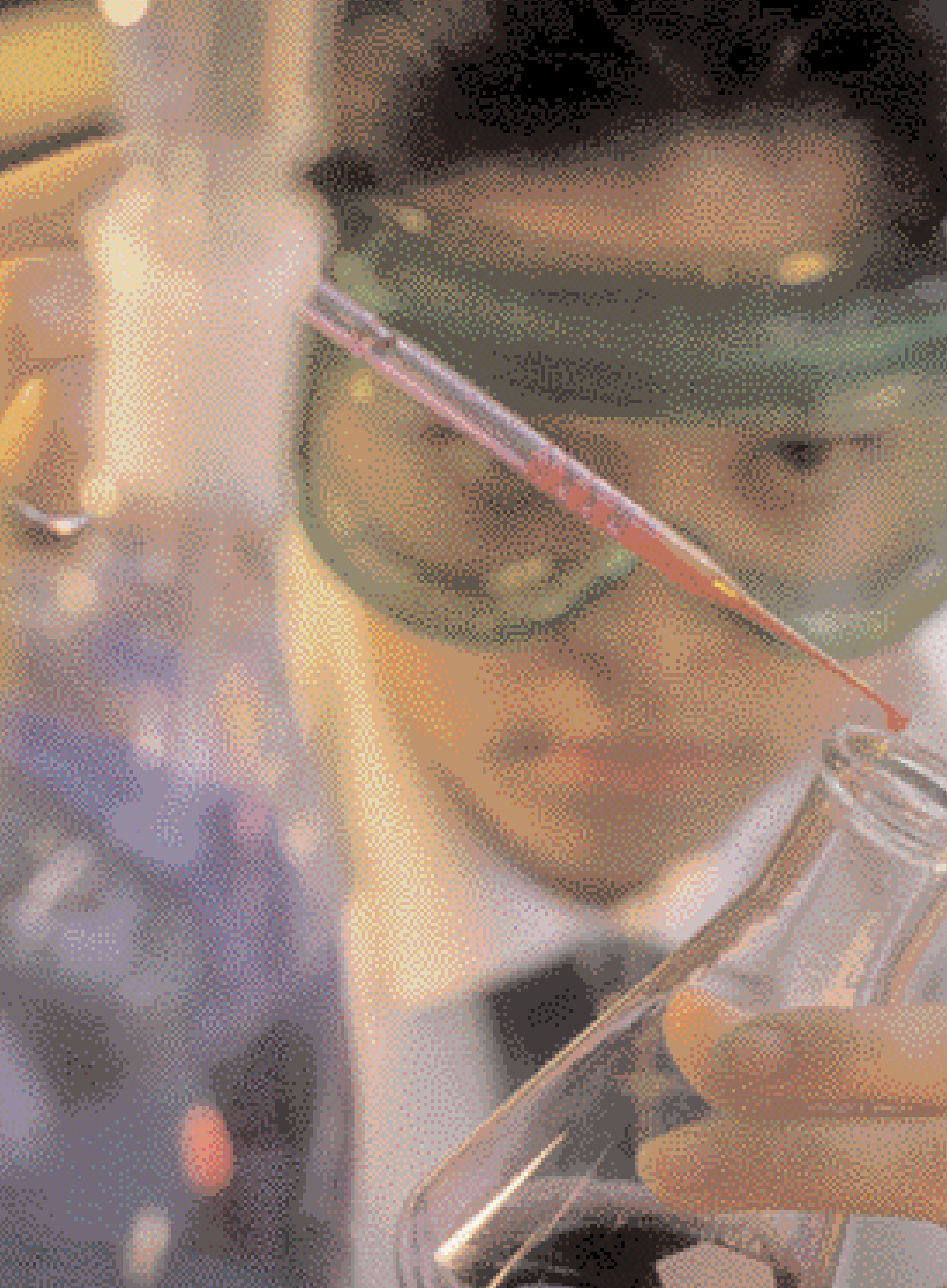

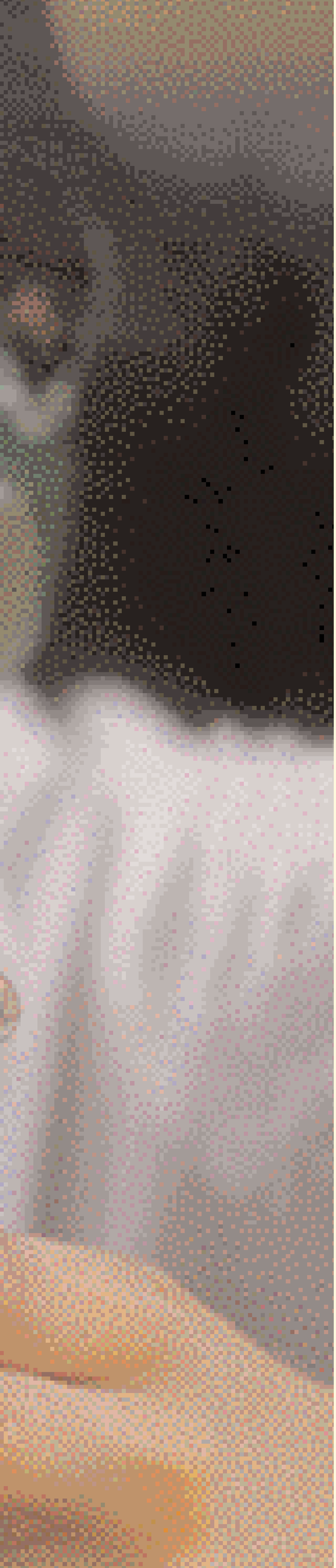

Skills Handbook

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1A Safety Conventions and Symbols

Safety Conventions in *Nelson Science 9*

When you perform the investigations in *Nelson Science 9*, you will find them challenging, interesting, and safe. However, you should be aware that accidents can happen. In this text, chemicals, equipment, and procedures that are hazardous are highlighted in red and are preceded either by the appropriate WHMIS symbol (illustrated below) or by one of the following:

 general caution  electrical hazard

You should always read cautions carefully and make sure you understand what they mean before you proceed. If you are in doubt about anything, be sure to ask someone who knows (e.g., your teacher, a classmate, or a parent).

Hazardous Household Product Symbols (HHPS)

You are probably familiar with the warning symbols in **Figure 1**. They appear on a number of products that are common in most households. These warning symbols were developed to indicate exactly why and to what degree a product is dangerous.

Workplace Hazardous Materials Information System (WHMIS) Symbols

The Workplace Hazardous Materials Information System (WHMIS) symbols in **Figure 2** were developed to standardize the labelling of dangerous materials used in all workplaces, including schools. Become familiar with these warning symbols and pay careful attention to them when they appear in *Nelson Science 9* and on any products or materials that you handle.

Figure 1

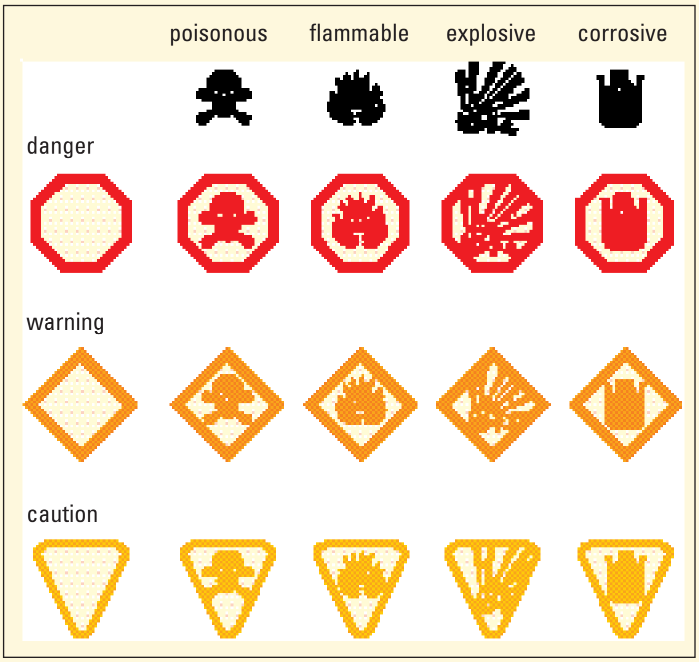
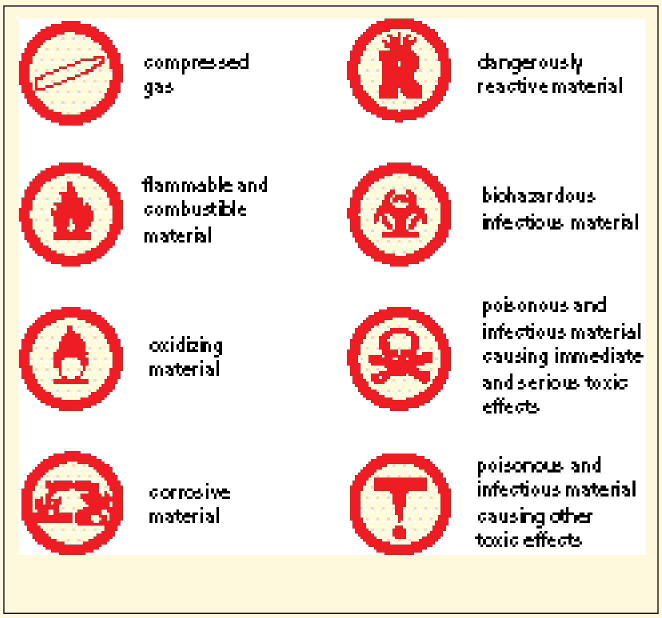


Figure 2



1B Safety in the Laboratory

The Importance of Safety

Certain safety hazards exist in any laboratory. You should know about them and about the precautions you must take to reduce the risk of an accident.

Why is safety so important? Think about the safety measures you already take in your daily life. Your school laboratory, like your kitchen or the squash court, need not be a dangerous place. In any situation, you avoid accidents when you understand how to use materials and equipment and follow proper procedures. What do you use to take cookies out of the oven? What safety precautions do you take when you play squash? What are the common safety procedures related to swimming and boating?

Safety in the laboratory combines common sense with the foresight to consider the worst-case scenario. The activities in this textbook have been tested and are safe, as long as they are done with proper care. While your teacher will give you specific information about safety rules for your classroom and for conducting investigations, you should always consider setting safety rules on your own.

Preventing Accidents

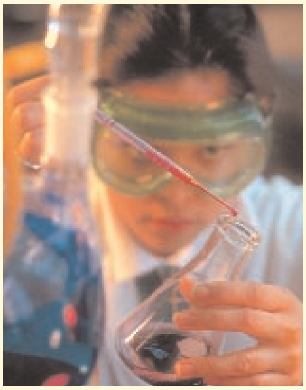
Most accidents that occur in the lab are caused by carelessness. Knowing the most common causes of accidents can help you prevent them. These include:

- applying too much pressure to glass equipment (including microscope slides and cover slips)
- handling hot equipment without proper precautions
- measuring and/or mixing chemicals incorrectly
- working in a messy or disorganized space
- paying too little attention to instructions and working distractedly
- failing to tie back long hair or loose clothing

Setting Safety Rules

Before You Start

1. Learn the location and proper use of the safety equipment available to you, such as safety goggles, protective aprons, heat-resistant gloves, eye wash station, broken glass container, first-aid kit, fire extinguishers, and fire blankets. Find out the location of the nearest fire alarm.
2. Inform your teacher of any allergies, medical conditions, or other physical impairments you may have. Do not wear contact lenses when conducting investigations—if a foreign substance became trapped beneath the lens, it would be difficult to remove it.
3. Read the procedure of an investigation carefully before you start. Clear the laboratory bench of all materials except those you will use in the investigation. If there is anything you do not understand, ask your teacher to explain. If you are designing your own experiment, obtain your teacher's approval before carrying out the experiment.
4. Wear safety goggles and protective clothing (a lab apron or a lab coat), and tie back long hair. Remove loose jewellery. Wear closed shoes in the laboratory, not open sandals.
5. Secure any potentially dangerous or fragile equipment that could be hazardous if tipped over. Use the appropriate stands, clamps, and holders.
6. Never work alone in the laboratory.



Working with Chemicals

7. Do not taste, touch, or smell any material unless you are asked to do so by your teacher. Do not chew gum, eat, or drink in the laboratory.
8. Be aware of where the MSDS (Material Safety Data Sheet) manual is kept. Know any relevant MSDS information for the chemicals you are using.
9. Label all containers. When taking something from a bottle or other container, double-check the label to be sure you are taking exactly what you need.
10. If any part of your body comes in contact with a chemical or specimen, wash the area immediately and thoroughly with water. If your eyes are affected, do not touch them but wash them immediately and continuously with cool water for at least 15 min and inform your teacher.
11. Handle all chemicals carefully. When you are instructed to smell a chemical in the laboratory, take a few deep breaths before waving the vapour toward your nose. This way, you can smell the material without inhaling too much into your lungs. Only this technique should be used to smell chemicals in the laboratory. Never put your nose close to a chemical.

12. Place test tubes in a rack before pouring liquids into them. If you must hold a test tube, tilt it away from you before pouring in a liquid.

13. Clean up any spilled materials immediately, following instructions given by your teacher.
14. Do not return unused chemicals to the original containers, and do not pour them down the drain. Dispose of chemicals as instructed by your teacher.

Heating

15. Whenever possible, use electric hot plates for heating materials. Use a flame only if instructed to do so. If a Bunsen burner is used in your science classroom, make sure you follow the procedures listed below.
    - Obtain instructions from your teacher on the proper method of lighting and adjusting the Bunsen burner (**Figure 1**).
    - Do not heat a flammable material (for example, alcohol) over a Bunsen burner. Make sure there are no flammable materials nearby.
    - Do not leave a lighted Bunsen burner unattended.
    - Always turn off the gas at the valve, not at the base, of the Bunsen burner.

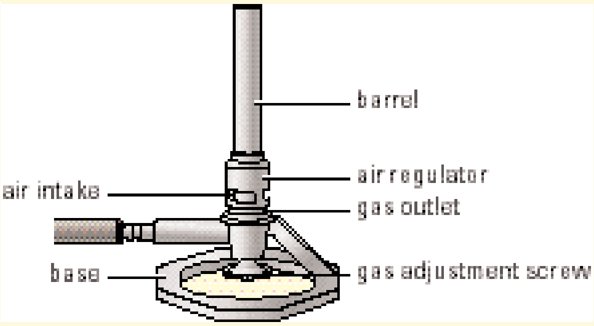


Figure 1
The Bunsen burner

16. When heating liquids in glass containers, make sure you use clean Pyrex or Kimax. Do not use broken or cracked glassware. If the liquid is to be heated to boiling, use boiling chips to prevent "bumping." Always keep the open end pointed away from yourself and others. Never allow a container to boil dry.
17. When heating a test tube over a flame, use a test-tube holder. Hold the test tube at an angle, with the opening facing away from you and others. Heat the upper half of the liquid first, then move it gently in the flame, to distribute the heat evenly.

18. Be careful when handling hot objects and objects that might be hot. Hot plates can take up to 60 min to cool completely. Test that they are cool enough to move by touching first with a damp paper towel. If you hear sizzling or see steam, wait a little longer! If you burn yourself, immediately apply cold water or ice, and inform your teacher.

Other Hazards

19. Keep water and wet hands away from electrical cords, plugs, and sockets. Always unplug electrical cords by pulling on the plug, not the cord. Report any frayed cords or damaged outlets to your teacher. Make sure electrical cords are not placed where someone could trip over them.
20. Be sure to have your teacher inspect any electric circuits before you turn on the electrical power.
21. Place broken and waste glass in the specially marked containers. Wear heavy gloves while picking up the pieces.
22. Follow your teacher's instructions when disposing of waste materials.
23. Report to your teacher all accidents (no matter how minor), broken equipment, damaged or defective facilities, and suspicious-looking chemicals.
24. Wash your hands thoroughly, using soap and warm water, after working in the science laboratory. This practice is especially important when you handle chemicals, biological specimens, and microorganisms.

Try This: Student Safety Contract

Many teachers have students sign Student Safety Contracts. They serve to show just how important safety really is. Create a Student Safety Contract that you and your teacher will sign that lists potential safety hazards and safety rules, and the reasons for these rules.

2A Controlled Experiments

Science is about observing things, asking questions, proposing solutions, and testing those solutions. One way of doing this is through controlled experiments. A controlled experiment is a test in which one variable (something that can change or vary in your experiment) is purposely and steadily changed to find out what (if any) effect occurs.

For instance, you may observe that plants grow upward and ask yourself, "Why?" Various solutions might suggest themselves. To test those solutions, you can design a controlled experiment. Perhaps you think that the reason plants grow upward is because they grow toward the light. This is your hypothesis. From your hypothesis, you can make a prediction that you can test through experimentation, for instance: "As the angle of light shining on plants steadily increases, the angle of the plants' growth should steadily increase."

To design a controlled experiment to test this hypothesis, you need to control, or keep constant, as many of the variables, or possible causes of the effect, as possible. You might conduct an experiment on five identical plants, ensuring that all growing conditions—water, nutrients, temperature, kind of light, etc.—are the same. You would then change one variable, the angle of light shone on the plant, and measure the results.

You can use a control group as well **(Figure 1)**. In the plant experiment, you could have a plant that has sunlight shining on it from directly above. If the hypothesis is correct, this plant will not grow at an angle. It is the control for the experiment, and the other plants are the test cases. The control is set up exactly like the test cases, but no variable is changed.

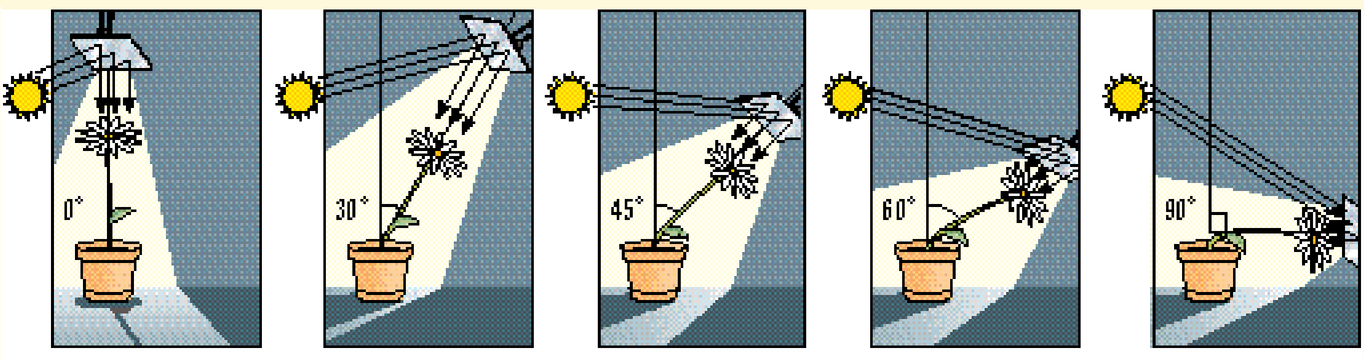
Unfortunately, scientists can never be sure that they have controlled all possible causes of the effects. Because of this, they can never be absolutely sure that the conclusions they make are true. However, the more the results match the prediction, the more confident the scientists can be about their hypotheses.

The Process of Scientific Inquiry in Controlled Experiments

Scientists use an inquiry process to find answers to their questions. This process is also referred to as the Scientific Method. There are common components for an inquiry that allow scientists to duplicate experiments so results can be validated and communicated. These components are outlined in the flow chart in **Figure 2**.

It is important that you follow this process and use the related skills whenever you are asked to design and conduct an experiment, if you expect to find reliable answers to the questions you pose. You can use the flow chart as an overall checklist. You can also refer to the more detailed sections in this Skills Handbook that deal with each of the specific skills necessary for each part of the process.

Figure 1



1 Asking a Question

All inquiry begins with curiosity. Our experience and observations of the world often lead us to ask questions. Ask a question that interests you or express an idea that can be tested. State the purpose of your experiment.

2 Making a Hypothesis

Research the subject of your question. Review the literature and find out as much as you can about previous information and discoveries surrounding your question.

Develop an educated guess that answers your initial question. This is your hypothesis. Make a prediction based on your hypothesis and state it as a cause-effect relationship.

3 Designing the Experiment

Identify all your variables.

Decide what materials and apparatus you will need to perform your experiment.

Write a procedure that explains how you will conduct your experiment. Be sure to take safety into account.

Draw a labelled diagram that illustrates your procedure and the materials and apparatus you will use.

Create a rough draft of tables for recording your data.

4 Conducting the Experiment

Follow the steps in the procedure carefully and thoroughly.

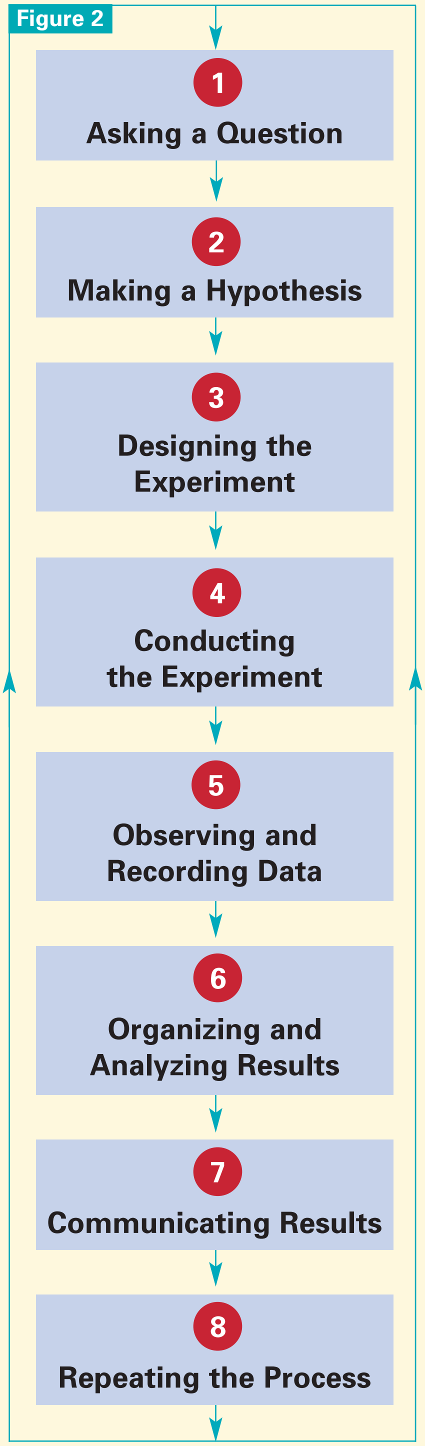
Use all equipment and materials safely, accurately, and with precision.

Record the variable(s) you are measuring, manipulating, and controlling.

Remember to repeat your experiment at least three times. If you are collecting quantitative data, take an average. This increases the accuracy and reliability of your results.

Make careful notes of everything that you observe during the experiment.

Figure 2



5 Observing and Recording Data

Describe the qualitative (anecdotal comments) and quantitative (numerical data) results clearly and accurately.

6 Organizing and Analyzing Results

When appropriate, create graphs to make better sense of quantitative data from your tables.

Study your qualitative observations and quantitative observations.

Identify patterns and trends.

Make a conclusion. Decide whether your results support, partially support, or refute your hypothesis.

Develop an explanation for your conclusion.

Apply your findings to your life today. Think about who will want to know about your discovery, how it will affect our lives, who it will benefit, and whether it could harm our world if used in a certain way.

Reflect on your experiment. Explore any sources of experimental error in your process. Think about any changes you would make if you were to conduct this experiment in the future.

7 Communicating Results

It is important that scientists share their findings. In order to have their investigations repeated and validated, it is common for scientists to publish details of their research, results, and conclusions.

8 Repeating the Process

Most scientists must complete an experiment many times before making important discoveries (e.g., a cure for cancer). If your experiment did not answer the question you initially asked, it must be revised and repeated until the question is answered or the problem is solved.

Try This — Getting It Right

Research two famous Canadian scientists, Dr. F. G. Banting and C. H. Best, then answer the following questions:

1. How many days, months, or years did it take Banting and Best to discover insulin?
2. Did they find the solution to their problem by doing their experiment once? If your answer was no, find out how many times they had to repeat their experiment before getting it right.

2B Correlational Studies

Is it wise for a pregnant woman to consume alcohol, or smoke, or drink coffee? In attempting to answer questions like these, it is often difficult to know all the variables, let alone control them. A correlational study is an alternative to a controlled experiment. In a correlational study, a scientist examines whether a variable is affecting another variable without purposely changing any of the variables. Instead, variables are allowed to change naturally.

You are probably more familiar with correlational studies than with experiments. These studies are frequently summarized in newspapers, under headlines like "Chemical X Suspected in Heart Disease." Next time you are reading a newspaper, try to decide which articles would be classified as correlational studies.

Correlational studies are often chosen to test hypotheses that may be unsafe, impossible, or unethical to test with a controlled experiment. For instance, you might observe that some students appear to be hard of hearing and that they also spend a lot of time listening to loud music. This might lead you to hypothesize that listening to loud music damages hearing. It would be unethical to make students listen to loud music and then measure hearing damage. However, you could ask many students what the volume settings are on their radios and tape and CD players, determine how loud those settings are with a sound meter, and then test the students' hearing. Graphing one variable against the other will suggest whether there is a relationship between them.

It is more difficult to isolate cause and effect in correlational studies. Any two variables can be compared. It is important for the scientist to assess whether a reasonable link is possible. As an extreme example, one could check the annual tea production in China against the frequency of taxi accidents in Hamilton and discover that the years of highest tea production correspond to the years of the greatest number of taxi accidents. Could you expect to predict the frequency of accidents in the future by the amount of tea grown in China? This kind of correlation is likely to be a coincidence.

The Process of Scientific Inquiry in Correlational Studies

The flow chart in **Figure 1** outlines the components that are important in designing a correlational study. By following this format, investigators can do science without doing experiments or fieldwork. Instead, they can use data banks, CD-ROMs, the Internet, interviews, and surveys to find relationships between two or more variables. They can also, of course, make their own observations and measurements. You can use this flow chart as a checklist to make sure you use all the steps necessary in completing a reliable correlational study.

Look at the flow charts outlining Controlled Experiment and Correlational Studies. Can you identify major similarities and differences between a controlled experiment and a correlational study?

Try This — What Kind of Investigation?

With a partner, look through some scientific journals and find five articles. Decide whether each article is a controlled experiment or a correlational study. Give reasons for your answers. Organize your information in a chart.

1 Making an Observation

Choose a topic that interests or puzzles you.

2 Asking a Question

Ask a question. State the purpose of the study.

3 Developing a Hypothesis

Research your subject. Review the literature and find out as much as you can about previous information, predictions, and discoveries surrounding your question.

Develop an educated guess that answers your initial question. This is your hypothesis.

Research alternative hypotheses and revise your original hypothesis.

4 Gathering Data

Your data can be collected by measuring, interviewing, or taking a survey. You can also use data collected by others (e.g., governments, banks, insurance companies, and scientific organizations).

Choose two variables for further study. (You are looking for one variable that may have a natural effect on the other.) Develop a hypothesis about them.

Develop or find ways to measure the two variables.

Plan to make as many measurements as it takes to get a continuous and wide collection of measurements of the variables.

Try to make measurements and observations in the same way each time.

5 Organizing and Recording Results

Plan appropriate tables to hold your observations.

6 Analyzing Results and Conclusions

Using the data in your tables, develop graphs in which the two variables you have chosen are plotted against each other.

Describe all results, including observations you made that you could not measure.

Describe the strengths and weaknesses of the methods you used.

Conclude whether the results support your original hypothesis. If not, suggest a modified hypothesis.

Make suggestions for future work on this topic.

7 Reporting on the Study

Tell others about your work and your conclusions. Consider any new questions that might require further study.

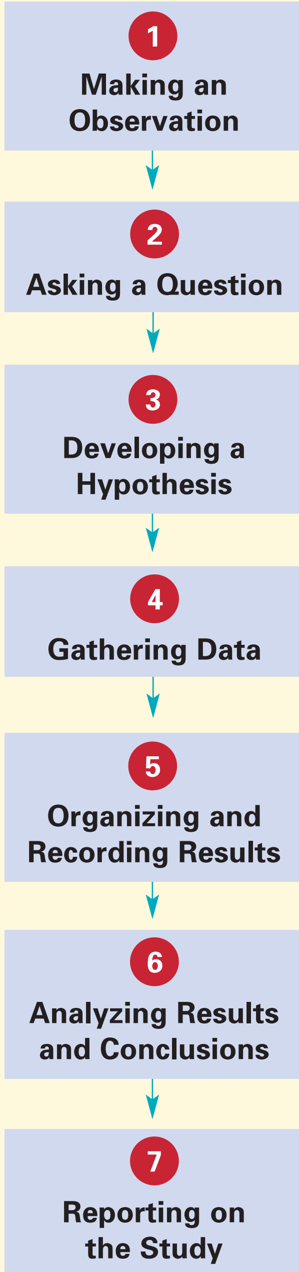


Figure 1

3 Research

3A Research Skills

There is an incredible amount of information available in our society, from a number of different sources, including the newspaper, the Internet, and the neighbourhood or school library. Your generation has the ability to access more information than any other generation in history. Information is simply information, however. Before you can make effective use of it, you must know how to gather information efficiently. As well, you must know how to assess its credibility.

Where do you obtain your information? Think about all the information sources that you interact with in the course of a typical day. Now think about where you might go to access other sources of information. Compare your list of available resources with the list shown in **Table 1**. Certainly, there is no shortage of resources.

General Research Tips

- Before you begin, list the most important words associated with your research, so you can search for appropriate topics.
- Brainstorm a list of possible resources. Rank the list, starting with the most useful source.
- Use a variety of resources.
- Ask yourself: "Do I understand what this resource is telling me?"
- Check when the resource was published. Is it up-to-date?
- Keep organized notes or files while doing your research.
- Keep a complete list of the resources you used, so you can make a bibliography when writing your report. (See Reporting Your Work on page 564, for proper referencing formats.)
- Review your notes. After your research, you may want to alter your original problem or hypothesis.

Table 1

Information Consultants (people who can help you locate and interpret information)		Reference Materials (sources of packaged information)	
teachers	business people	encyclopedias	bibliographies
nurses	scientists	magazines/journals	newspapers
public servants	librarians	videotapes	slides
volunteers	veterinarians	data bases	almanacs
lawyers	senior citizens	yearbooks	maps
parents	doctors	charts	radio
farmers	politicians	films	dictionaries
members of the media		biographies	textbooks
		pamphlets	television
		filmstrips	records
Places (sources beyond the walls of your school)		**Electronic Sources**	
public libraries	shopping malls	world wide web (www)	
parks	colleges	CD-ROMs	
research laboratories	government offices	on-line search engines	
historic sites	zoos	on-line periodicals	
universities	volunteer agencies	computer programs	
businesses	museums		
farms	hospitals		
art galleries			

Some Specific Research Tips

Using a Library

School libraries use an international system, known as the Dewey Decimal Classification System, to organize books into the major subject areas shown in **Table 2**.

Table 2

Catalogue #	Subject Area
000	Generalities
100	Philosophy & Psychology
200	Religion
300	Social Science
400	Language
500	Natural Science & Mathematics
600	Technology (Applied Sciences)
700	The Arts
800	Literature
900	Geography/History

Using On-line Sources

"Think of an [Internet] search engine as a dog whistle. Blow it in a kennel and you'll just attract dogs. Blow it in a zoo, and you'll get a few dogs, plus many other creatures with good high frequency hearing: maybe some lions or tigers, hyenas, coyotes, timber wolves, perhaps a moose… The point is this—the Internet is a zoo." from Jeffery K. Pemberton's column in *Online User* magazine, May/June 1996.

The Internet is a large and fairly unstructured network. Many Internet navigation programs access and make use of several search engines. Search engines are on-line tools that find web sites (or hits) based on key words you enter into the search. When researching on-line, consider these additional research tips.

- If you have a specific web site address, go to the direct source first.
- If you need to use a search engine, find two good search engines, bookmark them, and use them. While the "Search" buttons in navigation programs are useful, they will not always give you the best search engine for your purposes.
- Learn about the features of the search engine. The better search engines make use of Boolean logic, operations that are used to combine key words when searching the Internet. In these cases, adding the word "AND" can let you narrow your search by combining two key words. Adding the word "OR" can let you expand your search by joining together two key words. Lastly, adding the word "NOT" enables you to disregard a key word. Be sure to refine your search as you continue. For example, entering the word "music" may give you 1 678 243 hits but adding "AND guitar" will reduce your search results to 18 860 hits. Including "NOT classical" will further reduce your number of hits to 2340.
- Familiarize yourself with the advanced search option within each search engine.
- Look over the first few pages of hits before you start exploring each web site. Be patient and go with your intuition.

Try This: Canadian Scientists

With a partner, use the General Research Tips as a guide to research the contributions and life of one female Canadian scientist and one male Canadian scientist. You may want to choose your scientists from the following list:

Roger Daley (Meteorologist)
Birute Galdikas (Expert on Orangutans)
Gerhard Herzberg (Physicist)
Doreen Kimura (Behavioural Psychologist)
Julia Levy (Microbiologist)
John Polanyi (Chemist)
Endel Tulving (Expert on Human Memory)
Irene Uchida (Expert on Down Syndrome)

3B Critical Thinking

Communicating the results of your own work is important, but what about the work of others? Understanding and evaluating the work of others is an important part of communication. Think about how many messages, opinions, and pieces of information you hear and see every day. When you do research, you may access information via the Internet, textbooks, magazines, chat lines, television, radio, and through many other forms of communication. Is all of this information "correct"? Are all of these information sources "reliable"? How do we know what to believe and what not to believe?

Every day you see and hear extraordinary claims about objects and events (**Figure 1**). Often science, or the appearance of science, is used as a way of convincing us that the claims are true. Sometimes this method of reporting is used to get you to buy something or just to catch your interest. Even serious stories on scientific work are sometimes difficult to interpret, especially when they are reported in a way that makes the scientific work sound important, official, and somewhat mysterious.

To analyze information, you have to use your mind effectively and critically. When you encounter a "scientific" report in the media, analyze the report carefully, and see if you can identify the following:

- the type of investigation that is being reported (experiment or correlational study)
- the dependent and independent variables in any reported investigation (refer to Designing a Procedure, page 536)
- the strengths and weaknesses in the design of the investigation.

Try This **Scientific Journalism**

Analyze a scientific report or story from one of the following magazines by peforming the tasks listed above—

Scientific American	*Popular Mechanics*
Discover Magazine	*Maclean's*

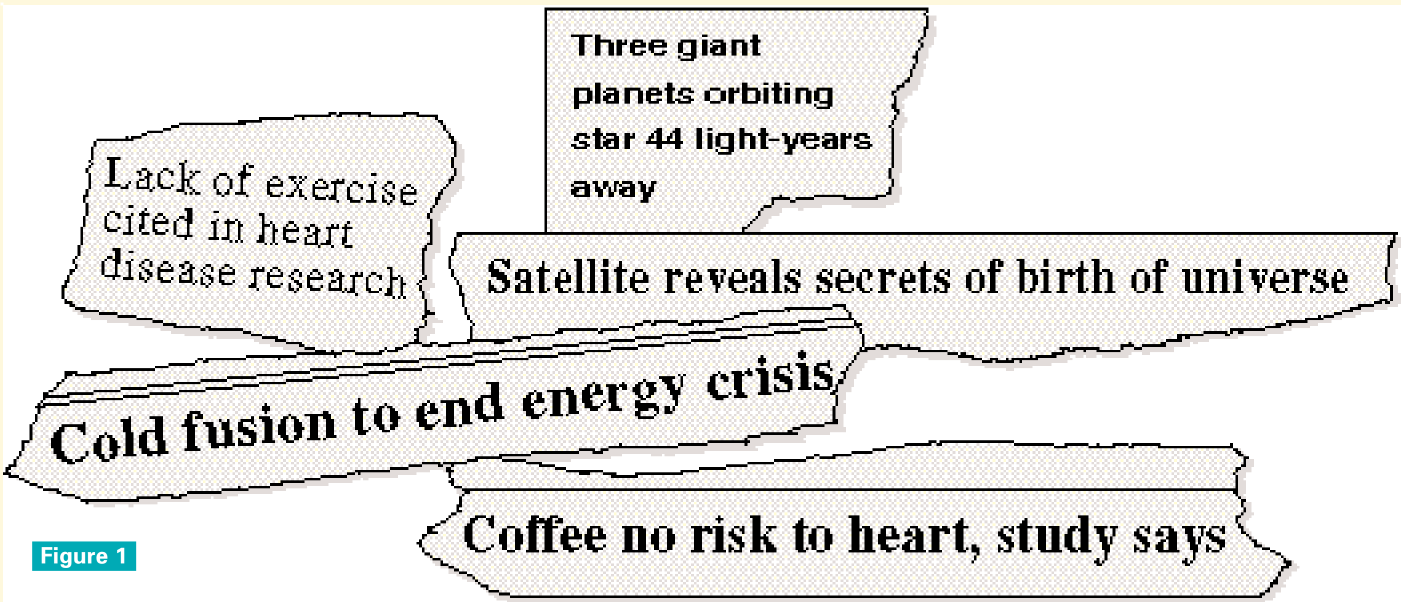


Figure 1

PERCS

A lot of research has been done to help people develop critical thinking skills. One very good, practical framework is known as PERCS. It was founded at Central Park East Secondary School (CPESS) in New York City, NY. In the interest of preparing themselves for their world, the students at CPESS use a series of questions to help them think critically about information and arguments. You might think of this framework as a box of useful "tools" that will allow you to effectively build an educated and critical opinion concerning an issue.

The PERCS Checklist

P = Perspective
From whose viewpoint are we seeing or reading or hearing?
From what angle or perspective?

E = Evidence
How do we know what we know?
What's the evidence and how reliable is it?

R = Relevance
So what?
What does it matter?
What does it all mean?
Who cares?

C = Connections
How are things, events, or people connected to each other?
What is the cause and what is the effect?
How do they "fit" together?

S = Supposition
What if….?
Could things be otherwise?
What are or were the alternatives?
Suppose things were different.

Try This **PERCS**

Try exercising your critical thinking skills. Reread the article that you selected in the last Try This or read the article below. Using the questions listed in the PERCS checklist, critically think about the article you chose.

Study Concludes Children of Smokers More Likely to Be Criminals

According to a study carried out by North American and European researchers this year, the child of a mother who smoked during pregnancy is more likely to commit a crime than the child of a mother who is a non-smoker.

Researchers looked at the statistics for violent and nonviolent crimes committed by men born around 1960 and investigated the smoking habits of their mothers during pregnancy. They found that the sons of women who smoked the most had a one in four probability of getting into trouble with the law.

The discoveries provide evidence to support the implementation of education campaigns aimed at persuading pregnant mothers not to smoke.

Suggestions for further study include an investigation into whether smoking affects fetal brain development, which might in turn affect antisocial behaviour. Alternatively, the observed factors might be coincidental, both possibly caused by genes carried by both mothers and sons.

4A Asking Questions and Hypothesizing

Asking Questions

Have you ever noticed that balloons stick to walls if you rub them on your head? This observation might lead you to wonder about a number of things: Does a balloon stick better if you rub it more times? Does the length or texture of a person's hair affect how well a balloon sticks? Does it matter how inflated the balloon is or what colour it is?

Each of these questions is the basis for a sound scientific investigation. With a little rewording, it will become clear how these questions can be tested. Not every question that you will want an answer for can be tested: some are too general, or too vague. Learning to ask questions that can be tested takes time and is a fundamental skill in scientific inquiry.

The first balloon-related question could be stated more usefully: "What is the effect of increasing the number of times that a balloon is rubbed on a person's head on the length of time that the balloon stays stuck to a wall?" You can probably already begin to plan an experiment that would answer this question. A testable question is often about cause-effect relationships. These questions often take the form: "What *causes* the change in variables?" and "What are the *effects* on a variable if we change another variable?" As you know, a variable is something that can change or vary in an investigation.

Scientists call the cause variable the independent variable. This is the one thing in the experiment that you purposely change. For instance, increasing the number of times that a balloon is rubbed on a person's head is

Try This: Can You Test It?

Decide whether each of the questions in **Table 1** would be testable or impossible to test. Then make up some testable questions of your own.

Table 1

Question	Testable		Not Testable
	Independent (Cause) variable	**Dependent (Effect) variable**	
What is the effect of increasing the number of times that a balloon is rubbed on a person's head on the length of time that the balloon stays stuck to a wall?	balloon rubbed on a person's head	the length of time the balloon stays stuck to a wall	?
Does listening to loud music affect a teenager's ability to hear?	?	?	?
Does a rock think?	?	?	?
Do tennis balls bounce differently when wet?	?	?	?
Is there extra-terrestrial life in our universe?	?	?	?

something you control: you are changing the independent variable. The effect variable is called the dependent variable. This is what you measure in your experiment (e.g., time, distance) and it "depends" on the variable you purposely change (independent variable). The amount of time the balloon stays on the wall is the dependent variable.

A scientific question that asks what happens to a dependent variable when we change the independent variable is a question you can test.

Hypothesizing

A suggested answer or reason why one variable affects another in a certain way is called a hypothesis. Often you have some idea about this even as you ask your question. Having noticed, for instance, that a balloon sticks to the wall after you rub it in your hair, you might predict that rubbing it more will make it stick longer. You might be wrong, of course, but your prediction is probably based on past observations, on logic, and on bits of scientific theory you may remember. If you're really interested, you may even do some research based on what you already know. If you then pull everything you know together and express it, you would have a hypothesis. For instance, you might predict that the balloon sticks to the wall because it is attracted by static electricity, and that rubbing the balloon more produces a greater static electric charge on the balloon.

Predictions and hypotheses go hand in hand (**Table 2**). The hypothesis is how you can explain a prediction. The prediction is what you test through your experiment. And, if the experiment confirms the prediction, you can have more confidence that your hypothesis is correct.

Table 2 **Sample Hypotheses and Predictions**

Hypothesis (possible reason for cause-effect relationship)	Prediction	
	Possible cause (independent variable)	Possible effect (dependent variable)
Candy contains sugar that is used for energy by germs in the mouth, and these germs produce an acid that decays the teeth.	As the amount of candy that a person eats increases…	…the number of tooth cavities increases.
A larger sail traps more air, which then provides a greater force to a boat.	As the size of the sail increases…	…the top speed of the sailboat increases.
Salt helps oxygen in the air combine with iron in the metal of a bicycle to form rust.	As the amount of salt on a road increases…	…the amount of rusting of the metal parts of a bicycle increases.

Try This Hypothesize

Now it's your turn. With a partner, think of a few hypotheses and predictions that could be tested. Use a chart similar to **Table 3** to record your thoughts.

Table 3
Hypotheses and Predictions of Cause-Effect Relationships

Hypothesis (possible reason for cause-effect relationship, an educated guess)	Possible cause (independent variable)	Possible effect (dependent variable)
?	?	?
?	?	?

4B Designing a Procedure

Now that you are an expert at asking testable questions and hypothesizing about their possible answers, it is time to learn to design an experiment that will test your hypothesis.

Remember that an independent variable is the possible cause and a dependent variable is what the effect will be. Another important variable in an experiment is called the controlled variable. One way to control an experiment is to control—keep constant—all known possible causes of the result except one. As is shown on page 526, for example, there are many factors that must remain the same in order for the experiment on plant growth to be reliable. What would the independent variable be in this experiment? What would the dependent variable be in this experiment? What must be controlled in this experiment to make the results reliable?

To design a procedure that will test your hypothesis, you must identify your variables and design a control. You must decide how you will change your variable, and what you will observe and/or measure with each change. You must also decide how regularly you will make your observations and how you will record them. This may require you to create some tables for recording your data. Obviously, you must also decide what materials and equipment you will use. It is useful to create a labelled diagram that illustrates the materials and equipment you will need, and the procedure you are going to use.

Writing a Procedure

This is an essential component of an experimental design. Anyone who is interested in learning about your experiment needs to be able to understand how it was performed, so that it can be duplicated exactly. Therefore, it is important that you be able to write an experimental procedure clearly, concisely, and accurately.

When writing a procedure you should use

- numbered steps
- passive voice (avoid using pronouns)
- past tense

For example, the first two steps of a procedure could look like this:

Procedure

1. The experiment was set up as shown in the diagram.
2. The temperature of the water was measured every 5 min.

Don't forget to consider all possible safety issues!

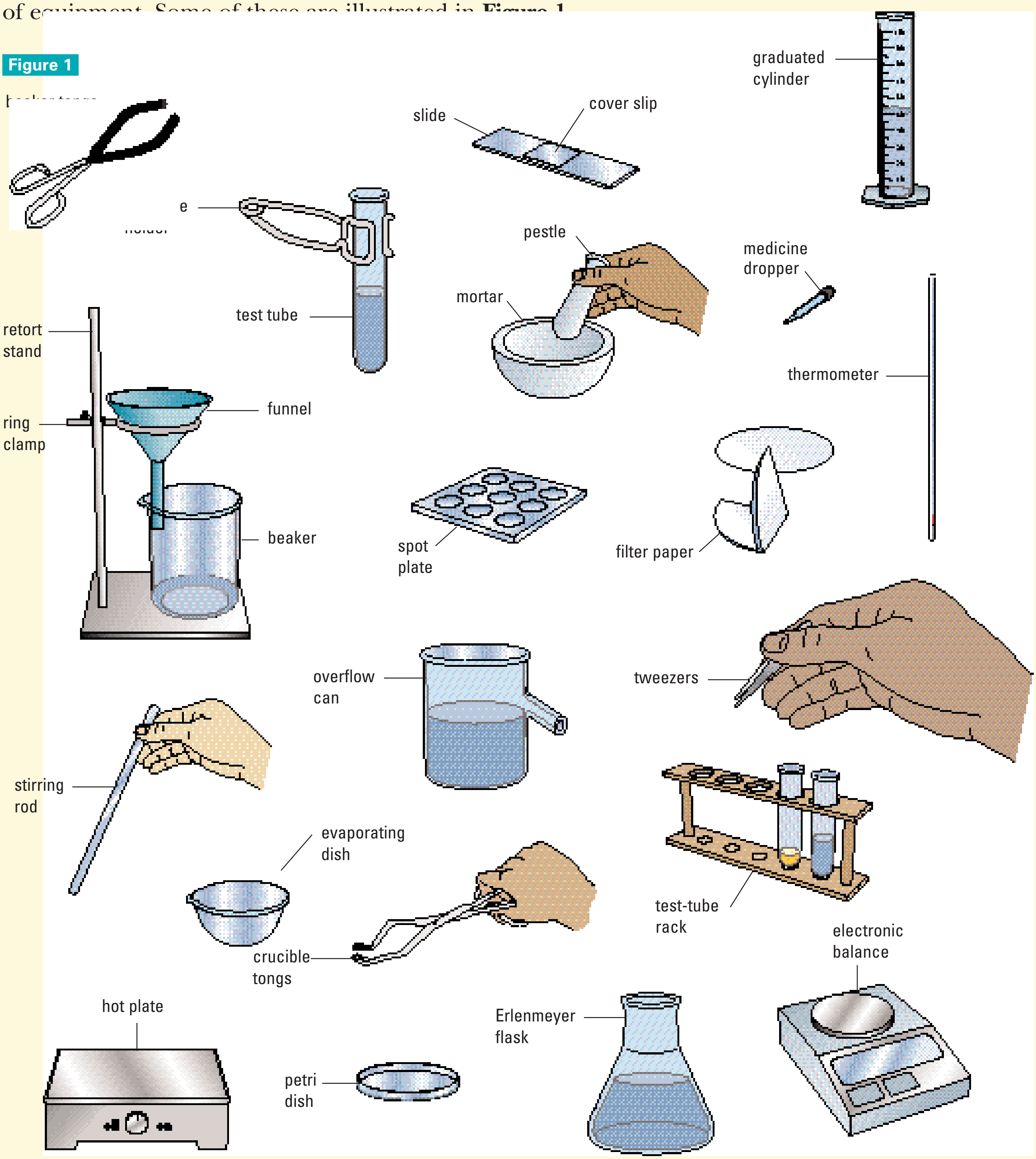
Try This: Write a Procedure

Think about how you would conduct an experiment that would give the answer to the question, *Do plants grow toward sunlight?* Write a procedure for this plant experiment, using the format explained above.

5A Laboratory Equipment

You can do many science investigations using everyday materials and equipment. In your science classroom, there are other pieces of equipment. Some of these are illustrated in **Figure 1**.

Figure 1



5B Using the Microscope

Because cells are small, you must make them appear larger than they really are in order to see and study them. To view cells closely, you will use a compound light microscope (**Figure 1**). It employs two lenses and a light source to make the object appear larger. The object is magnified by a lens near your eye, the ocular lens (sometimes called the eyepiece), and again by a second lens, the objective lens, which is just above the object. The comparison of the actual size of the object with the size of its image is referred to as magnification.

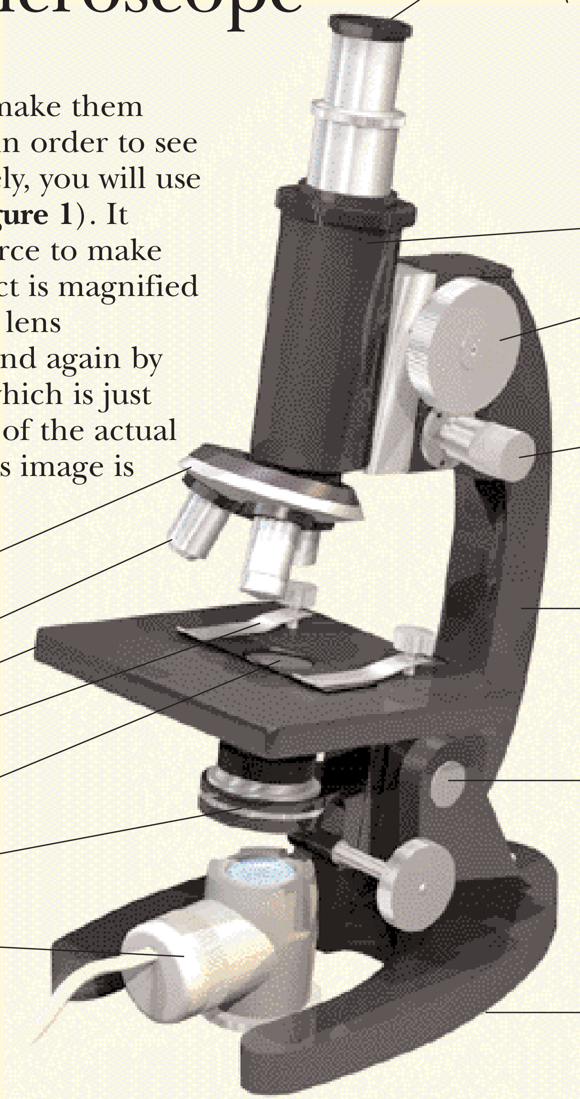


Figure 1 **Parts of the Microscope**

Structure	Function
stage	Supports the microscope slide. A central opening in the stage allows light to pass through the slide.
clips	Found on the stage and used to hold the slide in position.
diaphragm	Regulates the amount of light reaching the object being viewed.
objective lenses	Magnifies the object. Usually three complex lenses are located on the nosepiece immediately above the object or specimen. The smallest of these, the low-power objective lens, has the lowest magnification, usually four times (4X). The medium-power lens magnifies by 10X, and the long, high-power lens by 40X.
revolving nosepiece	Rotates, allowing the objective lens to be changed. Each lens clicks into place.
body tube	Contains ocular lens, supports objective lenses.
ocular lens	Magnifies the object, usually by 10X. Also known as the eyepiece, this is the part you look through to view the object.
coarse-adjustment knob	Moves the body tube up or down so you can get the object or specimen into focus. It is used with the low-power objective only.
fine-adjustment knob	Moves the tube to get the object or specimen into sharp focus. It is used with medium- and high-power magnification. The fine-adjustment knob is used only after the object or specimen has been located and focused under low-power magnification using the coarse adjustment.
condenser lens	Directs light to the object or specimen.

Basic Microscope Skills

The skills outlined below are presented as sets of instructions. This will enable you to practise these skills before you are asked to use them in the investigations in *Nelson Science 9*.

Materials

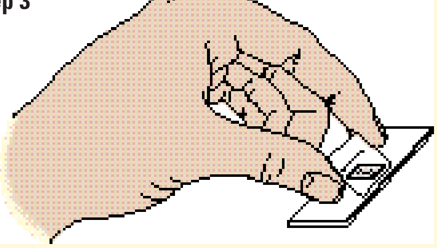
- newspaper that contains lower-case letter "f," or similar small object
- scissors
- microscope slide
- cover slip
- dropper
- water
- compound microscope
- thread
- compass or petri dish
- pencil
- transparent ruler

Preparing a Dry Mount

This method of preparing a microscope slide is called a dry mount, because no water is used.

1. Find a small, flat object, such as a lower-case letter "f" cut from a newspaper.
2. Place the object in the centre of a microscope slide.
3. Hold a cover slip between your thumb and forefinger. Place the edge of the cover slip to one side of the object. Gently lower the cover slip onto the slide so that it covers the object.

Step 3

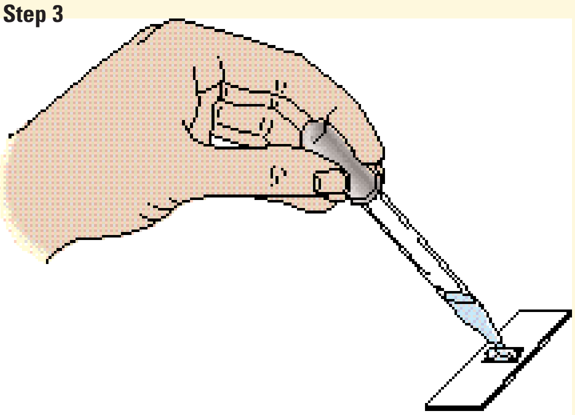


Preparing a Wet Mount

This method of preparing a microscope slide is called a wet mount, because water is used.

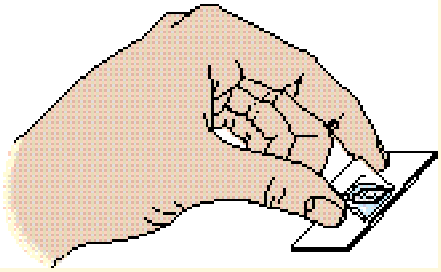
1. Find a small, flat object.
2. Place the object in the centre of a microscope slide.
3. Place two drops of water on the object.

Step 3



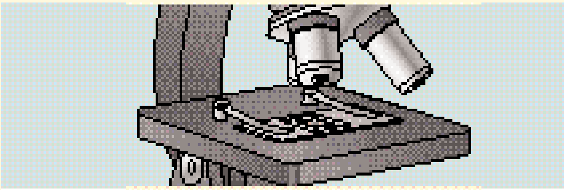
4. Holding the cover slip with your thumb and forefinger, touch the edge of the surface of the slide at a 45° angle. Gently lower the cover slip, allowing the air to escape.

Step 4



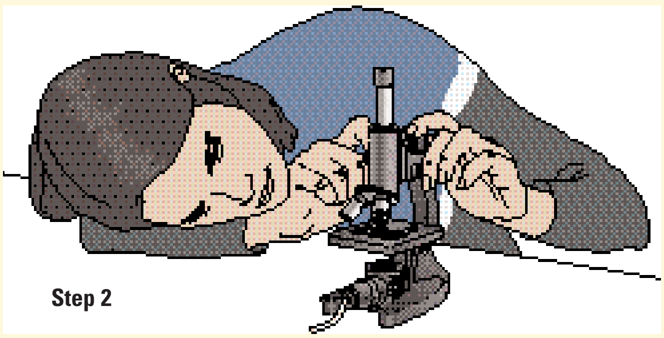
Positioning Objects Under the Microscope

1. Make sure the low-power objective lens is in place on your microscope. Then put either the dry or wet mount slide in the centre of the microscope stage. Use the stage clips to hold the slide in position. Turn on the light source.



Step 1

2. View the microscope stage from the side. Using the coarse-adjustment knob, bring the low-power objective lens and the object as close as possible to one another. Do not allow the lens to touch the cover slip.

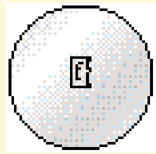


Step 2

3. View the object through the eyepiece. Slowly move the coarse-adjustment knob so the objective lens moves away from the slide, to bring the image into focus. Note that the object is facing the "wrong" way and is upside down.
4. Using a compass or a petri dish, draw a circle in your notebook to represent the area you are looking at through the microscope. This area is called the field of view. Look through the microscope and draw what you see. Make the object fill the same amount of area in your diagram as it does in the microscope.
5. While you are looking through the microscope, slowly move the slide away from your body. Note that the object appears to move toward you. Now move the slide to the left. Note that the object appears to move to the right.
6. Rotate the nosepiece to the medium-power objective lens. Use the fine-adjustment knob to bring the letter into focus. Note that the object becomes larger.

Never use the coarse-adjustment knob with the medium- or high-power objective lenses.

Step 6



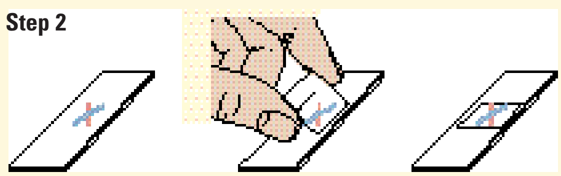
7. Adjust the object so that it is directly in the centre of the field of view. Rotate the nosepiece to the high-power objective lens. Use the fine-adjustment knob to focus the image. Note that you see less of the object than you did under medium-power magnification. Also note that the object seems closer to you.

Investigating Depth of Field

The depth of field is the amount of an image that is in sharp focus when it is viewed under a microscope.

1. Cut two pieces of thread of different colours.
2. Make a temporary dry mount by placing one thread over the other in the form of an X in the centre of a microscope slide. Cover the threads with a cover slip.

Step 2



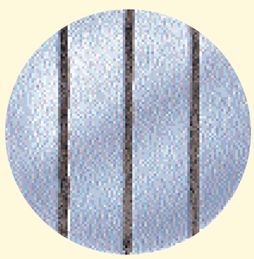
3. Place the slide on the microsocope stage and turn on the light.
4. Position the low-power objective lens close to, but not touching, the slide.

5. View the crossed threads through the ocular lens. Slowly rotate the coarse-adjustment knob until the threads come into focus.
6. Rotate the nosepiece to the medium-power objective lens. Focus on the upper thread by using the fine-adjustment knob. You will probably notice that you cannot focus on the lower thread at the same time. The depth of the object that is in focus at any one time represents the depth of field.
7. Repeat step 6 for the high-power objective lens. The stronger the magnification, the shallower the depth of field.

Determining the Field of View

The field of view is the circle of light seen through the microscope. It is the area of the slide that you can observe.

1. With the low-power objective lens in place, put a transparent ruler on the stage. Position the millimetre marks on the ruler immediately below the objective lens.
2. Using the coarse-adjustment knob, focus on the marks on the ruler.
3. Move the ruler so that one of the millimetre markings is just at the edge of the field of view. Note the diameter of the field of view in millimetres, under the low-power objective lens.



Step 3

4. Using the same procedure, measure the field of view for the medium-power objective lens.
5. Most high-power lenses provide a field of view that is less than one millimetre in diameter, so it cannot be measured with a ruler. The following steps can be followed to calculate the field of view of the high-power lens.

   Calculate the ratio of the magnification of the high-power objective lens to that of the low-power objective lens.

$$\text{Ratio} = \frac{\text{magnification of high-power lens}}{\text{magnification of low-power lens}}$$

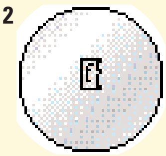
   Use the ratio to determine the field of diameter (diameter of the field of view) under high-power magnification.

$$\text{Field diameter (high power)} = \frac{\text{field diameter (low power)}}{\text{ratio}}$$

Estimating Size

1. Measure the field of view, in millimetres, as shown above.
2. Remove the ruler and replace it with the object under investigation.

Step 2



3. Estimate the number of times the object could fit across the field of view.
4. Calculate the width of the object:

$$\text{width of object} = \frac{\text{width of field of view}}{\text{number of objects across field}}$$

   Remember to include units.

Storage

When you complete an investigation using the micrscope, follow these steps:

1. Rotate the nosepiece to the low-power objective lens.
2. Remove the slide and cover slip (if applicable).
3. Clean the slide and cover slip and return them to their appropriate location.
4. Return the microscope to the storage area.

5C Using Star Maps

What Is a Star Map?

A star map shows the most easily seen stars in the sky, with many of the stars joined by lines into constellations. Each star map is designed for a range of latitudes, such as locations about 45° north of the equator. Thus, a star map designed for southern Canada cannot be used in Australia.

You can use a star map to help you recognize what you can see in the sky, and to observe the motions of objects as Earth goes through its cycles of rotation and revolution.

Maps for All Seasons

Different parts of the sky are visible during different times of the year. To show the different stars and constellations visible, different star maps have been designed for each of the seasons or even months.

Another way to take into consideration the changing skies is to use a seasonal star map (**Figure 1**) in which a "window" can be rotated to expose different parts of the map. Each visible section represents the portions of the sky that are visible at different times of the year. Activity 13.7 gives instructions on making this type of map.

Stargazing Trips

When you want to observe the night sky, consider these tips:

- Plan the trip in advance, taking into consideration the weather forecast, safety, transportation, location, what to wear, and what to bring.
- Choose a location far away, or at least screened away, from bright lights.
- Be prepared to record your observations.
- Before viewing, allow your eyes at least 10 min to adapt to the dark.
- Use a flashlight covered with red cellophane to view your star map.

Using a Star Map

To use a seasonal star map, follow these steps:

- Rotate the window to expose the part of the map closest to the current season or month.
- Hold the map, facing downward, above your head.
- Rotate the map so the top part (away from the window) is facing north. This means that Orion is facing south.
- Compare what you see in the sky with what is on the map.
- Also notice any planets or other objects besides stars.

Keeping Records

Use a table to record your observations. Possible titles for the columns are shown in **Table 1**. Be careful when recording dates because Dec. 15 becomes Dec. 16 after midnight.

Table 1

Date	Object seen	Description (including a diagram)	Location (including angles)	Questions I want answered
?	?	?	?	?
?	?	?	?	?

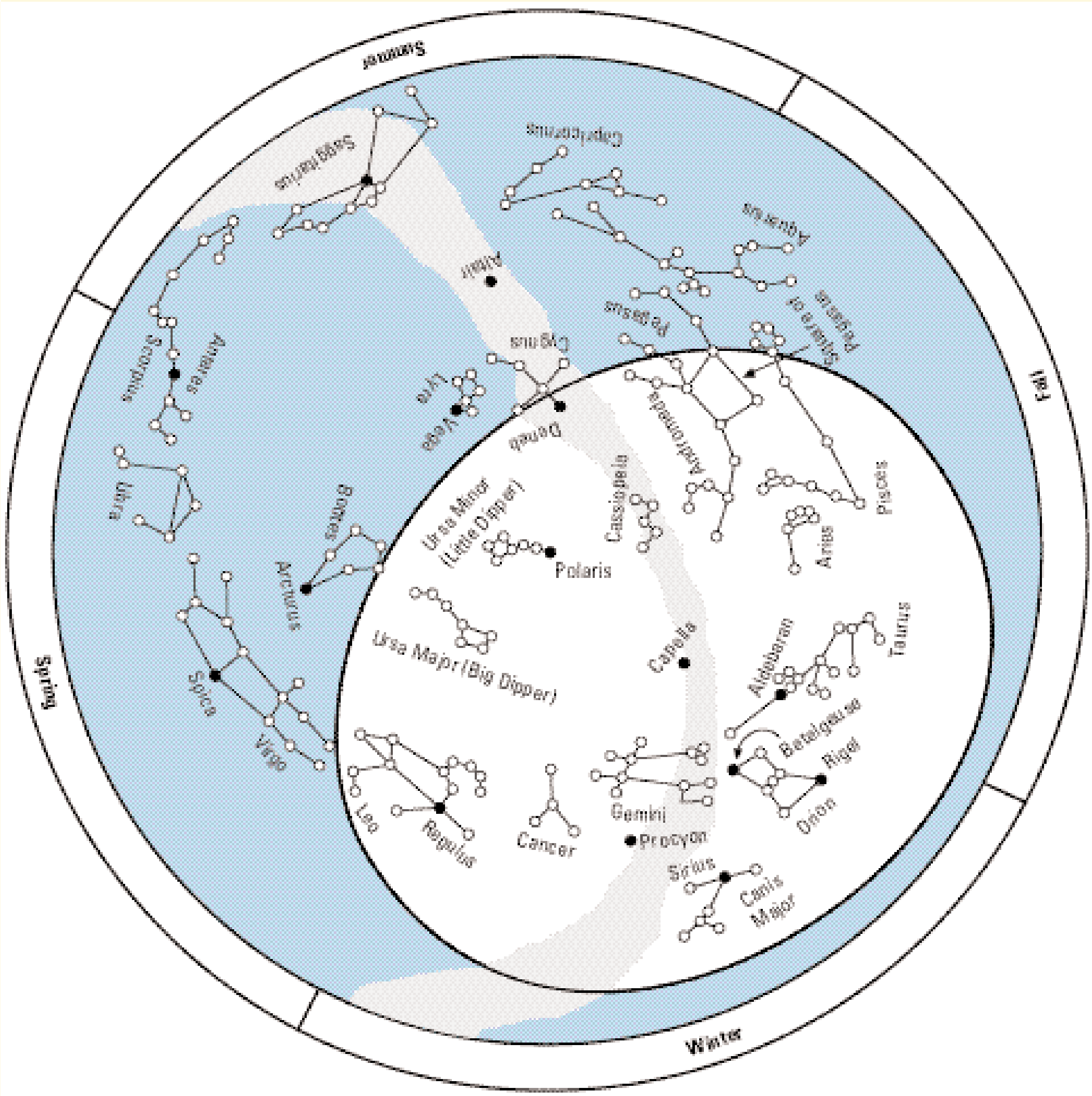


Figure 1

Only the unshaded part of the seasonal star map is visible during the winter months.

5D Drawing and Constructing Circuits

Sources of Electrical Energy

To provide the electrical energy in most of the circuits you use in this course you will be using combinations of dry cells or a special device called a power supply. Power supplies can be set to supply the voltage required.

The source used in the circuits you construct and test yourself will be a "direct current," or DC source of electrical energy. In DC circuits the current only flows in one direction around the circuit. We use DC circuits in this course because the operating voltages are much safer to use, generally below 28 V.

Wall outlets provide a different kind of electrical energy known as an "alternating current" or AC source. In AC circuits the electric current reverses its direction 60 times a second. AC appliances are specially designed for this energy source, and typically operate at 120 V or 240 V.

Drawing Circuit Diagrams

Before building a circuit, it is a good idea to draw a circuit diagram. This will remind you how components should be connected. There are some conventions to follow when drawing circuit diagrams: connecting wires are generally shown as straight lines or 90° angles, and symbols (shown in **Table 1**) are used to represent all components.

Safety Considerations

It is important to observe and use appropriate safety procedures, especially when you see ⚠.

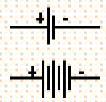
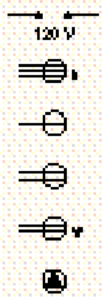
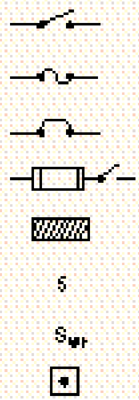
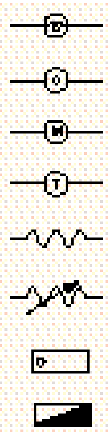
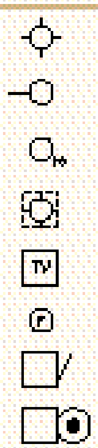
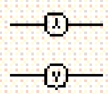
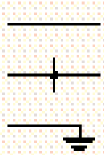
- Always ensure that your hands are dry, and that you are standing on a dry surface.
- Do not use faulty dry cells or batteries, do not connect different makes of dry cells in the same battery, and avoid connecting partially discharged dry cells to fully charged cells. Take care not to accidentally short-circuit dry cells or batteries.
- Do not use frayed or damaged connectors.
- Handle breakable components with care.
- Only operate a circuit after it has been approved by your teacher.

Constructing the Circuit

When constructing or modifying a circuit, always follow the instructions. If you are unsure of the procedure, ask for clarification. Check that all the components are in good working order.

- Check the connections carefully when linking connecting dry cells in series or in parallel. Incorrect connections could cause shorted circuits or explosions. Ask your teacher for clarification if you are unsure.
- When attaching connecting wires to meters, connect a red wire to the positive terminal and a black wire to the negative terminal of the meter. This will remind you to consider the polarity of the meter when connecting it in the circuit.
- Sometimes the ends of connecting wires do not have the correct attachments to connect to the device or meter. Use extra, approved attachment devices, such as alligator clips, but be careful to position the connectors so that they cannot touch one another.
- Open the switch before altering a meter connection or adding new wiring or components.
- If the circuit does not operate correctly, open the switch and check the circuit wiring and all connections to the terminals. If you still cannot find the problem, ask your teacher to inspect your circuit again.

Table 1 **Circuit Diagram Symbols**

	DC CIRCUITS		HOUSEHOLD CIRCUITS (additional symbols)	
Sources/Outlets		cell		wall outlet
		3-cell battery		range outlet
				single outlet
				double outlet (duplex)
				weatherproof outlet
				special-purpose outlet
Control Devices		switch		
		fuse		
		circuit breaker		
		switch and fuse		
		distribution panel		
		switch		
		weatherproof switch		
		push button		
Electrical Loads		light bulb		ceiling light
		clock		wall light
		motor		lampholder with pull switch
		thermostat		recessed fixture
		resistor		television outlet
		variable resistor (rheostat)		fan
		fluorescent fixture		buzzer
		heating panel		bell
Meters		ammeter		
		voltmeter		
Connectors		conducting wire		
		wires joined		
		ground connection		

5E Using the Voltmeter and the Ammeter

As we cannot see electrons flowing in electric circuits, we have to rely on instruments that can detect and measure electricity. There are at least two you are likely to use: the voltmeter and the ammeter.

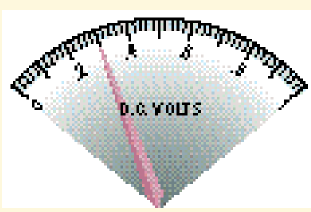
The Voltmeter

Figure 1

A voltmeter (**Figure 1**) measures the voltage difference between two different points in a circuit. The voltmeter can be connected across the terminals of a cell, to measure the voltage output of the cell, or across another component of a circuit, to measure the voltage drop across that component. In other words, the voltmeter is always connected in parallel with the component you want to investigate. The voltmeter could be digital (providing a digital readout) or analog (indicating voltage by the movement of a needle across a scale).

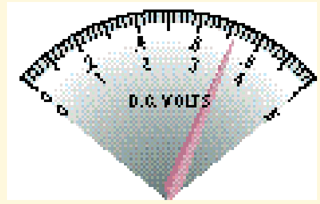
Reading an Analog Voltmeter

The needle on a voltmeter usually moves from left to right, with the zero voltage being on the left and the maximum voltage on the right of the scale. If the voltmeter scale has only one set of numbers, it is relatively easy to measure the voltage. Be sure that you know the voltage value represented by the smallest division on the scale.



The voltage in this circuit is 0.3 V.

Sample Problem: If the voltmeter has several sets of numbers, identify which set of numbers matches the voltage range selected by the switch on the voltmeter.



If the switch on this voltmeter indicates that the voltmeter is measuring a maximum of 1 V, the voltage in this circuit would be 0.72 V. However, if the switch indicates a maximum of 5 V, the voltage in the circuit would be 3.6 V.

The two leads that connect a voltmeter to any part of the electric circuit must be attached so that the negative terminal of the voltmeter is connected to a more negative part of the circuit than the positive terminal. If the leads were attached incorrectly, the needle would try to move to the left, but would be unable to do so, and would not give a reading.

The Ammeter

An ammeter measures the amount of electric current flowing in a circuit. To measure the electric current we connect the ammeter directly into the circuit itself. In whatever part of the circuit we wish to measure the current, a wire is disconnected and the ammeter is connected, in series, to complete the circuit. A typical ammeter is shown in **Figure 2**. Reading digital and analog ammeters is very similar to reading digital and analog voltmeters. The unit of current is the ampere (A) or milliampere (mA).

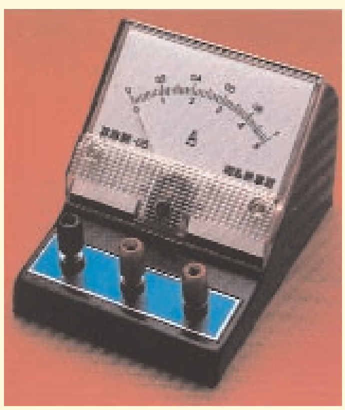
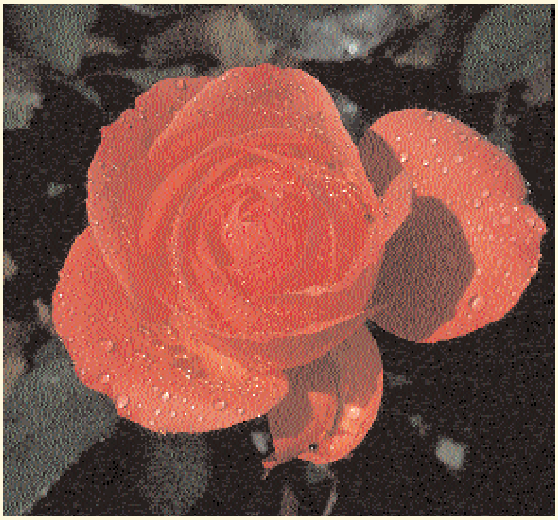


Figure 2

6 Observing and Recording Data

6A Obtaining Qualitative Data

An observation is information that you get through your senses. You observe that a rose is red and has a sweet smell. You may also note that it has sharp thorns on its stem. You may count the petals on the flower and the leaves on the stem and measure the length of the stem.



When people describe the qualities of objects and events, the observations are qualitative. The colour of the rose, the odour of the flower, and the sharpness of the thorns are all qualitative observations.

Scientists have grouped qualitative observations into several categories, based on the kind of qualities of the object or event being described. The following is a list of categories that can be used to qualitatively describe objects or events:

State of Matter: One of three states—solid, liquid, or gas.

Colour: Objects can be described as being any colour or any shade of colour. Materials that have no colour should be described as colourless.

Smell: Also known as odour. There are many words to describe smells, including pungent, strong, spicy, sweet, and odourless.

Texture: The surfaces of objects can have a variety of textures, including smooth, rough, prickly, fine, and coarse.

Taste: Objects can taste sweet, sour, bitter, or salty. Other tastes are combinations of these basic tastes. Objects that have no taste can be described as tasteless.

Shininess: Also known as lustre. Objects with very smooth surfaces that reflect light easily, like mirrors, are said to be shiny or lustrous. Objects with dull surfaces are said to be non-lustrous.

Clarity: Some substances let so much light through that letters can be read through them. These substances are said to be clear or transparent. Other substances that allow light through, but not in a way that allows you to see through them, are translucent. Objects that do not let light through are opaque.

Other qualitative descriptions include form (the shape of a substance), hardness, brittleness (how easily the substance breaks), malleability (the ability of the object to be changed into another shape), and viscosity (a liquid's resistance to flow).

Another important characteristic that can be described qualitatively is the ability of substances to combine with each other.

Recording Data

Scientists must record rough notes and observations. Using a science journal or log book will help you organize and keep track of your rough work while performing investigations.

Try This **Observing**

With a partner, search the classroom or the outside environment. Find five objects and make as many qualitative observations as you can about each one.

6B Obtaining Quantitative Data

Observations that are based on measurements or counting provide quantitative data, since they deal with quantities of things. The length of a rose's stem, the number of petals, and the number of leaves are quantitative observations.

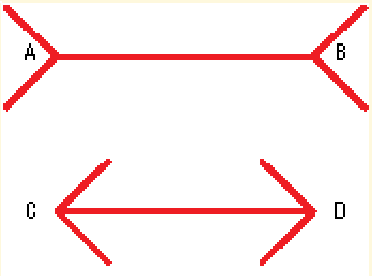


Figure 1
Which line is longer: AB or CD? Use a ruler.

In **Figure 1** you will find that AB and CD are the same length. Our senses can be fooled. That is one reason why quantitative observations are important in science and it is also the reason measurements must be made carefully.

Standards of Measurement

Units of measurement used to be based on local standards that the community had agreed to. Horse heights, for instance, are still measured in hands, based on the width of a hand, and measured from the ground to the horse's shoulder.

These standards may sound strange, but the unit of length that replaced most local standards, the metre, was based on an arc on Earth that ran from the equator, through Barcelona, Paris, and Dunkirk, to the North Pole. The length of this arc, divided by 10 000 000, equalled 1 m. That also sounds strange, but it established the first standard unit of length that the whole world could use.

Later, when more accurate measurements of Earth were possible, scientists abandoned this definition because it was not precise enough. The metre is now defined very accurately as the distance travelled by light in 1/299 792 458 s (3.33×10^{-9} s).

The metric system has been adopted by Canada. You should be familiar with, and use, the units from this international system (also called the SI system, from the French name: *Système International d'Unités*).

Base Units and Prefixes

There are seven base units, shown in **Table 1**.

Table 1 The Seven SI Base Units

Quantity	Unit	Symbol
length	metre	m
mass	kilogram	kg*
time	second	s
electric current	ampere	A
temperature	kelvin	K
amount of substance	mole	mol
light intensity	candela	cd

*The kilogram is the only base unit that contains a prefix. The gram proved to be too small for practical purposes.

Larger and smaller units are created by multiplying or dividing the value of the base units by multiples of 10. For example, the prefix *deca* means multiplied by 10. Therefore, one decametre (1 dam) is equal to ten metres (10 m). The prefix *kilo* means multiplied by 1000, so one kilometre (1 km) is equal to one thousand metres (1000 m). Similarly, each unit can be divided into smaller units. The prefix milli, for example, means divided by 1000, so one millimetre (1 mm) is equal to 1/1000 of a metre.

To convert from one unit to another, you simply multiply by a conversion factor. For example, to convert 12.4 m to centimetres, you use the relationship 1 m = 100 cm.

12.4 m = ? cm

$$12.4 \text{ m} \times \frac{100 \text{ cm}}{1 \text{ m}} = 1240 \text{ cm}$$

To convert 6.3 g to kilograms, you use the relationship 1000 g = 1 kg.

6.3 g = ? kg

$$6.3 \text{ g} \times \frac{1 \text{ kg}}{1000 \text{ g}} = 0.0063 \text{ kg}$$

Any conversions of the same physical quantities can be done in this way. The conversion factor is chosen so that, using cancellation, it yields the desired unit.

Once you understand this method of conversion, you will find that you can simply move the decimal point. Move it to the right when the new unit is smaller and to the left when the new unit is larger. As you can see from **Table 2**, not all the units and prefixes are commonly used.

Table 2 **Metric Prefixes**

Prefix	Symbol	Factor by which the base unit is multiplied	Example
giga	G	10^9 = 1 000 000 000	
mega	M	10^6 = 1 000 000	10^6 m = 1 Mm
kilo	k	10^3 = 1 000	10^3 m = 1 km
hecto	h	10^2 = 100	
deca	da	10^1 = 10	
		10^0 = 1	m
deci	d	10^{-1} = 0.1	
centi	c	10^{-2} = 0.01	10^{-2} m = 1 cm
milli	m	10^{-3} = 0.001	10^{-3} m = 1 mm
micro	µ	10^{-6} = 0.000 001	10^{-6} m = 1 µm

Table 3 shows the quantities that you should be familiar with.

Table 3 **Common Quantities and Units**

Quantity	Unit	Symbol
length	kilometre metre centimetre millimetre	km m cm mm
mass	tonne (1000 kg) kilogram gram	t kg g
area	hectare (10 000 m^2) square metre square centimetre	ha m^2 cm^2
volume	cubic metre litre cubic centimetre millilitre	m^3 L cm^3 mL
time	minute second	min s
temperature	degrees Celsius kelvin	°C K
force	newton	N
energy	kilojoule joule	kJ J
pressure	kilopascal pascal	kPa Pa

Problems in Measurement

Many people believe that all measurements are accurate and dependable. But there are many things that can go wrong when measuring. The instrument may be faulty. Another similar instrument may give different readings. There may be limitations that make the instrument unreliable. The person making the measurement may also make a mistake.

When measuring the temperature of a liquid, for instance, it is important to keep the bulb of the thermometer near the middle of the liquid. If the liquid is being heated and the thermometer is simply sitting in the container with its bulb at the bottom, you will be measuring the temperature of the bottom of the container, not the temperature of the liquid. There are similar concerns with most measurements. To be sure that you have measured correctly, repeat your measurement at least three times. If your measurements are close, calculate the average and use that number. To be more certain, repeat the measurements with a different instrument.

Try This Measuring Mass

Work as a group. Your teacher will give you a bottle of vitamin C tablets. Each tablet is advertised as having the same mass (measured in milligrams). Check to make sure this is true. Decide how your group will prove or disprove this. Be sure to record all data in a table. What is the average mass of one tablet? Compare your quantitative observations with those of other groups.

6C Scientific Drawing

Scientific drawings are done to record observations as accurately as possible. They are also used to communicate, which means they must be clear, well labelled, and easy to understand. Following are some tips that will help you produce useful scientific drawings.

Before You Begin

- Obtain some blank paper. Lines might obscure your drawing or make your labels confusing.
- Find a sharp, hard pencil (e.g., H or 2H). Avoid using pen, thick markers, or coloured pencils. Ink can't be erased—even the most accomplished artists change their drawings—and coloured pencils are soft, making lines too thick.
- Plan to draw large. Ensure that your drawing will be large enough that people can see details. For example, a third of a page might be appropriate for a diagram of a single cell or a unicellular organism. If you are drawing the entire field of view of a microscope, draw a circle with a reasonable diameter (e.g., 10 cm) to represent the field of view.
- Leave space for labels, preferably on the right side of the drawing.
- Observe and study your specimen carefully, noting details and proportions.

Drawing

- Simple, two-dimensional drawings are effective.
- Draw only what you see. Your textbook may act as a guide, but it may show structures that you cannot see in your specimen.
- Do not sketch. Draw firm, clear lines, including only relevant details that you can see clearly.
- Do not use shading or colouring in scientific drawings. A stipple (series of dots) shown in **Figure 1** may be used to indicate a darker area. Use double lines to indicate thick structures.

Label Your Drawing

- All drawings must be labelled fully in neat printing. Avoid printing labels directly on the drawing.
- Use a ruler. Label lines must be horizontal and ruled firmly from the structures being identified to the label (**Figure 2**).
- Label lines should never cross.
- If possible, list your labels in an even column down the right side.
- Title the drawing, using the name of the specimen and (if possible) the part of the specimen you have drawn. Underline the title.

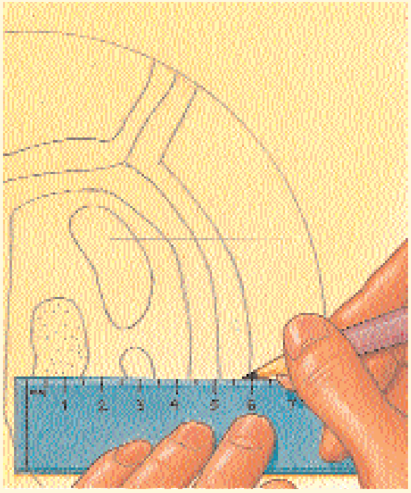


Figure 2

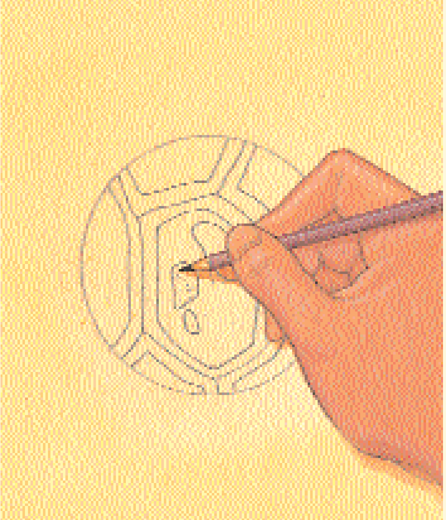


Figure 1

Scale Ratio

- To show the relation of the actual size to your drawing size, print the scale ratio of your drawing beside the title.

$$\text{scale ratio} = \frac{\text{size of drawing}}{\text{actual size of the specimen}}$$

For example, if you have drawn a nail (**Figure 3**) that is 5 cm long and the drawing is 15 cm long, then the scale ratio, which in this case is a magnification, is

$$\frac{15\text{ cm}}{5\text{ cm}} = 3\text{X}$$

actual size, 5 cm

Figure 3

The magnification is always written with an "X" after it. In a fully labelled drawing, the total magnification of the drawing should be placed at the bottom right side of the diagram. If the ocular lens magnified a specimen 10X, the low-power objective (4X) was used, and the scale ratio was 3X, the total magnification of the diagram would be as follows:

$$\begin{aligned}\text{Total Magnification} &= \text{Ocular Lens} \times \text{Low-Power Objective Lens} \times \text{Scale Ratio}\\ &= 10 \times 4 \times 3\\ &= 120\text{X}\end{aligned}$$

The total magnification should be written on the bottom right-hand side of the diagram, as shown in **Figure 4**.

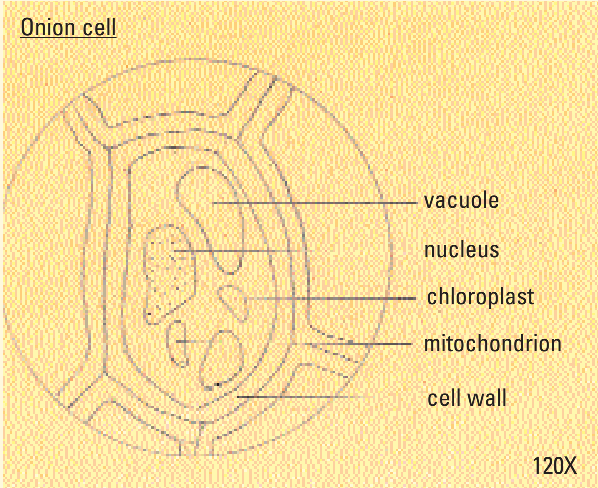


Figure 4

Checklist for Good Scientific Drawing

- ✔ Use blank paper and a sharp, hard pencil.
- ✔ Draw large. For example, the field of view for a microscope could be 10 cm in diameter.
- ✔ Do not shade or colour.
- ✔ Draw label lines that are straight and parallel and run outside the drawing. Use a ruler for this!
- ✔ Include labels, a title, and the total magnification.

Try This — Draw It

Obtain a specimen from your classroom. It could be a piece of your hair, chalk dust, or something else you would be interested in looking at under a microscope. Prepare a dry mount slide and focus your specimen under the medium-power objective lens. Complete a scientific drawing of your specimen. Use the checklist to ensure that your diagram is accurate and complete. When your drawing is complete, exchange it with your friend's drawing. Note the strengths and weaknesses of the drawing, keeping in mind all the features of a good scientific drawing. Evaluate your friend's drawing using the checklist.

6D Creating Data Tables

Creating effective data tables in your investigations will help you record and analyze your data. Constructing a useful data table is one of the first steps in making sense of your experimental data. Take a look at **Tables 1** and **2**. What similarities exist? What strategies should you employ when constructing your data tables?

The following checklist will help you in constructing effective data tables in your investigations:

- List the dependent variable(s) (the effect) along the top of the table.
- List the independent variable (the cause) along the side of the table.
- Be sure that each data table has a descriptive, yet concise, title.
- Be sure to include the units of measurement along with each variable when appropriate.
- If you include the results of your calculations in a table, be sure to show at least one sample calculation in your data analysis.

Table 1 Data Table for Electricity Investigation

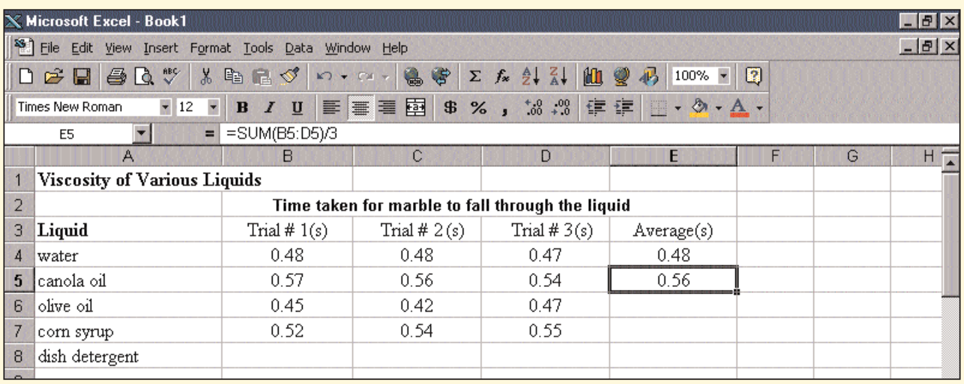
Resistor Point	Connection Reading (V)	Voltmeter Reading (A)	Ammeter Ratio	V/I
1	A	?	?	?
1	B	?	?	?
1	C	?	?	?
1	D	?	?	?
2	A	?	?	?
2	B	?	?	?
2	C	?	?	?
2	D	?	?	?

Table 2 Data Table for Reproduction Investigation

Phase	Number of cells	Percentage of total in phase
prophase	?	?
metaphase	?	?
anaphase	?	?
telophase	?	?

Spreadsheets

A workbook, worksheet, or spreadsheet (**Figure 1**) is an electronic file that helps with the collection, manipulation, and analysis of data. There are many popular computer programs (e.g., Microsoft Excel, Lotus 1-2-3) that use these very powerful tools for data collection and analysis. In general, the programs treat each table unit as a cell or compartment with a specific address. The user can perform various mathematical, statistical, or graphical operations on the data.



	A	B	C	D	E
1	Viscosity of Various Liquids				
2		Time taken for marble to fall through the liquid			
3	Liquid	Trial # 1(s)	Trial # 2(s)	Trial # 3(s)	Average(s)
4	water	0.48	0.48	0.47	0.48
5	canola oil	0.57	0.56	0.54	0.56
6	olive oil	0.45	0.42	0.47	
7	corn syrup	0.52	0.54	0.55	
8	dish detergent				

Figure 1

7A Understanding Graphs

The Need to Graph

Scientists and science students often create huge amounts of data while doing experiments and studies—maybe hundreds, even thousands, of numbers for every variable. How can this mass of data be arranged so that it is easy to read and understand? That's right—in a graph. The sample table below doesn't have thousands of pieces of data, but it does have enough to become confusing. Can you make sense of the data in **Table 1** by simple inspection?

Table 1

Electric Current and Voltage in a Simple (one-resistor) Electric Circuit

Power Supply Setting	Current (mA)	Voltage Drop (V)
1	0.8	2.1
2	1.6	3.8
3	2.5	4.1
4	3.9	7.8
5	4.4	8.8
6	4.8	10.5
7	5.0	10.8
8	7.3	14.6
9	7.9	15.8
10	8.9	15.9
11	9.8	17.9
12	10.5	20.2
13	11.1	24.1
14	12.6	24.8

A graph is an easy way to see where a relationship or pattern exists. As well, it allows you to see more precisely what the relationship is, so it can be accurately described in words and by mathematics. **Figure 1** is a point-and-line graph that shows the data from **Table 1**.

The graph shows the relationship between the two variables as a fairly straight line. It could be described by saying that as the current through the resistor steadily increased, the voltage drop through the resistor also steadily increased. This simple relationship between current and voltage leads to a more advanced scientific concept known as electrical resistance. In more complex relationships such as this, the need for a graph is even stronger. Data are much easier to visualize and understand in the organized form of a graph than as numbers in a table.

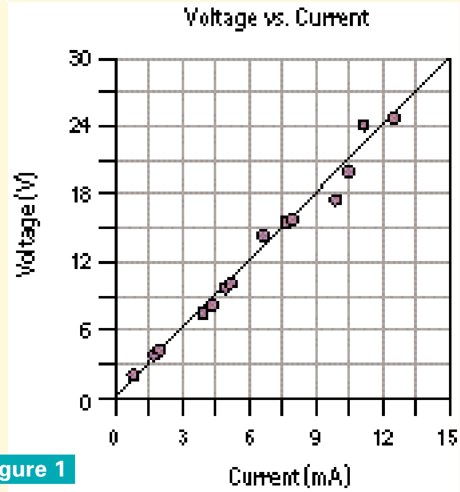


Figure 1

Types of Graphs

There are many types of graphs that you can use when organizing your data. You need to identify which type of graph is best for your data *before* you start drawing it. Three of the most useful kinds are point-and-line graphs, bar graphs, and circle graphs (also called pie graphs).

Point-and-Line Graphs

When both variables are quantitative, use a point-and-line graph. The graph in **Figure 2** was created after an experiment that measured the number of worms on the surface of soil (quantitative) and the volume of rain that fell on the soil (quantitative).

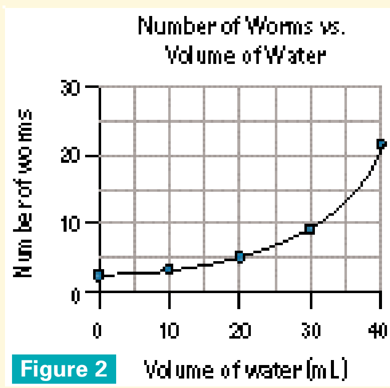


Figure 2

Bar Graphs

When at least one of the variables is qualitative, use a bar graph. For example, a study of the math marks of students (quantitative) who listened to different kinds of music (qualitative) while doing their math homework resulted in the graph in **Figure 3**. In this kind of graph, each bar stands for a different category, in this case a type of music. Notice also that the range on the vertical axis is chosen so that even the smallest bar is still visible.

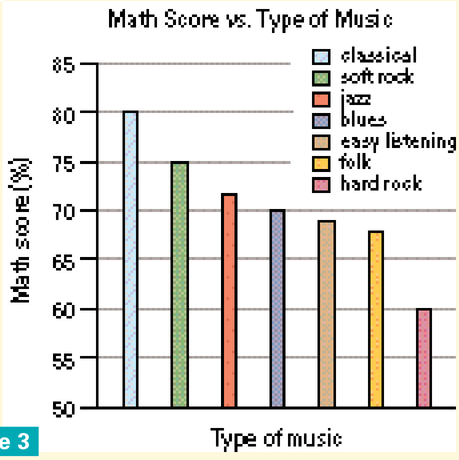


Figure 3

Circle Graphs

Circle graphs and bar graphs are used for similar types of data. If your quantitative variable can be changed to a percentage of a total quantity, then a circle graph is useful. For example, if you surveyed a class to find the students' favourite type of music, you could make a circle graph like **Figure 4**. In a circle graph, each piece stands for a different category (in this case, the kind of music preferred), and the size of the piece tells the percentage of the total that belongs in the category (in this case, the percentage of students who prefer a particular kind of music).

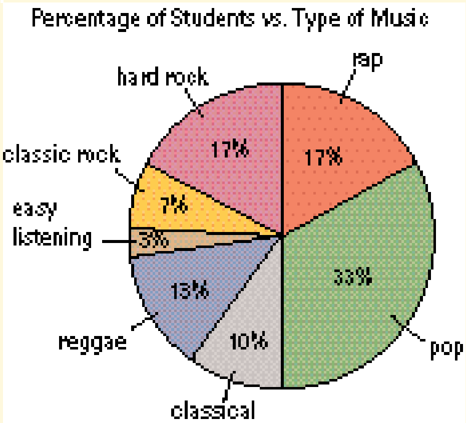


Figure 4

Try This Which Graph?

Copy and complete **Table 2**. Determine the type of graph that is most suitable to illustrate the relationship between the variables in each pair. Explain each of your choices.

Table 2

Pairs of variables	Most appropriate type of graph
1. Amount of sunlight Number of students late for school	?
2. Number of cars owned per person Country of residence	?
3. Lipstick colour Number of students wearing each colour	?
4. Lizard body temperature Time spent in sunlight	?

Reading a Graph

When data from an investigation are plotted on an appropriate graph, patterns and relationships become much easier to see and interpret—it is easier to tell if the data support your hypothesis. Looking at the data in a graph may also lead you to a new hypothesis.

What to Look for When Reading Graphs

Here are some guiding questions as you interpret the data on a graph:

- What variables are represented?
- What is the dependent variable? What is the independent variable?
- Are the variables quantitative or qualitative?
- If the data are quantitative, what are the units of measurement?
- Are two or more sample groups included?
- What do the highest and lowest values represent on the graph?
- What is the range (the difference between the highest and lowest values) of values for each axis?
- What patterns or trends exist between the variables?
- If there is a linear relationship, what might the slope (steepness) of the line tell us?
- Is this the best graph for the data?

Using Graphs for Predicting

If a graph shows a regular pattern, you can use it to make predictions. For example, you could use the graph in **Figure 5**, in which the mass of silver is plotted against volume, to predict the mass of 8 cm^3 of silver. To do this, you would extrapolate the graph (extend it beyond the measured points) assuming the observed trend would continue.

Some common sense is needed in extrapolation. Sometimes a pattern extends only over a certain range. For example, if you extrapolated the graph of bacterial growth in **Figure 6**, you would predict that after 24 hours there would be 280 000 000 000 000 000 cells. These would have a total mass of about 40 kg. In another day and a half, the cells' mass would be greater than the mass of Earth. Something will happen to break the pattern!

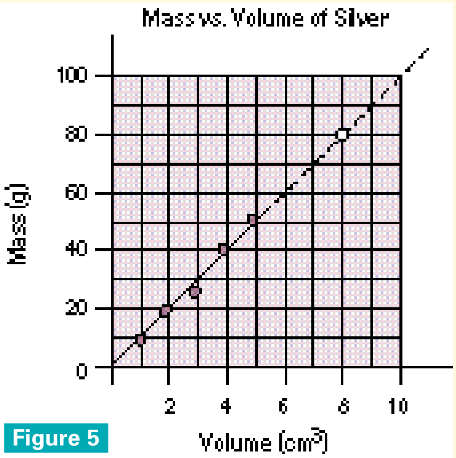


Figure 5

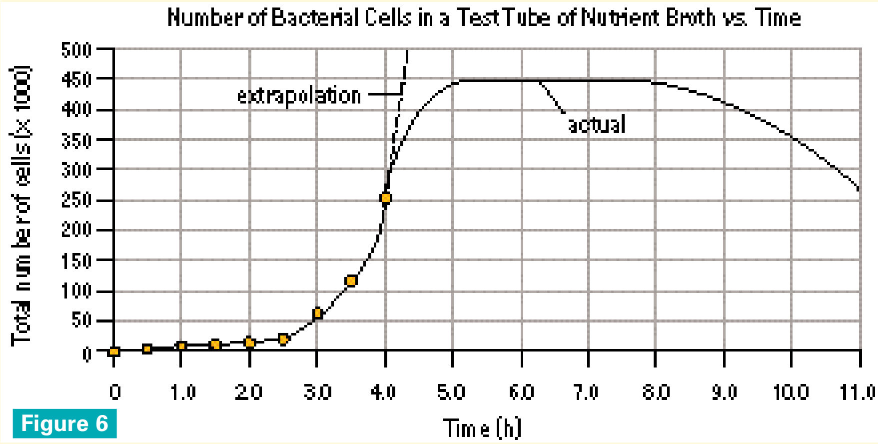


Figure 6

Try This: Read a Graph

Until the 1970s, small amounts of lead were added to gasoline to improve the performance of car engines. Eventually, when people became aware of the hazards of lead, leaded gasoline was phased out. As you are probably aware, leaded gasoline is no longer used in Canada.

Lead pollutes the air. In one experiment in Ontario, the amount of airborne lead was measured near expressways and at several other locations. **Figure 7** shows the results of this study. Take a close look at the results and answer the following questions:

1. In what year was the level of airborne lead highest?

2. Was the amount of lead in the air increasing or decreasing during the time shown in the graph?

3. In any year, is the amount of airborne lead near expressways more than or less than the average of all sites?

4. (a) On the basis of the data, form a hypothesis to explain the presence of lead in the air.

(b) Why do you think the amount of lead pollution changed over the measuring period?

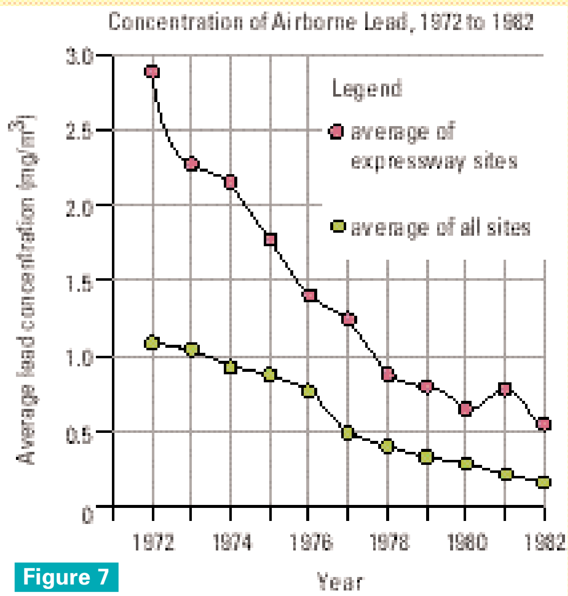


Figure 7

7B Constructing Graphs

Making Point-and-Line Graphs

Point-and-line graphs are common in mathematics, economics, geography, science, technology, and many other subjects. This section will help you become more skilled at drawing them and at understanding point-and-line graphs produced by others.

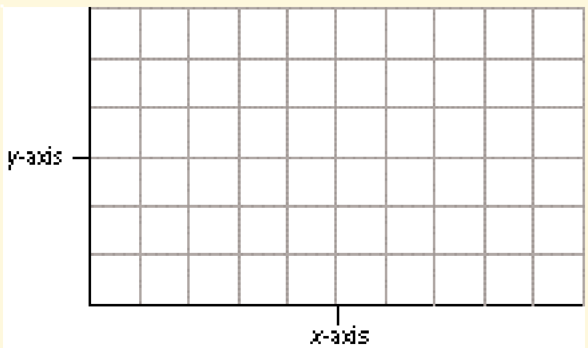
As an example, the data in **Table 1** are used to produce a graph. When making a point-and-line graph, follow these steps:

Table 1

Light level (cd)	Number of late students
45	16
34	12
27	14
15	9
35	15
12	12
20	12
78	22
65	19
88	24
85	23
92	24
14	8
10	7
7	2
30	11
36	11
47	17
58	23
58	18
46	14

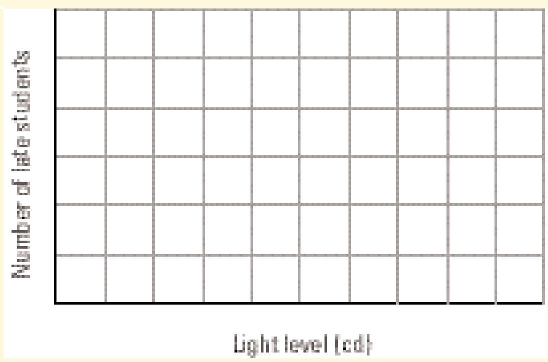
1. Construct your graph on a grid. The horizontal edge on the bottom of this grid is called the *x*-axis and the vertical edge on the left is called the *y*-axis. Don't be too thrifty with graph paper—if you draw your graphs large, they will be easier to interpret.

Step 1: Draw the axes.



2. Decide which variable goes on which axis, and label each axis, including the units of measurement. It is common to plot the dependent variable (number of late students) on the *y*-axis and the independent variable (light level in candelas, cd) on the *x*-axis.

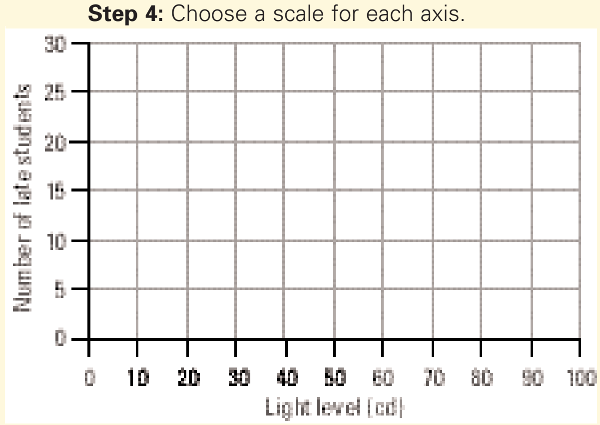
Step 2: Label each axis.



3. Determine the range of values for each variable. The range is the difference between the largest and smallest values. For the light levels in the table, the maximum is 92 cd, and the minimum is 7 cd, so the range is: 92 cd – 7 cd = 85 cd. For the number of late students, the range is 24 – 2 = 22.

4. Choose a scale for each axis. This will depend on how much space you have, and the range of values for each axis. Each line on the grid usually increases steadily in value by a convenient number, such as 1, 2, 5, 10, 20, 50, 100, etc. In the example, there are 10 lines for the *x*-axis and 6 for

Step 4: Choose a scale for each axis.



the y-axis. To calculate the increase in value for each line, divide the range by the number of lines:

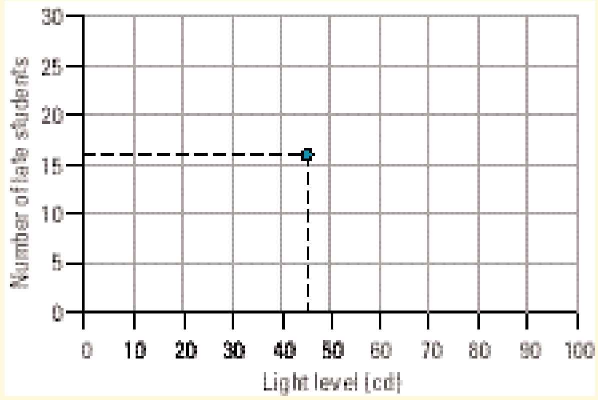
$$\frac{85\ \text{cd}}{10\ \text{lines}} = 8.5\ \text{cd/line}$$

Then, round up to the nearest convenient number, which in this case is 10. The scale on the light level axis should increase by 10 cd every space. Repeat the calculation for the y-axis:

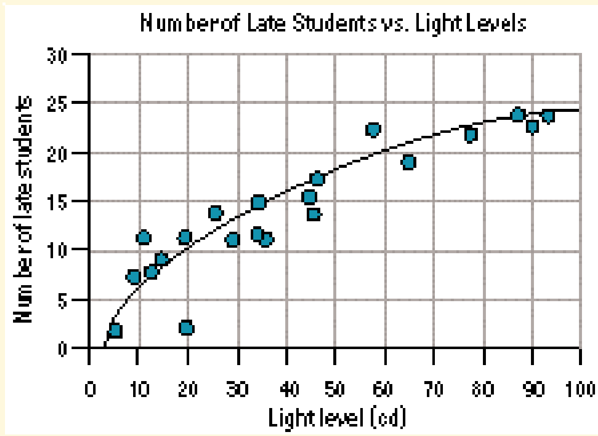
$$\frac{22\ \text{students}}{6} = 3.7\ \text{students/line, which is rounded up to 5.}$$

5. Plot the points. Start with the first pair of values from the data table, 45 cd and 16 late students. Place the point where an imaginary line starting at 45 on the x-axis meets an imaginary line starting at 16 on the y-axis.
6. After all the points are plotted, and if it is possible, draw a line through the points to show the relationship between the variables. It is unusual for all the points to lie exactly on a line. Small errors in each measurement tend to move the points slightly away from the perfect line. You must draw a line that comes closest to most of the points. This is called the line of best fit—a smooth line that passes through or between the points so that there are about the same number of points on each side of the line. The line of best fit may be a straight line or a curved line.
7. Title your graph (y-axis vs. x-axis).

Step 5: Start plotting points.



Step 6: Draw a line of best fit.



Try This — A Point-and-Line Graph

Make labelled point-and-line graphs, with appropriate lines of best fit, for the following sets of data in **Table 2**:

Table 2

(a)

Air temperature (°C)	Snake heart rate (beats/min)
7	11
33	62
24	39
11	31
27	73
4	22
34	80
25	54

(b)

Wind speed (km/h)	Average speed of cars (km/h)
0	100
10	82
20	84
30	73
40	75
50	68
60	72
70	71

Making Bar Graphs

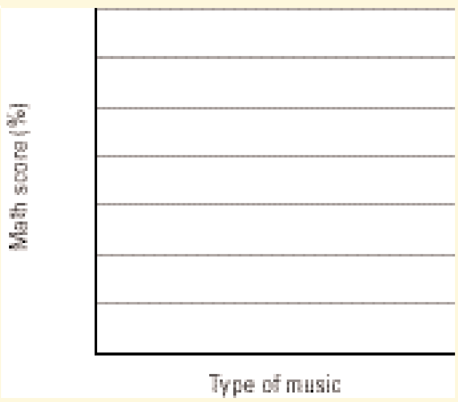
Bar graphs are useful when working with qualitative data and when a variable is divided into categories. In the following example science students did a study of the kind of music students listen to while doing mathematics problems, and got the results listed in **Table 3**. Follow these steps to plot a bar graph of this data.

Table 3

Type of music	Math score (%)
easy listening	69
hard rock	60
jazz	72
blues	70
classical	80
folk	68
soft rock	75

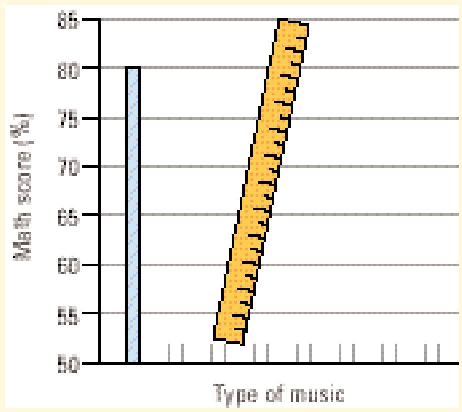
1. Draw and label the axes of your graph, including units. Some people prefer to have the bars based on the *x*-axis; others prefer to use the *y*-axis as the base. In the illustrations, the *x*-axis was chosen for the base.

Step 1: Draw the axes.



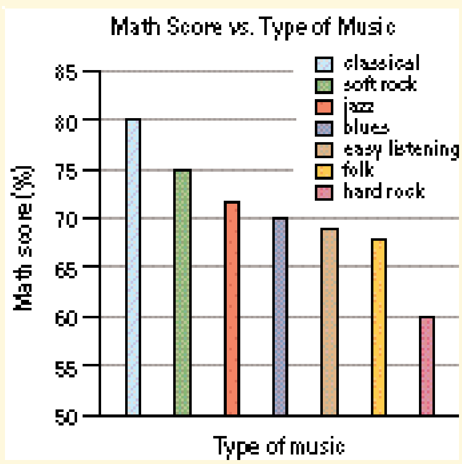
2. Develop a scale for the axis of the quantitative variable, just as you would for a point-and-line graph (pages 556–557). In this example, the *y*-axis increases by fives, starting below the lowest value. In the illustration, 50 was chosen as the starting point, so all the bars would be visible.
3. Decide how wide the bars will be, and how much space you will put between them. This decision is based on:
   - How much space you have. Measure the length of the axis on which the bars will be based, and divide that length by the number of bars. This will give you the maximum width of each bar.
   - How you want the graph to look. Decide how much less than the maximum width your bars will be, based on the visual appeal of thick and thin bars.
4. Draw in bars. Start by marking the width of each bar on the base axis. Then, draw in the top of each bar, according to your data table, and the sides. You can shade the bars equally, or make each bar different from the others. It is important, however, to keep the graph simple and clear.

Step 4: Draw the bars.



5. Identify each bar. There are several ways to do this. The best choice is the one that makes the graph easy to understand.

Step 5: The completed bar graph



Making Circle (or Pie) Graphs

If your quantitative variable can be changed to a percentage of a total quantity, a circle graph is useful. A sample circle graph is worked out below, using the data in **Table 4**.

Table 4

Type of music	Number of students who prefer that type	Percentage of total (% and decimal)	Angle of piece of pie (degrees)
rap	5	17% = 0.17	61.2
pop rock	10	33% = 0.33	118.8
classical	3	10% = 0.10	36.0
reggae	4	13% = 0.13	46.8
easy listening	1	3% = 0.03	10.8
classic rock	2	7% = 0.07	25.2
hard rock	5	17% = 0.17	61.2
TOTAL	30	100% = 1.00	360.0

Follow these steps to construct a circle graph.

1. Convert the values of your quantitative variable into percentages, and then into decimal form. In the sample, each number of students who prefer a type of music was turned into a percentage of the total number of students.

$$\text{Percentage} = \frac{\text{number}}{\text{total}} \times 100\%$$

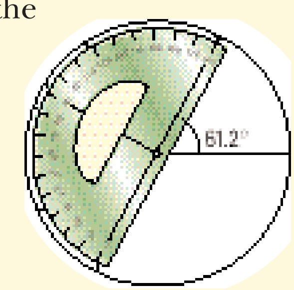
$$\text{Percentage for rap} = \frac{5}{30} \times 100\% = 17\% \text{ (decimal version} = 0.17)$$

2. Multiply the decimal version of each percentage by 360° (there are 360° in a circle) to get the angle of each "piece of the pie" within the circle.

$$\text{Angle of piece of pie for rap} = 0.17 \times 360° = 61.2°$$

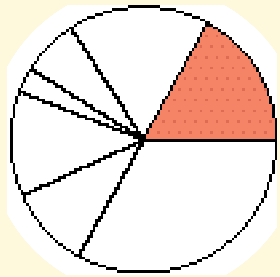
3. Draw a circle using a compass. To make the graph easy to read (and make), the circle should be big. The more pieces there are, the bigger the circle should be.

4. Draw in each piece of pie, using a protractor.



Step 4: Draw the pieces.

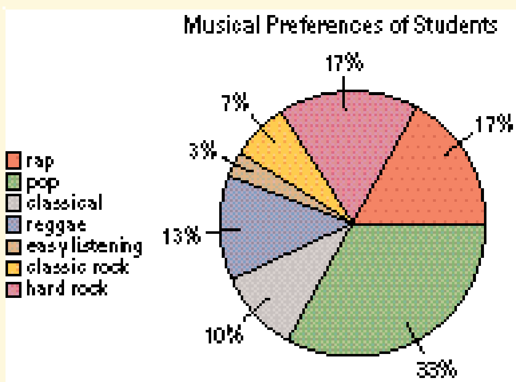
5. Shade each piece of pie using colours or patterns.



Step 5: Shade the pieces.

6. Label and title the graph. Put the percentages and the name of each category with its piece of pie (perhaps percentage inside and category outside the circle), or include them in a legend. Pick a title for your graph that describes the variables.

Step 6: The completed circle graph



Try This Graphing

Conduct a survey of your class or a larger group, and make bar and circle graphs from the data you collect. You could use one of the following variables or one of your own: favourite sport, favourite school subject, eye colour, birth order (i.e., first-born, second-born, etc.).

Using Computers for Graphing

You should be aware that there are many useful computer programs that can help with the graphing process. For example, Microsoft Excel is a very powerful spreadsheet/graphing program that allows for the construction of point-and-line, bar, and circle graphs as well as many other types of graphs. In addition, such programs can make use of statistical analysis to compute the best straight line or line of best fit.

7C Using Math in Science

Amazingly, nature can often be analyzed, described, and predicted mathematically. For example, the initial growth of a population of bacteria follows an exponential function, and the mass and volume of a substance, when graphed, prove to be directly proportional to one another. Incredibly, mathematicians and scientists have recently developed mathematical representations of snail shells, ferns, and coastlines. While mathematics can sometimes appear abstract and daunting, as a scientist, your ability to understand some fundamental mathematical "tools" will improve your analytical ability.

The following key mathematical "tools" will help you work through the *Nelson Science 9* program and in your further studies.

Scientific Notation

In your study of Space, you use some very large numbers, whereas in your study of Matter, you work with some very small numbers. For example, the average distance from the Sun to Earth is 150 000 000 000 m and the average radius of a hydrogen atom is 0.000 000 000 05 m. Because we don't want to spend the better part of our day writing out zeros, it is convenient to use a mathematical abbreviation known as scientific notation. The scientific notations for these two values are 1.50×10^{11} m and 5.0×10^{-11} m, respectively. Can you see how this works?

Essentially,

multiply by the number 10 a total of 11 times

$$1.5 \times 10^{11} = 1.5 \times 10 \times 10 \times 10 \times 10 \times 10 \times 10 \times 10 \times 10 \times 10 \times 10 \times 10$$

divide by the number 10 a total of 11 times

$$5.0 \times 10^{-11} = \frac{5.0}{10 \times 10 \times 10 \times 10 \times 10 \times 10 \times 10 \times 10 \times 10 \times 10 \times 10}$$

Significant Figures

Imagine you are given two pieces of string (**Figure 1**) and you wish to find the total length of string that you have. You measure the length of one piece of string with an accurate scale ruler and find that it is 12.72 cm long. You measure the length of the other piece of string with an old metre stick and find that piece of string to be 14 cm long. What is the total length of string that you have? If you claim the total length to be 26.72 cm, you have assumed that the second piece of string is 14 cm—was your old metre stick able to give you this level of precision? No. You can only come to the conclusion that you have a total rope length of 27 cm.

When we take measurements and manipulate numbers in science, we must look at the number of significant digits (or figures) in a number. The number of significant digits represents how carefully, and with what level of precision, the measurement was taken. Your calculator often registers a number with several significant digits regardless of where these numbers came from and what they mean.

Figure 1

Calculating Averages

There are many statistical methods that help us analyze the quantitative data that we collect. One of the most important of these is finding the average of a set of numbers. Calculating the average of a set of numbers allows you to reduce their findings to one representative value. For example, if we measure the heights of four students,

Suzanne	175 cm	Omar	145 cm
Jan	185 cm	Molly	180 cm

we could calculate that the average height of the group is

$$\text{average height} = \frac{175 + 185 + 145 + 180}{4} = 171 \text{ cm}$$

Slope of a Straight Line

When you plot data on a point-and-line graph (see Constructing Graphs, page 556), you may be able to connect the data points with a straight line. A straight line on a graph shows a direct relationship between the independent variable (usually on the horizontal axis) and the dependent axis (usually on the vertical axis). It is possible to represent this linear (or straight-line) behaviour with a mathematical equation that looks like this

$$y = mx + b$$

where y is the dependent variable, x is the independent variable, m is the slope (or steepness) of the line, and b is known as the y-intercept. Perhaps the most important of these constants is the slope of the line. To find the slope, choose two points on the line (x_1, y_1) and (x_2, y_2). The slope is equal to

$$m = \frac{\text{rise}}{\text{run}} = \frac{y_2 - y_1}{x_2 - x_1}$$

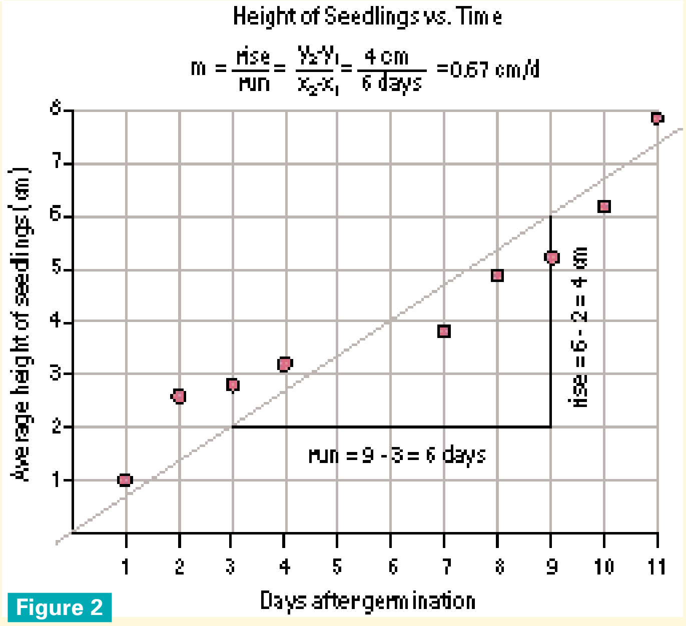


Figure 2

Predicting Using Formulas

Using various mathematical or experimental techniques, scientists are often able to connect and explain scientific phenomena by a mathematical formula. For example, in this book, you use the following relationship:

$$\text{density} = \frac{\text{mass}}{\text{volume}}$$

The predictive power of a formula such as this is impressive. For example, if you know the density of an object and its mass, you can predict its volume.

Sample Problem: A bag of milk has a density of 0.95 kg/L and a mass of 1.26 kg. Will you be able to pour the entire bag of milk into a 1-L pitcher?

density = 0.95 kg/L

mass = 1.26 kg

$$\text{density} = \frac{\text{mass}}{\text{volume}}, \text{ therefore}$$

$$\text{volume} = \frac{\text{mass}}{\text{density}} = \frac{1.26 \text{ kg}}{0.95 \text{ kg/L}} = 1.33 \text{ L}$$

So a 1-L pitcher will not hold all of the milk in the bag.

7D Reaching a Conclusion

Scientific investigations mean very little, if anything, unless the scientist states a conclusion about the results. A **conclusion** is a statement that explains the results of an investigation. This statement should refer back to your original hypothesis. State whether the results support, partially support, or reject your hypothesis. Don't worry if your hypothesis is incorrect—scientists usually need to revise and repeat experiments many times in order to obtain the solutions they are seeking. How many experiments do you think have been repeated in order to learn what we now know about cancer treatments?

Suppose you wanted to find out about the relationship between students' hearing ability and the volume of the music they listened to. Your hypothesis may be: "As students increase the volume of the music they listen to, their hearing ability will decrease." You design and conduct an experiment and obtain the data shown in **Figure 1**.

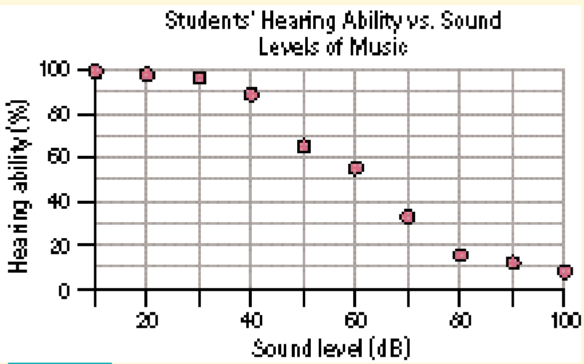


Figure 1

One conclusion from these results may read, "My hypothesis was correct. The results show that as the volume increases, there is a decline in students' ability to hear because..." Complete this concluding statement by providing an explanation for the results obtained. Can you think of any other possible hypotheses and conclusions that would explain these results? For example, you might hypothesize, "Students increase the volume when their hearing ability is low, because they couldn't hear the music otherwise." What would your conclusion be?

Reaching conclusions in science allows you to critically analyze the results using a mix of logic, common sense, understanding, and patience.

Try This Concluding

Reach an educated guess (hypothesis) for each of the following problems. Think about the conclusions you made—remember to refer back to your original hypothesis.

1. How many cubic metres of soil are required to fill a hole 6 m long, 2 m wide, and 2 m deep?
2. If 3 cats catch 3 mice in 3 min, how many cats would be needed to catch 100 mice in 100 min?

7E Reflecting on Ideas

It is always important to reflect on events in order to learn from them. This is one aspect of scientific inquiry that is sometimes neglected, especially with beginning scientists. Once an investigation has been completed, it is always advantageous to step back and think about what you did. What went well? What were the challenges? What could be improved? What would you do differently if you were to complete the investigation again? It is through reflecting on your actions that you will improve your work and increase your learning.

When reflecting on any investigation you performed, be sure to identify the types of experimental error that may have emerged at any point in the experimental process. These sources of error should be identified in the conclusion or discussion of your results. For example, say you completed an experiment and were able to conclude that plants did grow toward sunlight. What sources of experimental error could have occurred while performing this experiment? These could include such things as variations in air temperature, inconsistent exposure to light, or differences in soil composition. Be as specific as possible when stating experimental errors—it is not good enough to simply state, "It was due to human error."

Experimental errors decrease the validity of an experiment. But, more importantly, they allow you to revise your procedure. That revision will increase the reliability of the results the next time you perform the same investigation. Remember, experiments are a repeating process. (Refer back to the flow chart on scientific inquiry on page 527.) By repeating the process, you are improving your ideas and investigative skills.

Try This: Think About This

Reflect on your last science class. What worked well during that class? What could you have improved? What did you like about the class? What didn't you like about the class? What will you try to work on improving in your next science class?

8A Reporting Your Work

All investigators use a similar format to write reports, although the headings and order may vary slightly. Your report should reflect the process of scientific inquiry that you used in the investigation.

Cover Page: Make a cover page (**Figure 1**) that includes the following:
- the name of your school
- the course code
- the title of your investigation
- your name
- name of your partner(s) (if applicable)
- your instructor's name
- the due date

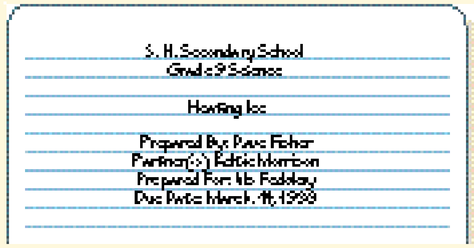


Figure 1
A cover page

Title: At the beginning of your written report, write the title of your experiment.

Introduction: Always begin with a brief explanation of pertinent theory underlying the experiment. This includes the information you discovered by researching your topic. This section is also referred to as your "review of literature."

Purpose, Question, or Problem: Make a brief statement about your investigation. This can also be written as a question.

Hypothesis: Write the hypothesis. Remember this is your "educated guess," based on your previous knowledge and the research you completed.

Materials: These include consumables (e.g., water, paper towels). Be specific about sizes and quantities. These also include nonconsumables (e.g., test tube, beaker). Make a detailed list of the materials you used.

Diagram: Make a full-page diagram of the materials and apparatus you used in the experiment (**Figure 2**). Remember to label and title the diagram. Your diagram can be placed at the end of your report, following the application.

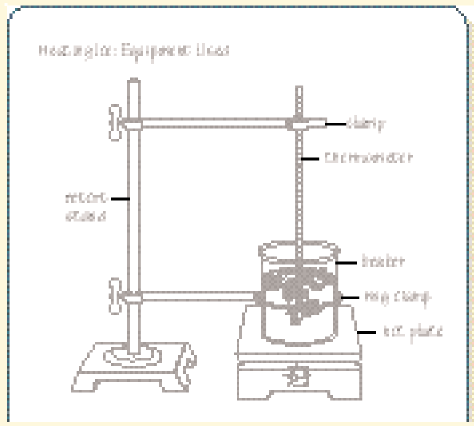


Figure 2
A diagram

Experimental Design: List the independent, dependent, and controlled variables in your experiment and summarize the procedure.

Procedure: The most important part of an investigation, when others are trying to determine if it is "good" or "bad" science, is the procedure. Many researchers read only the procedure section in a report, to gain insight into a procedure they could use themselves. To be sure that your work is judged fairly, make sure you leave nothing out! Remember to write this

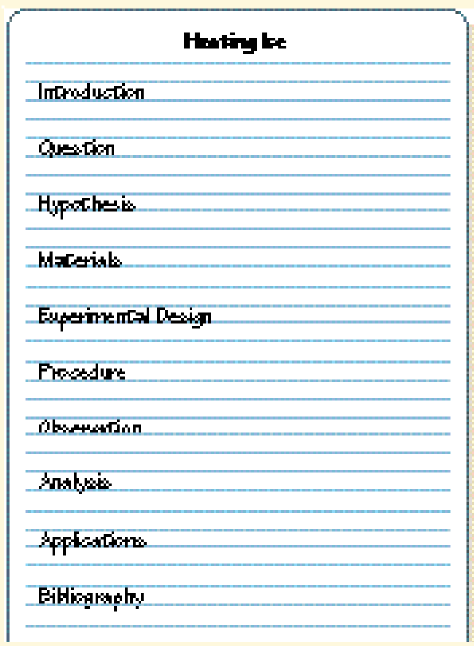


Figure 3
Your report should reflect the process of scientific inquiry

in numbered steps, past tense, and passive voice.

Observations/Results: Present your observations and results in a form that is easily understood. The data should be in tables, graphs, or illustrations, each with a title. Include any calculations that are used. The results of the calculations can be shown in a table.

Analysis/Conclusion: Summarize the investigation as you would if you were writing a book report. Refer back to your hypothesis. Was it correct, partially correct, or incorrect? Explain how you arrived at your conclusion(s). Justify your method and describe your results. Suggest a theory to support or interpret your results. If you were assigned questions with an investigation, you would answer them here. Discuss any sources of experimental error that may have affected your findings.

Applications: Describe how the new knowledge you gained from doing the investigation relates to your life and our society. It should answer the question, "Who cares?"

References/Bibliography: Give credit for the resources you used in your research. Always cite your source(s). Failing to do so is considered plagiarism (unacknowledged copying). It is unethical and illegal. Whenever you give credit to an author (including yourself from previous reports!) for the use of graphs, tables, diagrams, or ideas, use the following technique:

- Immediately after the information is used, give the last name of the source, the date of the publication, and the page reference. For example:

  The demand for electronic devices on board satellites has been a great stimulus to the development of microchips (Hawkes, 1992, p. 18).

The bibliography, at the end of your report, should be in alphabetical order of authors' last name. Be sure to use "hanging" indents, that is, indent every line after the first one. The format for books, journals, web sites, newspapers, and CD-ROMs differs. To make sure you cite your sources correctly, refer to the following examples:

- If the quotation or information comes from a book, use the following format, which includes the publisher's name and the city of publication:

  Hawkes, Nigel (1992), *Into Space*. New York: Gloucester Press.
- If the quotation or information comes from a journal or a magazine, use the following format. Include the volume number of the magazine (usually found on the Table of Contents page) and the page numbers of the article.

  Flamsteed, Sam (1997). "Impossible Planets." *Discover* 18 (9): 78–83.
- If the quotation or information comes from a newspaper, use the following format:

  Chandler, David. "New solar system is the first discovered outside our own." *Toronto Star*. April 16, 1999. Section A, p. 3.
- If the quotation or information comes from a web site, use the following format:

  Space Technologies Web Site, N.D. Available HTTP: http://www.space.gc.ca/ENG/About/SPATECH/welcome.html#Director [1999, April 6]

  If no date is given on the web site, use N.D.
- If the quotation or information comes from a CD-ROM, use the following format:

  Oxford English Dictionary Computer File: On Compact Disc. 2nd ed. CD-ROM. Oxford. Oxford UP, 1992.

Checklist for Writing a Report

Refer to this checklist whenever you are required to write a scientific report.

✔ Cover page
✔ Title of the investigation
✔ Introduction
✔ Purpose/Question
✔ Hypothesis
✔ Materials
✔ Diagram
✔ Experimental Design
✔ Procedure
✔ Observations/Results
✔ Analysis/Conclusion
✔ Applications
✔ References/Bibliography

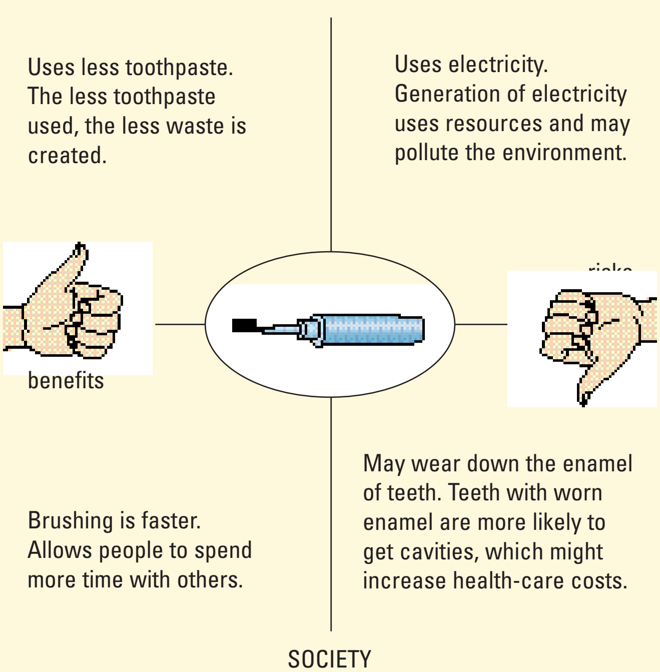
8B Exploring an Issue

In *Nelson Science 9*, you will have opportunities to explore many issues. Advances in science and technology need to be evaluated from many different perspectives—particularly since these advances are being made at an ever increasing rate.

Figure 1 shows a helpful way of organizing the advantages and disadvantages of a given issue related to science or technology.

Should you use an electric toothbrush?

Figure 1



Toward an Educated Opinion

The following process will help you evaluate the pros and cons of an issue and provide supporting evidence and arguments to the position you ultimately take on that issue.

1. Initial Research:

Choose an issue that really interests you. Gather at least two initial sources of information about it. Consider all the sources of information available to you (page 530).

2. Formulation of a Question

Put together a question around the issue. The question should be answerable, important to our society, and debatable. You are encouraged to "try this question out" on your classmates, teacher, and others.

3. Further Research

Continue your research on this topic. Find at least two additional sources of information on the issue. Be sure to scrutinize the credibility of your information. Remember PERCS (page 533)!

4. Reaching Your Position

Answer your question. Explain your position thoroughly. Be sure to consider the following:

- Have you included information from at least three articles?
- Have you stated your position clearly?
- Have you shown why this issue is relevant and important to our society?
- Have you included at least two solid arguments (with solid evidence) supporting your position?
- Have you included at least two arguments against your position and shown their respective faults?
- Have you analyzed the strong points and weak points of each perspective?

5. Communicating Your Position

There are several ways of communicating your position, each with its own format:

- Write a position paper or brief essay.
- Participate in a formal debate.
- Participate in a role-play activity, taking on the role of a specific, affected party.
- Write a letter to the editor of a newspaper.

8C Science Projects

Presenting Your Project

After you have completed your project, you may want to display your results in a science fair or present them to your class (**Figure 1**).

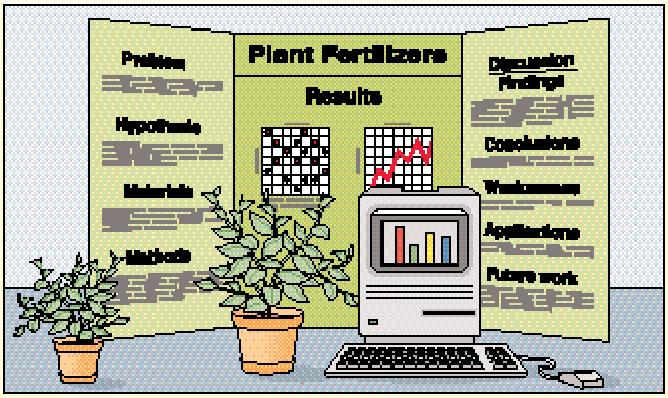
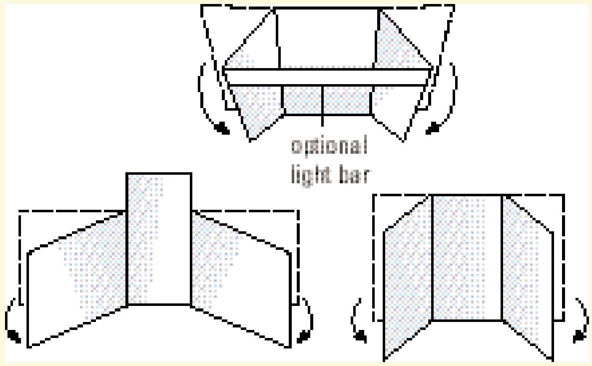


Figure 1
Your display

When constructing a display board, there are some things to keep in mind.

- Use a sketch to plan the layout.
- Collect a variety of display items (photos, sketches, charts, graphs, text).
- Use different sizes of letters for the text on your board. The most important ideas should have the largest letters.
- Place the title in a central location.
- Make all lettering neat and easy to read.
- Simple is best. Use the same kind of lettering throughout. If you are using colours or shapes to highlight important features, use only a few.
- Make sure your diagrams, graphs, and charts are neat.
- Place your results in a prominent position on the board.
- Try to place all your materials on the board before you start gluing or stapling. Have a classmate or a parent "critique" your display.
- Place only the most important information on the display board. If there is lots of space around wording and diagrams, the display will be more attractive.
- Make sure that nothing on your board is blocked by objects that will be in front of the board.
- Make sure things flow in a logical, easy-to-follow sequence.



Three different display boards

You may also want to display your project on the Internet or put together a computer-based presentation. Have a look at on-line science fairs on the Internet for ideas on how to put together your electronic display.

Your Oral Presentation

Plan your oral presentation well in advance. Prepare a point-form "speech" on cue cards or a computer-based presentation and be sure to consider the following questions:

- What was the goal of your project?
- Why was the topic interesting?
- How did you carry out your project?
- What were the major results of your project?
- What conclusion did you reach?
- How might your findings help others?
- On the basis of your results, is there another project that could be done?

It is best not to read your speech when presenting. But don't memorize every word. Just practise it several times. If you get stuck, use your display board as a guide. Another trick is to memorize the seven questions above, or write them on cards, and answer them as you speak.

9A Good Study Habits

Understanding anything—whether it is a life-saving technique in the swimming pool, a trumpet solo, or a science lesson—is an active process. Studying takes on many forms. It involves learning and understanding material. Developing the following study skills can help you in your learning. You can modify these tips to help you in other school courses and in recreational activities.

Your Study Environment

- **Organize your working area.** The place where you study at home and at school should be neat, tidy, and organized. Papers, books, magazines, or pictures that are strewn all over your working area will distract you from focusing on the work at hand.
- **Maintain a quiet study space.** Make sure that the place where you decide to study is removed from distractions such as the phone, stereo system, TV, friends, and annoying brothers and sisters. Popular study spaces include the school library, the public library, and your bedroom at home (if it has a working area). Any quiet place where you can be productive will work.
- **Make sure you feel comfortable in your study space.** You will be the most productive and study effectively if you are working in an area where you feel at ease—personalize your learning space.
- **Be prepared with all the materials you will need.** It is important that you have all your notebooks, textbooks, computer equipment, paper, pencil, pen, ruler, and anything else you use for your work in your study space. If you have to continually get up to find a book or eraser, you won't be able to accomplish as much as you had hoped.

Study Habits

- **Prepare for class by reading material ahead of time.** It is also helpful to read or view materials from other sources, such as science magazines, newspapers, the Internet, and television programs.
- **Take notes.** To make note taking easier, you may want to make up a shorthand method of recording ideas.
- **Review any notes you made in class the same day and add comments.** Then have a friend or relative quiz you on the material in the notes. Reinforce your understanding by answering the questions in the textbook—even if they are not assigned.
- **Use your notes and the textbook to prepare summaries.** Studying is most effective with a pen or pencil or your word processor, so you can write down the important ideas (**Figure 1**). You may want to write or type study cards to assist in making effective, point-form summaries of your notes. Look at the example in **Figure 2**. Notice there is a title at the top and all the information has been condensed into a point-form, easy-to-learn format. It's much more effective than learning material that is in paragraph form. Condense, condense, and condense!

Figure 1

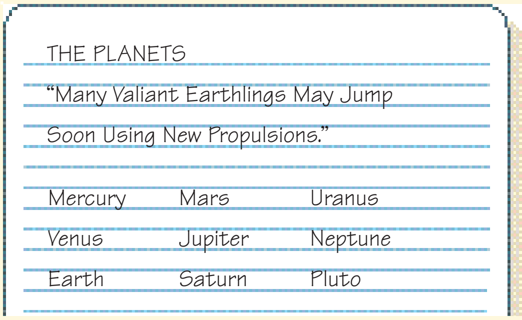


Figure 2

- **Draw a concept map to help you summarize a chapter, unit, or lesson.** (See Concept Mapping on page 572.) You may want to use the textbook summary at the end of the chapter.
- **"Practice makes perfect."** This is as true for science as it is for playing piano and shooting baskets. If you practise your science skills until they become almost automatic, you will have more time to think about how you will use them.
- **Schedule your study time.** This will help you avoid that most ineffective of all study methods, "cramming" before assignments and tests. Use a daily planner and take it with you to every class. Write all homework assignments, tests, projects, and extra-curricular commitments in it. This will assist you in organizing a daily "To Do" list that will ensure maximum use of your time.
- **Know your strengths and your weaknesses.** Take advantage of all opportunities to get help with areas in which you may have trouble. Use your strengths to help yourself and others. Form a study group and have regular meetings. You may be able to help others in some parts of the course. In turn, you may receive help from them.
- **Teach the material you have learned to someone who has not yet learned it.** Their questions will help you see what areas of the subject you need to learn more about and what areas you don't completely understand (**Figure 3**).
- **Take study breaks.** It is important that you set study goals and take a short study break after meeting each of the goals you set. For example, you could decide that you will take a study break after crossing two items off your "To Do" list. Taking study breaks will help you rejuvenate for the next tasks on your list and will assist you in completing all your work effectively and accurately.

Study Checklist

✔ Organize your study environment. (Is it quiet? comfortable? organized?)
✔ Read material ahead of time.
✔ Take notes.
✔ Review.
✔ Summarize. (Make study cards, if that technique works for you.)
✔ Draw a concept map.
✔ Practise.
✔ Schedule study time. (Use your daily planner and make a "To Do" list.)
✔ Know your strengths and weaknesses.
✔ Teach what you have learned.

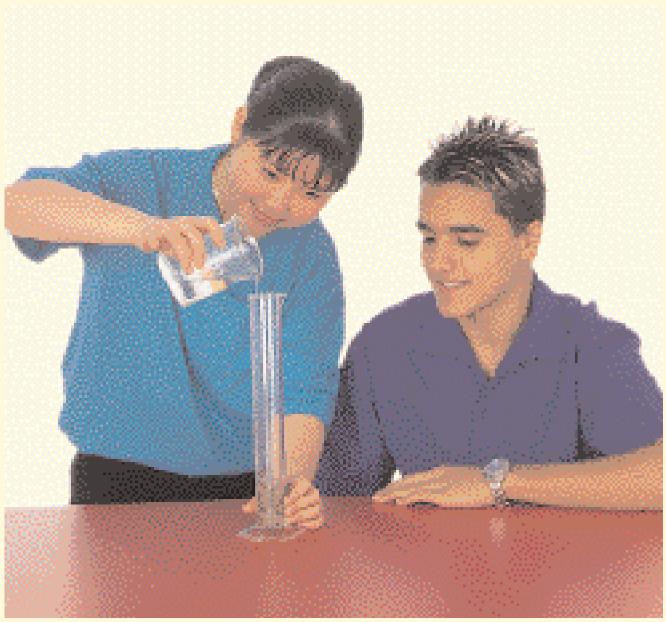


Figure 3

Try This Your Study Space

Draw pictures of your study environment at home and at school. List five good points about your study spaces and five things that could be changed in each of your study spaces to give you an even more effective learning environment.

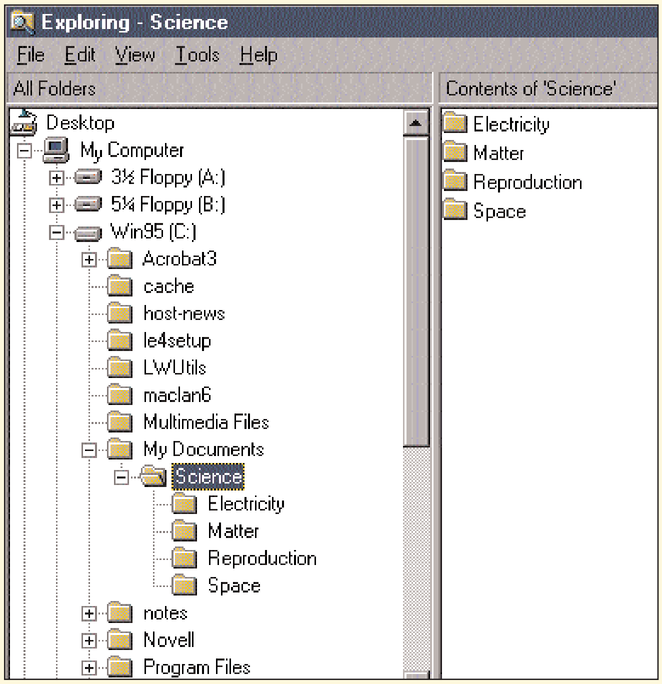
9B Using Your Computer Effectively

Computers are becoming more and more common in your learning. Most of you have access to this technology at some point every week. Like your notebook, it is important to keep your computer files organized. It is also necessary to use your computer effectively—there is a time for computer work and a time for computer games and recreational surfing of the Internet. The following hints can assist you in using your computer effectively in your learning. Remember, these hints can be modified to suit your needs.

Computer Hints

Create a "science" file for all your science work. It is important that any computer work you do is kept in one folder. Otherwise, your work could be saved in lots of different locations on your computer and this means that it could become easily misplaced or even lost.

Organize your science units in your science folder. Now that you have created a science folder, organize this folder into the various units that you will study this year. These include Electricity, Matter, Reproduction, and Space. Refer to the illustration on this page for a detailed glimpse of what your science folder might look like.



Think carefully about what to name each of your documents. Make sure that the names you give your documents allow you to easily identify what a particular document contains. Work that is called Science 1, Science 2, and Science 3 provides no indication of what the work actually is. Be as specific as possible.

Back up your work. Always make an extra copy of any work you do on the computer. Copy your work onto a disk or onto your school network. Too many times students lose their work because they do not take the time to do this. It really does save time in the long run. It's much better than having to complete a report or assignment all over again.

Maintain correct posture and form. It is important that you don't sit too close to the screen and that you sit in an upright position with your hands positioned correctly while typing. Incorrect hand positioning can eventually cause carpal tunnel syndrome. The study of how people interact effectively and safely with computers is part of what is termed "ergonomics."

Try This — Organize Your Files

The next time you are using a computer to complete schoolwork, try organizing your science files in a way that makes sense to you. You may decide to organize all the computer work you do in each of your courses.

9C Working Together

Scientific discoveries are almost always made by teams of people working together. Scientists share ideas, help each other design experiments and studies, and sharpen each other's conclusions. We have all worked in a group at one time or another. In the "real world," group work is necessary and usually more productive than working alone. It is therefore important for us to be able to work in teams.

While working with *Nelson Science 9*, you will spend much of your time doing science as scientists do it—in teams. In this activity, you will work as a team. After you finish, reflect on the advantages and disadvantages of teamwork.

Evaluate the effectiveness of the team—the strengths, weaknesses, opportunities, and challenges. Answer the following:

1. What were the *strengths* of your teamwork?
2. What were the *weaknesses* of your teamwork?
3. What were *opportunities* provided by working with your team?
4. What possible *challenges* did you see with respect to your teamwork?

Teamwork Tips

When you work together with other students in a team, follow these tips:

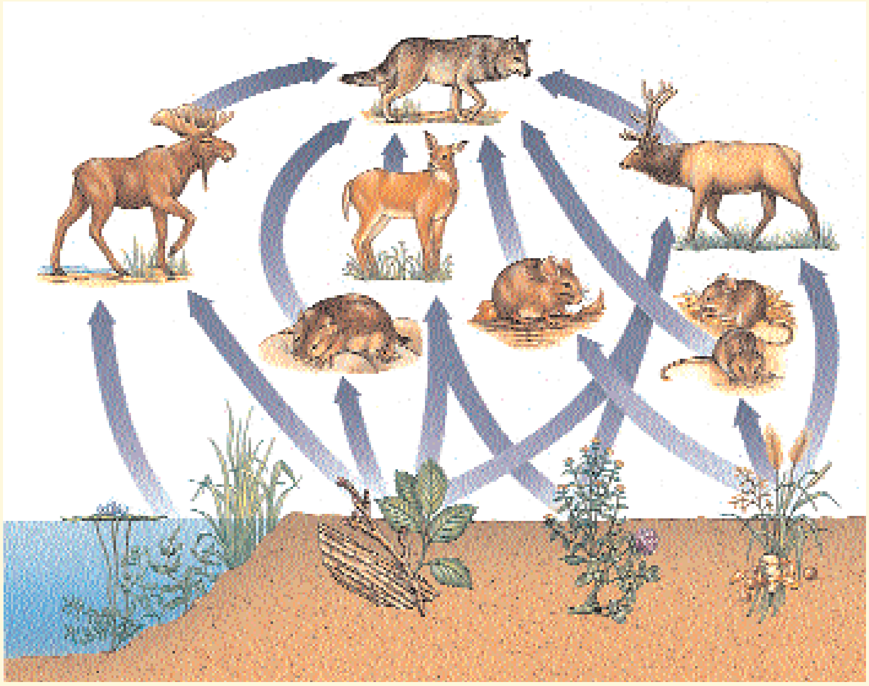
- Encourage all members to contribute to the work of the group.
- Respect everyone's contributions. There are many points of view and all perspectives should be considered. Keep an open mind. There should be no put-downs.
- Be prepared to compromise.
- Keep focused on the task at hand. Divide the various tasks among all group members.
- Support the team's final decision.
- When you are given the opportunity of picking your own team, be sure that the students you decide to work with complement your strengths and weaknesses.
- Can you think of any more tips that should be considered during group work?

Try This: Your Team Is Lost!

Your team is lost on a deserted island. You must survive on the island for at least five days. As a *team*, review the following list of items and choose the five things that your group would want on your island. The final decision should be reached by consensus! Be ready to share and support your decisions with the rest of the class.

flashlight with 4 batteries	12 chocolate bars
4 hats	groundsheet
box of matches	pen, pencil, paper
6 cans of beans	knife
map of island	rope
fruit (4 days' supply)	calculator
water	chewing gum
4 books	compass
Monopoly game	first-aid kit
can opener	comic books
laptop computer	

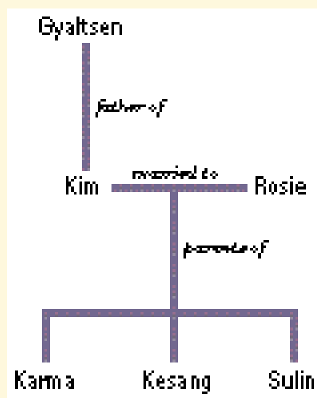
Concept Mapping



When you are trying to describe objects and events, it is sometimes helpful to record your ideas so that you can see them and compare them with those of other people. Instead of putting your ideas in sentences, they can be made into concept maps. A concept map is a collection of words (representing concepts) or pictures that you connect to each other with arrows and short descriptions. The map is a drawing of what is happening in your brain.

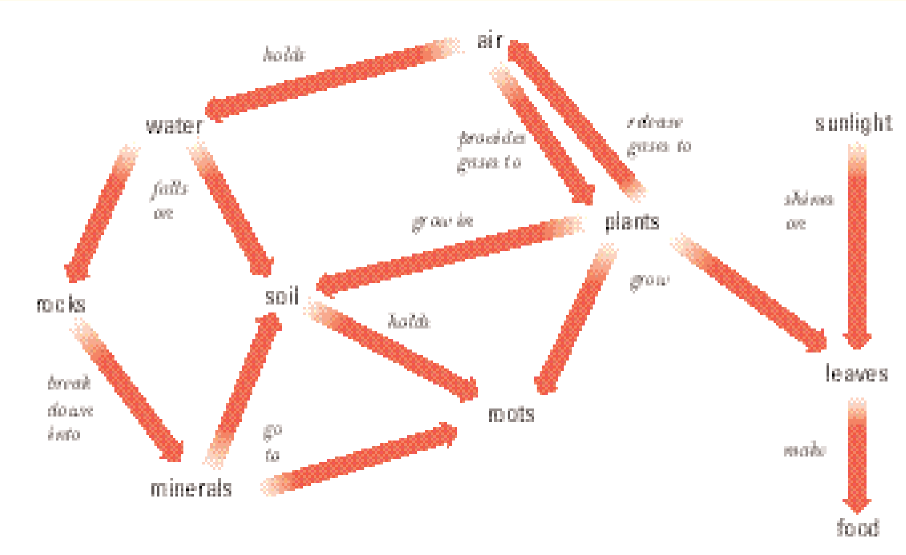
You may have seen concept maps similar to the one shown above. This concept map, called a food web, shows one way of thinking about animals and what they eat. The arrowhead points to the animal that eats the animal or plant at the other end of the arrow. The arrows describe the relationship between the organisms.

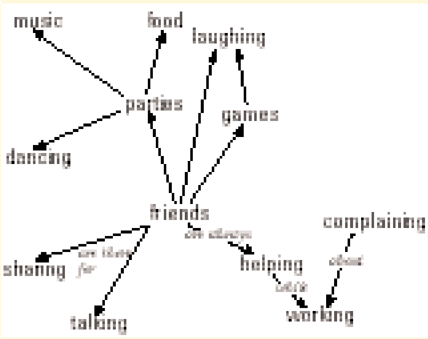
Concept maps can also be drawn of other topics and in other ways. For instance, the relationships between family members can be drawn using a concept map like the one to the right.

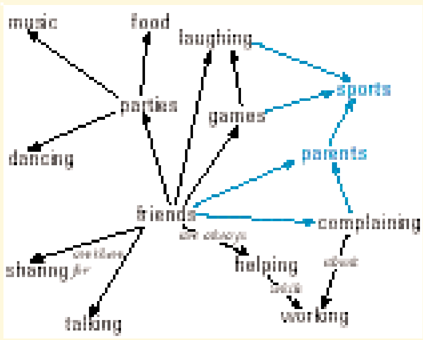


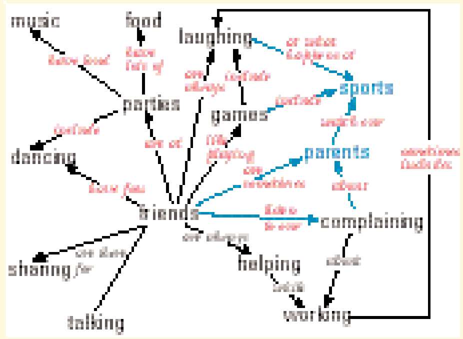
Concept maps can also be drawn to show a series of cause-and-effect relationships. You may find making this kind of map useful during a science investigation.

Sometimes concept maps can be used to show how your ideas change and become more complex as you work on a topic. You can see an example of this type of concept map on page 573.









Making a Concept Map

Here are some steps you can take to help you make a concept map.

1. Choose the central idea of your concept map.
2. Write the central idea and all related ideas on small scraps of paper.
3. Move the scraps of paper around the central idea so that the ideas most related to each other are close to each other. Ask yourself how they are related, and then use that information in the next steps.
4. On a big sheet of paper, write down all your ideas in the same pattern that you have arranged the scraps. Draw arrows between the ideas that are related.
5. On each arrow, write a short description of how the terms are related to each other.

As you go, you may find other ideas or relationships. Add them to the map.

When you gain new ideas—whether from research, from your investigations, or from other people—go ahead and change your concept map. You may want to add new ideas in a different colour of ink, to indicate your new ways of thinking about the ideas.

Try This Mapping "Science"

Develop a concept map on the topic Science. Include at least 10 related ideas. Try to include some connections to your other subject areas. When you have finished your concept map, share it with a classmate. Other ideas or concepts may come to you while you discuss your map. Add these ideas in a different colour.