1 Science is investigating

Planning page

Getting started

1.1 Steps in investigating page 2
- Activity page 3
- Activity page 4
- Activity page 5
- Experiment Testing Velcro

1.2 Processing data page 11
- Skillbuilder page 11 Drawing lines of best fit
- Investigate 1 Hooke's spring
- Experiment Measuring feet
- Animation Drawing a line of best fit
- Assessment task 1 A science investigation

1.3 Collecting data page 17
- Investigate 2 Estimating populations
- Investigate 3 Sampling physical factors

Main ideas
- Chapter 1 crossword

Review and Lab review
- Chapter 1 test

Essential Learnings for Chapter 1

Essential Learnings	References		
	Student book (page number)	**Workbook (page number)**	**Teacher Edition CD (Assessment task)**
Ways of working Plan investigations guided by scientific concepts and design and carry out fair tests	Evaluating an experiment pp. 3–4, 6	pp. 5–8 p. 11	Assessment task 1 A science investigation
Communicate scientific ideas, explanations, conclusions, decisions and data, using scientific argument and terminology, in appropriate formats	Tables and graphs pp. 11–16	pp. 8–10	Assessment task 1 A science investigation
Draw conclusions that summarise and explain patterns, and that are consistent with the data and respond to the question	Activity p. 14 Experiments pp. 6, 14 Investigate pp. 12, 18–21	pp. 7–10	
Reflect on different perspectives and evaluate the influence of people's values and culture on the applications of science	Science in action pp. 7–8		

QSA Science Essential Learnings by the end of Year 9

Vocabulary

conductivity
correlation
ethical
evaluate
extrapolate
interpolate
placebo
quadrat
reliable
transect
valid

Focus for learning

Students identify observations, inferences, an experiment and a prediction in an everyday situation (page 1).

Equipment and chemicals (per group)

Activity page 5	small pieces of Velcro (hooks and loops), hand lens or stereomicroscope
Experiment page 6*	small pieces of Velcro, spring balance, small clamp, needle and thread, glue
Investigate 1 page 12	helical spring, 50 g mass hanger and standard masses, stand and clamp, metre rule, brick or other heavy mass, graph paper
Experiment page 14*	metre rule or tape measure
Investigate 2 pages 18–19	large container of plastic-coated coloured paperclips, 1 m of heavy wire (fencing or coathanger wire), at least 5 m of string, small container (eggcup size) or kitchen measuring spoon, bar magnet (optional)
Investigate 3 pages 20–21	**Part A:** 4 buckets of pond water or specially prepared water, two 100 mL beakers or glass jars, thermometer, pH paper, universal indicator solution and colour card or swimming pool pH kit, distilled water **Part B:** 100 mL beaker or glass jar, conductivity kit or datalogger with conductivity probe **Part C:** 100 mL beaker and glass jar with screw lid, oxygen meter with probe (or dissolved oxygen kit)

Special preparations

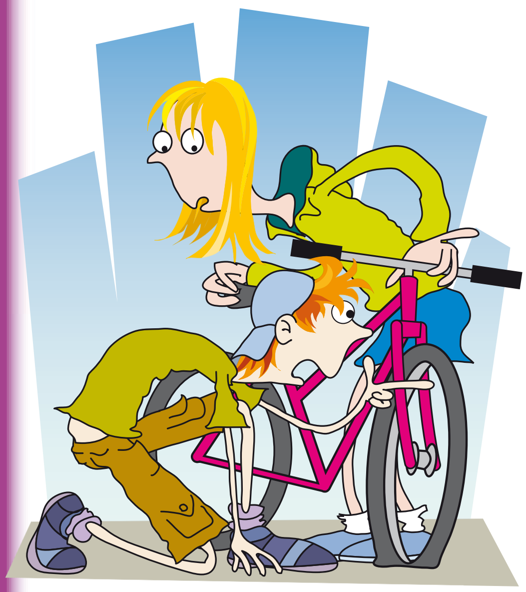
Investigate 3 pages 20–21 To make the specially prepared water for Part A, add 12 g $NaCl$, 3 g KCl, 4 g $CaCl_2$ and 2 g $NaHCO_3$ to 10 L of tap water. Adjust the pH to between 6.5 and 6 by adding drops of dilute HCl. Alternatively, water from a saltwater swimming pool can be used. Just leave the water in an open bucket for a day or two to remove the chlorine.

* Students to list the equipment they will need, which may be different from what is listed here.

1 Science is investigating

Getting Started

Science skills can be used to solve everyday problems. For example, suppose Emily's bicycle has a flat tyre and she wants to know why. Emily and her friend Nick investigate this.



Emily: *Hey Nick, my front tyre is flat! There must be a leak somewhere. We'll have to find out where the air is getting out before we can fix it.*
Nick: *Perhaps there's a nail in it.*
Emily: *I can't see one.*
Nick: *There might be a cut in the tyre.*
Emily: *No, it seems OK.*
Nick: *What about the valve? Someone told me you can test it by putting some spit on it. If air is getting out a bubble will form in the spit.*
Emily: *I'll try that . . . Hey look, the bubble is slowly getting bigger.*
Nick: *Then the valve must be leaking.*
Emily: *Well, let's go and get a new valve.*

In their investigation Emily and Nick used several science skills. Try to identify the following in their conversation:

- observations
- inferences
- an experiment
- a prediction

Starting point

1 Revise the science skills: observing, inferring, experimenting and predicting (see *ScienceWorld 2* Chapter 1, page 2). Observational skills involve using the senses of smell, touch, taste, sight and hearing, and the results can be recorded (quantitative or qualitative). Inferring is trying to answer 'why' questions scientifically. Experimenting is scientifically testing a hypothesis or prediction. Predicting is forecasting a future event based on past observations (making an educated guess).

2 In pairs, students could come up with their own everyday problem and write a scenario to be role played. Make sure the students can identify the same science skills in their conversations as listed in Getting Started (observations, inferences, and so on). After the students have completed their written role play they could swap with another group and write a constructive evaluation.

3 Ask the class to skim through the chapter and jot down any questions they have, or areas they would like to explore further. Get them to list possible ways in which they could answer their own questions. It might be useful to have them set goals for this chapter or the year in science. If so, make sure you give them review and self-evaluation time at the end of the chapter (or year).

4 Present to the class some science-related career options, or, better still, ask the students to compile their own list. To enable students to appreciate how many science-related vocations there are, have a large piece of coloured poster paper, titled 'Careers in Science', displayed in the room. The students should frequently add to it, and, if possible, indicate which branch of science the occupation mainly relates to.

5 The students could create a science careers journal for the entire year. They could add a journal entry each week. Each entry should include the name of the occupation, a brief description of what it involves, its area(s) of science, what type of training is required, and the student's interest level in pursuing such a career. (They may like to have their own ranking system.) Consider making this task an ongoing homework activity as it promotes science awareness and can be used as a teacher tool to initiate discussions.

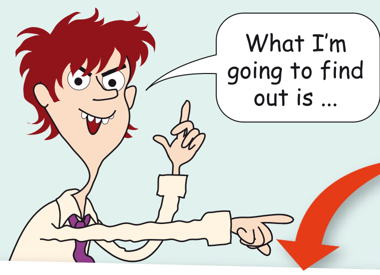
Hints and tips

- Hypotheses and generalisations are closely linked. Generalisations do not necessarily have to be tested, but hypotheses do as they are an explanation of 'observed' facts. A point worth considering is that in science we generally don't prove a theory, but disprove one.
- It would be useful to write an A4 'tick the box' handout sheet for the students using the information on this page. The sheet can then be used when they are doing their own investigations. Consider incorporating it as part of their assessment. One way to write the sheet is to divide the page in half—one side with the written tick list, and the other for the students' responses.

1.1 Steps in investigating

Planning an experiment

There are four main steps in a scientific experiment, as shown.



1 Planning the experiment

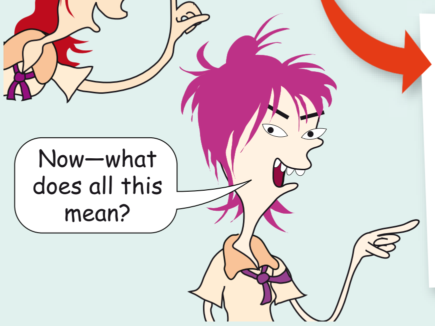
★ Identify the problem.
★ Identify the variables.
★ Write a research question or a hypothesis that can be tested.
★ Work out which variable you will change, which you will measure and which you will control.
★ Work out the method and select the equipment you will use.

2 Conducting the experiment

★ Carry out the experiment.
★ Observe, measure and record data.

3 Processing data

★ Organise the data, draw graphs and do calculations.
★ Identify patterns in the data and relationships between the variables.
★ Use scientific knowledge to explain the patterns and relationships.



4 Evaluating the experiment

★ Evaluate the design of the experiment and the methods used.
★ Discuss the results. Are they reliable?
★ Evaluate the findings in relation to the original problem, question or hypothesis.
★ Write a conclusion. Make sure it is valid.

Learning experience

The students could make their own posters or bookmarks showing the steps used in planning an experiment. Consider adding an extra step to incorporate a risk management plan (Planning and Safety Check). The students could individually come up with points they think are important, then pool their ideas as a class to generate a common set.

Activity

Planning an experiment

Imagine you work for a motoring organisation. You have read an overseas report that says that the brand of tyres used on a car makes little difference to its stopping distance when braking in an emergency. You decide to investigate this claim under Australian conditions, using the steps in investigating on the previous page.

1 In your own words, write down the problem to be investigated.
2 Rewrite the problem as a hypothesis—a generalisation that can be tested by an experiment.
3 What are the variables involved; that is, what factors could affect the results of the experiment?
4 What method will you use to test your hypothesis?
5 Which variable will you purposely change in your experiment? This is the independent variable.
6 Which variable will you measure? This is the dependent variable.
7 Which variables will you need to control?
8 What equipment will you need?
9 What data will you collect and how will you record it?
10 How will you know whether your hypothesis is correct or not?

Evaluating an experiment

When you have finished an experiment you should think carefully about how successful it was and whether you could improve it. This is called *evaluating an experiment*. For example, were you able to make accurate measurements? Did you repeat your measurements and calculate an average? The more measurements you make the more *reliable* the average will be, but three measurements are usually enough.

After evaluating the experiment, you may need to repeat it with some modifications. You also need to be able to evaluate other people's experiments. Scientists do this often, and they sometimes do the experiments themselves to see if they obtain the same results. They may be able to suggest ways to improve the experiment.

It is also important to check any conclusions or generalisations made from the data collected in an experiment to make sure they are logical or *valid*. Sometimes poor thinking or reasoning can lead to incorrect or invalid conclusions. Also, not everyone will reach the same conclusions after analysing the same data.

In the next activity you can practise evaluating an experiment and a conclusion.

Hints and tips

- A generalisation is a statement or conclusion, based on many observations, that holds true for most cases.
- It is important to explain why repeating a test to obtain an average of the results is an important part of experimenting. As a general rule, for quantitative data, three sets of results are usually sufficient. Consider explaining types of errors such as rounding, human and measurement errors to the class. Encourage gifted and talented students to incorporate an 'error statement' and 'possible improvements' section into their prac reports. This could be done in the *Discussion* section of the report.

Activity notes

- Allow time for the students to work individually, then review their answers in small groups or as a class.
- This is an important activity for the students to get right, so check they correctly understand it or future experimenting tasks may pose a challenge. All students need to be able to write scientifically using appropriate language.

Activity

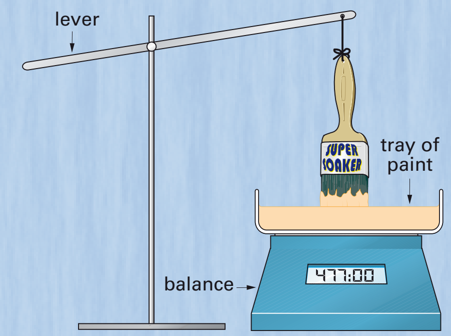
Part A: Evaluating an experiment

The manufacturer of a brand of paintbrush has made the following claim:

Scientific tests show that Super Soaker has a greater paint pick-up than any other brand.

Five brands of paintbrush were tested as follows.

1. Paint was added to the tray until the reading on the electronic balance was 500 g exactly.
2. The first brush was attached to the lever. It was lowered into the paint, then lifted out.
3. The new mass of the tray plus paint was recorded, and the mass of paint picked up was calculated by subtraction.
4. The same procedure was followed for all five brushes.
5. The test was repeated 4 times for each brush and the masses were averaged. The results in the data table on the right show the average masses.



Brand of paintbrush	Final mass of tray plus paint (g)	Mass of paint picked up (g)
Bettabrush	478	22
Easy Paint	491	9
Slurp	485	15
Super Soaker	**477**	**23**
Thickbrush	483	17

- What variables would need to be controlled in this experiment?
- Are the results reliable? Give a reason for your answer.
- Do you consider the manufacturer's claim to be correct? Explain.
- How could you improve the experiment?

Part B: Evaluating a conclusion

James and Tjanda wanted to know which was the best all-purpose pesticide. To do this they recorded the death rate for flies, mosquitoes and spiders using four different pesticides.

James concluded that Bingo was the best all-purpose spray, but Tjanda said that No More Flies was the best.

- Who do you agree with? Explain your choice clearly.

Pesticide	Percentage death rate		
	Flies	Mosquitoes	Spiders
Bingo	80	60	60
Bugaway	30	20	90
No More Flies	95	100	15
Zap	40	40	40

Activity notes

- As an alternative activity you could give the class a set of student results from an experiment they did last year or an experiment they will be doing this year. If you have *Choice* magazines the students could use them to find their own test and evaluate it.
- This activity could be discussed in small groups and answers recorded when there is general consensus. Make sure you emphasise to the students the importance of explaining their reasons. Encourage scientific, critical thinking and the quoting of relevant statistics if they are used in the report. This way the students can better see how the results relate to the conclusion.
- To reinforce scientific experimenting skills, students could design and implement their own experiment. They should be assessed on the design of their experiment (fair test, controlling variables) and on the language and layout of their report.

Homework

Ask students to design a simple but safe experiment to do at home. Plan the experiment using page 2 as a guide. (The tick box checklist would be ideal to use here—see Hints and tips, page 2.) Write the experiment up with the usual headings: *Date*, *Title*, *Aim*, *Materials/apparatus*, *Method*, *Results*, and *Conclusion*. Spend five minutes brainstorming ideas before making a decision on a suitable experiment.

Some suggestions are:

- Does a cup of hot water cool down faster with a metal spoon in it?
- Does the length of time you exercise affect your recovery heart rate?
- Which brand of paper towel is more absorbent?
- Which melts/freezes faster—water, juice, soft drink or milk?
- Does milk chocolate melt faster than white or dark chocolate?

Investigating Velcro

In the experiment on the next page you will investigate the strength of a Velcro strip. Before you do this, however, you need to know something about Velcro.

Activity

Your teacher will give you a small piece of Velcro (both hook and loop strips). Examine both strips using a hand lens or stereomicroscope.

- Sketch the appearance of the surface of both strips.
- Explain how the two strips link together.
- Can you make a join with two pieces of tape of the same type? Explain.

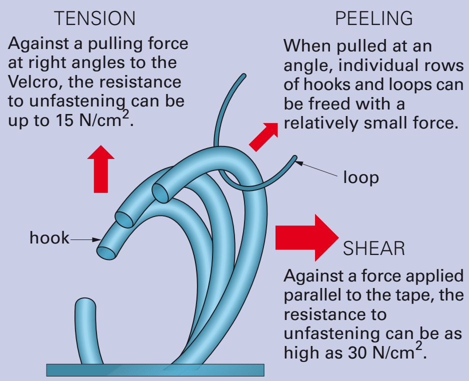
Fig 5 Velcro weed sticking to socks

Velcro

Velcro is a trademark name from the French words *velours* (velvet) and *crochet* (hook). A Swiss engineer Georges de Mestral had the idea for Velcro after getting burrs caught in his clothing and in his dog's fur while walking in the forest. When he examined the burrs under a microscope he found tiny hooks that could attach themselves to anything with loops in it, like hair or cloth. Velcro (or nylon press tape) is made in two parts, one with hooks and one with loops. It is now a universal fastener, for everything from disposable nappies to sandals.

A 5 mm square piece of Velcro may contain 3000 hooks and loops, although they will not all be hooked together. Two 5 cm squares pressed together can support the weight of a person weighing 80 kg! You may have seen Velcro jumping, where a person leaps off a trampoline and sticks to a Velcro wall.

As the diagram shows, less force is required to detach Velcro when it is pulled off at an angle than when it is pulled at right angles or parallel to the Velcro. This is because you are pulling a single row rather than all the hooks and loops together. This smaller force is sufficient to disconnect one row after another, producing the familiar ripping sound.



Hints and tips

Get students to read the Velcro passage aloud to the class. This is one way to identify students with language difficulties and those who are competent readers. If there are students known to have language difficulties, check beforehand if they mind reading aloud (often they still like to). Make a note of the students' reading abilities, particularly those with marked strengths or weaknesses.

Activity notes

Students could draw and label simple diagrams to explain their answers to the questions. Insist on clearly drawn, adequately sized and neatly labelled diagrams.

Learning experience

Generate a class list of as many items as possible that use Velcro in some way. Has the use of Velcro improved the item's use or made little difference?

Lab notes

- This is an interesting activity which will take about three lessons to do properly.
- Arrange with the lab technician to organise the necessary equipment.
- It's a good idea to get different groups to answer different research questions, or develop their own.
- Get the students to plan the experiment using page 2 as a guide. (The tick box checklist could be used here—see Hints and tips, page 2.)

Hints and tips

- It might be useful for students to have a quick-reference worksheet to put into the front of their prac books, listing the practical report headings and a brief summarised description of what each one means. ESL students or students with language difficulties may find this particularly helpful. The sheet could include the following headings and information:
  - — *Date*
  - — *Partners*
  - — *Aim*: statement(s) of what you are going to investigate or question(s) to investigate
  - — *Materials*: equipment or apparatus
  - — *Method*: labelled diagram and procedure steps
  - — *Results:* data tables, graphs, observations (qualitative and/ or quantitative)
  - — *Discussion*: answers any questions posed (inferences), error statements, possible improvements
  - — *Conclusion*: answers the question(s) in the *Aim*.
- Consider inserting the headings *Hypothesis* and *Prediction* between *Aim* and *Materials*. Getting the students to make a prediction is particularly useful as it compels them to think about what they expect to happen. Thinking about their prediction also helps them to evaluate their results objectively.

Experiment
TESTING VELCRO

Research questions

Rachel is thinking of buying a new pair of training shoes which use a Velcro strap instead of laces. She likes the idea because it is so easy to change into and out of her shoes.

Rachel is fascinated with the Velcro idea and wants to check whether the information on Velcro on the previous page is correct.

These are some of the questions she would like answered.

1 What peeling force is needed to unfasten the Velcro strip?

2 What shear force will be necessary to undo the strap off her shoe?

3 Will the strap keep its strength if it is unfastened and fastened many times?

4 Will the strength of the strap be affected by grit and material fluff that gets caught in the Velcro?

Designing your experiment

1 Work in a small group and discuss which test or tests you would like to do.

2 Write a hypothesis for your experiment.

3 Make a list of the equipment you will need.

4 Write a draft of your plan, including the variables you will be controlling and the data you are going to record.

5 Discuss the draft design with your teacher, then write your final design.

Hints and tips

1 You can buy hook and loop strips in cheap variety stores or in fabric stores.

2 You should record the results of the tests as the force used (in newtons) per area of Velcro (for example, per cm^2).

3 You will have to design a clever way to attach the force measurer (usually a spring balance) to the Velcro. Stitching, using a small clamp or gluing are three possible methods.

Planning and Safety Check

- Do a risk assessment to identify any safety hazards and decide on necessary precautions.
- Prepare a data table for your results. Remember, your results will be more reliable if you take at least three measurements and find the average.

Writing your report

Write a report of your experiment using the six headings Title, Aim, Materials, Method, Results, Discussion and Conclusion.

Your description of what you did needs to be good enough so that if someone else follows your method they will get very similar results. A diagram will help.

In the discussion, say how well your method worked and suggest how you might be able to get more reliable results.

In your conclusion you need to answer the research questions you investigated.

Science in action

Experiments using animals

No new drug can be put on the market until extensive information has been obtained on the effects it is likely to have on humans. One tragic example where this was not done properly was with the drug thalidomide. It was used in the 1950s to stop morning sickness and as a sleeping pill by pregnant women, but was later identified as a cause of deformities in newborn babies.

New drugs are usually tested first on laboratory animals, mainly rats and mice. Sometimes animals are also used to test the safety of food additives and household cleaning products. However, many people feel that this testing is unethical, and for this reason very few cosmetics are now tested this way.

Experiments involving living things require special methods. This is because no two individuals are the same. Also, it is not possible to control the behaviour of live subjects, or to control attitudes if people are used. However, scientists take care to control as many variables as possible. For example, if they were using mice they would control the following variables:

- genetic differences—all mice would be descended from the same stock
- age—all mice would be the same age
- environment—all mice would be kept in similar cages and be given the same food and water
- no diseases—the mice would be kept in the best of health.

When conducting such experiments scientists normally use a test group and a control group. The test group is given the drug and the control group is not. Any differences in response can then be said to be caused by the drug.

Experimenting on people

When experimenting with people, it is important that the subjects do not know whether they are in the test group or the control group. Suppose a drug company wants to test a new drug which they claim can help smokers give up smoking. A test group and a control group are given tablets—real ones for the test group and fake ones for the control group. However, the volunteers do not know which tablets they have been given. The fake tablets are called **placebos (pla-SEE-bows)** and appear to be exactly the same as the real tablets. After several months, the smoking behaviour of the volunteers is checked, and conclusions can then be drawn. This procedure is called a **blind experiment** because the subjects are unaware of (or blind to) whether they are in the test group or the control group.

A blind experimental design helps to overcome differences in the attitudes of the people involved in the trial. Some people may want to give up smoking more than others, and some may think that no treatment will work for them. Despite this special experimental design, however, the results may still be inconclusive. For example, suppose 20% of the test group give up smoking and 10% of the control group give up smoking. Before you can draw a conclusion from this, you need to analyse the data to decide whether the differences could have arisen by chance alone or whether there are real differences.

In some experiments the scientists are 'blind' as well as the subjects. This design is called a **double-blind experiment**. Suppose a scientist wanted to test a new ingredient X which is supposed to reduce acne (pimples). She could arrange for a large number of bottles of lotion to be made, half with X in them and half without. The bottles could then be numbered and given to volunteers to use. With this design, however, neither the volunteers nor the scientist would know which volunteers were using ingredient X and which were not. The scientist could then judge the effect on the pimples of each volunteer without prejudice. Only after the experiment would the scientist find out who had been given ingredient X.

The Venetian Bros Laboratory specialises in double blind experiments.

Hints and tips

Separate practical notebooks are a good idea for experiments as they allow for more teacher correction time when collected. The prac books could be clearly numbered on the front cover. Numbered prac books are great because, when submitted, any missing number is easily checked against the class roll and the student is immediately identified. You may find numbering student theory notebooks just as helpful because you could collect, say, numbers 1–10 for marking, then 11–20, and so on. It takes the pressure off collecting a whole class set at once and makes for easy record keeping.

Learning experience

Show students how to identify and summarise the key points of an article. It is a valuable skill and required for all aspects of study, especially in higher-level science. It may be useful to photocopy the Science in action article and get the students to use a coloured highlighter to highlight the key sentences.

Hints and tips

Monitor ESL students and those with learning difficulties. You may need to give extra time for them to complete the task. Encourage the students to write a list of any new words and their meanings. ESL students should translate their words and meanings into their native language.

Issues

What other questions do students have about the article they have just read? Have a class discussion or debate exploring the pros and cons of experiments using animals and people, and ethical and unethical experiments. Ask the students to write down their viewpoint before the class discussion/debate, and then again afterwards. Did their opinion change? Ask them to explain.

Homework

The Science in action task could be completed for homework, and follow-up time given in the next lesson to review answers.

Ethical or unethical experiments?

Some people say it is unethical for researchers to give sick people placebos, or no treatment, if effective treatments are already available.

A needle-exchange study with heroin addicts was conducted in 1997 in Anchorage, Alaska. Half of the addicts were given needles and the other half were not. The study was to see how many in each group got hepatitis B, even though there is an effective hepatitis B vaccine. The vaccine was offered to all participants after the study, but critics of the study claim it was designed to prove that needle-exchange programs work, rather than to help the addicts.

Questions

1 Explain the differences between a blind experimental design and a double-blind experimental design.

2 Suppose a drug company has developed a new drug called Nodec which they claim will reduce tooth decay. They arrange to test Nodec at your school using this method:
- Company representatives visit the school to explain the experiment and call for volunteers.
- They select 100 students and each student is examined to record the number of fillings.
- Each student is given a jar of tablets—either Nodec or a placebo. Students are to take one tablet each day. The drug company claims that their representatives do not know who is given Nodec and who is given the placebo.
- After 6 months the students are examined again and the data recorded. When the trial is complete, the drug company sends the following summary to the school.

	Total number of fillings	
	Before	After
Placebo (50 students)	56	73
Nodec (50 students)	47	59

a Evaluate the design of the experiment and the results obtained.

b On the basis of this experiment, would you use Nodec? Explain.

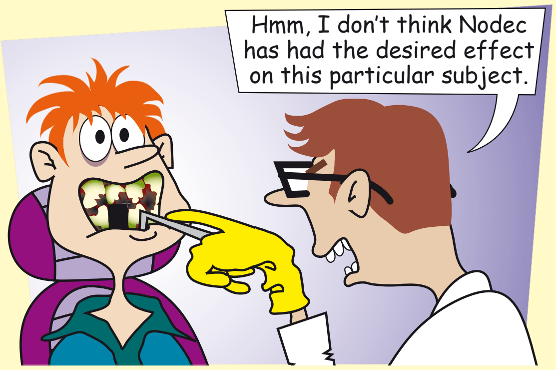
3 In a group discuss whether animals should be used to test drugs, cosmetics and other products intended for use by humans. You could research this topic on the internet or have a class debate.

4 Consider the Anchorage needle-exchange program described above.

a Do you think this study was ethical? Explain.

b Two of the principles of the Declaration of Helsinki (October 2000) are:
- Medical progress is based on research which ultimately must rest in part on experimentation involving humans.
- In medical research on humans, considerations relating to the well-being of the human should take precedence over the interests of science and society.

Were these principles used in the Anchorage needle-exchange study? Explain.

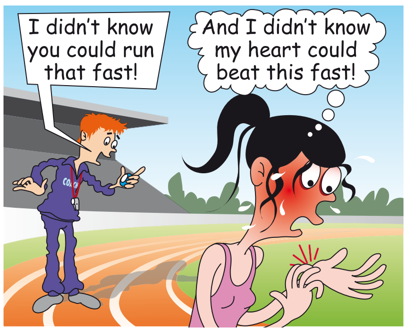


Check!

1 Match these four words with the four statements below:

inference observation
hypothesis prediction

- **a** My pulse rate is 56 beats per minute.
- **b** My pulse rate will increase when I run.
- **c** The more active you are the higher your pulse rate.
- **d** I think my pulse rate is caused by my heart beating.



2 What is a variable? Why is it so important to control variables in an experiment?

3 Write down in the correct order the four steps in an investigation.

4 **a** A magnet moving in and out of a coil of wire generates an electric current. What variables could be changed to produce a larger electric current?

b Milk left open out of a refrigerator turns sour much more quickly than unopened milk kept in a refrigerator. What variables can affect the rate at which milk turns sour?

c When a hot concentrated solution of copper sulfate was poured into a watch glass, small crystals started to grow around the edge of the solution. What variables could influence the growth of these crystals?

5 Jessica set up 5 pots, each containing 10 small cabbage plants. Each plant was 4–5 cm tall, and each pot had the same amount of soil in it. On the day after the cabbages were planted Jessica added different amounts of liquid fertiliser to each pot. From then on she watered the plants the same amount each day. She observed the growth of the plants over 10 days, and her results are shown below.

Jessie seemed unaware of the plants' attempts at telepathic communication.

- **a** What problem was Jessica investigating?
- **b** What variables did she control in her test?
- **c** What conclusions can you draw from her results?

Pot	Amount of liquid fertiliser added (mL)	Observations after 10 days	
		Colour of leaves	Average height (cm)
1	none	pale green	8
2	5	green	8
3	10	green	15
4	15	green	16
5	20	yellow	8

6 Dominic is a keen tennis player and has played on several different surfaces. He wants to know which surface causes balls to bounce highest. Design an experiment to answer this question. Make sure you list all the variables Dominic will have to control.

7 Work in a group and discuss how you investigate these research questions.

- **a** Which coloured flowers do bees prefer?
- **b** Do the phases of the moon affect the weather?

Check! solutions

1 The matching words are:
- a observation
- b prediction
- c hypothesis
- d inference

2 A variable is anything that can possibly change during the course of an experiment. In an experiment it is very important that only one variable is changed deliberately and another one is measured. All other variables should stay the same so that you can be sure about what has caused the change.

3 The four steps you should follow in an investigation are planning, conducting the investigation, processing data and evaluating your investigation.

4 a The variables that could produce a larger current are the strength of the magnet, the thickness of the wire in the coil, the number of turns in the coil and the rate of movement of the magnet.

b The variables that will affect the rate at which the milk goes sour are whether it is opened, the temperature of the milk, the type of milk and the age of the milk.

c The variables that could affect the rate of growth of the crystals are the concentration of the solution, the temperature of the solution and the rate of cooling.

5 a Jessica was investigating whether liquid fertiliser would affect the growth of cabbage seedlings.

b The variables she controlled were the number of cabbage plants in each pot, the size of the cabbage plants, the amount of soil in the pots, the amount of water for each pot and the time allowed for growth.

c From her results you can conclude that the best amount of liquid fertiliser to add for height and colour of the leaves is 15 mL.

6 There are quite a few possible ways to conduct this test. Here is one suggestion. Take three new tennis balls and drop them from a height of 3 m onto each type of court surface and measure how high they bounce. This could be repeated several times and the results averaged. It might be better to do this next to a wall on which the height can be easily measured. To do a fair test Dominic will have to control the number of drops, the balls, the height that they are dropped from and the temperature of the air.

7 a To be a valid experiment you would need to ensure that the only difference was the colour of the flowers and that everything else was the same (eg amount of nectar in the flowers, wind direction, scent).

b To do this research it would be very important to access good records that cover many years to see if there is some correlation between these two variables (ie moon phase and weather). Even so, it may be that there is some other factor which is affecting both!

8 Tom wanted to find out which type of nut contained the most stored energy. For each nut he followed the steps in the box below.

a Do you think Tom's conclusions would be valid?

b How could he improve his experiment?

1. *Put some water in a test tube and clamp it in place as shown.*
2. *Measure the temperature of the water.*
3. *Pick up the nut using a metal skewer and light it in a burner.*
4. *Heat the water in the tube using the flame from the nut.*
5. *Note the increase in temperature of the water.*
6. *Repeat steps 1 to 5 for the other nuts.*

Check! solutions

8 a No, Tom's conclusions would not be valid.

b This experiment could be improved by:

i using the same amount of water each time

ii ensuring the starting temperature of the water is the same each time

iii stopping the heating of the nut as soon as it catches alight.

challenge

1 Suggest why Velcro loses strength when it collects thread or fluff (called lint) during washing.

2 a For each of the following hypotheses write down the independent variable and the dependent variable.

A Punch brand batteries last longer than GoGo batteries.

B Small marble chips dissolve more quickly in acid than large chips do.

C Light-coloured clothing is cooler to wear than dark-coloured clothing.

D Iron rusts faster in sea water than in fresh water.

E The chirp rate of crickets increases in warmer weather.

b Design an experiment to test one of the hypotheses in **a**.

3 Four pairs of students carry out an experiment into the effects of exercise on pulse rate. Their methods are as follows.

A Kiri and Monique run on the spot for 2 minutes then take each other's pulse.

B Drew runs on the spot for 2 minutes. Felicity then measures his pulse.

C Samara takes Mimaki's pulse while Mimaki is seated. Mimaki then runs on the spot for 2 minutes and Samara takes her pulse again.

D Adam runs on the spot for 2 minutes then takes his own pulse. Bradley sits and takes his pulse.

Evaluate the method used by each pair of students. Which students are most likely to be able to make a valid conclusion about the effect of exercise on pulse rate? How could their experiment be improved?

4 When planning an experiment it is a good idea to use your knowledge of science to change the question you are investigating into a hypothesis. For example:

Question: Which part of your skin is most sensitive to touch?

Hypothesis: Fingertips are the part of your skin most sensitive to touch.

Use your knowledge of science to change the following questions into testable hypotheses.

a Which objects are attracted to a magnet?

b Do plants grow better under green plastic or clear plastic?

c What is steam?

d What causes silver to tarnish?

Challenge solutions

1 Velcro loses strength because the lint does not allow all of the hooks to match up with the loops on the other part of the Velcro material.

2 a

A The independent variable is the brand of battery and the dependent variable is how long the battery lasts.

B The independent variable is the size of the marble chips and the dependent variable is how quickly they dissolve.

C The independent variable is the colour of the clothing and the dependent variable is how cool the person wearing it feels.

D The independent variable is how much salt there is in the water and the dependent variable is how quickly the iron rusts.

E The independent variable is the temperature and the dependent variable is the chirp rate of the crickets.

b Various answers are possible. The important thing to do in any experiment is to change the independent variable in each case and measure the dependent variable while keeping all other variables constant.

3 Possible improvements for each experiment include:

A Each person's pulse should also be taken before any exercise is done.

B Only one person is being tested and, again, the pulse should be taken before any exercise.

C This is the most useful method but could be further improved by asking Mimaki to run for a longer time and measuring her pulse while she is actually running. There are now inexpensive devices available that can be used to do this.

D Both Adam and Bradley should measure their pulse before and after exercise.

4 Testable hypotheses are:

a Metallic objects are attracted to magnets.

b Plants will grow better under clear plastic than under coloured plastic.

c Steam consists of tiny droplets of water.

d Silver tarnishes because it reacts with oxygen in the air.

1.2 Processing data

Once you have done an experiment and collected your data you need to organise and display it. This makes it easier to identify any patterns or trends in the data. It also makes it easier to discover any cause-and-effect relationships or links between the variables. That is, does increasing (or decreasing) one variable have any effect on another variable?

Over 300 years ago an English schoolteacher called Robert Hooke found a relationship between the amount a spring stretches and the force used to stretch the spring. You can repeat Hooke's experiment yourself on the next page.

Skillbuilder

Drawing lines of best fit

In the next investigation you are going to use your data to draw a graph to show the relationship between two variables.

You will find that the points you plot on the graph will lie close to, but not exactly on, a straight line. You need to draw a **line of best fit**, rather than joining all the points. A line of best fit averages out any errors you made in your measurements in the investigation.

If you need help in drawing lines of best fit, the animation will show you how it is done.

For help with drawing lines of best fit, open the Drawing a line of best fit animation on the CD. Working with technology

Science in action

Writing a science magazine article

Robert Hooke 1635–1703

Robert Hooke has been described as the greatest experimental scientist of the 17th century. Yet he is not nearly as famous as his arch-rival, Isaac Newton.

Your task is to research information about Robert Hooke and write an interesting science magazine article (maximum 500 words) about him.

Structure of the science article

Here are some hints and tips on writing an article for a science magazine.

- Write more of a human interest story than a science story.
- The *introduction* is very important. You should entice your reader with emotion, drama, descriptions and quotations.
- The *body* of the article needs to expand the ideas from the introduction.
- The *conclusion* should be short and punchy and remind the reader of the key points of the story.
- Write in the active voice, eg 'Robert Hooke used his artistic talents to draw the organisms he saw with his newly invented microscope.'
- Avoid lengthy paragraphs. Two or three sentences will do for each paragraph.

Suggestions

- Use the websites below or search for *Robert Hooke* in your browser.
- Write your article on a word processor. You can download images from the websites.
- Make sure your article is scientifically and historically accurate. Don't make up information!

WEBwatch

Go to www.scienceworld.net.au and follow the links to the websites below.

Robert Hooke (1635–1703)
This site contains useful information and links to other sites.

Robert Hooke
This site is dedicated to Robert Hooke and has useful information and pictures which can be downloaded.

Robert Hooke—natural philosopher, inventor …
Interesting site with a large amount of information about his discoveries and achievements.

Hints and tips

To avoid students plagiarising information from unknown sources it may be appropriate to print off sets of information sheets for them to use. This way they will know that you will be able to easily check for copying. Also insist on them writing a bibliography (in the correct format).

Skillbuilder notes

- For more mathematically able or gifted and talented students, it is appropriate to show them how to use a computer program such as Excel to draw lines of best fit. Although regression analysis is required, at this year level these students should be able to understand the basics. Many students will have graphic calculators and these too can be used to draw lines of best fit.
- If the students are drawing their lines by hand, insist on one single (smooth) line in pencil.

Homework

The Webwatch activity could be completed as a homework task. Ask the students to write down at least five interesting points they found out from each website. This will help them with the Robert Hooke writing task on this page. You could set this task as a prerequisite to this lesson, and two days' notice would be sufficient time.

Learning experience

The Science in action writing task may be very daunting for the less literate students. Consider giving them the option of doing a multimedia task such as a PowerPoint or Flash presentation, or a podcast or vodcast.

Lab notes

- Make sure the stand is properly secured and does not move when the maximum load is applied.
- Limit the load so that the elastic limit is not exceeded and the spring permanently stretched.
- Emphasise to students that the line of best fit must go through the origin.
- It's a good idea to get students to repeat the experiment and average data, then account for any inconsistencies (random errors).
- When the students graph their data, be sure to remind them of the independent and dependent variables and how to scale a graph properly.
- If the students use a computer to draw their graphs, make sure they know how to do this. Drawing lines of best fit can pose a challenge and it might be easier to get the students to draw their lines by hand.

Investigate
1 HOOKE'S SPRING

Research question

What is the relationship between the force (load) on a spring and the extension of the spring?

Materials

- helical spring
- 50 g mass hanger and standard masses
- stand and clamp
- metre rule
- brick or other heavy mass
- graph paper

Planning and Safety Check

- Use the research question above to write a hypothesis linking the load and the extension of the spring.
- List the steps you will take in your experiment. Use the photo as a guide to setting up your apparatus.
- Draw up a suitable data table in which to record the load (mass added) and the extension (amount of stretch) of the spring.
- List any safety issues.

Planning hints

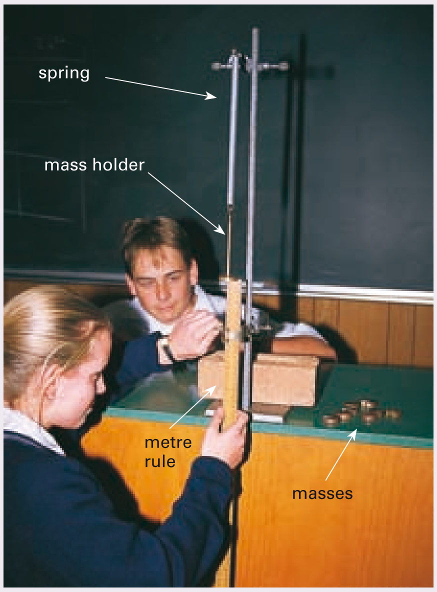
1 To find the load in newtons, divide the mass (in grams) by 100.

Working with technology You could enter your data into a computer spreadsheet such as Excel.

2 After adding the first mass, remove it and check that the spring returns to the zero mark. If it does not, you may not be able to form a valid conclusion from your results. Continue in this way by adding extra masses and recording the extensions. (If the spring does not return to the zero mark between measurements, it is best to stop the experiment and try another spring.)

Discussion

1 Look closely at your data. Do they support your hypothesis?



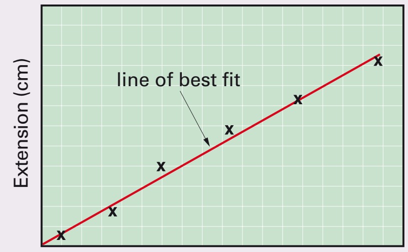
2 Which is the independent variable (the one you purposely changed in the experiment)?

3 Which is the dependent variable (the one you measured)?

4 Use graph paper to draw a line of best fit as shown below.

5 Compare your data with the data collected by other people. Explain any differences.

Spring extension vs load

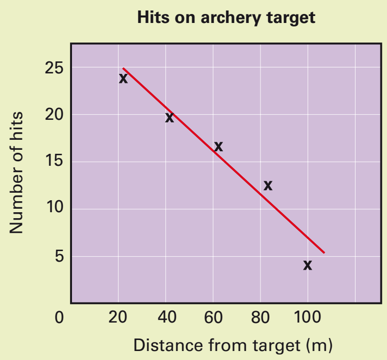


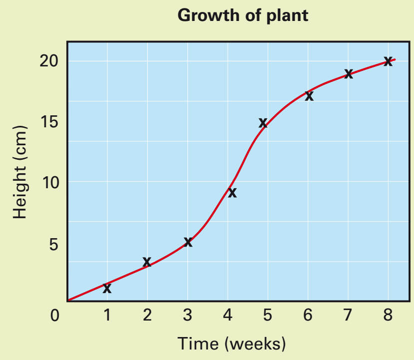
Interpreting graphs

Graphs are a very useful way of displaying patterns or trends in data. For example, the graph in the previous experiment shows that the extension of the spring and the load on the spring are directly related to each other. An increase in one variable causes an increase in the other. Similarly, a decrease in one causes a decrease in the other. The fact that the graph is a straight line means that the increases or decreases are proportionally equal. For example, if you double the load you double the extension, and if you triple the load you triple the extension.

Sometimes an increase in one variable causes a decrease in the other. For example, the number of hits on an archery target decreases as the distance from the target increases. In this case the variables are inversely related.

Note that a line of best fit does not go through all the points, but it does go close to them. It tends to 'average' the points and reduce any inaccuracies due to the experimental method used. It is also possible to draw a curve of best fit, as shown below.

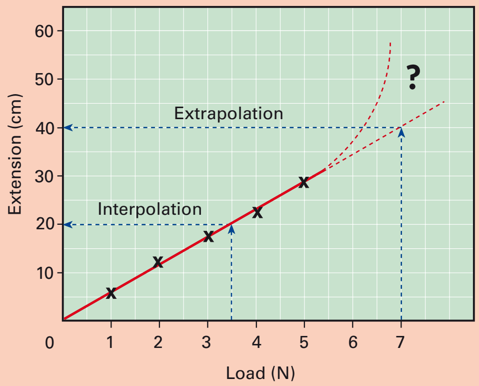




Predicting from graphs

Graphs not only show patterns but can also be used to make predictions. If the prediction is *between* two measurements the process is called **interpolating** (in-TERP-oh-late-ing). On the graph on the right, for a load of 3.5 N you can predict a spring extension of about 20 cm.

It is also possible to make predictions for values *beyond* the measured values. This process is called **extrapolating** (ex-STRAP-oh-late-ing). For example, for a load of 7 N you can extend the straight line and predict an extension of about 40 cm. However, the graph may not be a straight line at that point—for example it may curve upwards. (This is what happens if the spring does not return to its original length when the load is removed.) If this is the case your prediction of a 40 cm extension for a load of 7 N will be far too small. This is why you often see widely different predictions for such things as world population or global warming.



Hints and tips

- Don't assume all students can properly scale a graph or identify the dependent and independent variables. A useful exercise is to have some experimental results to practise graphing. About four or five sets with differing scales, variables and types of graphs would be plenty. Consider getting the students to draw a table of data from the graphs on this page. Some students find doing the reverse of what is normally done quite helpful.
- A way for the students to remember the difference between interpolation and extrapolation is that with **inter**polation you look **into** the data set you already have, but with **extra**polation you look outside your data set, that is, an **extra** outside the data set.
- Make sure to emphasise why lines of best fit are used. It may be useful to call the lines of best fit *prediction lines* or *prediction equations*, integrating science with mathematics and/or ICT.

Learning experience

Get students to compile a dot-point summary of the chapter so far. This can be added to later and used as a revision tool for tests or examinations.

Learning experience

Get the students to write down about five questions and answers relating to one of the graphs on this page. Collect the questions and conduct a quick quiz about the graphs. This gives the students further practice in interpreting graphs.

Hints and tips

- It is important to analyse any scatter graph correctly. Ask the students to comment on its form (linear or non-linear), direction (positive or negative trend) and the strength of the relationship. What can they conclude from the analysis?
- Mathematically able students could explore Pearson's product–moment correlation coefficient (**r**). Design an activity for them where they have to use technology to calculate the value of **r** and then interpret it. As an extension you may like to set a regression analysis task using collected experimental data. (In this context, regression analysis means to perform a least squares regression equation, calculate **r** and **r**^{2}, and interpret the results. Make sure the data is linear so as to avoid data transformations.)

Assessment task

Students could attempt *Assessment task 1: A science investigation*, found on the teacher CD, after the information on this page has been discussed.

Lab notes

- Students should take their shoes off and measure their feet outside the room in a ventilated area.
- It's a good idea to measure other groups (eg Year 7 students and adult staff) to compare results.

Scatter graphs

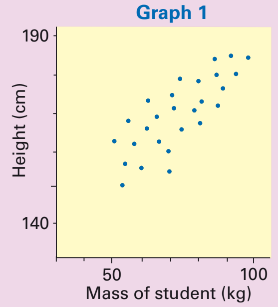
Suppose you want to see if there is a relationship between the mass and the height of students. You simply plot all the points and look for any *pattern* in the scatter of the points. This type of graph is called a **scatter graph**.

In Graph 1 there is an obvious trend. The taller the student, the heavier they are likely to be. There is a direct relationship between the two variables. We say there is a *high* **correlation** between them. In fact, you could draw a line of best fit through the points.

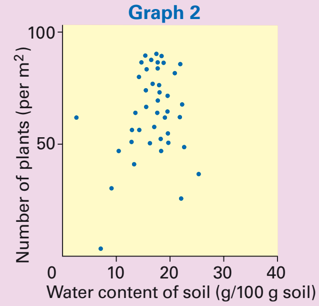
In Graph 2 there is no direct relationship, but there is *some correlation*. Most plants tend to grow in soils with water content between 10 and 25 g/100 g water.

In Graph 3 there is no relationship between the size of a person's head and their intelligence. There is *no correlation*.

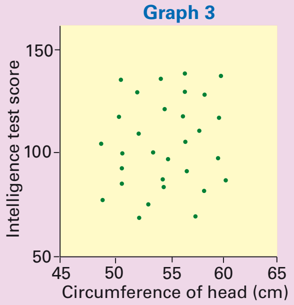
Graph 1



Graph 2



Graph 3



Experiment
MEASURING FEET

The problem to be solved

Is there any correlation between the length of a person's foot and their height?

Designing your experiment

1. Plan the details of your experiment. For example, how many people will you need to measure? Will you include children and adults in your sample? What equipment will you need?
2. Conduct your investigation and record your data in a suitable data table.
3. Draw a scatter graph of height versus foot length. Comment on the degree of correlation.
4. Write a report of your experiment, including the answer to the problem. Finally, evaluate the method you used. Are there things you could do to make your results more reliable?

If someone else did this experiment, do you think they would obtain the same results? Explain your answer.

Learning experience

As each student enters the room give them a printed word card (some words may need to be doubled up). Ask the students to write a definition for the word on their card. Then choose students to read aloud their definition, making sure all of the given words are done. Suggested words: *observation*, *inference*, *experiment*, *hypothesis*, *prediction*, *evaluation*, *conclusion*, *placebo*, *double-blind experiment*, *interpolation*, *extrapolation*.

Check!

1 Joshua investigated how far a wind-up toy frog moved with different numbers of turns of the winder.

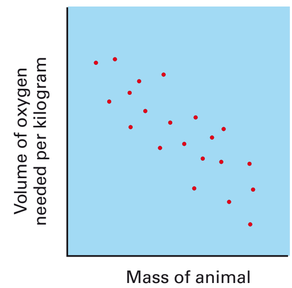
Number of turns	Distance travelled (cm)
5	23
10	47
15	70
20	90
25	117

a Use his results to draw a graph of best fit. (Try to make the graph fill the whole sheet of graph paper.)
b Write a generalisation linking the number of turns and the distance travelled.
c Use your graph to predict how far the frog will go with 12 turns.
d How many turns are needed to make the frog go 1 metre?

2 Plot the following data on a graph.

Air temperature (°C)	Distance hiked in one hour (km)
9	8.6
15	6.4
22	4.3
25	3.2
30	2.1

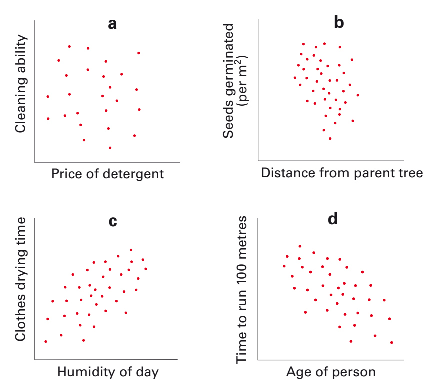
a Draw a line of best fit.
b Write a statement describing the relationship between the two variables.
c Use the graph to predict how far you would expect to be able to hike at 20°C and at 35°C.
d Which of these two predictions do you think is more accurate? Why?



3 The scatter graph above shows the results of an investigation.
a What was being investigated?
b Is there any correlation between the two variables? Explain your answer.
c Write a statement describing the relationship between the two variables
d Suggest a reason for the relationship.

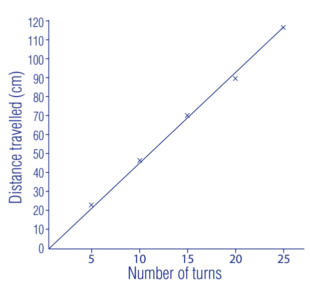
4 Look at the four scatter graphs below. Which ones show:
- a high correlation between the variables
- a low correlation between the variables
- no correlation between the variables

Give a reason for each choice.



Check! solutions

1 a Using the data given:

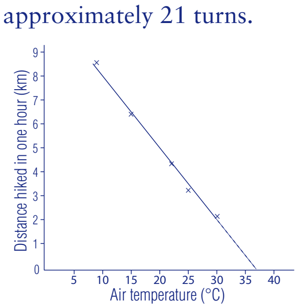


b The distance travelled by the wind-up toy is directly proportional to the number of turns of the winder.

c With 12 turns you would expect the frog to travel about 55 cm.

d To travel 1 m the toy would need approximately 21 turns.

2 a



b This is an inverse relationship, meaning that the higher the temperature, the less the distance that can be hiked in 1 hour.

c Using the graph, you can interpolate to estimate that the distance covered at 20°C would be approximately 5 km. You can extrapolate (dotted on the graph) to estimate that the distance travelled at 35°C would be approximately 0.6 km.

d The more accurate prediction is at 20°C because we cannot be sure what will happen outside the measured range. For example, the hiker could develop hyperthermia (too hot) and collapse.

3 a The investigation was about whether there is a relationship between the volume of oxygen used per kilogram for respiration and the mass of various animals.

b Yes, there is a correlation—the plotted points trend downwards to the right.

c The data shows that as an animal gets larger (independent variable) the amount of oxygen required per kilogram gets smaller.

d This observation can be explained because a large amount of oxygen is used to make heat to keep animals warm. Larger animals have relatively less skin and therefore lose less heat and consume less oxygen per kilogram.

4 a There appears to be no correlation between the price and cleaning ability of these detergents. This is because there is a fairly even spread of dots.

b There appears to be a low correlation because most seeds seem to germinate about the same distance from the tree.

c As the humidity increases so does the drying time. This can be seen by the general upward slope of the points towards the right.

d As you get older, your time to run 100 m decreases. This can be seen by the general downward slope of the points towards the right. However, you reach a peak and your times then start to *increase*.

To answer the question directly:
- **c** and **d** show a high correlation
- **b** shows a low correlation
- **a** shows no correlation.

challenge

1 The table shows the average stopping distance of a car on dry and wet roads.

a Which is the independent variable and which is the dependent variable?

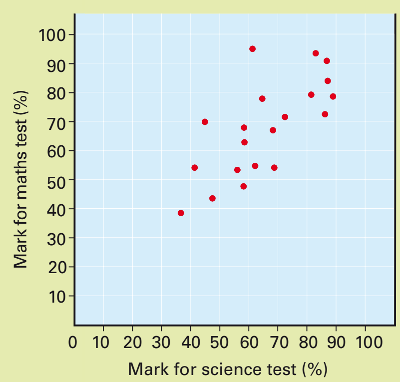
b Plot both sets of data on the one graph and draw curves of best fit. Label one curve 'dry road' and the other 'wet road'.

c What conclusions can you make from the graph?

d What variables do you think would have been controlled in this investigation?

Speed (km/h)	Stopping distance (m)	
	Dry road	Wet road
0	0	0
20	8	8.5
40	20.5	22
60	38	43
80	60.5	71
100	87.5	106
120	119	149

2 Use the scatter graph below to answer the questions at top right.



a Which two variables are plotted on the graph?

b What was the highest mark on the science test?

c What was the lowest mark on the maths test?

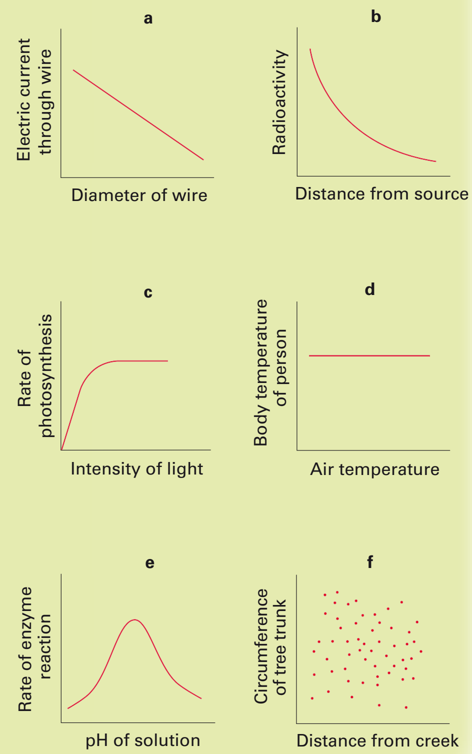
d What correlation is there between the two sets of marks?

e Draw a line of best fit through the points.

f If a student obtains a score of 70% on the science test, predict their score on the maths test.

g Compare your prediction with those made by others. Explain any differences.

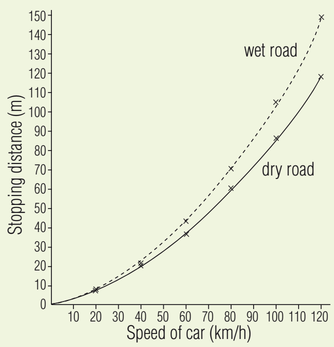
3 Write a sentence to describe the relationship between the variables in each of the six graphs below.



Challenge solutions

1 a The independent variable is the amount of water on the road. The dependent variable is the distance it takes for the car to stop when the brakes are applied.

b



c One conclusion you can reach is that on either surface stopping is less efficient at higher speeds. You can also conclude that it takes a greater distance to stop on a wet road than on a dry road.

d Several of the variables that would have been controlled in this investigation are the type of car, the driver and the road surface.

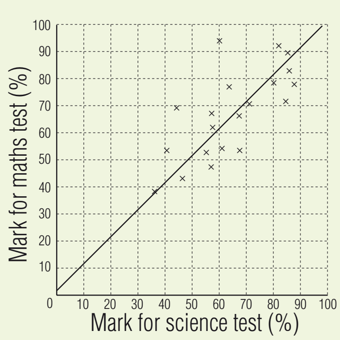
2 a The two variables that are plotted on the graph are the marks for the science test and the marks for the maths test.

b The highest mark on the science test was 89%.

c The lowest mark on the maths test was 39%.

d The graph shows that, generally, there is a direct relationship between the mark students get for their maths and science tests.

e



f Using a best-fit line you can predict a mark of about 73% for the maths test.

g You could say that the mark is probably between about 60% and 80% because a similar variation is shown by the other data on the graph.

3 The graphs show the following.

a A decrease in the electric current is proportional to the increase in the diameter of the wire. This is an inverse relationship.

b The decrease in radioactivity is not proportional to the distance from the source. Initially, the radioactivity decreases quickly but then it decreases less rapidly as it gets further away.

c At low light intensity the rate of photosynthesis is proportional to the light intensity. However, once the light intensity gets to a certain level, the rate of photosynthesis remains the same.

d As the air temperature increases, the human body temperature remains the same.

e As the pH of the solution increases, so does the rate of enzyme reaction. At a certain pH the rate reaches a maximum, then decreases as the pH increases further.

f There is no relationship between the circumference of the tree and its distance from the creek.

1.3 Collecting data

Some science investigations require you to collect data in the field. For example, you might be investigating the conditions of the water in a creek. You will have to take water samples and measure the pH, temperature and the amount of dissolved nutrients such as nitrates and phosphates, and test the clarity of the water. You might also want to find out the types and numbers of organisms that live in the creek.

Let's look at some techniques to collect data in the field.

Estimating numbers in a population

Some organisms, such as barnacles, are fixed in place in their habitat, while most other organisms are mobile and move from place to place. Different techniques are needed to study and count fixed and mobile organisms.

In field studies you can usually never count every organism in a population. You have to use methods to *sample* the population, and then *estimate* the total number.

The quadrat method

This method is used to study populations that are fixed in position. A **quadrat** is a square frame made of plastic, wire, wood or even string, which can be used to sample the organisms in a particular area.

Suppose you need to estimate the population of barnacles and molluscs in an area of a rocky shore. Quadrats vary in size but are usually 1 m × 1 m square; however, this is far too large to count small rocky shore organisms. A suitable quadrat might be 200 mm × 200 mm.

You can use the quadrat to count the various organisms in a number of different places chosen at random in the area. For a reliable estimate you should sample at least 10 places. The data can then be used to estimate the various populations in the selected habitat, or the population density per square metre.

Suppose you were studying a rocky shore and wanted to estimate the number of barnacles in a 10 m × 5 m area. You drop your 200 mm × 200 mm square quadrat at random over the selected area. You do this ten times and each time count the number of barnacles inside the quadrat.

Number of barnacles in each of the 10 quadrats:

5, 9, 5, 8, 11, 14, 7, 5, 10, 6 Total = 80 barnacles

Area of 1 quadrat = 200 mm x 200 mm
= 0.2 m x 0.2 m
= $0.04\ m^2$

Area of 10 quadrats = 10 x 0.04
= $0.4\ m^2$

$$\text{Population size} = \frac{\text{no. of barnacles in 10 quadrats}}{\text{area of 10 quadrats}} \times \text{total area}$$

$$= \frac{80}{0.4} \times 50$$

= 10 000 barnacles

The capture–recapture method

This sampling method is used to estimate mobile populations of organisms. In this method a sample of the population is caught, counted and tagged. The organisms are then released back into the habitat. After some time when they have dispersed throughout the population, a second sample is taken. Some organisms will be tagged, others will be untagged. Both are counted and an estimate is calculated as shown below.

Suppose 200 fish were caught in a lake. They were tagged and released. One month later, 100 fish were caught. Among these were 25 tagged fish that had been caught previously.

The capture–recapture method works on the principle that the proportion of tagged fish in the second sample is the same as the proportion of tagged fish in the total population.

$$\text{Proportion of tagged fish in 2nd sample} = \frac{25}{100}$$

$$\text{Proportion of tagged fish in 1st sample} = \frac{200}{\text{total}}$$

$$\frac{25}{100} = \frac{200}{\text{total}}$$

$$\text{Therefore, total} = \frac{100}{25} \times 200$$

$$= 800 \text{ fish}$$

So you can estimate there are 800 fish in the lake.

Hints and tips

- Some students may find the maths in this section challenging without using a calculator. Allow anyone experiencing difficulties to use a calculator as the main learning focus is mastering the technique, not the arithmetic. Write up a handout sheet which can be given to the class to practise the techniques. Give the students a set amount of time to try the questions by themselves before going through the solutions together, or set it as a homework task.
- Make sure the students know the method is called *quadrat* and not *quadrant*. Generate a class list of possible uses for this technique, and for the capture–recapture method.
- Consider organising a field trip with your class to try the methods out. Wetlands, coastal areas or other places with a natural water supply are often very interesting.

Issues

Is tagging of wildlife harmful and does it really assist scientists? Get the students to debate this topic. You could get the class to imagine they are a tagged creature and write about their feelings. Some may have the viewpoint that they are glad scientists are interested in their survival and see the tag as a positive. Others may think it is cruel, of no benefit and thus a negative. What is the general consensus of the class? What do they individually think? Why?

Learning experience

Reinforce the difference between a sample and a population. To help students understand how to estimate a sample, have some large laminated photos of a flock of birds, a forest or a school of fish, for example. Divide the photo into equal numbered portions (samples), assign pairs of students a portion to count, collect all the results and tally the scores. Is this a good estimate of the population? Do you get similar results if only one portion is counted and multiplied by the number of portions? Are both methods good estimates? Explain. When could these principles of estimation be applied (eg estimating crowds at an event, yearly changes to bird migration populations, counting stars in the night sky)?

Homework

Most students have access to a digital camera so ask them to take their own photo of a crowd. (These days it is standard that mobile phones have built-in cameras and the enlargement quality is often very good.) They should print out an A4-sized copy and then estimate the population. It is not necessary to print it out at photo quality—picture quality is fine. Examples of 'crowd' photos include leaves on a tree, a crowd at a sporting event, number of words on a page in a novel, blades of grass in a lawn, grains of sugar in a bowl, and so on.

Lab notes

Part A

- Emphasise that step 3 of the method needs to be done at random (ie eyes closed) so as not to bias the sample.
- Make sure all of the paperclips are collected and returned. If they are left in the grass they will be a health and safety hazard.
- Wooden toothpicks are a suitable alternative if paperclips aren't available.

Investigate

2 ESTIMATING POPULATIONS

Aim

To estimate the size of a population using the quadrat and capture–recapture methods.

Materials

- a large container of plastic-coated, coloured paperclips
- 1 m of heavy wire (fencing or coathanger wire)
- at least 5 m of string
- bar magnet (optional)

Planning and Safety Check

- It is best to work in groups of 3 or 4.
- Carefully read through the Method for Part A and B and decide which part you will do first.
- Prepare data tables for your results in both parts.

PART A
Quadrat method

Method

1 Bend the wire into a 200 mm x 200 mm square frame. This is your quadrat.

2 Count the paperclips. Then scatter them over an area of at least 2 m x 2 m in the room or outside.

Instead of dropping the quadrat at random, you will use a *transect*. This is a line across your area along which you place your quadrats. You take your 10 samples along this line.

3 Have two people hold the ends of the string and *without looking* lay it across the area containing the scattered paperclips.

4 Use the quadrat to take 10 samples along the transect.

Count and record the number of paperclips.

Discussion

1 Find the total number of paperclips in the 10 quadrats.

2 The area of the 200 mm x 200 mm quadrat is 0.04 m^2. Find the total area of the 10 quadrats.

3 Use the equation below to estimate the population of paperclips.

$$\text{Population size} = \frac{\text{no. of paperclips in 10 quadrats}}{\text{area of 10 quadrats}} \times \text{total area}$$

4 How does the estimated paperclip population compare with the known count of paperclips?

5 Calculate the population density in numbers per square metre. (Use the estimated population.)

6 Suggest ways to improve this investigation so that you obtain more accurate results.

7 What is the advantage in taking samples along a transect? Can you think of another way to sample the population which will give you reliable results?

PART B
Capture–recapture method

Method

1 Empty the container of paperclips on the desk. Select a colour and count all the paperclips of this colour. These represent your *tagged* paperclips in the total population.

Record this number.

2 Return the paperclips to the container and mix them up well.

3 Use a small container about the size of an eggcup or a kitchen measuring spoon to scoop out some paperclips. Alternatively you can dip a bar magnet into the paperclips.

4 Count the number of paperclips in the sample and also the number of the selected colour (tagged) paperclips.

Record your results.

5 Return the sample to the container, mix well and repeat Steps 3 and 4 for a total of 10 samples.

Discussion

1 Use the ratio formula below to calculate the estimated population size for each of the 10 samples.

$$\frac{\text{total no. tagged}}{\text{population size}} = \frac{\text{no. tagged recaptured}}{\text{no. in sample}}$$

2 Find the average population size for the 10 samples. Compare this with the known size of the population of paperclips.

3 Comment on the reliability of your results. Could you improve your method?

4 This method assumes that the number of individuals in a population remains the same throughout the sampling. Would this be true of a population of fish in a lake? What factors might affect this assumption?

Sampling in the field

Collecting data on the types and numbers of organisms is one part of a field study; obtaining data on the physical factors in the environment is the other part.

You know from previous studies in science that physical or abiotic factors such as temperature, availability of water, soil types and soil nutrients, and the pH of water and soil play a large part in determining the abundance and distribution of organisms in a particular habitat.

Fig 26 The rapid growth of blue-green algae is due to high water temperatures and large amounts of nutrients dissolved in the water.

Lab notes

Part B

Make sure the students can give you real-life examples of where the two methods of estimating populations could be used. If you have access to a dam or pond they could do their own investigation to estimate the population of a water creature. If you are in a region where there are a lot of flying insects they could net their samples and hence estimate the population for a given area.

Hints and tips

At the start of a lesson it is important to re-examine material covered from previous lessons. Giving the class a quick quiz based on the material they have already learned will give you an indication of whether any concepts need revising, and helps the students consolidate their ideas. Ask them to write the answers only (no need for the questions).

Learning experience

Revise the following words and meanings: *field study*, *data*, *physical factors*, *abiotic factors*, *pH*, *distribution*, *organism*, and *habitat*. The students could be given the list beforehand and asked to come to the lesson ready with the word's meaning and application/example. Alternatively, you could give them a 'match the word and meaning' worksheet to place into their notebooks.

Lab notes

- It is important that students have prior practice in sampling and using the equipment for measuring temperature, pH, etc.
- It's a good idea to repeat the tests and collect class data to reduce the effects of random error.

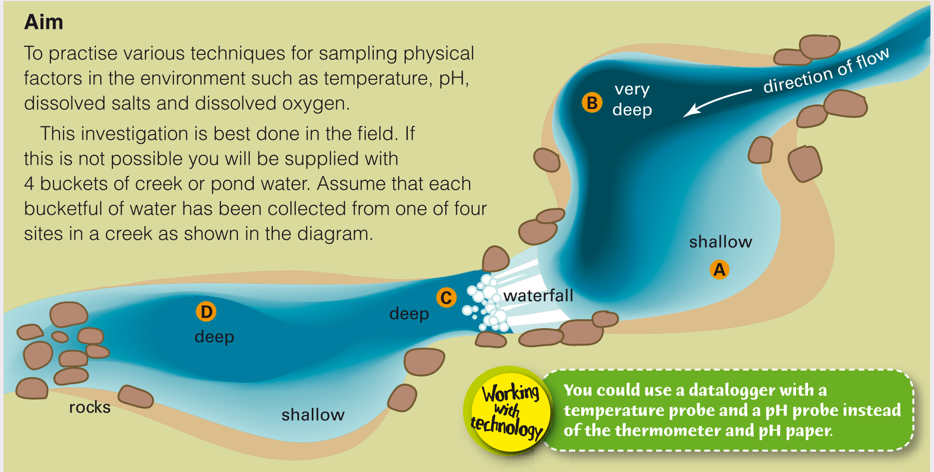
Investigate

3 SAMPLING PHYSICAL FACTORS

Aim

To practise various techniques for sampling physical factors in the environment such as temperature, pH, dissolved salts and dissolved oxygen.

This investigation is best done in the field. If this is not possible you will be supplied with 4 buckets of creek or pond water. Assume that each bucketful of water has been collected from one of four sites in a creek as shown in the diagram.



Working with technology: You could use a datalogger with a temperature probe and a pH probe instead of the thermometer and pH paper.

Planning and Safety Check

- Work in groups of 3 or 4.
- Carefully read through each part. Make sure you know what to do. Decide which part your group will do first, then discuss this with your teacher.
- Prepare data tables for your results in each part.
- Make a list of the safety issues in each part. Your teacher will discuss these as a class before you start.

PART A Temperature and pH

Materials

- 4 buckets of pond water or specially prepared water
- two 100 mL beakers or glass jars
- thermometer
- pH paper, universal indicator solution and colour card, or swimming pool pH kit
- distilled water

Method

1. Make sure your beakers are clean and rinsed in distilled water.
2. Number the buckets. Take about half a beakerful of water from the first bucket.
3. Use the equipment to find the temperature and pH of the water.

   Record the results in the data table.
4. Tip out the water and rinse the beaker in distilled water.
5. Repeat Steps 2 and 3 for the other 3 buckets of water and record your results.

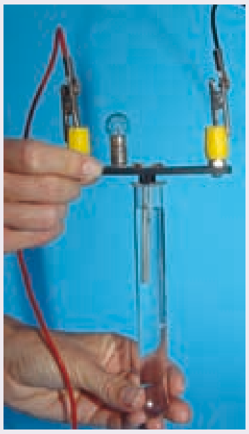
Discussion

1. Why is it necessary to rinse the beakers in distilled water after each test?
2. Reliable results are obtained when you take a number of samples and average the results. Would you average the data from all four sites in the creek or just some of the sites, or use individual readings? Use the map of the creek to justify your answer.

PART B
Conductivity

Conductivity is a measure of the amount of dissolved salts (nutrients) in the water. Water from a salt water swimming pool is tested for conductivity to determine how much dissolved salt is in the water.

A conductivity probe contains two metal electrodes. When the battery is switched on and the electrodes are dipped into the water, the ions in the water carry the current between the electrodes. A meter reads how much current flows. This reading is proportional to the concentration of the dissolved salts.



Materials

- 100 mL beaker or glass jar
- conductivity kit or datalogger with conductivity probe

Method

1 Clean the beaker and rinse it in distilled water.

2 Take a sample of about 50 mL from one of the buckets of water. Record the number of the bucket.

3 Use the equipment to find the conductivity of the water.

Record your results in the data table.

Discussion

1 Calculate the average conductivity of all four samples.

2 What conditions would change the conductivity of the water in a creek?

PART C
Dissolved oxygen

Dissolved oxygen (DO) is a very important factor in determining the distribution and abundance of aquatic organisms. Some organisms can survive only in water with high levels of dissolved oxygen, while others can tolerate very low levels.

Materials

- 100 mL beaker and glass jar with screw lid
- oxygen meter with probe, or DO test kit

Note: Your teacher will show you how to use the oxygen meter and probe if your school has one. Alternatively you will be shown how to use the dissolved oxygen (DO) test kit.

Method

1 Clean the beaker and rinse it in distilled water.

2 Without disturbing the surface of the water too much, slowly dip the beaker into a bucket of water and collect about 70 mL of water.

3 Use the oxygen meter or the DO test kit to find the level of dissolved oxygen in the water.

Record your results in the data table.

4 Repeat Steps 1 to 3 for the other buckets of water.

Record your results.

5 Take another water sample from any bucket and pour it into the glass jar. Screw the lid on and shake vigorously. Then test for DO.

Record your results.

Discussion

1 Compare the DO in the shaken jar with the water in each of the buckets. Account for the differences.

2 Why was it necessary to avoid disturbing the water when you took your samples from the buckets?

3 What biotic and abiotic factors might change the level of dissolved oxygen in a creek?

Lab notes

This is an ideal activity for datalogging, using whatever equipment you have available in your school.

Hints and tips

- A guest speaker from a local council or other body that looks after parks and gardens in your area could visit the class and give a presentation of their work. If possible, they could use a water testing kit and perform a class demonstration using water from a local creek or lake.
- Get the students to review the goals they set for this chapter (Starting point, page 1). How many of them have they achieved? Which ones need to be reconsidered? Ask them to write a self-evaluation of the chapter and submit it for your perusal. They should reflect on their personal learning, comment on areas that they found interesting, and indicate where improvements in their learning could be made. Suggest they try to balance their positives and negatives.

Check! solutions

1 a conductivity d population
b quadrat e sample
c transect f abiotic

2 a The total number of dandelions in the 10 quadrats is 71.
b The calculation is
$$\frac{71}{10} \times 250 = 1775$$
c An observation is that the distribution of dandelions is not very uniform. An inference is that different areas receive different amounts of sunlight and water.

3 The quadrat method is better in several situations, eg measuring non-moving organisms like plants (it avoids handling them and possibly being bitten or stung, and avoids any risk of harming any animals or plants).

Challenge solutions

1 a The size of the horse population can be estimated using the blue squares and the formula on page 18:
$$= \frac{15}{5} \times 25 = 75$$
b The size of the horse population can also be estimated using the yellow squares:
$$= \frac{14}{5} \times 25 = 70$$
c Generally the random squares gives a better estimate because a transect may follow a fence or river which is not a random sample.
d Selecting five numbers randomly (eg family birthdays or friends' house numbers) will give you a total that you can use to estimate the totals as shown in **a**. It is also a good idea to repeat this several times. The squares should always be selected at random.
e The quadrat method was used because they were using aerial photos of wild horses in a remote area. The capture–recapture method is sometimes not practical, particularly if the animals are difficult to catch, as in this case. The horses would also be dangerous to handle.

Check!

1 Match the words in the list below with their descriptions.

sample quadrat conductivity
transect population abiotic

a A measure of the concentration of ions in water
b A square frame used to count organisms in a particular area
c A line across a selected area which is used as a guide to sample organisms
d A number of organisms of the same kind in a particular area
e A small group of organisms selected from the total population
f The physical or non-living factors in the environment

2 The table (top right) shows the number of dandelion plants in a grassy area in 1 m x 1 m quadrats taken along a transect. The grassy area measured 10 m x 25 m.

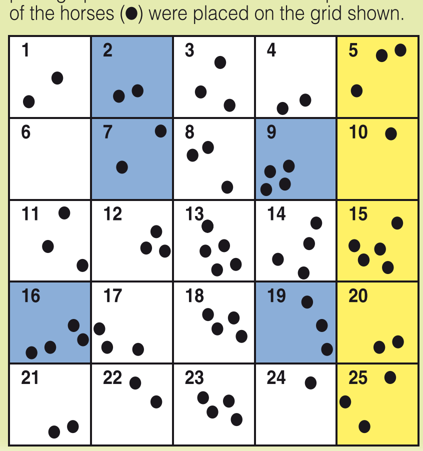
Quadrat	1	2	3	4	5	6	7	8	9	10
Number of dandelion plants	4	4	9	9	11	6	8	9	7	4

a Find the total number of dandelions in the 10 quadrats.
b Use the equation on page 17 as a guide to find the total population of dandelions in the grassy area.
c Use the data in the table to make an inference about the distribution of dandelions in the grassy area.

3 When sampling populations of organisms in the field, the quadrat method is sometimes preferred over the capture–recapture method.
Describe the situations in which the quadrat method would be the better sampling method to use.

challenge

1 The grid below shows the number of feral horses in a particular area. The horses were photographed from an aircraft and the positions of the horses (●) were placed on the grid shown.



Biologists want to estimate the size of the horse population so they can study their habits and try to reduce the damage that they cause to native wildlife.
The biologists used the quadrat method to sample the horses. They selected 5 squares at random (shown in blue) and also 5 squares along a transect (shown in yellow).
a Use the random squares (blue) to estimate the size of the horse population.
b Now use the transect squares (yellow) to estimate the horse population.
c Do your answers for **a** and **b** indicate that one method gives a more accurate estimate of the total horse population than the other? Explain.
d Select another 5 squares to show that results can vary when using the quadrat method. How did you select the quadrats?
e Why was the quadrat method used by the biologists? Could the biologists have used the capture–recapture method instead? Give reasons for your answer.

MAIN IDEAS

Copy and complete these statements to make a summary of this chapter. The missing words are on the right.

1 The four main steps in a scientific investigation are ______, doing the experiment, processing the data and ______ the experiment.

2 To obtain ______ results in an experiment you usually need to take repeated measurements and calculate an ______.

3 To evaluate an investigation you think about how you could improve the experiment and whether your conclusions are ______.

4 Processing data involves looking for ______ or trends showing relationships between the ______ being investigated.

5 Graphs of best fit drawn from experimental data can be used to make ______.

6 ______ graphs can be used to check what correlation there is between two variables.

7 Both the ______ method and capture–recapture method can be used to ______ the size of a population.

average
estimate
evaluating
patterns
planning
predictions
quadrat
reliable
scatter
valid
variables

Try doing the Chapter 1 crossword on the CD.

Working with technology

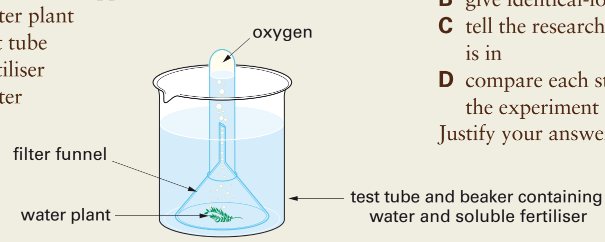
Main ideas solutions

1 planning, evaluating
2 reliable, average
3 valid
4 patterns, variables
5 predictions
6 scatter
7 quadrat, estimate

REVIEW

1 In testing the effectiveness of a dishwashing detergent you would not need to consider:
A the amount of detergent used
B the time of day
C the temperature of the water
D how the dishes were washed

2 Glen did an experiment to find out if fertiliser affects the amount of oxygen a water plant makes. He used the apparatus shown below. A suitable control for this experiment would be to use the same apparatus but without the:
A water plant
B test tube
C fertiliser
D water



3 From coral, a drug company has isolated a chemical (Z), which they claim reduces acne. They select 200 students with acne and photograph the areas of skin affected. Half of the students (the test group) are given a lotion containing Z. The other half (the control group) are given an identical lotion except that it contains no Z. To make this experiment a fair test of ingredient Z, the drug company should *not*:
A release any details of the trial to the public
B give identical-looking lotion to all students
C tell the researchers which group each student is in
D compare each student's acne before and after the experiment
Justify your answer.

Review solutions

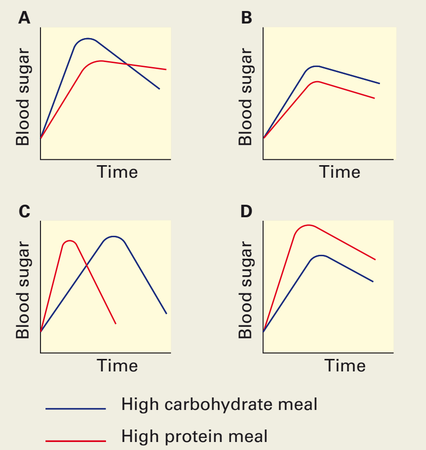
1 **B**

2 **C**

3 **C**—If the researchers know who gets the lotion containing Z and who doesn't, this may influence their observations of the effect of the lotions. To overcome this problem a procedure called a double-blind experiment is used (see page 7).

REVIEW

4 A biologist found that if you eat a meal containing a lot of carbohydrates your blood sugar level rises rapidly then drops off almost as rapidly. If you eat a meal containing a lot of protein, your blood sugar level rises more slowly to a lower peak. It also drops more slowly, but it does not fall as far as with a high carbohydrate meal.
Which graph correctly shows these findings?



5 Describe how you would use the capture–recapture method to estimate the population of mullet in a section of a river.

6 Two students used the quadrat method to estimate the population of periwinkles on a rocky platform close to the water's edge. The rocky platform measured 20 m × 5 m, and ten 1 m × 1 m quadrats were sampled along a transect.

Quadrat	1	2	3	4	5	6	7	8	9	10
Number of periwinkles	10	12	15	13	12	9	16	14	10	9

a Find the total number of periwinkles in the 10 quadrats.
b Estimate the periwinkle population on the rocky shore platform.
c Suggest why the quadrat method was used by the students instead of the capture–recapture method.

7 Nancy and Daniel were both given a new bicycle for Christmas. Nancy's was a mountain bike with 22 gears and Daniel's was a BMX with 10 gears. Nancy argued that her bike was safer because its larger wheels meant it would stop more quickly than Daniel's BMX with smaller wheels.
To settle the argument Nancy and Daniel rode their bikes down a hill and braked when they reached a particular spot on the road. Nancy stopped in 22 m and Daniel stopped in 14 m. Daniel claimed that Nancy was wrong—small wheels stop you more quickly than large wheels.
a What Nancy and Daniel did was not a fair test of wheel size and braking ability. List at least three uncontrolled variables that could have affected the results.
b Suggest ways in which Nancy and Daniel could improve their test.

8 Chung investigated the relationship between the diameter of ropes and their breaking strain.

Diameter of rope (cm)	Breaking strain (kg)
1	400
2	500
3	750
4	950
5	1100

a Use Chung's results to draw a graph of best fit.
b Write a statement of the relationship between the two variables.

Check your answers on page 331.

4 A

5 You catch, count and tag a sample of mullet (eg 20) in that section of the river. You then release the tagged mullet back into the river. After some time you catch a second sample (eg 10) and count how many are tagged (eg 2) and untagged (eg 8).

Proportion of tagged mullet in 2nd sample = proportion of tagged mullet in river

So $\frac{2}{10} = \frac{20}{\text{total}}$

Therefore $\text{total} = \frac{20 \times 10}{2} = 100$

So you estimate there are 100 mullet in this section of the river.

6 **a** Total number of periwinkles = 120

b Total area = 100 m^2

Area of 1 quadrat = 1 m^2

Area of 10 quadrats = 10 m^2

population = no. of periwinkles in 10 quadrats $\times \frac{\text{total area}}{\text{area of 10 quadrats}}$

$= 120 \times \frac{100}{10}$

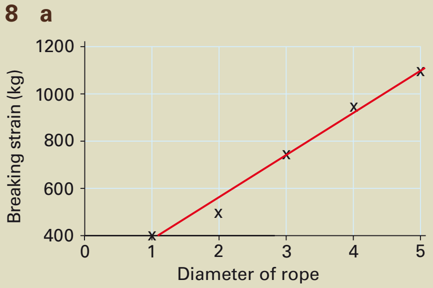
= 1200 periwinkles

c The quadrat method was used because the periwinkles are not mobile—they are fixed in position on the rocky platform.

7 **a** The uncontrolled variables were the type of bicycle, the condition of its brakes, the mass of the rider, the speed of the bike and how hard the rider braked.

b It would be best for the same person to test each bike, travelling at the same speed and braking the same way on both bikes. Ideally the bikes should be the same, with different-sized wheels, but this is not possible.

8 **a**



Note that the line does not go through all the points, but it goes close to them.

b As the diameter of the rope increases, the breaking strain also increases. (If you wanted to be quantitative you could say that the breaking strain increases by about 175 kg when the rope diameter increases by 1 cm.)