Science Skills Guide

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 the most 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 will be using 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

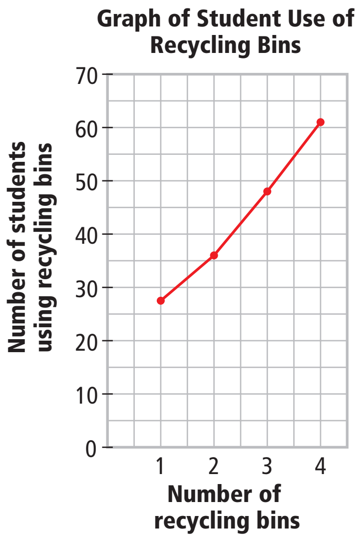
Suppose you have conducted a survey to find out how many students in your school are recycling drink containers. Out of 65 students whom you surveyed, 28 are recycling. To find out if having more recycling bins would encourage students to recycle cans and bottles, you place temporary recycling bins at 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

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. Make a mark at major intervals on your scale, as shown in the graph on the next page.
4. On the *x*-axis, you want to make sure you will be able to read your graph when it is complete, so make sure your intervals 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.

6. If it is appropriate, draw a line that connects all of the points on your graph. This might not be appropriate. Scientific investigations often involve quantities that change smoothly. In addition, experimental data points usually have some error. On a graph, this means that you should draw a smooth curve (or straight line) that has the general shape outlined by the points. This is called a line of best fit. If the points are almost in a straight line, draw a straight line as close to most of the points as possible. There should be about as many points above the line as there are below the line. If the data points do not appear to follow a straight line, then draw a smooth curve that comes as close to the points as possible. 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—Drawing a Line Graph

Make a line graph using the following data on the development of a fetus. The first column represents the time since conception, in months. Plot these values along the x-axis. The second column is the average length of a fetus at that stage of development. Plot these values along the y-axis. Draw a line of best fit. Be sure to include units. Give your graph a title.

Table 2 Development of a Fetus

Time since conception (months)	Average length (cm)
1	0.6
2	3.0
3	7.5
4	18.0
5	27.0
6	31.0
7	37.0
8	43.0
9	50.0

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.

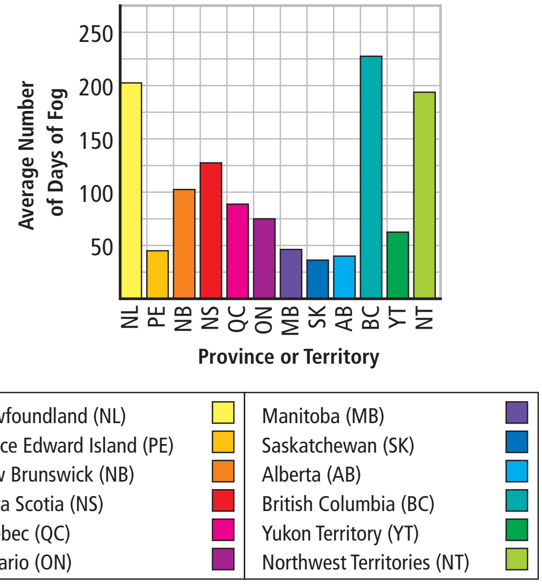
Example

To learn how to make a bar graph to display the data in Table 3 on the following page, examine the corresponding graph in the column next to the table as you read the steps below the table. 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 and Labrador	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

Average Number of Days of Fog per Year in Canadian Provinces and Territories before April 1, 1999



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. Because the names are so long to write, you might want to use a colour code with a key or abbreviated names to identify the provinces and territories on the x-axis.
2. Look at the data carefully in order to select an appropriate scale. Write the scale of your y-axis on the lines.
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 Labrador 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. 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—Drawing a Bar Graph

Construct a bar graph to display the data in Table 4, below, showing the average heart rates of adult animals in several different species.

Table 4 Heart Rate and Species

Species	Heart rate (beats per min)
codfish (in water at 18°C)	30
iguana (in hot sun)	90
duck (resting)	240
dog (resting)	100
human (resting)	70
elephant (resting)	30
white rat (resting)	350

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 percent 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 "piece of pie"
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

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:

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

3. To determine the degrees in the "piece of pie" that represents each type of bird, use the following formula.

$$\text{Degrees in ``piece of pie''} = \frac{\text{Percent for a type of bird}}{100\%} \times 360^\circ$$

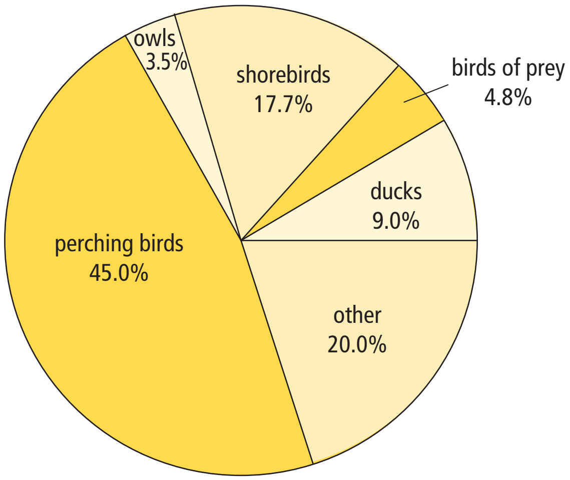
Round your answer to the nearest whole number. For example, the "piece of pie" for ducks is:

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

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—Drawing a Circle Graph

Make a circle graph using the following data on the elements in Earth's crust. Notice that the data are given in percent.

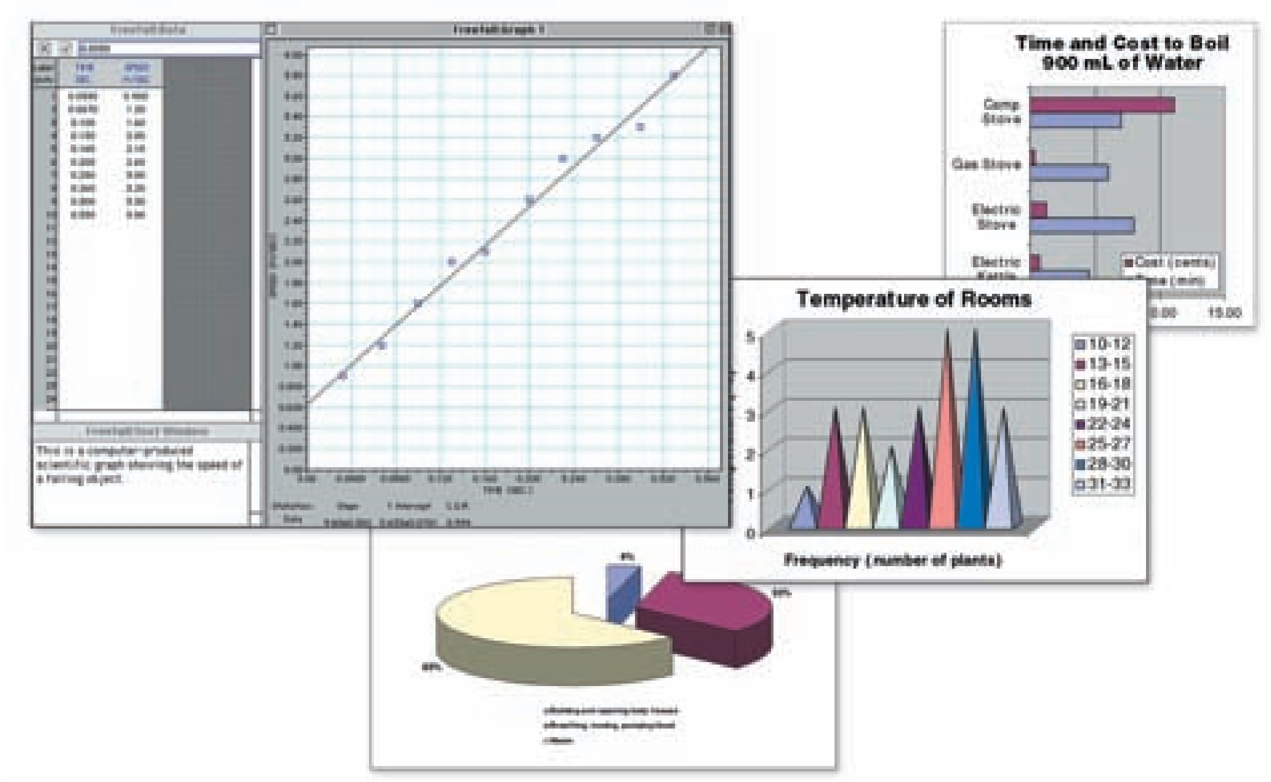
Table 6 Percent of Elements in Earth's Crust

Element	Percent of Earth's crust (%)
aluminum	8.0
calcium	2.4
iron	6.0
magnesium	4.0
oxygen	46.0
potassium	2.3
silicon	28.0
sodium	2.1
other	1.0

Graphing on a Computer

Computers are great tools 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 can.
4. Computers can be hooked up to sensors (thermometers, timers, and such) 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 change the incorrect number and print again. Imagine the time and effort involved if you had to redo your graph by hand.
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 isn't 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 helps scientists to discover patterns in their data and make predictions to test their inferences in a very precise manner.



Communicating Your Lab Work in a Lab Report

What if a scientist made a new and important discovery but didn't tell anyone? The discovery would do no good at all, because it would not be communicated to the scientific community. To communicate their discoveries, scientists submit papers to scientific journals, where they are published. Then other scientists can verify the results and use the results for further experiments of their own. Your lab reports are similar to scientific papers. The sample report below shows how you can use the headings in the Investigations to help you organize and write your report.

> Give your report a title and write it at the top of the page.

Acids and Bases in the Home

> Write the question or questions that you were trying to answer in the investigation. Use complete sentences to write the questions.

Question

Can you predict whether a household liquid will be an acid or base depending on its use?

> Make a hypothesis and write it out in a full sentence. In some investigations, you might have a prediction instead of a hypothesis. Your hypothesis or prediction should be something that can be verified or disproved. It also should be related directly to the question. If the investigation includes independent and dependent variables, the hypothesis should indicate a relationship between these variables.

Hypothesis

It is not possible to predict whether a household liquid is an acid or base.

> Make a list of all of the materials that you used. This list includes all of the pieces of laboratory apparatus that are used over and over. It also includes chemicals and other materials that will be discarded at the end of the investigation. If specific quantities of the chemicals were used, include the amounts.

Materials

8 test tubes	dilute acid
test tube rack	dilute base
glass stirring rod	vinegar
eye dropper	mayonnaise
labelling tape	liquid drain cleaner
paper towels	window cleaner
red litmus paper	cola soft drink
blue litmus paper	liquid laundry soap
water	

> Write out every step in the procedure very clearly. Include safety precautions. Notice that most of the procedure steps start with an action word such as "put" or "prepare." These steps should be written in a way that another person could follow them and repeat the investigation. If diagrams are needed to show how different pieces of apparatus fit together, include a diagram.
>
> If you collected data, include the data in a table. If you made a graph from your data, include the graph. Remember that you only include the data in this section. Save your analysis and conclusions for the later sections.

Procedure

CAUTION: Do not let any of the liquids get on your skin. If any liquid does, rinse your skin with a lot of water.

1. Prepare a data table with the following headings: Sample, Blue Litmus Paper, Red Litmus Paper. Make eight rows and write the name of the sample in the first column. Record the data in the other columns.
2. Put the eight test tubes in the test tube rack. Label each test tube with tape by writing the name of each of the eight liquids in the materials list on the tape.
3. With the eye dropper, put about 1 mL of each liquid into each of the test tubes with the correct label. Rinse the eye dropper with water between each type of liquid.
4. Place eight small pieces of red litmus paper and eight small pieces of blue litmus paper on a paper towel.

5. Use the eye dropper to transfer one drop of the dilute acid to a piece of red litmus paper. Transfer another drop of dilute acid to a piece of blue litmus paper.
6. Record the final colour of each piece of litmus paper.
7. Rinse the eye dropper with water and dry it with some paper towel.
8. Repeat steps 4 through 6 for each of the other seven liquids.

Data Table

Sample	Blue Litmus Paper	Red Litmus Paper
dilute acid	turned red	stayed red
dilute base	stayed blue	turned blue
vinegar	turned red	stayed red
mayonnaise	turned red	stayed red
liquid drain cleaner	stayed blue	turned blue
window cleaner	stayed blue	turned blue
cola soft drink	turned red	stayed red
liquid laundry soap	stayed blue	turned blue

In this section, you examine your data and look for connections between variables or other factors. The questions in the "Analyze" section of the Investigation will guide you through this section. Be sure to answer all of the questions in the "Analyze" section. If you made tables, you explain what these tables revealed. If you made graphs, you explain the meaning of the graphs.

Analyze

1. When acid was placed on red litmus paper, it stayed red. When acid was placed on blue litmus paper, it turned red.
2. When base was placed on red litmus paper, it turned blue. When base was placed on blue litmus paper, it stayed blue.
3. The following table shows the results for the household liquids.

Red litmus paper stayed red. Blue litmus paper turned red.	Red litmus paper turned blue. Blue litmus paper stayed blue.
vinegar	drain cleaner
mayonnaise	window cleaner
cola soft drink	liquid laundry soap

Finally, you compare your results with your hypothesis or prediction. You state whether your hypothesis or prediction was verified of disproved. In either case, you state any conclusions that your results revealed. Once again, the questions in the "Conclude and Apply" section in the Investigation will guide you in writing this section. Be sure to answer all of the questions. If your conclusions can be used in everyday life, state how they can be used.

Conclude and Apply

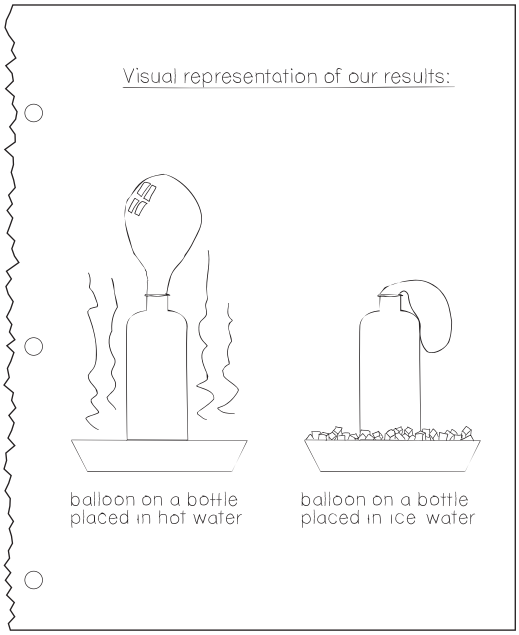
4. Acid turns blue litmus paper red but red litmus paper stays red.
5. Base turns red litmus paper blue but blue litmus paper stays blue.
6. Vinegar, mayonnaise, and cola soft drinks are acids.
7. Drain cleaner, window cleaner, and liquid laundry soap are bases.
8. The hypothesis is not correct. It is possible to predict whether a household liquid is an acid or base. Cleaning liquids are usually bases and food liquids are usually acids.

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.

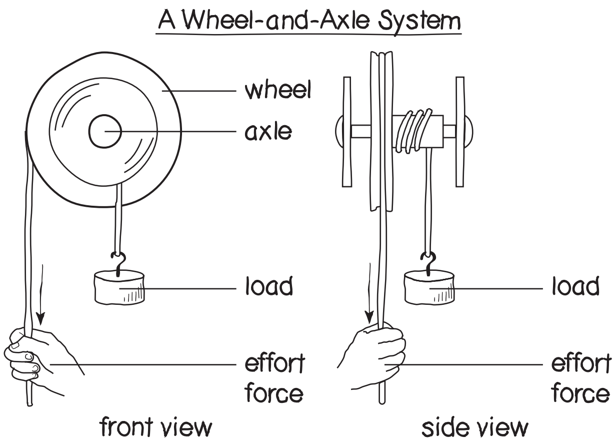
Examine the drawing shown below. It is taken from a Grade 8 student's lab report on an experiment to test the expansion of air in a balloon. The student's verbal description of results included an explanation of how the particle model can explain what happens to the balloon when the bottle is placed 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 points of comparison between them.



Making a Scientific Drawing

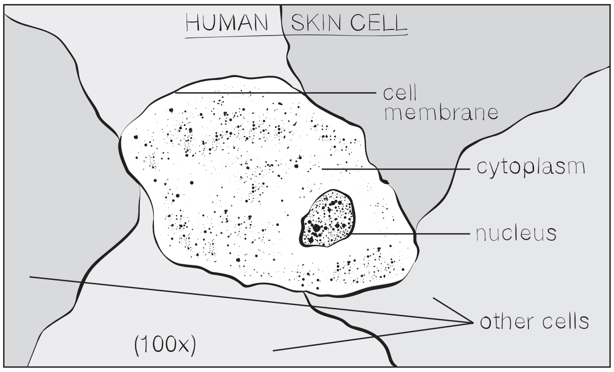
Follow these steps to make a good scientific drawing.

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. Pretend you know nothing about the object you have just observed, and think about what you would need to know if you were looking at it 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. Note: The drawing of a human skin cell shown here is from a Grade 8 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.

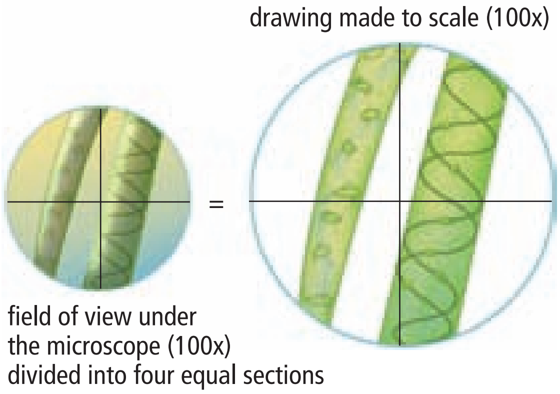


The stippling on this drawing of a human skin cell shows that some areas are darker than others.

Drawing to Scale

In Unit 4, you will be making drawings of objects that have been magnified using a microscope. 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.

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. Also 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. Also, 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.



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. It 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 proper procedure and care must be practised. Before you use your microscope, review its parts and their functions.

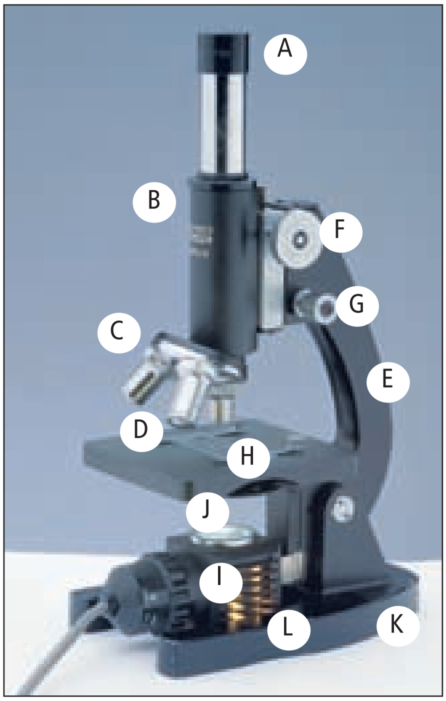
A. Eyepiece (or ocular lens)
You look through this part. It has a lens that magnifies the object, usually by 10 times (10×). The magnifying power is engraved on the side of the eyepiece.

B. Tube
Holds the eyepiece and the objective lenses at the proper working distance from each other.

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

D. 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.) For convenience, the objective lenses are referred to as low, medium, and high power. The magnifying power is engraved on the side of each objective lens.

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



L. Light source
Shining a light through the object being viewed makes it easier to see the details. Your microscope might have a mirror instead of a light. If it does, it must be adjusted to direct the light source through the lenses. CAUTION: Use an electric light, not sunlight, as the light source for focussing your mirror.

F. 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 with medium- and high-power magnification to bring the object into sharper focus.

H. 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
Directs light to the object being viewed.

J. Diaphragm
Controls the amount of light reaching the object being viewed.

K. Base
Supports the whole microscope

Using the Microscope

These are the basic steps for finding and viewing an object with the microscope.

1. Make sure the low power objective lens is in place and that it is set at its lowest position.
2. Use the stage clips to secure the slide to the stage.
3. Slowly turn the coarse adjustment knob to bring the object on the slide into focus.
4. Then use the fine adjustment knob to bring the object into sharper, clearer focus.
5. If you need to observe the object under higher magnification, rotate the revolving nosepiece to bring the medium power objective lens into place.
6. Use the fine adjustment knob to bring the larger image into focus. (**CAUTION!** Never use the coarse adjustment knob with the medium or high power objective lens.)
7. When you finish, return the low power lens into position. Then, using the coarse adjustment knob, move the low power lens to its lowest level.
8. When you return the microscope to its storage area, remember to use one hand to grasp it securely by the arm, and support the weight of the microscope with your other hand under the base. Hold the microscope in front of you, close to your body, as you bring it to the storage area. (**CAUTION!** Never move a microscope by holding it by the arm alone.)

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 on. If the microscope has no light, adjust your mirror.
- *Are you having trouble finding anything on the slide?* Be patient. Follow all of the steps outlined in this procedure from the beginning and 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 that you will examine 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. When you turn to medium and high power, you otherwise may not see the object you were viewing under low power.

How to Prepare Specimens for Viewing.

When using a compound microscope to view a specimen, the specimen must be placed on a small glass slide and covered with a very thin square of glass called a cover slip. There are two main types of specimen slides used in schools. These are permanent slides and wet mounts. Permanent slides may be used over and over. Often the specimen has been stained with a chemical to make certain parts of the specimen more visible. A special type of glue is used to permanently hold the cover slip in place.

The other type of specimen slide is called a wet mount. The wet mount is very useful when viewing living specimens, particularly microscopic organisms, as you can see them moving, eating, and even reproducing. A wet mount is a temporary specimen slide because the specimen is disposed of after viewing and the slide and cover slip can be reused.

How To Make a Wet Mount

1. Place the specimen/sample on a slide.
2. Using an eye dropper, add a drop of water. Sometimes a stain is used to make the specimen more visible. The water prevents living specimens from drying out.
3. Carefully put the cover slip over the specimen/sample as follows: Place the cover slip at an angle onto the slide so that it touches the drop of water. Using a tooth pick or other small pointer, slowly lower the cover slip onto the drop. This will prevent the formation of air bubbles under the cover slip, which will interfere with your viewing of the specimen. **CAUTION:** Be careful when handling the cover slip as it is very thin glass and can break easily.
4. If there is too much water and the cover slip is "floating around" you can remove some of the excess water by holding the edge of a paper towel next to the edge of the cover slip.
5. If there is too little water you can add more water by adding a drop next to the cover slip. This water will get pulled under the cover slip.
6. If you need to add stain to the specimen after you have made a wet mount, you can do this by putting a drop of the stain on one side of the cover slip. Then hold a paper towel to the other side of the cover slip. As water is pulled into the paper towel the stain will be pulled in under the cover slip to replace the water that was removed.
7. To view your specimen/sample, follow the directions for "using the microscope".
8. When you are finished viewing your specimen, dispose of the specimen as directed by your teacher. Then wash the slide as directed by your teacher. Because they are so fragile, cover slips are difficult to clean and should be disposed of in the broken glass container as directed by your teacher.

Instant Practice-Using the Microscope

You are now ready to practise using the microscope. Review the steps for using the microscope on page 479 before you begin.

1. Obtain a microscope and carry it to your workplace. Use both hands to carry the microscope in the upright position.
2. If the microscope has a built in power source, plug in the electrical cord.
3. Microscopes should always be stored with the nosepiece set on the low power lens. If it was not stored properly, rotate the nosepiece so that the low power lens is in position and clicked in place.
4. Place a prepared slide on the stage and secure it with the clips. Make sure that the object to be viewed is in the centre of the opening.
5. Look through the eyepiece and slowly turn the coarse-adjustment knob until the object is in focus. Use the fine-adjustment knob to sharpen the focus.
6. Watch from the side and rotate the nosepiece until the medium-power objective lens has clicked into place. **CAUTION:** Do not use the coarse-adjustment knob with the medium- or high-power objective lens in place.
7. Adjust the focus by slowly turning the fine-adjustment knob.
8. Watching from the side, rotate the nosepiece to the high-power objective lens until it has clicked into place.
9. Focus by slowly turning the fine-adjustment knob.
10. Make a sketch of the image that you see in the field of view.

Common Laboratory Equipment

When you do scientific experiments at school, you often will use equipment that is found in science laboratories throughout the world. In your science class this year and in future years, you will develop skills and safe practices in the use of laboratory equipment. A selection of equipment that you will be using is presented below and on the following page. Your teacher will show you how to use laboratory equipment properly and safely.

Protective equipment: specially designed coverings to protect your eyes, hands, and clothing from chemicals and heat that could cause harm or stains that are difficult to remove. For example, safety glasses (1), heat resistant gloves (2), and lab coats (3). Special rubber gloves are used to protect hands/skin from contact with chemicals.

Equipment for measuring: includes balances, graduated cylinders, and thermometers

balance (4): used to measure the mass of an object or sample of matter. A traditional balance works by balancing the mass of one thing against a known mass (as in an equal-arm or a triple-beam balance). Modern electronic balances, seen within photo below, measure and display mass directly.

graduated cylinder (5): used to measure the volume of a liquid or a granulated solid (one that can be poured, such as salt or sugar). Graduated cylinders come in different sizes to hold volumes of liquid that range from 10 mL to 1000 mL. The scale is divided (graduated) more finely than the scale on a beaker, so volume measurements are more precise and accurate.

Equipment for observing objects: includes tools that have lenses

microscope (6): used to magnify (make larger) objects up to 400 times their actual size. (High-tech microscopes can magnify objects up to millions of times their actual size.) Microscopes are useful for seeing details of extremely small items.

magnifying glass (7): used to magnify objects within a limited range so that various features are easier to observe. Magnifying glasses are useful because they allow objects to appear much larger than they are.

Equipment for heating objects: includes hot plates and burners

hot plate (8): used to heat liquids. Hot plates generate enough heat to boil water, but they do so without the

danger that is associated with flames from a burner. Hot plates are good for general heating of liquids in beakers or other flat-bottomed containers, but less useful for heating solids, or heating to very high temperatures. A Bunsen burner is the best choice in this situation.

Bunsen burner (9)*:* used to heat solids and liquids. Bunsen burners, like all burners, use fuel to produce an open flame, so extreme caution is necessary if they are to be used.

Glassware: includes beakers, test tubes, and flasks, and could be made of plastic instead of glass.

beaker (10)*:* used to hold, mix, and measure liquids. Beakers come in different sizes to hold volumes of liquid that range from 25 mL to 600 mL and more. For more precise and accurate measurements of the volume of liquids, you would use a graduated cylinder. Beakers can also be used for heating substances or for mixing larger amounts of chemicals.

test tube (11)*:* small tube that is closed at one end and used to hold samples of chemicals (usually liquids). The samples may be mixed with small amounts of other chemicals to observe possible changes. When heating substances in a test tube, make sure that the tube is made of material that will not break when heated.

flask: narrow-necked bottle with straight sides (Erlenmeyer flask, 12) or rounded sides (Florence flask, 13) used to hold, mix, and heat liquids. Only heat liquids within a flask that is approved to withstand heat.

Petri dish (14)*:* a clear, flat, round dish with a cover that can be used to hold small amounts of liquids or solids. (Petri dishes that contain a gelatin-like substance called agar can be used to grow bacteria, but this must be done under careful conditions.)

watch glass (15)*:* a concave disk that can be used as a cover (for a beaker, for instance) or to evaporate a small amount of liquid such as a solution.

stirring rod (16)*:* used to stir liquids and mixtures in beakers and flasks. Only use approved stirring rods to stir solutions.

Equipment for holding, supporting, containing, and transferring: includes stands, tongs, stoppers, and stationary holders

retort stand (17)*:* used, often along with a clamping device, to hold or support glassware so that chemicals can be heated or mixed and observed.

clamp (18)*:* a device that is usually attached to a stand to support or hold glassware such as a test tube, a flask, or a tube. A ring clamp is shown below. Other clamps are available for holding items in place. Remember to always put the clamp as low on the stand as possible to ensure the stand does not become top heavy.

tongs (19)*:* used to hold or move glassware such as test tubes or beakers. An example of test tube tongs appear in the photo below.

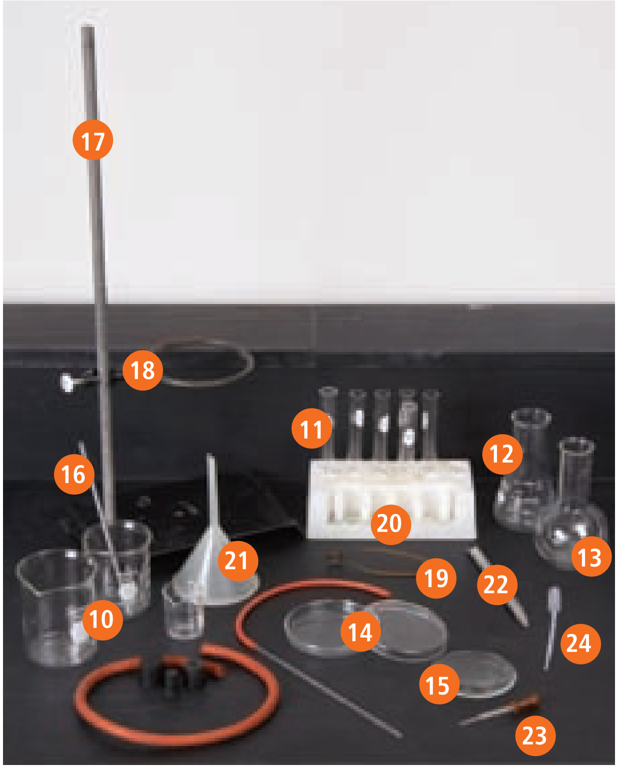
test tube rack (20)*:* used to hold one or more test tubes safely and securely, leaving your hands free for other tasks.

funnel (21): used to transfer liquids or granulated solids into containers that have small openings

scoopula (22)*:* used to transfer small amounts of solids to other equipment such as a test tube, beaker, flask, or watch glass. (You might also hear it referred to as a spatula scoop.) Remember to use a scoopula for transferring only one substance at a time to avoid cross contamination of chemicals.

eye dropper (23)*:* used to transfer very small volumes of liquid into other equipment. Some eye droppers are calibrated so that you can measure specific volumes ranging up to 1 mL. (You might also hear it referred to as a medicine dropper.)

pipette (24)*:* used to transfer small precise volumes of liquid from one container to another.



Designing and Conducting Experiments

A useful experiment usually starts with an observation. The observation might be as simple as watching a child on a playground swing such as the one shown below.

A swing has a rhythmic motion.

Observing and Inferring

If your observation can lead to the development of an experiment, you must be able to ask a question that can be answered by a scientific investigation. You might ask, "What features of a playground swing or any other swinging object determine the rhythm of the swinging motion?" To answer the question, you might think back to when you were younger. You knew that you could make a swing go higher, but it always seemed to swing back and forth at the same rate. You have narrowed the question down to what determines the rate at which a swinging object goes back and forth. You have inferred that some characteristic of a swinging object determines the rhythm. You could compare a child on a swing to some other previous experience. Maybe you bumped into a hanging planter at home and watched it swing. It seemed to swing faster than the child on the swing. The hanging planter is a shorter system than the child on the swing. You might infer that the length of the rope influences the rate of swinging. This is an idea that you can test by creating a model of a child on a swing. You can model a child on a swing by building a simple pendulum (see the photograph below).

Hypothesizing and Predicting

When you have developed a model, you can use it to formulate a hypothesis. You might think about the size of the mass at the end of the string on your pendulum. You might hypothesize that a heavier mass would swing faster. If this is the case, you could predict that a larger mass would cause the time for one complete swing to be shorter. The term that describes the length of time for the pendulum to swing from one end to the other and back again is the period. You are nearly ready to carry out your experiment. First, you must identify all of the variables involved when a pendulum swings.

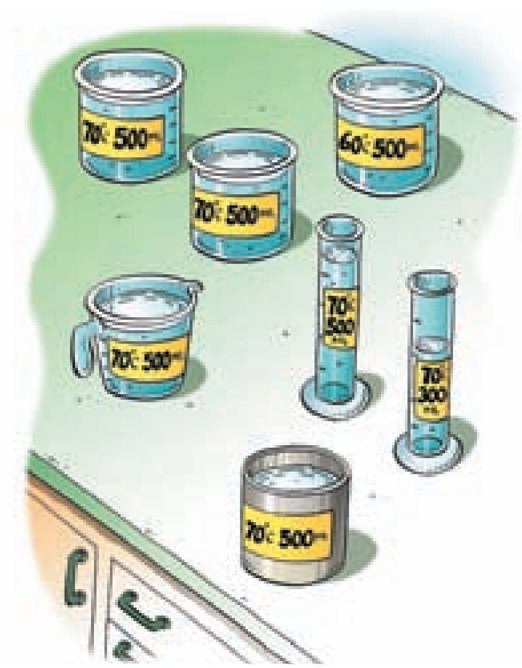
These students are modelling a child on a swing by setting up a pendulum.

Variables

A variable is anything that might affect the outcome of the experiment. The period of the pendulum is a variable. Other variables that might affect the period are:

- the mass of the pendulum bob (the object at the end of the string),
- the length of the string, and
- how far you pull the pendulum bob to one side before letting it go.

In order to carry out a fair test, you must test the effect of only one specific variable at a time. You must ensure that all the other variables do not change. Scientists say that you control the other variables. This is important because, if you changed both the mass of the bob and the length of the string and you observed a change in the period, you would not know whether the change in the mass or in the length of the string caused the period to change. Study the figure below and see if you can identify the variables in another experiment.

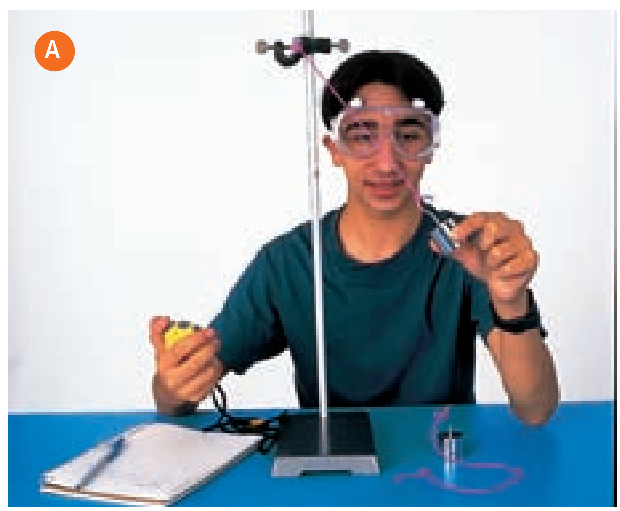


Examine the containers of water. Assume that you want to know what factors affect the length of time it takes for water to evaporate. How many variables can you find in the figure? What are those variables? How would you test each variable individually?

Independent, Dependent, and Controlled Variables

The variable that you choose to test is called the manipulated or independent variable. You can remember which variable is the independent variable by remembering, "I choose to test the Independent variable." You can select which independent variable you will test. The responding or dependent variable is the one that you observe to see if it has been affected by the changes to the independent variable. All of the other variables that you are not testing are controlled variables. They remain the same while you change the conditions of the independent variable. These concepts will become clear as you study the pictures of the student in the photographs.

In part (A) of the pendulum experiment, the length of the string is the independent/manipulated variable.

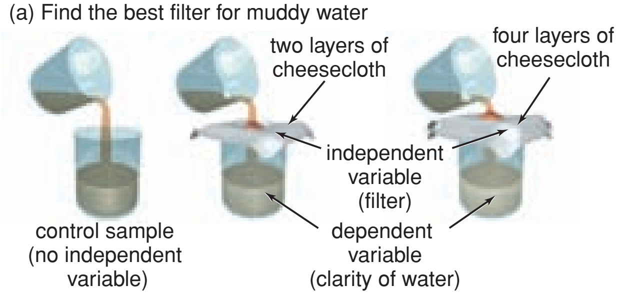


The student is testing two different lengths to see how they affect the period of the pendulum. He will start the stopwatch when he releases the pendulum bob and measure the time for one period. In this case, time is the dependent/responding variable. Notice that the student is using the same mass and he is holding the mass the same distance from the central position. These are the controlled variables.

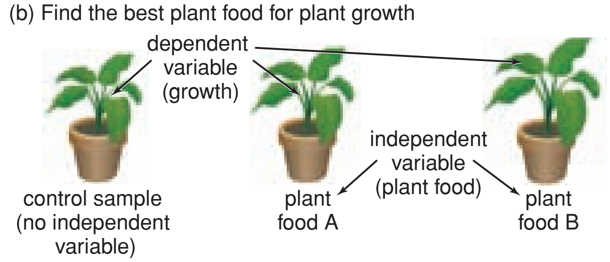
In part (B) of the pendulum experiment, the mass is the independent/manipulated variable. Notice that the length of the string is the same in both cases. The length of the string is now a controlled variable.

Control Sample

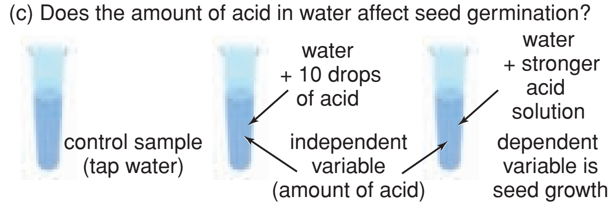
In many experiments, you need to have a control sample in which there is no independent/manipulated variable at all. Examine the figures below to understand when you need to have a control sample.



(a) If you compared only the two filters, you would not know whether the filters were doing anything at all. You need to compare both filters to the case in which there is no filter. The sample with no filter is the control sample.



(b) If you tested only the two plant foods and plant (B) grew taller than plant (A), you would not know if plant food A had any effect at all. You need to compare both plants with plant food to a third plant that received no plant food.



(c) To fully understand the effect of acid on seed germination, you have to compare the effect of two acid strengths to a control sample with water only and no acid.

Recording Data

Before you conduct an experiment, be sure that you know what tests you are going to perform and what measurements you will take. Prepare tables for your data before you start your experiment. Also, list values of the controlled variables with each data table. If you were going to do the pendulum experiment, you might make a table such as the one on the right.

Mass of Pendulum Bob		Length of string		Angle between string and vertical support	
Mass (g)	**Average Period (s)**	**Length (cm)**	**Average Period (s)**	**Angle (°)**	**Average Period (s)**
25		50		5	
50		100		10	
75		150		15	
100		200		20	
Values of Controlled Variables					
Length constant at 100 cm Angle constant at 10°		Mass constant at 50 g Angle constant at 10°		Length constant at 100 cm Mass constant at 50 g	

Note that the controlled variables are listed on the bottom row. Now you are ready to conduct your experiment.

After you have set up your apparatus and received your teacher's permission, you can begin to collect data. Taking one measurement is never enough. It is too easy to make an error in measurements. You need to take at least four measurements for each value of the independent/manipulated variable. You can then calculate an average value. Write your average value in the table.

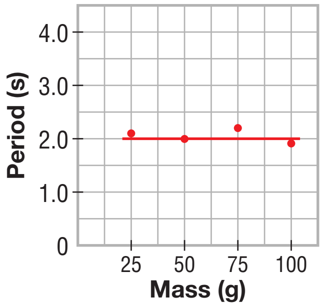
Often, it is easier to interpret your results if you graph your data. Your pendulum results might look like those in the table and graphs below. Because there is always some error in the data, the points will not lie on a smooth line. Therefore, draw a smooth line or curve close to the points.

Mass of Pendulum Bob	
Mass (g)	**Average Period (s)**
25	2.1
50	2.0
75	2.2
100	1.9
Length constant at 100 cm Angle constant at 10°	

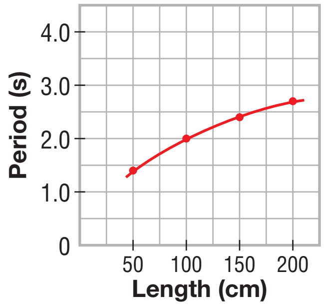
Length of string	
Length (cm)	**Average Period (s)**
50	1.4
100	2.0
150	2.4
200	2.7
Mass constant at 50 g Angle constant at 10°	

Angle between string and vertical support	
Angle (°)	**Average Period (s)**
5	2.1
10	1.9
15	2.2
20	2.0
Length constant at 100 cm Mass constant at 50 g	

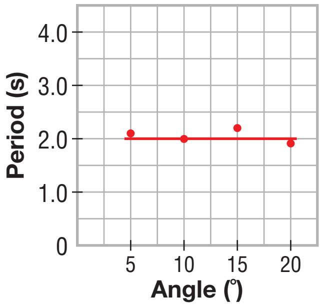
Period of Pendulum versus Mass of Pendulum Bob



Period of Pendulum versus Length of String



Period of Pendulum versus angle of String from Vertical



Summarize Results

Always write a summary of your results in a descriptive paragraph. Your summary of the pendulum experiment might be similar to this.

> When the mass of the pendulum bob was changed, the period stayed the same. When the length of the string was changed, the period changed. When the string was made longer, the period became longer. When the angle between the string and the vertical support stand was changed, the period stayed the same.

Conclusion

Finally, you will write a conclusion statement. Your conclusion will explain the meaning of the results. If your experiment was based on a hypothesis, your conclusion should state whether the results supported your hypothesis. Imagine that your hypothesis for the pendulum experiment had been:

> "A larger mass will make the pendulum swing faster than a smaller mass will make it swing. Therefore, the period of the pendulum will be shorter for larger masses."

Your conclusion statement would have to say that the results did not support your hypothesis. Your conclusion statement might read like this:

> "The results did not support the hypothesis that a large mass will produce a shorter period than will a small mass. Mass had no effect on the period of the pendulum. The angle between the string and the vertical support stand also had no effect on the period. The length of the string was the only variable that affected the period of the pendulum. As the string was made longer, the period of the pendulum swing also became longer."

Should you consider an experiment to be a failure if the results did not support your hypothesis? No! Your recorded data is valid. You demonstrated that the mass of the pendulum bob and the angle between the string and the support stand had no effect on the period. That information is just as important as the conclusion that the length of the string *did* determine the period of the pendulum.

Instant Practice

How could you design an experiment to test the question, "What effect does the size of the hole in tubing have on the rate at which water flows through the tube?" or "What factors affect the amount of sugar that will completely dissolve in water?" When you design your experiment, be sure to answer the following questions.

1. What are all of the possible variables that could affect your results?
2. What is your independent/manipulated variable?
3. What is your dependent/responding variable?
4. What are the controlled variables for this experiment?
5. How are you going to ensure that all of the controlled variables are held constant?
6. Do you need a control sample? If so, what will your control sample be?
7. What will be the form of the data that you are recording?
8. What will you need to put in your data table?
9. Will you need to graph the data? If so, what type of graph will you choose?

Plan your experiment and obtain your teacher's approval before conducting your experiment. **Note:** Be sure to include all necessary safety precautions.

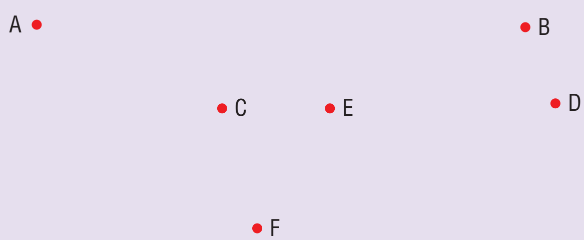
Measurement

Measuring Length

You can use a metre stick or a ruler to measure short distances. Metre sticks and rulers are usually marked off in millimetres and centimetres. To measure a distance, place the zero mark of the metre stick or ruler at one end of the distance to be measured and read the length at the other. Notice that the zero point is usually *not* at the end of the ruler.

Instant Practice

Use a ruler to measure the distance between the following pairs of points: A and D; C and E; B and F.



Measuring Area

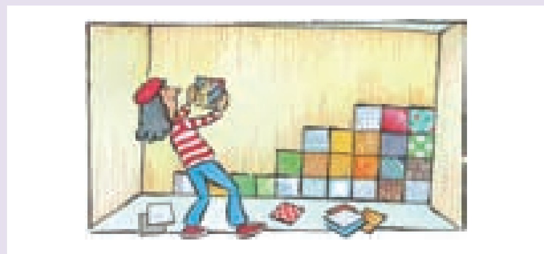
Area is the measure of the surface of an object. You might want to determine the area of a piece of paper, a wall, or the surface area of a cube. If the area of an object is made up of common geometric shapes, you can measure the dimensions of the shape and use mathematical formulas to calculate the area. A piece of paper, for example, is often rectangular. You would measure the length and the width and then use this formula to calculate the area of the paper:

$A = l \times w$ (area = length × width)

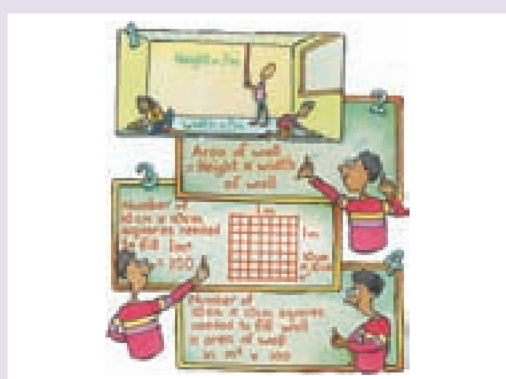
Note: When you are making calculations, always be sure to use the same units of measurement. If you mix centimetres and metres, your calculations will be incorrect.

Instant Practice

Imagine that you are in charge of an art project that will transform one wall of your classroom into a large mural to show a variety of patterns. You may use as many different patterns and materials as you like. However, each piece must be a 30 cm × 30 cm square. How many squares will you need to make your mural?



1. Choose the unit of measurement that will be most practical for the area of the mural.
2. Measure the height and width of the wall you will cover.
3. Calculate the area of the wall in the unit you have chosen.
4. Calculate the number of 30 cm × 30 cm squares to fill one square unit. For example, if you chose metres, the square unit would be square metres (m^2).
5. Multiply this number by the area of the wall in the square unit that you chose.



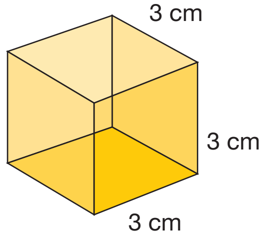
These students are using 10 cm × 10 cm squares. You are using 30 cm × 30 cm squares.

Measuring Volume

The volume of an object is the amount of space it occupies or the empty space in a hollow object. If an object is made up of common geometric shapes, you can measure the dimensions of the object and use mathematical formulas to calculate the volume:

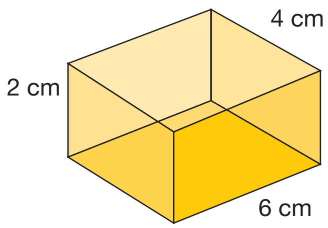
$V = l \times w \times h$

$V = 3\text{ cm} \times 3\text{ cm} \times 3\text{ cm}$
$= 27\text{ cm}^3$

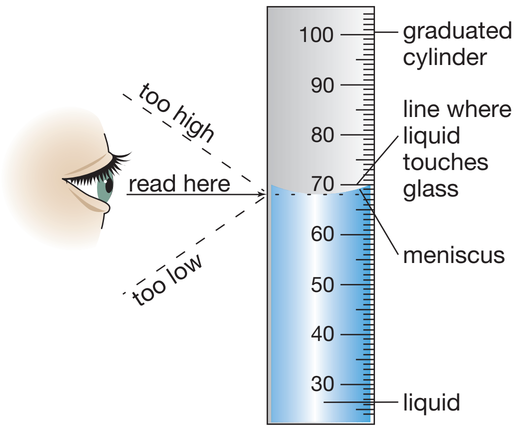


$V = l \times w \times h$

$V = 6\text{ cm} \times 4\text{ cm} \times 2\text{ cm}$
$= 48\text{ cm}^3$

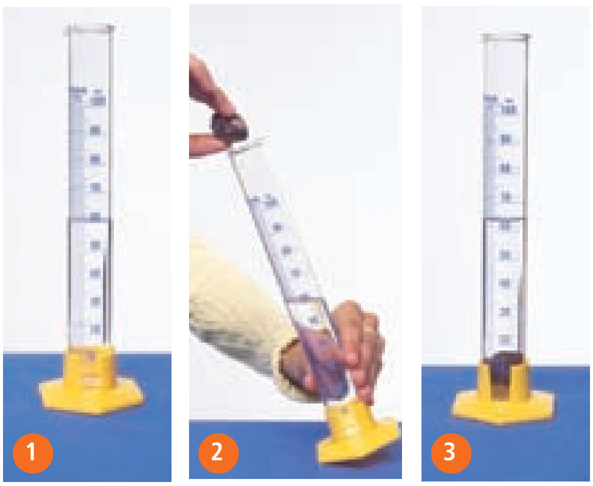


The volume of fluids is usually expressed in litres or millilitres. You can measure the volume of a liquid directly by using a graduated cylinder as shown below. To measure accurately, be sure that your eye is level with the *bottom* of the meniscus. The meniscus is the curved surface of the liquid, as shown below.



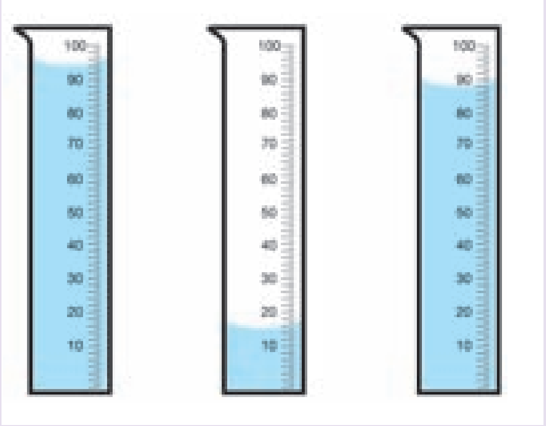
You can use liquids to help you measure the volume of an irregularly shaped solid. You would first measure a volume of a liquid such as water (Photo 1). Then, carefully slide the object into the water (Photo 2). Determine the total volume in the cylinder (Photo 3). The volume of the solid is equal to the difference between the volume before and after adding the solid.

Volume of object = volume of water with solid − volume of water only



Instant Practice

1. Read each volume shown below.



Measuring Mass

The mass of an object is the amount of matter that makes up the object. Mass is usually measured in milligrams, grams, kilograms, or tonnes. A balance is used for measuring mass. To measure the mass of a solid using a triple beam balance like the one shown here, follow these steps:

1. Set the balance to zero by sliding all three riders back to their zero points. Use the adjusting screw to be sure that the pointer rests at the zero point at the far end of the balance.
2. Place the object on the pan of the balance. The pointer will move up.
3. Slide the largest rider along until the pointer is just below zero. Then move the rider back one notch.
4. Repeat step 3 with the middle rider.
5. Adjust the smallest rider until the pointer swings equally above and below zero.
6. Add the readings on the three scales to find the mass.

To measure the mass of a powdery solid such as sugar, start by measuring the mass of an empty beaker. Next, pour the solid into the beaker. Then, measure the mass of the beaker and solid together. To find the mass of the solid, subtract the mass of the empty beaker from the mass of the solid and beaker.

$$\text{Mass of sugar} = \text{Mass of sugar and beaker} - \text{Mass of empty beaker}$$

Instant Practice

1. Which takes more "muscle" to carry: your favourite paperback book or a calculator? Find out by using a balance to compare their masses.
2. Write the steps you would take to find the mass of the contents of a glass of juice.

The mass of the empty beaker is 61.5 g.

The mass of the sugar and beaker together is 161.5 g. The mass of the sugar equals the mass of the sugar and beaker together minus the mass of the beaker: 161.5 g − 61.5 g = 100 g.

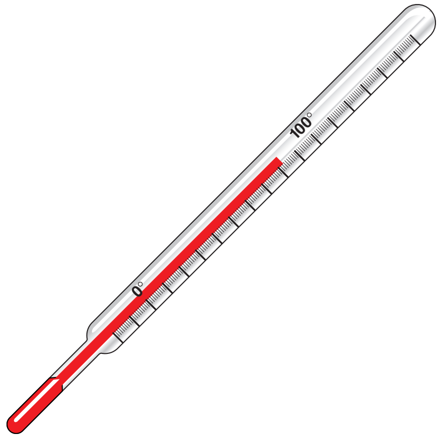
If you are using an electronic balance like this one, you can simply place the object on the pan and read the mass. To measure the contents of a beaker, you can place the empty beaker on the balance, hit the "Tare" button to reset the balance to zero, and then add the material to be measured into the beaker. The balance will subtract the mass of the beaker for you.

Measuring Temperature

Temperature is a measure of the average energy of motion of the particles in a substance. You can measure the temperature of a material by using a thermometer. You usually express the temperature of a substance in degrees Celsius. Zero degrees Celsius (0°C) is the freezing point of water. One hundred degrees Celsius (100°C) is the boiling point of water. The SI unit of temperature is the kelvin (K). Zero kelvins (0 K) is the coldest possible temperature. It is also called absolute zero. 0 K is equal to −273°C.

When using a thermometer to measure temperature, remember these three important tips:

- 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.



In school laboratories, you will probably use a thermometer like this one. The temperature scale is in degrees Celsius.

Instant Practice

Your teacher will supply your class with three large containers of water, each at a different temperature.

1. Twelve students will each be provided with a thermometer. When your teacher says "now," the students will take temperature readings of the water in the different containers. Four students will be asked to take a temperature reading of the water in one container. Four others will take the temperature reading of the water in the second container, and four others will take a reading of the water in the third container. Each student should keep the temperature reading a secret until putting it on a class chart.
2. Make a class chart on the chalkboard to record each of the students' temperature readings. The three columns will be:

Container 1	Container 2	Container 3
Temperature Reading (°C)	Temperature Reading (°C)	Temperature Reading (°C)

3. Each student will record the temperature reading of the water in the container used.
4. Did each person record the same temperature reading of the water in the same container? If the temperature readings were not all the same, explain why you think this might be so.

A digital thermometer like this one can be used to take your temperature.

Using Your Textbook as a Study Tool

This *Science Skill* will give you strategies to help you better understand what you read. It will also explain how to use textbook visuals.

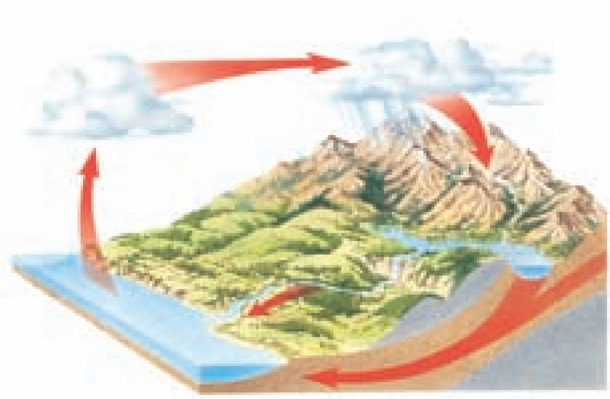
Using Your Textbook to Read for Information

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. Read the summary at the beginning of each section. You may not completely understand everything in the summary at first. When you finish 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, try to answer the questions in the Reading Checks. 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

Look at any terms that are in bold (dark, heavy) type. These terms have important definitions 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

When you reach any Check Your Understanding questions or Chapter Review questions, try to answer them. If you are unable to answer the questions, reread the material to find the answers. Ask your teacher to explain anything you still do not understand.

Societal Decision Making

Suppose you are part of an enthusiastic mixed hockey team that practises at an arena belonging to a town a few kilometres away. 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. There are days now when you just cannot get there because the roads are too icy.

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 cannot believe your eyes, 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. "Surely it is important to make our roads safer."

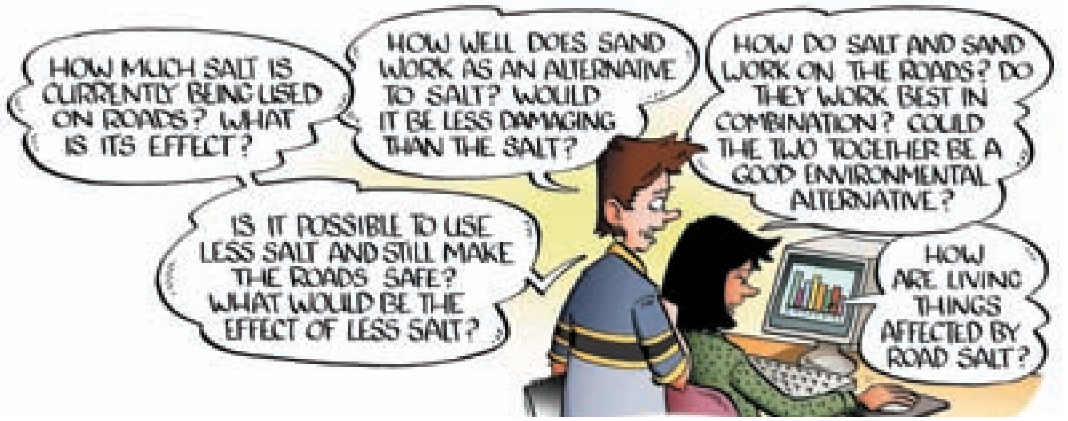
Gathering Information

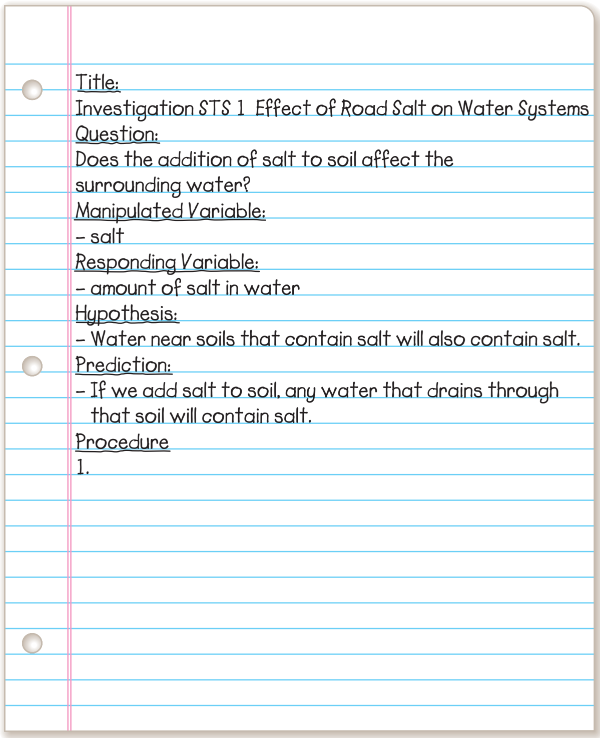
"It is," answers your friend, "but is there some way we can make the roads safer without doing so much harm to the plants at roadsides and to the drinking water in springs and wells? I was going to check the Internet to find information about these questions I have written down."

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

"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," you say. "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."




Title:
Investigation STS 1 Effect of Road Salt on Water Systems
Question:
Does the addition of salt to soil affect the surrounding water?
Manipulated Variable:
– salt
Responding Variable:
– amount of salt in water
Hypothesis:
– Water near soils that contain salt will also contain salt.
Prediction:
– If we add salt to soil, any water that drains through that soil will contain salt.
Procedure
1.

"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."

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 up to the town council or any other group to act responsibly; it is up to you and your friends. How easy is it for you to give up an undemanding way of doing a task in order to make an environmentally responsible decision?

Making a Decision

Issues rarely have easy answers. Those 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.

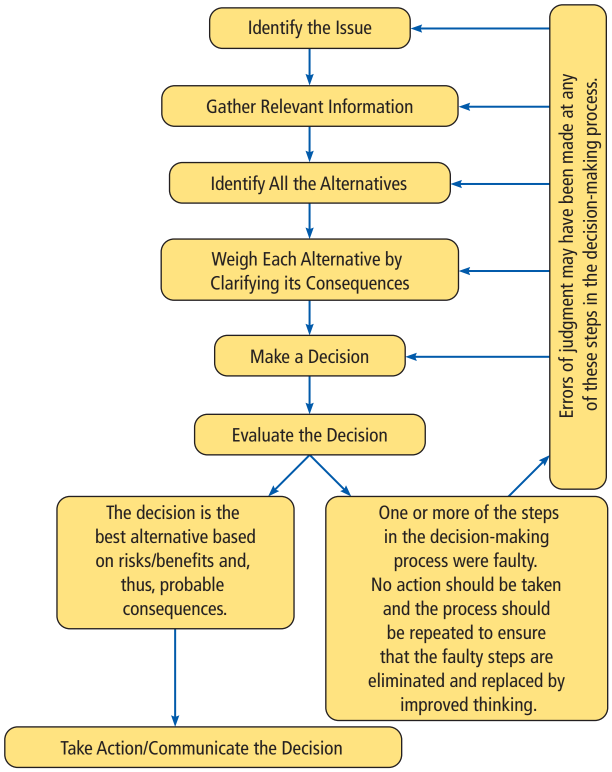
Over time, you can assess the effects of your actions: Are there fewer accidents on the salted/sanded roads? Does less salt end up in the water than when more salt alone is used?

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. If you look back over these pages, you will see that we have indeed developed a process that can be used for decision making.

Examine the flowchart below. You can see that you used every step in this process. As with science 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

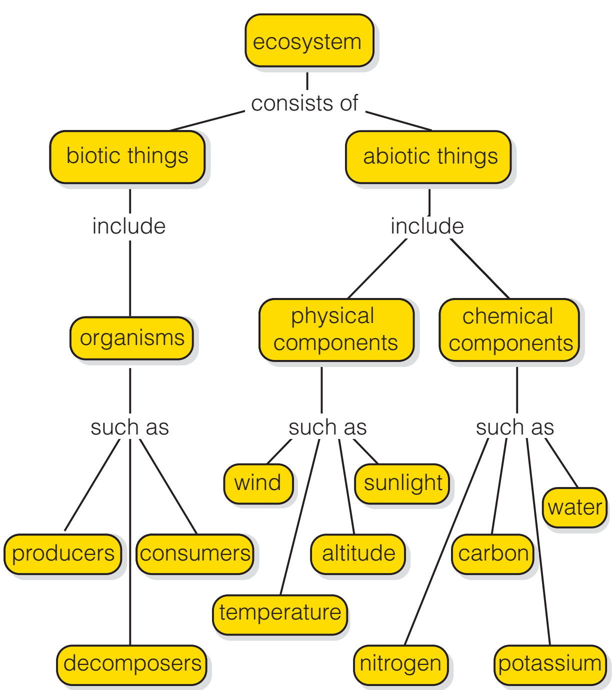
1. Describe two ways in which each of the following technological developments has affected society positively:
   (a) dam building
   (b) production of supertankers
   (c) mass production of the automobile
   (d) mass production of computers
   (e) harnessing nuclear reactions
2. Now describe two ways in which each of the above technologies has affected or might affect society negatively.
3. How would you evaluate whether each of the technologies in question 1 is "good" or "bad" for society?
4. For each of the technologies in question 1, record ideas you have on the kinds of scientific knowledge that were necessary for its development.
5. An issue has two or more possible solutions, and a decision must be made in favour of one solution over the others. In weighing the advantages and disadvantages of the solutions, is it important to take into account:
   (a) Who benefits from the solution?
   (b) Who is affected by the costs or disadvantages?
   (c) Should we be careful in selecting a solution based on who" proposes a solution? Why or why not?
6. As a class, discuss the possible shortage of fresh water. Identify possible solutions and consider the benefits and risks of each solution. Do the solutions involve the use of technology? Do we have enough scientific knowledge to assess the risks attached to each solution? Is there a simple answer? Is there a solution that does not interfere with the environment at all? If so, is it a realistic solution?

Using Graphic Organizers

A graphic organizer is a way of arranging ideas visually. A typical graphic organizer consists of a group of boxes or circles in which key terms or concepts are written. Lines connecting the boxes show how the concepts are connected. Sometimes a short phrase is written on the lines to explain the connection. Graphic organizers are tools that help you understand and remember new ideas and information. You can often recognize new relationships when you use a graphic organizer. Several examples of graphic organizers are described below. These graphic organizers are sometimes also called *concept maps*.

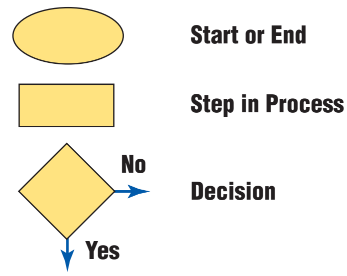
Network Tree

A graphic organizer called a network tree starts with a description of one central concept or idea written in a box. Terms that describe characteristics or smaller parts of the central concept are written in more boxes. The lines, or branches of the tree, show how the central concept is broken down into smaller parts. The example below shows the things that make up an ecosystem.

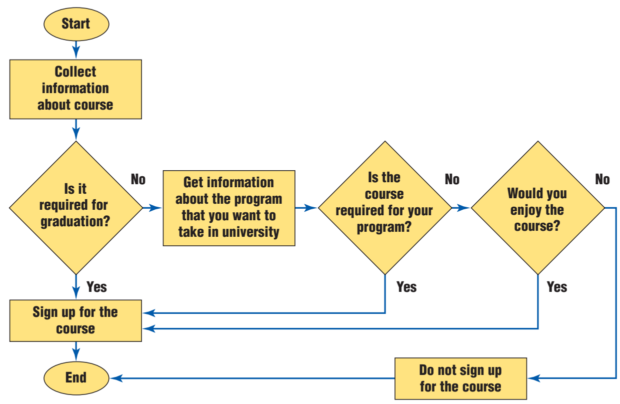


Flowchart

A flowchart is a graphic organizer that shows the steps in a procedure or a process. Flowcharts use specific shapes to represent specific types of steps. Three basic shapes and their meaning are shown here.

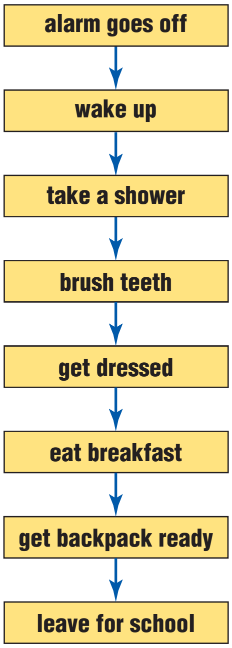


The following flowchart is a process for choosing classes you will take in school next year.



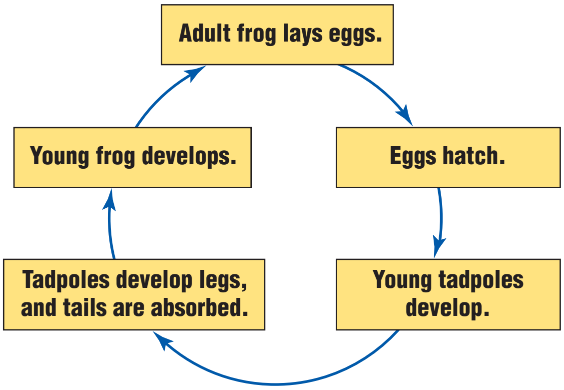
Events Chain

A graphic organizer called an events chain shows the order in which events occur. The events chain on the right shows what happens after your alarm goes off in the morning.



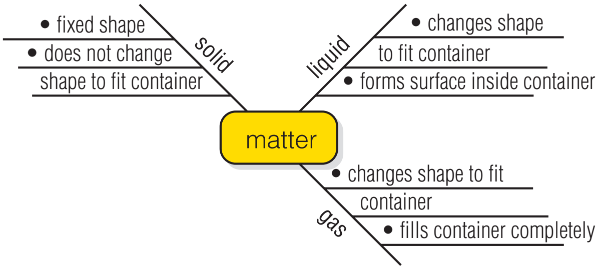
Cycle Map

A graphic organizer called a cycle map is like an events chain that has no beginning and no ending. The events occur over and over. Since the events are placed in a circle, you need arrows to show the order in which the events occur. The cycle map below shows the life cycle of a frog.



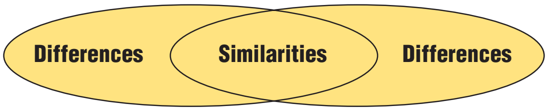
Spider Map

A graphic organizer called a Spider Map connects several objects or ideas to one central event or object. You can use a spider map for brainstorming. To draw a spider map, you place the most important event or object in the centre of the page. Then you write related ideas, events, or descriptions on lines drawn outward from the centre. These topics might not be related to each other, but they are related to the central topic. Finally, you write other ideas or descriptions on horizontal lines connected to the lines that point outward. The map soon begins to look like a spider, as shown here. This spider map describes the three states of matter. The central idea, matter, is the "body" of the spider. The related ideas, solid, liquid, and gas, are the "legs" of the spider.

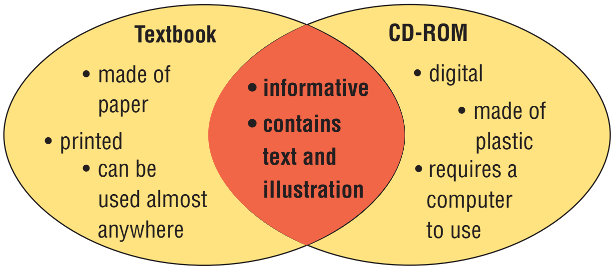


Venn Diagram

A graphic organizer called a Venn Diagram shows the similarities and differences among objects or ideas. Venn diagrams are made of two or more overlapping ovals or circles. Each oval represents a concept, an object, or an idea. In the area in which the ovals overlap, you write the similarities between the objects or ideas. You write the differences in the parts of the circles that do not overlap. Study the following example to see the similarities and differences between a print textbook and an e-book CD-ROM.



Example



Instant Practice

1. Use these words to produce a network tree: hockey, team sports, ice, diamond, field, bat, puck, hardball, cleats, ice skates, baseball, soccer ball, stick, soccer, feet.
2. Produce an events chain that starts with lunch and ends with your return home from school.
3. Produce a cycle map using the following words: summer, winter, fall, spring.
4. Make a Venn diagram to compare and contrast a video cassette and a DVD.
5. In a group, create a spider map based on one of the following topics:
   (a) food and nutrition
   (b) music
   (c) scientific discoveries
   (d) communication

Glossary

How to Use This Glossary

This Glossary provides the definitions of the Key Terms that are shown in boldface type in the text. (Instructional boldfaced words such as "observe" and "explain" are not included.) The Glossary entries also show the sections where you can find the boldfaced words. A pronunciation guide, using the key below, appears in square brackets after selected words.

a = mask	ee = leaf, clean	u = wonder, Sun
ae = same, day	ih = idea, life	uh = taken, travel
ah = car, farther	i = simple, this	uhr = insert, turn
aw = dawn, hot	oh = home, loan	
e = met, less	oo = food, boot	

A

abyssal plain [a-BIS-uhl] the wide open regions of the ocean floor between the continents and the mountain ranges at the centre of the ocean (2.1)

acid precipitation precipitation that carries acids formed by nitrogen and sulfur oxides, produced by burning coal and gasoline, that have combined with water in the air (3.3)

amplitude [AM-pli-tyood] the distance between the highest point (crest) on a wave and the rest position; also, the distance between the lowest point (trough) and the rest position (4.2)

angle of incidence (*i*) the angle between the incident ray and the normal (5.1)

angle of reflection (*r*) the angle between the reflected ray and the normal (5.1)

angle of refraction (*R*) the angle between the normal and the refracted ray (5.1)

aperture [A-pur-chur] an opening through which light enters a camera (6.3)

aquaculture [AW-kwa-kul-chur] the growing and harvesting of marine species in a controlled marine area (3.3)

Archimedes' principle [ar-ki-ME-dees] explains why some objects float in water while others sink; states that the buoyant force acting on an object equals the weight of the fluid displaced by the object; if the force of gravity is greater than the buoyant force, the object will sink, and vice versa (9.1)

arm of a microscope supports the eyepiece; carry a microscope by the arm (10.1)

astigmatism [a-STIG-muh-TIZ-um] a condition in the eye in which the cornea has a distorted shape, causing blurred vision (6.2)

atmosphere the air surrounding the planet (1.1)

average density the total mass of all of the substances that make up an object divided by the total volume of the object (9.1)

B

balanced forces the condition in which for every force acting on an object there is another force that is equal in strength and opposite in direction; the net force on the object is zero (9.1)

base of a microscope supports the entire microscope (10.1)

bays indented areas of coastland or areas in the coastline that are in between headlands (2.3)

bioindicator species organisms that are sensitive to pollution or other environmental changes; monitoring the numbers of these organisms helps scientists to gather information about the health of an ecosystem (3.2)

bioluminescence [BIH-oh-loom-in-ES-ens] light produced by chemical reactions in the bodies of some living marine organisms (3.2)

blind spot the area in the eye where the optic nerve enters the retina; has no light-sensing cells (6.2)

blindness any vision impairment that prevents a person from carrying out regular activities; ranges from partial to complete inability to detect light (6.2)

boiling the process by which a liquid is rapidly converted into a gas (7.1)

boiling point the temperature at which a substance is transformed from a liquid to a gas (7.1)

breaker the crest of a wave that topples forward, collapsing onshore (2.3)

buoyancy [BOY-uhn-see] the upward force on objects submerged in (under the surface of) or floating on a fluid (9.1)

buoyant force [BOY-unt] same as buoyancy (9.1)

C

cell the smallest, most basic functional system of any living thing (10.1)

cell membrane surrounds and protects the cell and controls the movement of substances into and out of the cell (10.2)

cell theory one of the key ideas of biology; helps scientists explain their observations of living things; states that all living things are made of cells and all cells come from other living cells (10.2)

cell wall tough, rigid structure that surrounds the cell membrane of plant cells (10.2)

change of state the process by which a substance is transformed from one state (solid, liquid, gas) to another state (7.1)

charge-coupled device (CCD) a detector at the back of a camera that absorbs light and provides the electrical signals needed to produce a digital image (6.3)

chloroplast [KLO-roh-plast] organelle found in plant cells that contains chlorophyll, which traps energy from the Sun (10.2)

circulatory system the heart and all of the vessels that transport blood to and from the heart ; also transports oxygen, nutrients, and wastes (11.2)

climate weather conditions of a specific area averaged over a long period of time, usually 30 years (3.1)

coarse adjustment knob of a microscope is used only with the low power lens and helps to bring the sample into focus (10.1)

colour blindness the ability to see only in shades of grey (6.2)

compound light microscope a microscope that has two sets of lenses (10.1)

compressibility the ability of a substance to be squeezed into a smaller volume or space (9.3)

compression wave a wave for which the action making the wave is back and forth along the direction in which the wave is moving (4.2)

concave lens lens that is indented in the centre; thinner in the centre than at the edges; causes light rays to diverge, or spread apart, which makes the image appear smaller (6.1)

concave mirror curved mirror for which the centre is behind the outer edges; the mirrored surface is curved inward (5.3)

concentration the amount of a substance dissolved in another substance, usually water (7.3)

condensation the change of state in which a gas is transformed into a liquid (7.1)

cone cells cone-shaped cells in the retina of the eye that absorb light and allow you to detect colour (6.2)

continental shelf the submerged, or underwater, part of the edge of the continents that slopes gradually away from land before dropping steeply downward (2.1)

continental slope the submerged area of the edge of the continents, beyond the continental shelf, that drops steeply down to the ocean basin (2.1)

controlled variable a variable that is held constant (not allowed to change) during an experiment (9.3)

convection the process of heat transfer from one place to another by the movement of warm fluids from place to place (3.1)

convex lens a lens that bulges outward on both sides; thicker in the centre than at the edges; causes light rays to converge, or point toward each other (6.1)

convex mirror curved mirror for which the centre protrudes out beyond the outer edges; the mirrored surface is curved outward (5.3)

Coriolis effect [kor-ee-OH-luhs] the change in the direction of winds and currents caused by the rotation of Earth (2.2)

cornea [COR-nee-a] a transparent tissue that covers the iris and pupil of the eyeball; helps to maintain the shape of the eye (6.2)

crest the highest part of a wave (2.3 ; 4.2)

crevasse [kru-VAWS] a deep crack in a glacier (1.3)

cytoplasm [SIH-toh-plaz-um] the jelly-like part of a cell that contains the organelles and dissolved substances (10.2)

D

density the amount of mass in a certain volume; how tightly packed together the material is in a substance (1.2; 8.1)

density current a movement or flow of water along the sea floor caused by the sinking of dense water (cold water has higher density than warm water, and highly salty water has higher density than water with low salinity) (2.2)

deposition the change of state in which a gas is transformed directly into a solid without going through the liquid state (7.1)

diaphragm [DIH-uh-fram] a ring that controls the amount of light entering a camera (6.3)

diffuse reflection reflection of light that does not produce an image but instead makes it possible to see what is on the surface of the reflecting material (5.1)

digestive system all of the organs that take in and process food and eliminate solid waste, including the mouth, stomach, and intestines (11.2)

displacement a technique for measuring the volume of an irregularly shaped object by measuring how much water it displaces or "takes the place of" (8.2)

drainage basin the area of land from which water drains into a certain body of water (1.3)

E

electromagnetic radiation a repetitive movement, not of particles, but of electric and magnetic energy through space (4.4)

endocrine system [EN-doh-crin] human body system that manufactures and releases hormones; composed of glands and ducts (11.2)

energy the capacity to apply force over a distance (4.2)

estuary an area of wetlands that builds up where a river meets the ocean (3.2)

evaporation the change of state in which a substance is transformed from a liquid into a gas (7.1)

excretory system the organs that filter the blood and eliminate water-soluble wastes; includes the kidneys and tubes and ducts connected to the kidneys (11.2)

extended ray an imaginary line that extends from a light ray in a straight line to show where the eye perceives an image to be located; may extend from an incident ray to a point behind a mirror, or from a refracted ray to a point in front of a lens (5.2)

eyepiece lens of a microscope or telescope through which the observer looks; contains a lens that magnifies the object being observed (10.1)

F

far-sighted a vision impairment in which distant objects are clearly visible but nearby objects appear fuzzy; caused by light rays converging to form an image behind the retina (6.2)

fine adjustment knob of a microscope is used with the medium and high power lenses to bring the sample precisely into focus (10.1)

flow rate the amount of fluid that flows past a point in a given amount of time (7.2)

fluid any thing that flows; a liquid or a gas (7.1)

focal length [FOH-cuhl] the distance from the centre of a lens to the focal point of the lens (6.1)

focal point of a mirror or lens is the point at which converging light rays meet or from which light rays diverge (5.3)

force anything that causes a change in the motion of an object; a push or pull on an object (4.2; 9.1)

freezing point the temperature at which a substance freezes or solidifies (1.2; 7.1)

frequency the number of repetitive motions, or vibrations, of a wave that occur in a given amount of time; measured in cycles per second or Hertz (Hz) (4.2)

G

gamma rays the portion of the electromagnetic spectrum with the highest energy, highest frequency, and lowest wavelength; result from nuclear reactions; used in cancer therapy (4.4)

gas the state of matter that takes the shape of its surroundings and fills its container (7.1)

genetic factors things that are inherited that can affect the balance of the body systems (12.2)

glacier a large compressed mass of ice and snow that does not melt away in the summer (1.3)

global warming the increase in the average temperatures of Earth's oceans and air near Earth's surface (1.3)

gravity the force that pulls all masses toward the centre of Earth or any large mass (1.3)

ground water precipitation that falls on land and sinks out of sight and remains in cracks underground (1.3)

H

headlands the parts of the coastline that project farther out into the ocean than the land next to them (2.3)

hertz cycles per second; unit used to measure frequency of a wave (4.2)

homeostasis ability of the body to maintain an internal balance (12.2)

hydraulics [HIH-drah-liks] the study of pressure in liquids (9.3)

hydraulic multiplication the ability to increase and transmit a force through a liquid from one point to another (9.3)

hydraulic systems devices that transmit applied force through a liquid to move something else (9.3)

hydrosphere all of the water on Earth including that in the atmosphere and lithosphere (1.1)

I

iceberg a large chunk of ice that has broken off a glacier and floats in the ocean (1.3)

image the likeness, or appearance, of an object as seen in a mirror or through a lens (5.2)

image distance the distance between the mirror or lens and the image (5.2)

immune system human body system that defends the body against diseases and infections; composed of lymph nodes, lymph vessels, and lymph tissue (11.2)

incident ray a ray that strikes a reflecting or refracting surface (5.1)

incompressible the inability of a substance to be squeezed into a smaller volume or space; describes liquids and solids (9.3)

infrared waves electromagnetic waves having wavelengths between 3×10^{-4} m and 7×10^{-7} m (4.4)

integumentary system [in-TEG-yoo-MEN-tuh-ree] human body system that serves as a waterproof protective barrier between the external environment and the body's internal environment; composed of skin (11.2)

invasive species a new or foreign species that is introduced into a food web (3.3)

inverted oriented in the direction opposite to that of the object; often referred to as "upside-down" (5.2)

iris [IH-ris] the coloured circle of muscle surrounding the pupil; controls the amount of light entering the eye (6.2)

iris diaphragm [DIH-uh-fram] of a microscope controls the amount of light reaching the specimen (10.1)

K

kinetic energy [ki-NET-ik] the energy of motion; any moving object or particle has kinetic energy (7.3)

L

law of reflection states that the angle of reflection of a light ray is equal to the angle of incidence, or the angle at which the ray strikes the reflecting surface (5.1)

lens a curved piece of transparent material, such as glass or plastic, that refracts light in a predictable way; can be used to focus an image (6.1)

lifestyle factors factors within a person's control that affect the balance of body systems; examples are diet and exercise (12.2)

light source of a microscope supplies the light needed to view the specimen (10.1)

liquid the state of matter that has a specific volume but its shape is determined by its container (7.1)

lithosphere [LITH-oh-sfeer] the solid rocky ground of Earth's crust (1.1)

M

magnification power the number of times larger an image appears under the lens (10.1)

mass the amount of matter an object has (8.2; 9.1)

mass-to-volume ratio the mass of an object divided by its volume; the way to determine the density of a substance or an object (8.2)

medium the material or substance through which a wave is moving (4.2)

melting the process of transformation of a substance from a solid to a liquid (7.1)

melting point the temperature at which a solid is transformed into a liquid (7.1)

microscope an optical device used to magnify extremely small objects, such as micro-organisms; composed of a combination of lenses (4.1)

microwaves electromagnetic waves having wavelengths between 0.3 cm and 30 cm (4.4)

mitochondria [mih-toh-KAWN-dree-uh] organelles in animal and plant cells that break down food particles to release the energy stored in them (10.2)

mitosis [mih-TOH-sis] the process of cell division, during which the genetic material duplicates and then separates into two identical sets of chromosomes (10.2)

muscular system the muscle tissues responsible for movement in the body (11.2)

N

neap tide [neep] the smallest tidal movements that occur when the Sun and the Moon are at right angles to each other (2.3)

near-sighted a vision impairment in which nearby objects can be seen clearly, but distant objects appear blurry; caused by light rays converging to form an image before they reach the retina (6.2)

nervous system the brain, spinal column, and all of the nerves that extend throughout the body; carries information about the body and the external surroundings to and from the brain; controls and coordinates body activities (11.2)

neutral buoyancy [BOY-uhn-see] the condition in which the forces acting on an object that is submerged in or floating on a fluid are balanced (9.1)

night blindness a vision impairment in which it is difficult or impossible to see in dim light; often caused by rod cells losing the ability to respond to light (6.2)

normal an imaginary line perpendicular to a surface such as a mirror or lens (5.1)

nucleus organelle in plant and animal cells that contains all of the genetic information that directs the development, reproduction, and maintenance of cells (10.2)

nutrients substances that make up the food you eat; include proteins, fats, and carbohydrates (12.1)

O

object distance the distance between the mirror or lens and the object (5.2)

objective lens the lens in a microscope or refracting telescope through which the light first enters; magnifies the object or specimen being observed; most microscopes have three objective lenses (10.1)

ocean current a large amount of ocean water that moves in a particular and unchanging direction (2.2)

ocean ridges the undersea mountain chains that are formed when magma oozes up and solidifies between tectonic plates that are moving apart (2.1)

opaque [oh-PAEK] material that prevents visible light from penetrating it; an object cannot be seen through such a medium (5.1)

optical centre the point where the principal axis intersects the centre of a lens (6.1)

optic nerve a nerve that transmits electrical signals from the eye to the brain (6.2)

organ a distinct structure containing different types of tissues that work together to perform a specific task (11.1)

organ system a group of organs that work together to perform a specific task (11.1)

organelle a structure inside a cell that performs a specific function (10.2)

overfishing more of a particular species of fish are removed from an area than can be replaced by reproduction (3.3)

P

particle model of light a model of light behaviour based on the assumption that light is a stream of particles that travel in a straight line (5.1)

particle theory of matter theory that all matter consists of tiny particles that follow five basic rules (7.1)

pascal a unit used to measure pressure; 1 Pa is equal to 1 N/m^2 (9.3)

phytoplankton [fih-toh-PLANK-tun] microscopic plant-like organisms that are a major source of food for many species of fish (3.2)

plane mirror a flat, smooth mirror, or reflecting surface (5.2)

pneumatic systems [NOO-mat-ic] devices in which a gas is used to transmit force; force is exerted on a gas in an enclosed space to compress the gas and build up force that can be used elsewhere (9.3)

pressure the force acting on a certain area of a surface (9.3)

principal axis a line that is normal, or perpendicular, to the centre of a mirror or lens (5.3)

pupil [PYOO-puhl] an opening through which light enters the eye; the black circle in the centre of your eye (6.2)

Pythagoras [puh-THAG-or-us] a Greek philosopher who believed that light beams were made up of tiny particles (4.1)

R

radiant energy energy, such as light, that spreads out from a source in all directions (4.4)

radio waves electromagnetic waves having wavelengths from a few centimetres to several kilometres long (4.4)

ray diagram demonstrates the path of light from an object using straight lines (5.1)

ray model of light a simplified model in which light is represented as a straight line, or ray, that shows the direction in which the light is travelling (5.1)

real image the image formed when reflected or refracted rays meet; when a screen is placed at the image position, the image can be seen on the screen (5.3)

rectilinear propagation [RECT-uh-LIN-ee-ar PROP-uh-GAE-shun] describes a property of light: light travels in straight lines (5.1)

reflected ray the ray leaving a reflecting surface after an incoming ray has struck the surface (5.1)

reflecting telescope a telescope that uses a combination of a concave mirror, a plane mirror, and a convex lens to collect and focus light from distant objects (6.3)

reflection the process in which light or another type of wave interacts with a surface and is sent back from the surface (4.3)

refracted ray a ray that describes the direction of light after passing from one medium to another of different density (5.1)

refracting telescope a telescope that uses a combination of lenses to focus light from distant objects (6.3)

refraction the changing of direction or bending of light or other type of wave when travelling from one medium to another medium having a different density (4.3)

reproductive system human body system that produces specialized sperm cells in the male and egg cells in the female that combine to produce offspring; composed of the ovaries, oviducts, uterus, and vagina in the female, and the testes, penis, and other glands and vessels in the male (11.2)

resolving power of a microscope is the ability to distinguish between two objects that are very close together; measured as the smallest distance between two objects for which the viewer can still see that there are two separate objects instead of just one (10.1)

respiratory system a group of organs that control breathing and exchange gases between the body and the surroundings (11.2)

retina [RE-tin-uh] a screen-like tissue at the back of the eye where an image is formed; contains light-sensitive rod and cone cells (6.2)

revolving nosepiece the section of the microscope that includes the objective lenses and can be rotated to place a specific lens in position (10.1)

rod cells specialized cells in the retina that absorb light and allow you to detect shapes and movement in low-light conditions (6.2)

run-off precipitation that falls to land and flows into creeks, streams, and rivers and eventually into the ocean (1.3)

S

salinity [suh-LIN-i-tee] the amount of salt dissolved in a specific amount of water (1.2)

sclera an opaque tissue that surrounds the cornea and helps to maintain the shape of the eye; the white region surrounding the iris (6.2)

skeletal system human body system that supports the body, provides protection for some organs, and works with the muscles to move parts of the body; composed of bone tissue (11.2)

snow blindness a condition of temporary partial or complete blindness cause by overexposure to sunlight that is reflected from snow (6.2)

solid state of matter that has a definite shape and volume (7.1)

solidification the change of state in which a liquid is transformed into a solid (7.1)

specific heat capacity the amount of heat needed to raise the temperature of a specific amount of a substance by 1.0°C (3.1)

spectrum the array of colours of light that result from the separation or dispersion of white light (4.3)

specular reflection [SPEK-yoo-lahr] type of reflection that produces an image of the surroundings (5.1)

spring tide the largest tidal movements that occur when Earth, the Moon, and the Sun are in a line (2.3)

stage the platform of a microscope on which the slide sits and is held in place by the clips (10.1)

static pressure occurs when force is applied to an enclosed fluid (a fluid that is not moving) (9.3)

sublimation the change of state in which a solid is transformed directly into a gas without going through the liquid state (7.1)

swell a long smooth wave that moves steadily without breaking (2.3)

system a group of individual parts that work together as a whole to accomplish a task (11.1)

T

telescope an optical device used to magnify distant objects, such as stars and planets; composed of a combination of lenses or lenses and mirrors (4.1)

thermocline part of the ocean below the surface where the temperature drops sharply with depth (2.2)

tidal range the difference between high tide and low tide (2.3)

tide slow rise and fall of the ocean caused by the gravitational pull of the Moon and the Sun (2.3)

tissue a group of similar cells that work together to carry out a specific function (11.1)

total magnification the number of times an image under a microscope has been magnified; found by multiplying the magnification power of the objective lens by the magnification power of the eyepiece lens (10.1)

translucent [tranz-LOO-sent] material that allows light to pass through but scatters it in the process; an object observed through such a material appears fuzzy (5.1)

transparent material that allows light to pass through with no change in the direction of the rays; an object can be clearly seen through such a medium (5.1)

transverse wave a wave for which the action making the wave is perpendicular to the direction in which the wave is travelling (4.2)

trench the deep area that is formed when an ocean plate collides with a continental plate and is forced to bend steeply down beneath the continental plate (2.1)

trough the lowest part of a wave (2.3; 4.2)

tsunami [tsoo-NAH-mee] a giant wave caused by an earthquake, volcanic eruption, or landslide on the ocean floor (2.3)

tube or barrel is the part of a microscope to which the eyepiece is attached and provides the pathway for light to travel from the objective lenses to the eyepiece (10.1)

U

ultraviolet waves electromagnetic waves with wavelengths between 4×10^{-7} m and 4×10^{-9} m (4.4)

unbalanced forces the condition in which, for every force acting on an object, there is no equal and opposite force acting on it; the net force on an object is not zero (9.1)

upright oriented in the same direction as the object; often referred to as "right-side up" (5.2)

upwelling vertical movement of water from the ocean floor, often caused by wind blowing surface water away from a shore (2.2)

V

vacuole [VAC-yoo-ohl] membrane-bound sack in the cytoplasm of cells in which materials or water are stored (10.2)

vertex the point at which the principal axis meets a mirror (5.3)

virtual image image that appears to be the source of light rays, though no rays are actually coming from it; if you place a screen at the position of a virtual image, no image will be visible on the screen (5.2)

viscosity [vis-KAW-si-tee] the "thickness" or "thinness" of a fluid; how easily a fluid flows (7.2)

visible light a form of energy that you can detect with your eyes (4.3)

volume the amount of space taken up by an object or substance (8.2)

W

water cycle the evaporation of water into a gas in the atmosphere and the precipitation of water in the air as it falls back to Earth in the form or rain or snow (1.1)

wave a disturbance or movement that transfers energy through matter or space, without causing any permanent displacement (4.2)

wave model of light a model in which light is a type of wave that travels through space and transfers energy from one place to another (4.3)

wavelength distance from one wave crest to the next; length of one unit of a wave that repeats itself (2.3, 4.2)

weather the short-term conditions in the atmosphere at a specific place and time (3.1)

weight the measure of the force of gravity acting on the mass of an object (9.1)

X

X rays electromagnetic waves with very short wavelengths, between about 3×10^{-9} m and about 1×10^{-12} m (4.4)

Z

zooplankton [ZOO-oh-plahk-tun] tiny animals that eat other types of plankton for food; also a food source for larger marine animals (3.2)

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