Science Skills Guide

Safety

Safety Symbols

The following safety symbols are used in ***BC Science 9*** to alert you to possible dangers. Be sure you understand each symbol used in an activity or investigation before you begin.

	Disposal Alert This symbol appears when care must be taken to dispose of materials properly.
	Thermal Safety This symbol appears as a reminder to use caution when handling hot objects.
	Sharp Object Safety This symbol appears when a danger of cuts or punctures caused by the use of sharp objects exists.
	Electrical Safety This symbol appears when care should be taken when using electrical equipment.
	Skin Protection Safety This symbol appears when use of caustic chemicals might irritate the skin or when contact with micro-organisms might transmit infection.
	Clothing Protection Safety A lab apron should be worn when this symbol appears.
	Fire Safety This symbol appears when care should be taken around open flames.
	Eye Safety This symbol appears when a danger to the eyes exists. Safety goggles should be worn when this symbol appears.

Instant Practice—Safety Symbols

Describe the safety symbols you might see in the following areas and why they would be there:

- technical arts room
- home economics room
- cafeteria
- your kitchen
- garage or storage shed

WHMIS Symbols

Look carefully at the WHMIS (Workplace Hazardous Materials Information System) safety symbols shown here. The WHMIS symbols are used throughout Canada to identify dangerous materials. Make certain you understand what these symbols mean. When you see these symbols on containers, use safety precautions.

Compressed Gas	Flammable and Combustible Material
Oxidizing Material	Corrosive Material
Poisonous and Infectious Material Causing Immediate and Serious Toxic Effects	Poisonous and Infectious Material Causing Other Toxic Effects
Biohazardous Infectious Material	Dangerously Reactive Material

Instant Practice—WHMIS Symbols

Methyl alcohol is both flammable and poisonous.

1. Draw the two symbols that are on its label.
2. Describe (a) the risks illustrated by the symbols, (b) precautions that you would take when working with the material, (c) where you might store it so that it is safe, and (d) first aid or emergency treatment.
3. If you did not know the answer to (d), where would you find this information?

Science Skill 2

Scientific Inquiry

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

Making Observations

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.

You probably already know that evaporation is the reason that the puddles are disappearing, but there are still lots of questions you can ask about evaporation. Although the two puddles were the same size, one 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 a question to ask: Does water always evaporate more quickly in the Sun than in the shade?

Beginning your observations of water puddles

Concluding your observations of water puddles

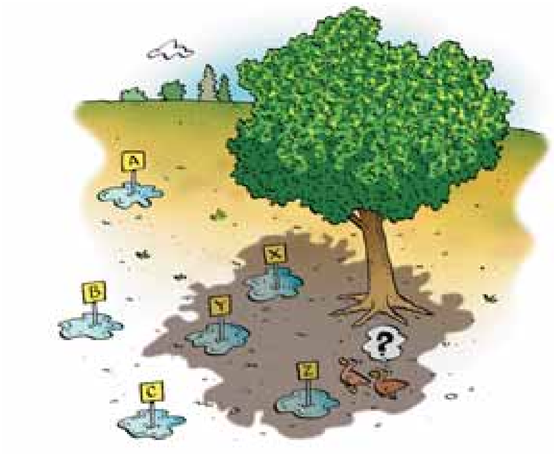
Instant Practice—Making Qualitative and Quantitative Observations

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

1. (a) The bowling ball is heavier than the basketball.
   (b) The red ball weighs 5 g more than the blue ball.
2. (a) The temperature increased by several degrees.
   (b) The temperature increased by 2°C.
3. (a) The water was lukewarm.
   (b) The water was cooler than the oil.
4. (a) The colour changed from blue to green.
   (b) The sound became louder as the vibrations increased.
5. (a) The second light bulb was the brightest.
   (b) The 60 W bulb was brighter than the 40 W bulb.
6. (a) The flight lasted nine minutes.
   (b) The flight lasted 2 h.

Stating an Hypothesis

Now you are ready to make an **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: Evaporation from natural pools of water is faster for pools in sunlight than for pools in shade.



Instant Practice—Stating an Hypothesis

Write an 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 studying and your score on quizzes
2. The relationship between types of atmospheric gases and global warming
3. Do batteries last the same amount of time in different devices?
4. Does the colour of flowers influence honeybee visitations?

Making a Prediction

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

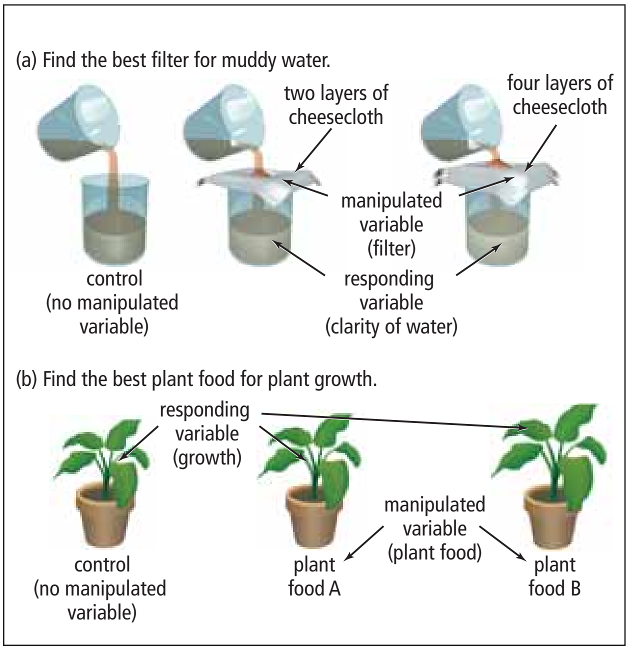
Identifying Variables

"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 **manipulated variable**. In this case, the manipulated 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 **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 manipulated variable does indeed cause a change. Look at the illustrations on the next page to see some examples of variables.



Designing 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.

Instant Practice—Identifying Variables

For each of the following questions, state your control, your manipulated variable, and your responding variable.

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

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 Skill 8** gives you more information on using models.

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 keep 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. An 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.

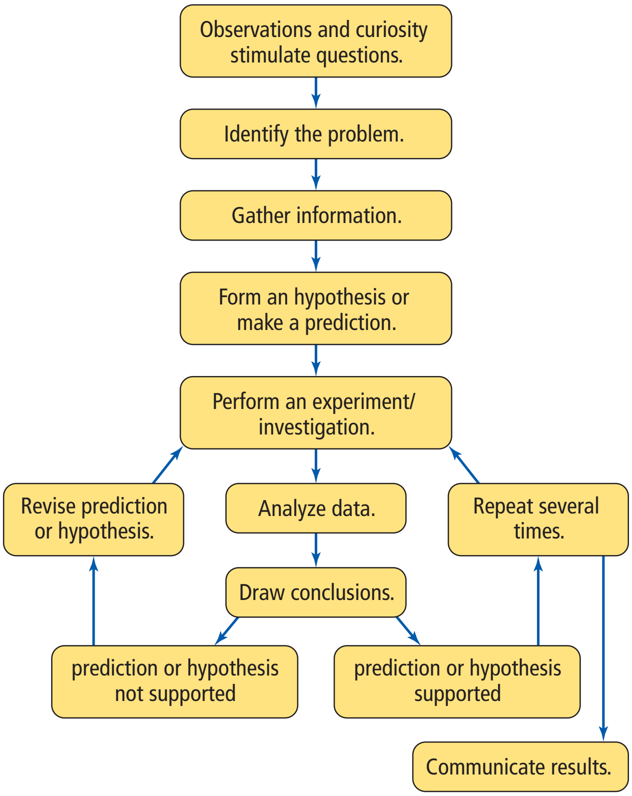
Scientists often set up experiments without knowing what will happen. Sometimes they deliberately set out to prove that something will not happen.

Eventually, when an hypothesis has been thoroughly tested and nearly all scientists agree that the results support the hypothesis, it becomes a **theory**.

A Process for Scientific Inquiry

One model of the scientific inquiry process is shown in the concept map below.

The Scientific Inquiry Process



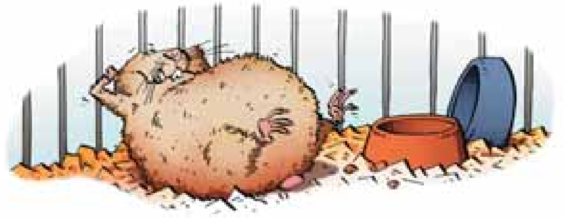
Technological Problem Solving

"Technology"—what does that word make you think of? Do you think of complicated electronic equipment? Do you think of the latest-model cars? Do you think of space exploration? Well, all of those have to do with technology, but think about this: 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?

These, too, are examples of technology. **Technology** is the use of scientific knowledge, as well as everyday experience, to solve practical problems. 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.

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 kinds of 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. Device must feed and water the hamster.
2. Hamster must be thriving at the end of the three-day period.
3. 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 good ideas. Like all other scientists, though, you will want to make use of 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 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.

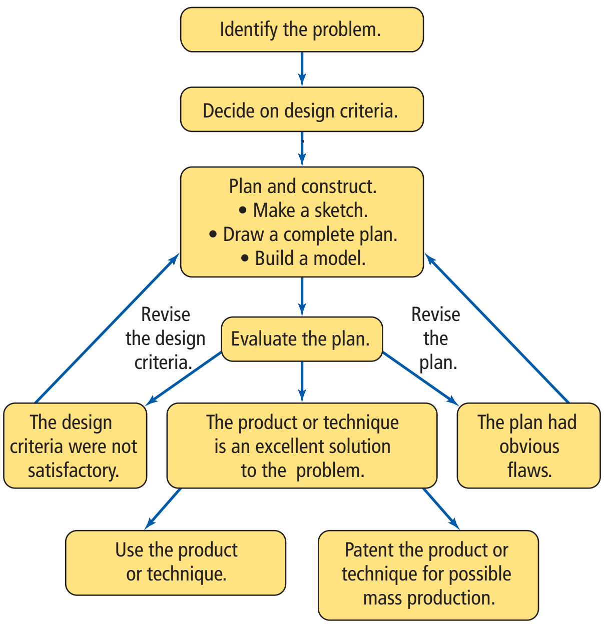
Evaluating

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 used and why they work better than (or not as well as) yours. What would you do differently if you were to redesign your device?

A Process for Technological Problem Solving

The problem-solving model you have just used is shown here.

Solving a Technological Problem



Societal Decision Making

Suppose you are part of a hockey team that practises at an arena in a town a few kilometres away. Every winter, there are days when you cannot get to the arena because the roads are too icy. The town council is in the middle of budget discussions, and one of the items under discussion is the salting of roads. The council is prepared to expand the salting program so that roads in your area will be salted in winter. You and your teammates are delighted. This will make your trip to the arena easier—and always possible.

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. You are surprised, but as you begin discussing the letter, you start to see your friend's point of view.

"What do you mean, damage the environment?" you ask. "Isn't it important to make our roads safer?"

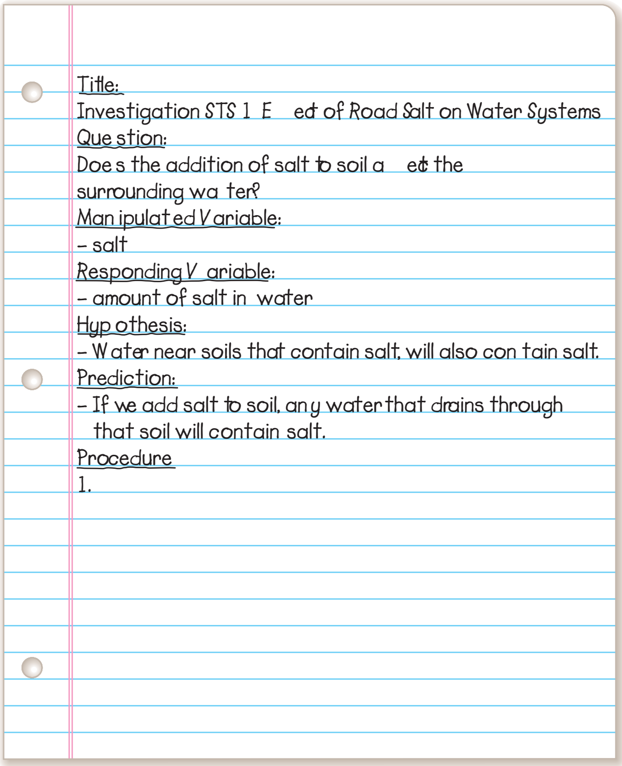
Gathering Information

"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 us see what we can find out from the Internet."

After researching you say, "Well, we found a lot of information, but I am still not completely convinced that salting the roads could cause a problem with our water. What sorts of things do we need to find out in order to answer that question?"

"We could do an investigation," your friend suggests. "Then I could use the results in my letter to the town council."



Identifying Alternatives

"I guess road salt does get into the water system," you admit after completing your investigation. "But we added quite a lot of salt. I wonder if any salt stays in the soil—maybe we could add less salt so that much less would get into the water, and our roads would still be safe for driving."

"Let us do some more research in the library and on the Internet, and see if we can find out how salt leaches through soil. Maybe we can also see what alternatives there are. We could look for something about using less salt on the roads—or even no salt."

Making a Decision

When you have all of the data that your scientific studies 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 your scientific data 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.

After all the data are in, and after all the persuading is done, it is time to take some action. The seemingly small actions done by you and your friends can have a snowball effect. You are very keen to show your sense of responsibility and community spirit by getting your ideas across to town council when one of your friends makes you stop and think. "I have noticed you putting a lot of salt out on your sidewalk," says your friend. "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?

Evaluating the Decision

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 town council. As a compromise, you might suggest a combination of salt and sand on the roads. Your scientific study 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.

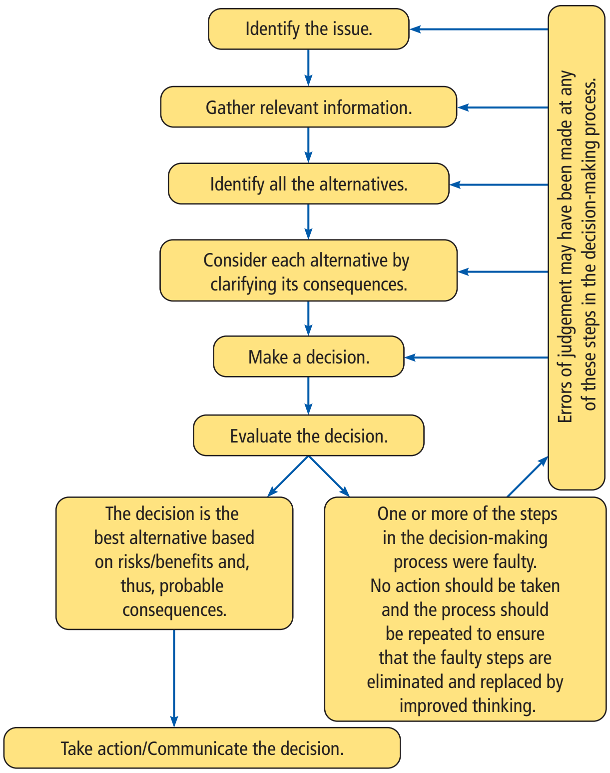
Over time, you can assess the effects of your actions: Are there fewer accidents on the salted/sanded roads? Does less salt end up in the water than when more salt alone is used?

A Process for Societal Decision Making

As you reached your decision, you went through various stages. Now you can think about how well each stage worked and how well you feel you completed each stage.

Examine the flowchart below. You can see that you used every step in this process. As with scientific inquiry and technological problem solving, having a process to use helps you to focus your thinking and stay on track.

A Process for Societal Decision Making



Instant Practice—Making Societal Decisions

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

1. Start by dividing your group into two pairs.
2. One pair will brainstorm and record the advantages of fossil fuel use and how it has affected members of our society in a positive way.
3. The second pair will brainstorm and record the disadvantages of fossil fuel use along with its negative impacts on society.
4. The pairs will then regroup, and both sides can present their findings. Record key points on a chart for comparison.
5. Determine which pair has the more convincing evidence for its view of the use of fossil fuels.
6. As a group, brainstorm alternative energy sources, including advantages and disadvantages of each. Determine the best alternative, based on the information you have brainstormed in steps 2 and 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 it. You can use line graphs, bar graphs, and circle graphs (pie charts).

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. To find out if more recycling bins would encourage students to recycle cans and bottles, you place temporary recycling bins at three other locations in the school. Assume that, in a follow-up survey, you obtained 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.

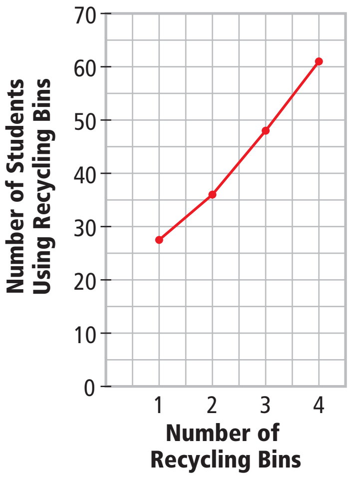
Table 1 Students Using Recycling Bins

Number of Bins	Number of Students Using Recycling Bins
1	28
2	36
3	48
4	62

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 until you have plotted all of the data for the four bins. Now, draw a line from one dot to the next.

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?



Instant Practice—Line Graphs

The level of ozone in the 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 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

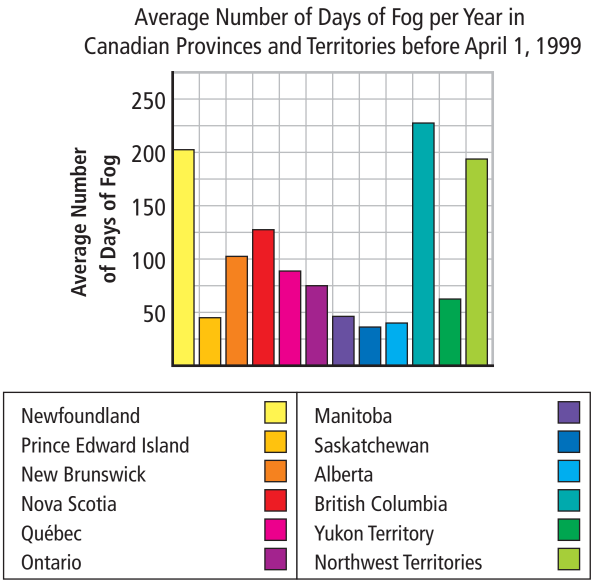
Bar graphs help you to compare a numerical quantity with some other category at a glance. The second category may or may not be a numerical quantity. It could be places, items, organisms, or groups, for example.

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 number of days of fog recorded during one year at one weather station in each of the provinces and territories.

Table 3 Average Number of Days of Fog per Year in Canadian Provinces and Territories (prior to April 1, 1999)

Province	Number of Days of Fog
Newfoundland	206
Prince Edward Island	47
New Brunswick	106
Nova Scotia	127
Québec	85
Ontario	76
Manitoba	48
Saskatchewan	37
Alberta	39
British Columbia	226
Yukon Territory	61
Northwest Territories	196



Procedure

1. Draw your *x*-axis and *y*-axis on a sheet of graph paper. Label the *x*-axis with the names of the provinces and territories and the *y*-axis with the average number of days of fog.
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 Newfoundland and 206 as the first pair of data, move along the *x*-axis the width of your first bar, then go up the *y*-axis to 206. 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, you might want to colour them so that each one stands out. If you have no colours, you could use cross-hatching, dots, or diagonal lines to distinguish one bar from another.
6. If you are comparing two or more manipulated variables that you have plotted on the *x*-axis, 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 Graphs

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	1.20

Constructing a Circle Graph

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

Example

To learn how to make a circle graph from the data in Table 5, study the corresponding circle 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 degrees in the section that represents each type of bird, use the following formula.

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

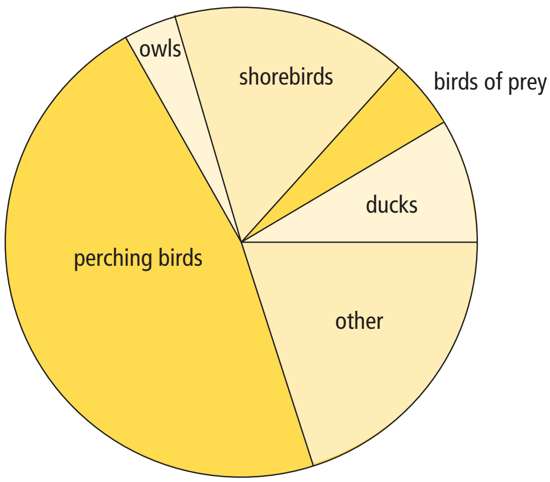
Round your answer to the nearest whole number. For example, the section for ducks is:

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

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—Circle Graph

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

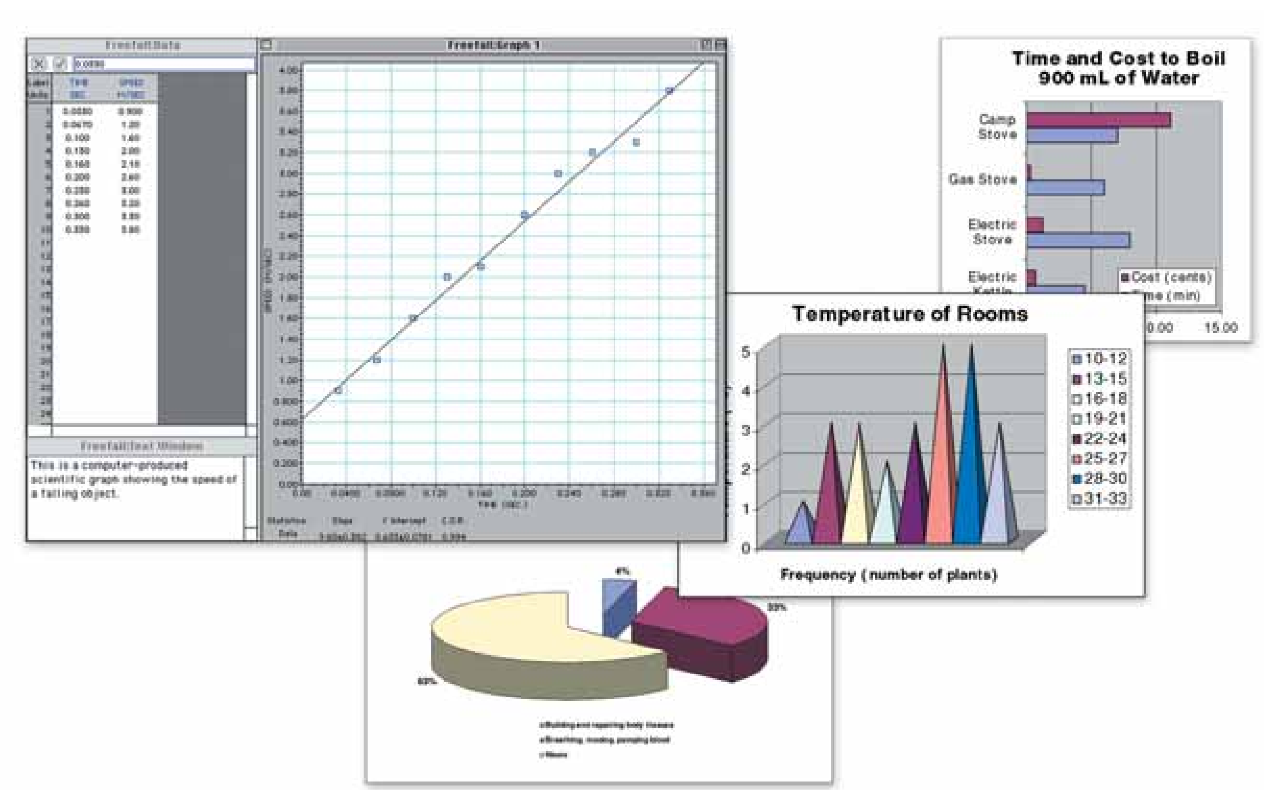
Table 6 World Energy Consumption in 2004

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

Graphing on a Computer

Computers are a useful tool for graph preparation for the following reasons.

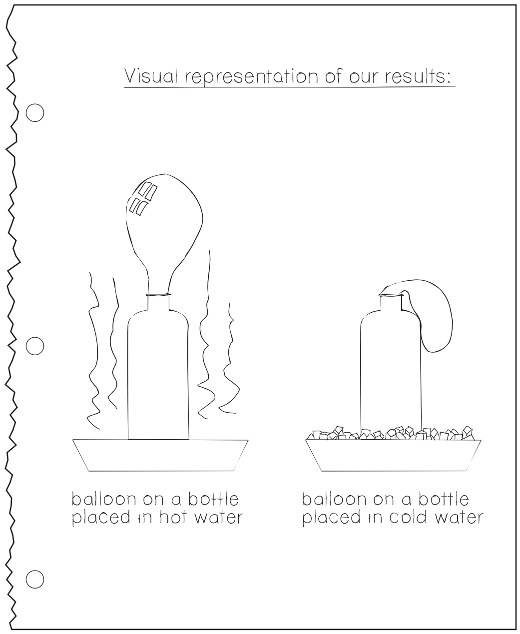
1. Data need only be entered once. As many graphs as you need can then be prepared without any more data entry.
2. Once the data are entered, you can use the computer to manipulate them. You can change the scale, zoom in on important parts of the graph, graph different parts of the data in different ways, and so on—all without doing any calculations!
3. Computers prepare graphs far more quickly than people working carefully.
4. Computers can be hooked up to sensors (thermometers, timers, etc.), so you do not need to read instruments and enter data by hand, with all the resulting possibilities for error. The computer can display the readings on a graph as data are collected (in "real" time), so you can quickly get a picture of how your experiment is going.
5. Errors can be corrected much more easily when working with a computer. Just correct the error and print again.
6. Computer graphs can be easily inserted into written lab reports, magazine articles, or Internet pages. It is possible to scan hand-drawn graphs into a computer, but it is not easy to do it well, and the resulting files are very large.
7. Once data have been entered into a computer, the computer can determine a line of best fit and a mathematical equation that describes the line. This line can help you to discover patterns in your data and make predictions to test your inferences.



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.

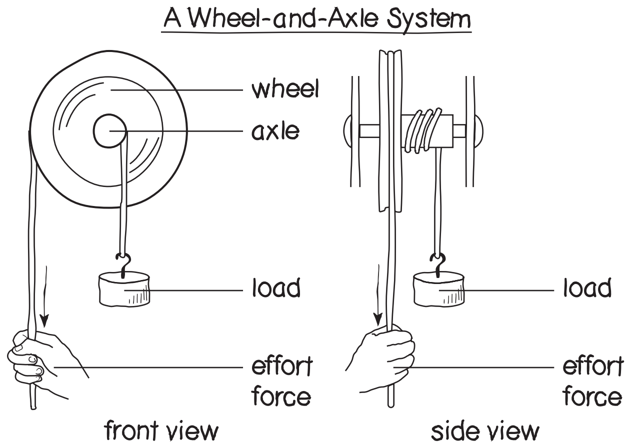
Examine the drawing shown below. It is taken from a student's lab report on an experiment to test the expansion of air in a balloon. The student's written description of results included an explanation of how the particle model can explain what happens to the balloon when the bottle is placed in hot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



Making a Scientific Drawing

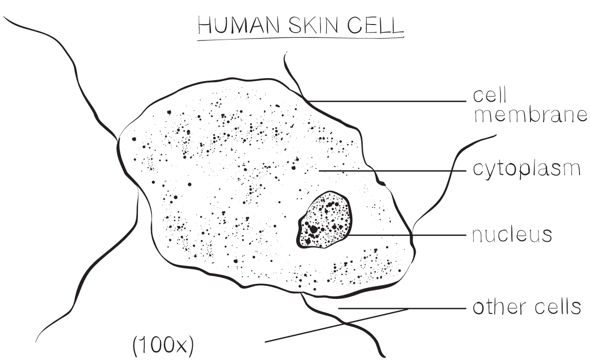
Follow these steps to make a good scientific drawing.

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 you observed. 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.

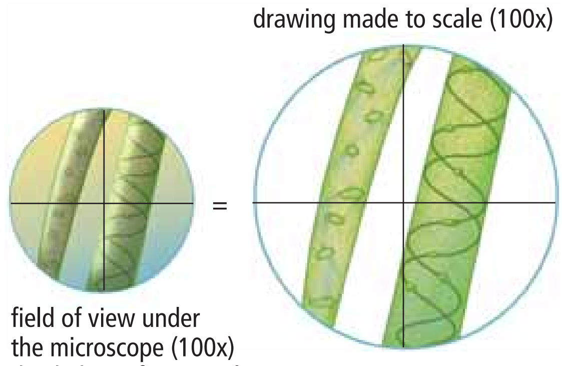


The stippling on this drawing of a human skin cell shows that some areas are darker than others.

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 here.
3. Using low or medium power, locate an object under the microscope. Imagine that the field of view is also divided into four equal sections.
4. Observe how much of the field of view is taken up by the object. Note the location of the object in the field of view.
5. Draw the object in the circle. Position the object in about the same part of the circle as it appears in the field of view. Draw the object so that it takes up about the same amount of space within the circle as it takes up in the field of view, as shown in the diagram.



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

Estimating and Measuring

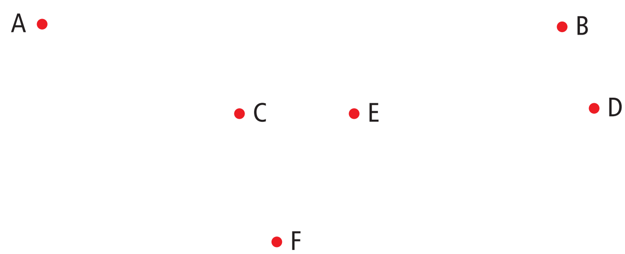
Estimating

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

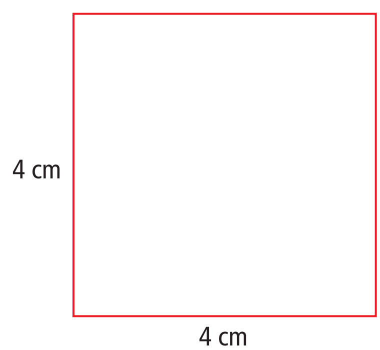
Scientists often make estimates when exact measurements are not essential. You will find it useful to be able to estimate as accurately as possible, too. For example, suppose you wanted to know how many ants live in a local park. Counting every ant would be very time-consuming—and the ants would be most unlikely to stay in one spot for your convenience! What you can do is count the number of ants in a typical square-metre area. 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

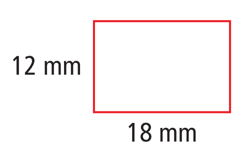
You can use a metre stick or a ruler to measure short distances. These tools are usually marked in centimetres and/or millimetres. Use a ruler to measure the length in millimetres between points A and F, C and E, F and B, and A and D. Convert your measurements to centimetres and then to metres.



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 $4\ \text{cm} \times 4\ \text{cm} = 16\ \text{cm}^2$.



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

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

Instant Practice—Estimating and Measuring

Imagine that all rulers within 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 your partner's estimates.
2. Measure the length and width of your textbook with your toothpick. How close was your estimate to the actual measurement?
3. Estimate the length and width of your desk in toothpick units. Compare your estimates with your partner's estimates.
4. Measure the length and width of your desk with your toothpick. How close was your estimate to the actual measurement?
5. 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? (Be creative!)
6. What is your estimate of the number of units you chose in (question 5) 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. A cubic metre is the space occupied by a $1 \text{ m} \times 1 \text{ m} \times 1 \text{ m}$ cube. This unit of volume is used to measure large quantities, such as the volume of concrete in a building. In this course, you are more likely to use cubic centimetres (cm^3) or cubic millimetres (mm^3) to record the volume of an object.

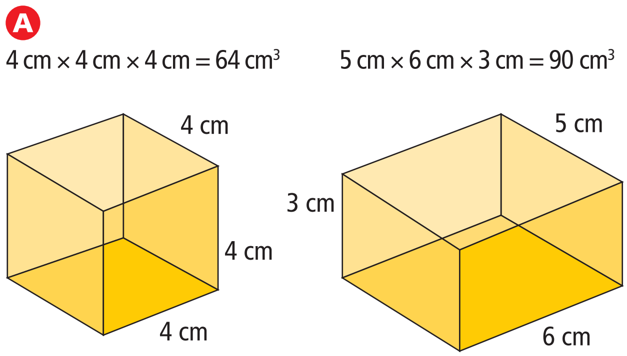
You can calculate the volume of a cube by multiplying its sides. For example, volume $= 1 \text{ cm} \times 1 \text{ cm} \times 1 \text{ cm} = 1 \text{ cm}^3$.

You can calculate the volume of a rectangular solid if you know its length, width, and height.

$$\text{volume} = \text{length} \times \text{width} \times \text{height}$$

If all the sides 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.

As you can see in Diagram A, the volume of a regularly shaped solid object can be measured directly.



Measuring the volume of a regularly shaped solid

The units used to measure the volume of liquids are called capacity units. The basic unit of volume for liquids is the litre (L). In this course, you also measure volume using millilitres (mL). Recall that 1 L = 1000 mL. You have probably seen capacity in litres and millilitres printed on juice, milk, and soft drink containers.

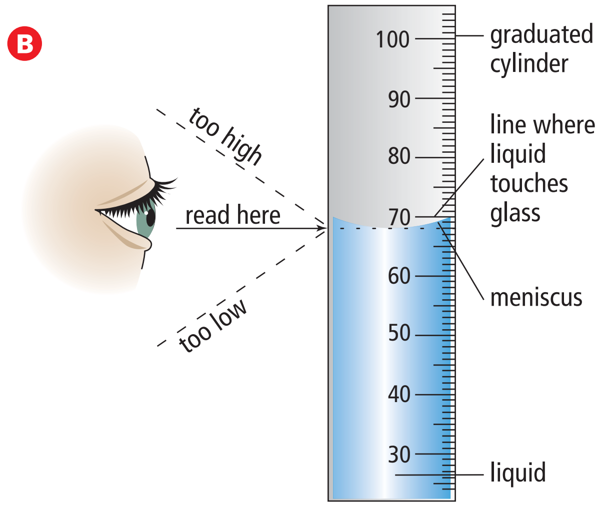
Cubic units and capacity units are interchangeable. For example:

$1\ cm^3 = 1\ mL$

$1\ dm^3 = 1\ L$

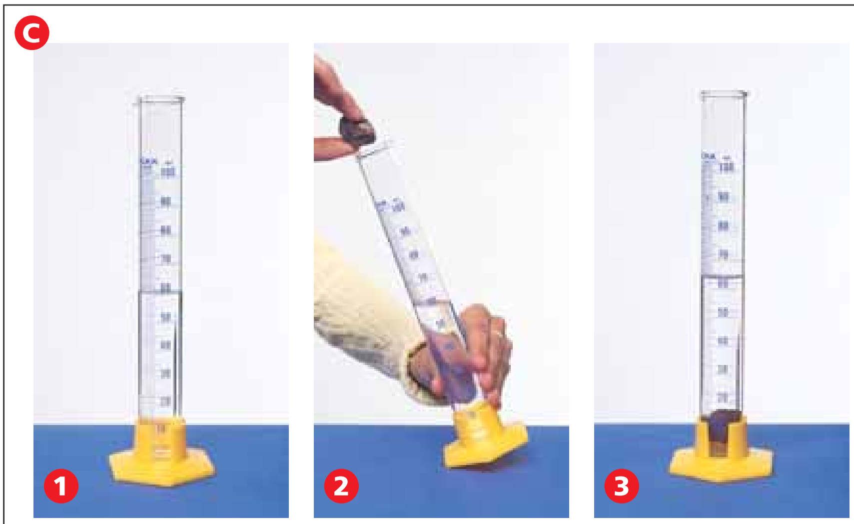
$1\ m^3 = 1\ kL$

The volume of a liquid can be measured directly, as shown in Diagram B. 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. This is done by determining the volume of a liquid it will displace.



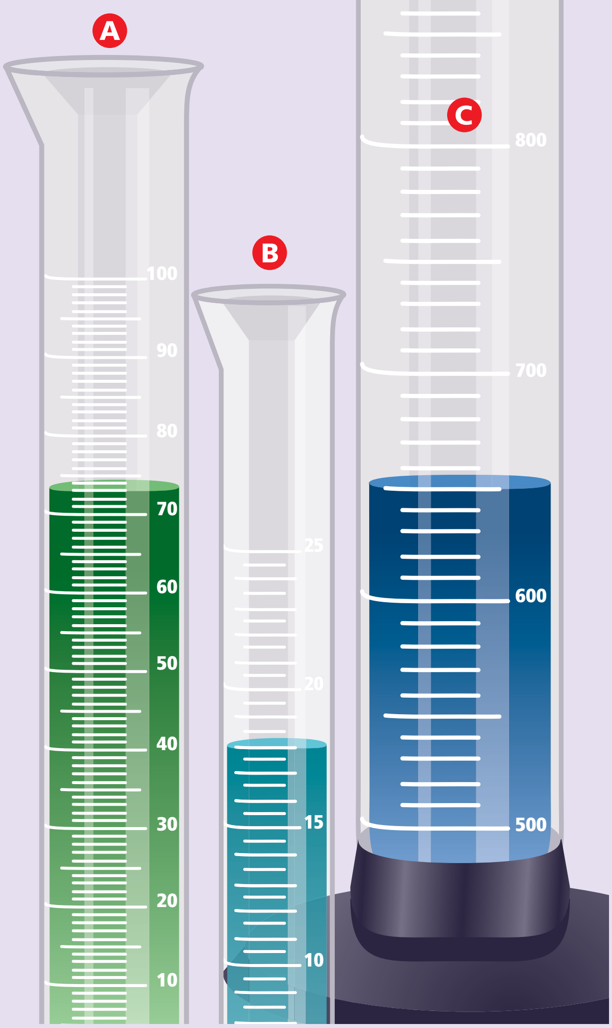
1. Record the volume of the liquid.
2. Carefully lower the object into the cylinder containing the liquid. Record the volume again.
3. The volume of the object is equal to the difference between the two volumes of the liquid. The equation below the photograph shows you how to calculate this.

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 following graduated cylinders.



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, such as a triple beam balance, for measuring mass.

Use the following steps to measure the mass of a solid object.

1. Set the balance to zero. Do this by sliding all three riders back to their zero points. Using the adjusting screw, make sure the pointer swings an equal amount above and below the zero point at the far end of the balance.
2. Place the object on the pan. Observe what happens to the pointer.
3. Slide the largest rider along until the pointer is just below zero. Then move it back one notch.
4. Repeat with the middle rider and then with the smallest rider. Adjust the last rider until the pointer swings equally above and below zero again.
5. Add the readings on the three scales to find the mass.

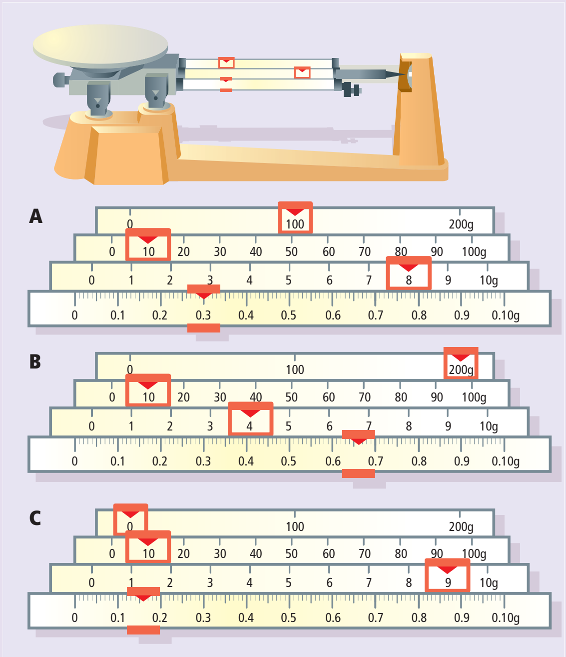
How can you find the mass of a certain quantity of a substance, such as table salt, that you have added to a beaker? First, find the mass of the beaker. Next, pour the salt into the beaker and find the mass of the beaker and salt together. To find the mass of the salt, simply subtract the beaker's mass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

The mass of the beaker is 160 g.

The mass of the table salt and beaker together is 230 g. Therefore, the mass of the salt is 70 g.

Instant Practice—Measuring Mass

Determine the masses represented on the following centigram balances.



Measuring Angles

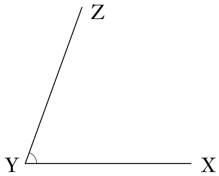
You can use a protractor to measure angles. Protractors usually have an inner scale and an outer scale. The scale you use depends on how you place the protractor on an angle (symbol =∠). Look at the following examples to learn how to use a protractor.

Example 1

What is the measure of ∠XYZ?

Solution

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



Example 2

Draw ∠ABC = 155°.

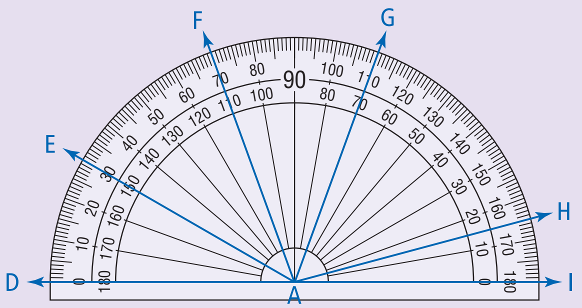
Solution

First, draw a straight line, AB. Place the centre of the protractor on B and line up AB with 0° on the inner scale. Mark C at 155° on the inner 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 (i) ∠FAG



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

(a) ABC 50° (c) XYZ 5° (e) HAL 90°
(b) QRS 85° (d) JKL 45°

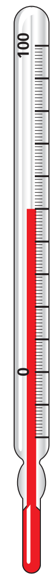
Measuring Temperature

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.

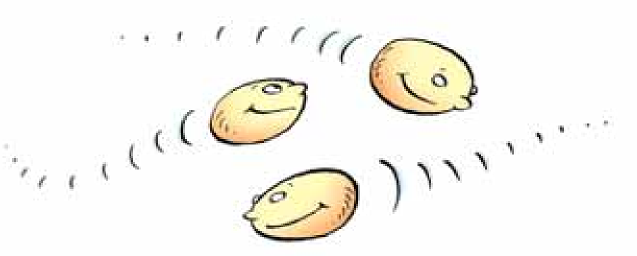
Using Models in Science

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 communicate their ideas to other scientists or to students. They also 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 models in the illustrations on this page. How can these models 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.



The particles shown here are models representing the atoms and molecules of a gas.

Instant Practice—Using Models

Models are used outside of the science laboratory as well as inside of it. How does using models help each of the following professions in their work?

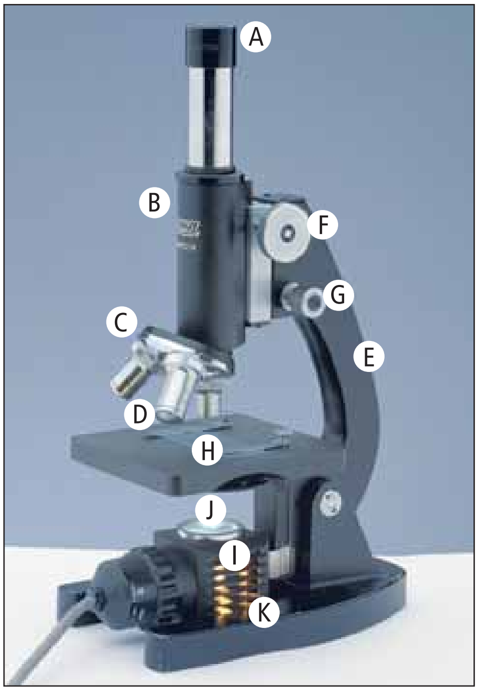
(a) architects
(b) aviation engineers
(c) theatre directors
(d) geographers
(e) landscape designers

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 Skill* 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×, 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.

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

G. Fine focus knob
Use the fine focus 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.

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.

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

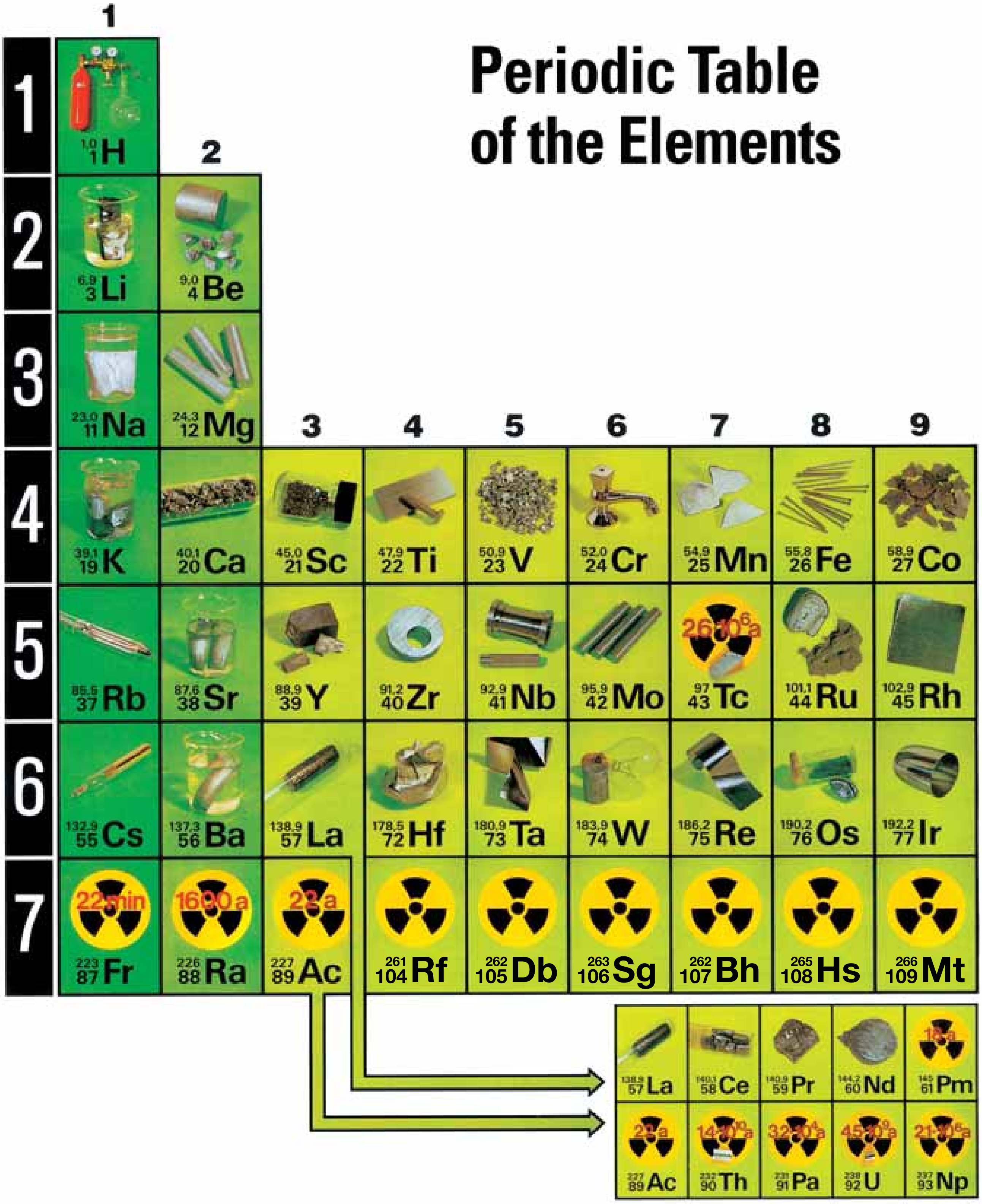
A common problem when working with microscopic specimens is that it may be difficult to observe structures clearly. You can use various stains to colour the structures that you want to see. Common stains used for biological specimens are:

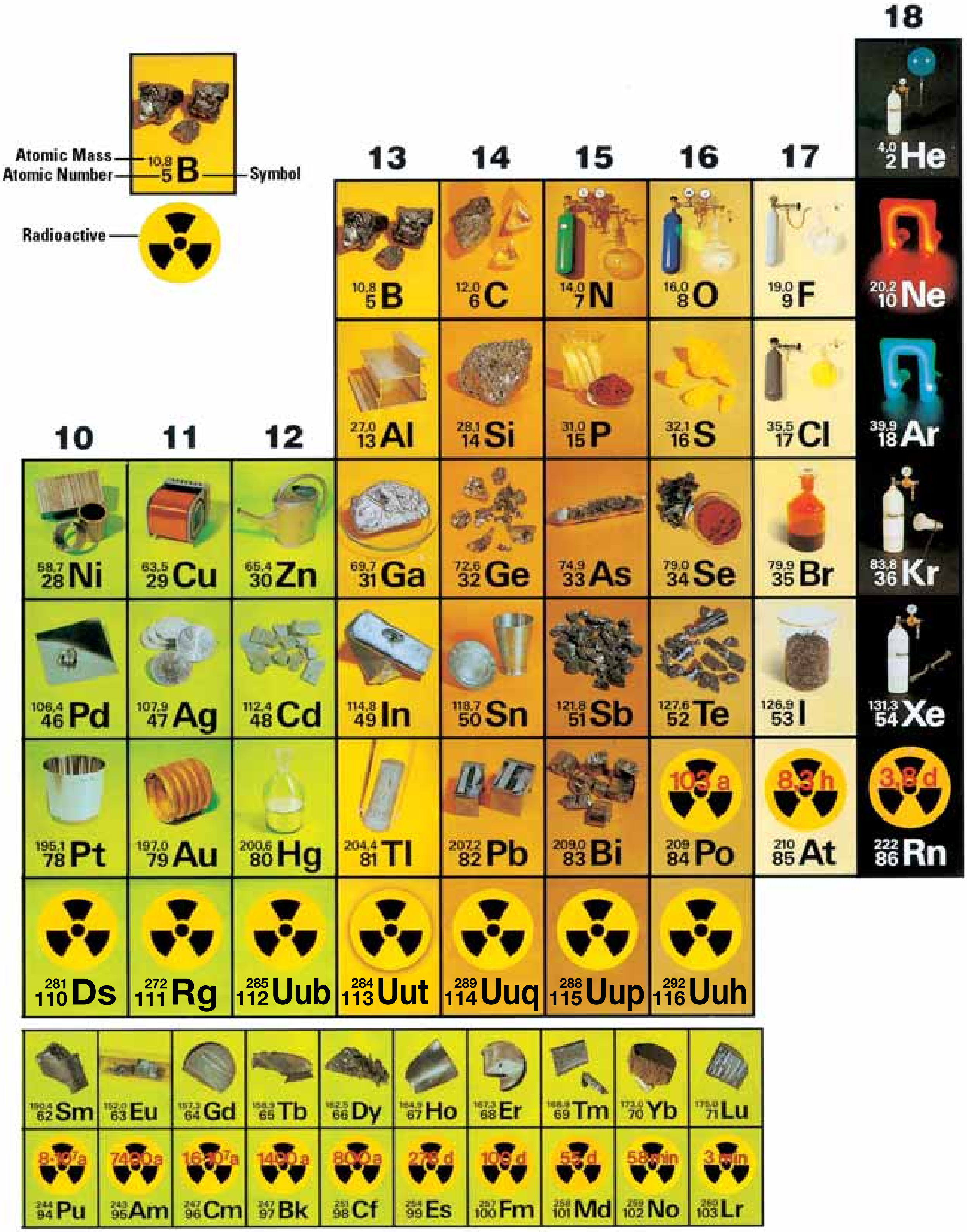
- Iodine—for staining starch
- Crystal violet—for staining bacterial cell walls
- Methylene blue—for observing nuclei in cheek cells

Suppose 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 and place them in a small amount of 1 M HCl for a few minutes to stop mitosis. **Warning:** HCl is a strong acid. Follow 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 1% toluidine blue to the root tip section. Leave the stain on for several minutes.
5. Blot off the extra stain with a paper towel. Add a few drops of water to the section to remove extra stain. Blot off. 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, edge first, and lower it carefully over your specimen.
7. If the section is too thick, carefully apply gentle pressure to flatten the section.
8. Place the slide on your microscope, and use the low power for your first observation.

Periodic Table of the Elements





Atomic Mass
Atomic Number
Symbol
10,8 5 B
Radioactive
10
11
12
13
14
15
16
17
18
4,0 2 He
10,8 5 B
12,0 6 C
14,0 7 N
16,0 8 O
19,0 9 F
20,2 10 Ne
27,0 13 Al
28,1 14 Si
31,0 15 P
32,1 16 S
35,5 17 Cl
39,9 18 Ar
58,7 28 Ni
63,5 29 Cu
65,4 30 Zn
69,7 31 Ga
72,6 32 Ge
74,9 33 As
79,0 34 Se
79,9 35 Br
83,8 36 Kr
106,4 46 Pd
107,9 47 Ag
112,4 48 Cd
114,8 49 In
118,7 50 Sn
121,8 51 Sb
127,6 52 Te
126,9 53 I
131,3 54 Xe
195,1 78 Pt
197,0 79 Au
200,6 80 Hg
204,4 81 Tl
207,2 82 Pb
209,0 83 Bi
103 a
209 84 Po
8,3 h
210 85 At
3,8 d
222 86 Rn
281 110 Ds
272 111 Rg
285 112 Uub
284 113 Uut
289 114 Uuq
288 115 Uup
292 116 Uuh
150,4 62 Sm
152,0 63 Eu
157,3 64 Gd
158,9 65 Tb
162,5 66 Dy
164,9 67 Ho
167,3 68 Er
168,9 69 Tm
173,0 70 Yb
175,0 71 Lu
244 94 Pu
243 95 Am
247 96 Cm
247 97 Bk
251 98 Cf
254 99 Es
257 100 Fm
258 101 Md
259 102 No
260 103 Lr

Names, Formulas and Charges of Some Common Polyatomic Ions

Table 1 Common 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	HCO_3^-
hydrogen sulphate	HSO_4^-
hydrogen sulphide	HS^-
hydrogen sulphite	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-}
sulphate	SO_4^{2-}
sulphite	SO_3^{2-}

Electron Arrangements of the First 20 Elements

Table 2 Electron Arrangements

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

Folding a Round Filter Paper

1. Fold the round pieces of filter paper in half.

2. Crease the fold.

3. Fold the paper in half again and crease it to produce a quarter circle.

4. Separate one outer layer of paper from the other three.

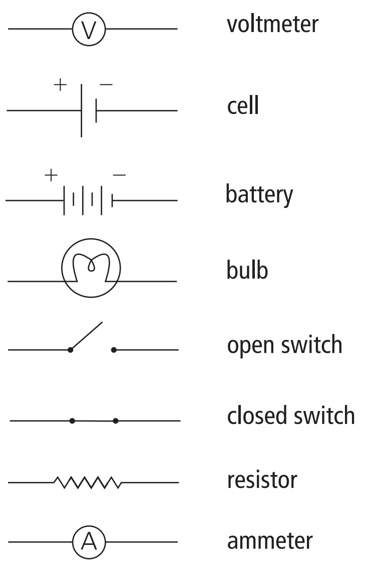
5. Make the opening wider by squeezing slightly together at the creases.

6. Place the cone of filter paper into a funnel and slightly dampen it.

Science Skill 11

Using Electric Circuit Symbols and Meters

Circuit Diagram Symbols



Using Meters to Measure Voltage and Current

Types of Meters

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

A. Digital meters display the numerical values directly.

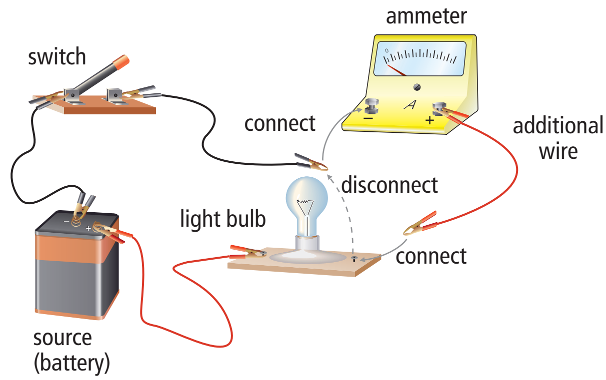
B. Analogue meters have a needle pointing to different scales.

The Terminals of a Meter

All meters have two terminals (connecting points) that you connect to the circuit. The negative terminal (−) is black. The positive terminal (+) is red. In a circuit, conventional current is defined as flowing from positive to negative. This means that current leaves the positive side of the battery or power supply and returns to the negative. In order not to damage the meter, you must take care to connect the meters so that the positive (red) terminal of the meter is connected to the positive side of the power source. That is, if you trace the current leaving the source it should enter the meter through its positive (+) terminal. The negative (−) terminal of the meter is always connected to the negative side of the source. The rule is "positive to positive, and negative to negative."

Connecting an Ammeter

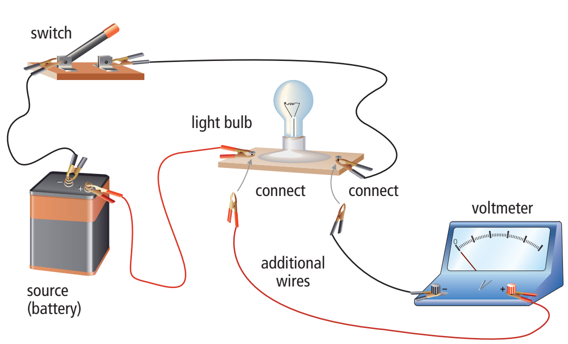
An **ammeter** is used to measure the electric current in a circuit. Electric current is the amount of charge passing a given point per second. To measure the current at a given location in an electric circuit, the ammeter must be connected so that all the current is allowed to pass through the ammeter. To do this, you must disconnect the circuit at the location where you wish to measure the current. Then insert the ammeter so that current leaving the power source enters the positive (red) terminal of the ammeter and leaves from the negative (black) terminal.



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

Connecting a Voltmeter

A **voltmeter** is a device used to measure electric potential difference, or voltage as it is more commonly called. A voltage exists between two points in a circuit such as across a battery, light bulb, or resistor. When connecting a voltmeter to a circuit, you do not need to disconnect or open the circuit. Since voltage is measured between two points of potential difference in a circuit, you connect the terminals of the voltmeter at these two points. Two wires from the terminals of the voltmeter are connected to opposite sides of the component where you wish to measure the potential difference. Again, as with the ammeter, the positive terminal of the voltmeter is connected on the positive side of the power source and the negative terminal of the voltmeter is connected on the negative side of the source.



Voltmeters are connected across a component in the circuit.

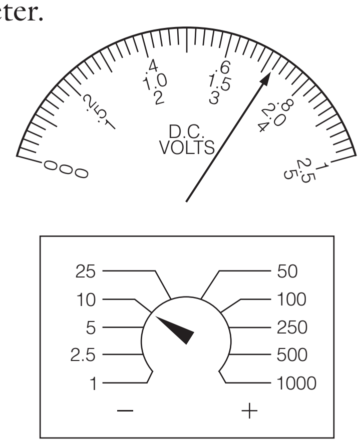
Connecting a Multimeter

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

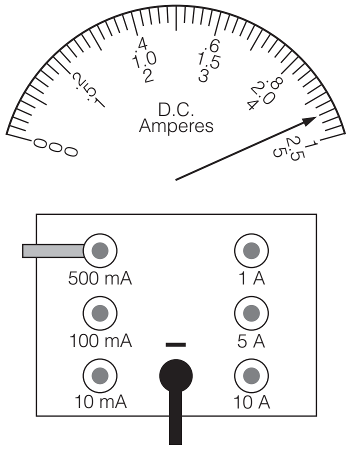
Reading a Meter

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

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



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



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

Instant Practice—Using Circuit Symbols and Electric Meters

1. Sketch the following circuit diagram symbols:
   (a) battery
   (b) light bulb
   (c) resistor
   (d) open switch
   (e) ammeter
   (f) voltmeter

2. State the colour that is associated with:
   (a) the positive terminal of a meter
   (b) the negative terminal of a meter

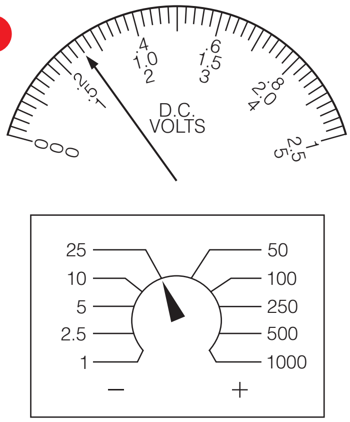
3. When you connect a meter to a circuit, to which side of the power source should you always connect the positive terminal of the meter?

4. For which type of meter do you need to disconnect the circuit before connecting the meter to the circuit?

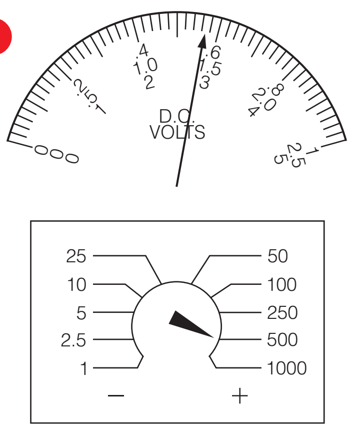
5. A student wishes to use a meter to collect the most accurate measurement without damaging the meter. Describe the correct approach for choosing the appropriate scale.

6. Determine the value of current or voltage indicated by meters A to D in the next column.

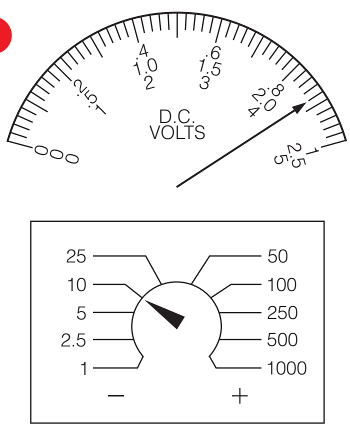
A



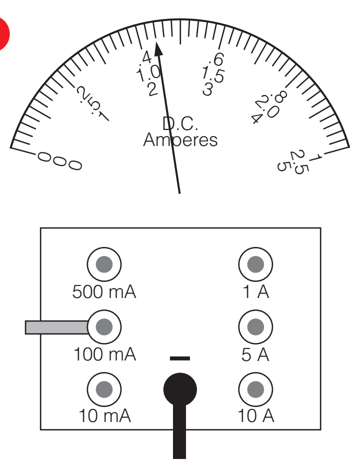
B



C



D



Using Your Textbook as a Study Tool

How can you use your textbook effectively to understand science concepts better? This *Science Skill* will give you strategies to help you better understand what you read. It will also explain how to use textbook visuals and describe different types of graphic organizers that can help you organize your information.

Using Your Textbook to Read for Information

Reading a textbook is different from reading a novel or magazine. A textbook contains many different terms and concepts that you must understand and apply throughout each section. Here are several strategies to help you record the information.

1. Before reading a section, scan the pages. While you are scanning, look at the pictures and try to predict what you think the section will be about. Try to figure out the definitions for bolded words with the help of the Glossary or from the sentence the bolded word is in.
2. A light brown shaded box at the beginning of each section summarizes the key ideas covered in the section. Read this summary. You may not completely understand everything in the summary at first. When you finish working through the section, reread this summary. If you still do not understand something in the summary, ask your teacher for help.
3. Rewrite the section headings and subheadings as questions. Then look for the answer to each question as you read.
4. When you finish reading the text under a heading or subheading, think about what you have just read. Then write brief notes that explain the key ideas discussed there. Try to do this without looking at the text. After you make your notes, go back to the text you have just read. Add or change anything you have just written to help you understand the text better.
5. As you read each section, you will encounter Reading Checks. You should be able to answer these questions. If you cannot answer them correctly, go back and review the material you just read.

Using Your Textbook Visuals

As you read each page, look at any photographs, illustrations, or graphs that appear on the page. Read the captions and labels that accompany the photographs as well as the titles of graphs. Think about the information each visual provides, and note how it helps you to understand the ideas presented in the text. For example, look closely at the illustration on this page. What information does it convey to you?

Water on Earth moves in an endless water cycle.

Using the Glossary

Notice the terms that are in bold (dark, heavy) type. These terms are important words that you will need in order to understand and write about the information in each topic. Make sure that you understand these terms and how they are used. Each boldfaced term appears in the Glossary at the back of this book.

Using the Review Questions

At the end of every section, you will find review questions under the heading Check Your Understanding. At the end of every chapter, there are questions in the Chapter Review. If you are unable to answer the questions at the end of the sections and chapters, reread the material to find the answers. Ask your teacher to explain anything you still do not understand.

Instant Practice—Reading for Information

1. Go to the unit your teacher tells you that your class will be studying next. Scan the unit to predict the key ideas you will be studying.
2. In the first section of the unit, use strategies 1 and 2 on the previous page before you read the section.
3. Read the first section of the unit using strategies 3 and 4 to make notes.

Using Graphic Organizers

A good way to organize information you are learning is to use a graphic organizer. One kind of graphic organizer you will find useful is a concept map.

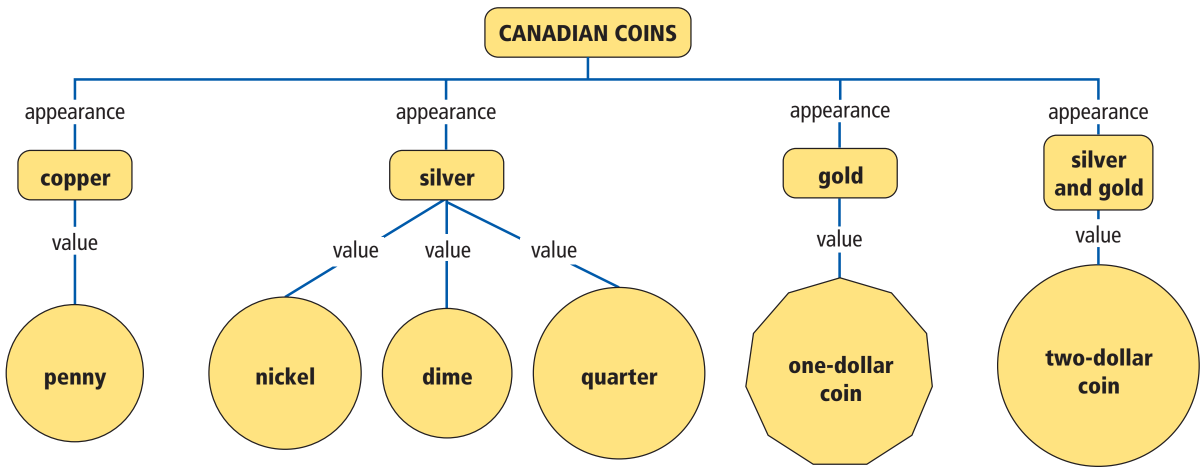
Concept Map

A concept map is a diagram that represents visually how ideas are related. Because the concept map shows the relationships among concepts, it can clarify the meaning of the ideas and terms and help you to understand what you are studying.

Study the construction of the concept map below. Notice how some words are enclosed while others are written on connecting lines. The enclosed words are ideas or terms called concepts. The lines in the map show related concepts, and the words written on them describe relationships between the concepts.

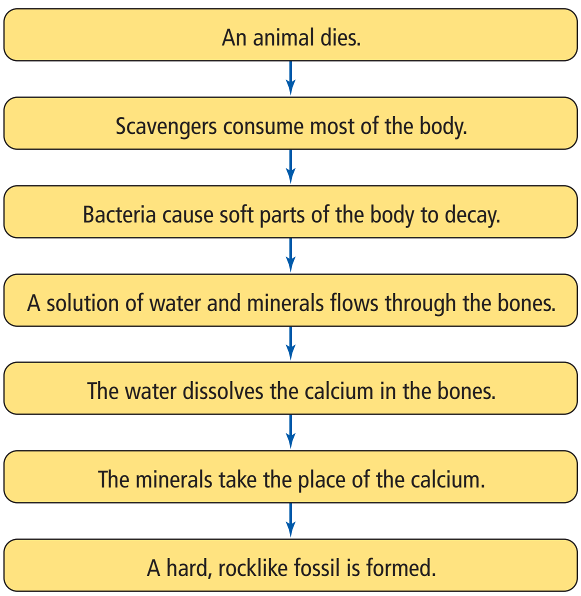
As you learn more about a topic, your concept map will grow and change. There is no single "correct" concept map, there are only the connections that make sense to you. Make your map as neat and clear as possible. Make sure you have reasons for suggesting the connections between the concepts.

When you have completed the concept map, you may have dozens of interesting ideas. Your map is a record of your thinking. Although it may contain many of the same concepts as other students' maps, your ideas may be recorded and linked differently. You can use your map for study and review. You can refer to it to help you recall concepts and relationships. At a later date, you can use your map to see what you have learned and how your ideas have changed.



Flowchart

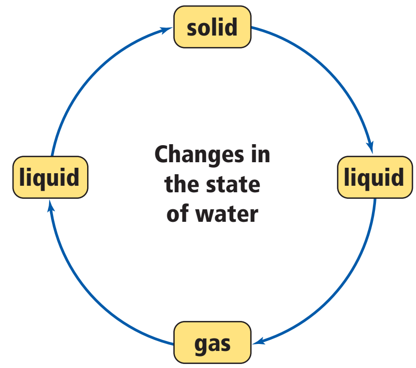
A flowchart describes ideas in order. In science a flowchart can be used to describe a sequence of events, the steps in a procedure, or the stages of a process. When making a flowchart, you must first find the one event that starts the sequence. This event is called the initiating event. You then find the next event and continue until you reach an outcome. Here is a flowchart showing how an animal fossil may be formed.



Cycle Chart

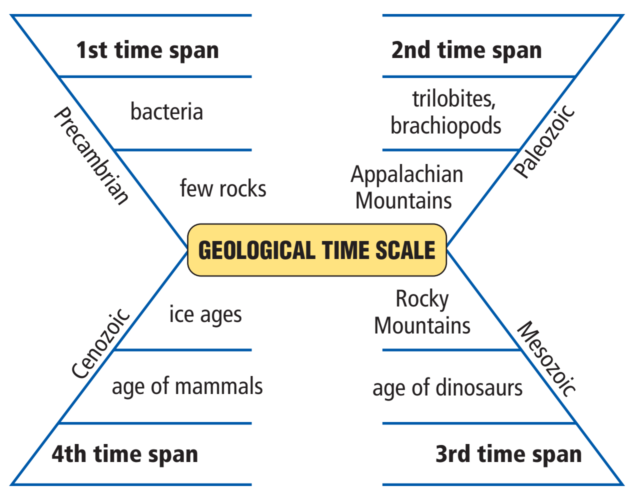
A cycle chart is a special type of flowchart. In a cycle chart, the series of events do not produce a final outcome. This type of chart has no beginning and no end.

To construct a cycle chart, you first decide on a starting point and then list each important event in order. Since there is no outcome and the last event relates back to the first event, the cycle repeats itself. Look at the cycle chart in the next column, which shows changes in the state of water.



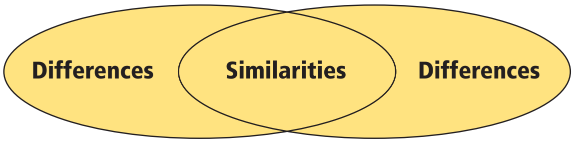
Spider Map

A spider map is a concept map that you may find useful for brainstorming. You may, for example, have a central idea and a jumble of associated concepts, but they may not necessarily be related to each other. By placing these associated ideas outside the main concept, you can begin to group these ideas so that their relationships become easier to understand. Examine the following spider map of the geological time scale to see how various concepts related to this time scale may be grouped to provide clearer understanding.

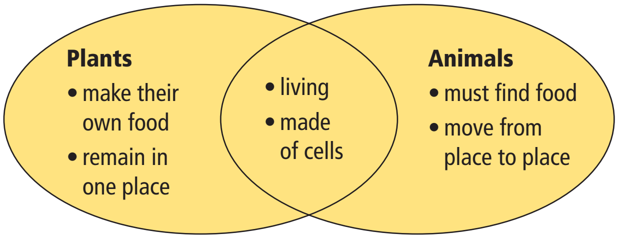


Venn Diagram

Comparing and contrasting information is another way to help solidify your learning. When you compare, you look for similarities between two concepts or objects. When you contrast, you look for differences. You can do this by listing ways in which two things are similar and ways in which they are different. You can also use a graphic organizer called a Venn diagram to do this, using two circles.



Example



Instant Practice—Graphic Organizers

1. Create a concept map with a sketch of the atom at the centre of the map. Include the following terms on the map: electrons, neutrons, protons, ions, nucleus, neutral, negative, and positive. Show how each term is connected to the atom and to other terms. Continue adding terms, connections, and sketches.
2. Create a flowchart that takes you through all the steps involved in carrying out a scientific investigation.
3. Design a spider map with the central theme of space exploration.
4. Create a Venn diagram in which you compare and contrast one of the following pairs.
   (a) bats and birds
   (b) hurricanes and tornadoes
   (c) your two favourite science topics

Units of Measurement 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 word joined to the beginning of another 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 measure, 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

Prefixes	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 = 1 000
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 1

The distance from Penticton to Prince Rupert is 1431 km. Express this distance in metres.

Solution

$$1431 \text{ km} = ? \text{ m}$$
$$1 \text{ km} = 1000 \text{ m}$$
$$1431 \text{ km} = 1431 \times 1000 \text{ m}$$
$$= 1\ 431\ 000 \text{ m}$$

Example 2

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

Solution

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

The next table lists most of the frequently used metric quantities you will encounter in your science classes.

Frequently Used Scientific Quantities, Units, and Symbols		
Quantity	**Unit**	**Symbol**
length	nanometre micrometre millimetre centimetre metre kilometre	nm μm mm cm m km
mass	gram kilogram tonne	g kg t
area	square centimetre square metre hectare	cm^2 m^2 ha
volume	cubic centimetre cubic metre millilitre litre	cm^3 m^3 mL L
time	second	s
temperature	degree Celsius	°C
force	newton	N
energy	joule kilojoule	J kJ
pressure	pascal kilopascal	Pa kPa
electric current	ampere	A
quantity of electric charge	coulomb	C
electrical resistance	ohm	Ω
frequency	hertz	Hz
power	watt	W

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. The heaviest blue whale ever recorded was a massive 190 tonnes. Express its mass in grams.
5. A student added 0.0025 L of food colouring to water. Express the volume in mL.

SI Units

In science classes, you will often be instructed to report your measurements and answers in SI units. The term SI is taken from the French name *Le Système international d'unités*. In SI, the unit of mass is the kilogram, the unit of length is the metre, the unit of time is the second, the unit of temperature is the kelvin, and the unit of electric current is the ampere. Nearly all other units are defined as combinations of these units.

Example 1

Convert 527 cm to SI units.

Solution

The SI unit of length is the metre.

1 m = 100 cm

$$527\ \cancel{cm} \times \frac{1\ m}{100\ \cancel{cm}} = 5.27\ m$$

Example 2

Convert 3.2 h to SI units.

Solution

The SI unit of time is the second.

1 min = 60 s; 1 h = 60 min

$$\frac{3.2\ \cancel{h} \times 60\ \cancel{min}}{\cancel{h}} \times \frac{60\ s}{1\ \cancel{min}} = 11\ 520\ s$$

Instant Practice—Converting to SI Units

Convert the following quantities to SI units.

1. 52 km
2. 43 min
3. 8.63 g
4. 45 973 mm
5. 537 891 cm
6. 1.75 h
7. 16 Mg (megagrams)
8. 100 km/h

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. The place table below shows the powers of 10 as numbers in standard form and in exponential form.

	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 the 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