

# TOPIC 1

## Science is ...

### 1.1 Overview

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 new investigations.

Observing, measuring, constructing tables, drawing graphs and forming conclusions are just some of the skills used in conducting scientific investigations.

#### 1.1.1 Think about Science

**assessment**

- What is the connection between a pendulum, a playground swing and a metronome?
- What can I measure with a computer?
- Which famous scientist saved the French wine industry from collapse?
- Why are graphs useful to scientists?
- How do you start your own scientific investigation?
- What do the letters CSIRO stand for?



#### LEARNING SEQUENCE

|  |    |
|--|----|
| <b>1.1</b> Overview                                | 1  |
| <b>1.2</b> Safety first                            | 3  |
| <b>1.3</b> Planning your own investigation         | 7  |
| <b>1.4</b> Record keeping and research             | 10 |
| <b>1.5</b> Controlling variables                   | 13 |
| <b>1.6</b> The main game                           | 16 |
| <b>1.7</b> Presenting your data                    | 19 |
| <b>1.8</b> Using data loggers                      | 26 |
| <b>1.9</b> Greats from the past                    | 29 |
| <b>1.10</b> Project: An inspiration for the future | 31 |
| <b>1.11</b> Review                                 | 33 |

Numerous **videos** and **interactivities** are embedded just where you need them, at the point of learning, in your learnON title at [www.jacplus.com.au](http://www.jacplus.com.au). They will help you to learn the concepts covered in this topic.

## 1.1.2 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. Explain to the other two students the area of research you have just read about. Try doing this without referring to your notes.

A data logger can be used for Investigation 1.1.



### INVESTIGATION 1.1

#### Milk now or later?

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

**AIM:** To compare the rate of cooling of hot coffee with and without the addition of milk

#### Materials:

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

#### Method and results

- 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.
1. 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            |                      |                               |

2. Plot line graphs of your results on the same set of axes. Put time on the horizontal axis and temperature on the vertical axis.
3. 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

4. Does hot coffee cool faster than warm coffee? How can you tell from your graph?
5. Did the two lines on the graph cross at any stage? What does this indicate?
6. Write a conclusion based on your results.
7. Does the length of the 'phone call' affect the results? Compare your graphs with those of other groups.
8. Why was it important to put exactly the same amount of water in both cups and to use the same type of cup?
9. What are the advantages and disadvantages of using a data logger for this experiment?
10. Explain how this experiment could be improved.

## learn on RESOURCES – ONLINE ONLY



Explore more with this weblink: CSIRO

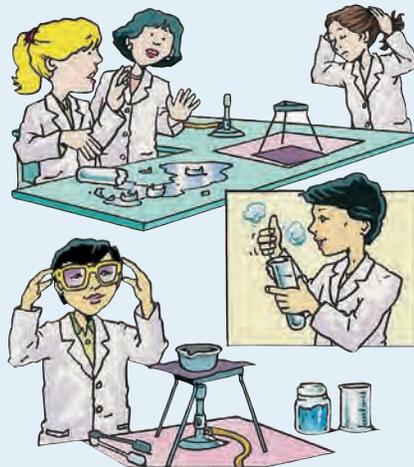
Use the CSIRO weblink in your Resources section to answer the questions on the previous page top.

## 1.2 Safety first

Conducting scientific investigations in a laboratory can be exciting, but accidents can happen if experiments 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.



## 1.2.1 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.

## 1.2.2 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 use.

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

Flammable substances are easily set on fire, so keep them away from flames. Ethanol is **flammable**.

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



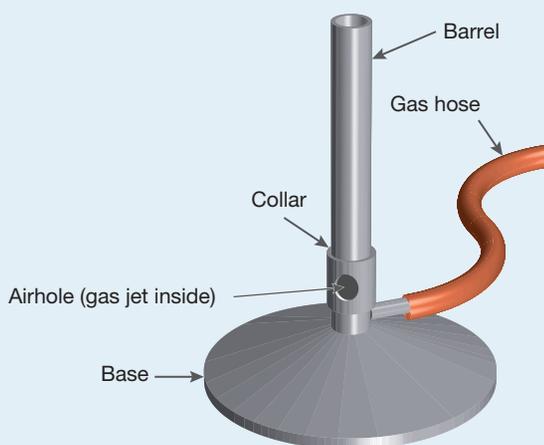
## 1.2.3 Heating substances

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.

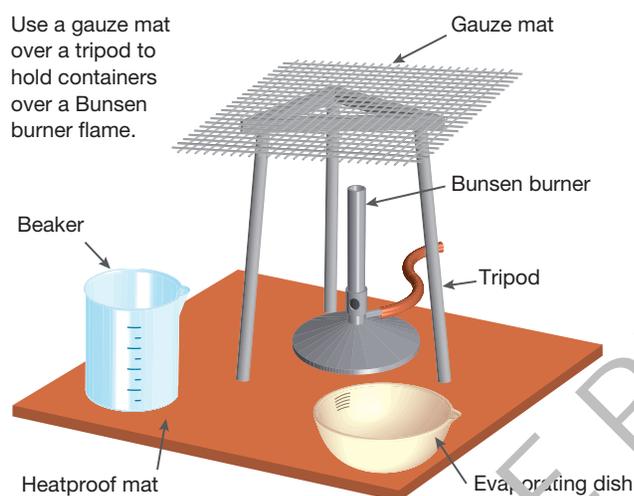
### A GUIDE TO USING THE BUNSEN BURNER

1. Place the Bunsen burner on a heat-proof mat.
2. Check that the gas tap is in the ‘off’ position.
3. Connect the rubber hose to the gas tap.
4. Close the airhole 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 airhole 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.



## 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

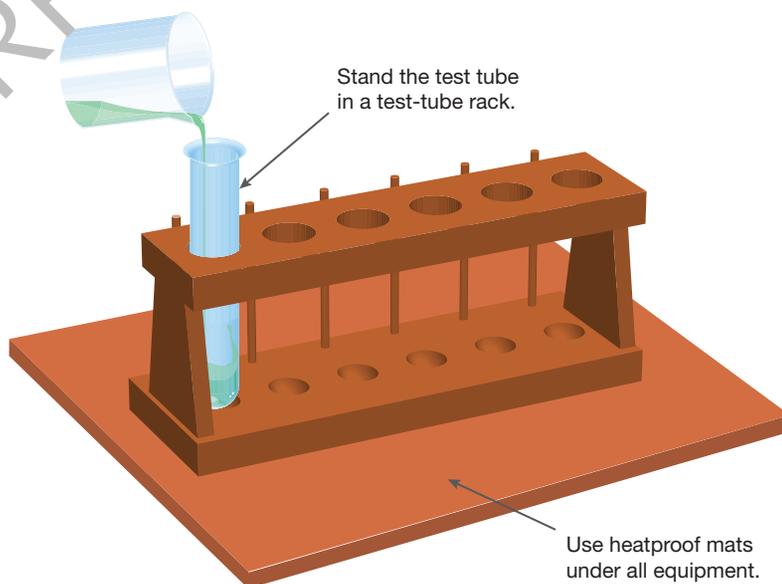
Tripods and gauze mats are not used when heating test tubes. Hold the test tube with a test-tube holder. Keep the base of the test tube above the flame. Make sure that the test tube points away from you and other students.



### 1.2.4 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 its base 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.



## 1.2.5 Using electricity safely

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.

## 1.2 Exercises: Understanding and Inquiring

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at [www.jacplus.com.au](http://www.jacplus.com.au). *Note:* Question numbers may vary slightly.

### 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?
3. Methylated spirits is a man-made 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.

-  **Explore more with this weblink:** Robert Bunsen  
Use the **Robert Bunsen** weblink in your Resources section to learn more about the man after whom the Bunsen burner was named.
-  **Try out this interactivity:** Using equipment  
Searchlight ID: int-0200
-  **Complete this digital doc:** Worksheet 1.1: Safety in the laboratory  
Searchlight ID: doc-18695
-  **Complete this digital doc:** Worksheet 1.2: Safety rules  
Searchlight ID: doc-18696

## 1.3 Planning your own investigation

Scientists learn new things by asking questions and then conducting investigations to find answers. You will take on the role of a scientist by planning an investigation of your own.

Discuss your ideas with others.

### 1.3.1 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 step and one of the most crucial parts in conducting your research project.

### 1.3.2 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. Even if none of the suggested topics appeals to you, they may help you to think of other ideas. For example, 'How strong is 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 for resources 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. Use reliable websites and do not rely on just one source.



#### 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?  
How strong is sticky tape?  
Which type of glue is best?  
How much weight can a plastic bag hold?  
Which food wrap keeps food freshest?  
How effective are pre-wash stain removers?  
Which fabrics burn faster?  
How can the growth of mould on fruit be slowed down?  
Which concrete mixture is strongest?  
What type of fishing line is the strongest?  
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?

### 1.3.3 The aim of the game

Your investigation should have a clear and realistic aim. Your aim 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 affect how far they 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 exposing 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 question below.

- Is my aim 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.

### 1.3.4 Forming a hypothesis

A **hypothesis** is a sensible guess about the outcome of an experiment. Your hypothesis should relate to your aim and should be testable 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 it. Sometimes, a number of teams of scientists test the same hypothesis with slightly

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



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 doesn'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.                   |

### 1.3 Exercises: Understanding and Inquiring

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#### Understand

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

#### Think

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

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**Complete this digital doc:** Worksheet 1.3: Observations and inferences  
Searchlight ID: doc-18697

# 1.4 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.

## 1.4.1 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 time
- Notes about conversations you had with teachers, friends, parents or experts 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 did. Include all the details you 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 will present your research to your class

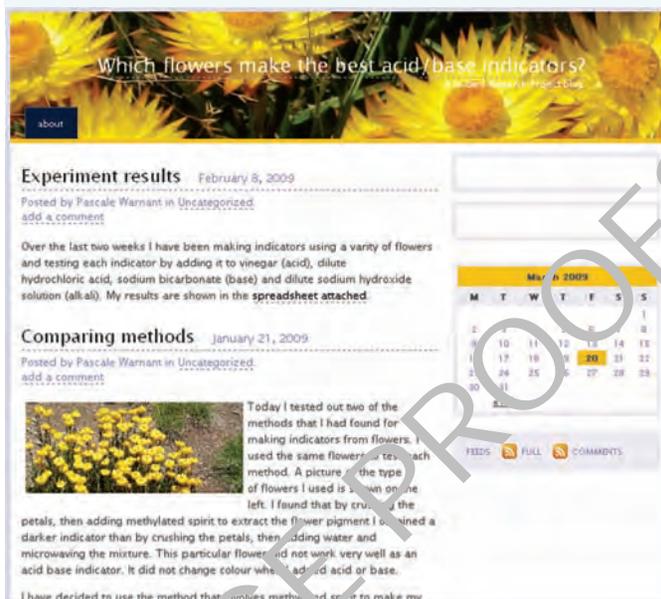
A logbook can be written by hand on paper, with a word-processing program on a computer, or it can even be written in an app or as a website. A blog is a website that has dated entries so it can be used as a logbook. It has the added advantage that you can invite other people, such as your friends, parents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

## 1.4.2 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 others have investigated your problem. Information already available about your topic might help you to design your experiments. It might also help you to explain your results.

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



Make notes on your topic.



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

### 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.

### Using the library

Another good place to start is the school library. There are several different types of information sources in the library, including those listed below.

#### Nonfiction books

Use the subject index catalogue to learn 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 collections of digital files of newspaper articles on topics of interest. Ask your school librarian if you don't know how to access these resources.

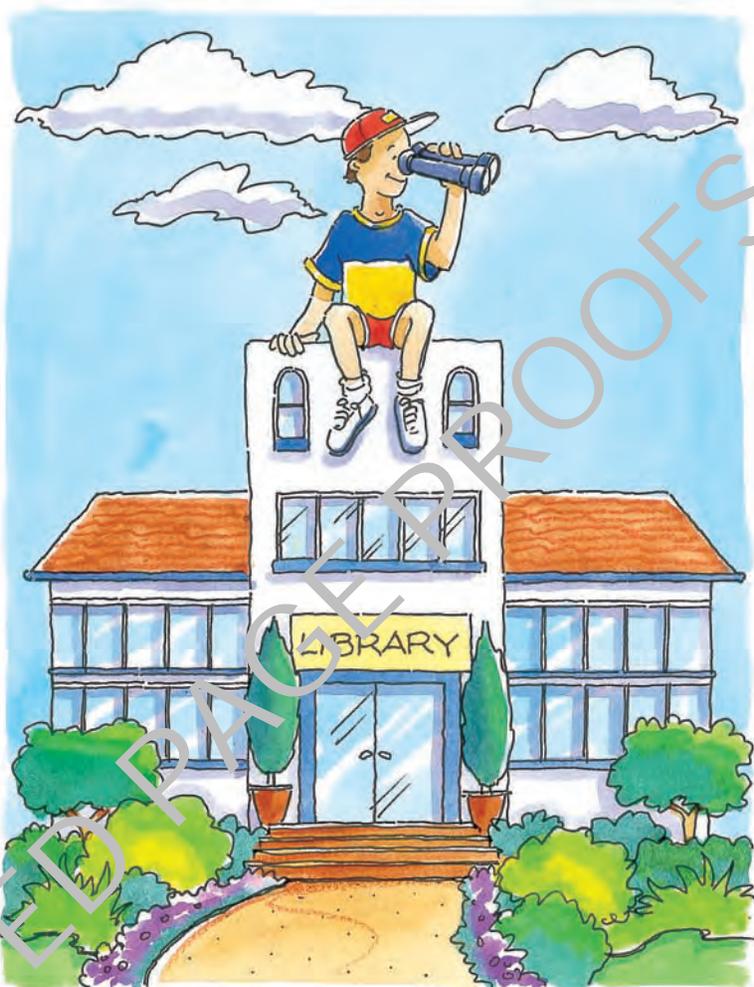
#### Audiovisual resources

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 also be available from the following sources.

Look for information beyond the library.



## 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 government webpages, which usually list contact details. A polite email to the appropriate department or agency is the best way to ask for help.

## Industry

Information on some topics can be obtained from certain industries. For example, if you were testing gloves for strength or batteries to find which ones last longest, the manufacturers might have useful information. Use the internet to find contact details. A polite email is often the best way to ask for help.

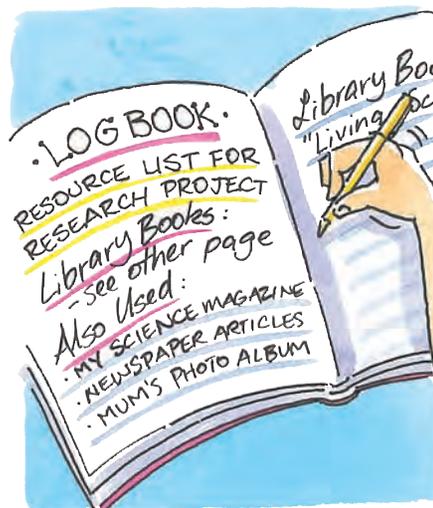
## Relatives or friends

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.

|                                       |                          |
|---------------------------------------|--------------------------|
| The internet:                         | <input type="checkbox"/> |
| School library:                       |                          |
| • nonfiction books                    | <input type="checkbox"/> |
| • reference books                     | <input type="checkbox"/> |
| • journals and magazines              | <input type="checkbox"/> |
| • information files                   | <input type="checkbox"/> |
| • audiovisual resources               | <input type="checkbox"/> |
| Beyond the library:                   |                          |
| • your science teacher                | <input type="checkbox"/> |
| • government departments and agencies | <input type="checkbox"/> |
| • industry                            | <input type="checkbox"/> |
| • relatives or friends                | <input type="checkbox"/> |
| • other sources                       | <input type="checkbox"/> |

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



## 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 you have used.

## 1.4 Exercises: Understanding and inquiring

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at [www.jacplus.com.au](http://www.jacplus.com.au). *Note:* Question numbers may vary slightly.

### 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

## 1.5 Controlling variables

To answer a question scientifically, you need to perform a controlled investigation. The investigation must also be reliable.

### INVESTIGATION 1.2

#### The period of a pendulum

**AIM:** To investigate the effects of mass and length on the period of a pendulum

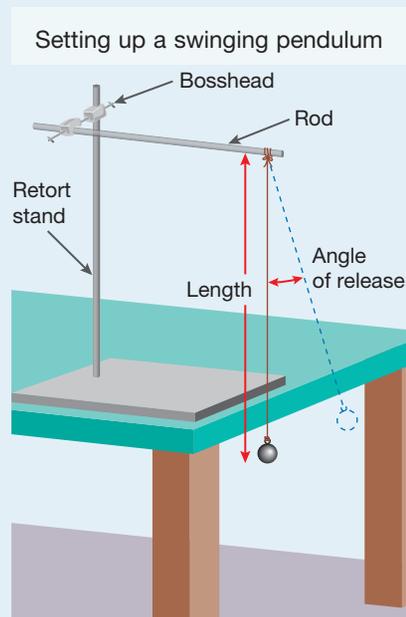
#### Materials:

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

#### Method and results

##### 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.
1. Copy the table below into your logbook, 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 to find the average time for 10 swings. Use this average to calculate the time taken for one complete swing (the period).



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

Length of pendulum = \_\_\_\_\_ cm

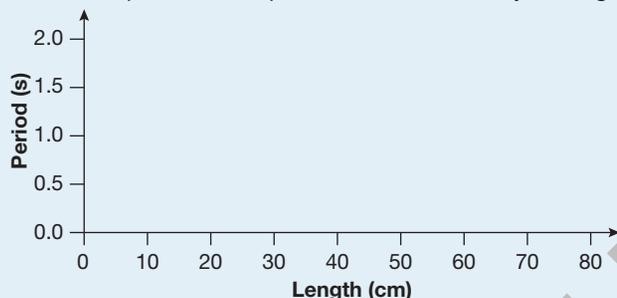
Angle of release = 20°

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

2. Record all the measurements in your table.
  - Repeat this procedure for three larger masses, completing the table as you go.

### Part 2: The effect of length

3. Construct a table like the one on page 15 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.
4. 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.
5. Draw a line graph to show how the period of the pendulum is affected by its length.



### Discuss and explain

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

In the simple investigation of a swinging pendulum in Investigation 1.2 on the previous page, variables are controlled. However, to be reliable as well, measurements in the investigation need to be accurate, repeated and averaged.

## 1.5.1 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.

## 1.5.2 Variables

There are several factors that 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.

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**.



### 1.5.3 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 independent 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? |   |
|--|---|
| <b>Independent variable</b>                                | <ul style="list-style-type: none"><li>• The mass of the pendulum</li></ul>  |
| <b>Dependent variable</b>                                  | <ul style="list-style-type: none"><li>• The period of the pendulum</li></ul>  |
| <b>Controlled variables</b>                                | <ul style="list-style-type: none"><li>• The length of the pendulum</li><li>• The angle of release</li><li>• The method of release</li></ul> |

## 1.5 Exercises: Understanding and inquiring

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at [www.jacplus.com.au](http://www.jacplus.com.au). *Note:* Question numbers may vary slightly.

### 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?
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 results supported your hypothesis.

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



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 **Complete this digital doc:** Worksheet 1.4: Fair testing  
Searchlight ID: doc-18698

## 1.6 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.

### 1.6.1 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

Choose a 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 you intend to conduct.

#### 5. Equipment

List any equipment you 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.

### 1.6.2 Performing your experiments

Once your teacher has approved your plan, 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 19–26.

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.

All observations and measurements should be recorded.



### 1.6.3 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 not applicable to 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 the variables in your investigation are 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 they are 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 19–26).

### Discussion

Discuss your results here. Begin by stating what your results indicate about the answer to your question. Explain how your results might be useful. Outline any weaknesses in your design or difficulties in measuring here. Explain how you could improve 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 detail 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/p.hgb.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.

## 1.6 Exercises: Understanding and inquiring

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at [www.jacplus.com.au](http://www.jacplus.com.au). *Note:* Question numbers may vary slightly.

### 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) Enter 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?

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Searchlight ID: doc-18699

## 1.7 Presenting your data

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

### 1.7.1 Using tables

When data are organised in a table, they are 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.

| 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              |

Include the measurement units in the headings.

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 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

### 1.7.2 Using graphs

Organising data as a graph is a widely recognised way to make a clear presentation. Graphs make it easier to read and interpret information, find trends and draw conclusions.

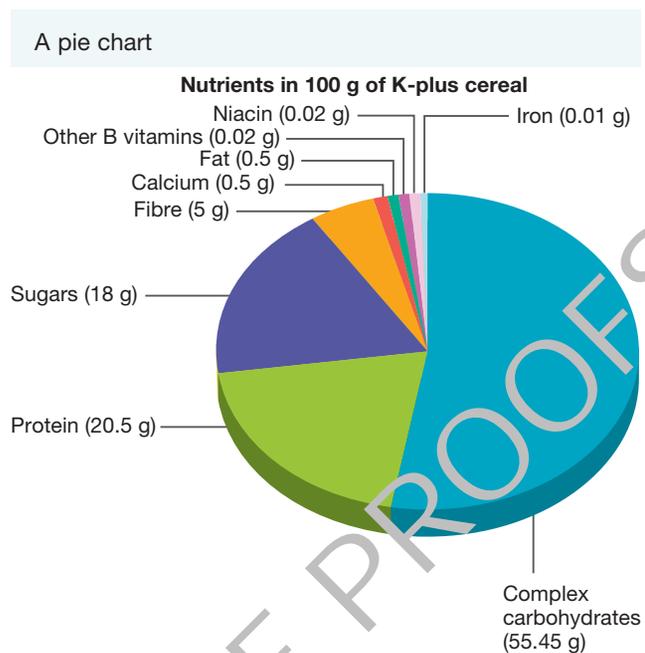
A graph, especially a line graph, can also be used to find values other than those used in the investigation. This can be done by interpolation or extrapolation (see the section on page 23).

### 1.7.3 Types of graphs

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

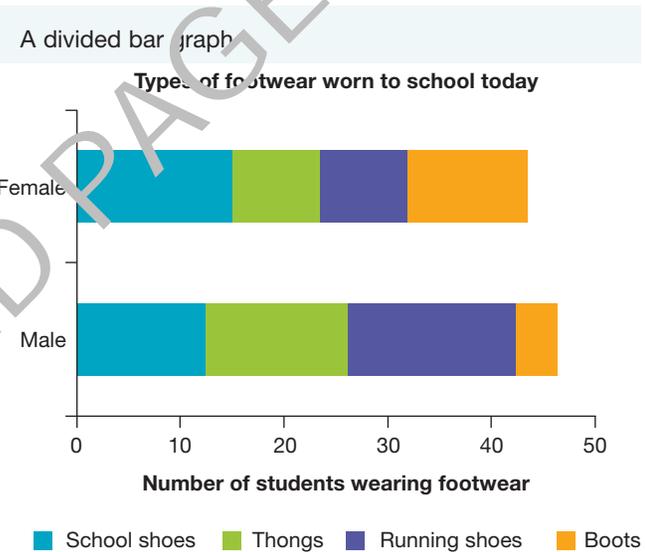
#### Pie charts (or sector graphs)

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 may 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.



#### Divided bar graphs

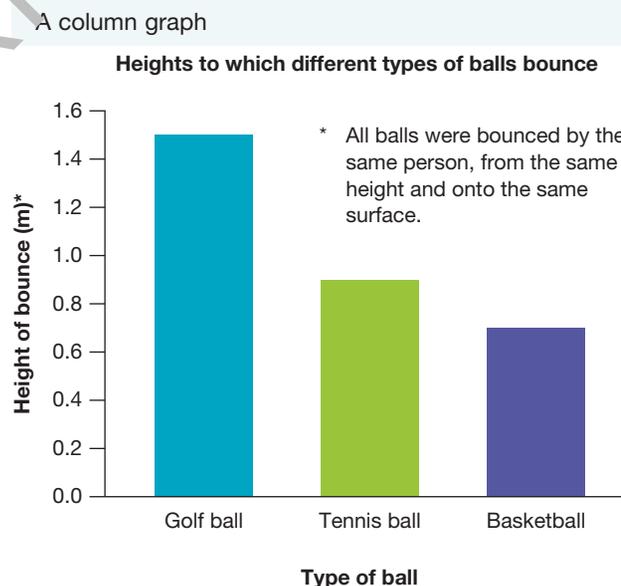
Divided bar graphs are also used to represent parts of a whole. However, the data are represented as a long rectangle, rather than a circle, divided into sections. The example below shows the type of footwear worn to school today by male and female students.



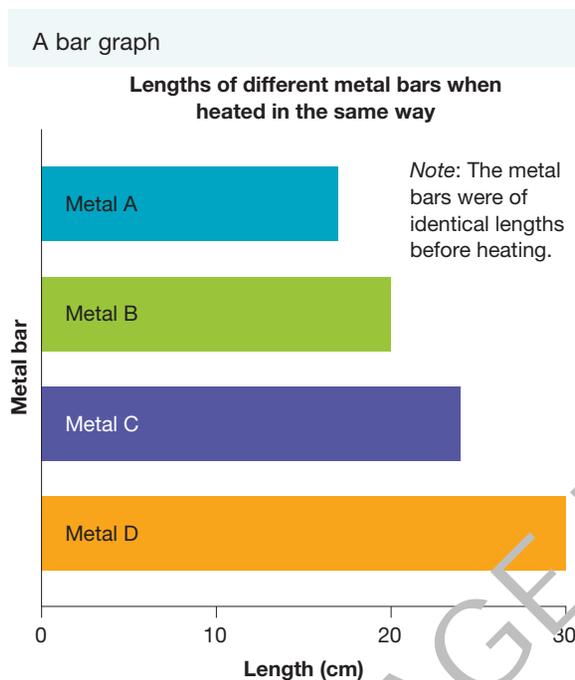
#### Column graphs and bar graphs

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 are 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.

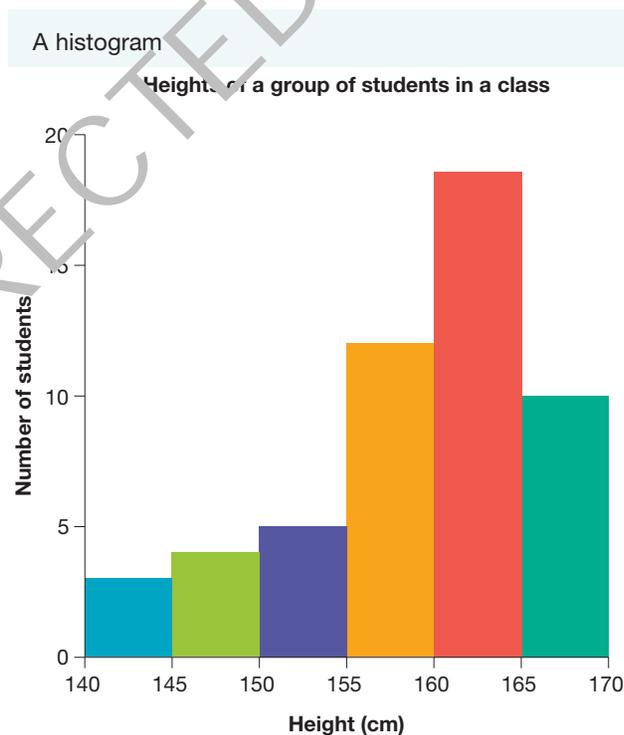


The example below shows the lengths of different metal bars when heated. Each bar represents a different metal.



## Histograms

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



## 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. A 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.

**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 5 seconds. The time of each measurement was chosen by the students and is the independent variable. The distance measured is therefore the dependent variable. Usually the independent variable is plotted on the 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 its units. The unit is written in brackets after the name of the variable.

**2. Title**

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

**1. Grid**

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

**Distance covered by a runner in 15 seconds**

**Data table**

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

**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.

**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.

**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 graph 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 a straight line because the temperature increases at a steady rate. A graph of the growth rate of a red panda (see pages 27–28) would be curved and irregular because pandas have growth spurts. Inspecting the data will help you decide whether your line should be straight or smooth and curved.

### 1.7.4 Interpolation

Line graphs can be used to estimate measurements that were not actually made in an investigation. The table next page top right 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 in the graph below). 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 by dotted line 2.

### 1.7.5 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 a spring stretched when various masses were attached

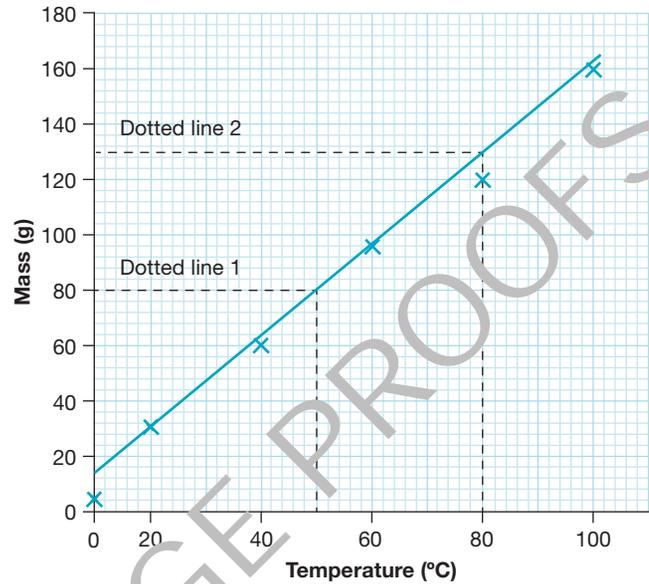
| Mass attached to the spring (kg) | Length by which spring stretched (cm) |
|----------------------------------|---------------------------------------|
| 0.0                              | 0                                     |
| 0.5                              | 8                               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

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

The data in the table above are plotted on the graph below. Values have been plotted up to a mass of 1.6 kg and an increase in length of 26 cm. 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 cm.

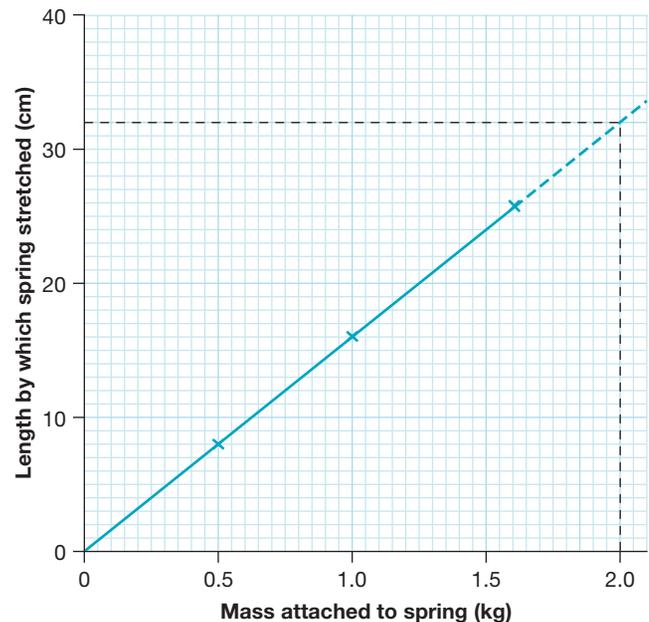
Using a line graph for interpolation

Effect of temperature on the amount of sugar dissolved in tea



Using a line graph for extrapolation

Effect of mass on spring stretch



### INVESTIGATION 1.3

#### Drawing a line graph

**AIM: To use a line graph to record data obtained in an experiment**

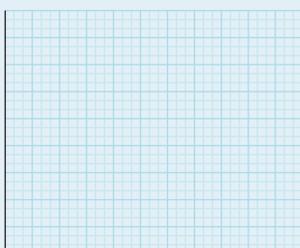
A student conducted an experiment to see how temperature affected the amount of sugar that would dissolve in a cup of tea. Each cup contained the same volume of tea, and the sugar was stirred in at an equal rate for each cup. The results obtained are shown in the table below.

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



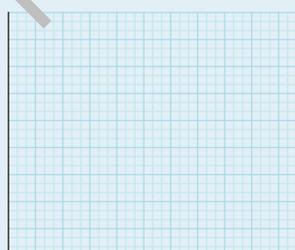
| Amount of sugar dissolved in one cup of tea |                             |
|---|-----------------------------|
| Temperature (°C)                            | Mass of sugar dissolved (g) |
| 0   | 4                           |
| 20  | 30                          |
| 40  | 60                      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

1. Set up the grid.



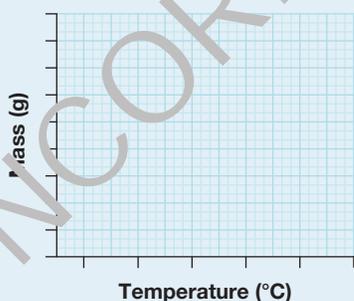
2. Give the graph a title.

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



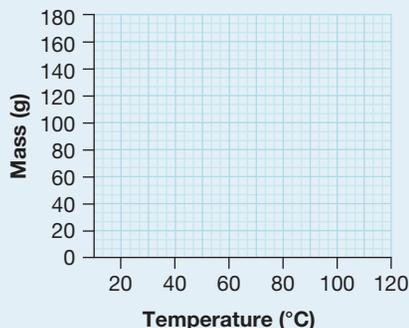
3. Set up the axes and label them.

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

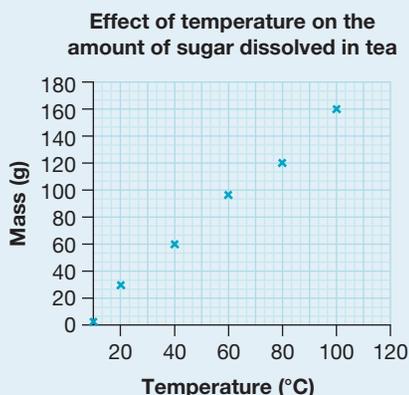


4. Place the scales on the axes.

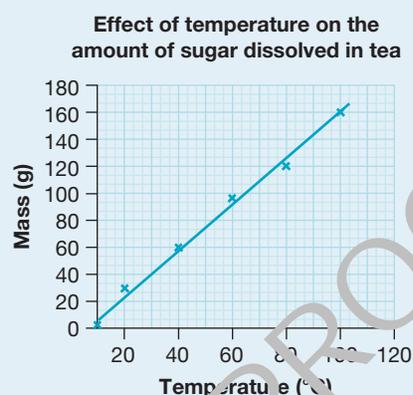
**Effect of temperature on the amount of sugar dissolved in tea**



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.



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.



## 1.7 Exercises: Understanding and inquiring

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at [www.jacplus.com.au](http://www.jacplus.com.au). *Note:* Question numbers may vary slightly.

### Analyse and evaluate

- The following table shows the uses of plastics in Australia.
  - Select a suitable graph type and prepare a graph from this table.
  - Choose two uses of plastic from your graph. For each use, state a particular item that is made of plastic.
  - There has been controversy about the waste products that humans create.
    - List some uses of plastics that contribute to waste products.
    - Suggest some action people can take to reduce the amount of plastic waste products.
- The data in the following table relate the speed of a car to its stopping distance (the distance the car travels after the brakes are applied).
  - Graph the data.
  - Make a conclusion about the information in the graph.
  - How could this information be applied to your everyday life?

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           |

Relationship between the speed of a car and its stopping distance

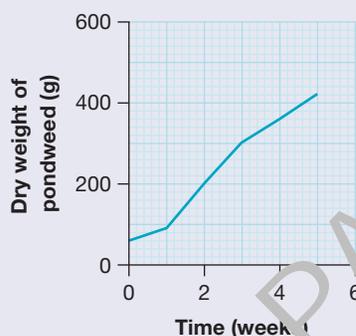
| Speed of car (m/s) | Stopping distance (m) |
|--------------------|-----------------------|
| 10                 | 12                    |
| 20                 | 36                    |
| 30                 | 72                    |
| 40                 | 120                   |

3. The boiling point of water changes with air pressure. For example, water does 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 show the boiling point of water at various air pressure values.
- Graph the data.
  - Describe the shape of your graph.
  - What is the pressure of the atmosphere at sea level?
  - Would it take a longer or shorter time to boil water at the top of Mount Everest compared with sea level? Explain your answer.
4. The following graph shows the increase in mass of a growing pondweed.
- What was the mass of the plant after 3 weeks of growth?

Boiling point of water at different air pressures

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

Increase in mass of pondweed with time



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

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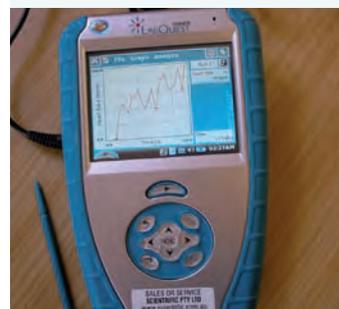
 Complete this digital doc: Worksheet 1.7: Data analysis  
Searchlight ID: doc-13701

## 1.8 Using data loggers

### 1.8.1 Data loggers in temperature measurement

In Investigation 1.1 Milk now or later on page 2, the measuring instrument you used was a thermometer. You looked at the thermometer every 30 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 automatically tabulated the temperature data and graphed it as well.

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



## 1.8.2 What is a data logger?

A data logger is a type of scientific recording instrument. It collects and stores measurements that 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.

Data loggers also tend to be portable and battery-powered, and can therefore be used for applications such as remote weather monitoring and car crash testing. You may have been in a car that has driven over two closely placed rubber strips on the road — these strips are connected to a data logger used to count traffic.

Of course, to be useful, the stored measurements must be easy to access. That is why the data logger is also attached to either a computer or a graphics calculator. The computer or calculator takes the data and, using special software that comes with the data logger, shows the data as a table, a graph or both.

## 1.8.3 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 up to several hundred degrees Celsius
- 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!

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



A data logger for measuring blood pressure



## 1.8 Exercises: Understanding and inquiring

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at [www.jacplus.com.au](http://www.jacplus.com.au). *Note:* Question numbers may vary slightly.

### Remember

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

| Word                    | Meaning   |
|-------------------------|---|
| a. Sensor               | A You may need to download the data from the data logger to one of these.                               |
| b. Data logger          | B Piece of information  |
| c. Computer             | C These are plugged into the data logger and take the measurements.                                     |
| d. Data logger software | D Allows you to input data into the data logger or computer by touching it with your finger or a stylus |
| e. Touch screen         | E Allows you to process the data collected by the data logger   |
| f. Data                 | F Collects and stores data from sensors connected to it   |

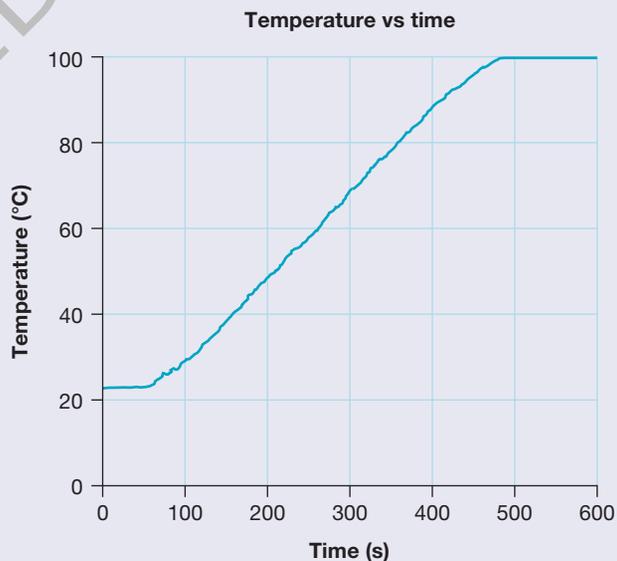
2. Sensors are devices that take the measurements that the data logger collects. Outline scientific investigations that could use data collected by sensors that measure:
- electric current
  - heart rate
  - motion
  - sound waves
  - light intensity.

### Analyse and evaluate

3. The graph at right shows data collected by a data logger for an experiment in which water was 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.

- How long did the whole experiment go for?
- About when did the heating of the water begin?
- What was the temperature of the water when heating began?
- What was the temperature of the water when heating finished?
- About when did the water begin to boil?
- Between 100 and 400 seconds, at what rate (in degrees per second) did the water temperature rise?
- 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.)



## 1.9 Greats from the past

### Science as a human endeavour

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?

#### 1.9.1 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.

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 received the Nobel Prize in Physics in 1921 for this.

Einstein's theories of relativity were so different from earlier theories 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. He 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.

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



#### 1.9.2 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.

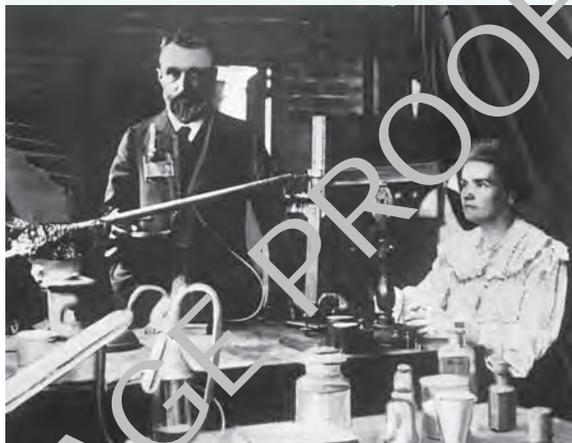
Isaac Newton was sent to Cambridge University at the age of 18. When the university closed down in 1665 as a result of the Great Plague, young Isaac went home for two years. There he developed his laws of gravitation and his three laws of motion. During his life, he also made discoveries about the behaviour 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.

### 1.9.3 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 3 years to earn enough money to study at the University of Paris, where she met her future husband, Pierre. They were very poor and spent most of their money on laboratory equipment, leaving 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 their 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 with husband Pierre in her laboratory



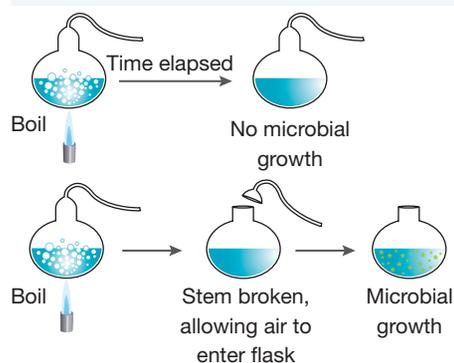
### 1.9.4 The germ of an idea

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 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.

One of Pasteur's experiments



## 1.9 Exercises: Understanding and inquiring

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### 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.

### Imagine

4. Imagine that you are one of the three scientists you chose 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 above about one of the following scientists: Michael Faraday (1791–1867), Charles Darwin (1809–1882), Lise Meitner (1878–1968), Barbara McClintock (1902–1992), Peter Doherty (1940–), Stephen Hawking (1942–).

## learn on RESOURCES — ONLINE ONLY

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

## learn on

### 1.10 Project: An inspiration for the future

#### 1.10.1 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 (AAS) 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



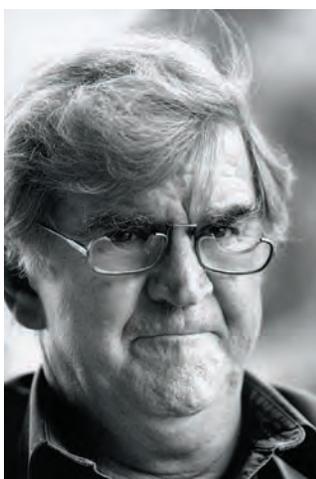
- Peter Doherty (1940– ): Veterinarian and immunologist



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



- Fred Hollows (1929–1993): Ophthalmologist



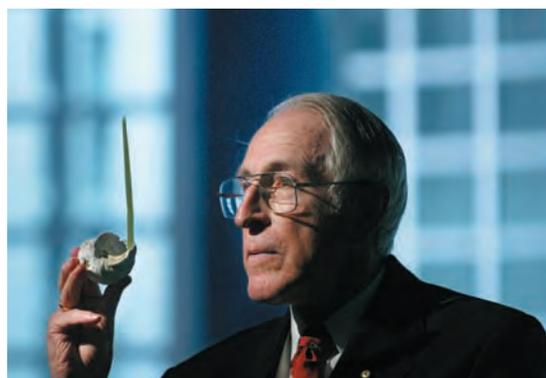
- Ian Frazer (1953– ). Immunologist



- Andrew Thomas (1951– ): Astronaut



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



### 1.10.2 Your task

You will create an 8–10 minute podcast 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 Industry, 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.

### 1.10.3 Process

Open the ProjectsPLUS application for this chapter in your Resources section. 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.

## 1.11 Review

### 1.11.1 The laboratory

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

### 1.11.2 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

### 1.11.3 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 forming conclusions
- identify data that support or discount a hypothesis
- form conclusions based on experimental results

### 1.11.4 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

### 1.11.5 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

#### ACTIVITY 1.1

Investigating  
doc-2861

#### ACTIVITY 1.2

Analysing investigations  
doc-2862

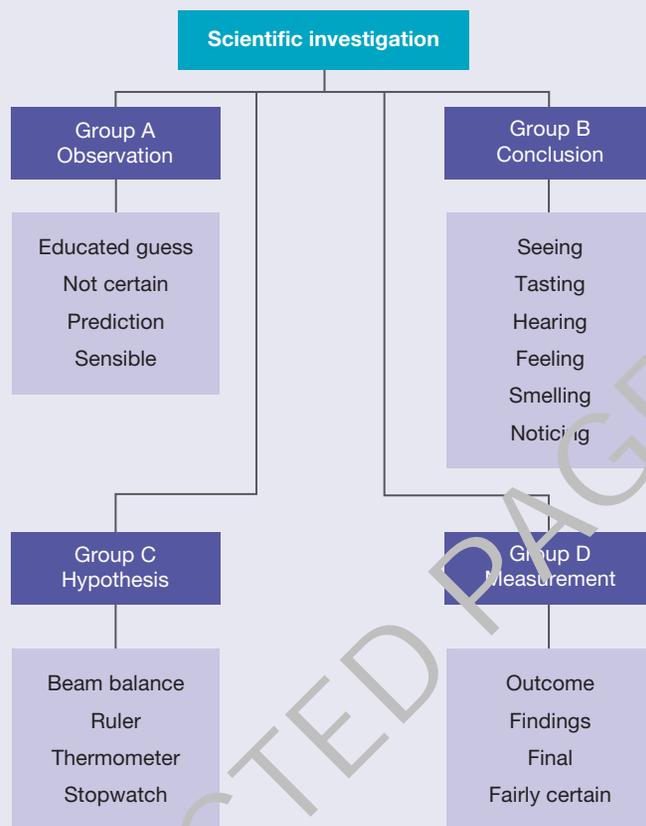
#### ACTIVITY 1.3

Designing investigations  
doc-2863

## 1.11 Review 1: Looking back

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at [www.jacplus.com.au](http://www.jacplus.com.au). *Note:* Question numbers may vary slightly.

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?



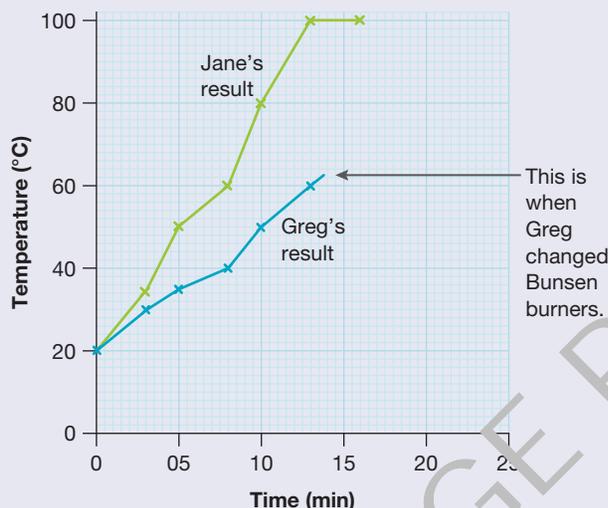
2. Bahir was sick of being bitten by mosquitoes. He counted several bites each evening when he sat outside to have dinner. He had heard that burning a citronella candle was a good way to keep mosquitoes away. Design an experiment to test Bahir's idea. List the independent and dependent variables, and the controlled variables needed to make this a fair test. Suggest a control for your experiment.
3. 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.
4. 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 next page top.
- (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.



5. Singalia and Sallyana are two red panda cubs born at Sydney's Taronga Zoo. The table on the next page 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 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     |

6. The table below shows the winning times for the men's 400 m freestyle swimming event. The data are from various Olympic Games from 1896 to 2012.

| Year | Name, country               | Time (min:s) |
|------|-----------------------------|--------------|
| 1896 | Paul Neumann, Austria       | 8:12.60      |
| 1900 | 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 | Tae-Hwan Park, Korea        | 3:41.86      |
| 2012 | Sun Yang, China             | 3:40.14      |

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

Date: 29 February

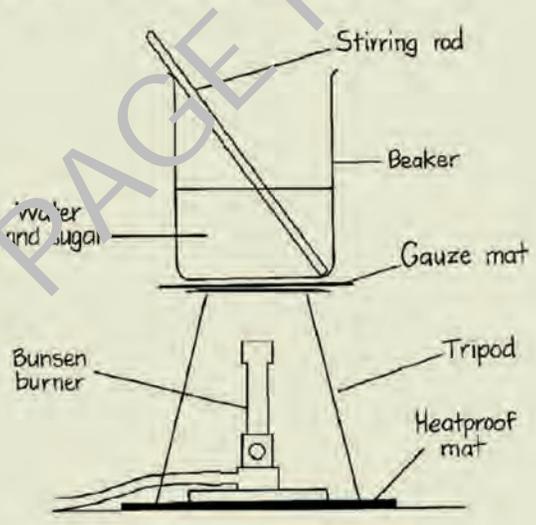
### Dissolving sugar

**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

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-  **Complete this digital doc:** Worksheet 1.8: Investigating: Puzzle  
Searchlight ID: doc-18702
-  **Complete this digital doc:** Worksheet 1.9: Investigating: Summary  
Searchlight ID: doc-18703

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