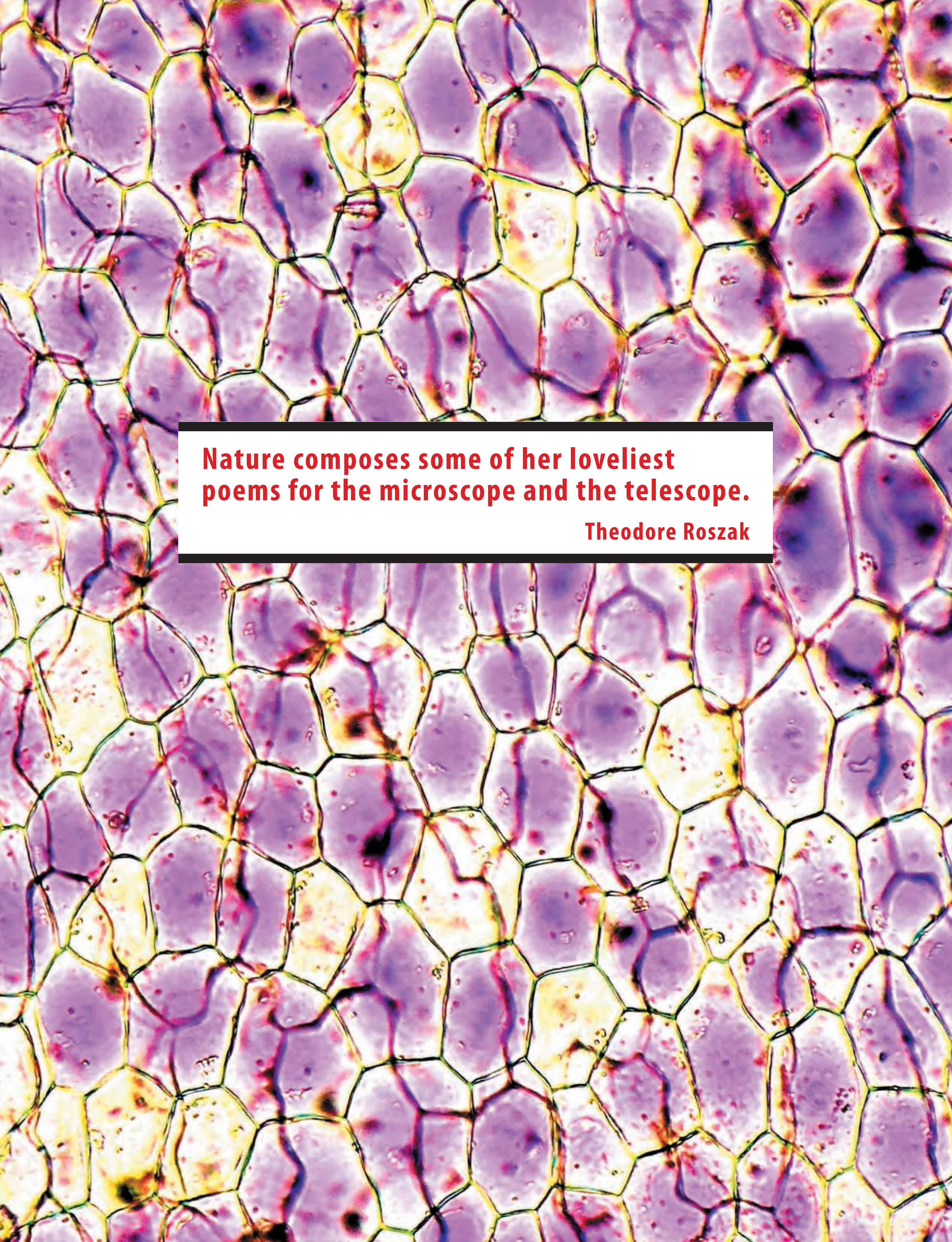


**Nature composes some of her loveliest poems for the microscope and the telescope.**

**Theodore Roszak**

# 1 Science is . . .

**Although science is a body of knowledge, it is also a way of solving problems and finding the answers to questions. Scientific knowledge is always growing and changing because scientists design and perform investigations. Observing, measuring, constructing tables, drawing graphs and forming conclusions are just some of the skills used in conducting scientific investigations.**

## OVERARCHING IDEAS

- Patterns, order and organisation
- Scale and measurement
- Matter and energy
- Stability and change

## GENERAL CAPABILITIES

Literacy

Numeracy

ICT competence

Critical and creative thinking

Personal and social competence

## SCIENCE AS A HUMAN ENDEAVOUR

Nature and development of science

Use and influence of science

## SCIENCE INQUIRY SKILLS

Questioning and predicting

Planning and conducting

Processing and analysing data and information

Evaluating

Communicating

## THINK ABOUT SCIENCE

- Why are graphs useful to scientists?
- How do you start your own scientific investigation?
- What do the letters CSIRO stand for?

A scientist studying paper chromatographs

YOUR QUEST

# Researching the CSIRO

## INVESTIGATE

1 What is the CSIRO?

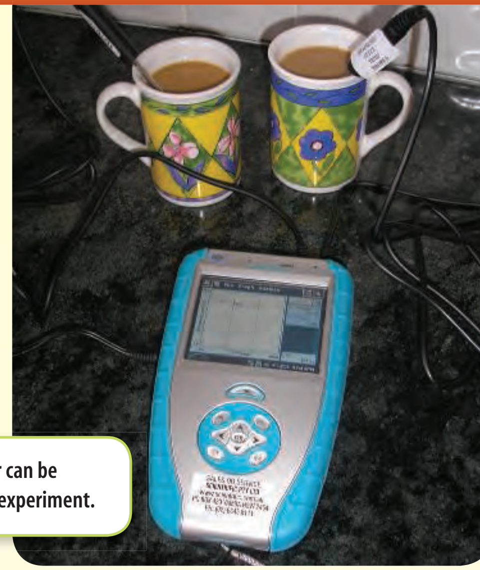
2 The CSIRO's website describes some of the research done by CSIRO scientists. Read the information provided for one area of research that the CSIRO is involved with and summarise this research in point form.

3 Form groups of three. Each student should explain to the other two students the area of research they have just read about. Try doing this without referring to your notes.

eBook*plus* **Weblink**

**CSIRO**

Use the **CSIRO** weblink in your eBookPLUS to answer the questions on the left.



A data logger can be used for this experiment.

## INQUIRY: INVESTIGATION 1.1

## Milk now or later?

You have just finished making yourself a cup of coffee when the phone rings. So that your coffee is as warm as possible, should you add the milk to your coffee now or after you have finished talking on the phone? Does your answer depend on the length of the phone call?

### KEY INQUIRY SKILLS:

- planning and conducting
- processing and analysing data and information

### *Equipment:*

*kettle* | *2 identical cups*
*instant coffee* | *milk*
*2 thermometers or a data logger with 2 temperature probes*
*2 measuring cylinders*

- Your teacher will assign a particular 'phone call' time to each group of students.
- Heat some water in a kettle and use it to make two cups of instant coffee. Use the same type of cup and the same amount of hot water and coffee powder.
- Place a thermometer or temperature probe in each cup of coffee. If you are using a data logger, set it to collect results for at least 10 minutes.
- Add 40 mL of milk to one of the cups.
- If you are using thermometers, record the temperature of the coffee in both cups every 30 seconds.
- After your phone call time has passed, add 40 mL milk to the second cup.
- Continue measuring the temperature in both cups every 30 seconds until 10 minutes has passed since you added the milk to the first cup.
- If you used thermometers, record your results in a table.

| Time (minutes) | Temperature (°C) | |
|---|---|---|
| | Milk added at time 0 | Milk added after 'phone call' |
| 0.0 | | |
| 0.5 | | |
| 1.0 | | |
| 1.5 | | |

- Plot line graphs of your results on the same set of axes. Put time on the horizontal axis and temperature on the vertical axis.
- If you used a data logger, a graph is plotted automatically. If necessary, adjust the settings so that the graph shows the temperatures measured by both probes on the same set of axes. Put the graph into the results section of your experiment report.

### DISCUSS AND EXPLAIN

1 Does hot coffee cool faster than warm coffee? How can you tell from your graph?

2 Did the two lines on the graph cross at any stage? What does this indicate?

3 Write a conclusion based on your results.

4 Does the length of the 'phone call' affect the results? Compare your graphs with those of other groups.

5 Why was it important to put exactly the same amount of water in both cups and to use the same type of cup?

6 What are the advantages and disadvantages of using a data logger for this experiment?

7 Explain how this experiment could be improved.

# 1.1 SCIENCE INQUIRY SKILLS

# Safety first

Conducting scientific investigations in a laboratory can be exciting, but accidents can happen if they are not carried out carefully. There are certain rules that must be followed for your own safety and the safety of others.

Doing experiments in science can be exciting, but accidents can happen if investigations are not carried out carefully. There are certain rules that must be followed for your own safety and the safety of others.

**ALWAYS . . .**

- follow the teacher's instructions
- wear safety glasses and a laboratory coat or apron, and tie back long hair when mixing or heating substances
- point test tubes away from your eyes and away from your fellow students
- push chairs in and keep walkways clear
- inform your teacher if you break equipment, spill chemicals or cut or burn yourself
- wait until hot equipment has cooled before putting it away
- clean your workspace — don't leave any equipment on the bench
- dispose of waste as instructed by your teacher
- wash your hands thoroughly after handling any substances in the laboratory.

**NEVER . . .**

- enter the laboratory without your teacher's permission
- run or push in the laboratory
- eat or drink in the laboratory
- smell or taste chemicals unless your teacher says it's ok. When you do need to smell substances, fan the odour to your nose with your hand
- leave an experiment unattended
- conduct your own experiments without the teacher's approval
- put solid materials down the sink
- pour hazardous chemicals down the sink (check with your teacher)
- put hot objects or broken glass in the bin.

## Handy hints

- Use a **filter funnel** when pouring from a bottle or container without a lip.
- Never put wooden test-tube holders near a flame.
- Always turn the tap on before putting a **beaker**, **test tube** or **measuring cylinder** under the stream of water.
- Remember that most objects get very hot when exposed to heat or a naked flame.
- Do not use tongs to lift or move beakers.

## Working with dangerous chemicals

Your teacher will tell you how to handle the chemicals in each experiment. At times, you may come across warning labels on the substances you are using.


Always wear gloves and **safety glasses** when using chemicals with this symbol. Corrosive substances can cause severe damage to skin and eyes. Acid is an example of a **corrosive** substance.


These substances are easily set on fire so keep them away from flames. Methylated spirits is **flammable**.


Chemicals with this label can cause death or serious injury if swallowed or breathed in. They are also dangerous when touched without gloves because they can be absorbed by the skin. Mercury is a **toxic** substance.

## Heating substances

Many experiments that you will conduct in the laboratory require heating. In school laboratories, heating is usually done with a

Bunsen burner. A Bunsen burner provides heat when a mixture of air and gas is lit.

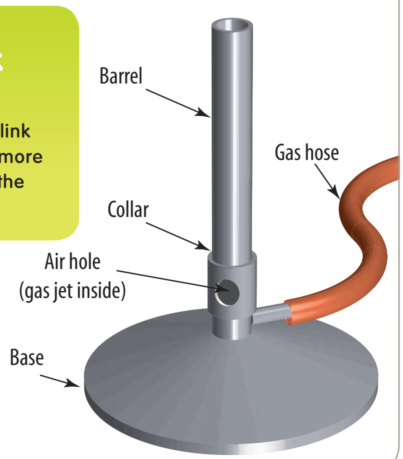
Bunsen burners heat objects or liquids with a naked flame. Always tie hair back, and wear safety glasses and a laboratory coat or apron when using a Bunsen burner.

### A GUIDE TO USING THE BUNSEN BURNER

1. Place the Bunsen burner on a heatproof mat.
2. Check that the gas tap is in the 'off' position.
3. Connect the rubber hose to the gas tap.
4. Close the air hole of the Bunsen burner collar.
5. Light a match and hold it a few centimetres above the barrel.
6. Turn on the gas tap and a yellow flame will appear.
7. Adjust the flame by moving the collar until the air hole is open and a blue flame appears.
8. Remember to close the collar to return the flame to yellow when the Bunsen burner is not in use.

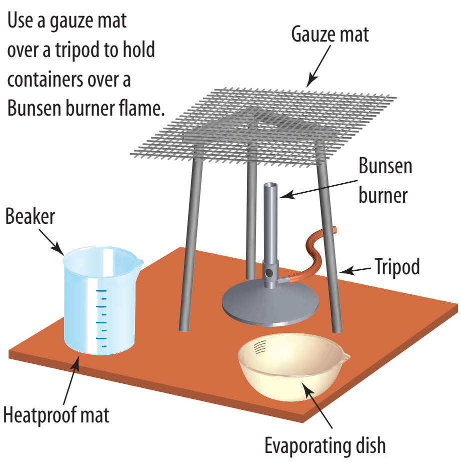
eBook*plus* **Weblink**

**Robert Bunsen**
Use the **Robert Bunsen** weblink in your eBookPLUS to learn more about the man after whom the Bunsen burner was named.




### HEATING CONTAINERS

Beakers and evaporating dishes can be placed straight onto a gauze mat for heating. Never look directly into a container while it is being heated. Wait until the equipment has cooled properly before handling it.



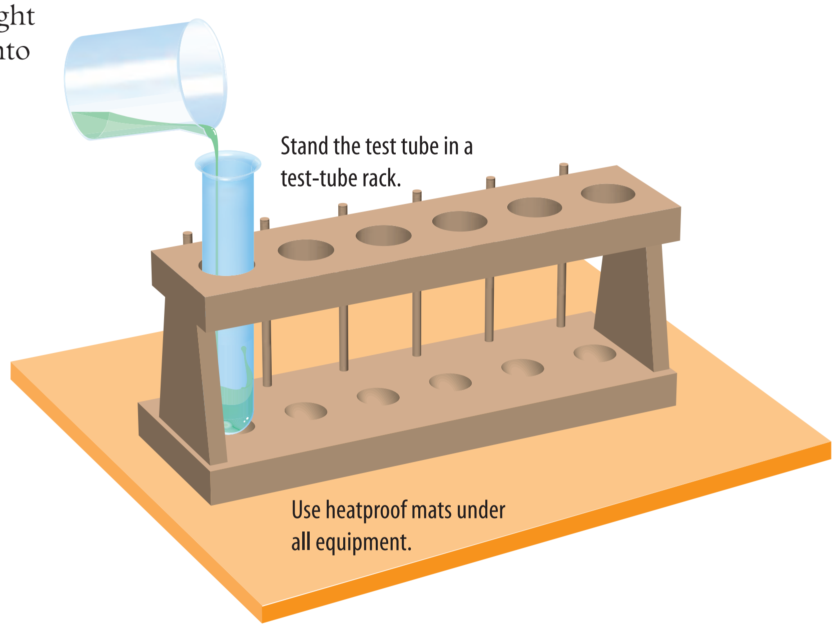

### HEATING A TEST TUBE

Tripods and gauze mats are not used when heating test tubes. Hold the test tube with the test-tube holder. Keep the base of the test tube above the flame. Make sure that the test tube points away from you and other students.

## Glassware

### POURING A LIQUID INTO A TEST TUBE

Pour liquids carefully into the test tube from a beaker or measuring cylinder. Use a filter funnel when pouring from bottles or containers without a lip.

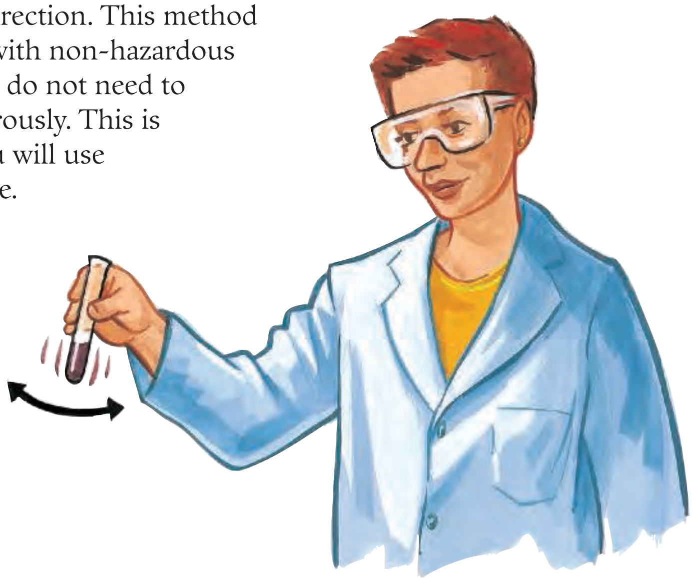


## SHAKING A TEST TUBE

There are two ways to shake substances in a test tube.

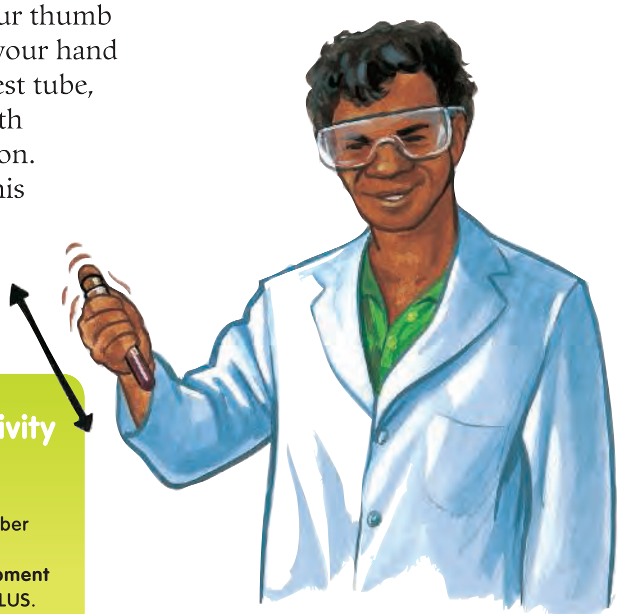
### Method 1

Hold the top of the test tube and gently move the base of the test tube in a sideways direction. This method is good to use with non-hazardous substances that do not need to be shaken vigorously. This is the method you will use most of the time.



### Method 2

Use a stopper when a substance needs to be mixed by shaking vigorously. Place an appropriately sized stopper into the mouth of the test tube. With your thumb over the stopper and your hand securely around the test tube, shake the test tube with an up and down motion. Shake a test tube in this way only if instructed to do so by the teacher.



eBookplus **Interactivity**

**Using equipment**
Identify the equipment you will need to perform a number of laboratory processes by completing the **Using equipment** interactivity in your eBookPLUS.
**int-0200**

# Using electricity safely

eBookplus

Electrical equipment in the science laboratory should be used with great care, just as it should be in the home or workplace. Never:

- place heavy electrical appliances near the edge of a bench or table
- allow water near electrical cords, plugs or power points
- place objects other than the correct electrical plug into a power point
- use appliances with damaged cords or exposed wires.

## UNDERSTANDING AND INQUIRING

### UNDERSTAND

1 Explain, with the aid of a diagram, how to safely heat a liquid in a test tube using a Bunsen burner. Ensure all relevant safety rules are included in your explanation.

2 How should a substance in a test tube be shaken if you are not instructed to shake it vigorously with a stopper in the mouth of the test tube?

3 Methylated spirits is a flammable liquid. What does this mean?

### THINK

4 List the dangers of each of the following examples of unsafe behaviour in the science laboratory.
 (a) Not wearing safety glasses while heating a liquid in a beaker
 (b) Using an electronic balance to measure the mass of a substance before cleaning up some spilled water on the bench next to it

5 Why should you always wear gloves when working with:
 (a) corrosive substances?
 (b) toxic substances?

6 Long hair should be tied back when heating or mixing substances in the laboratory. Why is this so?

7 Explain why a test tube should be standing in a test-tube rack when you are pouring a liquid into it.

### CREATE

8 Draw a flowchart to illustrate the correct method for lighting a Bunsen burner. Use pictures or cartoons as well as words.

9 Which one safety rule do you feel is the most important when you are mixing two liquids and heating them? Create a poster to illustrate the rule.

10 Identify the equipment you will need to perform a number of laboratory processes by completing the **Using equipment** interactivity in your eBookPLUS. **int-0200**

work sheets
1.1 Safety in the laboratory
1.2 Safety rules

1.2 SCIENCE INQUIRY SKILLS

# Planning your own investigation

Discuss your ideas with others.

## Formulating your question

Before you define your question in detail, you need to find a topic that interests you. Selecting your topic is the first and one of the most crucial steps in conducting your research project.

## Finding a topic

1. Start by searching for a general area of interest. List your hobbies and other interests.
2. Do you have a friend or relative who might be able to help you in a scientific investigation? Write down the topic areas in which you could get help.
3. Discuss the possible research topics you have already written down with a group of fellow students. Listen carefully to their ideas. They might help you to decide on your own topic. Write down your ideas.
4. Have a look through the list of ideas below left. Even if none of the suggested topics appeals to you, they may help you to think of other ideas. For example, 'The strength of sticky tape' could lead you to consider topics such as the strength of glass, wood, paper, plastics or some other material. 'Brainstorm' possible topics with your friends and make your own list of suggested investigations.
5. Search in a library or at home for books or newspaper articles about the topic areas that you have already written down. You might also find magazines or journals that include articles about these topic areas. Conduct an internet search.

### SOME IDEAS FOR TOPICS

How do fertilisers affect the growth of plants?

Can plants grow without soil?

What makes algae grow in an aquarium?

What is the best shape for a boomerang?

What type of wood gives off the most heat while burning?

What makes iron rust?

Which paint weathers best?

Which battery lasts longest?

The strength of sticky tape

Which type of glue is best?

How much weight can a plastic bag hold?

Which food wrap keeps food fresher?

The effectiveness of pre-wash stain removers

Which fabrics burn faster?

Comparing fabrics for warmth

How can the growth of mould on fruit be slowed down?

Which concrete mixture is strongest?

Comparing the strength of fishing lines

Does the thickness of a rubber band affect how far it stretches?

What type of paper aeroplane flies furthest?

What is the best recipe for soap bubble mixture?

Do tall people jump higher and further than short people?

What type of fabric keeps you warmest in winter?

## The aim of the game

Your investigation should have a clear and realistic aim. It should be very specific. The aim of an investigation is its purpose, or the reason for doing it. Some examples of aims are:

- to find out how the weight and shape of paper aeroplanes affects how far they will fly
- to compare the effect of different fertilisers on the growth of pea plants
- to find out whether different coloured lights affect the growth of algae in an aquarium
- to find out how the exposure of iron to salty water affects how quickly it rusts.

'To find out if the weight of paper planes makes them fly better' is not a suitable aim because 'fly better' has not been defined. 'Fly better' could mean fly further, fly in a straighter line or stay in the air longer. A better aim would be 'To find out how the weight of paper planes affects their flight distance and time in the air.'

When you have decided what your aim is, make sure that it is realistic. You should be able to answer 'yes' to each of the questions on the following page.

### WHAT DOES IT MEAN?

The word *experiment* comes from the Latin word ***experimentum***, meaning 'trial' or 'test'.

- Is my question simple and clear enough?
- Will I be able to get the background information that I need?
- Is the equipment I need for my experiments available or can it be made?
- Is the question a safe one to investigate?

If you answer no to any of these questions you need to 'rethink' your aim.

## Forming a hypothesis

A **hypothesis** is a sensible guess about the outcome of an experiment. It should relate to your aim and should be able to be tested with an experimental investigation. The results of your investigation will either support (agree with) or not support (disagree with) the hypothesis. It is not possible to prove conclusively that a hypothesis is correct.

When scientists make a hypothesis, they usually carry out a number of experiments to test that hypothesis. Sometimes, a number of teams of scientists test the same hypothesis with slightly different experiments. Even if the results of each experiment agree with the hypothesis, the scientists could never say that the hypothesis is proven to be correct. They would say that each experiment has provided further evidence to support the hypothesis.

Your hypothesis should be based on what you know about the topic or what you have already observed. For example, if you are trying to design the best parachute for a toy, you should read about parachutes before writing your hypothesis. You might also recall that when you are walking in the rain a cotton T-shirt soaks up a lot of water and becomes heavy, whereas a nylon jacket does not soak up water. As a result, your hypothesis might be: 'Closely woven nylon is a better fabric to use for a parachute than loosely woven cotton.' A statement that cannot be tested with a scientific experiment is not a suitable hypothesis.

The table below shows how problems and observations can lead to hypotheses.

| Problem | Observation | Hypothesis |
|---|---|---|
| The television remote control doesn't work. | If I press the 'on' button on the remote control, the television won't come on. | The batteries in the remote control are flat. |
| My hair is sometimes dry and frizzy. | My hair is driest soon after washing it with Mum's shampoo. | Mum's shampoo dries out my hair. |
| No parrots come to our bird feeder. | There is bread in the bird feeder, and magpies and miner birds feed there. | Parrots prefer wheat seeds. |

**Will nylon be better? Your own experience might help you form a hypothesis.**

### UNDERSTANDING AND INQUIRING

#### UNDERSTAND

1. List four questions you should ask about your aim before it is final.
2. Define the term 'hypothesis'.
3. How can a hypothesis be tested?

#### THINK

4. Why is 'to find out which glue is best' not a suitable aim? Write a more suitable aim for an investigation about glue.
5. Is each of the following statements a suitable hypothesis? If not, justify your answer.
   (a) White chocolate tastes better than dark chocolate.
   (b) Washing powder X removes tomato sauce stains faster than washing powder Y.
   (c) Plants grow faster under red light than under green light.
   (d) Sagittarians are nicer people than Leos.
   (e) Playing video games increases the muscle strength in your thumbs.
   (f) Playing video games affects the development of social skills.
   (g) Science teachers are more interesting people than English teachers.
   (h) Science teachers perform better in IQ tests than English teachers.
6. Consider the table on the left. Describe how you could test each of the three hypotheses.

work sheet 1.3 Observations and inferences

# Record keeping and research

Scientists do experiments to test hypotheses, which are based on observations as well as the previous discoveries of other scientists.

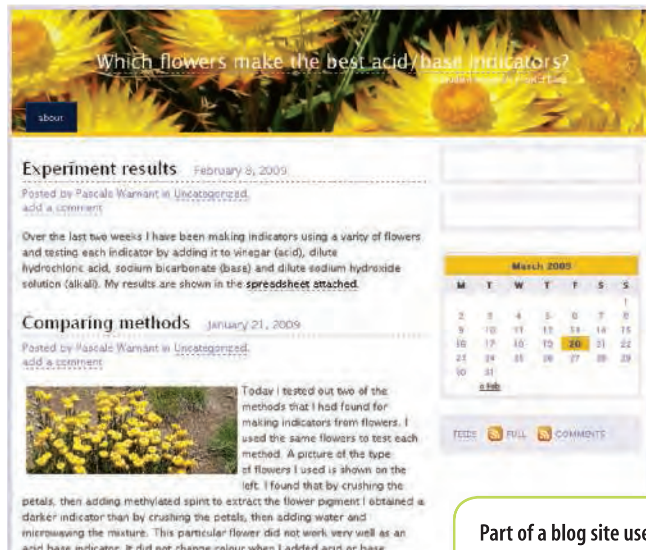
Before designing their experiments scientists do background research, which usually includes reading reports written by other scientists. Scientists also need to keep records of all their observations and any changes they make to the design of their experiments. When you conduct your own research investigation, you will probably be asked to do this by keeping a logbook.

## What is a logbook?

A logbook is a document in which you keep a record of all the work you do towards an investigation. Each entry should be dated like a diary. In your logbook, you might include the following items.

- A timeline or other evidence of planning your use of time
- Notes about conversations you have had with teachers, friends, parents or experts on your project and how these conversations affected your project. Make sure you record each person's details so you can acknowledge their contribution in your report.
- Notes from library research you have done for your project. Include all the details you will need for your bibliography.
- A plan or rough outline of the method you will use for your experiment(s)
- Notes about any problems you encountered during your project and how you dealt with these
- Information on any changes you made to your original plan
- Results of all your experiments (these may be presented roughly at this stage)
- A plan or storyboard for your presentation if you are required to present your research to your class

A logbook can be written by hand on paper, or with a word-processing program on a computer, or it can even be in the form of a website. A blog is a website that has dated entries so it can be used as a logbook. It has the added advantage that you can invite other people, such as your friends, parents and teachers, to look at your work and post comments. You should check with your teacher on the format required for your logbook.




Part of a blog site used by a researcher to share the results of her investigations into acid–base indicators

## Researching your topic

Before you start your own experiments, you should find out more about your topic.

As well as increasing your general knowledge of the topic, you need to find out whether your problem has been investigated by others. Information already available about your topic might help you to design your experiments. It might also help you in explaining your results.

Make notes on your topic as you find information. You may be able to include some relevant background information in your report.

Make notes on your topic.

### USING THE LIBRARY

The best place to start is the school library. There are several different types of information sources in the library. They usually include those listed on the following page.

### Nonfiction books

Use the subject index catalogue to find out where to find books with information about your topic. Your library catalogue is most likely to be stored in a computer database. You might need to ask the librarian to help you use the catalogue at first. It is a good idea to browse through the contents list of science textbooks. Your topic may appear.

### Reference books

These include encyclopaedias, atlases and yearbooks. The index of a good encyclopaedia is a great place to start looking for information.

### Journals and magazines

There are quite a few scientific journals that are suitable for use by school students. They provide up-to-date information. Your library may have an index for journals, such as 'Guidelines', which you can use to find articles on your topic. You may, however, need to browse. Some journals to look for are: *New Scientist*, *Ecos*, *Australasian Science*, *Habitat*, *Popular Science*, *Choice* and *Helix*.

### Information file

Many school libraries keep information files of newspaper articles on topics of interest or even collections of articles on CD-ROM. Ask your school librarian if you don't know how to use these resources.

### Audiovisual resources

The library may have slides, videos and audio tapes that can be used or borrowed. These resources can be located using the subject index catalogue.

## BEYOND THE LIBRARY

Information on your topic may be available from the following sources.

### Your science teacher

This may seem obvious, but many people don't even think to ask. Your science teacher may also be able to direct you to other sources of information.

### Government departments and agencies

Federal, state and local government departments and agencies may be able to provide you with information or advice on your topic. Try searching through the government listing at the front of the white pages of the phone book. Addresses to write to are usually listed. A polite letter to the appropriate department or agency is the best way to ask for help.

### The internet

The internet provides a wealth of information on almost every topic imaginable. Use a search engine such as Google or Yahoo! The success of your search will depend on a thoughtful choice of keywords. Take the time to find out how to take full advantage of the search engine before you use it.

### Industry

Information on some topics can be obtained from certain industries. For example, if you were testing glues for strength, or batteries to find which ones

Look for information beyond the library.

last longest, the manufacturers might have useful information. Use the yellow or white pages of the phone book to find addresses. A polite letter is often the best way to ask for help.

### Relatives or friends

Perhaps you or a relative know somebody who works in your area of interest. Let your friends and relatives know about your intended research.

In your logbook complete a checklist like the one below to see if you have thoroughly searched sources of information.

School library:

- nonfiction books ☐
- reference books ☐
- journals and magazines ☐
- information file ☐
- audiovisual resources ☐

Beyond the library:

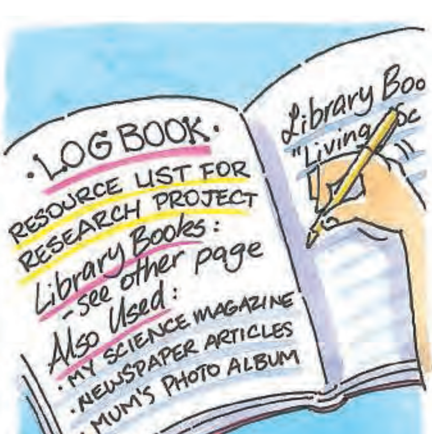
- your science teacher ☐
- government departments and agencies ☐
- the internet ☐
- industry ☐
- relatives or friends ☐
- other sources ☐

## HOW TO USE INFORMATION

Make notes on information that is *relevant* to your research topic. Think about what you really need to know. You need information that will help you to:

- plan your experiments
- understand your results later on
- show in your report how your research relates to everyday life or why your research is important.

You will need to keep an accurate list in your logbook of the steps you have taken and the resources that you have used.




In your logbook keep an accurate list of resources that you have used.

## UNDERSTANDING AND INQUIRING

### UNDERSTAND

1 Why is a logbook a bit like a diary?

2 Define the term 'blog'.

3 List the resources that you could use to research your investigation topic:
(a) in your school library
(b) outside the school library.

### THINK

4 Imagine you are a scientist. Assess the advantages and disadvantages of maintaining a blog rather than keeping a logbook in your office.

5 You can find information about science topics in science textbooks and on the internet.
(a) Explain why you would not find the results of scientific research that was done last month in a science textbook.
(b) Outline some advantages and disadvantages of using the internet as a source of information.

6 Your school and local library probably have an online catalogue.
(a) Explain what an online catalogue is.
(b) Distinguish between online catalogues and search engines such as Google.

7 Use the **Wikipedia** weblink in your eBookPLUS to answer the following questions about Wikipedia, an online encyclopedia.

eBook*plus*

(a) When did Wikipedia start?
(b) Who founded Wikipedia?
(c) How is Wikipedia different from other online encyclopedias such as World Book Online and Encarta Online?
(d) Some of the information in Wikipedia is not reliable. Explain what 'reliable' means and why that might be the case for Wikipedia.
(e) How could you assess whether a particular piece of information you found on Wikipedia was reliable?
(f) Outline some reasons why people may wish to put inaccurate information on Wikipedia.
(g) Discuss whether certain people should be banned from contributing to Wikipedia. Give reasons for your answer.
(h) Which Wikipedia entries are most likely to be highly reliable: those that have been edited many times by a large number of people, or those that have been written by only one person and never edited? Explain your answer.

8 Use the **Wiki** weblink in your eBookPLUS to have a go at writing a class wiki on a topic of your choice.

# 1.4 OVERARCHING IDEAS

# Scale and measurement

In order to answer a question scientifically, a controlled investigation needs to be performed. The investigation must also be reliable.

In the simple investigation of a swinging pendulum below, variables are controlled. However, to be reliable as well, measurements in the investigation need to be accurate, repeated and averaged.

**INQUIRY: INVESTIGATION 1.2**

## The period of a pendulum

### KEY INQUIRY SKILLS:

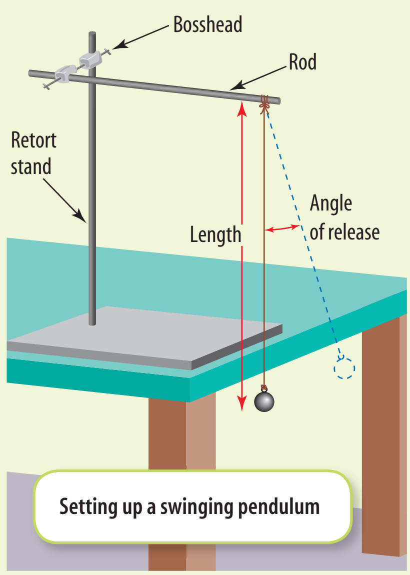
- planning and conducting
- processing and analysing data and information

***Equipment:***

*length of string (at least 80 cm long)*
*set of slotted masses*
*retort stand with bosshead*
*pair of scissors and a one-metre ruler*
*stopwatch or clock with a second hand*

### Part 1: The effect of mass

- Set up your pendulum so it can swing freely. Start with the largest possible length and the smallest weight.
- Copy the table below right into your workbook and record the mass and the length of the pendulum in it. The length should be measured from the top of the pendulum to the bottom of the swinging mass, as shown in the diagram.
- Pull the mass aside so that the angle of release is about 20°. Take note of the height from which the mass is released so that this angle of release is used throughout the experiment.
- Release the pendulum. Measure the time taken for 10 complete swings of the pendulum. Repeat your measurement at least twice so that you can find the average time for 10 swings. Use this average to calculate the time taken for one complete swing (the period). Record all the measurements in your table.

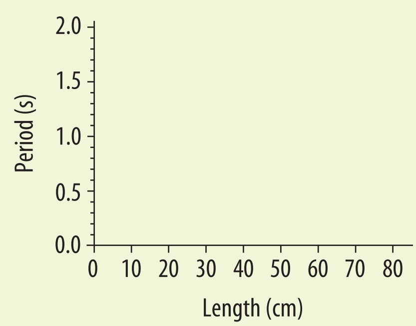


Setting up a swinging pendulum

- Repeat this procedure for three larger masses, completing the table as you go.

### Part 2: The effect of length

- Construct a table like the one on page 13 to identify all of the variables that need to be considered for an investigation of the effect of length on the period of a pendulum.
- Construct a second table in which to record your measurements. Remember that this time you'll be testing four different lengths without changing the mass. Use the same procedure as you did in part 1 for measuring the period.
- Draw a line graph to show how the period of the pendulum is affected by its length.




### DISCUSS AND EXPLAIN

1. How does the mass of the pendulum affect its period?
2. How does the length of the pendulum affect its period?
3. The period of most standard clock pendulums is one second. Use your graph to predict the length of a standard clock pendulum.
4. Explain why it is a good idea to measure the time for 10 swings rather than just one.

**The effect of mass on the period of a pendulum**

Length of pendulum = _______ cm
Angle of release = 20°

| Mass (grams) | Time taken for 10 complete swings (seconds) | | | | Period (seconds) |
|---|---|---|---|---|---|
| | Trial 1 | Trial 2 | Trial 3 | Average | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |

# In the swing of things

When was the last time you were on a swing? A playground swing is simply a large **pendulum**. Pendulums are used mainly as measuring instruments. Their most well-known use is in clocks, such as grandfather clocks.

A playground swing is simply a large pendulum.

A pendulum is a suspended object that is free to swing to and fro. Each complete swing is called an **oscillation**. The time taken for one complete oscillation of a pendulum is called its **period**.

# Variables

There are several factors that could affect the period of a pendulum. They include:

- the length of the pendulum
- the total mass that is swinging
- the height from which the pendulum is released.

These factors are called **variables**. The variable that you are measuring (in this case the period of the pendulum) is called the **dependent variable**. The variable that you are investigating is called the **independent variable**. In Investigation 1.2 on the previous page, you investigated two independent variables, the mass of the pendulum and the length of the pendulum.

# Fair testing

Scientific investigations must be **fair tests**. In a fair test, only one variable is changed at a time — the independent variable. In the first part of Investigation 1.2, the independent variable is the mass of the pendulum. All variables other than the dependent variable must be controlled; that is, they must be kept the same. If they were not, you couldn't tell which variable was affecting the period of the pendulum. You might find it helpful when designing your own investigations to use a table like the one below to identify all the variables.

**Experiment: How does mass affect the period of a pendulum?**

| | |
|---|---|
| Independent variable | • The mass of the pendulum |
| Dependent variable | • The period of the pendulum |
| Controlled variables | • The length of the pendulum<br>• The angle of release<br>• The method of release |

## UNDERSTANDING AND INQUIRING

### UNDERSTAND

1 What is a variable?

2 Explain the difference between a dependent variable and an independent variable.

3 Why is it important to control variables in a scientific investigation?

### THINK

4 In Investigation 1.2 you conducted three trials for each measurement and calculated an average. List two or more reasons for the repetition.

5 A metronome is an 'upside-down' pendulum. To make the period of the metronome longer, should you move the sliding mass up or down?

A metronome's period is changed by moving the sliding mass up or down.

6 What are (i) the independent variable and (ii) the dependent variable in:
(a) part 1 of Investigation 1.2?
(b) part 2 of Investigation 1.2?

### INVESTIGATE

7 Predict whether the angle of release affects the period of a pendulum and write down your hypothesis. Perform an investigation to test your hypothesis and write a brief report. In your conclusion, state clearly whether your hypothesis was supported by your results.

eBook*plus*

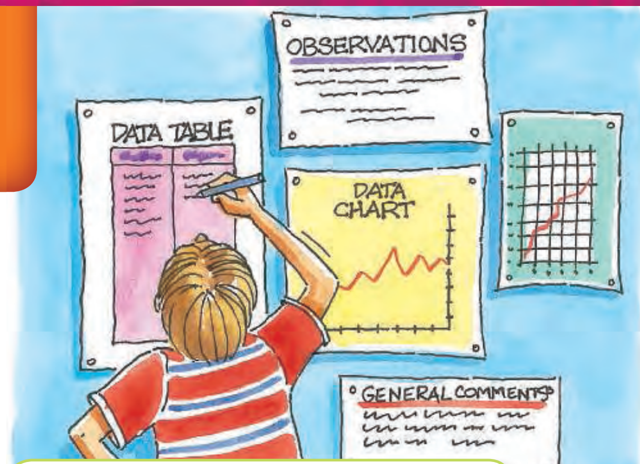
8 Identify the temperature on a number of different thermometers by completing the **Reading scales** interactivity in your eBookPLUS. **int-0201**

work sheet 1.4 Fair testing

1.5 SCIENCE INQUIRY SKILLS

# The main game

Now that you've selected your topic, defined your aim, formed a hypothesis, done some research and understood the importance of variables, it's almost time to start gathering data.



All observations and measurements should be recorded.

## Getting approval

Almost all scientists need the approval of their employer before they commence an investigation. As a student, you should not commence an investigation until your plan has been approved by your teacher.

**1. Title**

Decide on the likely title — you may decide to change it before your work is completed.

**2. The aim or problem**

Briefly state what you intend to investigate or the question you intend to answer.

*Aim: To study the behaviour of slaters*
*Problem: What makes algae grow in an aquarium?*

**3. Hypothesis**

Make an educated guess about the answer to your problem or what you expect to find out. It is important to be creative and objective and to use logical reasoning when devising a hypothesis and testing it.

**4. Outline of experiment**

Explain how you intend to test your hypothesis, and briefly outline the experiments that you intend to conduct.

**5. Equipment**

List any equipment that you will need for your experiments.

**6. Resources**

List the sources of information that you have used or intend to use. This list should include library resources, organisations and people.

## Performing your experiments

Once your plan has been approved by your teacher, you may begin your experiments. Detail how you conducted your experiments in your logbook. All observations and measurements should be recorded. Use tables where possible to record your data. Use graphs to display your data.

Some information about using tables, graphs and data loggers is provided on pages 16–23.

Where appropriate, measurements should be repeated and an average value determined. All measurements — not just the averages — should be recorded in your logbook.

Photographs should be taken if appropriate.

You might need to change your experiments if you get results you don't expect. If things go wrong, record what happened. Knowing what went wrong allows you to improve your experiment and technique. Any major changes should be checked with your teacher.

## Writing your report

You can begin writing your report as soon as you have planned your investigation, but it cannot be completed until your observations are complete. Your report should be typed or neatly written on A4 paper. It should begin with a 'table of contents', and the pages should be numbered. Your report should include the following headings (unless they are inappropriate for your investigation).

### ABSTRACT

Briefly describe your experiments and your main conclusions. Even though this appears at the beginning of your report it is best not to write it until after you have completed the rest of your report.

### INTRODUCTION

Present all relevant background information. Include a statement of the problem that you are investigating, saying why it is relevant or important. You could also explain why you became interested in the topic.

## AIM

State the purpose of your investigation — that is, what you are trying to find out.

## HYPOTHESIS

Using the knowledge you already have about your topic, make a guess about what you will find out by doing your investigation.

## MATERIALS AND METHOD

Describe in detail how you carried out your experiments. Begin with a list of the equipment used and include photographs of your equipment if appropriate. The description of the method must be detailed enough to allow somebody else to repeat your experiments. It should also convince the reader that your investigation is well controlled. Labelled diagrams can be used to make your description clear. Using a step-by-step outline makes your method easier to follow.

## RESULTS

Observations and measurements (data) are presented in this section. Wherever possible, present data as a table so that it is easy to read. Graphs can be used to help you and the reader interpret data. Each table and graph should have a title. Ensure that you use the most appropriate type of graph for your data (see pages 16–21).

## DISCUSSION

Discuss your results here. Begin with a statement of what your results indicate about the answer to your question. Explain how your results might be useful. Any weaknesses in your design or difficulties in measuring could be outlined here. Explain how you could have improved your experiments. What further experiments are suggested by your results?

## CONCLUSION

This is a brief statement of what you found out and may link with the final paragraph of your 'Discussion'. It is a good idea to read your 'Aim' again before you write your conclusion. Your conclusion should also state whether your hypothesis was supported. Don't be disappointed if it is not supported. Some scientists deliberately set out to reject hypotheses!

## BIBLIOGRAPHY

Make a list of books and other printed or audiovisual material to which you have referred. The list should include enough information to allow the source of information to be easily found by the reader. Arrange the sources in alphabetical order.

For each printed resource, list the following information in the order shown:

- author(s) (if known)
- title of book or article
- publisher or name of journal/ magazine (if not in title)
- place of publication (if given)
- date of publication
- chapter or pages used.

For example:

Breidahl, H., Australia's Southern Shores, Lothian, Melbourne, 1997, Chapter 2.

For websites, list the following:

- name of the website
- date the site was updated
- URL address
- date accessed.

For example:

'Millipede Mayhem', last updated 14 March 2008, http://www.csiro.au/csiro/channel/pchgb.html, accessed 30 November 2011.

## ACKNOWLEDGEMENTS

List the people and organisations who gave you help or advice. You should state how each person or organisation assisted you.

## UNDERSTANDING AND INQUIRING

### UNDERSTAND

1 In which section of your investigation report should you write each of the following?
   (a) A list of the books and other resources you used to find information for your project
   (b) A table showing all the measurements you recorded
   (c) A diagram of the equipment you used
   (d) The purpose of the experiment
   (e) A brief summary of your investigation and findings
   (f) A statement that relates the results back to the aim and outlines what your results show

### THINK

2 When scientists write up their investigations for publication in a scientific journal, the abstract is one of the most important parts of the report. Explain why the abstract is usually read by many more people than the full report.

3 Explain why it is important for scientists to publish their investigations in scientific journals and to read the reports written by other scientists.

### INVESTIGATE

4 There have been instances where scientists have faked their results or committed other types of scientific misconduct.
   (a) Use the words 'scientific misconduct' in a search engine to find examples of such instances.
   (b) Why do you think that some scientists might be tempted to fake or fabricate their results?
   (c) Explain why cases of scientific misconduct are damaging to all scientists.
   (d) What do you think might happen to scientists who are found to have faked their results?

work sheet 1.5 Scientific reports

# 1.6 SCIENCE INQUIRY SKILLS

# Presenting your data

Observations and measurements obtained from an investigation are called **data**. Having collected the data, it is important to present it clearly so that another person reading or studying it can understand it. Tables and graphs are a great way to organise data.

## Using tables

When data is organised in a table it is easier to read and trends are more easily identified. An example of a simple table is shown below; it includes all the features you need to remember when constructing a table.

Always include a title for your table.

Include the measurement units in the headings.

**Temperature of the Earth at different depths**

| Depth (km) | Temperature (°C) |
|---|---|
| 0 | 15 |
| 1 | 44 |
| 2 | 73 |
| 3 | 102 |
| 4 | 130 |
| 5 | 158 |
| 6 | 187 |
| 7 | 215 |
| 8 | 242 |

The column headings show clearly what has been measured.

Use a ruler to draw lines for rows, columns and borders.

Enter the data in the body of the table. Do not include units in this part of the table.

You may need to construct more complex tables, like the one below, to present your student research project results.

**Do large paper aeroplanes fly further than small paper aeroplanes?**

Labels

| | | | | |
|---|---|---|---|---|
| Width of paper (cm) | | 21 | 15 | 9 |
| Length of paper (cm) | | 14 | 10 | 6 |
| Distance (m) | Trial 1 | 4.5 | 6.2 | 3.2 |
| | Trial 2 | 4.9 | 5.9 | 3.6 |
| | Trial 3 | 4.6 | 5.8 | 3.5 |
| | Average | | | |

Units

## Using graphs

Organising data as a graph is a widely recognised way of making a clear presentation. It makes the information easier to read, interpret, show trends and make conclusions.

A graph, especially a line graph, can also be used to find values other than those used in the investigation. This can be done by interpolation or extrapolation (see the section later in this unit).

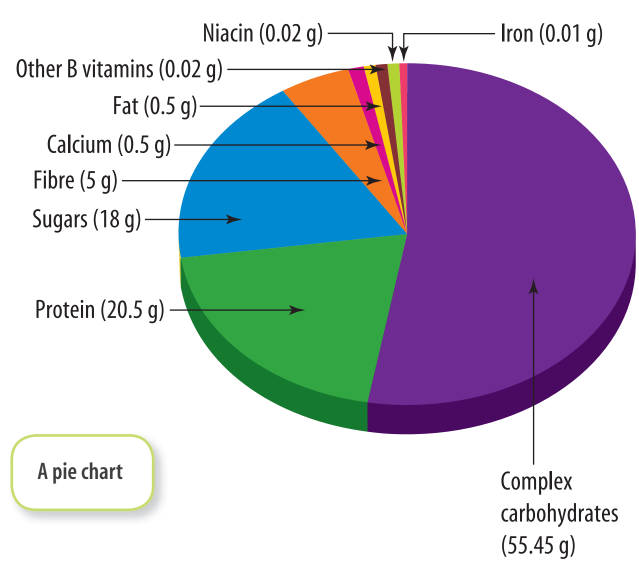
## Types of graphs

Five different types of graphs commonly used in scientific reports are pie charts, column graphs and bar graphs, divided bar graphs, histograms and line graphs.

### PIE CHARTS (OR SECTOR GRAPHS)

A pie chart (also known as a sector graph) is a circle divided into sections that represent parts of the whole. This type of graph can be used when the data can be added as parts of a whole. The example below shows the food types, vitamins and minerals that make up the nutrients in a breakfast cereal.

**Nutrients in 100 g of K-plus cereal**

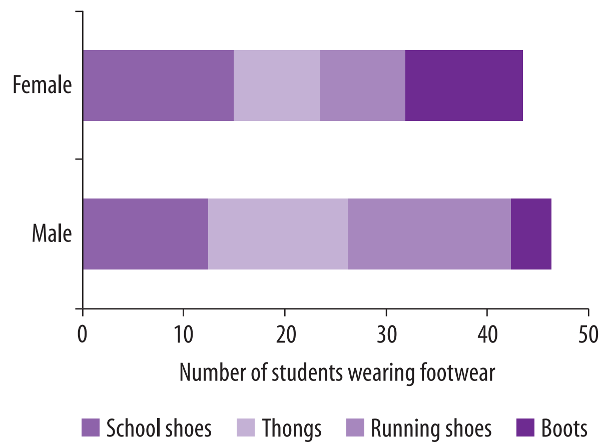



A pie chart

### DIVIDED BAR GRAPHS

Divided bar graphs are also used to represent parts of a whole. However, the data is represented as a long rectangle, rather than a circle, divided into sections. The example below shows the type of footwear worn to school today by male and female students.

**Types of footwear worn to school today**



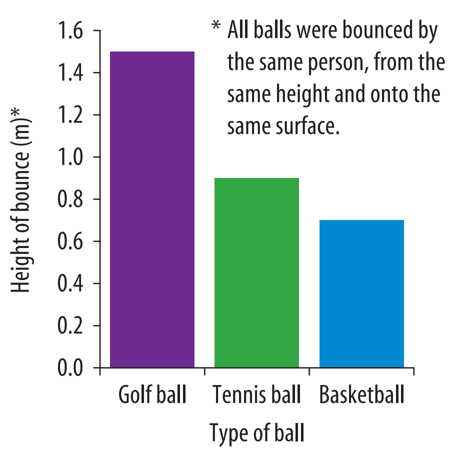

A divided bar graph

## COLUMN GRAPHS AND BAR GRAPHS

A column graph (sometimes called a bar graph) has two axes and uses rectangles (columns or bars) to represent each piece of data. The height or length of the rectangles represents the values in the data. The width of the rectangles is kept constant. This type of graph can be used when the data cannot be connected and is therefore not continuous.

The example below shows data on the average height to which different balls bounced during an experiment. Each column represents a different type of ball.

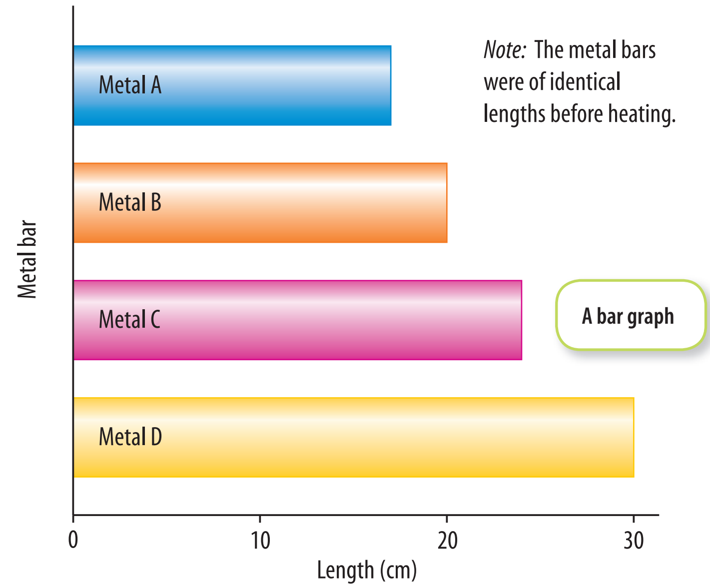
**Heights to which different types of ball bounce**




A column graph

The example below shows the lengths of different metal bars when heated. Each bar represents a different metal.

**Lengths of different metal bars when heated in the same way**

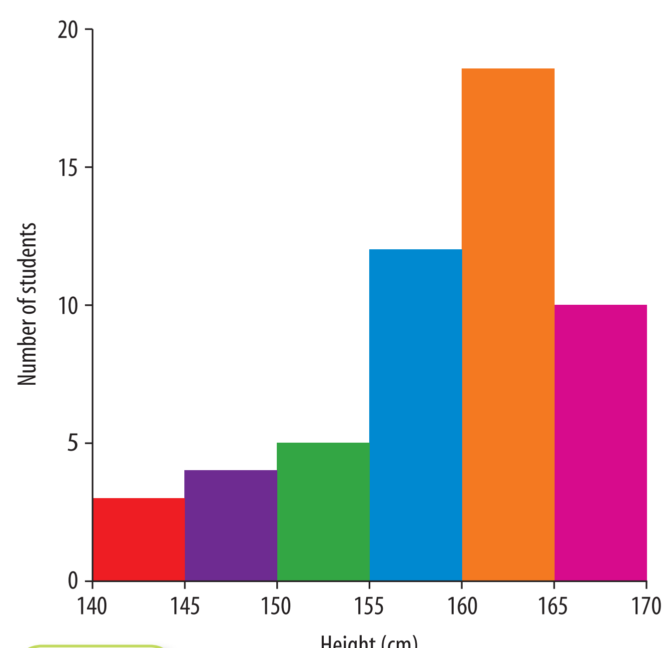



A bar graph

## HISTOGRAMS

Histograms are similar to column graphs except that the columns touch each other because the data is continuous. They are often used to present the results of surveys. In the histogram below, each column represents the number of students that reached a particular height.

**Heights of a group of students in a class**




A histogram

## LINE GRAPHS

A line graph has two axes — a horizontal axis and a vertical axis. The horizontal axis is known as the $x$-axis, and the vertical axis is known as the $y$-axis. The line graph is formed by joining a series of points or drawing a line of best fit through the points. Each point represents a set of data for two variables, such as height and time. Two or more lines may be drawn on the same graph. Line graphs are used to show continuous data — that is, data in which the values follow on from each other. The features of line graphs are shown below.

**1. Grid**

Graphs should always be drawn on grid paper to ensure that the values are accurately placed. Drawing freehand on lined or plain paper is not accurate enough for most graphs.

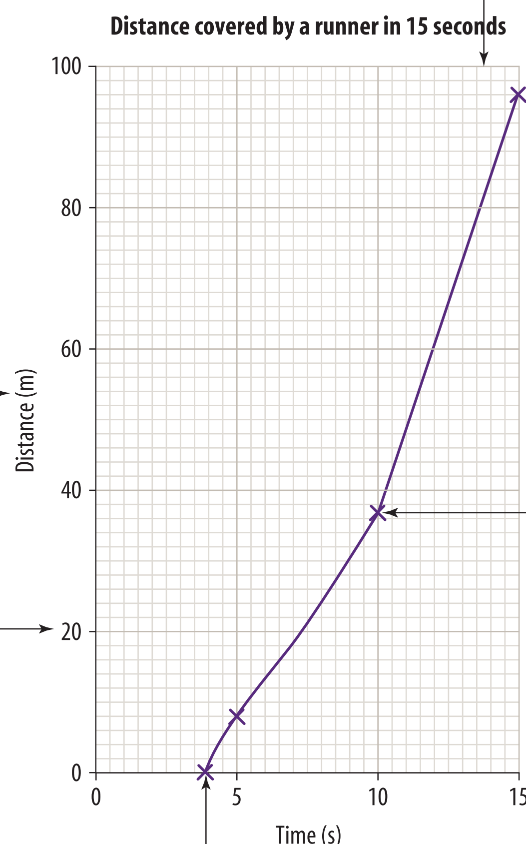
**2. Title**

Tell the reader what the graph is about! The title should describe the results of the investigation or the relationship between variables.

**3. Setting up and labelling the axes**

Graphs represent a relationship between two variables. When choosing which variable to put on each axis, remember that there is usually an independent variable (which the investigator chooses) and a dependent variable. For example, if students wish to find out how far a runner could run in 15 seconds, they may choose to measure the distance covered every five seconds. The time of each measurement has been chosen by the students and is the independent variable. The distance that is measured is therefore the dependent variable. Usually the independent variable is plotted on the horizontal x-axis and the dependent variable on the vertical y-axis.

After deciding on the variable for each axis, you must clearly label the axes with the variable and the units in which the variables are measured. The unit is written in brackets after the name of the variable.




**Data table**

| Distance (m) | Time (s) |
|---|---|
| 0 | 4 |
| 8 | 5 |
| 37 | 10 |
| 96 | 15 |

**4. Setting up the scales**

Each axis should be marked into units that cover the entire range of the measurement. For example, if the distance ranges from 0 m to 96 m, then 0 m and 100 m could be the lowest and highest values on the vertical scale. The distance between the top and bottom values is then broken up into equal divisions and marked. The horizontal axis must also have its own range of values and uniform scale (which does not have to be the same scale as the vertical axis).

The most important points about the scales are:

- they must show the entire range of measurements
- they must be uniform: that is, show equal divisions for equal increases in value.

**5. Putting in the values**

A point is made for each pair of values (the meeting point of two imaginary lines from each axis). The points should be clearly visible. Include a point for (0, 0) only if you have the data for this point.

**6. Drawing the line**

A line is then drawn through the points.

A line that follows the general direction of the points is called a 'line of best fit' because it best fits the data. It should be on or as close to as many points as possible. Some points follow the shape of a curve, rather than a straight line. A curved line that touches all the points can then be used.

The type of data you are graphing may lead you to expect either a straight line or a curve. For example, you might expect the increase in temperature of water being boiled to be presented as a straight line because the temperature increases at a steady rate. A graph of the growth rate of a red panda (see page 27) would be curved and irregular because pandas have growth spurts. Inspection of the data will help you to decide whether your line should be a straight line or a smooth, curved line.

# Interpolation

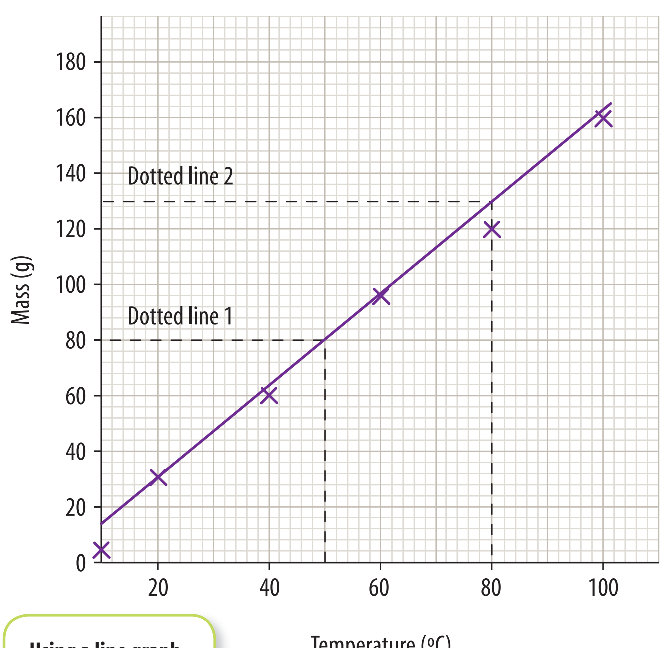
Line graphs can be used to estimate measurements that were not actually made in an investigation. The table below shows the results of an experiment in which a student measured how many spoons of sugar dissolved in a cup of tea at various temperatures.

**Amount of sugar that dissolves in one cup of tea at different temperatures**

| Temperature (°C) | Mass of sugar dissolved (g) |
|---|---|
| 0 | 4 |
| 20 | 30 |
| 40 | 60 |
| 60 | 98 |
| 80 | 120 |
| 100 | 160 |

The student did not measure how much sugar dissolved at 50°C, but we can work this out by interpolation. First we need to plot the data collected in the experiment. Then we read off the graph the amount of sugar that would dissolve at 50°C (shown by dotted line 1). The same procedure can be used to work out the water temperature that would be needed to dissolve 130 g of sugar in one cup of tea. This is shown in the graph below by dotted line 2.

**Effect of temperature on the amount of sugar dissolved in tea**




**Using a line graph for interpolation**

# Extrapolation

In many cases it is also possible to assume that the two variables will hold the same relationship beyond the values that have been plotted. This is called extrapolation. Consider the table below, which shows the results obtained when different masses were attached to a spring and the increase in length of the spring was measured.

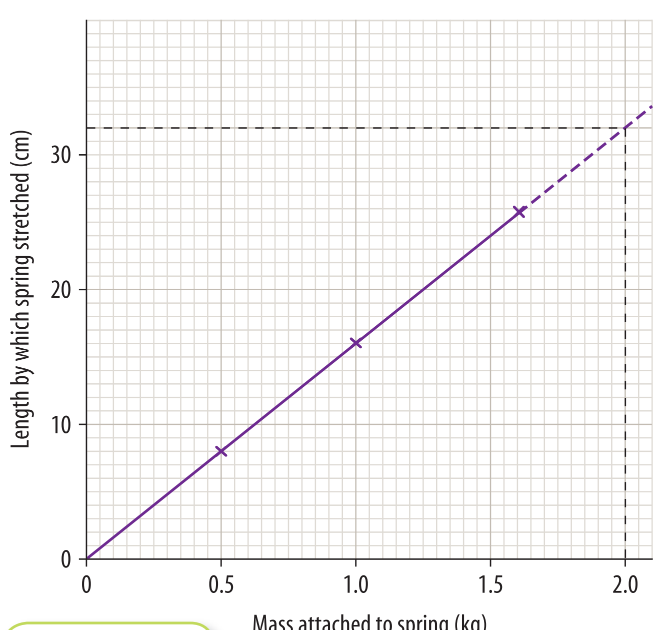
**Amount that a spring stretched when various masses were attached to it**

| Mass attached to the spring (kg) | Length by which spring stretched (cm) |
|---|---|
| 0.0 | 0 |
| 0.5 | 8 |
| 1.0 | 16 |
| 1.6 | 26 |
| ? | 32 |

If you want to predict the mass needed to stretch the spring by 32 centimetres, you need to plot the data on a graph and extrapolate the value.

The data in the table above has been plotted on the graph below. Values have been plotted up to a mass of 1.6 kg and an increase in length of 26 centimetres. The line on the graph has been projected onwards (as the dotted lines show). This extrapolation shows that a mass of 2 kg will stretch the spring 32 centimetres.

**Effect of mass on spring stretch**




**Using a line graph for extrapolation**

## INQUIRY: INVESTIGATION 1.3

# Drawing a line graph

**KEY INQUIRY SKILLS:**

- processing and analysing data and information

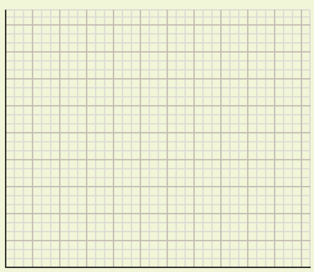
A student conducted an experiment to see how temperature affected the amount of sugar that would dissolve in a cup of tea. Each cup contained the same volume of tea, and the sugar was stirred in at an equal rate for each cup. The following results were obtained.

Graph the data in the table at right using the steps and diagrams below.

**Amount of sugar dissolved in one cup of tea**

| Temperature (°C) | Mass of sugar dissolved (g) |
|---|---|
| 0 | 4 |
| 20 | 30 |
| 40 | 60 |
| 60 | 98 |
| 80 | 120 |
| 100 | 160 |

1 Set up the grid.

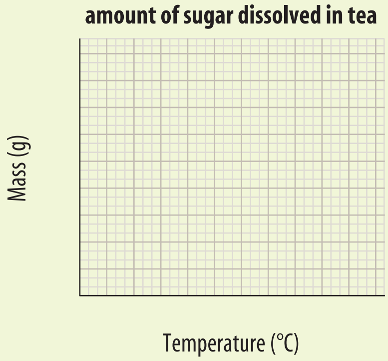


2 Give the graph a title.

**Effect of temperature on the amount of sugar dissolved in tea**

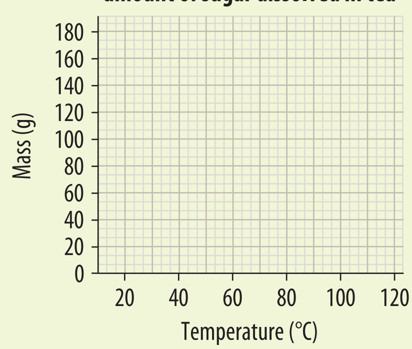
3 Set up the axes and label them.

**Effect of temperature on the amount of sugar dissolved in tea**



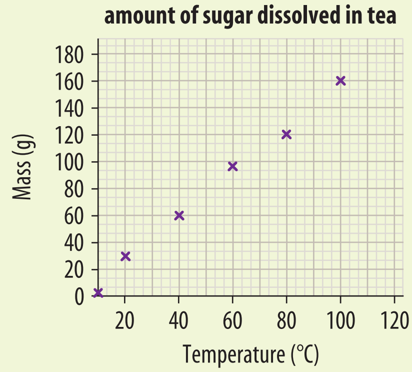

4 Place the scales on the axes.

**Effect of temperature on the amount of sugar dissolved in tea**



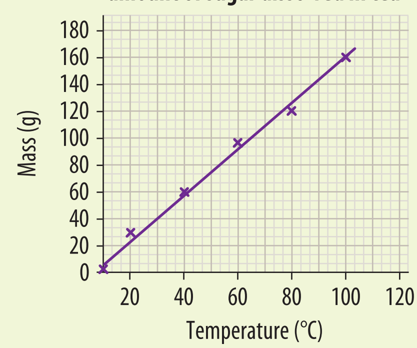

5 Plot each pair of values as a point marked with an x. Make sure each point is clearly visible. Don't forget to plot (0, 4) because you have the data for this point.

**Effect of temperature on the amount of sugar dissolved in tea**




6 Draw a line of best fit; that is, a line drawn in between the points so that some points are on the line, some are below it and some are above.

**Effect of temperature on the amount of sugar dissolved in tea**



## UNDERSTANDING AND INQUIRING

### ANALYSE AND EVALUATE

1 The following table shows the uses of plastics in Australia.

**Uses of plastics in Australia**

| Use | Percentage (%) |
|---|---|
| Agriculture | 4.0 |
| Building | 24.0 |
| Electrical/electronic | 8.0 |
| Furniture and bedding | 8.0 |
| Housewares | 4.0 |
| Marine, toys and leisure | 2.0 |
| Packaging and materials handling | 31.0 |
| Transport | 5.0 |
| Others | 14.0 |

(a) Select a suitable graph type and prepare a graph from this table.
(b) Choose two uses of plastic from your graph. For each use, state a particular item that is made of plastic.
(c) There has been recent controversy about the waste products that humans create.
(i) List some uses of plastics that would contribute to waste products.
(ii) Suggest some action people can take to reduce the amount of plastic waste products.

2 The data in the following table relates the speed of a car to its stopping distance (the distance the car travels after the brakes are applied).

**Relationship between the speed of a car and its stopping distance**

| Speed of car (m/s) | Stopping distance (m) |
|---|---|
| 0 | 0 |
| 10 | 12 |
| 20 | 36 |
| 30 | 72 |
| 40 | 120 |

(a) Graph the data.
(b) Make a conclusion about the information in the graph.
(c) How could this information be applied to your everyday life?

3 The boiling point of water changes with air pressure. For example, water may not boil at 100°C at the top of Mount Everest, where the air pressure is less than the pressure at sea level. The following data shows the boiling point of water at various air pressure values.

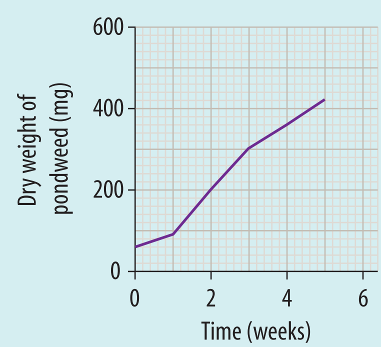
**Boiling point of water at different air pressures**

| Air pressure in kilopascals (kPa) | Boiling point of water (°C) |
|---|---|
| 0 | 0 |
| 1 | 20 |
| 7 | 40 |
| 21 | 60 |
| 45 | 80 |
| 101 | 100 |
| 200 | 120 |

(a) Graph the data.
(b) Describe the shape of your graph.
(c) What is the pressure of the atmosphere at sea level?
(d) Would it take a longer or shorter time to boil water at the top of Mount Everest, compared with the time it would take at sea level? Explain your answer.

4 The following graph shows the increase in mass of a growing pondweed.

**Increase in mass of pondweed with time**




(a) What was the mass of the plant after 3 weeks of growth?
(b) How long did it take for the plant to grow to 250 grams?
(c) Predict the mass of the plant after 6 weeks of growth.
(d) Can you be sure that your extrapolation for part (c) is accurate? Suggest reasons why it may not be accurate.
(e) Would the interpolations from parts (a) and (b) be more accurate than your extrapolation? Discuss your ideas in class.

work sheets
1.6 Scientific drawing skills
1.7 Data analysis

1.7 SCIENCE INQUIRY SKILLS

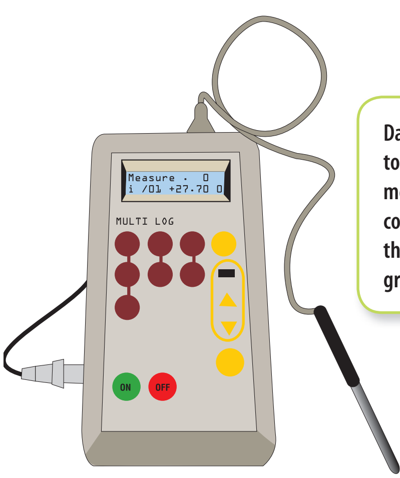
# Using data loggers

## What is a data logger?

A data logger is a type of scientific recording instrument. It collects and stores measurements. These are called data because they are numbers. A data logger has to be attached to a measuring instrument called a **sensor**. The sensor does the measuring and sends the measurements to the data logger.

The real advantage of working with a data logger is that it can store thousands of individual measurements. The measurements can be taken in quick succession or over a long period of time, and the data logger can be programmed to do this automatically. This is why scientists often use data loggers in their work.

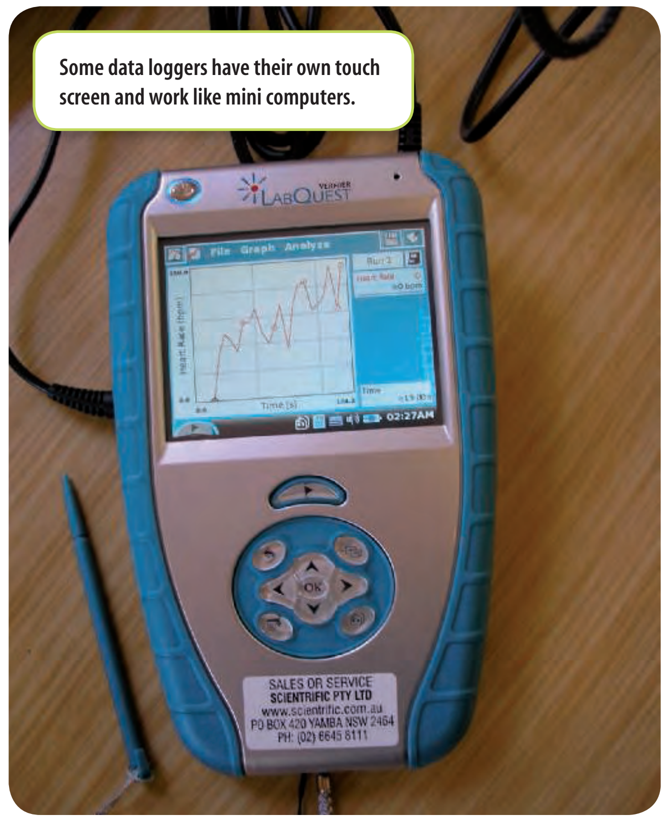
Of course, to be at all useful, the stored measurements must be easily accessed. That is why the data logger is also attached to either a computer or an instrument called a graphics calculator. The computer or calculator takes the data and, using special software that comes with the data logger, it shows the data as a table, a graph or both.




Data loggers are attached to sensors that take the measurements, and to computers that can show the data in tables and graphs.

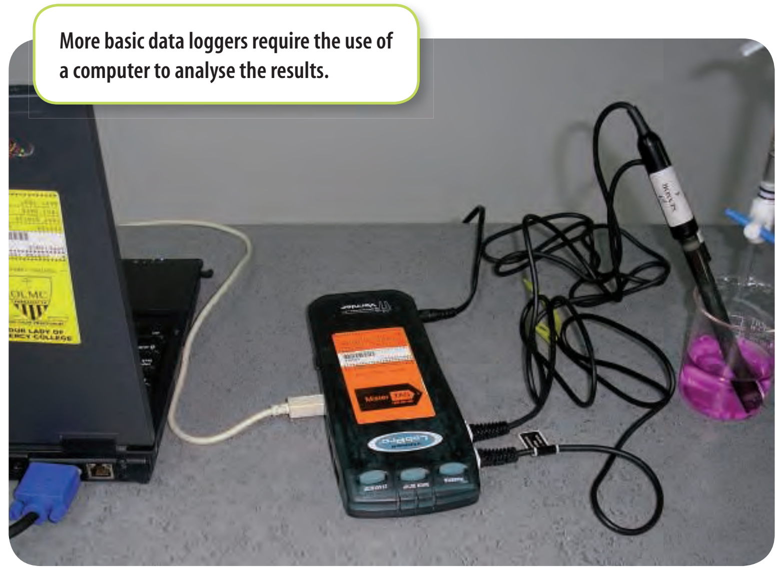
## Data loggers in temperature measurement

In Investigation 1.1 on page 3, the measuring instrument you used was a thermometer. You looked at the thermometer every thirty seconds and observed the temperature, which you wrote down in a table. You then made a line graph of temperature against time. If you had used a data logger with a temperature sensor instead of the thermometer, it could have taken the temperature every second and sent it to a computer that would have automatically tabulated the temperature data and graphed it as well.




Some data loggers have their own touch screen and work like mini computers.

More basic data loggers require the use of a computer to analyse the results.



## Other uses for data loggers

Data loggers can be used for just about any experiment where measurements are taken. All that is needed is the appropriate sensor to be plugged in. It is even possible to plug in several sensors to take different measurements at the same time.

Some of the many different sensors that are available include:

- temperature sensors capable of measuring several hundred degrees
- light intensity sensors
- soundwave sensors (microphones)
- motion sensors
- magnetic field sensors
- acceleration sensors
- force sensors
- electric current and voltage sensors
- humidity sensors
- blood pressure sensors
- heart rate sensors.

One type of sensor that isn't necessary is a time sensor (stopwatch) because the data logger has its own inbuilt clock that is very accurate. In fact, one of the most useful things about data loggers is their ability to collect measurements at very small and precise time intervals, even as many as a thousand measurements in one second!

### UNDERSTANDING AND INQUIRING

#### REMEMBER

1 Match each of the words listed below with its meaning:

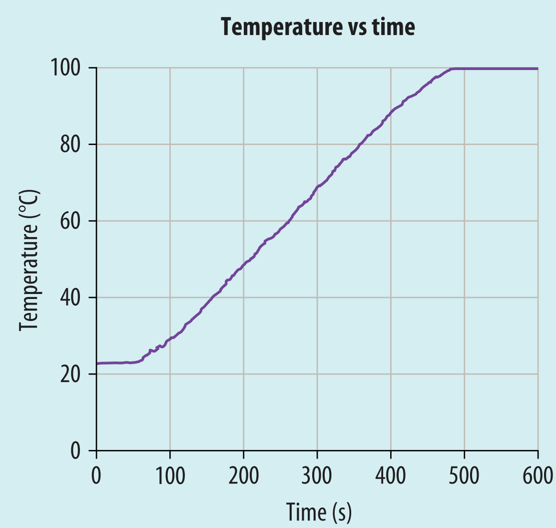
| Word | Meaning |
|---|---|
| (a) Sensor | (i) You may need to download the data from the data logger to one of these. |
| (b) Data logger | (ii) Piece of information |
| (c) Computer | (iii) These are plugged into the data logger and they take the measurements. |
| (d) Data logger software | (iv) Allows you to input data into the data logger or computer by touching it with your finger or a stylus |
| (e) Touch screen | (v) Software that allows you to process the data collected by the data logger |
| (f) Data | (vi) A device that can collect and store data from sensors connected to it |

2 Sensors are the devices that take the measurements that the data logger collects. Outline scientific investigations that could use data collected by sensors that measure:
(a) electric current
(b) heart rate
(c) motion
(d) sound waves
(e) light intensity.

#### ANALYSE AND EVALUATE

3 The graph at right shows data collected by a data logger for an experiment in which water is heated to boiling point in a beaker. A temperature sensor was used to take the measurements.

If you were at this computer, you could scroll through every temperature measurement in the table. The computer has graphed all this data. Now let's see how much you've learned about interpreting line graphs.
(a) How long did the whole experiment go for?
(b) About when did the heating of the water begin?
(c) What was the temperature of the water when heating began?
(d) What was the temperature of the water when heating finished?
(e) About when did the water begin to boil?
(f) Between 100 and 400 seconds, at what rate (in degrees per second) did the water temperature rise during heating?
(g) The water continued to be heated even when its temperature reached boiling point, yet its temperature did not rise beyond 100°C. What has happened to all the energy that was being put into the water if it isn't causing the water temperature to rise? (*Hint:* Think about what happens to water while it is boiling.)



# Greats from the past

eBookplus **eLesson**

**Career spotlight: scientist**
Watch this video lesson to learn what it takes to be a scientist.
**eles-0766**

Who is the greatest scientist of all time? Is it Curie, Einstein, Newton or Pasteur? Or is it one of the people who saved millions of lives by discovering X-rays, penicillin or vaccination?

## The slow starter

Albert Einstein (1879–1955) is most well known for his theory of relativity (there are actually two theories of relativity) and the equation $E = mc^2$, which describes how mass can be converted into energy.

Albert Einstein was certainly a slow starter. Although he was fascinated by mathematics, Einstein performed badly at school and left at the age of 15. He returned later and trained as a teacher in Switzerland. Einstein often failed to attend lectures and passed university exams by studying the notes of his classmates.

Einstein's first job was as a junior clerk in a patent office. His work was not demanding and he spent a lot of time doing 'thought' experiments.

Einstein's first wife, Mileva, was a mathematician. He discussed many of his new ideas with her.

At the age of 26, Einstein began to publish his ideas. These ideas altered our view of the nature of the universe by changing existing laws and discovering new ones.

Einstein explained the photoelectric effect, in which light energy is transformed into electrical energy, and was awarded the Nobel Prize in Physics in 1921 for this explanation.

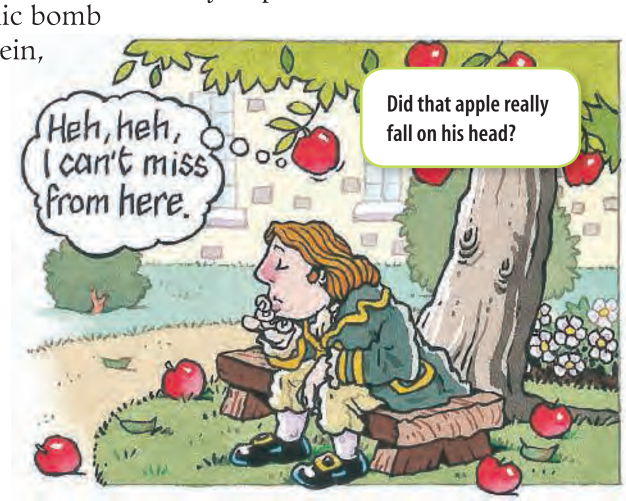
Einstein's theories of relativity were so different from earlier theories about the universe that they were not believed or understood by most scientists. His theory of special relativity explains the behaviour of objects that travel at speeds close to the speed of light. His theory of general relativity explains the effect of gravity on light and predicts that time 'slows down' in the presence of large gravitational forces. These theories provide useful clues about the development and future of the universe.

Einstein's theories suggested that mass could be converted into energy. This idea led to the development of the atomic bomb and nuclear power. Einstein, who was Jewish, fled Germany in 1933 to live and work in the United States. Einstein was an active opponent of nuclear weapons and was involved in the peace movement long before atomic bombs destroyed Hiroshima and Nagasaki at the end of World War II.

## Did that apple really fall on his head?

Sir Isaac Newton (1642–1727) is probably most well known for his laws of gravitation, which explain the motion of the planets around the sun. According to some historians, his ideas about gravity arose after an apple fell on his head. We'll probably never know if this is true.

Isaac Newton was sent to Cambridge University at the age of 18. When the university closed down in 1665 as a result of the Great Plague, young Isaac went home for two years. There he developed his laws of gravitation and his three laws of motion. During his life, he also made discoveries about the behaviour of light and invented a whole new branch of mathematics, called calculus. Much of the scientific knowledge that has been acquired since the seventeenth century is built upon Newton's discoveries during that amazing two-year period.




Did that apple really fall on his head?

# A family affair

Marie Curie (1867–1934) became the first scientist to win two Nobel Prizes when she was awarded the Nobel Prize in Chemistry in 1911 for her discovery of two new elements, polonium and radium. Radium was used in the treatment of cancer until cheaper and safer radioactive materials were developed. Marie Curie's first Nobel Prize, for the study of radioactivity, was shared with her husband, Pierre, and fellow scientist Antoine-Henri Becquerel in 1903.

As a child, Marie Sklodowska (her birth name) wanted to study science. However, girls were forbidden to attend university in her native country of Poland. She worked as a private tutor for three years so that she could earn enough money to study at the University of Paris. It was there that she met her future husband, Pierre. They were very poor and spent most of their money on laboratory equipment, leaving them with very little money for food. In fact, they often couldn't afford to eat. After Pierre was knocked down and killed by a speeding wagon, Marie continued her research in radioactivity, pioneering the development of radioactive materials for use in medicine and industry. She became the first female teacher at the University of Paris and worked hard to raise money for scientific research.

Marie Curie in her laboratory

# The germ of an idea

Louis Pasteur (1822–1895) proved that infectious diseases were caused by microbes. His ideas became known as 'germ theory'. He also developed several vaccines that made people immune to diseases such as rabies and smallpox. In doing this he has been responsible for saving the lives of millions of people and countless animals.

Pasteur removed the body fluids of rabbits infected with rabies and made a vaccine for the disease from their dried-out bodies.

Pasteur began his scientific career in physics and chemistry, but became interested in microbes when he was using light to investigate the differences between chemicals in living and non-living things.

Pasteur's next challenge was to rescue the French wine industry. Wine (and beer) became sour very quickly and this was beginning to have an impact on the French economy, which relied heavily on the export of wine. Pasteur showed that the souring was caused by acids produced by the action of bacteria in the wine. Pasteur invented a process that rapidly heated some of the ingredients of the wine. The rapid heating killed most of the offending microbes without altering the flavour of the wine. The process, known as pasteurisation, was later adapted to slow down the souring of milk.

## UNDERSTANDING AND INQUIRING

### THINK

1 Make a quick list of your 'Top 3' scientists of all time. For each one, answer the following questions.
   (a) What impact does their work have on your life?
   (b) Did they just happen to be in the 'right place at the right time'?
   (c) Did they work under adverse conditions?
   (d) Did their work save lives?
   (e) Did their work have any destructive influence?
   (f) What other special qualities make them great?

2 Is it fair to select the single 'greatest' scientist of all time? Explain your answer.

3 Louis Pasteur conducted many of his experiments on animals. Many of them would now be considered cruel. However, the experiments saved many human lives.
   (a) Present the arguments for and against the use of animals in such experiments.
   (b) Were the animal experiments justified? Write a brief statement supporting your opinion.
   (c) Use the **Louis Pasteur** weblink in your eBookPLUS to learn more about this French scientist.

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### IMAGINE

4 Imagine that you are one of the three scientists whom you have chosen as the greatest scientists of all time. Write a short speech (3–5 minutes) about your life and work, and deliver it to your class. Illustrate your speech with models, diagrams or photographs.

### INVESTIGATE

5 Write a biography similar to the four presented on these pages about one of the following scientists:
   Michael Faraday (1791–1867)
   Charles Darwin (1809–1982)
   Lise Meitner (1878–1968)
   Barbara McClintock (1902–1992)
   Peter Doherty (1940– )
   Stephen Hawking (1942– )

# STUDY CHECKLIST

## THE LABORATORY

- identify and safely use a range of equipment used to perform scientific investigations
- use specialised equipment to make accurate observations and measurements
- use digital technology such as dataloggers to make and record measurements

## PLANNING AND CONDUCTING INVESTIGATIONS

- work individually and with others to identify a problem to investigate
- use information from investigations and scientific knowledge to make predictions and form hypotheses
- undertake research using a variety of sources
- develop a logical procedure for undertaking a controlled experiment
- recognise the need to control variables and distinguish between dependent and independent variables
- use repetition of measurement to increase the reliability of data

## PROCESSING AND ANALYSING DATA AND INFORMATION

- accurately record observations and measurements
- organise data clearly using tables and spreadsheets
- construct an appropriate type of graph to present your data
- use tables, spreadsheets and graphs to identify trends and patterns, and assist in the formation of conclusions
- identify data that support or discount a hypothesis
- form conclusions based on experimental results

## EVALUATING AND COMMUNICATING

- reflect on your methods and make suggestions for improvements to your investigations
- use information from investigations and scientific knowledge to evaluate claims
- discuss ideas and investigations with others
- use a scientific report with scientific language, clear diagrams, tables and graphs where necessary to describe your investigations and their findings

## SCIENCE AS A HUMAN ENDEAVOUR

- identify the contributions of individual scientists, including Australians, to scientific knowledge
- describe some scientific discoveries that have had a major impact on our understanding of the world

## INDIVIDUAL PATHWAYS

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| Activity 1.1 | Activity 1.2 | Activity 1.3 |
|---|---|---|
| Investigating | Analysing investigations | Designing investigations |
| **doc-2861** | **doc-2862** | **doc-2863** |

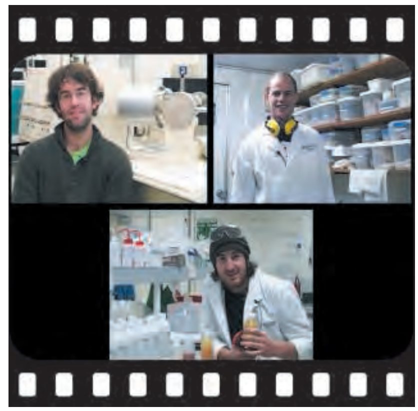
# ICT

## eBook*plus* Summary

### eLESSON

**Career spotlight: scientist**

In this video lesson you will meet a water scientist, a palaeontologist and a geologist, and learn what it takes to be a scientist. With insight into work in the lab and in the field, you will get some useful advice to help you decide whether this could be an attractive career for you.

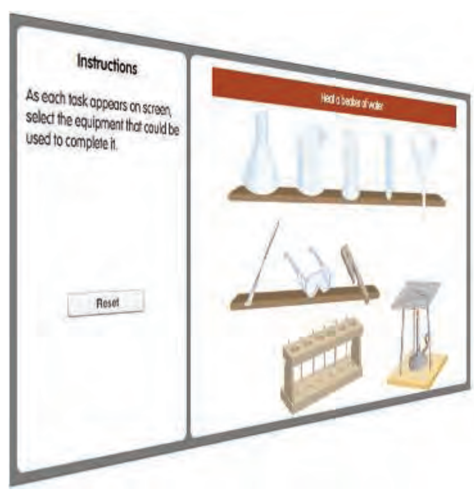


Searchlight ID: eles-0766

### INTERACTIVITIES

**Using equipment**

In this interactivity, you are given a number of scientific processes and you must indicate which equipment from a selection of items commonly found within a laboratory you would use to complete the processes. Instant feedback is provided.




Searchlight ID: int-0200

**Reading scales**

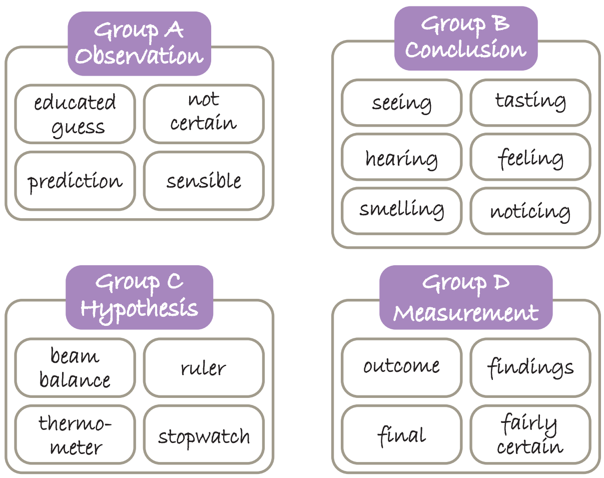
This interactivity challenges your knowledge of scales by testing your skill in identifying temperatures on a number of different thermometers. Instant feedback is provided.

Searchlight ID: int-0201

# LOOKING BACK

1 The affinity diagram below organises some of the ideas used by scientists into four groups. Each category name is a single word and represents an important part of scientific investigations. However, the category names have been jumbled up. What are the correct categories for groups A, B, C and D?

**Scientific investigation**




2 Bahir was sick of being bitten by mosquitoes. He counted several bites each evening when he sat outside to have dinner. He had heard that a burning citronella candle was a good way to keep mosquitoes away. Design an experiment to test Bahir's idea. List the independent and dependent variables and the controlled variables needed to make this a fair test. Suggest a control for your experiment.

3 Singalia and Sallyana are two red panda cubs born at Sydney's Taronga Zoo. The table above right shows their masses during their first 22 weeks. The photograph below shows one of the cubs being weighed.

(a) Graph both sets of data onto a grid. Use different symbols for the points for each panda and label each line with the panda's name. You may have to extend the vertical axis to fit in the scale for the pandas' masses (or else convert the masses to kilograms and plot in kilograms).

(b) Describe the growth of each of the panda cubs. How do they compare with each other?

(c) How long did it take the cubs to double their mass measured in week 1?

(d) Did the pandas grow at the same rate during the 22 weeks?

(e) Which were the fastest and slowest growth periods for each panda?

(f) What age was each of the cubs when it reached 1 kg?

(g) At what age would you predict each cub to reach 1.5 kg? Explain how you made your prediction. What assumption did you make to answer the question?

**Red panda cubs' masses (grams)**

| Week | Singalia | Sallyana |
|---|---|---|
| 1 | 213 | 219 |
| 2 | 285 | 290 |
| 3 | 330 | 349 |
| 4 | 365 | 377 |
| 5 | 403 | 408 |
| 6 | 465 | 452 |
| 7 | 536 | 514 |
| 8 | 564 | 576 |
| 9 | 594 | 610 |
| 10 | 650 | 637 |
| 11 | 703 | 680 |
| 12 | 714 | 740 |
| 13 | 814 | 796 |
| 14 | 872 | 812 |
| 15 | 956 | 806 |
| 16 | 1111 | 786 |
| 17 | 1043 | 890 |
| 18 | 1130 | 1000 |
| 19 | 1163 | 1083 |
| 20 | 1182 | 1162 |
| 21 | 1225 | 1218 |
| 22 | 1335 | 1270 |

4 Four students each measured the temperature in the same classroom using a thermometer. Their results are shown in the table below.

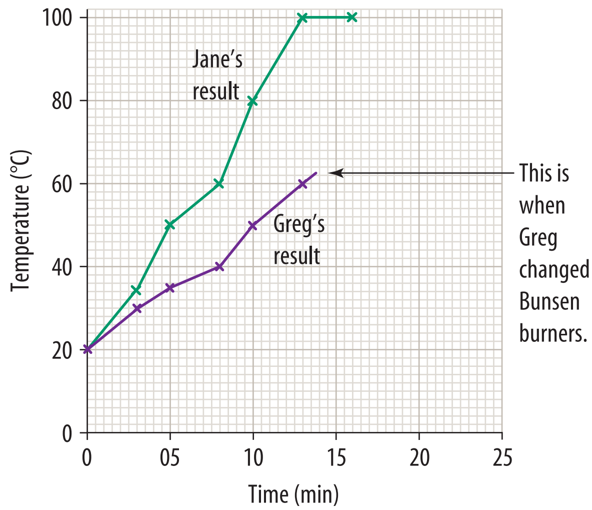
**Temperature as measured by each of four students in the same classroom**

| Student | Temperature (°C) |
|---|---|
| 1 | 23.5 |
| 2 | 24.0 |
| 3 | 25.0 |
| 4 | 22.0 |

(a) Construct a bar graph of these results.

(b) Propose some possible reasons for the differences between measurements.

5 Jane and Greg decided to test how quickly water would boil when using either the yellow flame or blue flame of the Bunsen burner. They set up identical experiments, except that Jane used a blue flame and Greg used a yellow flame. Their results are graphed below.




(a) How long did it take for Jane's water to boil?
(b) What was the temperature of Greg's water when Jane's water boiled?
(c) In your own words, explain how you worked out the answers for these two questions.
(d) Jane removed her beaker and Greg quickly placed his beaker over Jane's Bunsen burner. Assuming that the temperature of Greg's beaker did not drop while swapping Bunsen burners, predict the time at which his water would boil. Using your own words, explain how you predicted this.

6 The following table shows the winning times for the men's 400 m freestyle swimming event. The data is from various Olympic Games from 1896 to 2008.

| Year | Name, country | Time (min:s) |
|---|---|---|
| 1896 | Paul Neumann, Austria | 8:12.60 |
| 1908 | Henry Taylor, Great Britain | 5:36.80 |
| 1920 | Norman Ross, USA | 5:26.80 |
| 1932 | Buster Crabbe, USA | 4:48.40 |
| 1948 | Bill Smith, USA | 4:41.00 |
| 1960 | Murray Rose, Australia | 4:18.30 |
| 1972 | Bradford Cooper, Australia | 4:00.27 |
| 1984 | George DiCarlo, USA | 3:51.23 |
| 1996 | Danyon Loader, New Zealand | 3:47.97 |
| 2000 | Ian Thorpe, Australia | 3:40.59 |
| 2004 | Ian Thorpe, Australia | 3:43.10 |
| 2008 | Taehwan Park, Korea | 3:41.86 |

(a) Is data available for each Olympics every 4 years?
(b) Construct a line graph of the times for the men's 400 m freestyle over these years. Take into account your answer to part (a).
(c) Use your graph to estimate the winning time for this event in the 1956 Melbourne Olympic Games.
(d) Discuss how the winning times have changed over the 112-year period.
(e) Suggest some reasons for the change in winning times.
(f) Discuss how you believe the times for the men's 400 m freestyle might change over the next 40 years.

7 Create a storyboard that tells the story of the main events in the life of one of these famous scientists.
(a) Albert Einstein
(b) Sir Isaac Newton
(c) Marie Curie
(d) Louis Pasteur

8 Below is part of a report on an experiment about dissolving sugar.

Date: 29 February

Dissolving sugar

Aim:

To find out how much sugar will dissolve in hot water compared with cold water

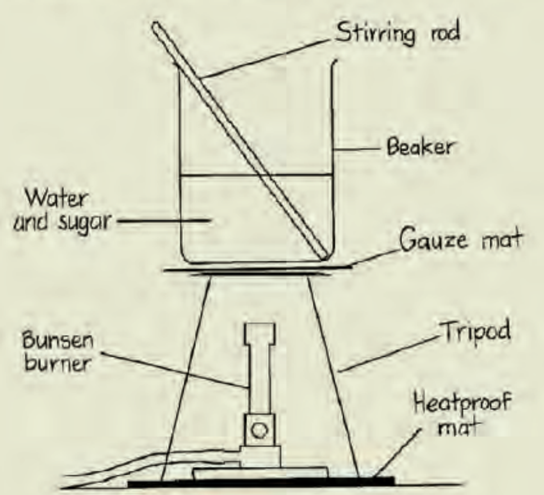
Materials:

Beaker, heatproof mat, Bunsen burner, tripod, gauze mat, matches, spatula, stirring rod, sugar, water

Method:

1. A spatula was used to add sugar to 100 mL of cold water in a beaker. The sugar was stirred and more added until no more would dissolve. The amount of sugar dissolved was recorded.

2. The mixture of sugar and water was heated with a Bunsen burner for 4 minutes and the extra amount of sugar that could be dissolved was recorded.




Results:

Amount of sugar dissolved in cold water = 2 spatulas
Extra amount of sugar dissolved in hot water = 4 spatulas
Total amount of sugar dissolved in hot water = 6 spatulas

(a) Write a 'Discussion' section for this report.
(b) Write a conclusion for this report.
(c) How could this investigation be improved?

work sheets 1.8 Investigating: Puzzle
1.9 Investigating: Summary

**projects*plus***

# An inspiration for the future

**SEARCHLIGHT ID: PRO-0071**

## Scenario

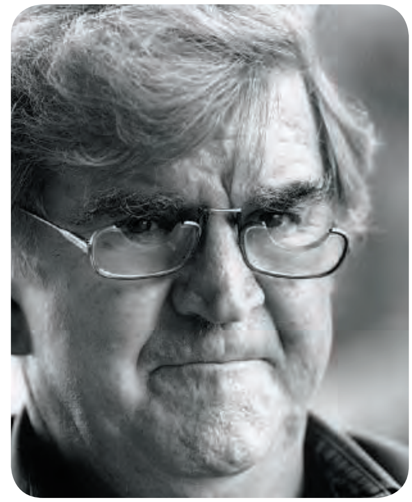
The Florey Medal was established in 1998 by the Australian Institute of Policy and Science in honour of the Australian Nobel Prize-winning scientist Sir Howard Florey, who developed penicillin. It is awarded biennially to an Australian biomedical researcher for significant achievements in biomedical science and human health advancement.

In a similar spirit, the Australian Academy of Science hopes next year to establish an award for outstanding science students. The AAS wishes to name the medal after an Australian scientist who provides the greatest inspiration for young people considering a future career in science. After months of consultation, they have narrowed the choices down to the following:

- David Unaipon (1872–1967): Inventor


- Peter Doherty (1940– ): Veterinarian and immunologist

- Fred Hollows (1929–1993): Ophthalmologist

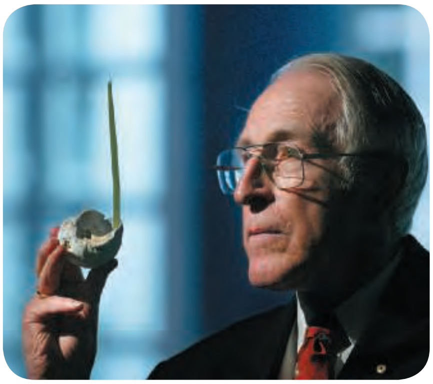


- Andrew Thomas (1951– ): Astronaut

- Fiona Wood (1958– ): Plastic surgeon and burns specialist

- Ian Frazer (1953– ): Immunologist

- Graeme Clark (1935– ): Otolaryngeal surgeon and engineer



## Your task

You will create a podcast of between eight and ten minutes' duration that is in the format of an interviewer discussing with a number of different people which of these scientists would be the best choice to name the AAS medal after. The interviewees (played by group members) should be people who would be likely to have an interest or stake in the award. Examples could include a member of the AAS medal panel, the Minister for Innovation, Industry, Science and Research, the head of a university science or science education department, a high school science teacher, or even a high school science student. Each interviewee should have their own preference as to which scientist should be selected and at least four scientists should be discussed during the interview.

## Process

- Open the ProjectsPLUS application for this chapter in your eBookPLUS. Watch the introductory video lesson, click the 'Start Project' button and then set up your project group. You can complete this project individually or invite other members of your class to form a group. Save your settings and the project will be launched.
- Navigate to your Research Forum. Here you will find topic headings that will be the starting points for your research. In this case, you will need to start by researching the life and work of each of the scientists on the shortlist. You may also add your own research topics.

**MEDIA CENTRE**

**Your Media Centre contains:**

- a sample podcast
- a 'Create your own podcast' document
- weblinks to research sites on these Australian scientists
- an assessment rubric.

- Start your research. Make notes about different aspects of the life and work of each of the scientists and what characteristics make them an inspiration for future scientists. Enter your findings as articles under your topic headings in the Research Forum. You should each find at least three sources (other than the textbook and at least one offline, such as a book or encyclopaedia) to help you discover extra information. You can view and comment on other group members' articles and rate the information they have entered. When your research is complete, print your Research Report to hand in to your teacher.
- Visit your Media Centre. Listen to the sample podcast *Maths in crisis* from the Audio section to get a feel for how your interview/discussion should be formatted. The transcript of this interview can be downloaded from the Template section.
- Use the transcript as a template to help you write a script for your podcast. All members of your group must play a role, either as the interviewer or as one of the interviewees. Note that it is assumed that all of the interviewees are in the same studio, so there can be discussion and comments between interviewees as well as between interviewer and interviewee.
- Download the article *Create your own podcast* from the Documents section of the Media Centre and use it as a guide to turn your scripted interview into a podcast.

**SUGGESTED SOFTWARE**

- ProjectsPLUS
- GarageBand (Mac users) or Audacity (PC users)
- Word or other word processing software
- Internet access

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