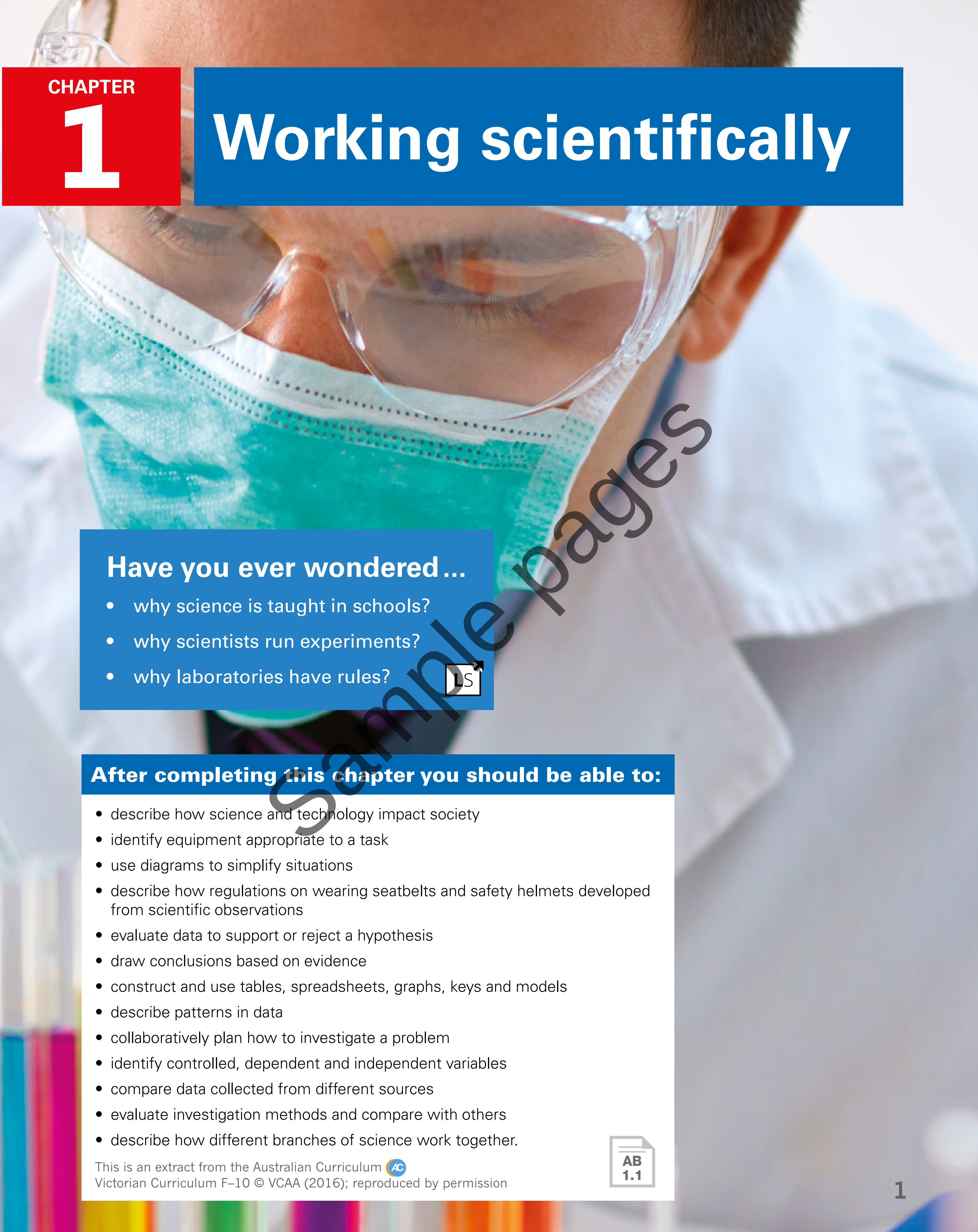


CHAPTER 1

Working scientifically

Have you ever wondered...

- why science is taught in schools?
- why scientists run experiments?
- why laboratories have rules?

LS

After completing this chapter you should be able to:

- describe how science and technology impact society
- identify equipment appropriate to a task
- use diagrams to simplify situations
- describe how regulations on wearing seatbelts and safety helmets developed from scientific observations
- evaluate data to support or reject a hypothesis
- draw conclusions based on evidence
- construct and use tables, spreadsheets, graphs, keys and models
- describe patterns in data
- collaboratively plan how to investigate a problem
- identify controlled, dependent and independent variables
- compare data collected from different sources
- evaluate investigation methods and compare with others
- describe how different branches of science work together.

AB 1.1

MODULE
1.1 Science and the laboratory

Scientists study the world around them to find out how it works. They investigate the living world of animals, plants, bugs and germs, and they study the planet and environments they live on and in. They investigate the physical world of substances like plastics and metals, and chemicals like water and acids. They explore forms of energy such as heat, light and sound. They even study things that are out of this world, like other planets, stars and galaxies.

STEM 4 fun

Can you create a phone?

PROBLEM

Create a phone that allows you to have a conversation when standing three metres apart.

SUPPLIES foam cups, plastic cups, paper cups, empty tins, wool, wire, cotton, cardboard, foil, twine

PLAN AND DESIGN Design the solution—what information do you need to solve the problem? Draw a diagram. Make a list of materials you will need and steps you will take.

CREATE Follow your plan. Construct your solution to the problem.

IMPROVE What works? What doesn't? How do you know it solves the problem? What could work better? Modify your design to make it better. Test it out.

REFLECTION

1 What area of STEM did you work in today?
2 In what career do these activities connect?
3 How did you use mathematics in this task?

Science is important

The world is very complex and is becoming more complex every day. New technology is constantly being developed and new issues are frequently hitting the headlines. For example, HD televisions, Blu-ray, smart phones and tablet computers were not common ten years ago. Laptop computers, mobile phones, email and the internet are only a little older. Likewise the issues of climate change were not heard of until relatively recently.

Developments in science have also caused argument and debate. Cloning, the use of stem cells to repair damage in the body, and genetically modified food have all been developed from scientific discovery. Society has split into those who support the use of these new discoveries and those who do not. Climate change, and what we as humans should do to control it, has also split society into those who believe that it is happening and those who do not. There is even debate among those who do believe it is happening: some believe that it is caused by human activity, while others believe it could be part of a natural cycle.

Whatever its cause, glaciers like the one in Figure 1.1.1 are melting at a higher-than-normal rate. Older issues, such as whether nuclear power should be used in Australia, are being debated again because of our increasing energy needs. As a future adult and voter you will need an understanding of science to help you decide what we should do about these issues and any new issues that arise. To make good decisions about our future, you will need an understanding of science.

FIGURE 1.1.1 Climate change: do we believe the evidence that temperatures are rising because of human activity or do we reject it based on other evidence?

The branches of science

The subject of science covers many different areas, ranging from acids to aardvarks, electricity to emus, rats to rocks, Venus to viruses, and much, much more. Science covers so many different areas that it must be split into different **branches** or **disciplines**, some of which are shown in Figure 1.1.2. Scientists tend to work in one particular branch of science. This allows them to explore it in detail and develop a deep understanding of it without being distracted by what is going on in the other branches.

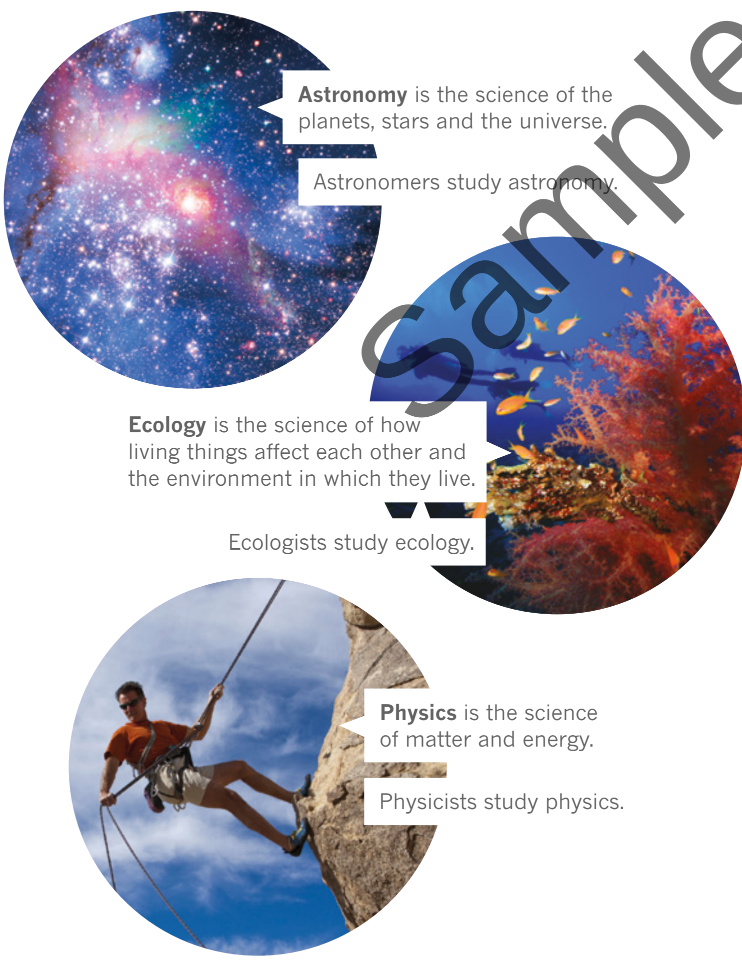


FIGURE 1.1.2 The main branches of science

Working with Science

BUSHFIRE AND CLIMATE SCIENTIST

Dr Sarah Harris

Understanding climate and bushfire patterns is an important part of predicting where and when bushfires might occur. By using this knowledge, firefighters can be more prepared and better equipped to manage bushfires. Bushfire and climate scientists use geology, biology, chemistry and mathematics to study, map and model fire and weather trends.

FIGURE 1.1.3 Dr Sarah Harris

Dr Sarah Harris is a bushfire and climate scientist at Monash University (Figure 1.1.3). In her work, she models climate and bushfires to forecast when bushfires might happen, to understand the impact of bushfires and to map planned burns. Dr Harris works with fire and emergency services, the Bureau of Meteorology and other government departments to work out the best ways to prepare for and manage bushfires to minimise their impact.

Bushfires in Australia are frequent and severe. Scientists predict that climate change will increase extreme weather events such as drought and heatwaves. For this reason, bushfire and climate research will continue to be an important field of study. To become a bushfire or climate scientist, you will need a Bachelor of Science, majoring in environmental management or earth sciences. After your degree, you can continue studying to become a research scientist, or work for government departments. You might like this job if you enjoy working in teams, analysing data, observing patterns and using your knowledge to solve environmental problems.

Review

1. Why do you think bushfire and climate scientists are important?
2. Why do you think it is important that scientists work with the community and government departments?

Sub-branches of science

The branches of science are so broad that they are split into smaller sub-branches. For example, geology covers so much material that a geologist would find it impossible to study it all. Instead geologists tend to specialise by working in a sub-branch like petrology (the study of rocks), palaeontology (fossils), vulcanology (volcanoes) or seismology (earthquakes).

Likewise, physicists might specialise in acoustics (sound), optics (light) or mechanics (forces and energy) and chemists might specialise in organic, inorganic, analytical or physical chemistry.

There are so many types of living things that biologists specialise in the study of only one type of living thing, such as animals (zoologists study zoology), plants (botanists study botany) or germs (microbiologists study microbiology) (Figure 1.1.4). Even sub-branches are sometimes too big. For example, zoology covers so many different types of animals that it is split into smaller sub-branches such as insects (entomologists study entomology), spiders (arachnologists study arachnology) and fish (ichthyologists study ichthyology).

Prac 1
p. 11

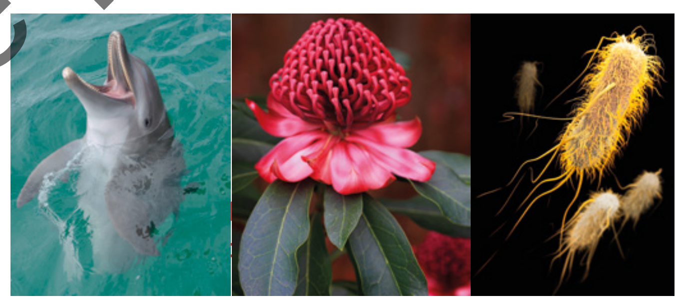


FIGURE 1.1.4 Some of the sub-branches of biology (left to to right): zoology, botany, microbiology

SciFile

The many branches of science

There are lots of other very specific sub-branches of science. Some more examples include teuthology (the study of octopuses), mycology (the study of fungi), chiropterology (the study of bats), carpology (the study of fruits and seeds) and oology (the study of eggs).

The laboratory

A scientist works in a **laboratory**. Laboratories are where scientists run most of their experiments and make most of their observations, measurements and discoveries. Your idea of a laboratory is probably a large room equipped with Bunsen burners, sinks, glassware, balances and chemicals that is occupied by people in white coats and safety glasses. This is the type of laboratory that chemists tend to work in and the type of laboratory that you will eventually work in at school. It might look something like Figure 1.1.5.

FIGURE 1.1.5 To most of us, the laboratory is a place full of Bunsen burners, glassware and people in white coats.

Different scientists have very different ideas about what a laboratory is. For marine biologists, the laboratory could be a coral reef. The laboratory of a zoologist might be a rainforest, and a laptop computer and video camera could be their most important equipment. The laboratory of an astronomer will be wherever their telescope is mounted. Figure 1.1.6 shows a palaeontologist at work in her laboratory. Her equipment is most likely a spade and brushes to clear the soil away from around the fossil. Sturdy boots, overalls and a hat will be far more important to her than a white coat. Scientists like her will usually have another laboratory in which they can test the samples they collected outdoors. For example, an ecologist might collect samples of polluted water from a creek but then analyse them back in their other laboratory.

FIGURE 1.1.6 For palaeontologists, the laboratory could be the place in which a dinosaur fossil has been found.

Equipment

Tools and equipment are a necessary part of most jobs. A builder uses power drills and saws, nail guns and measuring tapes, while a chef uses ovens, pots and pans, sieves and measuring spoons. Scientists use equipment too, to help them carry out experiments and to help them describe what they observe more accurately. Each branch of science uses its own specific tools and equipment. An astronomer will not see much without a telescope, and a microbiologist needs a microscope to see bacteria that are invisible to the naked eye. Physicists need devices like ammeters and voltmeters to measure electrical current, and ecologists need pH meters to determine how acidic creek water is.

Technology also plays an important role. Devices like smartphones and tablets provide the ability to photograph and record video of investigations. Digital probes and sensors can be connected to devices to collect a range of data. Software enables scientists to work with the data they collect, create models, and share and engage with scientific research. However, there is a set of basic scientific equipment common to most laboratories, including the ones at school.

Balances

The beam balances, electronic balances and spring balances shown in Figure 1.1.7 can all be used to measure the **mass** of an object. Mass is a measure of how much matter there is in an object.

In the laboratory, mass is usually measured in grams (g) or kilograms (kg).

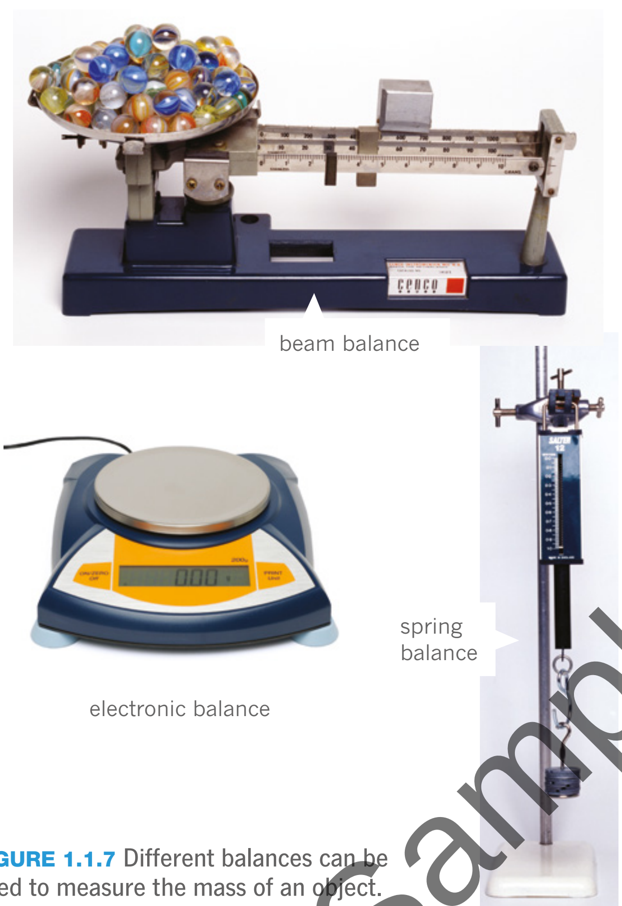


FIGURE 1.1.7 Different balances can be used to measure the mass of an object.

Glassware

Glassware such as beakers, conical flasks, test-tubes and watch-glasses allows you to mix and heat chemicals. Most glassware in the laboratory is made of Pyrex, a special type of glass that is less likely than normal glass to crack when it is heated to high temperatures or cooled quickly. Some common pieces of equipment are shown in Figure 1.1.8.

Beakers and conical flasks usually have markings up their sides, but the markings only indicate rough volumes. You would use a measuring cylinder to measure more accurate volumes. Volume is normally measured in the laboratory in millilitres (mL). Larger volumes are measured in litres (L).

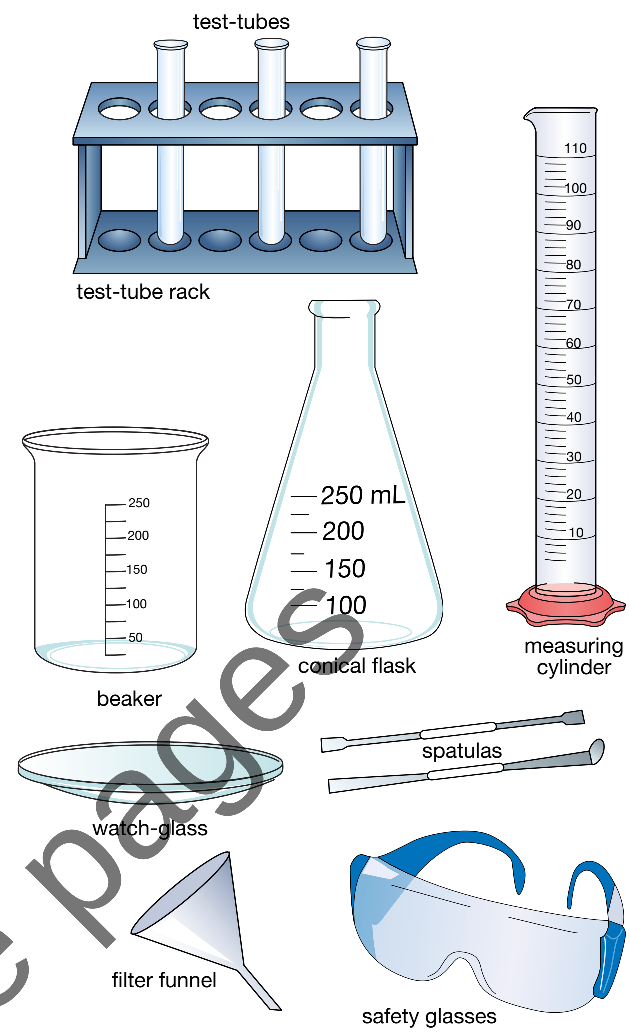


FIGURE 1.1.8 Equipment commonly used in the laboratory

AB 1.3

Heating equipment

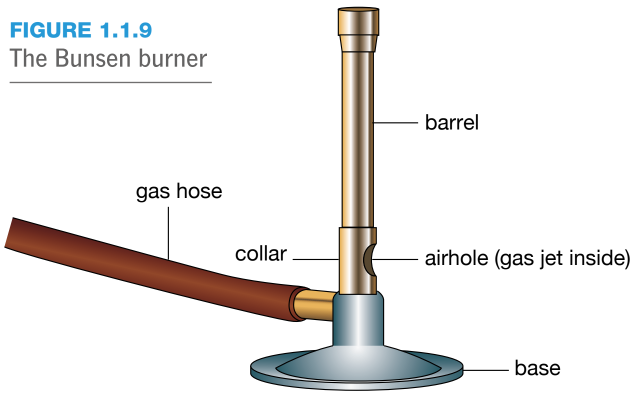
Hotplates and **Bunsen burners** are some of the most important and dangerous pieces of equipment that you will use in the school laboratory. Both get extremely hot and can cause serious burn injuries if you use them incorrectly.

The Bunsen burner

Prac 2 p. 12
Prac 3 p. 13

Figure 1.1.9 shows the parts of the Bunsen burner. The collar controls the amount of air that enters the burner as well as controlling the heat and colour of the flame. When you *shut* the airhole, very little air is able to mix with the gas. The gas does not burn well as it is the oxygen in air that is needed for fire to burn. It produces a pale yellow flame that is easily visible and relatively cool. This is shown in Figure 1.1.10. For these reasons, the yellow flame is called the **safety flame**. It is also a dirty flame, because it leaves a layer of black carbon soot on anything that is heated in it.

FIGURE 1.1.9
The Bunsen burner



If you *open* the airhole, then a lot of air will enter, which means a lot more oxygen is able to enter. The gas will burn with no smoke, and will be extremely hot (about 1500°C). This flame is noisy. It has a blue colour and is sometimes difficult to see. At the very base of the flame, there is a small cone of unburnt gas. As Figure 1.1.10 shows, the hottest part of the flame is just above this cone.

FIGURE 1.1.10 The yellow flame is easy to see and relatively cool. The blue flame is much hotter and almost invisible. This makes it much more dangerous.

AB 1.2

Other equipment used for heating

A kitchen stove isn't very useful unless you have frying pans, saucepans, tongs and stirring spoons to help you cook the food safely. A hotplate and Bunsen burner also need additional equipment to help you heat objects safely. Some of this equipment is shown in Figure 1.1.11.

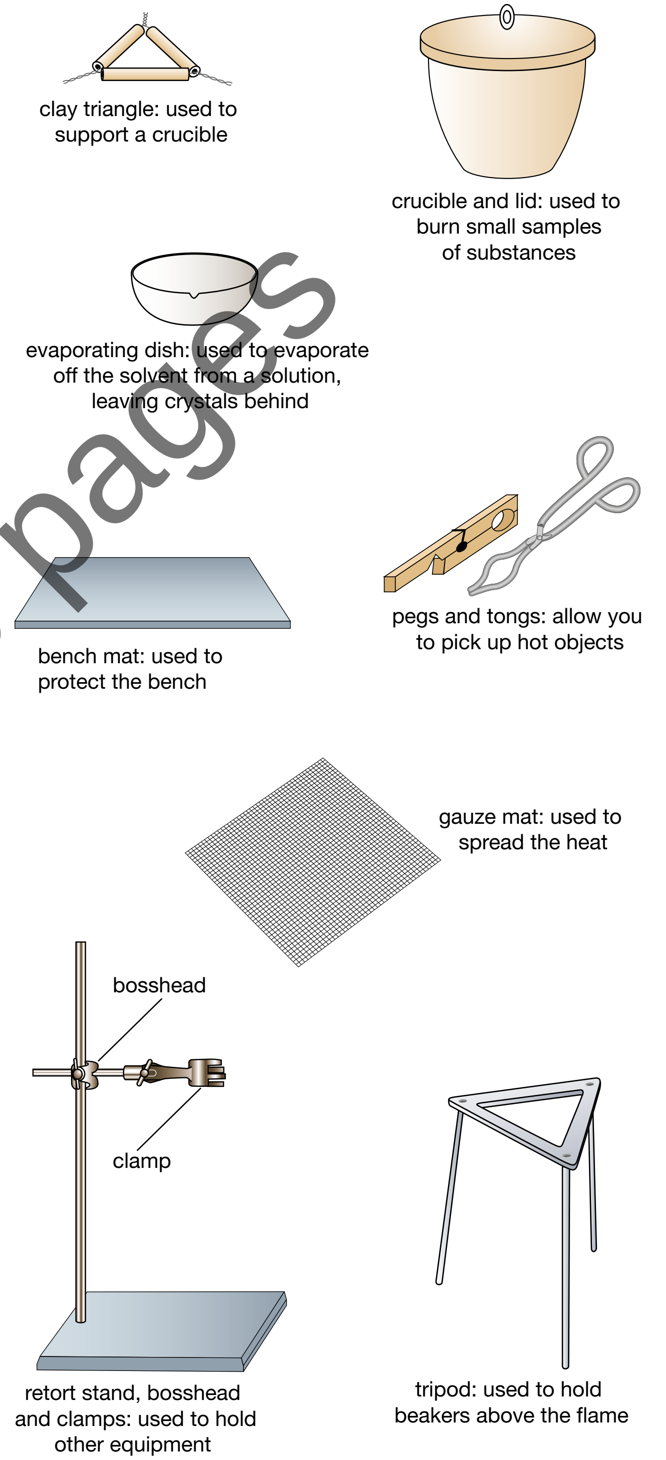


FIGURE 1.1.11 The hotplate and Bunsen burner need additional equipment to make them useful.

Drawing equipment

Scientists do not draw equipment realistically but as simple two-dimensional (2D) line-drawings, ‘splitting’ the equipment down the middle to show its **cross-section**.

Figure 1.1.12 shows how scientists draw some of the most common equipment used in the laboratory.

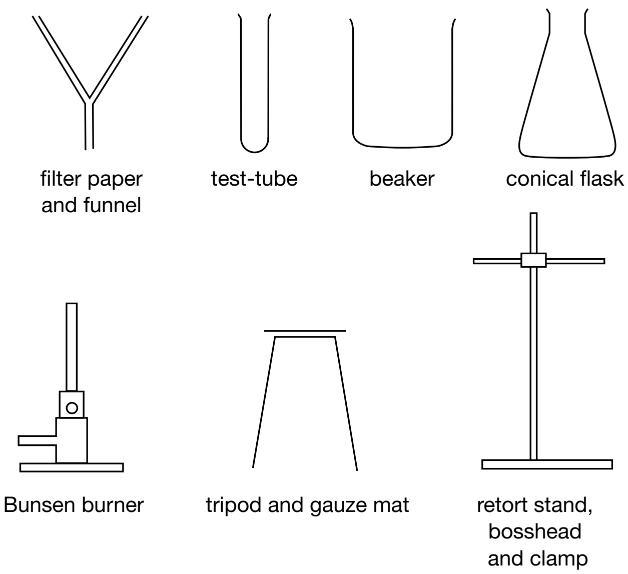


FIGURE 1.1.12 Scientists draw scientific equipment as simple, two-dimensional cross-sections.

AB 1.5

Safety

Science can be fun. Experiments are part of that fun, but they can also be very dangerous. Hotplates and Bunsen burners can burn, and Bunsen flames can set clothes or hair on fire. Acids are corrosive and can burn badly, especially if splashed into your eyes (Figure 1.1.13). Many other chemicals are **toxic**, being poisonous if you sniff or taste them. Broken glassware can cut, and small fragments can easily enter your eyes.

FIGURE 1.1.13 This warning sign lets you know a substance is corrosive.

Safety rules

The laboratory can be safe if we all follow some simple rules. Although each school, each laboratory and each teacher will have their own set of rules that you must follow, some rules are common to all laboratories:

- Always follow instructions from your teacher or laboratory technician.
- Move around the lab in a safe way. Do not run, push or shove.
- Always wear safety glasses when using chemicals.
- Do not eat, taste, drink or sniff anything in the lab.
- Treat all glassware with care.
- Make sure that test-tubes cannot roll off a bench when not in use.
- Always tell your teacher if you break something or if you are unsure about what to do.
- Hot glass that is placed under cold water will crack. Make sure glassware has cooled down before placing in cold water.

Your teacher and school will give you a list of any other rules that you need to follow in your laboratory.

Other rules apply when you are heating something:

- Always tie back long hair; otherwise it is a fire risk.
- When you need to leave a Bunsen burner on, turn it to a visible yellow safety flame.
- Only use matches to light Bunsen burners.
- Always use tongs to pick up objects that have been heated.
- When you are heating a test-tube, ensure that it is pointed away from everyone (including you).
- Hotplates and Bunsen burners, tripods and gauze mats remain hot for a long time. Allow them to cool before you pack them away.

Safety in the laboratory is really just common sense.

AB 1.4

Your local experts

If you are confused about equipment, safety, or what you are supposed to do in a laboratory, then there are usually two experts you can turn to:

- Your science teacher is trained in science and has lots of experience in carrying out scientific investigations safely.
- Your laboratory technician (lab tech) will usually be found working behind the scenes in a science department. He or she may come into your laboratory to help your science teacher out, especially if an experiment is particularly dangerous. Your lab tech is trained in safety, the laboratory, its equipment and chemicals.

SCIENCE AS A HUMAN ENDEAVOUR

Use and influence of science

Scientists in Antarctica

Antarctica is one of the most remote and untouched places on Earth. It is incredibly cold, windy, dry and largely covered in ice. Due to its extreme conditions, very few land animals and plants can survive there. However, marine animals such as penguins, seals, whales and krill live in Antarctic waters, along with hundreds of different types of algae and bacteria.

FIGURE 1.1.14 These scientists are drilling into ice to collect ice core samples for research in Antarctica.

SciFile

Antarctica is very, very cold!

Antarctica contains 90% of Earth's ice and 79% of its water. Its ice sheets are up to 4 km thick and cover 98% of its surface. The coldest temperature ever recorded was in Antarctica in 1983—the temperature dropped to –89.2°C.

No humans live in Antarctica permanently, but 1000 scientists live there in winter and 4000 live there in summer. These scientists come from 28 countries and they work together on more than 100 projects in biology, astronomy, geology and environmental science. There are 76 research stations and 20–30 camps across the continent.

The unique conditions in Antarctica provide a natural laboratory that is unlike anywhere else in the world. Antarctic research from Antarctica has contributed to our scientific knowledge in several important areas.

Space science

Antarctica is an ideal place to observe space since there is no light pollution from cities and during winter it is almost always dark. Astronomers in Antarctica are detecting stars, galaxies, gravity waves and planets outside our solar system.

Climate change

Antarctica once had a much milder climate and important information about climate change is in the ice. Scientists drill and extract ice cores and rock to learn about past climate change to help predict the impacts of future climate change (Figure 1.1.14).

Oceanography

The ocean surrounding Antarctica helps to regulate Earth's weather. Studying this ocean helps scientists understand how changes in the ocean's temperature, currents and chemistry impact weather patterns.

Biological adaptation and conservation

The organisms that live in Antarctica provide scientists with information on how animals evolve, adapt and survive in extreme environments. With this information scientists are better able to manage and conserve its unique species and ecosystems.

REVIEW

1. Scientists often work with other scientists from different organisations or different countries. This is called collaboration. Why do you think collaboration is important in science?
2. Why is Antarctica an important place for scientific investigation?
3. Scientists from many different fields of science are working in Antarctica. What are some of the branches of science being used there?
4. Scientists often work with other scientists from different branches of science. Why do you think this is important?

MODULE 1.1

Review questions

Remembering

1 Define the terms:
   a cross-section b toxic c safety flame.

2 What term best describes each of the following?
   a the study of space
   b the study of behaviour
   c the study of chemicals.

3 List seven important branches of science.

4 Name an essential piece of equipment for:
   a a microbiologist
   b an astronomer.

5 What temperature can a blue Bunsen burner flame get to?

6 List four dangers that you will meet in the laboratory.

7 Draw 2D diagrams showing the following equipment:
   a beaker b conical flask.

Understanding

8 Explain why everyone needs to have an understanding of science.

9 A biologist usually specialises in one sub-branch of biology. Explain why.

10 Why are all laboratories different?

11 a The markings on beakers and conical flasks cannot be used to measure out volumes accurately. Explain why.
   b What piece of equipment is used to measure volumes accurately?

12 A yellow flame will burn you if you are careless, but it is called the safety flame. Explain why.

Applying

13 Identify the branch and sub-branch of science being investigated in the STEM4fun on page 2.

14 Identify whether the following observations would be made by watching a yellow Bunsen burner flame or a blue Bunsen burner flame:
   a dirty
   b noisy
   c almost invisible
   d extremely hot
   e closed airhole.

15 For each of the following investigations, identify the branch and sub-branch that is being studied.
   a Abdul is counting how many eggs a cockroach has laid.
   b Hon is studying the crystals embedded in a rock.
   c Travis is investigating how light bends as it passes through glass.
   d Lisa is photographing the bones of a dinosaur.
   e Francesca is measuring the growth of a seedling.

Analysing

16 Refer to the contents pages (pages iv–v) and classify chapters 2–8 as biology, chemistry, physics, geology or astronomy (space).

17 What are the similarities and differences between a beaker and a conical flask?

18 Discuss what the following safety signs are saying.

a

b

c


Evaluating

19 Some branches of science cover two or more other branches. State what two branches of science are studied in biochemistry.

20 Propose reasons why:
   a you should light a match before you turn on the gas to the Bunsen burner
   b long hair should be tied back when you are using the Bunsen burner
   c eating and drinking is banned in the laboratory
   d you should turn a Bunsen burner to a yellow flame if you need to leave it.

Creating

21 You are using a Bunsen burner to heat water in a beaker. Construct a scientific diagram (2D line drawing) to show how your equipment looks.

22 Construct a sign that warns people that Bunsen burners are hot. Your sign must be in two colours only and use no words.

MODULE 1.1 Practical investigations

1 • Blowing up balloons

Questioning & Predicting | Planning & Conducting

In the laboratory, you will need to follow safety instructions and instructions on how to run experiments.

Purpose

To follow instructions to blow up a balloon in a strange way.

Timing

30 minutes

Materials

- up to 500 mL water
- 1.25 L PET plastic soft-drink bottle and cap
- balloon
- drawing pin

Procedure

1. Hold on to the open end of the balloon and drop the rounded end inside the soft-drink bottle. Secure the balloon by stretching its mouth over the mouth of the bottle as shown in Figure 1.1.15.
2. Put your mouth over the end of the soft-drink bottle and try to blow up the balloon. Record what happens.
3. Use the drawing pin to make a hole in the wall of the bottle near its base.
4. Try to blow up the balloon again. While keeping your mouth on the bottle, cover the pinhole with your finger. Record what you see.
5. Remove your finger. Record what you see.
6. Blow up the balloon again and cover the pinhole with a finger.
7. Pour water into the blown-up balloon. Remove your finger and record what you see.

Results

Record all your observations in your workbook.

Review

1. Propose a reason why:
   a. it was almost impossible to blow up the balloon without the pinhole
   b. the pinhole allowed the balloon to inflate
   c. a blocked pinhole kept the balloon inflated
   d. water rushed out of the balloon when your finger was removed from the pinhole.
2. Assess how well you followed the instructions for this experiment. For example, Question 1 outlines what should have happened. If you experienced all that, then you probably followed the instructions well. If you did not, or if you needed assistance along the way, then you probably did not follow the instructions well.

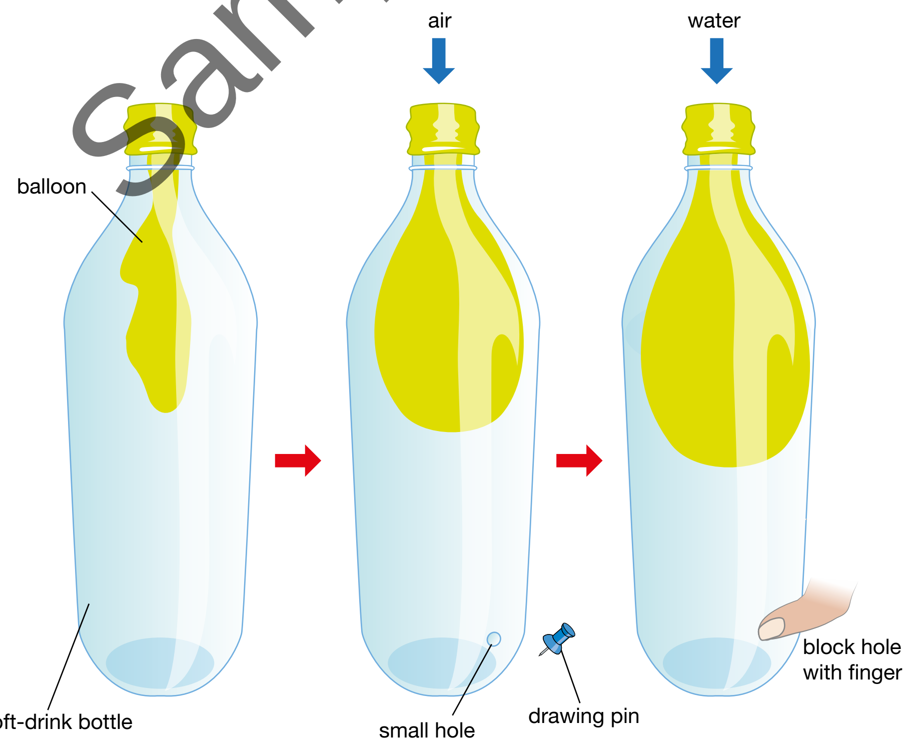


FIGURE 1.1.15

MODULE **1.1**

Practical investigations

2 • The Bunsen burner

Planning & Conducting | Processing & Analysing

Purpose

To light a Bunsen burner and produce a yellow flame and a blue flame.

Timing

45 minutes

Materials

- Bunsen burner, bench mat and matches
- pin

SAFETY

Tie long hair back so it won't get in the flame.

Whenever you are not using the Bunsen burner, set its flame to yellow so that you can see it.

Equipment will be hot, so let it cool before packing it away.

Procedure

Copy the table in the Results section into your workbook. Give your table a title.

Part A: Lighting the Bunsen burner

1. Follow the instructions in the skill builder to light a Bunsen burner.
2. Switch between opening and shutting the airhole. Observe what colour flames are produced.
3. Turn off the Bunsen burner and allow it to cool.

Part B: Unburnt gas

4. Push a pin through the wood near the top of an unlit match. Balance the match on the top of the Bunsen burner so that the match head is in the centre of its barrel.
5. Light the Bunsen burner as usual and quickly turn it to a blue flame. Figure 1.1.16 shows the correct set-up.

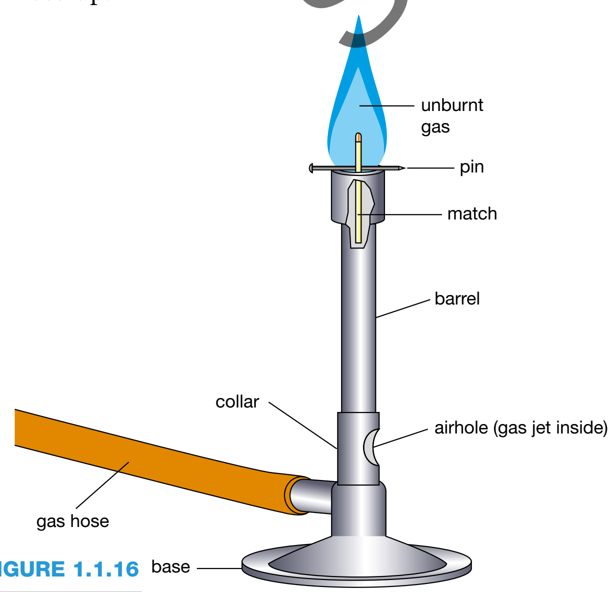


FIGURE 1.1.16

Results

Record all your observations in your results table.

Airhole	Was the flame noisy or quiet?	Flame colour	Other observations
closed			
half-closed			
open			

Review

1. Why should the airhole be closed when you light a Bunsen burner?
2. Describe what happened to the match in the barrel of the Bunsen burner.
3. Explain your observations.

SkillBuilder

Lighting the Bunsen burner

1. Place the Bunsen burner on a heatproof bench mat and connect its hose to the gas jet.
2. Turn the collar of the Bunsen burner so that the airhole is completely closed.
3. Light a match.
4. Turn on the gas at the gas tap.
5. Hold the lit match about 1 cm over the top of the barrel.
6. If the match blows out then immediately turn the gas off and start again.
7. When lit, the Bunsen burner should produce a bright yellow flame.
8. To obtain a blue flame, turn the collar so that the airhole is opened.
9. This sometimes causes the flame to blow out. If it does, turn off the Bunsen burner and follow the steps above to light it again. Then, to obtain a blue flame, adjust the airhole so that it is not completely open.

MODULE 1.1 Practical investigations

SPARKlab alternative available for this activity. Manual data entry option.

3 • Investigating the flame

Questioning & Predicting | Processing & Analysing

Purpose

To determine which flame is hot, which is cool, which is dirty and which is clean.

Timing
45 minutes

Materials

- Bunsen burner, bench mat and matches
- old, 'bald' gauze mat
- small piece of broken white porcelain
- tongs

SAFETY

Tie long hair back so it won't get in the flame.

Whenever you are not using the Bunsen burner, set its flame to yellow so that you can see it.

Equipment will be hot, so let it cool before packing it away.

Procedure

Copy the table in the Results section into your workbook. Give your table a title.

Part A: Hot or cool?

1. Set up and light the Bunsen burner.
2. Set it to a yellow flame.
3. With tongs, hold the gauze mat vertically in the flame so that it touches the top of the burner as shown in Figure 1.1.17.
4. Set the flame to blue and repeat step 3.
5. Carefully draw diagrams of any heat markings that you see.

Part B: Clean or dirty?

6. With tongs, hold the small piece of porcelain in a blue flame and record your observations.
7. Set the flame to yellow and repeat step 6.

Results

Record your observations in your results table.

Title:

Flame colour	Gauze mat	Porcelain
yellow		
blue		

Review

1. The wire of the gauze mat will glow red if it is really hot. Which flame (yellow or blue) made the wire glow red?
2. Describe the markings caused by the blue flame.
3. Where was the flame the hottest and where it was the 'coolest'?
4. Compare what happened to the porcelain in the yellow flame and the blue flame.
5. Which flame could be called 'dirty'?
6. Was this was the hot flame or the cool flame?

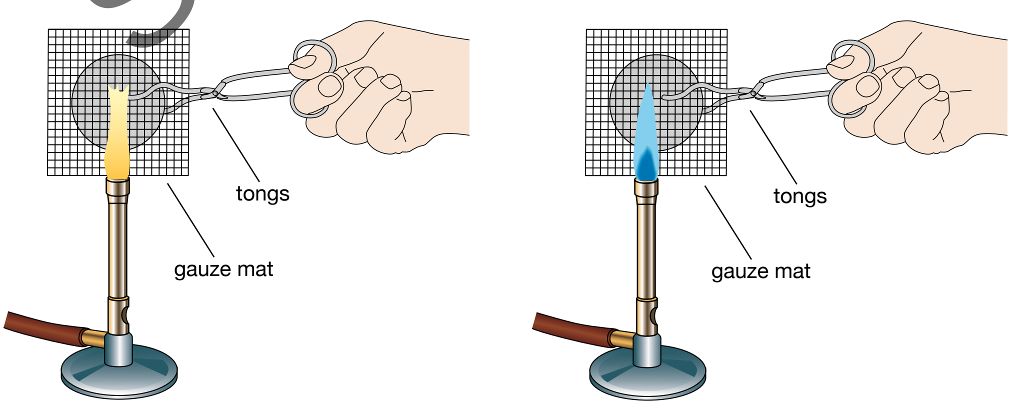
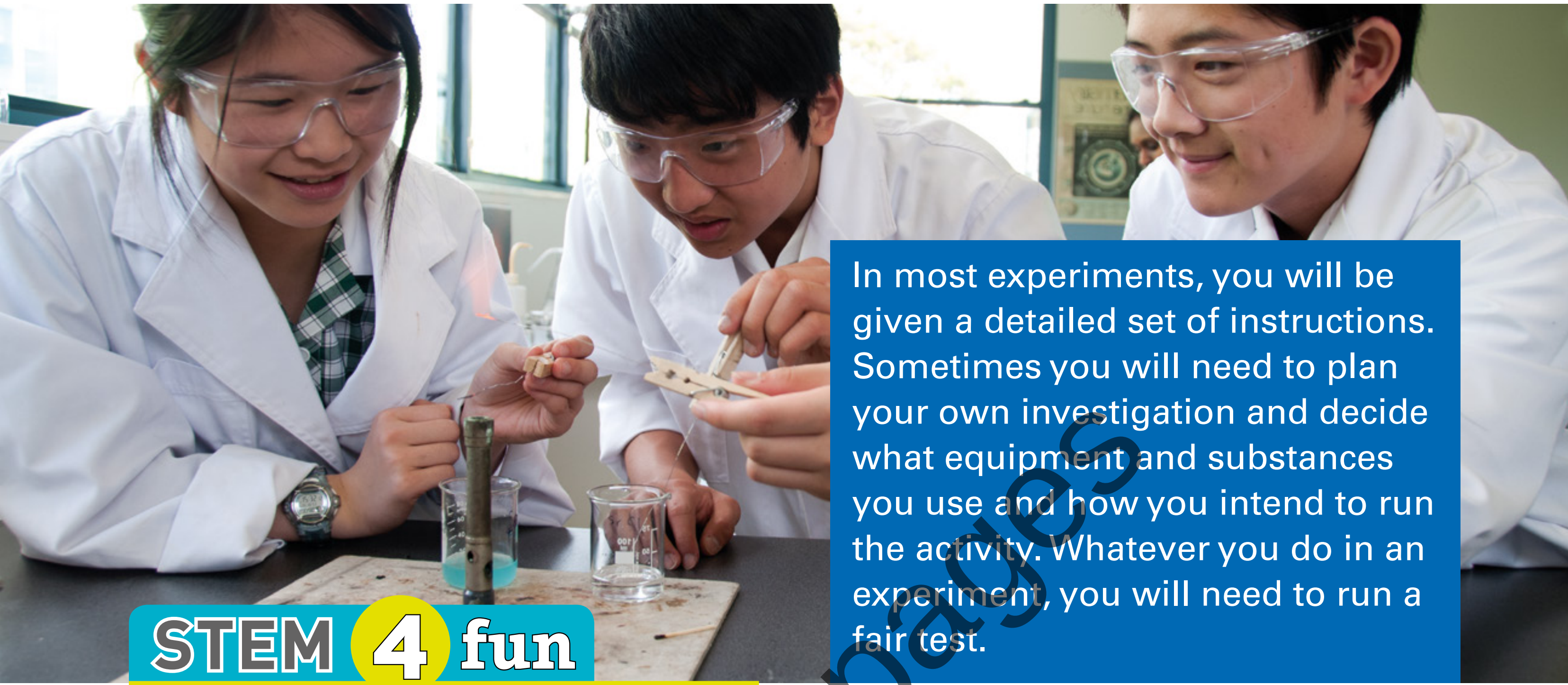


FIGURE 1.1.17

MODULE 1.4

Planning your own investigation



In most experiments, you will be given a detailed set of instructions. Sometimes you will need to plan your own investigation and decide what equipment and substances you use and how you intend to run the activity. Whatever you do in an experiment, you will need to run a fair test.

STEM 4 fun

Can you grow gummy bears?

YES

PROBLEM

Find the best way to increase the mass and length of a gummy bear.

SUPPLIES packet of gummy bears, cups, water, apple juice, vinegar, lemon juice, salt water, soda water, cordial, ruler, scales

PLAN AND DESIGN Design the solution. What information do you need to solve the problem? Draw a diagram. Make a list of materials you will need and steps you will take

CREATE Follow your plan. Produce your solution to the problem.

IMPROVE What works? What doesn't? How do you know it solves the problem? What could work better? Modify your design to make it better. Test it out.

REFLECTION

1 What area of STEM did you work in today?
2 How did you use mathematics in this task?
3 What did you do today that worked well? What didn't work well?

Teamwork

Science requires teamwork. In the laboratory, you will frequently work as part of a team, particularly when doing experiments, your own investigations or research. Working in a team allows you to pool everyone's talents. Scientists usually work in teams too. As Figure 1.4.1 shows, some teams have only two members. One way to organise a team is to find out what each person is already good at. For example, the best person to analyse and plot your measurements is probably someone who has used computer spreadsheets and graphing programs before.

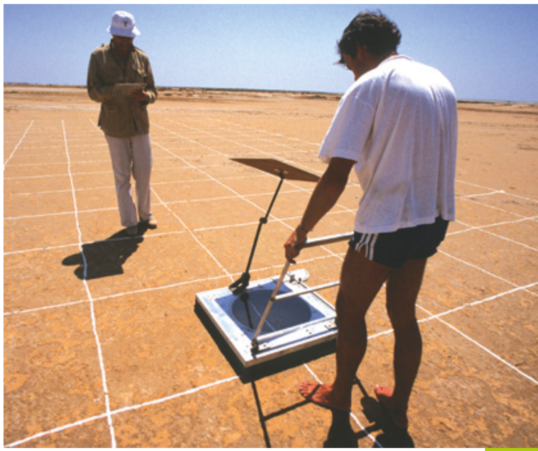


FIGURE 1.4.1 By working as part of a team, scientists can share their skills.

Identifying variables

Many different factors influence what happens in an experiment. In science, these factors are known as **variables**. Think of the time it takes someone to run 100 metres. The time taken will depend on many variables, such as the age and fitness of the runner, the shoes being worn, the direction of the wind and whether the surface was grass, concrete or sand.

Any experiment that you carry out must be a **fair test**. To be fair, you should change only one variable at a time. Otherwise you won't be able to work out what variable caused any change. All the other variables must be controlled, being kept exactly the same.

In any experiment you should be able to identify the:

- **dependent variable**: this is what you are trying to measure. It depends on all the other variables. It might change as a result of a change in an independent variable. For the 100-metre run, the dependent variable is the time taken to run 100 metres.
- **independent variable**: this is what you are trying to test to see what effect it has on the dependent variable. For the 100-metre run, you might want to test what effect different running surfaces have on the time taken to run 100 metres. In this case, the running surface is the independent variable.
- **controlled variables**: these are all the other variables that you don't want to test right now. These are kept constant. In the 100-metre run, you are testing the surface, so every other variable needs to be kept the same. The age and fitness of the runner, the type of shoes they are wearing and the wind direction would all need to be kept constant.

FIGURE 1.4.2 The type of ball and the surface it is dropped onto are two variables that will affect the height to which the ball bounces.

Figure 1.4.2 shows a ball bouncing on a racquet. When a ball is dropped onto a surface such as a racquet, many variables influence the height the ball bounces back to. The height of a bounce (bounce height) is the dependent variable because it depends on other (independent) variables. Just a few of these are the:

- type of ball that is being bounced
- type of surface it is being bounced on
- height the ball drops from (drop height).

Let's say you decide to test how the drop height of a ball affects the bounce height. Your variables are therefore:

- dependent variable: bounce height. This is what you are measuring and will be the basis of your aim.
- independent variable: drop height. This is what you are changing.
- controlled variables: the type of ball and surface. These must be kept the same throughout the experiment.

Your purpose therefore would be: *To test how drop height affects bounce height.*

Developing a hypothesis

Think about what is likely to happen in the experiment. Write down what you think might logically happen. This is your **hypothesis**. For the ball-drop experiment, your hypothesis might be: *Increasing the drop height will increase the height the ball bounces to.* The prediction might be: *As the drop height increases, the ball bounce height will also increase.*

Developing your procedure

Your procedure must test the effect of only the independent variable you chose earlier. All other variables must be kept the same. In this ball-bounce experiment, you need to test one type of ball (such as a tennis ball) and one type of surface (for example, onto a concrete path). The only thing you can change is the height from which you drop the ball. Figure 1.4.3 shows how this might be done. If you want to change another variable, then you need to run a new and separate experiment.

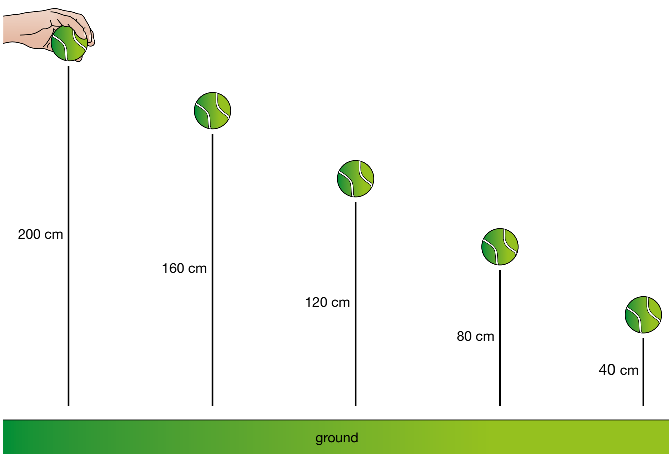


FIGURE 1.4.3 Try to test five or more different heights and make sure they are not too close to each other. Patterns are difficult to see if there are less than five measurements or if the measurements are too close together.

Choosing appropriate equipment

Once you have a rough procedure in mind, you can then work out what equipment you need.

For the bouncing tennis ball investigation, the starting height of the ball could be measured with a metre ruler or tape measure. The bounce height is more difficult to measure because the ball is moving all the time. You could mark off its height on a wall next to the bounce or you could video the motion on a smartphone, computer tablet or digital camera. You will need a hard flat surface to bounce the ball on.

Assessing risks

Before you start any actual practical work, you must assess how safe your planned procedure is. If there are any risks, then you need to find ways to minimise them or you need to change your procedure to something safer. For example, is there a chance you might get burnt? If so, then your team might need to wear heatproof gloves. In the bouncing ball investigation, dropping the ball from the roof would be spectacular but would also be very dangerous. To keep everyone safe, drop the ball from heights of less than 2 m instead.

Putting your results in a table

Here you are measuring drop height and bounce height. An appropriate results table would look like the one shown in Table 1.4.1. A spreadsheet would look very similar.

TABLE 1.4.1 Results table

Drop height (cm)	Bounce height (cm)
0	0
50	30
100	62
150	95
200	120
250	148

Plotting a graph

When plotting a graph, you first need to decide which type of graph you need to use. Line graphs are used when you have two sets of continuous measurements like height, mass or time.

The results from the ball-drop experiment have two sets of continuous numbers and so a line graph is the most appropriate graph to plot. It might look like the one in Figure 1.4.4.

Bar graphs are used when one set of results is discrete. For example, bar graphs would be a good way of showing the way bounce height changed when the type of ball or type of surface was changed.

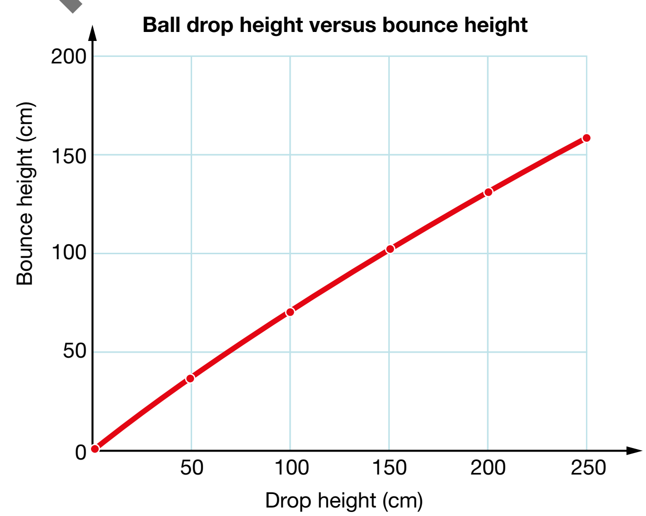


FIGURE 1.4.4 Two sets of measurements require a line graph.

Your conclusion

Your conclusion must answer the purpose or aim of your experiment. Depending on what you tested, an appropriate purpose and conclusion would be:

Purpose: To test what increasing drop height does to bounce height.

Conclusion: Increasing drop height causes bounce height to increase.

Prac 1 p. 36
AB 1.8

SCIENCE AS A HUMAN ENDEAVOUR

Nature and development of science

Teamwork across different branches of science

Big problems require big teams with a range of skills from different branches of science.

FIGURE 1.4.5 The mountain pygmy-possum is endangered. Teams of scientists are working to make sure it doesn't become extinct.

There are fewer than 500 mountain pygmy-possums (*Burramys parvus*) left in NSW. The species is classified as endangered (which means it might die out) and scientists are working to prevent it from becoming extinct. The possum lives in the mountains of the Kosciuszko National Park. In summer and autumn it eats Bogong moths, beetles, millipedes and spiders, and sometimes the seeds of plants. In winter, it hibernates, sleeping under a cover of snow that insulates it from the freezing cold. You can see a pygmy-possum in Figure 1.4.5.

To protect the possum, scientists need to find out why their numbers are falling. This research needs a variety of different skills that only come from being part of a team made up of scientists working in different branches of science (Figure 1.4.6).

REVIEW

1. Why do scientists from different branches of science need to work together to save the mountain pygmy-possum?
2. Sending a crew to Mars will require scientists with a wide variety of skills.
   a. List some of the big problems these scientists will have to solve.
   b. Identify the branches of science these scientists will need to specialise in to overcome these problems.

Ecologists need to find out whether the possums are being affected by the area being divided up into smaller parts by the local ski industry.

Botanists need to find out whether bushfires are damaging the plants whose seeds the possums eat.

Zoologists determined that foxes and feral cats were eating the possums.

Climate scientists need to find out whether less snow and a higher snowline will affect the possum's survival.

Chemists need to know whether the levels of arsenic in local Bogong moths and possum poo are similar to the levels found naturally.

FIGURE 1.4.6 Branches of science working together

MODULE 1.4

Review questions

Remembering

1 Define the terms:
- **a** variables
- **b** fair test.

2 What term best describes each of the following?
- **a** a variable that is kept the same through an experiment
- **b** the variable that is changed during the experiment
- **c** the variable that changes naturally because another variable is changed.

3 In the STEM4fun activity on page 31, gummy bears were placed in different solutions. For this activity, what is a logical:
- **a** aim
- **b** hypothesis?

4 What advantages does working in a team bring?

5 List variables that are likely to affect the:
- **a** amount of sugar that will dissolve in a cup of tea
- **b** number of visitors to a swimming pool
- **c** growth of a plant
- **d** time taken to cook a potato
- **e** number of times you go to the toilet in a day.

Understanding

6 Explain why only one variable should be changed in any single experiment.

7 Why must you assess risks when you are designing an investigation?

8 Explain why you should try to collect five or more results in an experiment.

Applying

9 Identify which of the following sets of drop heights would give the best idea of what happens when drop height is increased.
- **A** 10 mm, 20 mm, 30 mm, 40 mm, 50 mm
- **B** 5 cm, 10 cm, 15 cm, 20 cm, 25 cm
- **C** 50 cm, 100 cm, 150 cm, 200 cm, 250 cm
- **D** 10 m, 20 m, 30 m, 40 m, 50 m

10 Identify likely aims that would have led to these conclusions.
- **a** Tennis balls bounced best on concrete. They did not bounce as well on short grass and bounced poorly on long grass.
- **b** Superballs bounced best, followed in order by tennis balls and volleyballs. Squash balls were the worst bouncers.

11 Identify the variables that are likely to affect the amount of detergent froth produced when washing the dishes.

12 Use the rules for writing a good conclusion to write an appropriate conclusion that meets these aims:
- **a** to test if fishing line is stronger than string
- **b** to prove that water boils at 100°C
- **c** to determine how much water a sponge can hold.

Evaluating

13 Bob ran an experiment on bouncing balls and recorded the following results.

Range of balls tested on different surfaces for bounce height

Ball	Surface	Drop height (cm)	Bounce height (cm)
tennis	sand	30	1
squash	concrete	300	30
golf	gravel	100	5
volleyball	grass	50	10

On the basis of his results, he claimed that squash balls bounced better than tennis balls.
- **a** State the dependent variable that Bob tested.
- **b** Identify how many variables Bob changed during the experiment.
- **c** Assess whether the experiment was a fair test.
- **d** Do you agree with Bob's conclusion? Justify your answer.

Creating

14 Georgie heard an old tale that if you want an avocado to ripen quickly, then it should be placed in a brown paper bag with a banana. She thought this sounded weird and wanted to see if it was true. Write an experiment for Georgie to test if the tale was true or not. Make sure that your test is fair.

MODULE **1.4**

Practical investigations

• STUDENT DESIGN •

1 • Planning your own investigation

Planning & Conducting | Processing & Analysing

Purpose

To design and run an experiment that tests a single variable.

Timing 75 minutes

Materials

Choose your own, depending on your choice of topic.

SAFETY

A Risk Assessment is required for this investigation.

Procedure

1 List the variables that are likely to affect the:
- bounce height of a ball
- amount of sugar that can be dissolved in a cup of tea
- adhesive strength of sticky-tape
- stretch of an elastic band or another elastic material such as stockings
- strength of paper.

2 Choose ONE of the topics listed in step 1 of the procedure and design an experiment that will test ONE of its variables. In your workbook, write a hypothesis that describes what you expect when you change that variable. For example, 'We expect that a tennis ball will bounce higher than a soccer ball when dropped from the same height.'

3 Write your procedure in your workbook.

4 Before you start any practical work, assess your procedure. List any risks that your procedure might involve and what you might do to minimise those risks. Show your teacher your procedure and your assessment of its risks. If they approve, then collect all the required materials and start work.

Results

Construct a table and a graph (column, bar or line graph) to display your results.

Review

1 a Construct a conclusion for your investigation.
  b Assess whether your hypothesis was supported or not.

2 Construct a scientific report describing what you did in your prac. In it, you should include a:
  a table of results
  b graph.

3 Identify other variables that would affect your experiment.

CHAPTER 1

Chapter review

Remembering

1 Define the terms:
- **a** meniscus
- **b** cross-section
- **c** hypothesis
- **d** variable.

2 Name the branch of science that studies:
- **a** living things
- **b** chemicals
- **c** forces and energy
- **d** behaviour
- **e** the Earth
- **f** space
- **g** the environment.

3 List three sub-branches for each of:
- **a** biology
- **b** geology
- **c** physics
- **d** chemistry.

4 Name the two experts you can turn to in the laboratory.

5 State two metric units commonly used for:
- **a** distance
- **b** volume
- **c** mass.

6 Which abbreviation is correct for these units?
- **a** degrees Celsius
  - **A** deg C **B** deg
  - **C** °C **D** C
- **b** seconds
  - **A** sec **B** secs
  - **C** S **D** s

7 What is one qualitative and one quantitative observation for each of the following?
- **a** a can of soft drink
- **b** yourself.

Understanding

8 Which of these observations are qualitative and which are quantitative?
- **a** The cow went ‘moo’.
- **b** The car was travelling at 60 km/h.
- **c** The Dockers won by 25 points.
- **d** The Broncos won by a lot.

9 Describe the features of a safety flame.

10 Why are the senses of taste and smell rarely used in science?

Applying

11 Identify the equipment in these jumbled words.
- **a** kaeber
- **b** aluspat
- **c** burccile.

12 Identify the best SI unit to measure the:
- **a** time to run the 100 m sprint
- **b** mass of a car
- **c** volume of water in a sink.

13 Identify the type of graph (bar, column, pie or line) from the clues below.
- **a** It shows percentages.
- **b** It has two sets of measurements.
- **c** It has discrete groups along its bottom, horizontal axis.
- **d** It has discrete groups along its vertical axis.

Analysing

14 Compare the types of work done by a detective and a scientist.

Evaluating

15 Propose reasons why the Bunsen burner gas must be turned on after the match is lit.

16 **a** Assess whether you can or cannot answer the questions on page 1 at the start of this chapter.
b Use this assessment to evaluate how well you understand the material presented in this chapter.

Creating

17 Use following ten key terms to construct a visual summary of the information presented in this chapter.

laboratory	equipment
experiment	safety
observations	measurements
units	quantitative
variables	qualitative

AB 1.10

CHAPTER 1

Inquiry skills

Research

1 Processing & Analysing Evaluating

Three-part inquiry question

Select your entry point and complete the relevant parts of this inquiry. The Nobel Prize for Physiology or Medicine is awarded in most years. In 2005, it was awarded to a pair of Australian researchers: Dr Barry Marshall and Dr Robin Warren.

a What are the criteria used for the award of a Nobel Prize in Physiology or Medicine? What discovery or discoveries led to their being awarded the Nobel Prize? Explain why this research was so important.

b Describe the experiment performed by Dr Marshall. What hypothesis was Dr Marshall testing? What was the independent variable in the experiment? What was the dependent variable? What were some other variables that may have affected the outcome of the experiment? How did Dr Marshall control these? What evidence was collected by Drs Marshall and Warren that supported their hypothesis? Explain why it was so difficult for their conclusions to be accepted by the wider medical profession.

c After completing their initial investigations, Drs Marshall and Warren needed to try their proposed treatment on volunteer patients. What was the treatment proposed by Dr Marshall? Before any experiment can be performed using vertebrates (animals with backbones), including humans, they must be approved by an ethics committee. What are ethics committees? What is their function?

Consider that you are a member of the ethics committee evaluating the research of Drs Marshall and Warren and their proposed treatment. Discuss any issues that you can see with testing a new treatment on people. Make sure you consider the concept of 'informed consent' in your answer. Taking into account the issues that you have identified, would you give approval for the human trial to take place? Give reasons for your opinion.

2 Processing & Analysing

Fire blankets, eyewashes and fume hoods are common safety equipment in the laboratory. For each, find:

- an image
- what it is used for
- how it is used
- its location in your science laboratory.

Present your research as a plan of the laboratory with attached images and descriptions.

3 Processing & Analysing

Scientific investigations are regularly reported in the newspaper, on websites and in scientific magazines such as *Cosmos* and *Scientific American*. Find an article that discusses a scientific investigation and:

- give the names of the scientists involved
- summarise what they found out.

Present your information in whichever way you choose.

4 Planning & Conducting

Research the history of the metric (or SI) system of units.
Summarise the main events in its history as ten dot points.

5 Planning & Conducting

Scientists around the world eagerly awaited the landing of the Mars *Polar Lander* in 1999. One important mission of the lander was to search for water. However, after descending into the Martian atmosphere, the lander was never heard from again. Find:

- when it was launched from Earth
- what its mission on Mars was to be
- when it crashed
- what caused it to crash.

Present your research as four short paragraphs in a Word document, as four pages in a PowerPoint presentation or as four panels in a poster.

CHAPTER 1

Inquiry skills

Thinking scientifically

The Three Bears returned home and found someone had been eating their porridge. Being scientific bears, they were interested in how fast different-sized bowls cooled. They filled them with hot porridge and measured the temperature every minute. Their results are shown in the table.

TABLE 1.5.1 Temperature change over time in each bowl

Time (min)	Temperature of Papa Bear's porridge (°C)	Temperature of Mama Bear's porridge (°C)	Temperature of Baby Bear's porridge (°C)
0	60	58	61
1	55	48	50
2		39	48
3	45	31	30
4	40		20
5	35	18	10

1 Identify which bowl cooled the fastest.

Mama Bear then sketched line graphs to show what was happening. These are shown in Figure 1.5.1.

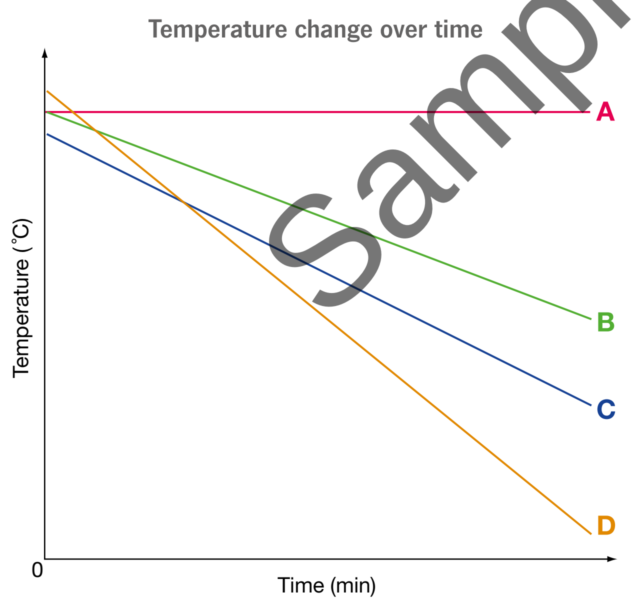


FIGURE 1.5.1

2 Which of the graphs in Figure 1.5.1 most likely represents each of the following?
- a Papa Bear's bowl
- b Mama Bear's bowl
- c Baby Bear's bowl.

3 Which of the following variables are unlikely to have much effect on the cooling of the porridge?
- A size of bowl
- B amount of porridge
- C amount of sugar in porridge
- D starting temperature of porridge.

4 Baby Bear misread his thermometer once. Which temperature reading is most likely to be wrong?
- A 50°C
- B 48°C
- C 30°C
- D 20°C

5 Papa Bear forgot to read his thermometer once. What was the most likely missing temperature?
- A 31°C
- B 53°C
- C 50°C
- D 18°C

6 Mama Bear also forgot to read her thermometer. What was the most likely missing temperature?
- A 30°C
- B 24°C
- C 20°C
- D 18°C

CHAPTER 1

Glossary

aim: what you are trying to do

analysis: looking for trends in the results

astronomy: the study of space

Bunsen burner

bar graph: used when one set of observations is discrete. Bars are horizontal

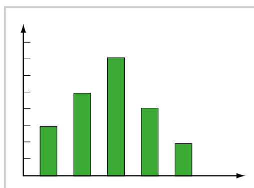
biology: the study of living things

branches: sub-groups of science. Also known as disciplines.

Bunsen burner: used in the laboratory to provide heat

chemistry: the study of chemicals and their reactions

column graph: used when one set of observations is discrete. Columns are vertical.



column graph

conclusion: what you have found out

continuous: measurements that vary without breaking or falling into categories or groups

controlled variables: held constant throughout an experiment

cross-section: split down the middle

dependent variable: will change naturally as you change the other variables

disciplines: sub-groups of science. Also known as branches

discrete: measurements that fall into categories or groupings

ecology

ecology: the study of the environment

experiment: a practical investigation performed mainly inside a laboratory

fair test: changing only one variable at a time

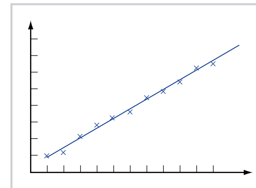
fieldwork: a practical investigation performed mainly outside in nature

geology: the study of Earth

hotplate: heating device

hypothesis: educated guess

independent variable: what you change in an experiment

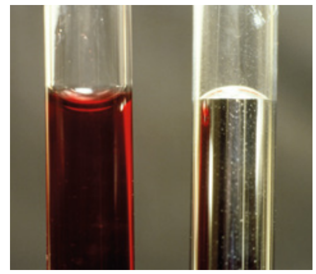


line graph

laboratory: where a scientist works

line graph: used when there are two sets of continuous measurements

mass: amount of matter



meniscus

meniscus: curved surface of liquids in narrow tubes

method: tells how you did the experiment

physics: the study of forces and energy

pie graph: used to show proportions. Also known as a sector graph

psychology

practical investigation: experiment or fieldwork

procedure: tells how you did the experiment

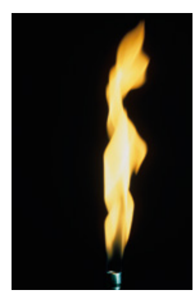
psychology: the study of behaviour

purpose: what you are trying to do (aim)

qualitative observations: observations in words only

quantitative observations: measurements including numbers

results: the measurements and observations made in an experiment



safety flame

safety flame: yellow flame

sector graph: used to show proportions. Also known as a pie graph

toxic: poisonous

variables: factors that influence an experiment

AB 1.9