Guide to the Toolkits and Appendices

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Science Skills Toolkit 1

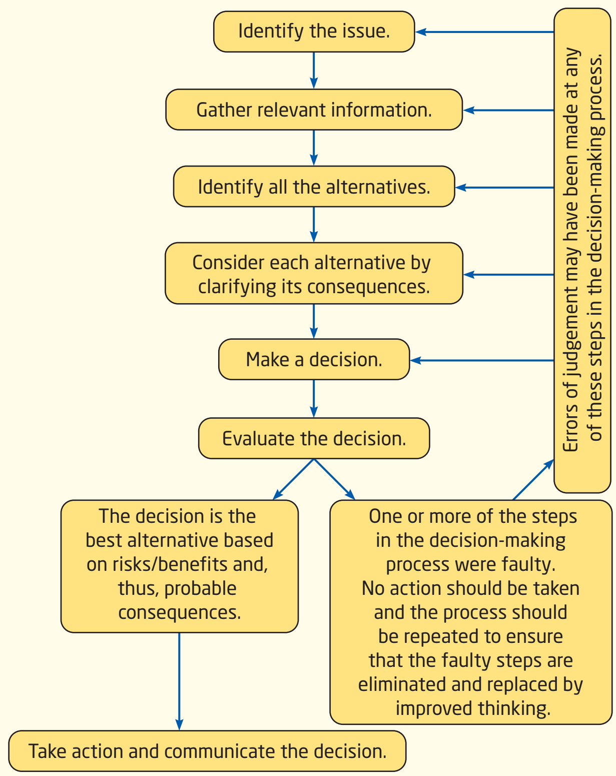
Analyzing Issues—Science, Technology, Society, and the Environment

Can you think of an issue that involves science, technology, society, and the environment? How about the use of salt to de-ice roads in the winter? Roads are safer in winter when they are clear of ice and snow.

However, what if you found out that the salt may eventually reach your drinking water and could have negative effects on aquatic ecosystems? How might you use science and technology to solve this problem?

Suppose your town council is in the process of deciding whether to expand its road salting program. How will you analyze this issue and determine what action to take? The concept map on this page shows a process to help you focus your thinking and stay on track.

A Process for Analyzing Issues



Identifying the Issue

Soon after hearing the news about the road salting, you go to your friend's house. You find your friend sitting in front of the computer, composing a letter to the town council. In it, your friend is asking that the salting program not be expanded to your area. "I heard that the salt can damage the environment, but how bad can it be?" you ask. "And, isn't it important to make our roads safer?"

Gathering Information

"It is," answers your friend, "but is there some way we can make the roads safer without doing so much harm to the plants at roadsides and to the drinking water in springs and wells? I was going to research to find information about these questions I have written down."

"Whew," you say. "There is an awful lot to think about here. Let's see what we can find out from the Internet."

The Internet and other sources, such as books or experts, are great places to find information about an issue. One thing that is important to do when gathering information is to look for bias. **Bias** is a personal and possibly unreasonable judgement of an issue. For example, a person who makes his or her living putting salt on the roads may have a bias that salt does not harm the environment. It is important to check the source of information to determine whether it is unbiased. Refer to **Science Skills Toolkit 12** for more information about how to research information.

Another important part of gathering information is taking notes so that you can analyze what you have learned. You may read about different viewpoints or solutions and advantages and disadvantages for each one. It is helpful to be able to organize your notes in the form of a graphic organizer such as a concept map, a flowchart, or a Venn diagram. You will find information on using graphic organizers in **Study Toolkit 4** on pages 566–567.

Identifying Alternatives

Your research may lead you to ask new questions about alternative solutions and how successful they might be. For example, you might think about how a combination of salt and sand would work to keep roads clear of ice. Would this be a safer environmental alternative? Answering these questions often leads to more research or possibly doing your own scientific inquiry.

Making a Decision

When you have all of the information that your research can provide, your decision will still involve some very human and personal elements. People have strong feelings about the social and environmental issues that affect them. Something that seems obvious to you might not be so obvious to another person. Even the unbiased scientific evidence you found during your research might not change that person's mind. If you are going to encourage a group to make what you consider a good decision, you have to find ways to persuade the group to think as you do.

Evaluating the Decision

After you have made a decision, it is important to evaluate your decision. Is the decision the best alternative considering the risks and benefits? Have you thought about the possible consequences of the decision and how you might respond to them? If you determine that your decision-making process was faulty—if, for example, you based your decision on information that you later learned was false—you should begin again. If you find that you are comfortable with your decision, the next step is to take action.

Taking Action

Issues rarely have easy answers. People who are affected have differing, valid points of view. It is easier for you to act as an individual, but if you can persuade a group to act, you will have greater influence. In the issue discussed here, you might write a letter to your town council. As a compromise, you might suggest a combination of salt and sand on the roads. Your research can provide you with appropriate statistics. As a group, you could attend a town council meeting or sign a petition to make your views known.

Over time, you can assess the effects of your actions: Are there fewer accidents on the salted/sanded roads? Does less salt end up in the water than when more salt alone is used?

Sometimes taking action involves changing the way you do things. After you have presented your findings to the town council, one of your friends makes you stop and think. "I have noticed you putting a lot of salt out on your sidewalk," your friend says. "You could use a bit of time and muscle power to chip away the ice, but that is not the choice you make." You realize your friend is right—it is not only up to the town council or any other group to act responsibly; it is also up to you and your friends. How easy is it for you to give up an easy way of doing a task in order to make an environmentally responsible decision?

Instant Practice—Analyzing Issues

We live in an energy-intensive society. One of the most common sources of the energy we use is fossil fuels. Complete the following exercise in a group of four.

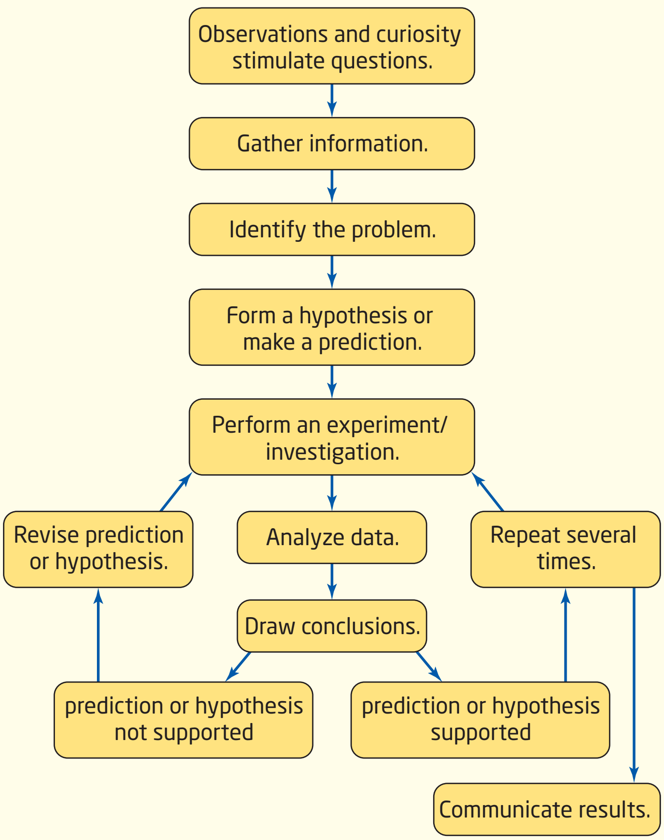
1. Start by dividing your group into two pairs.
2. One pair will research and record the advantages of using fossil fuels and how this use has affected members of our society in a positive way.
3. The second pair will research and record the disadvantages of using fossil fuels and their negative impacts on society.
4. The pairs will then regroup, and both sides can present their findings. Record key points on a chart for comparison.
5. Determine which pair has the more convincing evidence for its point of view concerning the use of fossil fuels.
6. As a group, research alternative energy sources, including advantages and disadvantages of each. Determine the best alternative, based on the information you found in steps 2 and 3 above.

Science Skills Toolkit 2

Scientific Inquiry

Scientific inquiry is a process that involves many steps, including making observations, asking questions, performing investigations, and drawing conclusions. These steps may not happen in the same order in each inquiry. There is no universal scientific method. However, one model of the scientific inquiry process is shown here:

The Scientific Inquiry Process



Making Observations and Asking Questions

The rain has stopped, and the Sun is out. You notice that a puddle of water has disappeared from the sidewalk. What happened to that puddle? You could probably quickly answer that question, but how would you prove your answer? You would need to carry out a scientific inquiry.

Gathering Information and Identifying the Problem

First, you might observe what happens to some other puddles. You would watch them closely until they disappeared and record what you observed.

One observation you might make is "The puddle is almost all gone." That would be a **qualitative observation**, an observation in which numbers are not used. A little later, you might also say, "It took five hours for the puddle to disappear completely." You have made a **quantitative observation**, an observation that uses numbers.

Although the two puddles were the same size, one disappeared (evaporated) much more quickly than the other one did. Your quantitative observations tell you that one evaporated in 4 h, whereas the other one took 5 h. Your qualitative observations tell you that the one that evaporated more quickly was in the sun. The one that evaporated more slowly was in the shade. You now have identified one problem to solve: Does water always evaporate more quickly in the sun than in the shade?

Beginning your observations of puddles

Concluding your observations of puddles

Instant Practice—Making Qualitative and Quantitative Observations

Copy the observations below in your notebook. Beside each observation, write "Qual" if you think it is a qualitative observation and "Quan" if you think it is a quantitative observation.

1. **a.** The bowling ball is heavier than the basketball.
   b. The red ball weighs 5 g more than the blue ball.
2. **a.** The temperature increased by several degrees.
   b. The temperature increased by 2°C.
3. **a.** The water was lukewarm.
   b. The water was cooler than the oil.
4. **a.** The owl ate 3 mice.
   b. The owl was larger than the nighthawk.
5. **a.** The second light bulb was the brightest.
   b. The 60 W bulb was brighter than the 40 W bulb.
6. **a.** The colour of the surface water in the lake was green.
   b. The lake contained 15 species of fish.

Stating a Hypothesis

Now you are ready to make a **hypothesis**, a statement about an idea that you can test, based on your observations. Your test will involve comparing two things to find the relationship between them. You know that the Sun is a source of thermal energy, so you might use that knowledge to make this hypothesis: If a puddle of water is in the sunlight, then the water will evaporate faster than if the puddle is in the shade.

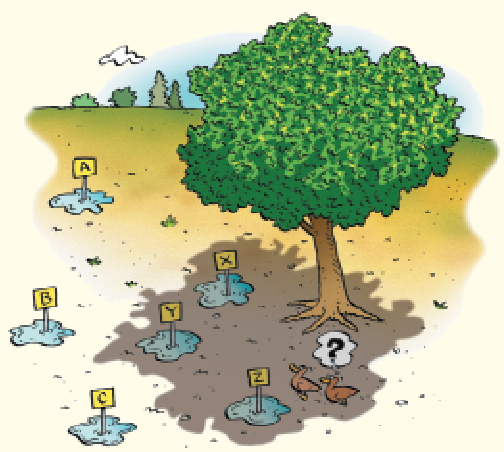
Instant Practice—Stating a Hypothesis

Write a hypothesis for each of the following situations. You may wish to use an "If...then..." format. For example: *If* temperature affects bacterial growth, *then* bacterial culture plates at a higher temperature will have more bacterial colonies than those at a lower temperature.

1. The relationship between temperature and the state of water
2. The relationship between types of atmospheric gases and global warming
3. The amount of time batteries last in different devices
4. The effect of the colour of flowers on honeybee visitations

Making a Prediction

As you prepare to make your observations, you can make a **prediction**, a forecast about what you expect to observe. In this case, you might predict that puddles A, B, and C will dry up more quickly than puddles X, Y, and Z.



Performing an Investigation

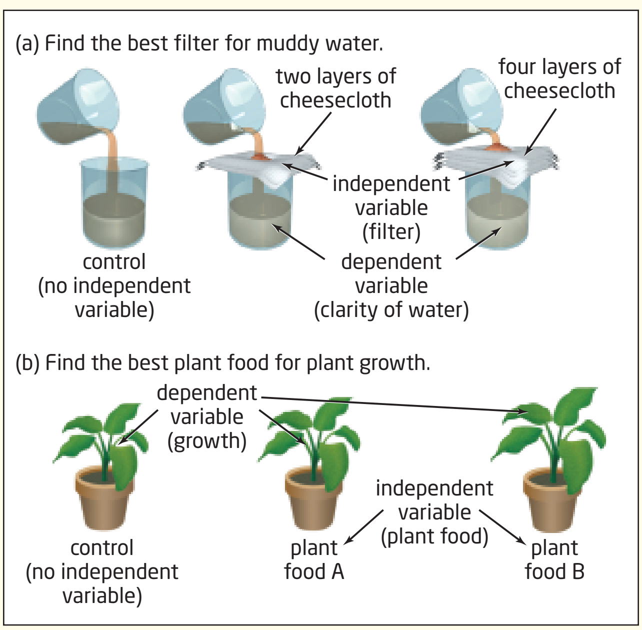
As you know, there are several steps involved in performing a scientific investigation, including identifying variables, designing a fair test, and organizing and analyzing data.

Identifying Variables "But wait a minute," you think, as you look again at your recorded observations. "There was a strong breeze blowing today. What effect might that have had?" The breeze is one factor that could affect evaporation. The Sun is another factor that could affect evaporation. Scientists think about every possible factor that could affect tests they conduct. These factors are called **variables**. It is important to test only one variable at a time.

You need to control your variables. This means that you change only one variable at a time. The variable that you change is called the **independent variable** (also called the manipulated variable). In this case, the independent variable is the condition under which you observe the puddle (one variable would be adding thermal energy; another would be moving air across it).

According to your hypothesis, adding thermal energy will change the time it takes for the puddle to evaporate. The time in this case is called the **dependent variable** (also called the responding variable).

Often, experiments have a **control**. This is a test that you carry out with no variables, so that you can observe whether your independent variable does indeed cause a change. Look at the illustration below to see some examples of variables.

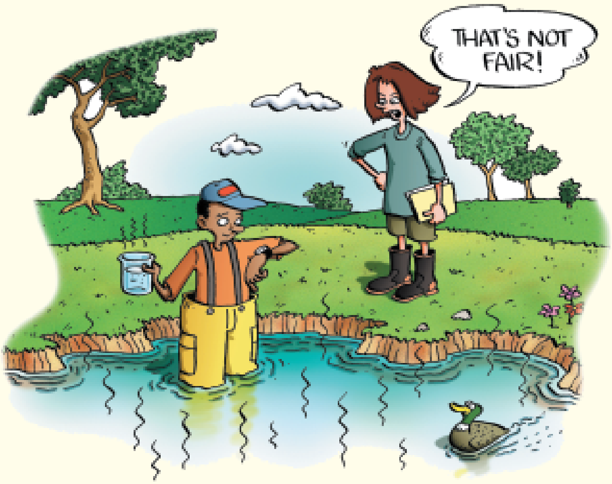


Instant Practice—Identifying Variables

For each of the following questions, state your control, your independent variable, and your dependent variable.

1. Does light travel the same way through different substances?
2. Does adding compost to soil promote vegetable growth?
3. How effective are various kinds of mosquito repellent?

Controlling Variables for a Fair Test If you consider more than one variable in a test, you are not conducting a **fair test** (one that is valid and unbiased), and your results will not be useful. You will not know whether the breeze or the Sun made the water evaporate.



As you have been reading, a question may have occurred to you: How is it possible to do a fair test on puddles? How can you be sure that they are the same size? In situations such as this one, scientists often use **models**. A model can be a mental picture, a diagram, a working model, or even a mathematical expression. To make sure your test is fair, you can prepare model puddles that you know are all exactly the same. **Science Skills Toolkit 11** gives you more information on using models.

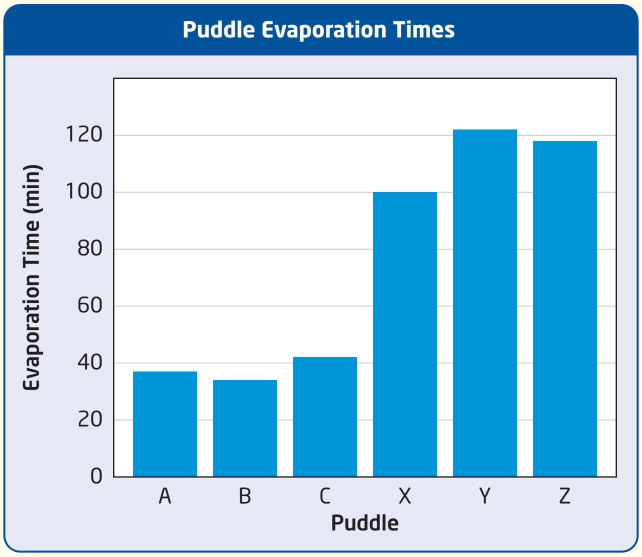
Before you begin your investigation, review safety procedures and identify what safety equipment you may need. Refer to page xiv in this textbook for more information on safety.

Recording and Organizing Data Another step in performing an investigation is recording and organizing your data. Often, you can record your data in a table like the one shown below. Refer to **Science Skills Toolkit 7** for more information on making tables.

Puddle Evaporation Times

Puddle	Evaporation Time (min)
A	37
B	34
C	42
X	100
Y	122
Z	118

Analyzing and Presenting Data After recording your data, the next step is to present your data in a format so that you can analyze it. Often, scientists make a graph, such as the bar graph below. For more information on constructing graphs, refer to **Math Skills Toolkit 3**.



Forming a Conclusion

Many investigations are much more complex than the one described here, and there are many more possibilities for error. That is why it is so important to record careful qualitative and quantitative observations.

After you have completed all your observations, you are ready to analyze your data and draw a **conclusion**. A conclusion is a statement that indicates whether your results support or do not support your hypothesis. If you had hypothesized that the addition of thermal energy would have no effect on the evaporation of water, your results would not support your hypothesis. A hypothesis gives you a place to start and helps you design your experiment. If your results do not support your hypothesis, you use what you have learned in the experiment to come up with a new hypothesis to test.

Scientists often set up experiments without knowing what will happen. Sometimes they deliberately set out to prove that something will *not* happen.

Eventually, when a hypothesis has been thoroughly tested and nearly all scientists agree that the results support the hypothesis, it becomes a **theory**. For example, you will learn about the big bang theory of the origin of the universe in Unit 3 of this textbook.

Science Skills Toolkit 3

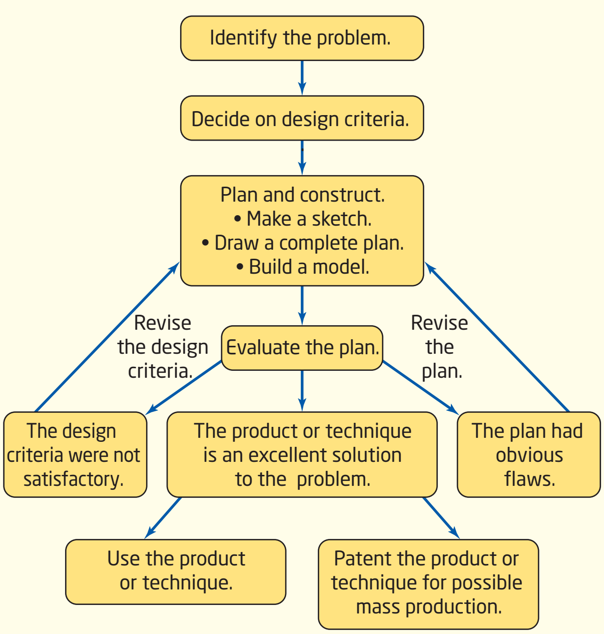
Technological Problem Solving

Technology is the use of scientific knowledge, as well as everyday experience, to solve practical problems. Have you ever used a pencil to flip something out of a tight spot where your fingers could not reach? Have you ever used a stone to hammer bases or goal posts into the ground? Then you have used technology. You may not know why your pencil works as a lever or the physics behind levers, but your everyday experiences tell you how to use a lever successfully.

A Process for Technological Problem Solving

People turn to technology to solve problems. One problem-solving model is shown below.

Solving a Technological Problem



Identifying the Problem

When you used that pencil to move the small item you could not reach, you did so because you needed to move that item. In other words, you had identified a problem that needed to be solved. Clearly identifying a problem is a good first step in finding a solution. In the case of the lever, the solution was right before your eyes, but finding a solution is not always quite so simple.

Suppose school is soon to close for a 16-day winter holiday. Your science class has a hamster whose life stages the class observes. Student volunteers will take the hamster home and care for it over the holiday. However, there is a three-day period when no one will be available to feed the hamster. Leaving extra food in the cage is not an option because the hamster will eat it all at once. What devices could you invent to solve this problem?

First, you need to identify the exact nature of the problem you have to solve. You could state it as follows.

> The hamster must receive food and water on a regular basis so that it remains healthy over a certain period and does not overeat.

Identifying Criteria

Now, how will you be able to assess how well your device works? You cannot invent a device successfully unless you know what criteria (standards) it must meet.

In this case, you could use the following as your criteria.

1. The device must feed and water the hamster.
2. The hamster must be thriving at the end of the three-day period.
3. The hamster must not appear to be "overstuffed."

How could you come up with such a device? On your own, you might not. If you work with a team, however, each of you will have useful ideas to contribute.

Planning and Constructing

You will probably come up with some good ideas on your own. Like all other scientists, though, you will want to use information and devices that others have developed. Do some research and share your findings with your group. Can you modify someone else's idea? With your group, brainstorm some possible designs. How would the designs work? What materials would they require? How difficult would they be to build? How many parts are there that could stop working during the three-day period? Make a clear, labelled drawing of each design, with an explanation of how it would work.

Examine all of your suggested designs carefully. Which do you think would work best? Why? Be prepared to share your choice and your reasons with your group. Listen carefully to what others have to say. Do you still feel yours is the best choice, or do you want to change your mind? When the group votes on the design that will be built, be prepared to co-operate fully, even if the group's choice is not your choice.

Get your teacher's approval of the drawing of the design your group wants to build. Then gather your materials and build a **prototype** (a model) of your design. Experiment with your design to answer some questions you might have about it. For example, should the food and water be provided at the same time? Until you try it out, you may be unsure if it is possible (or even a good idea) for your invention to deliver both food and water at the same time. Keep careful, objective records of each of your tests and of any changes you make to your design.

You might find, too, that your invention fails in a particular way. Perhaps it always leaks at a certain point where two parts are joined. Perhaps the food and water are not kept separate. Perhaps you notice a more efficient way to design your device as you watch it operate. Make any adjustments and test them so that your device works in the best and most efficient way possible.

Evaluating

When you are satisfied with your device, you can demonstrate it and observe devices constructed by other groups. Evaluate each design in terms of how well it meets the design criteria. Think about the ideas other groups tried out and why they work better than (or not as well as) yours. What would you do differently if you were to redesign your device?

Estimating and Measuring

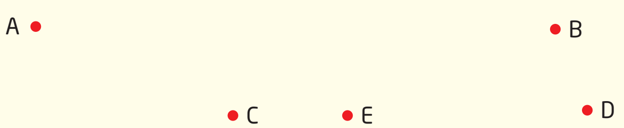
Estimating

How long will it take you to read this page? How heavy is this textbook? You could probably answer these questions by **estimating**—making an informed judgement about a measurement. An estimate gives you an idea of a particular quantity but is not an exact measurement.

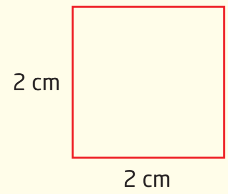
For example, suppose you wanted to know how many ants live in a local park. Counting every ant would be very time-consuming. What you can do is count the number of ants in a typical square-metre area. Then, multiply the number of ants by the number of square metres in the total area you are investigating. This will give you an estimate of the total population of ants in that area.

Measuring Length and Area

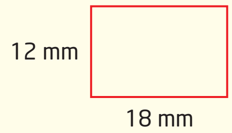
You can use a metre stick or a ruler to measure short distances. These tools are usually marked in centimetres and/or millimetres. Use a ruler to measure the length in millimetres between points A and C, C and E, E and B, and A and D below. Convert your measurements to centimetres and then to metres.



To calculate an area, you can use length measurements. For example, for a square or a rectangle, you can find the area by multiplying the length by the width.



Area of square is $2\ \text{cm} \times 2\ \text{cm} = 4\ \text{cm}^2$



Area of rectangle is $18\ \text{mm} \times 12\ \text{mm} = 216\ \text{mm}^2$

Make sure you always use the same units—if you mix up centimetres and millimetres, your calculations will be wrong. Remember to ask yourself if your answer is reasonable (you could make an estimate to consider this).

Instant Practice—Estimating and Measuring

Imagine that all rulers in the school have vanished. The only measurement tool that you now have is a toothpick.

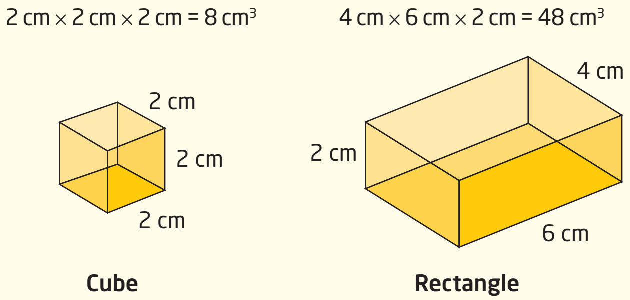
1. Estimate the length and width of your textbook in toothpick units. Compare your estimates with a classmate's estimates.
2. Measure the length and width of your textbook with your toothpick. How close was your estimate to the actual measurement?
3. If you had a much larger area to measure, such as the floor of your classroom, what could you use instead of toothpicks to measure the area? (Be creative!)
4. What is your estimate of the number of units you chose (in question 3) for the width of your classroom?

Measuring Volume

The **volume** of an object is the amount of space that the object occupies. There are several ways of measuring volume, depending on the kind of object you want to measure.

As you can see in Diagram A below, the volume of a regularly shaped solid object can be measured directly. You can calculate the volume of a cube by multiplying its sides, as shown on the left in Diagram A. You can calculate the volume of a rectangular solid by multiplying its length × width × height, as shown on the right in Diagram A.

A



Measuring the volume of a regularly shaped solid

If all the sides of a solid object are measured in millimetres (mm), the volume will be in cubic millimetres (mm^3). If all the sides are measured in centimetres (cm), the volume will be in cubic centimetres (cm^3). The units for measuring the volume of a solid are called cubic units.

The units used to measure the volume of liquids are called capacity units. The basic unit of volume for liquids is the litre (L). Recall that 1 L = 1000 mL.

Cubic units and capacity units are interchangeable. For example,

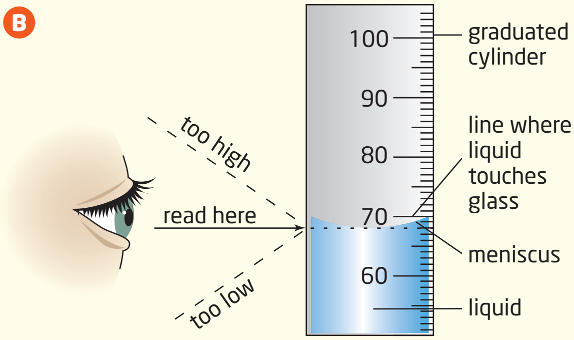
$1\ cm^3 = 1\ mL$

$1\ dm^3 = 1\ L$

$1\ m^3 = 1\ kL$

The volume of a liquid can be measured directly, as shown in Diagram B below. Make sure you measure to the bottom of the **meniscus**, the slight curve where the liquid touches the sides of the container. To measure accurately, make sure your eye is at the same level as the bottom of the meniscus.

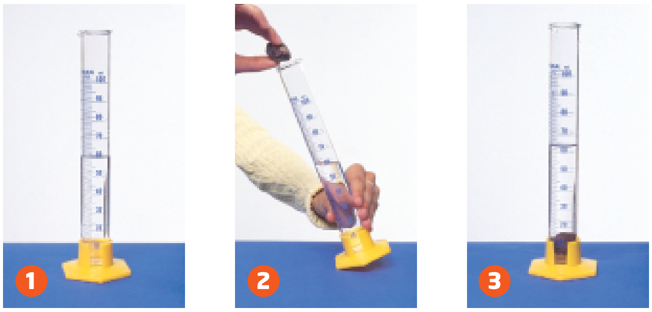
B



Measuring the volume of a liquid

The volume of an irregularly shaped solid object, however, must be measured indirectly, as shown in Diagram C below. This is done by determining the volume of a liquid it will displace.

C



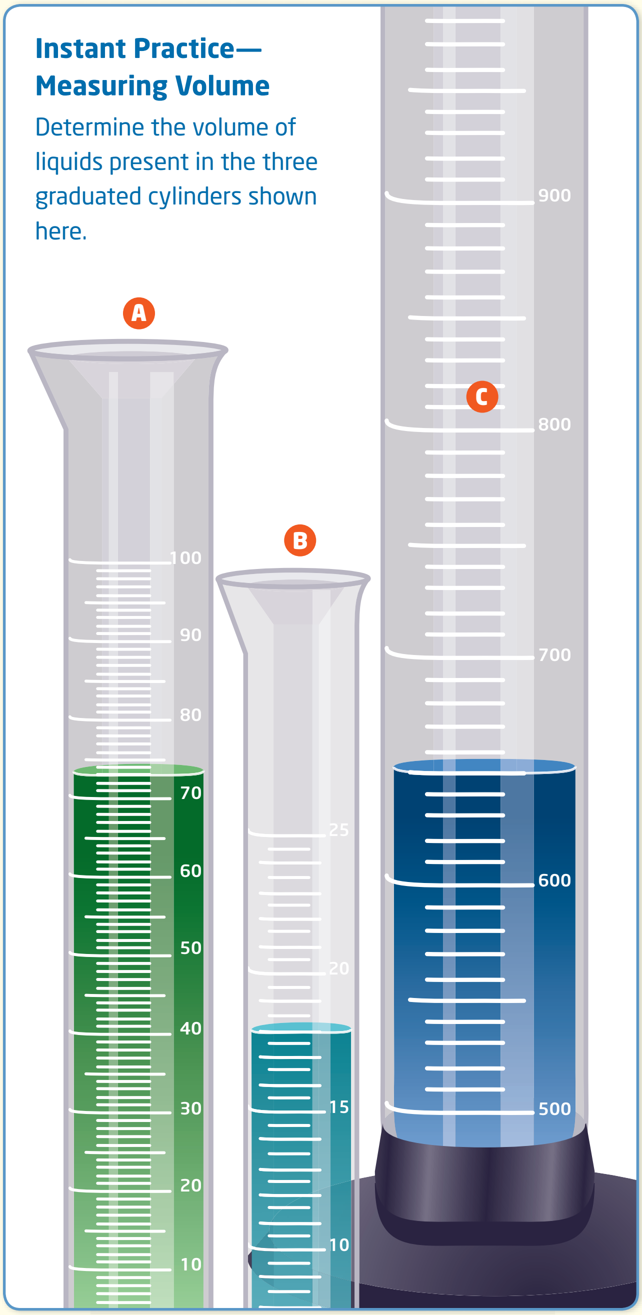
1. Record the volume of the liquid.
2. Carefully lower the object into the cylinder containing the liquid. Record the volume again.
3. The volume of the object is equal to the difference between the two volumes of the liquid. The equation below the photographs shows you how to calculate this volume.

Measuring the volume of an irregularly shaped solid

volume of object = volume of water with object – original volume of water
= 85 mL – 60 mL
= 25 mL

Instant Practice—Measuring Volume

Determine the volume of liquids present in the three graduated cylinders shown here.



Measuring Mass

Is your backpack heavier than your friend's backpack? You can check by holding a backpack in each hand. The **mass** of an object is the amount of matter in a substance or object. Mass is measured in milligrams, grams, kilograms, and tonnes. You need a balance for measuring mass.

How can you find the mass of a certain quantity of a substance, such as table salt, that you have added to a beaker? First, find the mass of the beaker. Next, pour the salt into the beaker and find the mass of the beaker and salt together. To find the mass of the salt, simply subtract the beaker's mass from the combined mass of the beaker and salt.

Instant Practice—Measuring Mass

Use the following information to determine the mass of the table salt. The mass of a beaker is 160 g. The mass of the table salt and beaker together is 230 g.

Measuring Angles

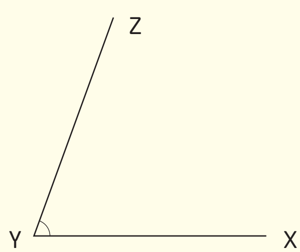
You can use a protractor to measure angles. Protractors usually have an inner scale and an outer scale. The scale you use depends on how you place the protractor on an angle (symbol = ∠). Look at the following examples to learn how to use a protractor.

Example 1

What is the measure of ∠XYZ?

Solution

Place the centre of the protractor on point Y. YX crosses 0° on the inner scale. YZ crosses 70° on the inner scale. So ∠XYZ is equal to 70°.



Example 2

Draw ∠ABC = 155°.

Solution

First, draw a straight line, AB. Place the centre of the protractor on B and line up AB with 0° on the outer scale. Mark C at 155° on the outer scale. Join BC. The angle you have drawn, ∠ABC, is equal to 155°.

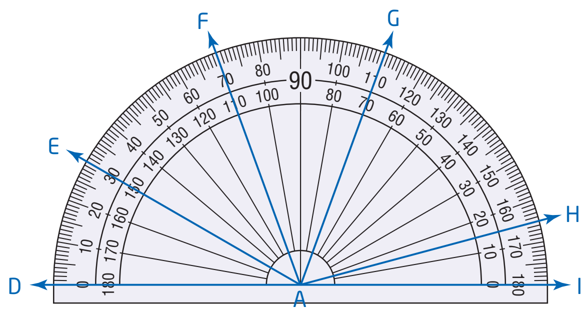
Instant Practice—Measuring Angles

1. State the measure of each of the following angles using the following diagram.

a. DAF **d.** HAF **g.** EAG

b. DAH **e.** GAD **h.** EAI

c. IAG **f.** DAI



2. Use a protractor to draw angles with the following measurements. Label each angle.

a. ABC 50° **c.** XYZ 5° **e.** HAL 90°

b. QRS 85° **d.** JKL 45°

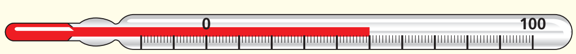
Measuring Temperature

Temperature is a measure of the thermal energy of the particles of a substance. In the very simplest terms, you can think of temperature as a measure of how hot or how cold something is. The temperature of a material is measured with a thermometer.

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

The SI unit of temperature is the kelvin (K). Zero on the Kelvin scale (0 K) is the coldest possible temperature. This temperature is also known as absolute zero. It is equivalent to –273°C, which is about 273 degrees below the freezing point of water. Notice that degree symbols are not used with the Kelvin scale.

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. This means that on the Kelvin scale, water freezes at 273 K and boils at 373 K.



Tips for Using a Thermometer

When using a thermometer to measure the temperature of a substance, here are three important tips to remember.

- Handle the thermometer extremely carefully. It is made of glass and can break easily.
- Do not use the thermometer as a stirring rod.
- Do not let the bulb of the thermometer touch the walls of the container.

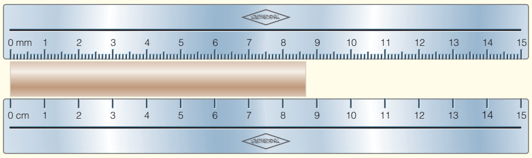
Science Skills Toolkit 5

Precision and Accuracy

No measuring device can give an absolutely exact measure. So how do scientists describe how close an instrument comes to measuring the true result?

Precision Quantitative data from any measuring device are uncertain. You can describe this uncertainty in terms of precision and accuracy. The term **precision** describes both the exactness of a measuring device and the range of values in a set of measurements.

The precision of a measuring instrument is usually half the smallest division on its scale. For example, the bottom ruler below is graduated in centimetres, so it is precise to ± 0.5 cm. The length of the object above the ruler would be reported as 9.0 ± 0.5 cm, because it is closer to 9 cm than to 8 cm, and the uncertainty must be included in the measurement. The top ruler below is graduated in millimetres, so it is precise to ± 0.05 cm. The length of the object below the ruler would be reported as 8.7 ± 0.05 cm.



A precise measuring device will give nearly the same result every time it is used to measure the same object. Consider the following measurements of a 50 g weight on a balance. Both give the same average mass, but Scale B is more precise because it has a smaller range of measured values (± 0.3 versus ± 0.5).

Measurements of Mass on Two Scales

	Scale A Mass (g)	Scale B Mass (g)
Trial 1	49.9	49.9
Trial 2	49.8	50.2
Trial 3	50.3	49.9
Average	50.0	50.0
Range	± 0.5	± 0.3

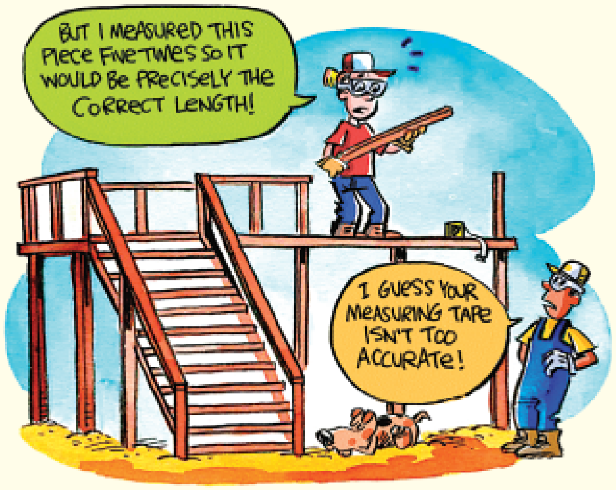
Accuracy How close a measurement or calculation comes to the true value is described as **accuracy**. To improve accuracy, scientific measurements are often repeated and combined mathematically. The average measurements in the table on this page are more accurate than any of the individual measurements.

The darts in diagram A below are very precise, but they are not accurate because they did not hit the bull's-eye. The darts in diagram B are neither precise nor accurate. However, the darts in diagram C are both precise and accurate.

A precise but not accurate

B neither precise nor accurate

C precise and accurate



Instant Practice—Precision and Accuracy

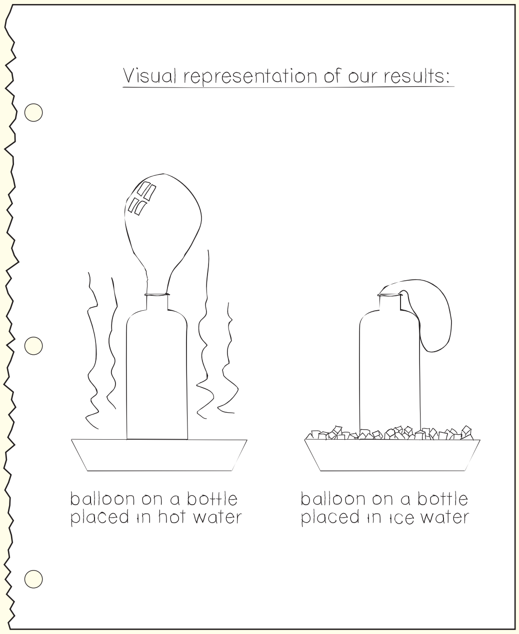
1. A student measures the temperature of ice water four times, and each time gets a result of 10.0°C. Is the thermometer precise and accurate? Explain your answer.
2. Two students collected data on the mass of a substance for an experiment. Each student used a different scale to measure the mass of the substance over three trials. Student A had a range of measurements that was ±0.06 g. Student B had a range of measurements that was ±0.11 g. Which student had the more precise scale?

Science Skills Toolkit 6

Scientific Drawing

Have you ever used a drawing to explain something that was too difficult to explain in words? A clear drawing can often assist or replace words in a scientific explanation. In science, drawings are especially important when you are trying to explain difficult concepts or describe something that contains a lot of detail. It is important to make scientific drawings clear, neat, and accurate.

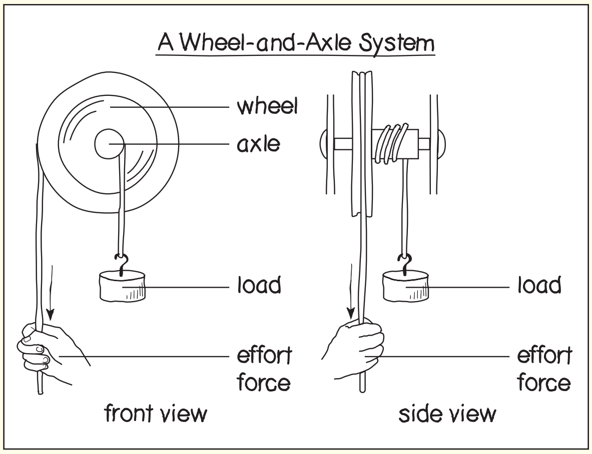
Examine the drawing shown below. It is taken from a student's lab report on an experiment to test the expansion of air in a balloon. The student's written description of results included an explanation of how the particle model can explain what happens to the balloon when the bottle is placed in hot water and in ice water. As you can see, the clear diagrams of the results can support or even replace many words of explanation. While your drawing itself is important, it is also important to label it clearly. If you are comparing and contrasting two objects, label each object and use labels to indicate the points of comparison between them.



Making a Scientific Drawing

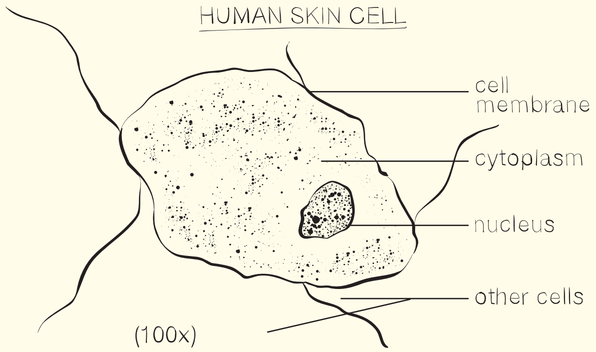
Follow these steps to make an effective scientific drawing.

1. Use unlined paper and a sharp pencil with an eraser.
2. Give yourself plenty of space on the paper. You need to make sure that your drawing will be large enough to show all necessary details. You also need to allow space for labels. Labels identify parts of the object you are drawing. Place all of your labels to the right of your drawing, unless there are so many labels that your drawing looks cluttered.
3. Carefully study the object that you will be drawing. Make sure you know what you need to include.
4. Draw only what you see, and keep your drawing simple. Do not try to indicate parts of the object that are not visible from the angle of observation. If you think it is important to show another part of the object, do a second drawing, and indicate the angle from which each drawing is viewed.



5. Shading or colouring is not usually used in scientific drawings. If you want to indicate a darker area, you can use stippling (a series of dots). You can use double lines to indicate thick parts of the object.

6. If you do use colour, try to be as accurate as you can and choose colours that are as close as possible to the colours in the object you are observing.
7. Label your drawing carefully and completely, using lower-case (small) letters. Think about what you would need to know if you were looking at the object for the first time. Remember to place all your labels to the right of the drawing, if possible. Use a ruler to draw a horizontal line from the label to the part you are identifying. Make sure that none of your label lines cross.
8. Give your drawing a title. The drawing of a human skin cell shown below is from a student's notebook. This student used stippling to show darker areas, horizontal label lines for the cell parts viewed, and a title—all elements of an excellent final drawing.

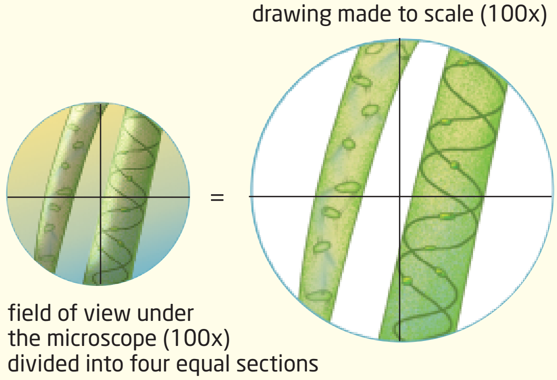


The stippling on this drawing of a human skin cell shows that some areas are darker than others.

Drawing to Scale

When you draw objects seen through a microscope, the size of your drawing is important. Your drawing should be in proportion to the size of the object as the object appears when viewed through the microscope. This type of drawing is called a **scale drawing**. A scale drawing allows you to compare the sizes of different objects and to estimate the actual size of the object being viewed. Here are some steps to follow when making scale drawings of magnified objects.

1. Use a mathematical compass to draw an accurate circle in your notebook. The size of the circle does not matter. The circle represents the microscope's field of view.
2. Imagine the circle is divided into four equal sections (see the diagram below). Use a pencil and a ruler to draw these sections in your circle, as shown below.
3. Using low or medium power, locate an object under the microscope. Imagine that the field of view is also divided into four equal sections.
4. Observe how much of the field of view is taken up by the object. Note the location of the object in the field of view.
5. Draw the object in the circle. Position the object in about the same part of the circle as it appears in the field of view. Draw the object so that it takes up about the same amount of space within the circle as it takes up in the field of view, as shown in the diagram.



Instant Practice—Scale Drawings

Design a scale drawing of your bedroom, using the shape of the floor rather than a circle as in the example given above. Include scale drawings of the furniture in your room. When you are finished, label the fire escape routes.

Science Skills Toolkit 7

Creating Data Tables

Scientific investigation is about collecting information to help you answer a question. In many cases, you will develop an hypothesis and collect data to see if your hypothesis is supported. An important part of any successful investigation includes recording and organizing your data. Often, scientists create tables in which to record data.

Planning to Record Your Data Suppose you are doing an investigation on the water quality of a stream that runs near your school. You will take samples of the numbers and types of organisms at three different locations along the stream. You need to decide how to record and organize your data. Begin by making a list of what you need to record. For this experiment, you will need to record the sample site, the pH of the water at each sample site, the types of organisms found at each sample site, and how many of each type of organism you collected.

Creating Your Data Table Your data table must allow you to record your data neatly. To do this you need to create

- headings to show what you are recording
- columns and rows that you will fill with data
- enough cells to record all the data
- a title for the table

In this investigation, you will find multiple organisms at each site, so you must make space for multiple recordings at each site. This means every row representing a sample site will have at least three rows associated with it for the different organisms.

If you think you might need extra space, create a special section. In this investigation, leave space at the bottom of your table, in case you find more than three organisms at a sample site. Remember, if you use the extra rows, make sure you identify which sample site the extra data are from. Your data table might look like the one at the top of this page.

Observations Made at Three Sample Stream Sites

headings show what is being recorded

columns and rows contain data

Sample Site	pH	Type of Organism	Number of Organisms
1		beetle	3
		snail	1
		dragonfly larva	8
2		beetle	6
		dragonfly larva	7
3		snail	5
		leech	1
		dragonfly larva	2

extra rows to collect data in case you need to add observations

Instant Practice—Creating Data Tables

1. You are interested in how weeds grow in a garden. You decide to collect data from your garden every week for a month. You will identify the weeds and count how many there are of each type of weed. Design and draw a data table that you could use to record your data.
2. Many investigations have several different experimental treatments. Copy the following data table into your notebook and fill in the missing title and headings. The investigation tests the effect of increased fertilizer on plant height. There are four plants, and measurements are being taken every two days.

Day 1	Plant 1	5 mL	
	Plant 2	10 mL	10 cm
		15 mL	
		20 mL	

Science Skills Toolkit 8

Using a Microscope

The light microscope is an optical instrument that greatly increases our powers of observation by magnifying objects that are usually too small to be seen with the unaided eye. The microscope you will use is called a compound light microscope because it uses a series of lenses (rather than only one, as in a magnifying glass) and it uses light to view the object.

A microscope is a delicate instrument, so you must use proper procedure and care. This *Science Skills Toolkit* reviews the skills that you will need to use a microscope effectively. Before you use your microscope, you need to know the parts of a microscope and their functions.

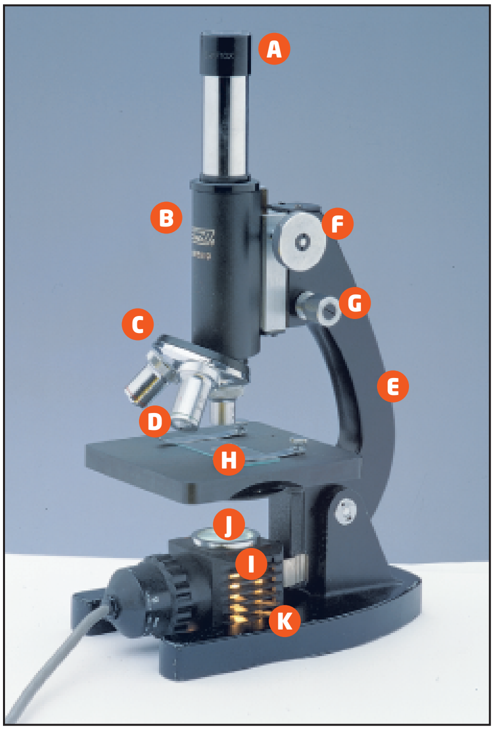
A Eyepiece (or ocular lens)
You look through the eyepiece. It has a lens that magnifies the object, usually by 10 times (10×). The magnifying power is engraved on the side of the eyepiece.

B Tube
The tube holds the eyepiece and the objective lenses at the proper working distance from each other.

C Revolving nosepiece
This rotating disk holds two or more objective lenses. Turn it to change lenses. Each lens clicks into place.

D Objective lenses
The objective lenses magnify the object. Each lens has a different power of magnification, such as 4×, 10×, and 40×. (Your microscope may instead have 10×, 40×, and 100× objective lenses.) The objective lenses are referred to as low, medium, and high power. The magnifying power is engraved on the side of each objective lens. Be sure you can identify each lens.

E Arm
The arm connects the base and the tube. Use the arm for carrying the microscope.



K Light source
Shining a light through the object being viewed makes it easier to see the details. If your microscope has a mirror instead of a light, adjust the mirror to direct light through the lenses. CAUTION: Use an electric light, not sunlight, as the light source for focussing your mirror.

F Coarse-adjustment knob
The coarse-adjustment knob moves the tube up and down to bring the object into focus. Use it only with the low-power objective lens.

G Fine-adjustment knob
Use the fine-adjustment knob with medium- and high-power magnification to bring the object into sharper focus.

H Stage
The stage supports the microscope slide. Stage clips hold the slide in position. An opening in the centre of the stage allows light from the light source to pass through the slide.

I Condenser lens
The condenser lens directs light to the object being viewed.

J Diaphragm
The diaphragm controls the amount of light reaching the object being viewed.

Science Skills Toolkit 9

The GRASP Problem Solving Method

Solving any problem is easier when you establish a logical, step-by-step procedure. One useful method for solving numerical problems includes five basic steps: **Given**, **Required**, **Analysis**, **Solution**, and **Paraphrase**. You can easily remember these steps because the first letter of each word spells the word **GRASP**.

Example of the GRASP Problem Solving Method

Ruby can afford to spend $45.00 this month on electricity. The company that supplies her home with electrical energy charges 10.9¢ per kWh. Based on her budget, how many kWh of electrical energy can she use in a month?

Given—Organize the given data.

budget = $45.00
cost of electrical energy = 10.9¢/kWh

Required—Identify what information the problem requires you to find.

amount of electrical energy that can be used (kWh)

Analysis—Decide how to solve the problem.

1. Convert cents into dollars. (The units given for Ruby's budget—dollars—do not match the units given for the cost of 1 kWh of electrical energy—cents. Both units need to be the same.)
2. Calculate the number of kWh Ruby can afford to use.

   total cost = amount of energy used × cost per unit of energy

Solution—Solve the problem.

1. Convert units

   $\$1.00 = 100¢$

   $10.9¢ =$

   $$(10.9¢) \times \left(\frac{\$1.00}{100¢}\right) = \$0.109$$

2. Use the total cost equation.

total cost = (amount of energy used)(cost per unit of energy)

$$\frac{\text{total cost}}{\text{cost per unit of energy}} = \frac{(\text{amount of energy used})\cancel{(\text{cost per unit of energy})}}{\cancel{\text{cost per unit of energy}}}$$

$$\text{amount of energy used} = \frac{\text{total cost}}{\text{cost per unit of energy}}$$

$$\text{amount of energy used} = \frac{\$45.00}{\$0.109}$$

= 413 kWh

Paraphrase—Restate the solution and check your answer.

Restate Ruby has a budget of $45.00 and electrical energy costs 10.9¢, so she can afford to use 413 kWh of electrical energy this month.

Check Multiply the cost of electrical energy by the answer, and you should get $45.00. Round off the numbers to do a quick estimate. If you multiply $0.11 by 400 kWh, you get $44.00, so you know that your answer is reasonable.

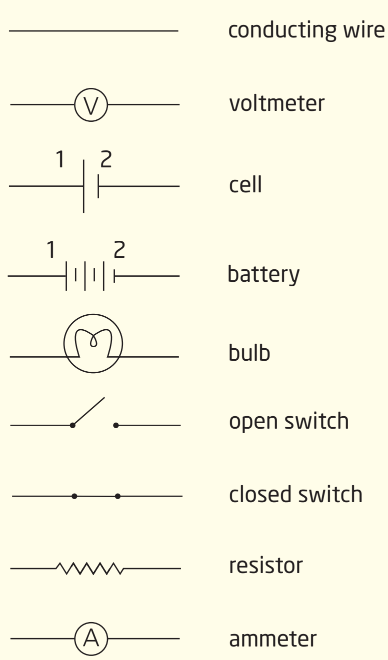
Instant Practice—Using GRASP

The company that supplies Ruby's electrical energy raises the price to 11.1¢/kWh. Use the GRASP method to calculate how much Ruby's monthly energy bill will be if she uses 375 kWh.

Science Skills Toolkit 10

Using Electric Circuit Symbols and Meters

Circuit Diagram Symbols



Using Meters to Measure Voltage and Current

Types of Meters

The meters you use in your classroom are either analogue meters or digital meters. **Analogue meters** have a needle pointing to a dial. **Digital meters** display measured values directly as numbers, similar to how a digital watch displays the time directly.

The Terminals of a Meter

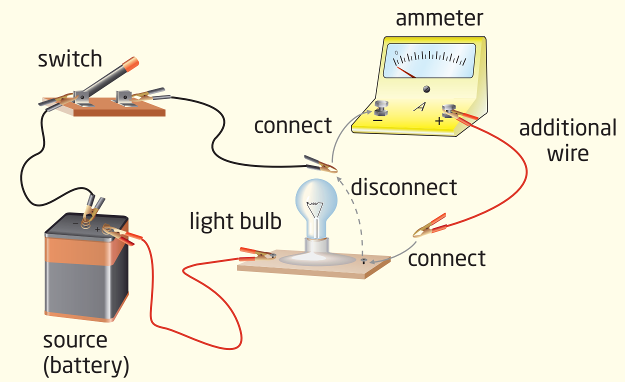
All meters have two terminals (connecting points) that you connect to the circuit. The negative terminal (–) is black. The positive terminal (+) is red. In order not to damage the meter, you must take care to connect the meter so that its positive (red) terminal is connected to the positive side of the power source. That is, you should be able to trace from the positive (+) terminal on the meter back to the positive terminal at the source. The negative (–) terminal of the meter is always connected to the negative side of the source. The rule is "positive to positive, and negative to negative."

Connecting an Ammeter

An ammeter is used to measure the electric current in a circuit. Electric current is the amount of charge passing a given point per second. To measure the current at a given location in an electric circuit, the ammeter must be connected so that all the current is allowed to pass through the ammeter. To do this, disconnect one end of a wire to give the same effect as cutting the circuit where you wish to measure the current. Imagine the ammeter and its connecting wires completing the circuit you just disconnected. Make sure the positive terminal on the ammeter traces back to the positive terminal at the source.

A Analogue meters have a needle pointing to different scales.

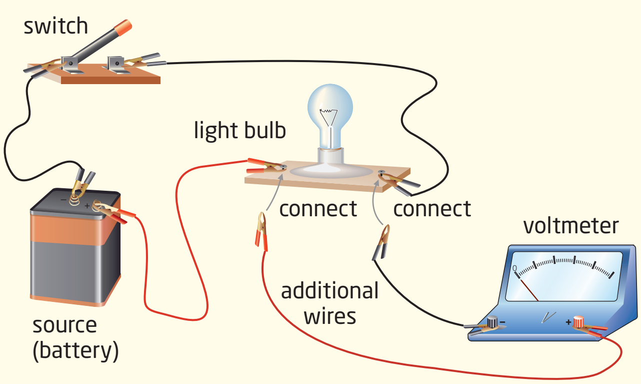
B Digital meters display the numerical values directly.



To measure the current through the light bulb, first disconnect the wire connected to the light bulb. Then insert the ammeter into the circuit.

Connecting a Voltmeter

A **voltmeter** is a device used to measure electric potential difference, or voltage, as it is often called. A potential difference exists between two points in a circuit such as across a battery, light bulb, or resistor. When connecting a voltmeter to a circuit, you do not need to disconnect or open the circuit. Potential difference is measured between two points in a circuit. Therefore, connect the terminals of the voltmeter to the two connections on the component where you wish to measure the potential difference. Remember the rule "positive to positive and negative to negative," and make sure you can trace the connections on the voltmeter back to the same type of terminal at the source.



Voltmeters are connected across a component in the circuit.

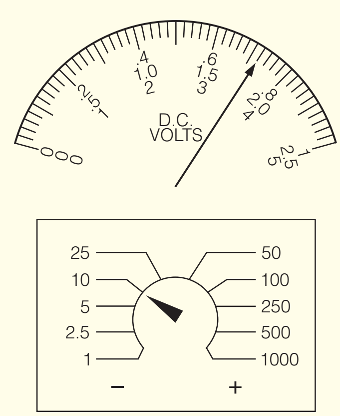
Connecting a Multimeter

Modern digital meters can also be multimeters. Multimeters can be used to measure voltage, current, and other electrical properties. When using a multimeter, it is important that you position the dial on the correct setting for your application. As well, the connecting wires must be inserted into the correct meter terminals.

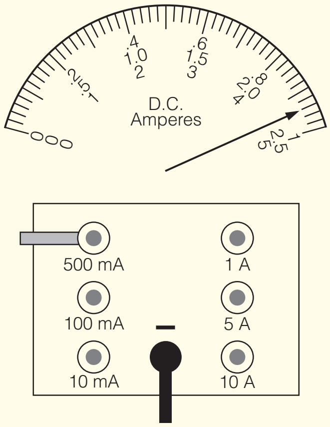
Reading a Meter

A digital meter is easy to read since the measured value is displayed directly as numbers. In order to get the most accurate reading on a digital meter, the meter needs to be set to the appropriate scale. The dial on a digital meter has several settings. For example, if the dial is set on the 2 V range, the meter will measure voltages between zero and 2 V. Moving the dial to the 200 V setting will allow the meter to measure between zero and 200 V, but with less accuracy. Therefore, when using meters, you must choose the best setting for your measurement. The best approach is to set the meter on the largest scale to obtain an approximate value. Then lower the scale until you have the highest possible reading without going off scale.

This approach is the same for analogue meters. Some analogue meters have a dial, similar to a digital meter, that is used to change the scale. In other analogue meters, the scale is changed by how the wires are connected to the terminals. Once the scale is selected, you obtain your reading from the most appropriate display on the meter.



This voltmeter has its dial set at 10 V. To determine the measured potential difference, look for a number at the top of the scale with the same first digit as 10. The top scale has a maximum value of 1, so now the 1 represents 10 V. To read the scale, multiply the number the needle is pointing to by 10. The dial is reporting 7.2 V.

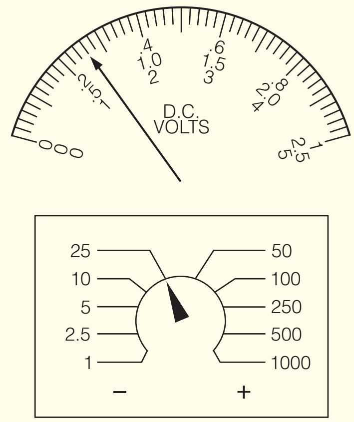


This ammeter has the positive wire connected to the 500 mA scale. The 5 on the bottom scale is the first digit in 500 mA, so the 5 now represents 500 mA. The needle is pointing to 4.7, so the meter is reporting 470 mA of current.

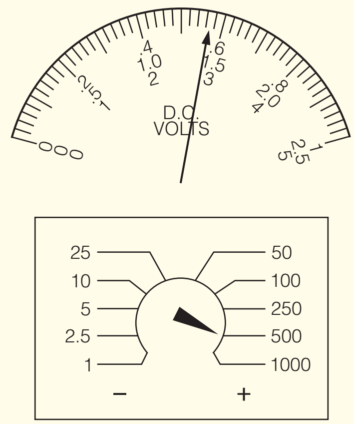
Instant Practice—Using Electric Circuit Symbols and Meters

1. Sketch the following circuit diagram symbols:
   a. battery
   b. light bulb
   c. resistor
   d. open switch
   e. ammeter
   f. voltmeter
2. State the colour that is associated with
   a. the positive terminal of a meter
   b. the negative terminal of a meter
3. When you connect a meter to a circuit, to which side of the power source should you always connect the positive terminal of the meter?
4. For which type of meter do you need to disconnect the circuit before connecting the meter to the circuit?
5. A student wishes to use a meter to determine the most accurate measurement possible without damaging the meter. Describe the correct approach for choosing the appropriate scale.
6. Determine the value of current or voltage indicated by meters A to D shown in the next column on this page.

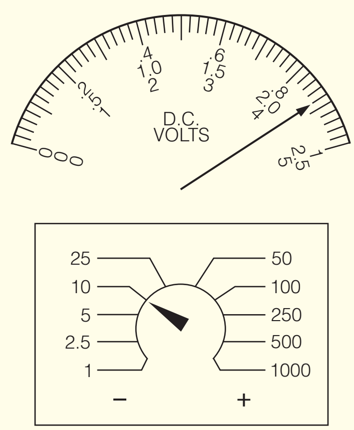
A



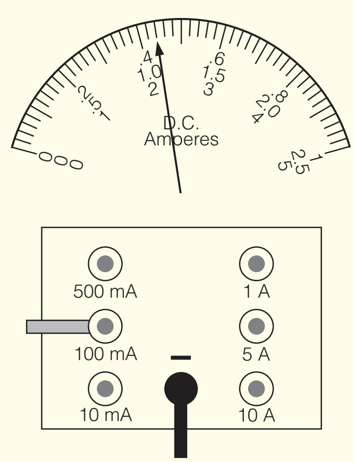
B



C



D



Science Skills Toolkit 11

Using Models and Analogies in Science

Scientists often use models and analogies to help communicate their ideas to other scientists or to students.

Using Models

When you think of a model, you might think of a toy such as a model airplane. Is a model airplane similar to a scientific model? If building a model airplane helps you learn about flight, then you could say it is a scientific model.

In science, a model is anything that helps you better understand a scientific concept. A model can be a picture, a mental image, a structure, or even a mathematical formula. Sometimes, you need a model because the objects you are studying are too small to see with the unaided eye. You may have learned about the particle model of matter, for example, which is a model that states that all matter is made of tiny, invisible particles. Sometimes a model is useful because the objects you are studying are extremely large—the planets in our solar system, for example. In other cases, the object may be hidden from view, like the interior of Earth or the inside of a living organism. A mathematical model can show you how to perform a calculation.

Scientists often use models to test an idea, to find out if an hypothesis is supported, and to plan new experiments in order to learn more about the subject they are studying. Sometimes, scientists discover so much new information that they have to modify their models. Examine the model shown in the photograph below. How can this model help you learn about science?

You can learn about day and night by using a globe and a flashlight to model Earth and the Sun.

Instant Practice—Using Models

How does using models help each of the following professionals in their work?

a. architects
b. aviation engineers
c. theatre directors
d. geographers
e. landscape designers

Using Analogies

An analogy is a comparison between two things that have some characteristic in common. Scientists use analogies to help explain difficult concepts. For example, scientists sometimes refer to plants as the lungs of Earth. Recall that plants take in carbon dioxide (CO_2) from the atmosphere to use during photosynthesis. Plants then release the oxygen (O_2) produced by photosynthesis back into the atmosphere.

In a sense, the plants are "breathing" for Earth. When animals breathe, they take oxygen into their lungs and give off carbon dioxide.

Instant Practice—Using Analogies

Use an analogy to help explain how organisms in a food web are connected.

Science Skills Toolkit 12

How to Do a Research-Based Project

Imagine if your teacher simply stated that he or she wanted you to complete a research-based project on endangered species. This is a really big topic, and it is now your job to decide which smaller aspect of the topic you will research. One way to approach a research project is to break it up into four stages—exploring, investigating, processing, and creating.

Explore—Pick a Topic and Ask Questions

You need to start by finding out some general things about endangered species. Make a list of questions as you conduct your initial research, such as, What factors cause species to become endangered? Why does it matter? What types of species are endangered? Suppose, in the course of your research, you decided to learn more about polar bears. A good research question about polar bears would be, Why are polar bears endangered? An even better question could be, What can I do to help prevent polar bear extinction? Both of these questions are deep and can be subdivided into many subtopics.

Investigate—Research Your Topic

When putting together a research project, it is important to find reliable sources to help you answer your question. Before you decide to use a source that you find, you should consider whether it is reliable or whether it shows any bias.

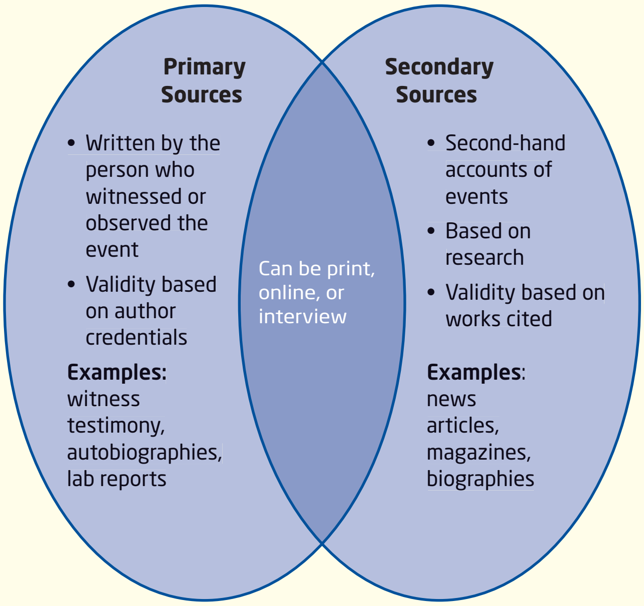
Sources of Information There are many sources of information. For example, you can use a print resource, such as an encyclopedia from the reference section of the library.

Another approach is to go on-line and check the Internet. When you use the Internet, be careful about which sites you choose to search for information. You need to be able to determine the validity of a website before you trust the information you find on it. To do this, check that the author is identified, a recent publication date is given, and the source of facts or quotations is identified. It is also important that the website is published by a well-known company or organization.

You may also want to contact an expert on your topic. A credible expert has credentials showing his or her expertise in an area. For example, an expert may be a doctor or have a master's degree. Alternatively, an expert could have many years of experience in a specific career or field of study.

No matter which sources you use, it is your responsibility to be a critical consumer of information and to find trustworthy sources for your research.

You should also ask yourself if the sources you are using are primary or secondary.



Two other things to check for in a source are reliability and bias. To check for reliability, try to find the same "fact" in two other sources. But keep in mind that even if you cannot find the same idea somewhere else, the source may still be reliable if it is a research paper or if it was written by an author with strong credentials. To check for bias, look for judgemental statements. Does the author tend to favour one side of an issue more than another? Are all sides of an issue treated equally? A good source shows little bias.

Source	Information	Reliability	Bias	Questions I Have
The Canadian Encyclopedia website	Polar bears inhabit ice and coastlines of arctic seas.	• author: Brian Knudsen • secondary source • has links to external sites that are reliable	only lists facts	• Why do they live on ice? • Why don't they move south?
Polar Bears International website	shrinking sea ice habitat	• date at bottom of page 2009 • non-profit organization	designed to save the polar bear	• Why is the ice shrinking?

Recording Information As you find information, jot it down on sticky notes or use a chart similar to the one shown above. Sticky notes are useful because you can move them around, group similar ideas together, and reorganize your ideas easily. Using a different colour for each sub-question is even better! Remember to write the source of your information on each sticky note. In addition to writing down information that you find as you research, you should also write down any questions you think of as you go along.

Process—Ask More Questions and Revise Your Work

Now that you have done some research, what sub-questions have you asked? These are the subtopics of your research. Use the subtopics to find more specific information. If you find that you have two or three sub-questions that have a lot of research supporting them and a few that do not have much research, do not be afraid to "toss out" some of the less important questions or ideas.

Avoiding Plagiarism Copying information word-for-word and then presenting it as though it is your own work is called *plagiarism*. When you refer to your notes to write your project, put the information in your own words. It is also important to give credit to the original source of an idea.

Recording Source Information Research papers always include a bibliography—a list of relevant information sources the authors consulted while preparing them. Bibliographic entries give the author, title, and facts of publication for each information source. Sometimes, you may want to give the exact source of information within the paper. This is done using footnotes. *Footnotes* identify the exact source (including page number) of quotations and ideas. Ask your teacher how you should prepare your list of works cited and your footnotes.

Create—Present Your Work

Before you choose a format for your final project, consider whether your researched information has answered the question you originally asked. If you have not answered this question, you need to either refine your original question or do some more research! You also need to consider who the audience is for your project. How you format your final project will be very different if it is meant for a Grade 2 class compared to the president of a company or a government official. You could present your project as a computer slide presentation, a graphic novel, a video, or a research paper.

Instant Practice

1. Describe the steps you should follow in preparing a project on the topic of renewable forms of energy.
2. The following example is not an effective question on which to base a research project: *How many moons does Jupiter have?* Modify the question to make it an effective research question.
3. Assume that the target audience for your project is a group of Grade 6 students from a local elementary school. What aspects of your project would you need to modify so that you are reaching the intended audience? What would be the best format to use to present your project to your audience?

Math Skills Toolkit 1

The Metric System and Scientific Notation

Throughout history, people have developed systems of numbering and measurement. When different groups of people began to communicate with each other, they discovered that their systems and units of measurement were different. Some groups within societies created their own unique systems of measurement.

Today, scientists around the world use the metric system of numbers and units. The metric system is the official system of measurement in Canada.

The Metric System

The metric system is based on multiples of 10. For example, the basic unit of length is the metre. All larger units of length are expressed in units based on metres multiplied by 10, 100, 1000, or more. Smaller units of length are expressed in units based on metres divided by 10, 100, 1000, or more.

Each multiple of 10 has its own prefix (a syllable joined to the beginning of a word). For example, *kilo-* means multiplied by 1000. Thus, one kilometre is 1000 metres.

$$1 \text{ km} = 1000 \text{ m}$$

The prefix *milli-* means divided by 1000. Thus, one millimetre is one thousandth of a metre.

$$1 \text{ mm} = \frac{1}{1000} \text{ m}$$

In the metric system, the same prefixes are used for nearly all types of measurements, such as mass, weight, area, and energy. A table of the most common metric prefixes is given at the top of the next column.

Commonly Used Metric Prefixes

Prefix	Symbol	Relationship to the Base Unit
giga-	G	$10^9 = 1\ 000\ 000\ 000$
mega-	M	$10^6 = 1\ 000\ 000$
kilo-	k	$10^3 = 1000$
hecto-	h	$10^2 = 100$
deca-	da	$10^1 = 10$
—	—	$10^0 = 1$
deci-	d	$10^{-1} = 0.1$
centi-	c	$10^{-2} = 0.01$
milli-	m	$10^{-3} = 0.001$
micro-	μ	$10^{-6} = 0.000\ 001$
nano-	n	$10^{-9} = 0.000\ 000\ 001$

Example

There are 250 g of cereal in a package. Express this mass in kilograms.

Solution

$$1 \text{ kg} = 1000 \text{ g}$$
$$250 \text{ g} \times 4 = 1000 \text{ g}$$
$$\frac{1000}{4} \text{ g} = 250 \text{ g}$$
$$\frac{1}{4} \text{ kg} = 0.25 \text{ kg}$$

Instant Practice—Using Metric Measurements

1. A hummingbird has a mass of 3.5 g. Express its mass in mg.
2. For an experiment, you need to measure 350 mL of dilute acetic acid. Express the volume in L.
3. A bald eagle has a wingspan up to 2.3 m. Express the length in cm.
4. A student added 0.0025 L of food colouring to water. Express the volume in mL.

Exponents of Scientific Notation

An exponent is the symbol or number denoting the power to which another number or symbol is to be raised. The exponent shows the number of repeated multiplications of the base. In 10^2, the exponent is 2 and the base is 10. So 10^2 means 10×10.

Powers of 10

	Standard Form	Exponential Form
Ten thousands	10 000	10^4
Thousands	1000	10^3
Hundreds	100	10^2
Tens	10	10^1
Ones	1	10^0
Tenths	0.1	10^{-1}
Hundredths	0.01	10^{-2}
Thousandths	0.001	10^{-3}
Ten thousandths	0.0001	10^{-4}

Why use exponents? Consider this. Mercury is about 58 000 000 km from the Sun. If a zero were accidentally added to this number, the distance would appear to be 10 times larger than it actually is. To avoid mistakes when writing many zeros, scientists express very large and very small numbers in scientific notation.

Example 1

Mercury is about 58 000 000 km from the Sun. Write 58 000 000 in scientific notation.

Solution

In scientific notation, a number has the form $x \times 10^n$, where x is greater than or equal to 1 but less than 10, and 10^n is a power of 10.

58 000 000. ← The decimal point starts here. Move the decimal point 7 places to the left.

$= 5.8 \times 10\ 000\ 000$

$= 5.8 \times 10^7$

When you move the decimal point to the left, the exponent of 10 is positive. The number of places you move the decimal point is the number in the exponent.

Example 2

The electron in a hydrogen atom is, on average, 0.000 000 000 053 m from the nucleus. Write 0.000 000 000 053 in scientific notation.

Solution

To write the number in the form $x \times 10^n$, move the decimal point to the right until there is one non-zero number to the left of the decimal point.

The decimal point starts here. → 0.000 000 000 053
Move the decimal point 11 places to the right.

$= 5.3 \times 0.000\ 000\ 000\ 01$

$= 5.3 \times 10^{-11}$

When you move the decimal point to the right, the exponent of 10 is negative. The number of places you move the decimal point is the number in the exponent.

Instant Practice—Scientific Notation

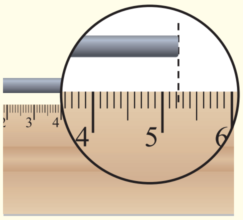
1. Express each of the following in scientific notation.
   - **a.** The approximate number of stars in our galaxy, the Milky Way: 400 000 000 000 stars
   - **b.** The approximate distance of the Andromeda Galaxy from Earth: 23 000 000 000 000 000 000 km
   - **c.** The estimated distance across the universe: 800 000 000 000 000 000 000 000 km
   - **d.** The approximate mass of a proton: 0.000 000 000 000 000 000 000 0017 g
2. Change the following to standard form.
   - **a.** 9.8×10^5 m
   - **b.** 2.3×10^9 kg
   - **c.** 5.5×10^{-5} L
   - **d.** 6.5×10^{-10} s

Math Skills Toolkit 2

Significant Digits and Rounding

Significant Digits

Significant digits represent the amount of uncertainty in a measurement. The significant digits in a measured quantity include all the certain digits plus the first uncertain digit. In the example below, the length of the rod is between 5.2 cm and 5.3 cm. Suppose we estimate the length to be 5.23 cm. The first two digits (5 and 2) are certain (we can see those marks), but the last digit (0.03) was estimated. The measurement 5.23 cm has three significant digits.



Use these rules to determine the number of significant digits (s.d.) in a measurement.

1. All non-zero digits (1–9) are considered significant.

   Examples:
   - 123 m (3 s.d.); 23.56 km (4 s.d.)

2. Zeros between non-zero digits are also significant.

   Examples:
   - 1207 m (4 s.d.); 120.5 km/h (4 s.d.)

3. Any zero that follows a non-zero digit *and* is to the right of the decimal point is significant.

   Examples:
   - 12.50 m/s^2 (4 s.d.); 60.00 km (4 s.d.)

4. Zeros used to indicate the position of the decimal are *not* significant. These zeros are sometimes called spacers.

   Examples:
   - 500 km (1 s.d.); 0.325 m (3 s.d.); 0.000 34 km (2 s.d.)

5. All counting numbers have an infinite number of significant digits.

   Examples:
   - 6 apples (infinite s.d.); 125 people (infinite s.d.)

Using Significant Digits in Mathematical Operations

When you use measured values in calculations, the calculated answer cannot be more certain than the measurements on which it is based. The answer on your calculator may have to be rounded to the correct number of significant digits.

Rules for Rounding

1. When the first digit to be dropped is less than 5, the preceding digit is not changed.

   Example: 6.723 m rounded to two significant digits is 6.7 m.

2. When the first digit to be dropped is 5 or greater, increase the preceding digit by one.

   Example: 7.237 m rounded to three significant digits is 7.24 m. The digit after the 3 is greater than 5, so the 3 is increased by one.

Adding or Subtracting Measurements

Perform the mathematical operation, and then round off the answer to the value having the fewest *decimal places*.

Example: x = 2.3 cm + 6.47 cm + 13.689 cm
= 22.459 cm
= 22.5 cm

Since 2.3 cm has only one decimal place, the answer can have only one decimal place.

Multiplying or Dividing Measurements

Perform the mathematical operation, and then round off the answer to the least number of *significant digits* of the data values.

Example: x = (2.342 m)(0.063 m)(306 m)
= 45.149 076 m^3
= 45 m^3

Since 0.063 m has only two significant digits, the answer must have two significant digits.

Math Skills Toolkit 3

Organizing and Communicating Scientific Results with Graphs

In your investigations, you will collect information, often in numerical form. To analyze and report the information, you will need a clear, concise way to organize and communicate the data.

A graph is a visual way to present data. A graph can help you to see patterns and relationships among the data. The type of graph you choose depends on the type of data you have and how you want to present them. You can use line graphs, bar graphs, and pie graphs (pie charts).

The instructions given here describe how to make graphs using paper and pencil. Computer software provides another way to generate graphs. Whether you make them on paper or on the computer, however, the graphs you make should have the features described in the following pages.

Drawing a Line Graph

A line graph is used to show the relationship between two variables. The following example will demonstrate how to draw a line graph from a data table.

Example

Suppose you have conducted a survey to find out how many students in your school are recycling drink containers. Out of 65 students that you surveyed, 28 are recycling cans and bottles. To find out if more recycling bins would encourage students to recycle cans and bottles, you add one recycling bin per week at different locations around the school. In follow-up surveys, you obtain the data shown in **Table 1**. Compare the steps in the procedure with the graph on the next page to learn how to make a line graph to display your findings.

Table 1 Students Using Recycling Bins

Number of Recycling Bins	Number of Students Using Recycling Bins
1	28
2	36
3	48
4	60

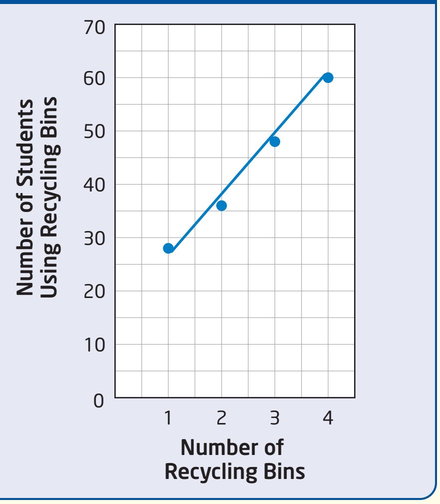
Procedure

1. With a ruler, draw an x-axis and a y-axis on a piece of graph paper. (The horizontal line is the x-axis, and the vertical line is the y-axis.)
2. To label the axes, write "Number of Recycling Bins" along the x-axis and "Number of Students Using Recycling Bins" along the y-axis.
3. Now you have to decide what scale to use. You are working with two numbers (number of students and number of bins). You need to show how many students use the existing bin and how many would recycle if there were a second, a third, and a fourth bin. The scale on the x-axis will go from 0 to 4. There are 65 students, so you might want to use intervals of 5 for the y-axis. That means that every space on your y-axis represents 5 students. Use a tick mark at major intervals on your scale, as shown in the graph on the next page.
4. You want to make sure you will be able to read your graph when it is complete, so make sure your intervals on the x-axis are large enough.
5. To plot your graph, gently move a pencil up the y-axis until you reach a point just below 30 (you are representing 28 students). Now move along the line on the graph paper until you reach the vertical line that represents the first recycling bin. Place a dot at this point (1 bin, 28 students). Repeat this process for all of the data.

6. If it is possible, draw a line that connects all of the points on your graph. This might not be possible. Scientific investigations often involve quantities that do not change smoothly. On a graph, this means that you should draw a smooth curve (or straight line) that most closely fits the general shape outlined by the points. This is called a **line of best fit**. A best-fit line often passes through many of the points, but sometimes it goes between points. Think of the dots on your graph as clues about where the perfect smooth curve (or straight line) should go. A line of best fit shows the trend of the data. It can be extended beyond the first and last points to indicate what might happen.

7. Give your graph a title. Based on these data, what is the relationship between the number of students using recycling bins and the number of recycling bins?

Number of Students Using Recycling Bins vs. Number of Bins Available



Instant Practice—Line Graph

The level of ozone in Earth's upper atmosphere is measured in Dobson units (all the ozone present in a column of air above a particular point). Using the information in the table below, create a line graph showing what happened to the amount of ozone over Antarctica during a period of 40 years.

Table 2 Ozone Levels in Earth's Upper Atmosphere

Year	Total Ozone (DU)
1960	300
1965	280
1970	280
1975	275
1980	225
1985	200
1990	160
1995	110
2000	105

Constructing a Bar Graph

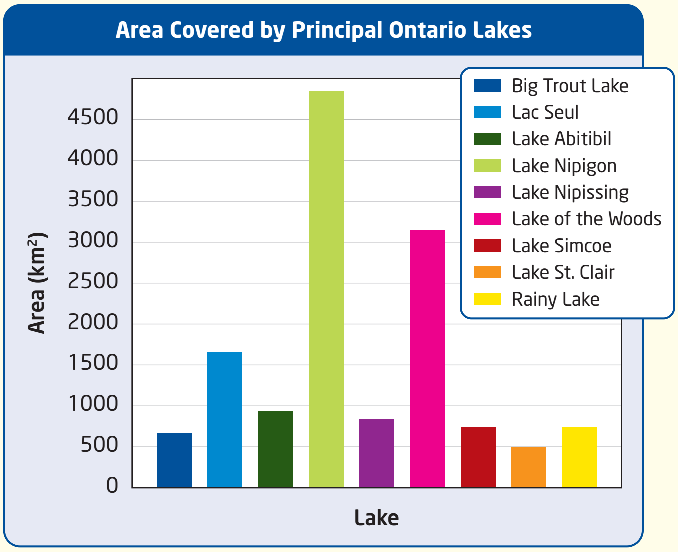
Bar graphs help you to compare a numerical quantity with some other category at a glance. The second category may or may not be a numerical quantity. It could be places, items, organisms, or groups, for example.

Example

To learn how to make a bar graph to display the data in **Table 3** on the next page, examine the graph in the column next to the table as you read the steps that follow. The data show the area in square kilometres of principal Ontario lakes, not including the Great Lakes.

Table 3 Area Covered by Principal Ontario Lakes

Lake	Area (km^2)
Big Trout Lake	661
Lac Seul	1657
Lake Abitibi	931
Lake Nipigon	4848
Lake Nipissing	832
Lake of the Woods	3150
Lake Simcoe	744
Lake St. Clair	490
Rainy Lake	741



Procedure

1. Draw your x-axis and y-axis on a sheet of graph paper. Label the x-axis "Ontario Lakes" and the y-axis "Area (km^2)."
2. Look at the data carefully in order to select an appropriate scale. Write the scale of your y-axis.
3. Decide on a width for the bars that will be large enough to make the graph easy to read. Leave the same amount of space between each bar.
4. Using Big Trout Lake and 661 as the first pair of data, move along the x-axis the width of your first bar, then go up the y-axis to 661. Use a pencil and ruler to draw in the first bar lightly. Repeat this process for the other pairs of data.
5. When you have drawn all of the bars, add labels on the x-axis to identify the bars. Alternatively, use colour to distinguish among them.
6. If you are using colour to distinguish among the bars, you will need to make a legend or key to explain the meaning of the colours. Write a title for your graph.

Instant Practice—Bar Graph

Make a vertical bar graph using the following table of each planet's gravitational force in relation to Earth's gravity.

Table 4 Gravitational Pull of Planets

Planet	Gravitational Pull (*g*)
Mercury	0.40
Venus	0.90
Earth	1.00
Mars	0.40
Jupiter	2.50
Saturn	1.10
Uranus	0.90
Neptune	1.10

Constructing a Pie Graph

A pie graph (sometimes called a pie chart) uses a circle divided into sections (like pieces of pie) to show the data. Each section represents a percentage of the whole. All sections together represent all (100 percent) of the data.

Example

To learn how to make a pie graph from the data in **Table 5**, study the corresponding pie graph on the right as you read the following steps.

Table 5 Birds Breeding in Canada

Type of Bird	Number of Species	Percent of Total	Degrees in Section
Ducks	36	9.0	32
Birds of prey	19	4.8	17
Shorebirds	71	17.7	64
Owls	14	3.5	13
Perching birds	180	45.0	162
Other	80	20.0	72

Procedure

1. Use a mathematical compass to make a large circle on a piece of paper. Make a dot in the centre of the circle.
2. Determine the percent of the total number of species that each type of bird represents by using the following formula.

$$\text{Percent of total} = \frac{\text{Number of species within the type}}{\text{Total number of species}} \times 100\%$$

For example, the percent of all species of birds that are ducks is

$$\text{Percent that are ducks} = \frac{\text{36 species of ducks}}{\text{400 species}} \times 100\% = 9.0\%$$

3. To determine the number of degrees in the section that represents each type of bird, use the following formula.

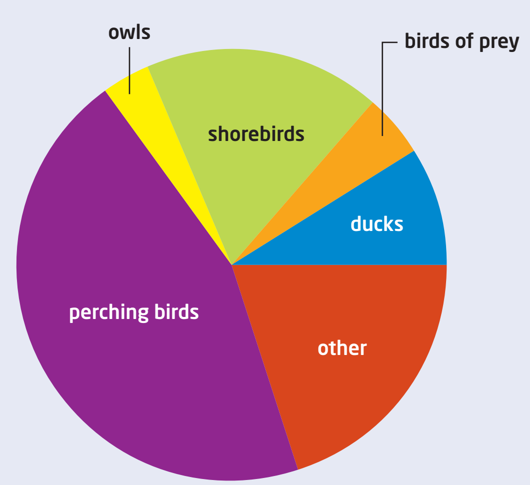
$$\text{Degrees in "piece of pie"} = \frac{\text{Percent for a type of bird}}{100\%} \times 360°$$

Round your answer to the nearest whole number. For example, the section for ducks is

$$\text{Degrees for ducks} = \frac{9.0\%}{100\%} \times 360° = 32.4° \text{ or } 32°$$

4. Draw a straight line from the centre to the edge of the circle. Use your protractor to measure 32° from this line. Make a mark, then use your mark to draw a second line 32° from the first line.
5. Repeat steps 2 to 4 for the remaining types of birds.

Species of Birds Breeding in Canada



Instant Practice—Pie Graph

Use the following data on total energy (oil, gas, electricity, etc.) consumption for 2004 to develop a pie graph to visualize energy consumption in the world.

Table 6 World Energy Consumption in 2004

Area in the World	Consumption (quadrillion btu)
North America	120.62
Central and South America	22.54
Europe	85.65
Eurasia	45.18
Middle East	21.14
Africa	13.71
Eastern Asia and Oceania	137.61

Study Toolkit Overview

At the beginning of every chapter, you will find a Study Toolkit page. Each Study Toolkit page features three of the many helpful study strategies that are described below. Using these strategies can help you understand and remember what you read.

Preparing for Reading

Before you begin to read a chapter, browse through the chapter to get a general sense of what you will be learning.

- *Previewing text features* involves flipping through the chapter to see how it is organized and how the features of the textbook support the main ideas in the chapter.
- *Making connections to visuals* means relating visuals, such as photographs, illustrations, and graphic text, to your own experiences and to the text that accompanies each visual.

Reading Effectively

While you are reading, you can apply these strategies to help you understand what you are reading:

- *Asking questions* helps you engage actively in reading the text and gives you a purpose for continuing to read.
- *Identifying the main idea and details* helps you figure out what is the most important information in the text you are reading. You can also use this strategy after reading, to help you organize what you have learned.
- *Making connections to prior knowledge* helps you relate what you already know to what you are learning.
- *Making inferences* helps you figure out the meaning of the text by combining information in the text with what you already know and by "reading between the lines."
- *Monitoring comprehension* ensures that you stop from time to time as you are reading to ask yourself whether you have understood what you have read.
- *Skim, scan, or study* helps you alter your reading speed based on your purpose for reading.
- *Visualizing* helps you transform a chunk of text into an image in your mind to help you understand and remember details and comparisons in the text.

Reading Graphic Text

Reading tables, graphs, and diagrams is different from reading text. The three strategies below can help you identify elements that are specific to each type of graphic text so you can interpret what the graphic text represents:

- *Interpreting diagrams* requires you to read and understand the parts of the diagram and then relate the parts to each other and to the concepts explained in the text.
- *Interpreting graphs* requires you to understand the organization and functions of the parts of a graph, such as axes, points, and lines. It also requires you to pay attention to the graph's title and caption.
- *Interpreting tables* requires you to examine data that have been organized in rows and columns with explanatory headings. Keep in mind that the title of a table gives information about the table's purpose and meaning.

Word Study

Science textbooks include many words that may be unfamiliar to you. Use the following strategies to help you determine the meanings of new words:

- Identify the *base word*. The base word is the main part of the word, which is distinct from a prefix, suffix, or combining part.
- Examine the smaller words that make up *compound words*.
- *Create a word map* to analyze a word beyond its definition—for example, by identifying its opposites and by listing synonyms for the word.
- Consider the *multiple meanings* of a word when it appears in different contexts.
- Identify the *suffixes* that change the meaning of a word. A suffix is a small word part at the end of a word.
- Analyze *word families* to understand relationships among words that have common parts, such as the same base.
- Look up *word origins* in a dictionary to deepen your understanding of a word.

Organizing Your Learning

Taking notes in class is only the first step in understanding a new concept. You may want to organize what you have learned in a way that helps you remember key concepts and helps you study for tests.

- *Comparing and contrasting* involves identifying the similarities and differences between two concepts or things.
- *Identifying cause and effect* helps you understand why and how events occur, as well as their consequences.
- *Making study notes* means identifying the most important information and recording it in a way that makes sense to you.
- *Summarizing* involves stating the main ideas of a paragraph or a section of text in your own words. You can summarize text using a list, a drawing, point-form notes, a table, or a graphic organizer.
- *Using graphic organizers* helps you to organize information in a visual format.

On the following pages, you will find more information about some of the strategies listed above.

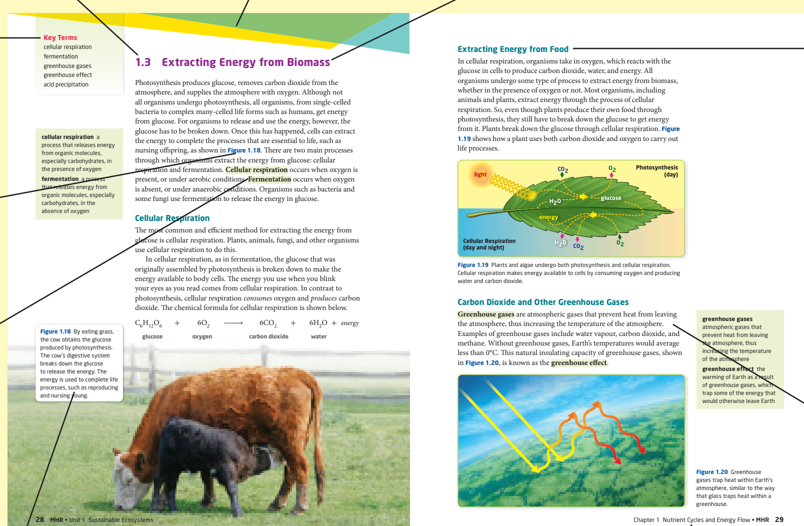
Study Toolkit 1

Preparing for Reading: Previewing Text Features

Before you begin reading a textbook, become familiar with the book's overall structure and features. If you look at the Table of Contents on page v, you will see that this textbook is divided into four *units*. Each unit is divided into three *chapters*. Each chapter is subdivided into numbered *sections*.

As well as the Table of Contents, this textbook has many other features designed to help you find your way while reading. Examine the sample pages below. They include several text features that will help you understand the content.

- numbered sections: the number of the chapter (1), followed by the number of the section (3)
- a multicoloured banner across the top of the page signals the beginning of a new section
- each section heading is printed in large purple type
- a Key Terms box appears in the margin at the beginning of each section
- each subheading is printed in blue type that is smaller than the type used for the section headings
- figure numbers are printed in blue boldface type in the body text and in the caption
- key terms, cued by boldface type and green highlighting, are defined in the margin
- body text appears in clear, readable type



- captions are printed in type that is different from type used for the body text
- page numbers and footers (include "MHR" standing for McGraw-Hill Ryerson; the unit number and title on the left-hand page; and the chapter number and title on the right-hand page)

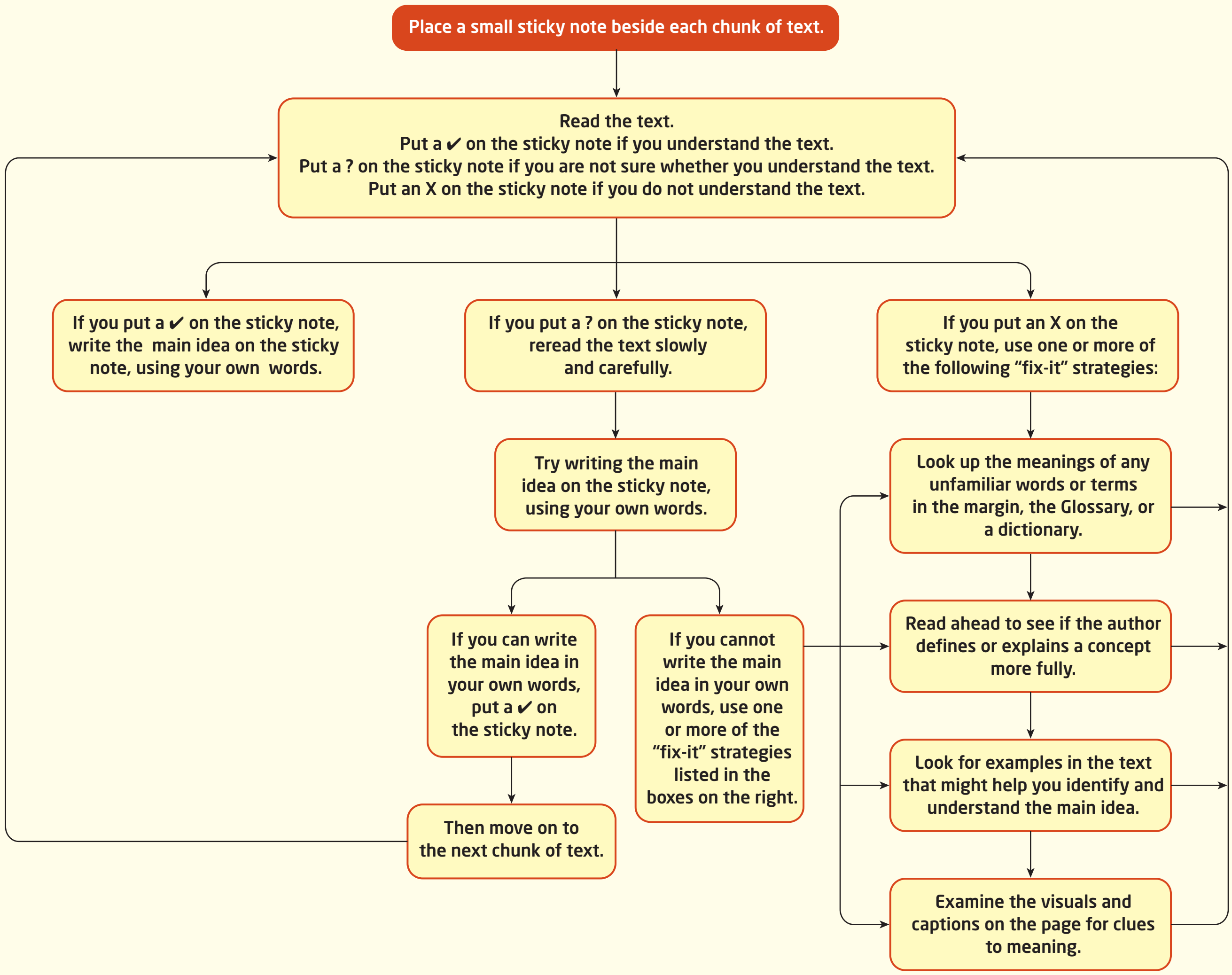
Instant Practice

1. Describe two ways to identify the key terms in a section.
2. Describe two ways to learn more about a visual in this textbook.

Study Toolkit 2

Reading Effectively: Monitoring Comprehension

When you are reading text that contains new ideas and new key terms, stop after each chunk of text to make sure that you understand what you have just read. An effective way to do this is to use the steps in the following flowchart.



Instant Practice

1. Make a list of steps you could follow if you were not sure that you had understood a section of text. Number your steps.
2. Make a bulleted list of the four "fix-it" strategies, using your own words. Post your list for easy reference.

Study Toolkit 3

Word Study: Common Base Words, Prefixes, and Suffixes in Science

Understanding how words are put together can help you figure out their meanings. The list below includes some common *base words* that are used in science. Also listed are some common *prefixes* and *suffixes*, which change the meaning of a base word when they are combined with the base word.

Base Word	Definition	Example
conduct	To direct or lead	A **semiconductor** allows electrons to move fairly well between atoms.
electr(o)	Having to do with electricity	An **electroscope** is a device for detecting an electric charge.
phot(o)	Having to do with light	A **photometer** measures the amount of light that is emitted from a source.
resist	To hold off; to prevent or oppose	A **resistor** decreases the electric current that is flowing through a component.
sustain	To keep going; to maintain	**Unsustainable** means not able to keep going.
Prefix	**Definition**	**Example**
bio-	Having to do with life	**Biomass** is the total mass of living organisms in a group or an area.
dis-	Not; the opposite of; having an absence of	A **disinfectant** helps to remove and prevent infection.
infra-	Below; beneath	**Infrared** light has a longer wavelength (and thus a lower frequency) than red light.
iso-	Same; equal	An **isotope** has the same number of protons as other atoms of the same element, but a different number of neutrons.
non-	Not; having an absence of	A **non-metal** is an element that does *not* have the properties of a metal.
Suffix	**Definition**	**Example**
-al	Relating to	**Environmental** means relating to the environment.
-ic	Relating to; characterized by	**Atomic** means relating to an atom.
-ity	Having to do with a state or quality	**Reactivity** is the quality of being reactive.
-ion	Having to do with an action or a process	**Evolution** means the process of evolving.
-oid	Resembling; having the form or appearance of	A **metalloid** shares some properties with metals and some properties with non-metals.

Instant Practice

1. Use the table to predict the meaning of *conductivity*.
2. Think of a word that ends in one of the suffixes listed above. (You can browse through this textbook or a dictionary to find a word, if you wish.) Explain the meaning of your word. Compare your word and definition with words and definitions that your classmates suggest.

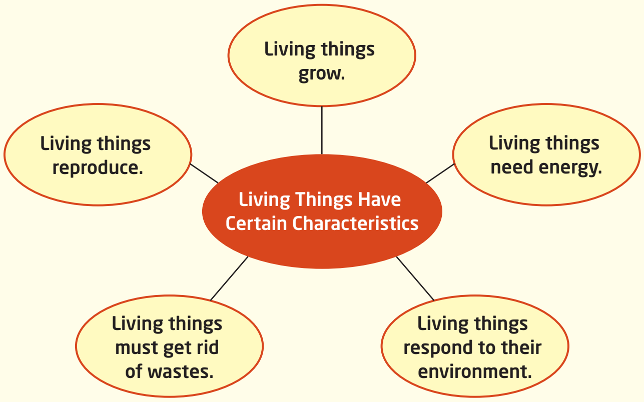
Study Toolkit 4

Organizing Your Learning: Using Graphic Organizers

When deciding which type of graphic organizer to use, consider your purpose: to brainstorm, to show relationships among ideas, to summarize a section of text, to record research notes, or to review what you have learned before writing a test. Several different graphic organizers are shown on these two pages.

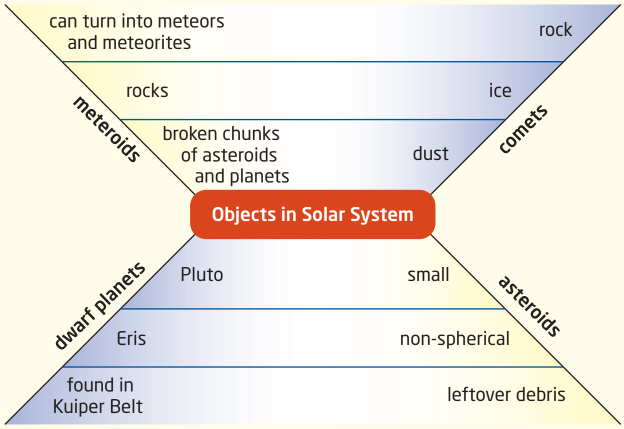
Main Idea Web

A *main idea web* shows a main idea and several supporting details. The main idea is written in the centre of the web, and each detail is written at the end of a line going from the centre.



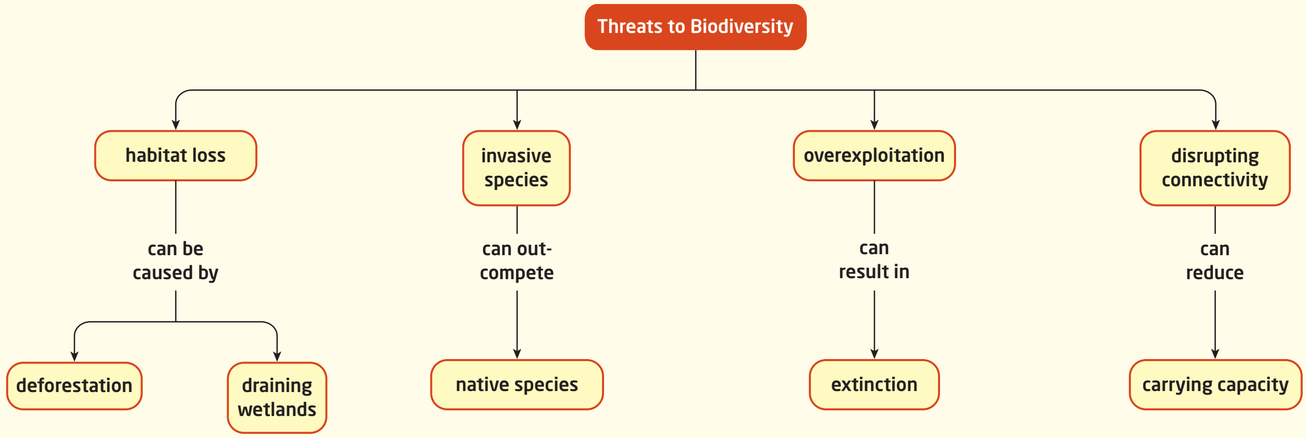
Spider Map

A *spider map* shows a main idea and several ideas associated with the main idea. It does not show the relationships among the ideas. A spider map is useful when you are brainstorming or taking notes.



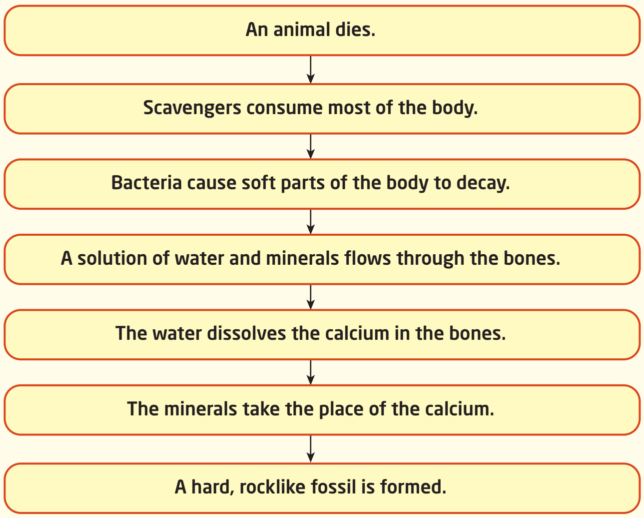
Concept Map

A *concept map* uses shapes and lines to show how ideas are related. Each idea, or concept, is written inside a circle, a square, a rectangle, or another shape. Words that explain how the concepts are related are written on the lines that connect the shapes.



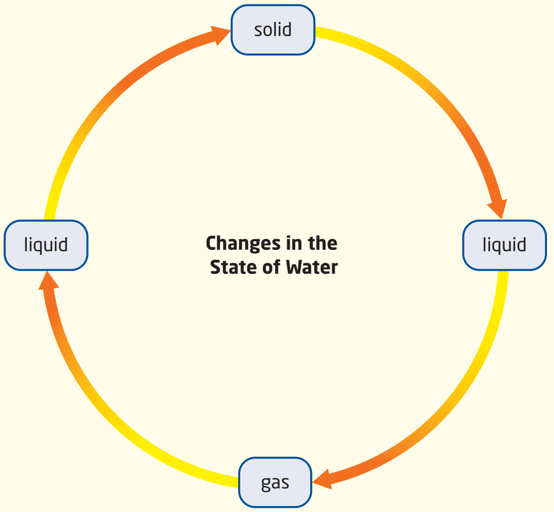
Flowchart

A *flowchart* shows a sequence of events or the steps in a process. A flowchart starts with the first event or step. An arrow leads to the next event or step, and so on, until the final outcome. All the events or steps are shown in the order in which they occur.



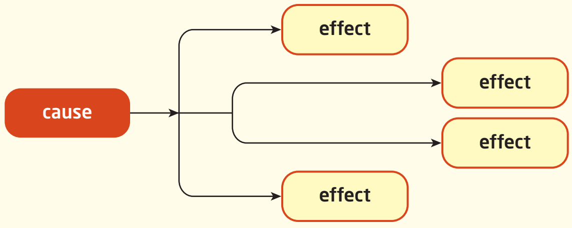
Cycle Chart

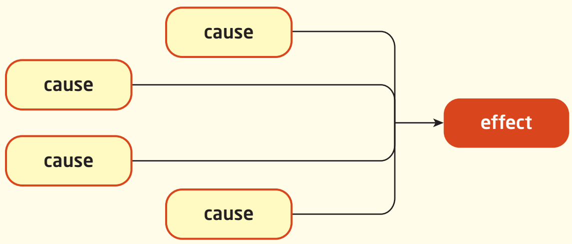
A *cycle chart* is a flowchart that has no distinct beginning or end. All the events are shown in the order in which they occur, as indicated by arrows, but there is no first or last event. Instead, the events occur again and again in a continuous cycle.



Cause-and-Effect Map

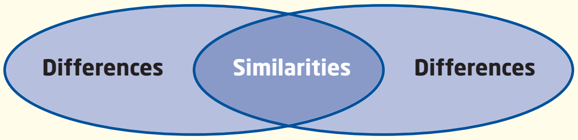
The first *cause-and-effect map* below shows one cause that results in several effects. The second map shows one effect that has several causes.

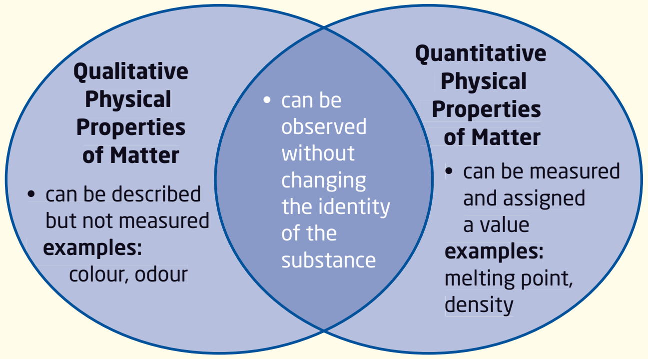




Venn Diagram

A *Venn diagram* uses overlapping shapes to show similarities and differences among concepts.





Instant Practice

1. Create a Venn diagram that shows the similarities and differences between two of your favourite science topics.
2. Draw a spider map that reflects your prior knowledge about your body's cells.