same data on a graph that does not have a broken scale. The number of species has only increased 20 percent from 1996 to 2002. Both graphs have correct data, but must be read carefully. Always analyze the measurements and graphs that you come across. If there is a surprising result, look closer at the scale.

section 3 review

Summary

Scientific Illustrations

- Drawings and illustrations can help people visualize complex concepts.
- A drawing can include details you see and those that are hidden.
- Photographs are an exact representation of an object at a single moment in time.

Tables and Graphs

- Tables display information while graphs are used to summarize data.
- A line graph shows the relationship between two variables, a bar graph shows the relationship among variables, and a circle graph shows the parts of a whole.
- It is important to pay close attention to the scale on graphs in order to analyze the information.

Self Check

1. **Explain** how to use **Figure 16** to find the number of endangered species in 1998.
2. **Infer** what type of graph you would use to display data gathered in a survey about students' after-school activities.
3. **Think Critically** Why is it important to be careful when making or using graphs?
4. **Describe** a time when an illustration would be helpful in everyday activities.
5. **Identify** when you would use a broken scale.

Applying Skills

6. **Use a Spreadsheet** Make a spreadsheet to display how the total mass of a 500-kg elevator changes as 50-kg passengers are added one at a time.