

# Tools of Life Scientists

## Terms to Learn

compound light microscope  
electron microscope  
area  
volume  
mass  
temperature

## What You'll Do

- ◆ Describe the tools life scientists use for seeing.
- ◆ Explain how life scientists use computers.
- ◆ Explain the importance of the International System of Units.

Life scientists use various tools to aid them in their work. These tools are used to make observations and to gather, store, and analyze information.

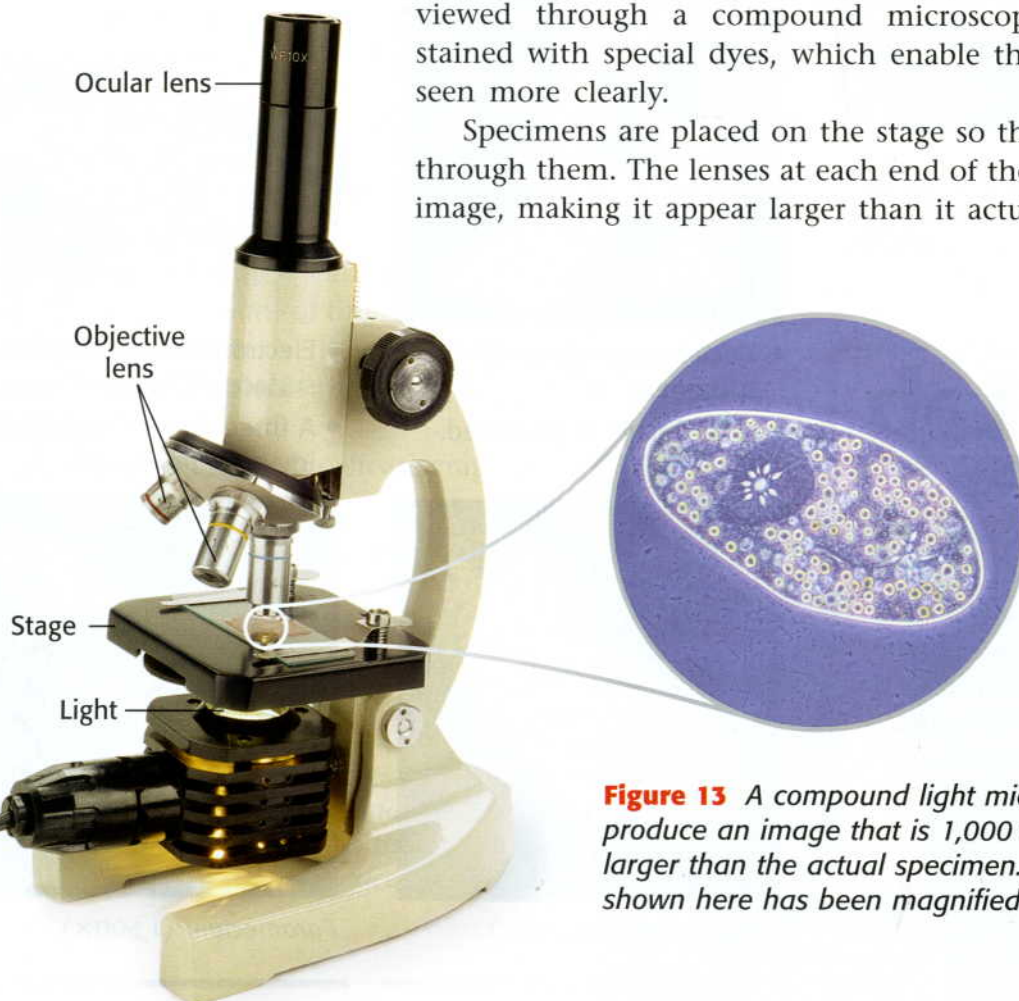
## Tools for Seeing

If you look at a jar of pond water, you may see some scum and a few creatures swimming around. But examine that same water under a microscope or with a magnifying lens, and presto!—a complex community of organisms suddenly appears.

To make accurate observations of organisms and parts of organisms that are too small to be seen with the naked eye, life scientists use tools that can magnify. People have used glass as a magnifier for almost 3,000 years. Today life scientists use magnifying lenses and microscopes.

**Compound Light Microscope** One type of microscope commonly used today is the compound microscope, shown in **Figure 13**. The **compound light microscope** is made up of three main parts—a tube with lenses, a stage, and a light. Specimens viewed through a compound microscope are sometimes stained with special dyes, which enable the specimens to be seen more clearly.

Specimens are placed on the stage so that the light passes through them. The lenses at each end of the tube magnify the image, making it appear larger than it actually is.



**Figure 13** A compound light microscope can produce an image that is 1,000 times (1,000x) larger than the actual specimen. The paramecium shown here has been magnified 200x.

# LabBook

A hidden world  
all around you?  
See what it  
means on  
page 689 of  
your LabBook.



**Electron Microscope** In **electron microscopes**, tiny particles of matter called electrons are used to produce magnified images. Living specimens cannot be examined with an electron microscope because the process that prepares specimens for viewing kills them. There are two kinds of electron microscopes used in life science—the transmission electron microscope and the scanning electron microscope.

Transmission electron microscopes can magnify specimens up to 200,000 times ( $200,000\times$ ) their actual size. The scanning electron microscope can produce images that are up to 100,000 times their actual size. The images that electron microscopes produce are clearer and more detailed than those made by compound microscopes. **Figure 14** shows each kind of electron microscope, with a description of its specialized purpose and an example of the image that it can produce.

**Figure 14** *The transmission electron microscope produces a greatly magnified image. The scanning electron microscope provides a clear view of surface features.*

## Transmission Electron Microscope



- Electrons pass through the specimen.
- A flat image is produced.

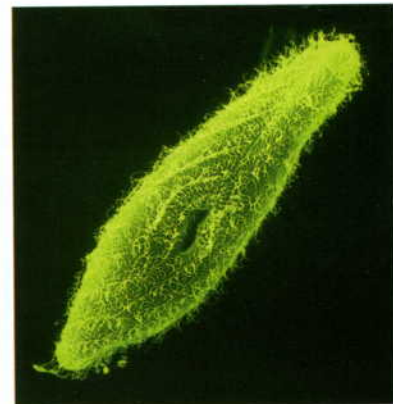


*Paramecium* ( $15,000\times$ )

## Scanning Electron Microscope



- Electrons bounce off the surface of the specimen.
- A three-dimensional (3-D) image is produced.



*Paramecium* ( $1,500\times$ )

## Quick Lab

### See for Yourself

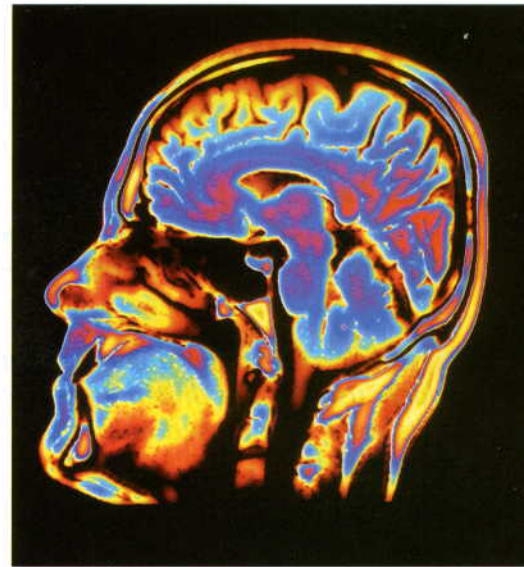
Take a look at one of your fingernails. In your ScienceLog, draw and describe what you see. Then, look at your nail with a **magnifying lens**. How does this affect what you can see? Draw and describe how your nail looks when it is magnified.

**X Rays** Life scientists also use several tools to help them see internal structures of organisms. For almost a century, X rays have provided pictures of internal body structures such as the bones, heart, and lungs. If you have ever broken a bone, you have had an X ray, such as the one shown in **Figure 15**. X rays have also been used to help life scientists learn about the structures of proteins, which are important to the life processes of every organism.



**Figure 15** This X ray shows a broken arm.

**CT Scans and MRI** CT (computed tomography) scans and MRI (magnetic resonance imaging) usually provide clearer, more detailed images of internal tissues than do X rays. In a CT scan, such as the one shown in **Figure 16**, low-dosage X-ray beams are passed through the body at different angles. Often a dye is injected to help highlight the tissues. MRI uses short bursts of a magnetic field and produces images like the one shown in **Figure 17**. With CT scans and MRI, data are transferred to a computer that creates an image that an expert can interpret. Both of these techniques are especially useful for studying the brain and spinal tissue.

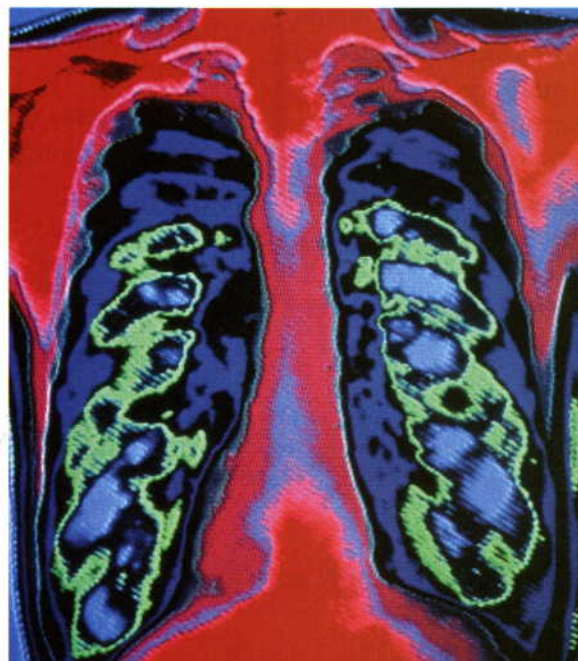


**Figure 16** The internal tissues of the brain are shown in this CT scan.

## Computers

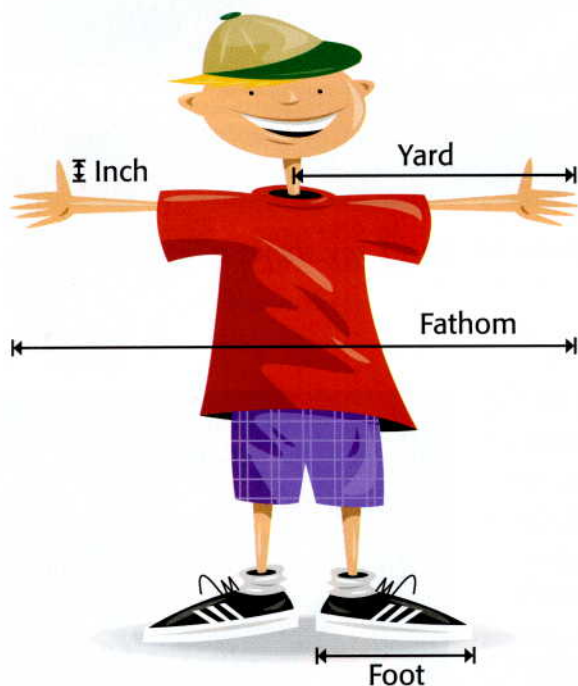
Since the first electronic computer was built in 1946, improvements in technology have made computers more powerful and easier to use. The amount of information that a computer can collect, store, organize, and analyze is enormous. Modern computers can complete billions of calculations in the same amount of time that it took early computers to do thousands. With the help of computers, life scientists are able to solve problems that they were not able to solve in the past.

Computers can be used to create graphs, solve complex mathematical problems, and analyze data. Computers also help scientists share data and ideas with each other and prepare reports and articles about their research.



**Figure 17** This image, showing blood circulation through the lungs, was produced with MRI.

## Systems of Measurement



**Figure 18** The modern English system is widely used in the United States. The units were once based on parts of the human body.

The ability to make accurate and reliable measurements is an important tool in science. There are many different systems of measurement used throughout the world. At one time in England, the standard for 1 inch was three grains of barley arranged end to end. Even modern standardized units were once based on parts of the body, as shown in **Figure 18**. Such systems were not very reliable because they were based on objects that varied in size.

In the late 1700s, the French Academy of Sciences began to develop a global measurement system now known as the International System of Units, or SI. Today most scientists and almost all countries use this system. Using SI measurements helps scientists share and compare their observations and results.

The table below contains commonly used SI units for length, volume, mass, and temperature. Prefixes are used with these units to change them to larger or smaller units. For example, *kilo* means 1,000 times and *milli* indicates 1/1,000 times. All units are based on the number 10, which makes conversions from one unit to another easier.

### Common SI Units

#### Length



#### meter (m)

kilometer (km)	1 km = 1,000 m
decimeter (dm)	1 dm = 0.1 m
centimeter (cm)	1 cm = 0.01 m
millimeter (mm)	1 mm = 0.001 m
micrometer ( $\mu\text{m}$ )	1 $\mu\text{m}$ = 0.000 001 m
nanometer (nm)	1 nm = 0.000 000 001 m

#### Volume



#### cubic meter ( $\text{m}^3$ )

cubic centimeter ( $\text{cm}^3$ )	1 $\text{cm}^3$ = 0.000 001 $\text{m}^3$
liter (L)	1 L = 1 $\text{dm}^3$ = 0.001 $\text{m}^3$
milliliter (mL)	1 mL = 0.001 L = 1 $\text{cm}^3$

#### Mass



#### kilogram (kg)

gram (g)	1 g = 0.001 kg
milligram (mg)	1 mg = 0.000 001 kg

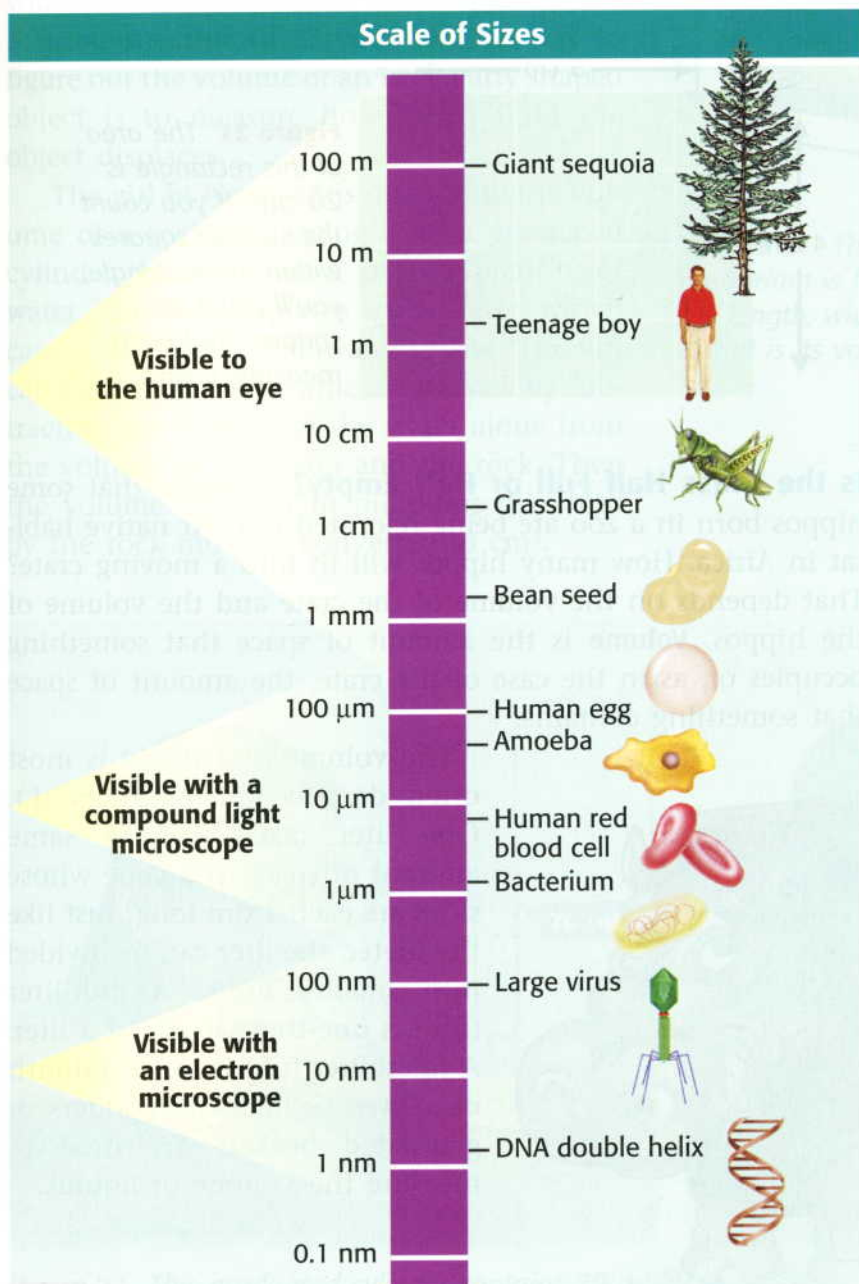
#### Temperature



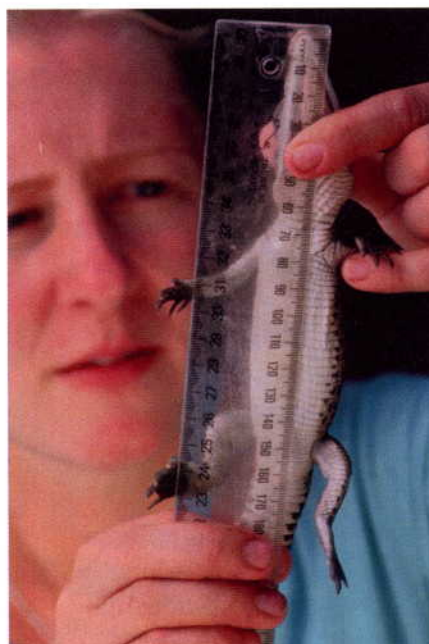
#### Kelvin (K)

Celsius ( $^{\circ}\text{C}$ )	$0^{\circ}\text{C}$ = 273 K
	$100^{\circ}\text{C}$ = 373 K

**The Long and the Short of It** How long is a lizard? A life scientist, like the one in **Figure 19**, would probably use millimeters (mm) to describe a small lizard's length. If you divide 1 m into 1,000 parts, each part equals 1 mm. This means that 1 mm is one-thousandth of a meter. Although that seems pretty small, some organisms and structures are so tiny that even smaller units must be used. To describe the length of microscopic objects, scientists use micrometers ( $\mu\text{m}$ ) or nanometers (nm). The scale in **Figure 20** compares the sizes of different organisms.



**Figure 20** This scale compares organisms that can be seen with the naked eye with organisms and structures that are microscopic.



**Figure 19** This scientist is measuring a lizard's length using a metric ruler.

## Activity

Measure the width of your desk, but do not use a ruler. Pick an object to use as your unit of measurement. It could be a pencil, your hand, or anything else. Use that unit to determine how wide your desk is, and compare your measurement with those of your classmates. Explain why it is important to use standard units of measurement.

**TRY at HOME**

## MATHBREAK

### Finding Area

You can use the equation at right to find the area of any rectangular surface.

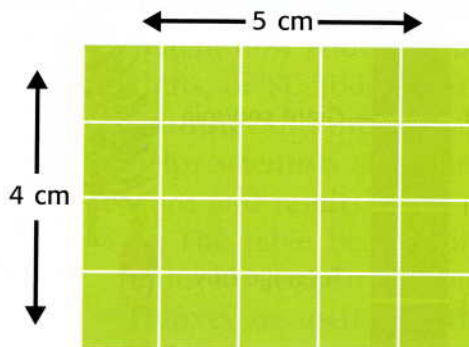
1. What is the area of a square with sides measuring 5 m?
2. What is the area of the top of your desk?
3. A rectangle has an area of  $36 \text{ cm}^2$  and a length of 9 cm. What does its width measure?

**Area** How much carpet would it take to cover the floor of your classroom? Answering this question involves finding the area of the floor. **Area** is a measure of how much surface an object has.

Some quantities, such as area, can't be expressed with one measurement. That is, they are formed from combinations of two or more measurements. To calculate area, first measure the length and width, and then use the following equation:

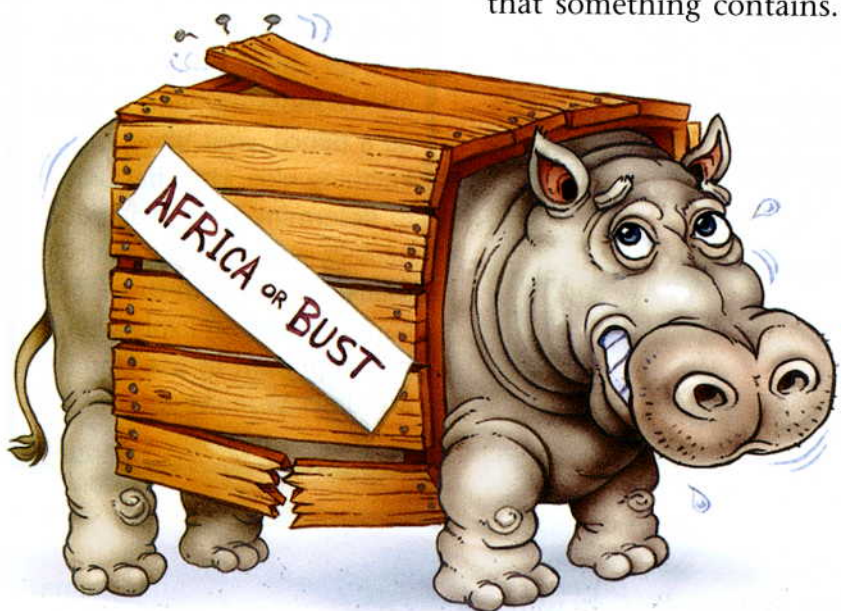
$$\text{Area} = \text{length} \times \text{width}$$

The units for area are called square units, such as  $\text{m}^2$ ,  $\text{cm}^2$ , and  $\text{km}^2$ . **Figure 21** will help you understand square units.



**Figure 21** The area of this rectangle is  $20 \text{ cm}^2$ . If you count the smaller squares within the rectangle, you'll count 20 squares that each measure  $1 \text{ cm}^2$ .

**Is the Glass Half Full or Half Empty?** Suppose that some hippos born in a zoo are being relocated to their native habitat in Africa. How many hippos will fit into a moving crate? That depends on the volume of the crate and the volume of the hippos. **Volume** is the amount of space that something occupies or, as in the case of the crate, the amount of space that something contains.

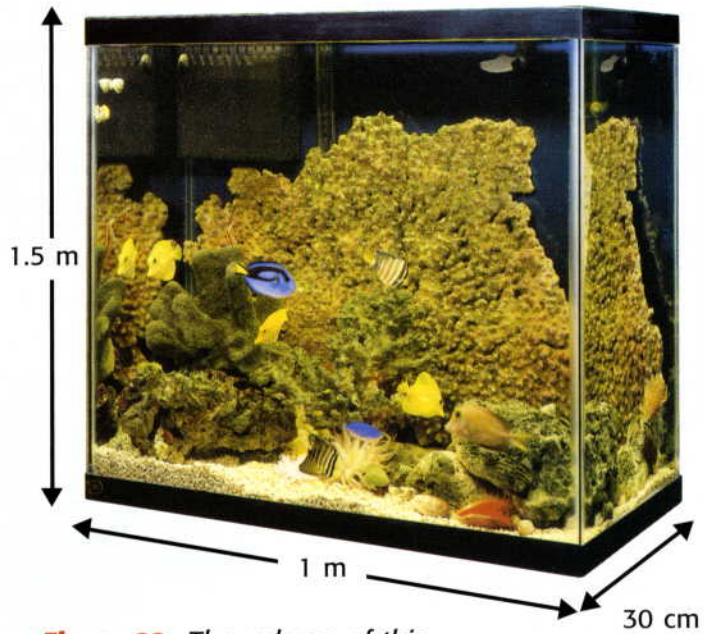


The volume of a liquid is most often described using liters (L). One liter takes up the same amount of space as a cube whose sides are each 1 dm long. Just like the meter, the liter can be divided into smaller units. A milliliter (mL) is one-thousandth of a liter. A microliter ( $\mu\text{L}$ ) is one-millionth of a liter. Graduated cylinders or graduated beakers are used to measure the volume of liquids.

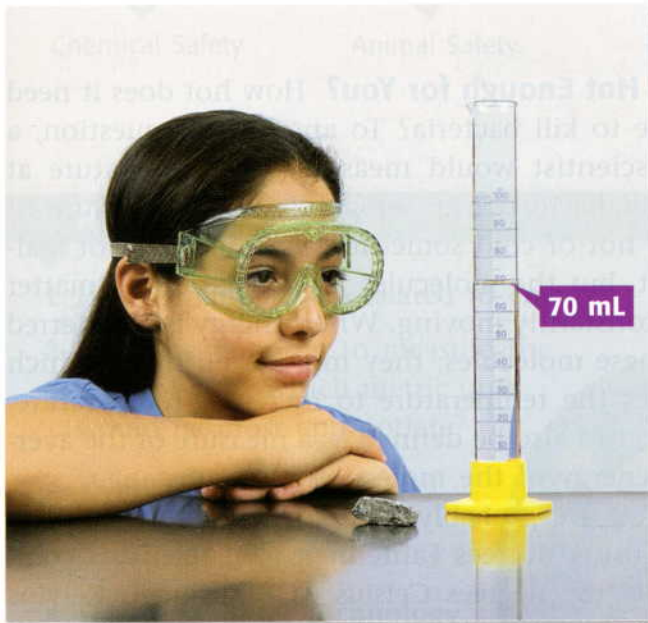
The volume of a solid object, such as a crate, is described using cubic meters ( $m^3$ ). Smaller objects can be measured in cubic centimeters ( $cm^3$ ) or cubic millimeters ( $mm^3$ ). One  $cm^3$  is equal to one mL. To calculate the volume of a cube (or any other rectangular shape), multiply the length by the width by the height. Find the volume of the aquarium in **Figure 22**.

An object like a hippo or a rock has an irregular shape. If you multiplied its length, width, and height, you would not get a very accurate measure of its volume. One way to figure out the volume of an irregularly shaped object is to measure how much fluid the object displaces.

The girl in **Figure 23** is measuring the volume of a rock by placing it in a graduated cylinder that contains a known quantity of water. The rock displaces some water, which causes the level of the water to rise. The girl can figure out the volume of the rock by subtracting the volume of the water alone from the volume of the water and the rock. Then the volume of water in milliliters displaced by the rock must be converted to  $cm^3$ .

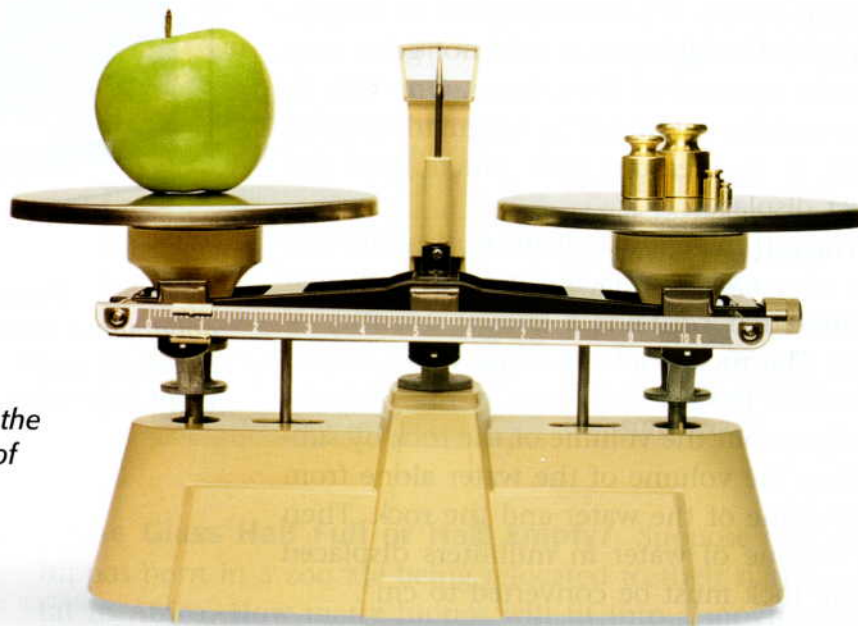


**Figure 22** The volume of this aquarium is found by multiplying its length, width, and height. What is its volume?

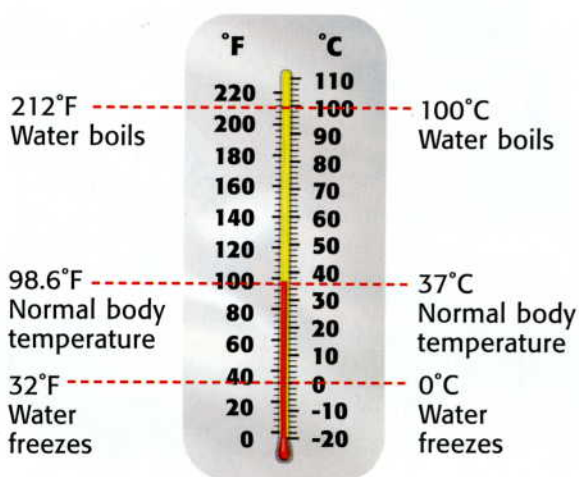


**Figure 23** This graduated cylinder contains 70 mL of water. After the rock was added, the water level moved to 80 mL. Because the rock displaced 10 mL of water and because  $1\text{ mL} = 1\text{ cm}^3$ , the volume of the rock is  $10\text{ cm}^3$ .

**A Massive Undertaking** **Mass** is the amount of matter that makes up an object. The kilogram (kg) is the basic unit for mass. The mass of a very large object is described using kilograms (kg) or metric tons. A kilogram equals 1,000 g; therefore, a gram is one-thousandth of a kilogram. A metric ton equals 1,000 kg. Grams are used to describe the mass of small objects. A medium-sized apple has a mass of about 100 g. As shown in **Figure 24**, mass can be measured with a balance.



**Figure 24** The mass of the apple equals the mass of the weights.



**Figure 25** Water freezes at 0°C and boils at 100°C. Your normal body temperature is 37°C, which is equal to 98.6°F.

**Is It Hot Enough for You?** How hot does it need to be to kill bacteria? To answer this question, a life scientist would measure the temperature at which bacteria die. **Temperature** is a measure of how hot or cold something is. You may not realize it, but the molecules that make up all matter are constantly moving. When energy is transferred to these molecules, they move even more, which causes the temperature to increase. Temperature, then, can also be defined as a measure of the average energy of the molecules of a substance.

You are probably used to describing temperature using degrees Fahrenheit (°F). Scientists commonly use degrees Celsius (°C), although Kelvins are the official SI units for temperature. You will use °C in this book. The thermometer in **Figure 25** shows the relationship between °F and °C.

## Safety Rules!

Life science is exciting and fun, but it can also be dangerous. So don't take any chances! Always follow your teacher's instructions, and don't take shortcuts—even when you think there is little or no danger.

Before starting an experiment, get your teacher's permission and read the lab procedures carefully. Pay particular attention to safety information and caution statements. The diagram below shows the safety symbols used in this book. Get to know these symbols and what they mean. Do this by reading the safety information starting on page 682. **This is important!** If you are still unsure about what a safety symbol means, ask your teacher.



Stay on the safe side by reading the safety information on page 682.

**This is a must before doing an experiment!**

## Safety Symbols



Eye Protection



Clothing Protection



Hand Safety



Heating Safety



Electric Safety



Sharp Object



Chemical Safety



Animal Safety



Plant Safety

## REVIEW

1. How is temperature related to energy?
2. If you were going to measure the mass of a fly, which metric unit would be most appropriate?
3. What are two benefits of using the International System of Units?
4. **Understanding Technology**  
What tool was used to produce the image at right? How can you tell?



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