Guide to the Toolkits and Appendices

TOOLKITS

APPENDICES

Science Skills Toolkit 1

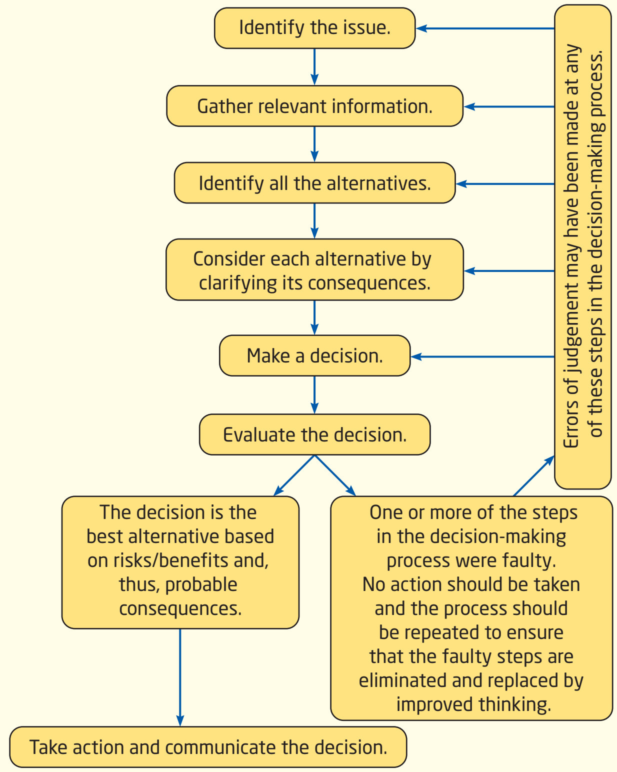
Analyzing Issues—Science, Technology, Society, and the Environment

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 10** 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 565–566.

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

One way to reduce the generation of greenhouse gases is to reduce energy use. One way to reduce energy use is to replace old appliances with energy-efficient appliances. But isn't it just as wasteful to replace older appliances that still work? Complete the following activity in a group of four.

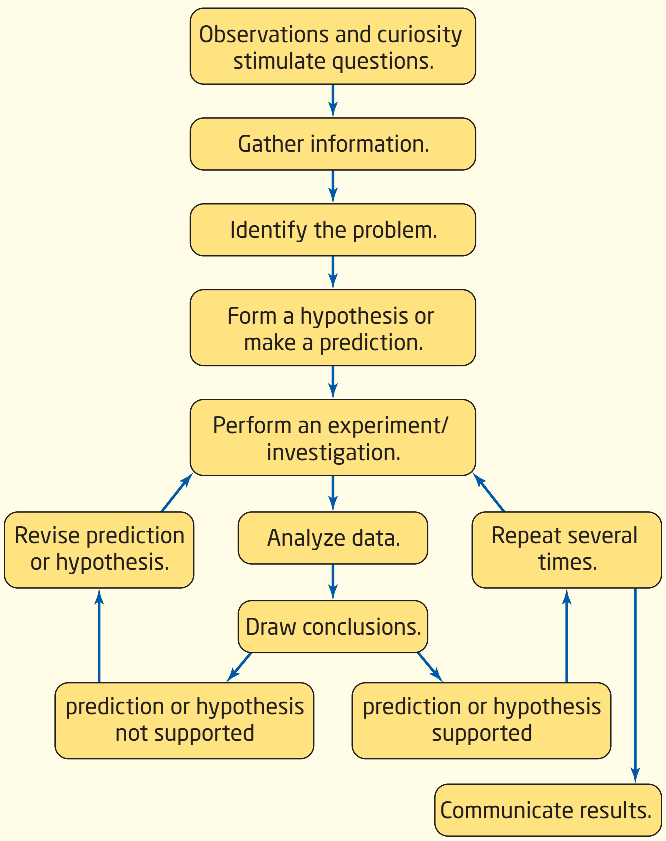
1. Start by dividing your group into two pairs.
2. One pair will research and record the advantages of replacing an older washing machine with a new, energy-efficient washing machine.
3. The second pair will research and record the disadvantages of replacing an older washing machine with a new, energy-efficient washing machine.
4. The pairs will then regroup, and both sides can present their findings. Record key points in a table for comparison.
5. Determine which pair has the more convincing evidence for its point of view on replacing an old appliance.
6. As a group, research different appliances to learn how older and newer models differ, including advantages and disadvantages of each. What variations in energy efficiency are available? Determine the appliances that it makes the most sense to replace, 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 reaction in test tube A produced more solid product than the reaction in test tube B.
   b. The reaction in test tube A produced 3.8 g of solid product.
2. a. The solution became warmer.
   b. The solution increased in temperature by 3.5°C.
3. a. The image in the mirror was smaller than the object.
   b. The image in the mirror was inverted.
4. a. At 2:00 P.M., the winds were travelling at 25 km/h.
   b. In the morning, the winds were faster than they were in the evening.
5. a. The solution was clear and blue.
   b. To the beaker was added 20.0 mL of solution.
6. a. The angle of incidence is equal to the angle of reflection.
   b. The angle of incidence is greater than 90°.

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 way that light is affected by travelling through different media
4. the effect of varying pH on algae growth

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

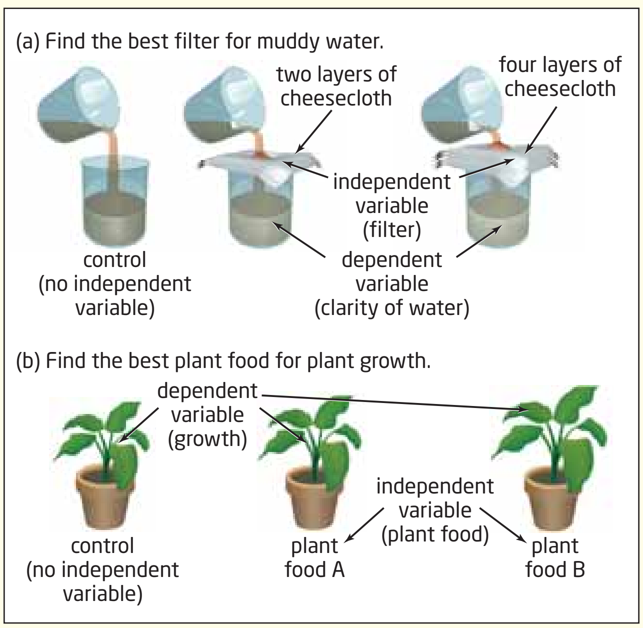
As you know, there are several steps involved in performing a scientific investigation, including identifying variables, designing a fair test, and organizing and analyzing data.

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 9** gives you more information on using models.

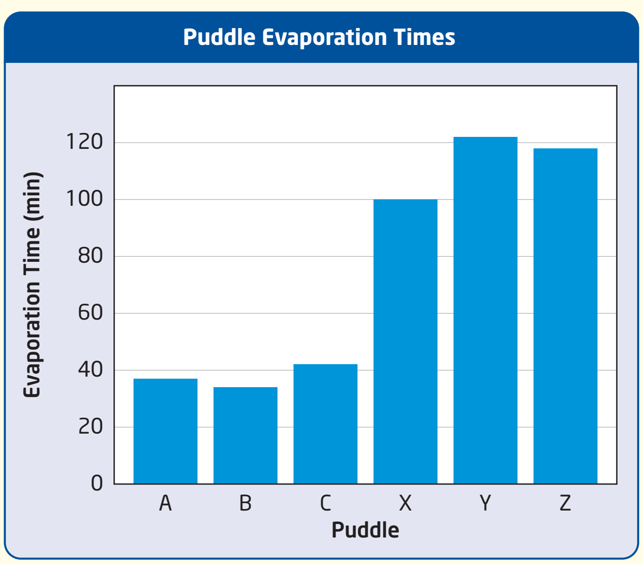
Before you begin your investigation, review safety procedures and identify what safety equipment you may need. Refer to page xiv in this textbook for more information on safety.

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 cell theory, which describes the structure of living things, in Unit 1 of this textbook.

Science Skills Toolkit 3

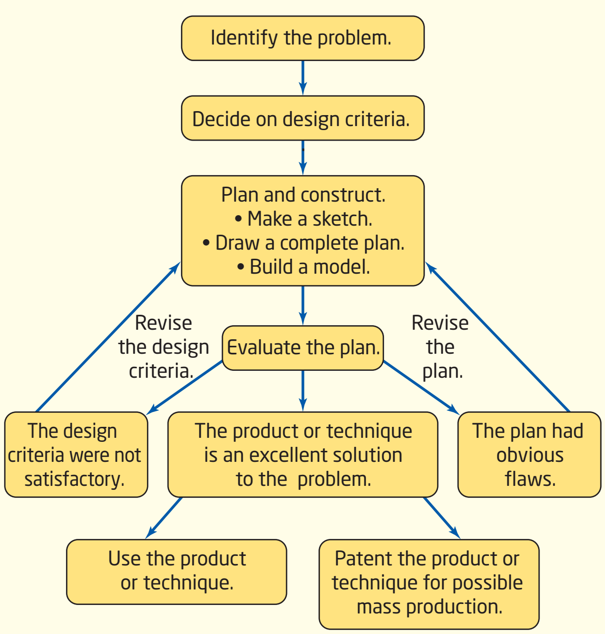
Technological Problem Solving

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

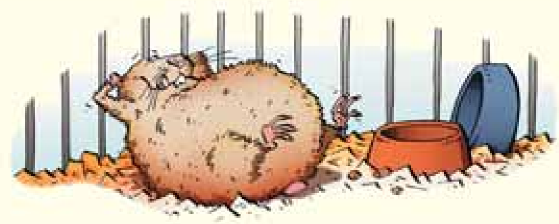
People turn to technology to solve problems. One problem-solving model is shown below.

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?

Instant Practice—Technological Problem Solving

Suppose that you have collected an ice core sample that you want to store and keep frozen for at least a day. You do not have access to a source of electricity, and you do not have a ready-made refrigeration or insulating device.

1. Identify the problem. What is the exact nature of the challenge you face?
2. State at least three criteria that your solution must satisfy.
3. Design a device to solve the problem. Make a labelled sketch to show your proposed design.
4. Ask a friend to propose alterations or improvements to your design.
5. With the approval of your teacher, build your device and test it.
6. Evaluate the success of your device. Propose improvements.

Science Skills Toolkit 4

Estimating and Measuring

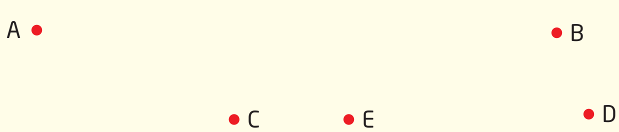
Estimating

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.

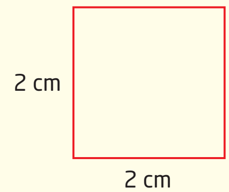
For example, suppose you wanted to know how many ants live in a local park. Counting every ant would be very time-consuming. What you can do is count the number of ants in a typical square-metre area. Then, multiply the number of ants by the number of square metres in the total area you are investigating.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

Measuring Length and Area

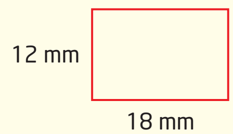
You can use a metre stick or a ruler to measure short distances. These tools are usually marked in centimetres and/or millimetres. Use a ruler to measure the length in millimetres between points A and C, C and E, E and B, and A and D below. Convert your measurements to centimetres and then to metres.



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 $2\ cm \times 2\ cm = 4\ cm^2$



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

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

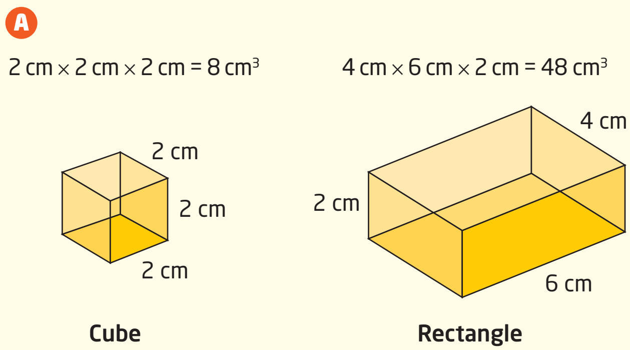
Imagine that all rulers in the school have vanished. The only measurement tool that you now have is a toothpick.

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.



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.

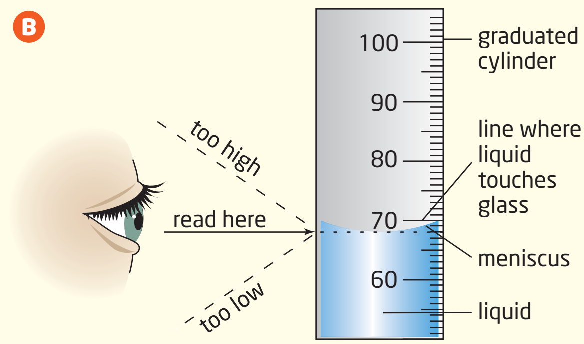
Cubic units and capacity units are interchangeable. For example,

$1\ cm^3 = 1\ mL$

$1\ dm^3 = 1\ L$

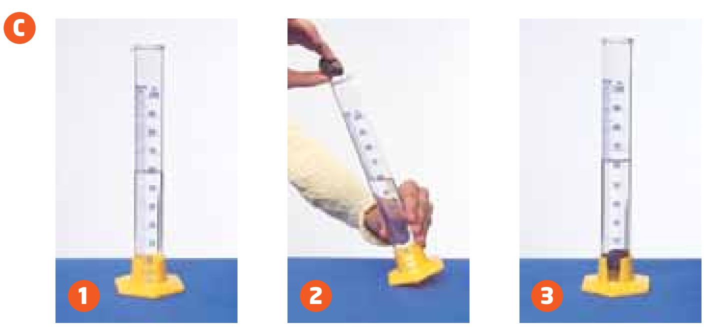
$1\ m^3 = 1\ kL$

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.



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.



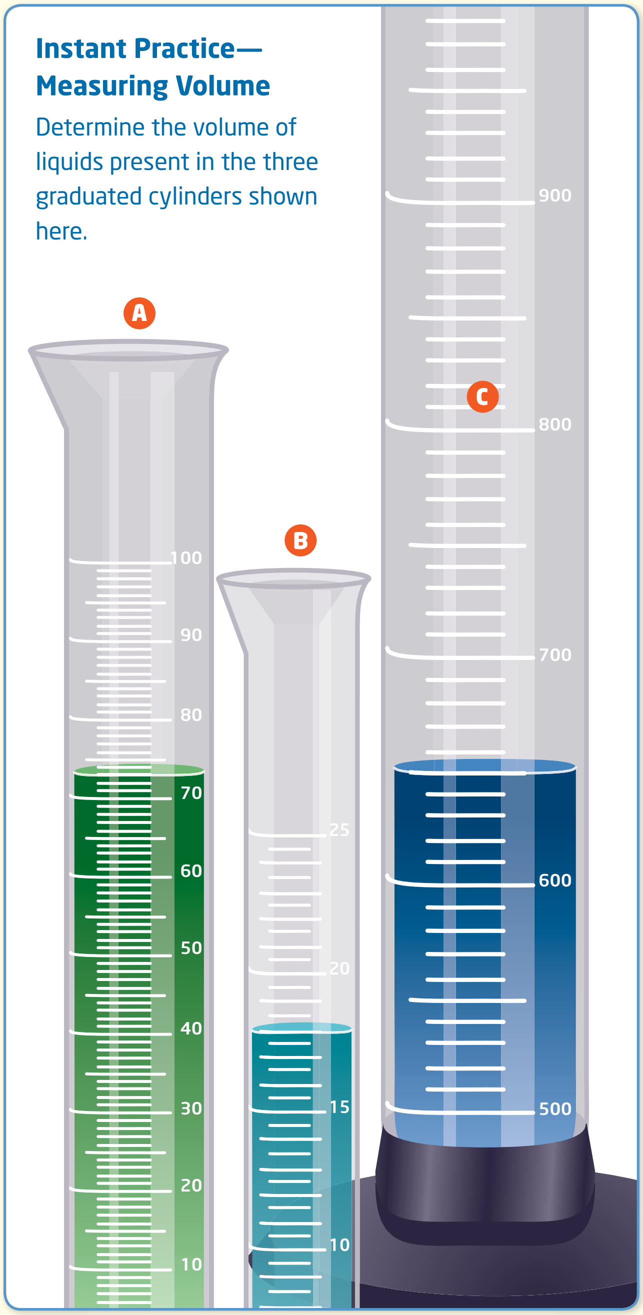
1. Record the volume of the liquid.
2. Carefully lower the object into the cylinder containing the liquid. Record the volume again.
3. The volume of the object is equal to the difference between the two volumes of the liquid. The equation below the photographs shows you how to calculate this volume.

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

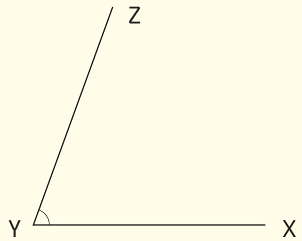
You can use a protractor to measure angles. Protractors usually have an inner scale and an outer scale. The scale you use depends on how you place the protractor on an angle (symbol = ∠). Look at the following examples to learn how to use a protractor.

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

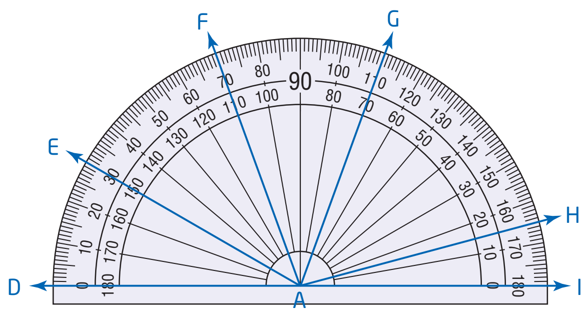
Draw ∠ABC = 155°.

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°

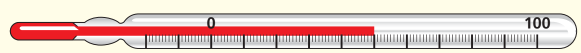
Measuring Temperature

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.

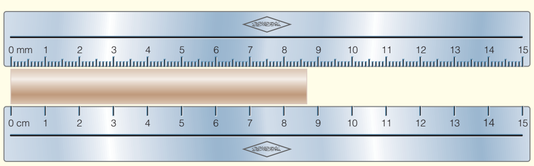
Science Skills Toolkit 5

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.

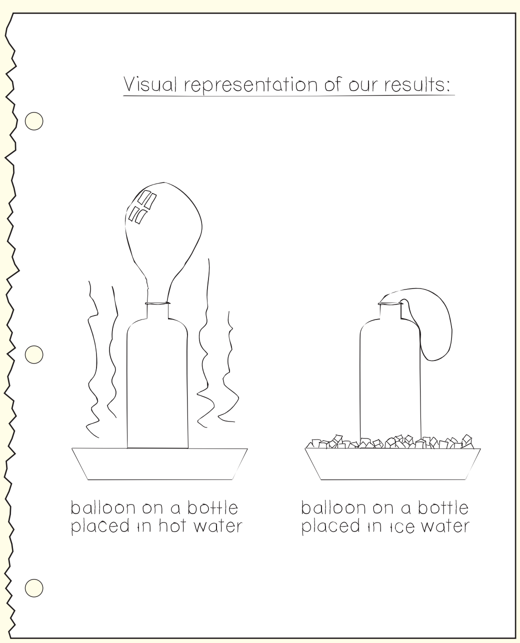
2. Two students collected data on the mass of a substance for an experiment. Each student used a different scale to measure the mass of the substance over three trials. Student A had a range of measurements that was ±0.06 g. Student B had a range of measurements that was ±0.11 g. Which student had the 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.

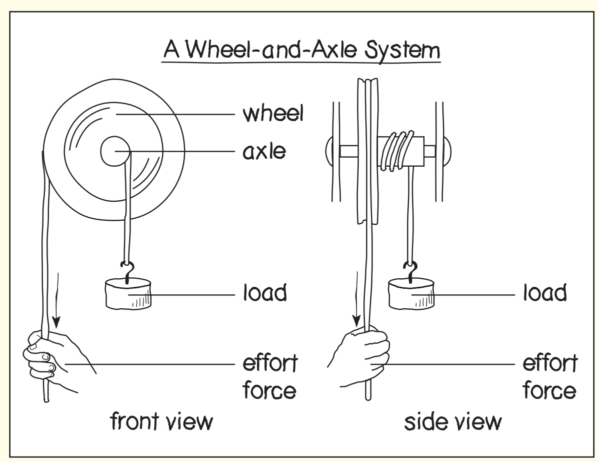
Examine the drawing shown below. It is taken from a student's lab report on an experiment to test the expansion of air in a balloon. The student's written description of results included an explanation of how the particle model can explain what happens to the balloon when the bottle is placed in hot 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.

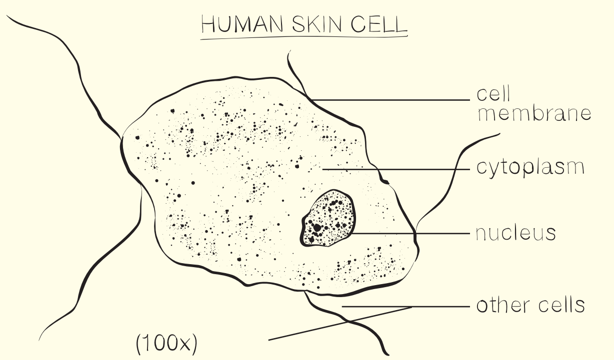


5. Shading or colouring is not usually used in scientific drawings. If you want to indicate a darker area, you can use stippling (a series of dots). You can use double lines to indicate thick parts of the object.

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.

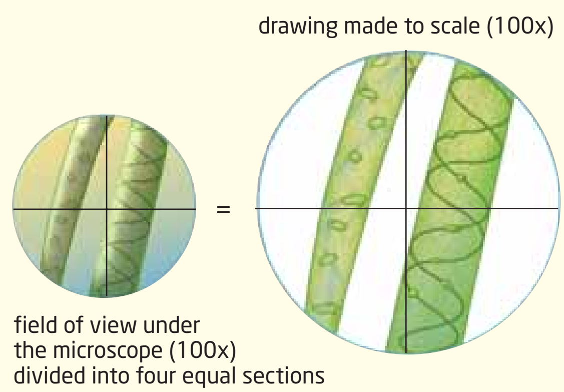
1. Use a mathematical compass to draw an accurate circle in your notebook. The size of the circle does not matter. The circle represents the microscope's field of view.

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—Drawing to Scale

Design a scale model of your classroom. Use the shape of the floor rather than a circle, which was used for the field of view above. Include scale drawings of the furniture and other large objects in your classroom. Label your model to show where you and your classmates sit. Also label any safety equipment in your classroom, as well as doors and windows.

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

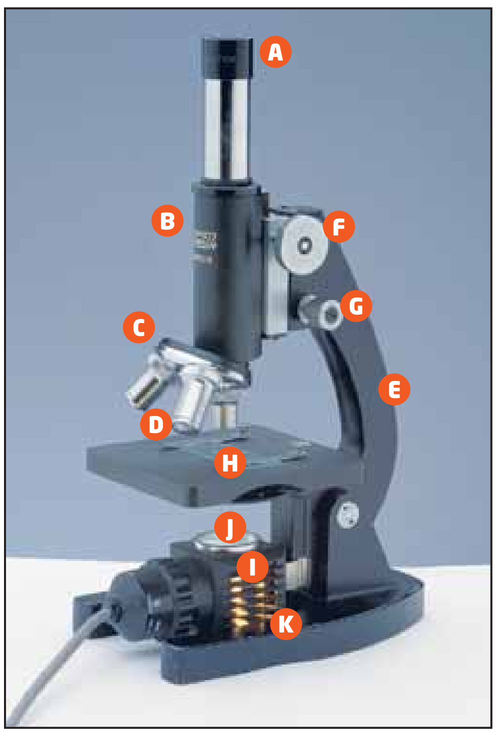
Using a Microscope

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.

Troubleshooting

You may encounter difficulties when using your microscope. The following list details the more common problems and how you can deal with them.

- *You cannot see anything.* Make sure the microscope is plugged in and the light is turned on. If the microscope has no light, adjust your mirror.
- *Are you having trouble finding anything on the slide?* Be patient. Make sure the object being viewed is in the middle of the stage opening. While watching from the side, lower the low-power objective as far as it will go. Then look through the ocular lens and slowly raise the objective lens using the coarse-adjustment knob.
- *Are you having trouble focussing, or is the image very faint?* Try closing the diaphragm slightly. Some objects are almost transparent. If there is too much light, a specimen may be difficult to see or will appear "washed out."
- *Do you see lines and specks floating across the slide?* These are probably structures in the fluid of your eyeball that you see when you move your eyes. Do not worry; this is normal.
- *Do you see a double image?* Check that the objective lens is properly clicked into place.
- *Do you close one eye while you look through the microscope with the other eye?* You might try keeping both eyes open. This will help prevent eye fatigue. It also lets you sketch an object while you are looking at it.
- Always place the part of the slide you are interested in at the centre of the field of view before changing to a higher-power objective lens. Otherwise, when you turn to medium and high power, you may not see the object you were viewing under low power.

Instant Practice—Applying Stains

When working with microscopic specimens, it is often difficult to observe the structures in the specimens clearly. You can use various stains to colour the structures you want to see. Common stains that are used for biological specimens are

- iodine, for staining starch
- crystal violet, for staining bacterial cell walls
- methylene blue, for observing nuclei in cheek cells

Suppose that you want to observe the stages of mitosis in an onion root tip.

1. Slice off the root tips from a green onion, or from a yellow onion that has been allowed to grow in water for a few days.
2. Cut off the root tips. Place them in a small amount of 1 M $HCl(aq)$ for a few minutes to stop mitosis. CAUTION: $HCl(aq)$ is a strong acid. Follow the safety rules for working with acids.
3. Slice a very thin section of the onion root tip, and place it on a microscope slide.
4. Add several drops of a stain, such as 1% toluidine blue, to the root tip section. Leave the stain on the section for several minutes.
5. Blot off the extra stain with a paper towel. Add a few drops of water to the section to remove the extra stain, and then blot off the water. Repeat, if necessary. There should not be a lot of stain left on the section.
6. Add one drop of water. Place a cover slip on the microscope slide, edge first. Carefully lower the cover slip over the section.
7. If the section is too thick, carefully apply gentle pressure to flatten the section.
8. Place the slide on a microscope. Use the low power for your first observation.

Science Skills Toolkit 9

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

Describe how you could use a model to help you explain the following concept to a Grade 8 student: Two hydrogen molecules react with one oxygen molecule to form two water molecules.

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 you explain the functions of the various parts of a cell.

Science Skills Toolkit 10

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.

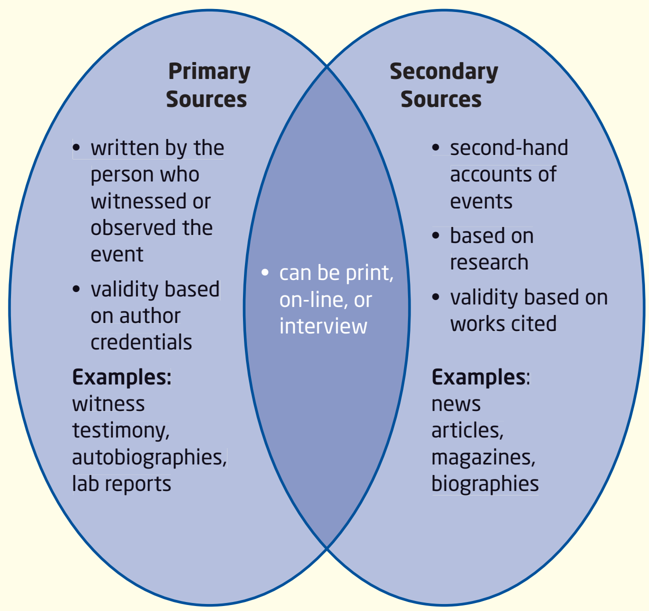
Sources of Information There are many sources of information. For example, you can use a print resource, such as an encyclopedia from the reference section of the library.

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.



Reliability and Bias 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 when preparing a project on the topic of acid precipitation.
2. The following example is not an effective question on which to base a research project: "What is the pH range of acid precipitation?" 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. How would you need to modify your project for this target audience? What would be the best format to use to present your project to your audience?

Science Skills Toolkit 11

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

A concave mirror has a focal length of 12 cm. An object with a height of 2.5 cm is placed 40.0 cm in front of the mirror.

a. Calculate the image distance.
b. Calculate the image height.

Given—Organize the given data.

focal length, $f = 12$ cm
object height, $h_o = 2.5$ cm
object distance, $d_o = 40.0$ cm

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

image distance, d_i (cm)
image height, h_i (cm)

Analysis—Decide how to solve the problem.

The units are consistent, so no conversions are required. The mirror equation and the magnification equation are needed.

$$\frac{1}{f} = \frac{1}{d_i} + \frac{1}{d_o} \quad \text{and} \quad \frac{h_i}{h_o} = \frac{-d_i}{d_o}$$

Solution—Solve the problem.

a. Use the mirror equation to find d_i.

$$\frac{1}{d_i} = \frac{1}{f} - \frac{1}{d_o}$$
$$= \frac{1}{12 \text{ cm}} - \frac{1}{40.0 \text{ cm}}$$
$$= \frac{10}{120 \text{ cm}} - \frac{3}{120 \text{ cm}} = \frac{7}{120 \text{ cm}}$$
$$d_i = \frac{120 \text{ cm}}{7} = 17.14 \text{ cm}$$

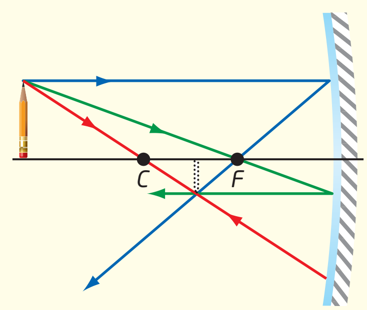
b. Use the magnification equation to find h_i.

$$\frac{h_i}{h_o} = \frac{-d_i}{d_o}$$
$$\frac{h_i}{2.5 \text{ cm}} = \frac{-17.14 \text{ cm}}{40.0 \text{ cm}}$$
$$h_i = 2.5 \text{ cm}\left(\frac{-17.14 \text{ cm}}{40.0 \text{ cm}}\right)$$
$$h_i = -1.07 \text{ cm}$$

Paraphrase—Restate the solution and check your answer.

Restate The image is 17 cm (after rounding) from the mirror. The sign is positive, so the image is in front of the mirror. The height of the image is 1.1 cm (after rounding). The image height is negative, so the image is inverted.

Check The value of *C* is twice the value of *F*, so *C* is 2 × 12 cm = 24 cm. The object is at 40 cm, so it is beyond *C*. Therefore, the image should be closer to the mirror than the object, smaller than the object, and inverted. All of these characteristics agree with the answers. The ray diagram below verifies the solution.



Instant Practice—Using GRASP

Use the GRASP method to solve the following problems.

1. A concave mirror has a focal length of 6.0 cm. An object with a height of 0.60 cm is placed 10.0 cm in front of the mirror.
   a. Calculate the image distance.
   b. Calculate the image height.
2. A concave mirror has a focal length of 3.0 cm. An object with a height of 0.8 cm is placed 1.5 cm in front of the mirror.
   a. Calculate the image distance.
   b. Calculate the image height.

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.

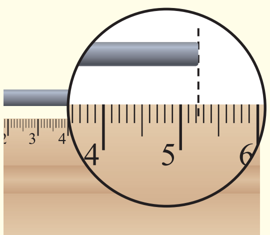
Instant Practice—Scientific Notation

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

You might think that a measurement can be an exact quantity. But in fact, whenever you take a measurement, you are only making an estimate. **Accuracy** is the difference between a measurement and its true value. No measuring device is 100 percent accurate. For example, the illustration below shows a ruler measuring the length of a rod. The ruler can give a quite accurate reading, as it is divided into millimetre marks. But the end of the rod falls between two marks. There is still uncertainty in the measurement.



Significant Digits

Significant digits are used to 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 above, the length of the rod is between 5.2 cm and 5.3 cm. We must estimate the distance between the 2 mm and 3 mm marks. 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.

Determining the Number of Significant Digits

The following rules will help you determine the number of significant digits in a given measurement.

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

Examples:
- 123 m – three significant digits
- 23.56 km – four significant digits

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

Examples:
- 1207 m – four significant digits
- 120.5 km/h – four significant digits

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 – four significant digits
- 6.0 km – two significant digits

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

Examples:
- 500 km – one significant digit (the decimal point is assumed to be after the final zero)
- 0.325 m – three significant digits
- 0.000 34 km – two significant digits

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

Examples:
- 6 apples – infinite number of significant digits
- 125 people – infinite number of significant digits

Instant Practice

Determine the number of significant digits in each measurement.

a. 25 g

b. 584 mL

c. 0.003 56 km

d. 505.2 m

e. 1.030 L

f. 12 000 cm

g. 0.0070 kg

Using Significant Digits in Mathematical Operations

When you use measured values in mathematical operations, the calculated answer cannot be more certain than the measurements on which it is based. Often the answer on your calculator will 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. The digit after the 7 is less than 5, so the 7 does not change.

2. When the first digit to be dropped is 5 or greater, the preceding digit is increased 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:
Add the following measured lengths and express the answer to the correct number of significant digits.

$$
\begin{aligned}
x &= 2.3 \text{ cm} + 6.47 \text{ cm} + 13.689 \text{ cm} \\
&= 22.459 \text{ cm} \\
&= 22.5 \text{ cm}
\end{aligned}
$$

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:
Multiply the following measured lengths and express the answer to the correct number of significant digits.

$$
\begin{aligned}
x &= (2.342 \text{ m})(0.063 \text{ m})(306 \text{ m}) \\
&= 45.149\,076 \text{ m}^3 \\
&= 45 \text{ m}^3
\end{aligned}
$$

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

Instant Practice

Perform the following calculations, rounding off your answer to the correct number of significant digits.

a. (2.475 m) + (3.5 m) + (4.65 m)

b. (47 g) – (12.27 g) – (8.384 g)

c. (15.3 cm) × (0.2265 cm)

d. (12.34 km) / (0.50 h)

e. (12 mL) × (3.56 mL) / (4.060 mL)

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

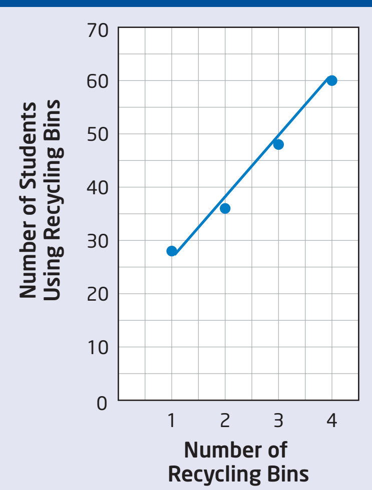
Procedure

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

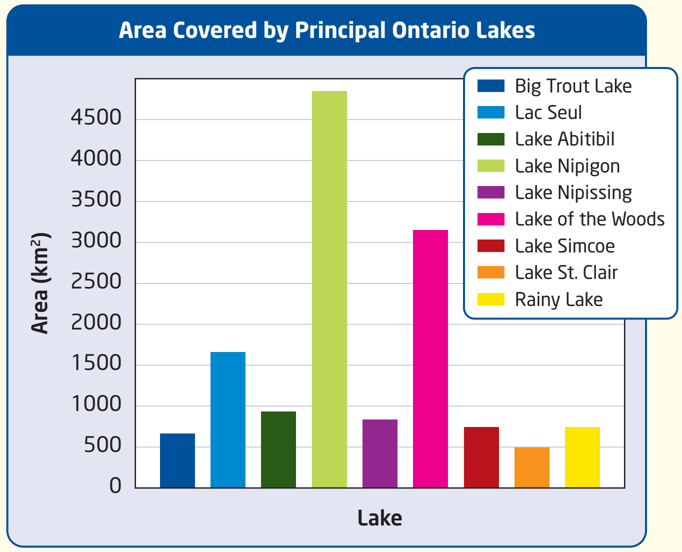
Bar graphs help you to compare a numerical quantity with some other category at a glance. The second category may or may not be a numerical quantity. It could be places, items, organisms, or groups, for example.

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.

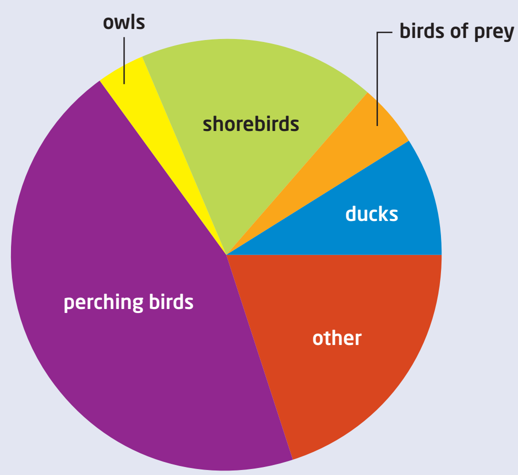
$$\text{Degrees in “piece of pie”} = \frac{\text{Percent for a type of bird}}{100\%} \times 360°$$

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:

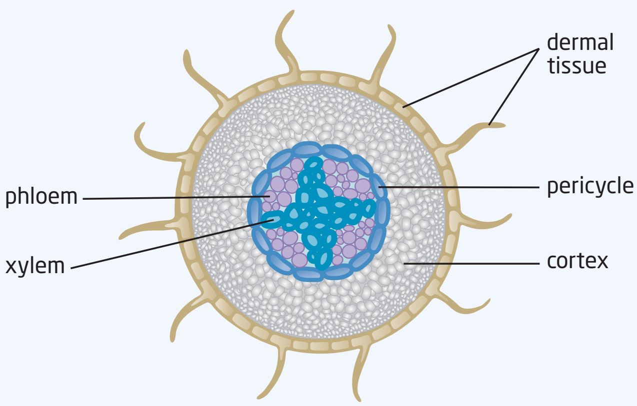
- *Asking questions* helps you engage actively in reading the text and gives you a purpose for continuing to read.
- *Identifying the main idea and details* helps you figure out what is the most important information in the text you are reading. You can also use this strategy after reading, to help you 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.

- *Interpreting cross sections* requires you to examine a drawing that shows the insides of an object, as though it has been sliced open either horizontally or vertically through its centre. It requires you to visualize the object in three dimensions. You also need to pay attention to the title or caption that accompanies the drawing.



This cross section shows the structure of a typical root of a plant. You will learn more about the structure of roots in Chapter 2.

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 *word parts* that combine to form multisyllabic words. The names of compounds, for example, hydrofluoric acid, are formed by combining the word part *hydro* indicating hydrogen and *fluor* (indicating fluorine) and the ending *-ic acid.*
- 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.
- *Synthesizing* is the process of combining information from a variety of sources with prior knowledge to gain a new understanding of a topic.

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*.

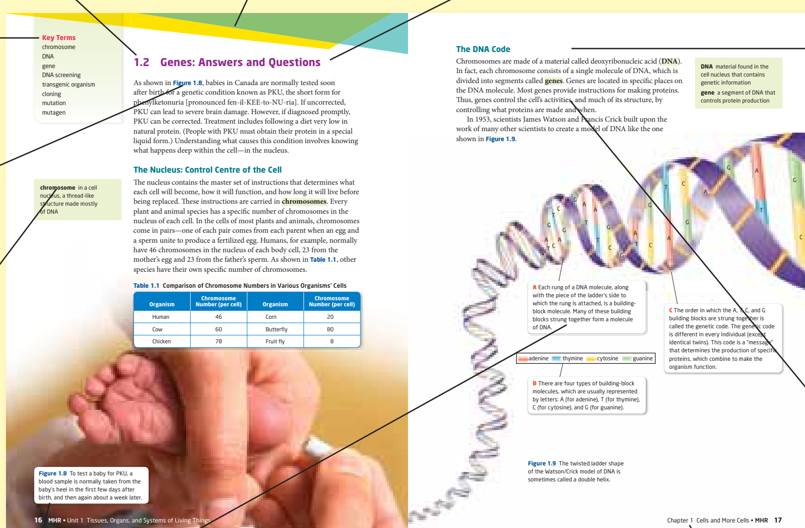
As well as the Table of Contents, this textbook has many other features designed to help you find your way while reading. Examine the sample pages below. They include several text features that will help you understand the content.

Numbered sections: the number of the chapter (1), followed by the number of the section (2).

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 and labels 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.

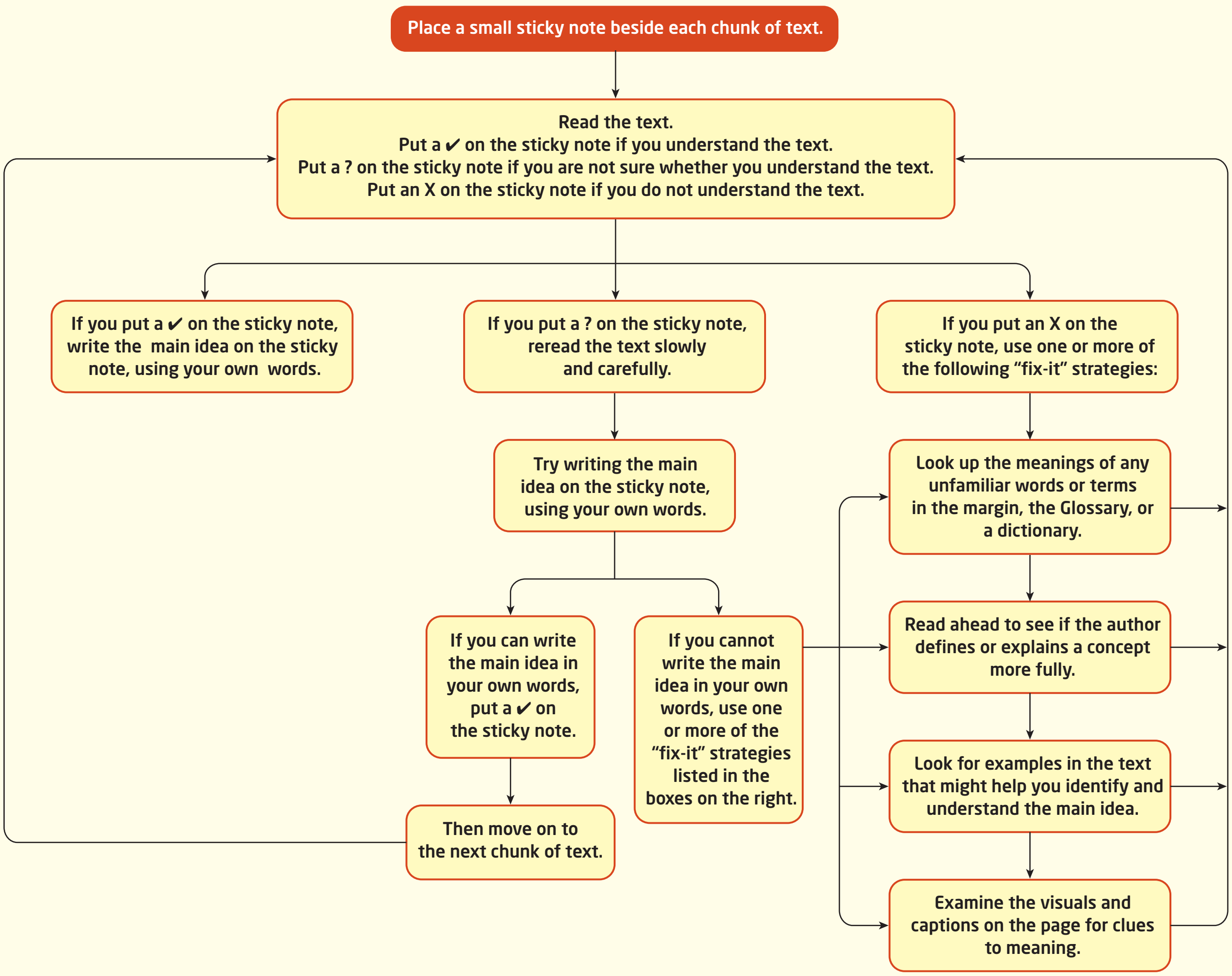
Instant Practice

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
climate	Having to do with climate	A **climatograph** is a graph of climate data for a specific region.
gene	A segment of DNA that controls protein production	Your **genetic code** is the order in which your genes are strung together.
mutate	To change or alter	A **mutation** in biology means a change in the DNA of an organism.
Prefix	**Definition**	**Example**
co-	With; together	A **covalent** bond forms when two atoms share electrons.
de-	From; away from; out of	A **decomposition** reaction in chemistry occurs when a compound breaks down (decomposes) into two or more simpler compounds or elements.
micro-	Small; tiny	A **microorganism** is an organism that is so small that it cannot be seen by the unaided eye.
poly-	Much; many; more than one	A **polyatomic** ion is an ion that is composed of more than one atom.
trans-	Across; through	A **transgenic** organism is an organism whose genetic information has been altered by the insertion of another species' genes.
Suffix	**Definition**	**Example**
-ar	Relating to	**Cellular** means relating to a cell.
-ic	Relating to; characterized by	**Embryonic** means relating to an embryo.
-ory	Relating to	**Circulatory** means relating to the circulation of the blood.
-ion	Having to do with an action or a process	**Refraction** means the process of refracting (the bending of light as it travels, at an angle, from one material to another material).
-sis	Having to do with a process or condition	A **synthesis** reaction in chemistry occurs when two or more reactants combine to produce a new product.

Instant Practice

1. Use the table to predict the meaning of *hydrochloric.*
2. Think of a word that begins with one of the prefixes 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.

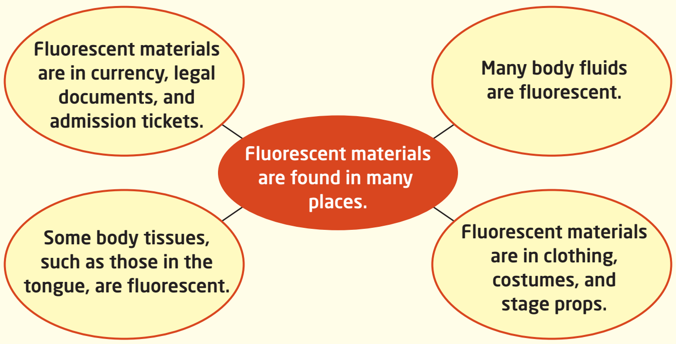
Study Toolkit 4

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.

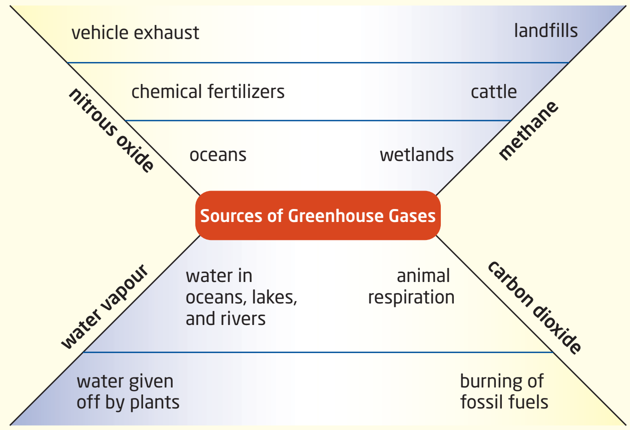
Main Idea Web

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.



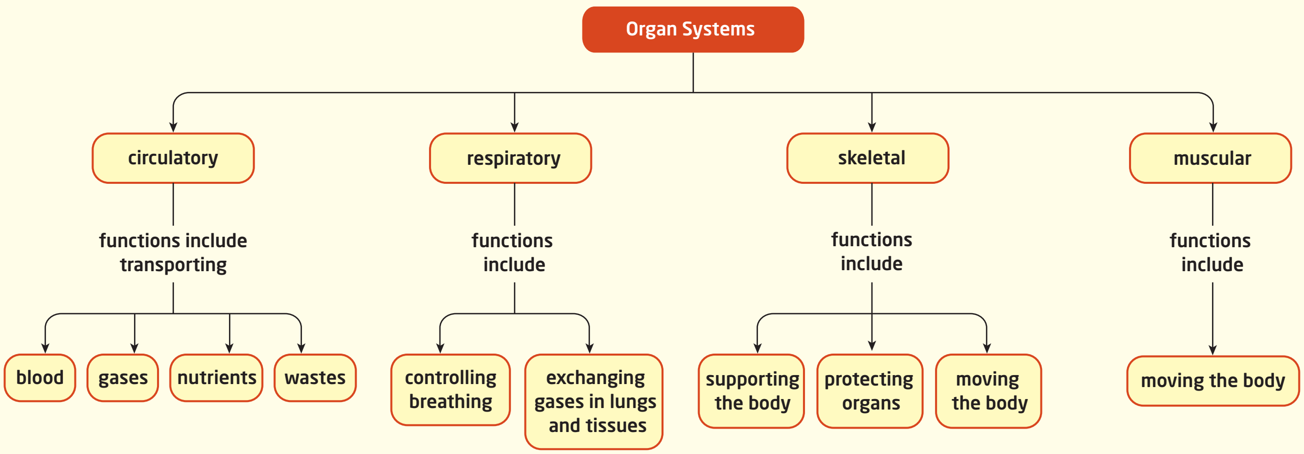
Spider Map

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.



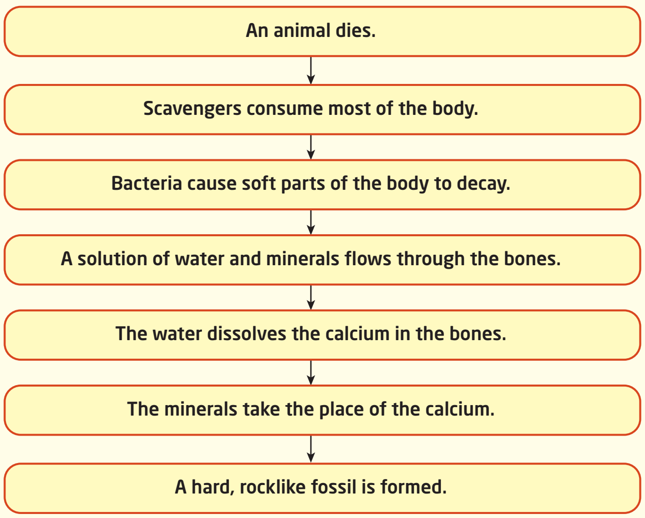
Concept Map

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.



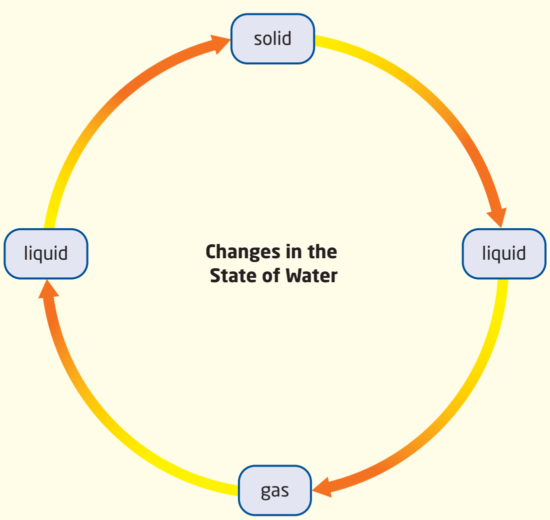
Flowchart

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.



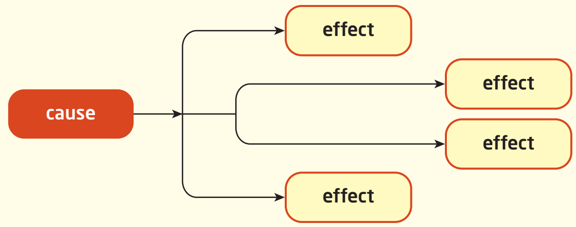
Cycle Chart

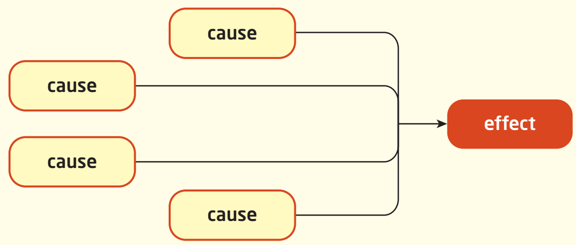
A *cycle chart* is a flowchart that has no distinct beginning or end. All the events are shown in the order in which they occur, as indicated by arrows, but there is no first or last event. Instead, the events occur again and again in a continuous cycle.



Cause-and-Effect Map

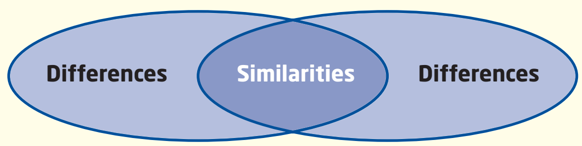
The first *cause-and-effect map* below shows one cause that results in several effects. The second map shows one effect that has several causes.

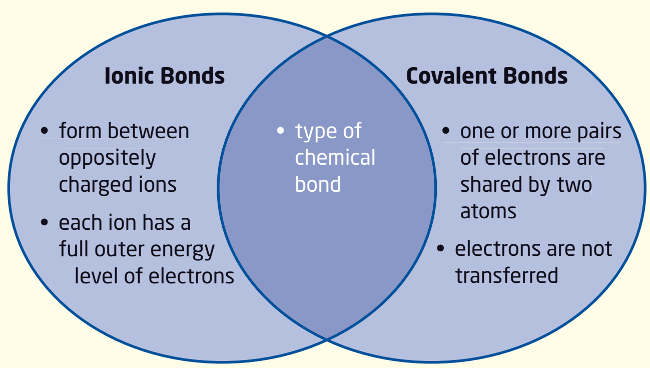




Venn Diagram

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 organ systems in the human body.
2. Draw a spider map that shows your prior knowledge of Canada's biomes.

Appendix A

Chemistry References

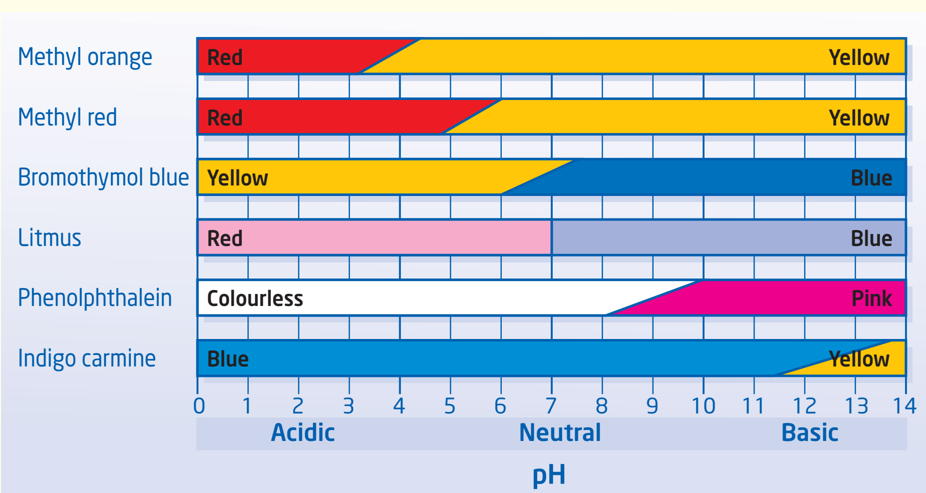
Names, Formulas, and Charges of Some Polyatomic Ions

Name	Formula
Acetate	CH_3COO^-
Ammonium	NH_4^+
Carbonate	CO_3^{2-}
Chlorate	ClO_3^-
Chlorite	ClO_2^-
Chromate	CrO_4^{2-}
Cyanide	CN^-
Dichromate	$Cr_2O_7^{2-}$
Hydrogen carbonate, bicarbonate	HCO_3^-
Hydrogen sulfate, bisulfate	HSO_4^-
Hydrogen sulfide, bisulfide	HS^-
Hydrogen sulfite, bisulfite	HSO_3^-
Hydroxide	OH^-
Hypochlorite	ClO^-
Nitrate	NO_3^-
Nitrite	NO_2^-
Perchlorate	ClO_4^-
Permanganate	MnO_4^-
Phosphate	PO_4^{3-}
Phosphite	PO_3^{3-}
Sulfate	SO_4^{2-}
Sulfite	SO_3^{2-}

Electron Arrangements of the First 20 Elements

Atom			Ion		
H	1 p	1	H^+	1 p	0
			H^-	1 p	2
He	2 p	2	He	Does not form an ion	
Li	3 p	2, 1	Li+	3 p	2
Be	4 p	2, 2	Be^{2+}	4 p	2
B	5 p	2, 3	B^{3+}	5 p	2
C	6 p	2, 4	C^{4-}	6 p	2, 8
N	7 p	2, 5	N^{3-}	7 p	2, 8
O	8 p	2, 6	O^{2-}	8 p	2, 8
F	9 p	2, 7	F^-	9 p	2, 8
Ne	10 p	2, 8	Ne	Does not form an ion	
Na	11 p	2, 8, 1	Na^+	11 p	2, 8
Mg	12 p	2, 8, 2	Mg^{2+}	12 p	2, 8
Al	13 p	2, 8, 3	Al^{3+}	13 p	2, 8
Si	14 p	2, 8, 4	Si^{4-}	14 p	2, 8, 8
P	15 p	2, 8, 5	P^{3-}	15 p	2, 8, 8
S	16 p	2, 8, 6	S^{2-}	16 p	2, 8, 8
Cl	17 p	2, 8, 7	Cl^-	17 p	2, 8, 8
Ar	18 p	2, 8, 8	Ar	Does not form an ion	
K	19 p	2, 8, 8, 1	K^+	19 p	2, 8, 8
Ca	20 p	2, 8, 8, 2	Ca^{2+}	20 p	2, 8, 8

Acid-Base Indicators



Appendix B

Properties of Common Substances

KEY TO SYMBOLS:
Common names of substances are enclosed in parentheses.
(*) **water solution of a pure substance** (e) **element** (c) **compound**

Name	Formula	Melting Point (°C)	Boiling Point (°C)	Density (g/cm³ or g/mL)
acetic acid (vinegar) (c)	CH_3COOH	16.6	118.1	—
aluminum (e)	Al	659.7	2519	2.7
ammonia (c)	NH_3	−77.8	−33.4	less dense than air
ammonium nitrate (c)	NH_4NO_3	169.6	210	1.73
argon (e)	Ar	−189	−185	denser than air
arsenic (e)	As	—	—	5.727 (grey), 4.25 (black), 2.0 (yellow)
barium (e)	Ba	727	1897	3.62
beryllium (e)	Be	1280	2471	1.85
boron (e)	B	2075	4000	2.37(brown), 2.34 (yellow)
bromine (e)	Br_2	−7.2	58.8	3.12
calcium (e)	Ca	845	1484	1.55
calcium carbonate (limestone) (c)	$CaCO_3$	decomposes at 900°C	—	2.93
calcium hydroxide (slaked lime) (c)	$Ca(OH)_2$	decomposes at 522°C	—	2.24
calcium oxide (lime) (c)	CaO	2580	2850	3.3
carbon (diamond) (e)	C	3500	3930	3.51
carbon (graphite) (e)	C	4492	4492	2.25
carbon dioxide (c)	CO_2	—	—	—
chlorine (e)	Cl_2	−101.6	−34.6	denser than air
copper (e)	Cu	1084	2562	8.95
copper(II) nitrate (c)	$Cu(NO_3)_2$	—	—	—
copper(II) sulfate (bluestone) (c)	$CuSO_4•5H_2O$	decomposes at 150°C	—	2.28
ethanol (ethyl alcohol) (c)	C_2H_5OH	−114.5	78.4	0.789
fluorine (e)	F_2	−270	−188	—
gold (e)	Au	1063	2856	19.3
glucose (c)	$C_6H_{12}O_6$	146	decomposes before it boils	1.54
helium (e)	He	−272.2	−268.93	—
hematite (c)	Fe_2O_3	1565	—	5.24
hydrochloric acid (*)	HCl	varies	varies	varies
hydrogen (e)	H_2	−259	−253	much less dense than air
hydrogen peroxide (c)	H_2O_2	−0.4	150.2	1.45
iodine (e)	I_2	114	184	4.95
iron (e)	Fe	1535	2861	7.86
lead (e)	Pb	327.4	1750	11.34
lithium (e)	Li	179	1340	0.534
magnesium (e)	Mg	651	1107	1.74
magnesium chloride (c)	$MgCl_2$	708	1412	2.3
magnetite (c)	Fe_3O_4	—	—	5.18
mercury (e)	Hg	−38.9	356.6	13.6
methane (c)	CH_4	−182.5	−161.5	—
neon (e)	Ne	−248	−246	—
nickel (e)	Ni	1455	2913	8.90
nitrogen (e)	N_2	−209.9	−195.8	slightly less dense than air
nitrogen dioxide (c)	NO_2	—	—	—
oxygen (e)	O_2	−218	−183	slightly denser than air
ozone (e)	O_3	−192.5	−112	denser than air
platinum (e)	Pt	1769	3824	21.41
polyethylene (polythene) (c)	$(C_2H_4)n$	—	—	—
potassium (e)	K	63.5	759	0.86
propane (c)	C_3H_8	—	−42.17	—
selenium (e)	Se	217	684.9	4.81
silicon (e)	Si	1410	3265	2.33
silicon dioxide (silica) (c)	SiO_2	1600	—	—
silver (e)	Ag	961	2162	10.5
sodium (e)	Na	97.5	892	0.971
sodium chloride (table salt) (c)	NaCl	801	1465	2.16
sodium fluoride (c)	NaF	988	1695	2.56
sucrose (sugar) (c)	$C_{12}H_{22}O_{11}$	170	decomposes at 186°C	1.59
sulfur (brimstone) (e)	S_8	112.8	444.6	2.07
tin (e)	Sn	231.9	2602	7.31
titanium (e)	Ti	1666	3287	4.5
uranium (e)	U	1130	4131	19.05
water (c)	H_2O	0	100	1.00
xenon (e)	Xe	−111.9	−107.1	—
zinc (e)	Zn	419	907	7.14

DEFINITIONS:
deliquescent: able to absorb water from the air to form a concentrated solution
sublime: to form a vapour directly from a solid

Appearance (at room temperature: 20°C)	Comments
colourless liquid with pungent smell	used in the manufacture of cellulose ethanoate; vinegar is a 5 to 7 percent solution in water
silver-white metal	used in aircraft, cooking utensils, and electrical apparatus
very soluble gas with pungent smell	used as refrigerant and in manufacture of resins, explosives, and fertilizers
white, soluble, crystalline salt	used in explosives and as a fertilizer
inert gas	used in electric lights
grey, black, or yellow solid	used in semiconductors and alloys; compounds are very poisonous and are used in medicine and as pesticides
silver-white solid	used in X-ray diagnosis
hard, white metal	used for corrosion-resistant alloys
brown, amphorous powder or yellow crystals	used for hardening steel and for producing enamels and glasses
red-brown liquid	used to make certain pain-relieving drugs; liquid causes severe chemical burns; vapour is harmful to lungs
soft, white metal that tarnishes easily	very abundant; essential to life
white solid	main ingredient in chalk and marble
white solid	aqueous solution used to test for CO_2
white solid	used in cement and for marking lines on playing fields
colourless, solid crystals	very hard; used for drilling through rock
grey-black solid	very soft; used in lubricants, pencil leads, and electrical apparatus
colourless gas with a faint tingling smell and taste	does not support combustion and is denser than air; used in fire extinguishers and as a refrigerant at −78.5°C
green gas	poisonous; used to kill harmful organisms in water
shiny, reddish solid	soft metal; good conductor of heat
blue, solid crystals	used in pesticides
colourless liquid	derived from fermentation of sugar; used as solvent or fuel; found in wine
greenish yellow gas	similar to chlorine
shiny, yellow solid	very soft metal; highly resistant to tarnishing
white solid	simple sugar; human body converts most sugars and starches to glucose
nonflammable inert gas	used as refrigerant; provides inert atmosphere for welding; used to fill air ships and balloons
rusty red colour	found in iron ore and rusted iron
colourless liquid	corrosive acid; properties vary according to concentration
colourless gas	highly flammable; liquid form used as rocket fuel
colourless liquid	thick and syrupy when pure; an antiseptic
violet-black, solid crystals	crystals sublime readily to form poisonous violet vapour
shiny, silver solid	rusts readily; soft when pure
shiny, blue-white solid	soft metal; forms poisonous compounds
silver-white metal (least dense solid known)	used in alloys; its salts have various medical uses
light, silvery-white metal that tarnishes easily in air	used in alloys and photography; compounds used in medicine; essential to life
white, deliquescent substance	
shiny, black, crystalline solid	strongly magnetic
shiny, silvery liquid	only liquid metal; forms poisonous compounds
odourless, flammable gas formed from decaying organic matter	main constituent in natural gas
colourless, odourless gas	discharge of electricity at low pressures through neon produces an intense orange-red glow
silvery-white, magnetic metal that resists corrosion	used for nickel plating and coinage, in alloys, and as a catalyst
colourless gas	will not burn or support burning; makes up 80 percent of air
brown gas	causes reddish-brown colour in smog
colourless gas	must be present for burning to take place; makes up 20 percent of air
bluish gas	used for purifying air and water and in bleaching; atmospheric layer blocks most of the Sun's ultraviolet light
silver-white solid	used in jewellery; alloyed with cobalt, used in pacemakers
tough, waxy, thermoplastic material	polymer of ethylene; used as insulating material; flexible and chemically resistant
silvery-white, soft, highly reactive, alkali metal	essential to all life; found in all living matter; salts used in fertilizers
colourless gas	flammable; used as fuel
non-metal resembling sulfur; silvery-grey, crystalline solid	used in manufacture of rubber and ruby glass; used in photoelectric cells and semiconductors
steel-grey metalloid similar to carbon in its chemical properties	used in pure form in semiconductors and alloys and in the form of silicates in glass
hard, granular powder; insoluble in water	main constituent of sand; used in clocks and watches as quartz
shiny, white solid	soft metal; best-known conductor of electricity
soft, silvery-white metal; very reactive	used in preparation of organic compounds, as coolant, and in some types of nuclear reactors
white, crystalline solid	used to season or preserve foods
colourless, crystalline substance	used in water fluoridation and as an insecticide
white solid	made from sugar cane or sugar beets
yellow solid	used to make dyes, pesticides, and other chemicals
shiny, slightly yellow solid	soft metal; rust resistant
lustrous white solid	alloys are widely used in the aerospace industry
metallic grey solid	used as a nuclear fuel (usually converted into plutonium)
colourless liquid	good solvent for non-greasy matter
inert gas	used in fluorescent tubes and light bulbs
hard, bluish-white metal	used in alloys such as brass and galvanized iron

Appendix C

Numerical Answers and Answers to Practice Problems

Unit 1

Section 1.2 Review page 28

6. 25 093.75 min or 418.23 h or 17.43 days

Section 1.3 Review page 39

5. 20 (or 10 in each daughter cell)

Chapter 1 Review page 53

23. a. interphase, 631; prophase, 100; metaphase, 15.4; anaphase, 15.4; telophase, 38.5

Unit 1 Review pages 128-131

1. d **2.** d **3.** c **4.** c **5.** b
21. 65 536
38. a **39.** c **40.** b **41.** c **42.** a

Unit 2

Section 4.3 Review page 168

3. a. 2Fe, 6I
b. 3Ca, 6O, 6H
c. 3Ca, 6N, 18O
d. 3N, 12H, 3Cl, 12O
7. a. not balanced; Al; $2Al(s) + 3F_2(g) \rightarrow 2AlF_3(s)$
b. not balanced; H and O; $Ca(OH)_2(aq) + 2HCl(aq) \rightarrow CaCl_2(aq) + 2H_2O(\ell)$
c. balanced
d. not balanced; K, N, O; $K_2SO_4(aq) + 2AgNO_3(aq) \rightarrow Ag_2SO_4(s) + 2KNO_3(aq)$
8. chemical equation: $2Na(s) + 2H_2O(\ell) \rightarrow H_2(g) + 2NaOH(aq)$

Chapter 4 Review pages 174-175

8. a. 3; *tri-*
b. 8; *octa-*
11. a. 4H, 2O, 2Na, 2F
b. 6Br, 2Fe, 6I
c. 1Pb, 2N, 6O, 2Na, 2I
d. 6K, 2P, 20O, 6N, 24H, 3S
12. a. $Mg_3N_2(s) \rightarrow 3Mg(s) + N_2(g)$
b. $4Mn(s) + 3O_2(g) \rightarrow 2Mn_2O_3(s)$
c. $CO_2(g) + 4H_2(g) \rightarrow CH_4(g) + 2H_2O(g)$
d. $2PbO(s) \rightarrow 2Pb(s) + O_2(g)$
e. $2C_2H_6(g) + 7O_2(g) \rightarrow 4CO_2(g) + 6H_2O(g)$
f. $Cu(s) + 2AgNO_3(aq) \rightarrow 2Ag(s) + Cu(NO_3)_2(aq)$
g. $C_3H_8(g) + 5O_2(g) \rightarrow 3CO_2(g) + 4H_2O(g)$
h. $3PbCl_4(aq) + 4K_3PO_4(aq) \rightarrow 12KCl(aq) + Pb_3(PO_4)_4(s)$
13. a. chemical equation: $N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$
b. chemical equation: $CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$
c. chemical equation: $2Al(s) + O_2(g) \rightarrow Al_2O_3(s)$
d. chemical equation: $6H_2O(\ell) + 6CO_2(g) \rightarrow C_6H_{12}O_6(s) + 6O_2(g)$
e. chemical equation: $CaCl_2(aq) + 2K(s) \rightarrow 2KCl(aq) + Ca(s)$
f. chemical equation: $BaSO_4(aq) + 2NaOH(aq) \rightarrow Na_2SO_4(aq) + Ba(OH)_2(s)$
g. chemical equation: $TiCl_4(g) + 2Mg(\ell) \rightarrow Ti(s) + 2MgCl_2(\ell)$
16. a. $2NH_3 \rightarrow N_2 + 3H_2$; Nitrogen is diatomic ($N_2$).
b. $C + O_2 \rightarrow CO_2$; Atoms are already balanced.
20. b. $2Mg(s) + O_2(g) \rightarrow 2MgO(s)$
c. 16 g of oxygen; According to the law of conservation of mass, if the total mass of the product is 40 g, then the combined mass of the reactants (magnesium and oxygen) must also be 40 g; 40 g – 24 g = 16 g

Section 5.1 Review page 189

3. $4Fe(s) + 3O_2(g) \rightarrow 2Fe_2O_3(s)$
5. $2H_2O \rightarrow 2H_2(g) + O_2(g)$
7. a. $2Ca(s) + O_2(g) \rightarrow 2CaO(s)$; synthesis
b. $8Ca(s) + S_8(s) \rightarrow 8CaS(s)$; synthesis
c. $2CsCl(s) \rightarrow 2Cs(s) + Cl_2(g)$; decomposition
8. a. $3Mg(s) + N_2(g) \rightarrow Mg_3N_2(s)$; synthesis reaction
b. $2K_2O(s) \rightarrow 4K(s) + O_2(g)$; decomposition reaction
c. $2Na(s) + Br_2(\ell) \rightarrow 2NaBr(s)$; synthesis reaction

Section 5.2 Review page 198

2. a. $Ca(s) + 2AgNO_3(aq) \rightarrow 2Ag(s) + Ca(NO_3)_2(aq)$
b. No reaction
c. $2Al(s) + 6HCl(aq) \rightarrow 2AlCl_3(aq) + 3H_2(g)$
6. a. single; $Cl_2(g) + 2CsBr(aq) \rightarrow Br_2 + 2CsCl$
b. double; $2AgNO_3(aq) + Na_2CrO_4(aq) \rightarrow Ag_2CrO_4 + 2NaNO_3$
c. double; $MgCl_2(aq) + 2AgNO_3(aq) \rightarrow 2AgCl + Mg(NO_3)_2$
d. single; $F_2(g) + 2NaI(aq) \rightarrow I_2 + 2NaF$
7. single displacement; $2Al(s) + 3CuSO_4(aq) \rightarrow Al_2(SO_4)_3(aq) + 3Cu(s)$; copper

Chapter 5 Review pages 214-215

9. $2H_2(\ell) + O_2(\ell) \rightarrow 2H_2O(g)$; synthesis
12. a. $Li(s) + NaCl(aq) \rightarrow LiCl(aq) + Na(s)$
b. $2Al(s) + 3Cu(NO_3)_2(aq) \rightarrow 3Cu(s) + 2Al(NO_3)_3(aq)$
c. No reaction
14. a. $Cl_2(g) + CaBr_2(aq) \rightarrow CaCl_2 + Br_2$
b. $6Li(s) + N_2(g) \rightarrow 2Li_3N$
c. $AgNO_3(aq) + NaCl(aq) \rightarrow AgCl + NaNO_3$
d. $PbO_2(s) \rightarrow Pb + O_2$
e. $3Fe(ClO_4)_2(aq) + 2Al(s) \rightarrow 2Al(ClO_4)_3 + 3Fe$
f. $Ba(NO_3)_2(aq) + MgSO_4(aq) \rightarrow Mg(NO_3)_2 + BaSO_4$
g. $BaCl_2(aq) + Na_2CrO_4(aq) \rightarrow 2NaCl + BaCrO_4$
h. $4Rb(s) + O_2(g) \rightarrow 2Rb_2O$
i. No reaction
j. $8Mg(s) + S_8(s) \rightarrow 8MgS$

Section 6.1 Review page 228

7. a. $HClO_3(aq) \rightarrow H^+(aq) + ClO_3^-(aq)$; acid
b. $KOH(aq) \rightarrow K^+(aq) + OH^-(aq)$; base

Section 6.3 Review page 246

1. $H_2SO_4 + 2KOH \rightarrow 2H_2O + K_2SO_4$; potassium sulfate, K_2SO_4

Chapter 6 Review pages 252-253

16. a. $2HBr(aq) + Ca(OH)_2(aq) \rightarrow CaBr_2(aq) + 2H_2O(\ell)$
b. $2LiOH(aq) + H_2SO_3(aq) \rightarrow Li_2SO_3(aq) + 2H_2O(\ell)$
c. $3Mg(OH)_2(aq) + 2H_3PO_4(aq) \rightarrow Mg_3(PO_4)_2(aq) + 6H_2O(\ell)$
18.

Indicator	Colour	pH Estimate
Methyl orange	yellow	3.2 – 4.4
Bromothymol blue	yellow	< 6.0
Phenolphthalein	pink	> 8.2

28. b. 100 times

Unit 2 Review pages 258-262

1. b **2.** c **3.** b **4.** a **5.** d
7. a. synthesis; $S_8(s) + 8O_2(g) \rightarrow 8SO_2(g)$
b. decomposition; $2HF(g) \rightarrow H_2(g) + F_2(g)$
c. double displacement or neutralization; $H_2SO_4(aq) + 2NaOH(aq) \rightarrow Na_2SO_4(aq) + 2HNO(\ell)$
d. double displacement; $Fe(NO_3)_3(aq) + 3KOH(aq) \rightarrow FeOH_3(s) + 3KNO_3(aq)$
e. single displacement; $2Al(s) + 3CuCl_2(aq) \rightarrow 2AlCl_3(aq) + 3Cu(s)$
8. a. chemical equation: $4Na(s) + O_2(g) \rightarrow 2Na_2O(s)$
b. chemical equation: $Mg(s) + CuCl_2(aq) \rightarrow Cu(s) + MgCl_2(aq)$
c. chemical equation: $MgCO_3(s) \rightarrow MgO(s) + CO_2(g)$

d. chemical equation: $CrCl_3(aq)$ + $3KOH(aq) \rightarrow 3KCl(aq)$ + $Cr(OH)_3(s)$
e. chemical equation: $2Al(s)$ + $3H_2SO_4(aq) \rightarrow 3H_2(g)$ + $Al_2(SO_4)_3(aq)$
10. a. 4 **b.** 13 **c.** 6
14. a. $2CO + O_2 \rightarrow 2CO_2$
23. b. double displacement; $Hg(NO_3)_2$ + $Na_2SO_4 \rightarrow 2NaNO_3 + HgSO_4$
29. b **30.** d **31.** a **32.** a **33.** c

Unit 3

Section 8.3 Review page 338
8. 110% increase

Section 9.3 Review page 381
5. 12 480 kg/year of CO_2; 6240 kg/year of CH_4

Unit 3 Review pages 392-396
1. d **2.** a **3.** b **4.** c **5.** c
35. c **36.** c **37.** b

Unit 4

Section 10.3 Review page 430
6. $h_i = -1.67$ cm; $d_i = 9.167$ cm

Section 10.4 Review page 438
6. $h_i = 2.5$ cm; $d_i = -1.875$ cm

Chapter 10 Review pages 444-445
20. 3 m
24. c. $h_i = 3.3$ cm; $d_i = 13.3$ cm

Section 11.1 Review page 456
3. 2.04×10^8 m/s
7. 0°

Chapter 11 Review pages 482-483
13. a. 1.53
b. 1.24×10^8 m/s
c. 2.20×10^8 m/s
d. 1.92

Section 12.2 Review page 501
5. $h_i = -3.67$ cm; $d_i = 66.7$ cm
7. $h_i = 4.0$ cm; $d_i = 19$ cm

Unit 4 Review pages 524-527
1. b **2.** d **3.** a **4.** d **5.** a
19. $F_1 = F_2 = 3.75$ cm
33. b **34.** c **35.** a **36.** c **37.** b

Answers to Practice Problems

Chapter 4 page 157
1. a. NF_3
b. PBr_3
c. NH_3
d. SF_2
e. P_2O_6
f. CCl_4

Chapter 4 page 165
1. a. chemical equation: $2Mg(s) + O_2(g) \rightarrow 2MgO(s)$
b. chemical equation: $4Fe(s) + 3O_2(g) \rightarrow 2Fe_2O_3(s)$
c. chemical equation: $N_2(g) + 3Br_2(g) \rightarrow 2NBr_3(g)$
2. $CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(g)$

Chapter 5 page 184
1. a. $3Ca(s) + N_2(g) \rightarrow Ca_3N_2(s)$
b. $4K(s) + O_2(g) \rightarrow 2K_2O(s)$
c. $12Cs(s) + P_4(s) \rightarrow 4Cs_3P(s)$
d. $2Al(s) + 3F_2(g) \rightarrow 2AlF_3(s)$
2. $H_2(g) + Cl_2(g) \rightarrow 2HCl(g)$

Chapter 5 page 187
1. a. $2AuCl_3(s) \rightarrow 2Au(s) + 3Cl_2(g)$
b. $MgF_2(s) \rightarrow Mg(s) + F_2(g)$
c. $2Li_2O(s) \rightarrow 4Li(s) + O_2(g)$
d. $2CsCl(s) \rightarrow 2Cs(s) + Cl_2(g)$
2. $2Cr_2O_3(s) \rightarrow 4Cr(s) + 3O_2(g)$
3. $2NaN_3(s) \rightarrow 2Na(s) + 3N_2(g)$

Chapter 5 page 193
1. a. $3SnCl_4(aq) + 4Al(s) \rightarrow 3Sn(s) + 4AlCl_3(aq)$
b. $CuF_2(aq) + Mg(s) \rightarrow MgF_2(aq) + Cu(s)$
c. No reaction
d. $Au(NO_3)_3(aq) + 3Ag(s) \rightarrow 3AgNO_3(aq) + Au(s)$
e. $2Al(s) + Fe_2O_3(s) \rightarrow Al_2O_3 + 2Fe(s)$
f. $2Li(s) + 2HCl(aq) \rightarrow 2LiCl(aq) + H_2(g)$
2. $CuSO_4(aq) + Mg(s) \rightarrow MgSO_4(aq) + Cu(s)$

Chapter 5 page 196
1. a. $Pb(NO_3)_2(aq) + 2KI(aq) \rightarrow PbI_2 + 2KNO_3$
b. $SrCl_2(aq) + Pb(NO_3)_2(aq) \rightarrow PbCl_2 + Sr(NO_3)_2$
c. $AlCl_3(aq) + 3CuNO_3(aq) \rightarrow 3CuCl + Al(NO_3)_3$
d. $KCl(aq) + AgNO3(aq) \rightarrow KNO_3 + AgCl$
e. $CaI_2(aq) + Na_2CO_3(aq) \rightarrow CaCO_3 + 2NaI$
2. $2K_3PO_4(aq) + 3MgI_2(aq) \rightarrow Mg_3(PO_4)_2 + {}_6KI$

Chapter 6 page 224
1. HBr; Br^-; bromide ion
2. a. HCl
b. HNO_3
c. HF
d. H_2SO_4

Chapter 6 page 227
1. NaOH(aq); Na^+, sodium ion
2. a. $Ca(OH)_2$
b. $Al(OH)_3$
c. $Be(OH)_2$
d. LiOH
e. $Mn(OH)_2$
f. $Ni(OH)_2$

Chapter 10 page 427
1. a. 15 cm
b. −0.9 cm
2. a. −2 cm
b. 2 cm
3. a. 4.8 cm
b. −1.8 cm
4. 68 cm
5. 90 cm

Chapter 10 page 436
1. a. −0.66 m
b. 0.11 m
2. a. −2.92 cm
b. 2.08 cm
3. a. −1.33 cm
b. 2.00 cm
4. a. −0.46 m
b. 0.17 m
5. a. −0.24 m
b. 0.088 m
6. a. −0.7 cm
b. 11 cm
7. a. −39 cm
b. 12 cm

Chapter 11 page 455
1. 1.82×10^8 m/s
2. 1.97×10^8 m/s
3. a. 2.42 **b.** diamond
4. A: Diamond; B: Flint; C: Crown

Chapter 12 page 500
1. $d_i = 15.4$ cm; $h_i = -1.80$ cm
2. $d_i = 225$ cm; $h_i = -11.3$ cm
3. $d_i = -280$ cm; $h_i = 14.0$ cm
4. $f = 28.8$ cm; $h_o = 24.0$ cm

Periodic Table of the Elements

metal

metalloid

non-metal

Atomic Number → 22 (ion charge(s) 4+ 3+)
Symbol → Ti
Name → Titanium
Atomic Mass → 47.9

O natural

Db synthetic

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	1 1+ **H** Hydrogen 1.0																	2 0 **He** Helium 4.0
2	3 1+ **Li** Lithium 6.9	4 2+ **Be** Beryllium 9.0											5 **B** Boron 10.8	6 **C** Carbon 12.0	7 3– **N** Nitrogen 14.0	8 2– **O** Oxygen 16.0	9 1– **F** Fluorine 19.0	10 0 **Ne** Neon 20.2
3	11 1+ **Na** Sodium 23.0	12 2+ **Mg** Magnesium 24.3											13 3+ **Al** Aluminum 27.0	14 **Si** Silicon 28.1	15 3– **P** Phosphorus 31.0	16 2– **S** Sulfur 32.1	17 1– **Cl** Chlorine 35.5	18 0 **Ar** Argon 39.9
4	19 1+ **K** Potassium 39.1	20 2+ **Ca** Calcium 40.1	21 3+ **Sc** Scandium 45.0	22 4+ 3+ **Ti** Titanium 47.9	23 5+ 4+ **V** Vanadium 50.9	24 3+ 2+ **Cr** Chromium 52.0	25 2+ 3+ 4+ **Mn** Manganese 54.9	26 3+ 2+ **Fe** Iron 55.8	27 2+ 3+ **Co** Cobalt 58.9	28 2+ 3+ **Ni** Nickel 58.7	29 2+ 1+ **Cu** Copper 63.5	30 2+ **Zn** Zinc 65.4	31 3+ **Ga** Gallium 69.7	32 4+ **Ge** Germanium 72.6	33 3– **As** Arsenic 74.9	34 2– **Se** Selenium 79.0	35 1– **Br** Bromine 79.9	36 0 **Kr** Krypton 83.8
5	37 1+ **Rb** Rubidium 85.5	38 2+ **Sr** Strontium 87.6	39 3+ **Y** Yttrium 88.9	40 4+ **Zr** Zirconium 91.2	41 3+ 5+ **Nb** Niobium 92.9	42 2+ 3+ **Mo** Molybdenum 95.9	43 7+ **Tc** Technetium (98)	44 3+ 4+ **Ru** Ruthenium 101.1	45 3+ 4+ **Rh** Rhodium 102.9	46 2+ 4+ **Pd** Palladium 106.4	47 1+ **Ag** Silver 107.9	48 2+ **Cd** Cadmium 112.4	49 3+ **In** Indium 114.8	50 4+ 2+ **Sn** Tin 118.7	51 3+ 5+ **Sb** Antimony 121.8	52 2– **Te** Tellurium 127.6	53 1– **I** Iodine 126.9	54 0 **Xe** Xenon 131.3
6	55 1+ **Cs** Cesium 132.9	56 2+ **Ba** Barium 137.3	57 3+ **La** Lanthanum 138.9	72 4+ **Hf** Hafnium 178.5	73 5+ **Ta** Tantalum 180.9	74 6+ **W** Tungsten 183.8	75 4+ 7+ **Re** Rhenium 186.2	76 3+ 4+ **Os** Osmium 190.2	77 3+ 4+ **Ir** Iridium 192.2	78 4+ 2+ **Pt** Platinum 195.1	79 3+ 1+ **Au** Gold 197.0	80 2+ 1+ **Hg** Mercury 200.6	81 1+ 3+ **Tl** Thallium 204.4	82 2+ 4+ **Pb** Lead 207.2	83 3+ 5+ **Bi** Bismuth 209.0	84 2+ 4+ **Po** Polonium (209)	85 1– **At** Astatine (210)	86 0 **Rn** Radon (222)
7	87 1+ **Fr** Francium (223)	88 2+ **Ra** Radium (226)	89 3+ **Ac** Actinium (227)	104 **Rf** Rutherfordium (261)	105 **Db** Dubnium (262)	106 **Sg** Seaborgium (263)	107 **Bh** Bohrium (262)	108 **Hs** Hassium (265)	109 **Mt** Meitnerium (266)	110 **Ds** Darmstadtium (281)	111 **Rg** Roentgenium (272)	112 **Uub*** Ununbium (285)	113 **Uut*** Ununtrium (284)	114 **Uuq*** Ununquadium (289)	115 **Uup*** Ununpentium (288)	116 **Uuh*** Ununhexium (292)		118 **Uuo*** Ununoctium (294)

* Temporary names

58 3+ 4+ **Ce** Cerium 140.1	59 3+ 4+ **Pr** Praseodymium 140.9	60 3+ **Nd** Neodymium 144.2	61 3+ **Pm** Promethium (145)	62 3+ 4+ **Sm** Samarium 150.4	63 3+ 2+ **Eu** Europium 152.0	64 3+ **Gd** Gadolinium 157.3	65 3+ 4+ **Tb** Terbium 158.9	66 3+ **Dy** Dysprosium 162.5	67 3+ **Ho** Holmium 164.9	68 3+ **Er** Erbium 167.3	69 3+ 2+ **Tm** Thulium 168.9	70 3+ 2+ **Yb** Ytterbium 173.0	71 3+ **Lu** Lutetium 175.0
90 4+ **Th** Thorium 232.0	91 5+ 4+ **Pa** Protactinium 231.0	92 6+ 4+ 5+ **U** Uranium 238.0	93 5+ 3+ 4+ 6+ **Np** Neptunium (237)	94 4+ 6+ 3+ 5+ **Pu** Plutonium (244)	95 3+ 4+ 5+ 6+ **Am** Americium (243)	96 3+ **Cm** Curium (247)	97 3+ 4+ **Bk** Berkelium (247)	98 3+ **Cf** Californium (251)	99 3+ **Es** Einsteinium (252)	100 3+ **Fm** Fermium (257)	101 2+ 3+ **Md** Mendelevium (258)	102 2+ 3+ **No** Nobelium (259)	103 3+ **Lr** Lawrencium (262)

Based on mass of C-12 at 12.00.

Any value in parentheses is the mass of the most stable or best known isotope for elements that do not occur naturally.