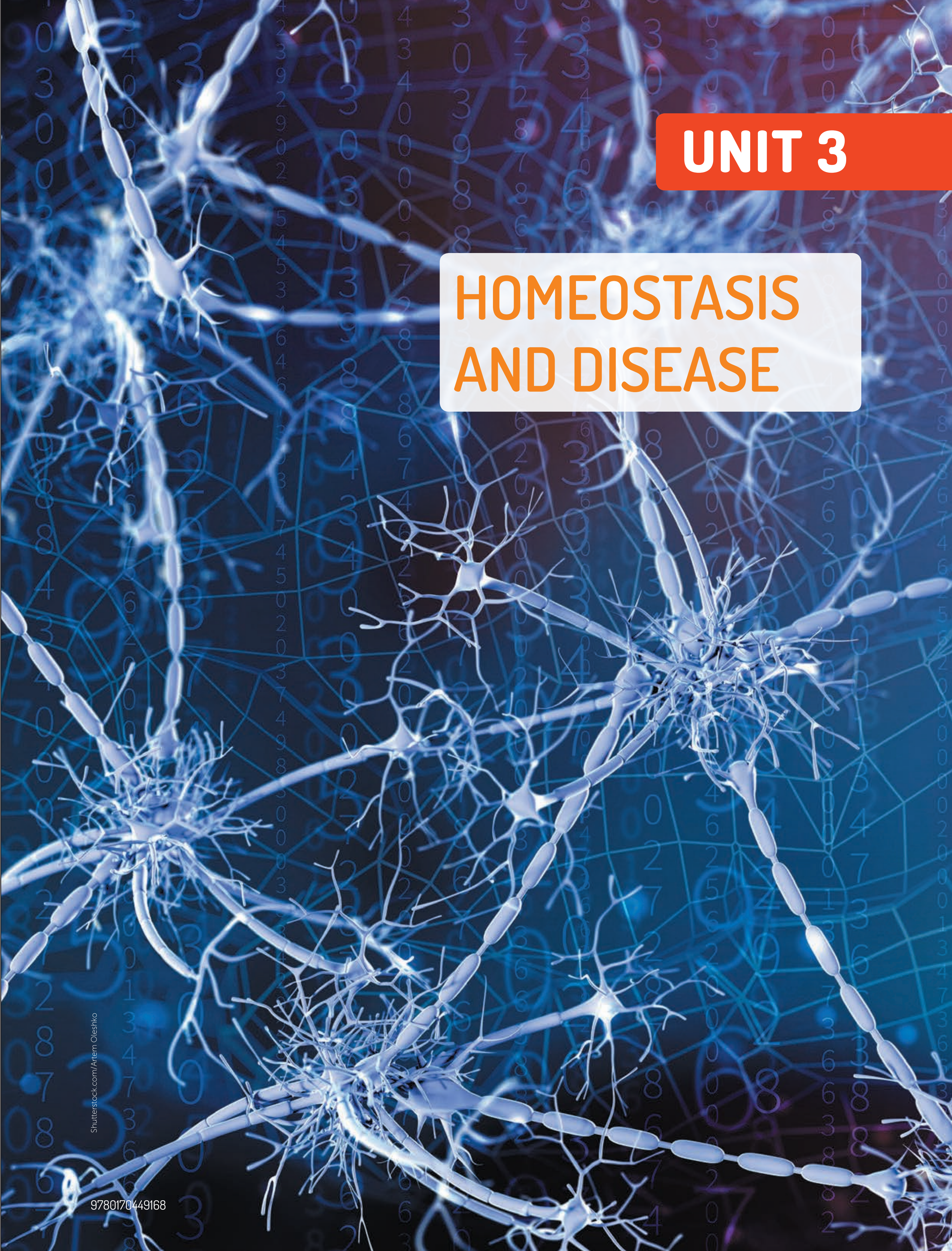

UNIT 3

HOMEOSTASIS AND DISEASE

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1 INVESTIGATING HUMAN BIOLOGY

UNITS 3 & 4 CONTENT

SCIENCE INQUIRY SKILLS

» identify, research and construct questions for investigation; propose hypotheses; and predict possible outcomes
» design investigations, including the procedure(s) to be followed, the materials required, and the type and amount of primary and/or secondary data to be collected; conduct risk assessments; and consider research ethics, including animal ethics
» conduct investigations, including the collection of data related to homeostasis and the use of models of disease transmission, safely, competently and methodically for the collection of valid and reliable data
» represent data in meaningful and useful ways, including the use of mean, median, range and probability; organise and analyse data to identify trends, patterns and relationships; discuss the ways in which measurement error, instrumental accuracy, the nature of the procedure and the sample size may influence uncertainty and limitations in data; and select, synthesise and use evidence to make and justify conclusions
» communicate to specific audiences, and for specific purposes, using appropriate language, nomenclature, genres and modes, including scientific reports

Source: School Curriculum and Standards Authority, Government of Western Australia

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Herbert Spencer, an English philosopher who lived from 1820 to 1903, neatly summarised what science is all about: science is a process of inquiry aimed at finding answers to problems and discovering new knowledge about the natural world. The knowledge discovered as a result of scientific inquiry becomes a part of science. That is, science means two things: a process of discovery and the knowledge that is discovered. The information presented in this book is science. It is some of our present knowledge about the human species, knowledge that has been obtained by scientific investigation.

1.1 TYPES OF INVESTIGATIONS

Scientists use a range of techniques to expand our knowledge.

Observations

Observation is an essential part of science. Any investigation, regardless of the procedure used, will involve some form of observation. In investigations based on observation, scientists are looking for patterns. When a pattern becomes evident it may be possible to draw tentative conclusions.

An example of an investigation based on observation is the discovery that peptic ulcers are caused by a bacterial infection. In 1979, Dr Robin Warren, a pathologist at the Royal Perth Hospital, observed the presence of bacteria in samples of stomach tissue that he was examining. Continued observation over the next few years showed that the bacteria were often present in the stomachs of patients suffering from stomach inflammation. Warren's discovery was not taken seriously because, at the time, it was believed that the stomach contents were too acidic for bacteria to survive.

In collaboration with Dr Barry Marshall, a doctor specialising in stomach disease, Warren was able to show that a particular species of bacterium was present in the majority of cases of stomach and duodenal ulcers. They also found that it was rare to have an ulcer without being infected by the bacterium that Warren had discovered. Marshall and Warren went on to culture the bacterium and to show that it did indeed cause ulcers. As a result of their discovery it became easy to treat stomach and duodenal ulcers with antibiotics. The discovery that the bacterium *Helicobacter pylori* was the cause of ulcers began with simple observation and became one of the most significant events in Australian medical history. Robin Warren and Barry Marshall were awarded the Nobel Prize in Physiology or Medicine in 2005.

What is *Helicobacter pylori?*

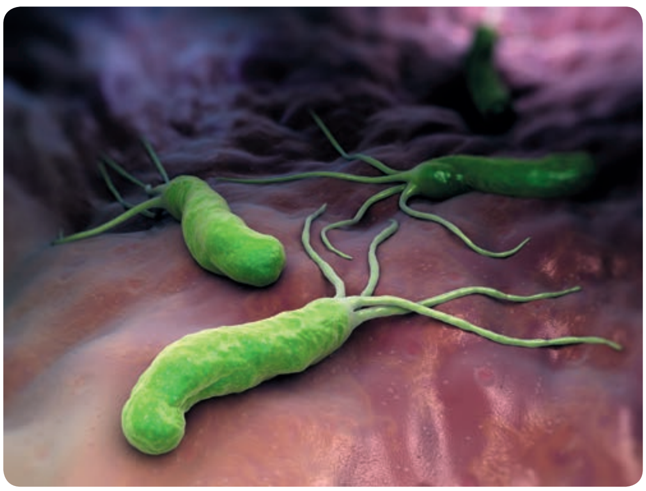

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FIGURE 1.1 *Helicobacter pylori* bacteria

Another example of systematic observation is when it is used to gain knowledge of animal behaviour. Jane Goodall, the first person to observe the social organisation of chimpanzees in the wild, documented the interactions of chimps with one another, their social hierarchy, their tool making and many other features of their society. She began her observations in 1960, and her work is being continued today through the Jane Goodall Institute.

FIGURE 1.2 Jane Goodall observing the behaviour of chimpanzees

Controlled experiments

Controlled experiments, sometimes called fair tests, are designed to investigate relationships between factors (or variables). They involve changing one variable while all the other variables are kept the same. Any differences in the results should be due to the changed variable.

Howard Florey, an Australian working at Oxford in England, used controlled experiments to demonstrate the effectiveness of penicillin in treating bacterial infections. In 1940 a crucial experiment to test the effectiveness of penicillin as an antibiotic was carried out. Eight mice, all the same weight and age, were each injected with 100 million streptococci, a type of bacterium. Previous experiments had shown that an injection of that size would kill all mice injected. After the injection of streptococci, four of the mice were put back in their cages and given no further treatment. The other four mice were given injections of penicillin. The mice in the control group – those that did not receive penicillin – all died within 12 hours. Mice in the experimental group, which were given penicillin, survived for many days – one for more than six weeks.

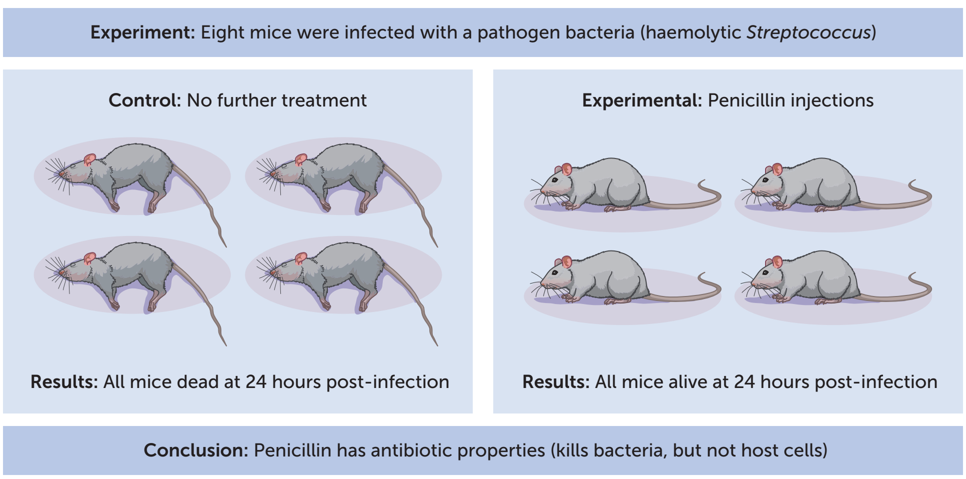


FIGURE 1.3 A controlled experiment was used to investigate the effectiveness of penicillin

The only difference between the mice in the two groups was the injection of penicillin, so the survival of those mice was good evidence that penicillin was effective in combating bacterial infections. Further positive feedback from repeated controlled experiments gave Florey and his co-workers the confidence to try penicillin on humans suffering from bacterial infections. The results were outstanding. Florey and his colleague Ernst Chain were awarded the Nobel Prize in Physiology or Medicine in 1945.

Surveys

A **survey** is a process of systematically collecting, analysing and interpreting information about an aspect of a study. Surveys are usually designed to collect data from a large number of subjects. The information may be collected using a questionnaire or by interview. Using the large amount of information collected, the researcher can then look for patterns in the data.

Dr Karl's survey

Dr Karl Kruszelnicki was stimulated by a listener to his radio program to carry out a survey into the origins of belly button lint. The survey was conducted over the Internet, with 4799 people responding, and publicised on the radio station Triple J. The patterns in the responses revealed that people more likely to have belly button lint are male, hairy, with a concave belly button, and that the amount of lint increases with age. This was a light-hearted exercise, but it does demonstrate the principles involved in conducting a survey. In 2002, 'Dr Karl' received an Ig Nobel Prize for his efforts. Ig Nobel Prizes are awarded for research that makes people laugh and then makes them think.

Trial and error

Trial and error sounds like a random process, but when used in scientific research it is systematic. The process involves one attempt to solve a problem being followed by another. Each trial is recorded, and the results allow the investigator to gradually home in on the solution to a problem. Thomas Edison, who developed the electric light globe, had to find a suitable material for the filament in the light globe. Using trial and error, he examined more than 600 different materials before finding one that was satisfactory.

Many new drugs, such as antibiotics, have been discovered using trial and error. Chemical compounds extracted from plants can be tested on cultures of bacteria to see whether they have any effect. Those that show promise can then be subjected to further testing under different conditions. Meticulous records of the results of each trial must be kept. Such research is often prolonged and tedious, but it is often the only way to find effective substances.

Case studies

A **case study** is an in-depth investigation of one particular person or situation. Case studies are frequently used in areas such as education and business management. However, they may also be useful in some areas of science. For example, in medicine the progress of a particular disease in one person may be documented. Such a case study can extend or help to confirm what is already known about the disease.

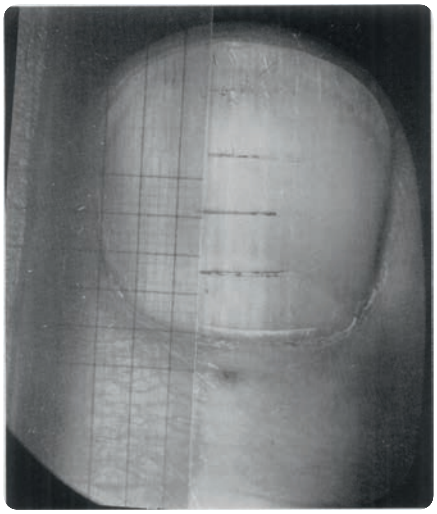
Longitudinal studies

A **longitudinal study** is conducted over a long period of time. It is similar to a case study but is more prolonged. Longitudinal studies may take place over many years, even decades. They can also be done retrospectively, which means that the researcher can examine records of past events to build up a picture of change over time.

The Busselton Health Study is a longitudinal study of the population of Busselton, a coastal town in the south-west of Western Australia. Begun in 1966 and continuing today, it is the world's longest-running study of the health of a population.

A longitudinal study on a smaller scale was carried out by an American doctor, William Bean, who studied the growth of his fingernails for 35 years. He did this by filing a horizontal line on his thumbnail just above the cuticle and recording how long it took the mark to reach the tip of his thumbnail. From his records he was able to calculate the growth rate. In 1980, after 35 years of measurements, Bean was able to conclude that the growth of his nails had slowed from 0.123 mm a day when he was 32 years of age to 0.095 mm a day at the age of 67.

Busselton Health Study



William B Bean, 'A Discourse on Nail Growth and Unusual Fingernails', American Clinical and Climatological Association (1962;74:152-167)

FIGURE 1.4 Dr William Bean used lines in his fingernails to study their growth rate in a longitudinal study

Key concept

Scientists use a range of different methods to acquire new knowledge, including observations, controlled experiments, surveys, trial and error, case studies and longitudinal studies.

Questions 1.1

RECALL KNOWLEDGE

1 List the methods of investigation used in science.

2 Describe how observation led to our current understanding of stomach and duodenal ulcers in humans.

3 Classify each of the following as either a controlled experiment, survey, case study or longitudinal study.

- **a** A scientist analysed information about the diets and health conditions of 500 people in Western Australia.
- **b** The ability to concentrate in school was investigated in 30 students. Fifteen students drank only water at breakfast, while the other 15 students drank coffee with the same breakfast.
- **c** Casey suffers from epilepsy. Her doctors have been keeping records of the frequency, length and triggers for her seizures for the last 30 years.

APPLY KNOWLEDGE

4 Discuss the implications for an investigation if more than one variable is changed.

5 Explain why trial and error is often a long investigation process.

6 State how case studies and longitudinal studies are:

- **a** similar
- **b** different.

1.2 CONDUCTING INVESTIGATIONS

As we have seen, there are many ways of conducting investigations in science; however, they are all done in a methodical and systematic way. The exact method used will be the one that best suits the situation. Many investigations lead to the testing of a hypothesis and follow a similar pattern, called the **scientific method**, as follows:

1 Recognise a problem and define a question.

2 Collect as much information as possible relating to the problem.

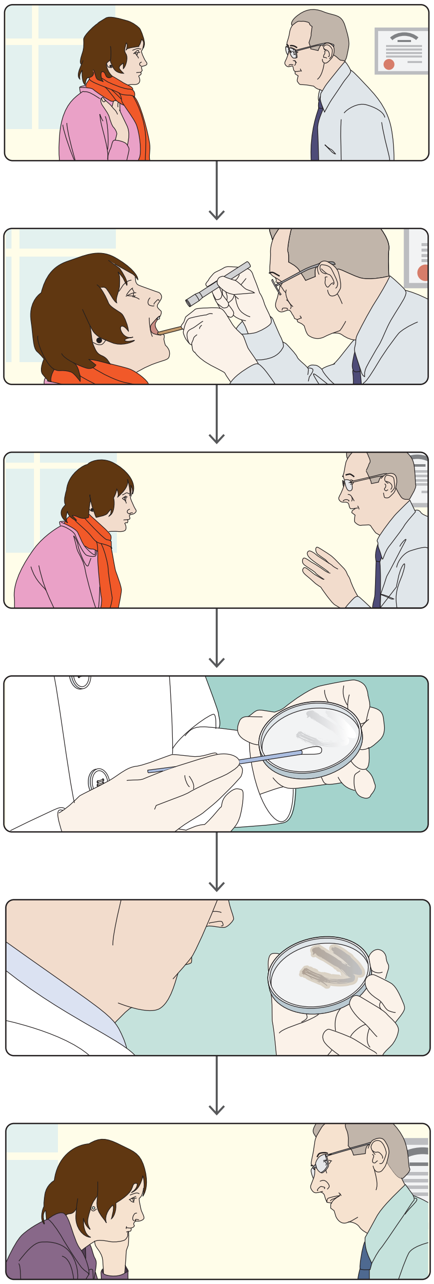
3 Propose a **hypothesis** – a possible explanation for the problem. The hypothesis is written as a statement that can be tested.

4 Test the hypothesis using an experiment.
5 Analyse and interpret the data collected from the experiment.
6 Draw conclusions about whether the hypothesis was supported or disproved.
7 Report on the investigation.

Note that although a hypothesis may be disproved, it cannot be proved. The results of an experiment can only provide *support* for the hypothesis. As Albert Einstein said:

> *No amount of experimentation can ever prove me right; a single experiment can prove me wrong.*

The scientific method outlined above can be applied to many problem-solving situations. Figure 1.5 shows how a doctor uses the scientific method to arrive at a diagnosis. A mechanic would probably use the same method to solve the problem of why a car won't start.



Problem
A patient with a sore throat visits a doctor. The doctor recognises the problem and formulates a question: *'What is causing the patient's sore throat?'*

Collect information
The doctor asks the patient how long her throat has been sore; takes the patient's temperature; feels the throat for swelling; looks carefully inside the patient's mouth.

Propose a hypothesis
The doctor proposes a hypothesis: *'The sore throat is caused by a bacterial infection.'*

Test the hypothesis
The doctor takes a swab from the patient's throat and sends it for testing at a laboratory.

Analyse and interpret data
The laboratory staff examine the culture from the patient's swab and check for disease-causing bacteria. They send their findings to the doctor.

Draw conclusions
As a result of the information from the pathology laboratory, the doctor decides that the patient's sore throat is caused by an infection of *Streptococcus*. The doctor's hypothesis is supported by the data collected from the test.

FIGURE 1.5 The scientific method

Scientific method
This website has one interactive that describes the scientific method and another that shows how it is applied in astronomy.

How science works
This website provides a series of modules designed to answer the question: 'What is science and how does it work?'

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Key concept

The scientific method provides a systematic approach to conducting investigations in order to test a hypothesis.

Some scientists are critical of descriptions of the 'scientific method' because of the many different ways of gathering data. One of the main criticisms of using this 'method' as a model of scientific investigation is that it does not give enough weight to the importance of observation as a means of obtaining knowledge. In some investigations, observation alone can lead to new understanding without the need for any experimentation.

Despite the criticisms, the scientific method is a useful model because it can be applied to many investigations. When you conduct investigations yourself, you will find the model a useful planning tool.

Literature review

One of the early steps in the scientific method is to 'collect as much information relating to the problem as possible'. One way of collecting information is to carry out a literature review. A **literature review** is a survey of the material that has been written about the subject under consideration. Literature reviews used to involve long hours of library research; however, the Internet has made them much easier to carry out.

The purposes of a literature review are as follows:

- To help the researcher define the problem: defining the problem carefully helps in the design of an investigation that will contribute to solving the problem.
- To find out what is already known about the problem: this prevents duplication of effort and allows the researcher to build on knowledge that is already available.
- To assess research methods: methods used by others may be used or adapted for the researcher's own investigation.
- To allow researchers to relate their findings to what is already known: this is particularly useful for the final report on an investigation. It is also helpful in considering areas for further research.

Safety

It is important that an investigation presents no danger to the participants or to the investigators. Examine the design of your investigation to make sure that any associated safety risks are minimised and controlled. Consider the need for safety devices such as fire extinguishers, fire blankets, fume hoods and eye washes. Also assess the need for personal protection such as safety glasses, gloves, face masks and protective clothing. For some investigations it may be necessary to assess the participants. For example, do they have any allergies to the substances being used? Do they have health problems that could be affected by the activities involved?

Safety considerations should include not just the physical safety of the people involved, but also factors such as whether the participants will feel insecure, threatened or embarrassed.

Ethics

Ethics are a set of moral principles or values. They are standards that are observed by most people in our society. **Ethical behaviour** is behaviour that follows those principles or values. In scientific research, especially research involving human participants, there are many ethical issues.

The following are some of the principles that an investigation involving humans must satisfy if it is to be ethically sound:

- *Voluntary participation* – the subjects should not be pressured into taking part in the investigation.
- *Informed consent* – the subjects should be fully informed about the objectives of the research, the procedures to be followed, any possible risks and the potential benefits of the research; consent should only be sought after all information has been given.
- *No risk of harm* – as mentioned in the section on safety, there should be no risk of physical or psychological harm.
- *Confidentiality* – the identities of participants will not be revealed except to people directly involved in the study.

Just as humans must be treated in an ethical way, so too must animals. The requirements for investigations involving animals are set out in the *Australian Code for the Care and Use of Animals for Scientific Purposes, 8th edition (2013)*. The code sets out detailed requirements, but in general terms any use of animals in research or teaching should be:

- valid
- humane
- justifiable
- considerate.

Controlling variables

A **variable** is any factor that may change during an experiment.

The **independent variable** is the factor that is being investigated – it is deliberately changed to determine its effect. This variable is deliberately made different in the control and the experimental groups in an experiment. By comparing the results from the control and experimental groups, the effect of the independent variable can be determined.

The independent variable may also be called the experimental variable or the manipulated variable.

The **dependent variable** is the factor that changes in response to the changes made to the independent variable. It is sometimes called the responding variable. The hypothesis should state the predicted relationship, or trend, between the independent variable and the dependent variable.

Controlled variables are the factors that are kept the same for both the control and the experimental groups in an experiment.

In any experiment it is important that, with the exception of the independent variable, all variables are kept the same for the control and the experimental group of subjects. If one or more is not kept the same, it is impossible to tell which variable is causing any difference between the two groups of subjects.

Sometimes it is difficult or impossible to keep all variables the same. **Uncontrolled variables** are variables that are not kept the same for the control and the experimental groups in an experiment. They may have been overlooked by the experimenter, or they may have been impossible to control. If there are uncontrolled variables in an investigation, this must be taken into account when interpreting the results.

Repetition and replication

Scientific experiments always involve repetition or replication. **Repetition** means doing the same experiment many times. **Replication** means having a number of identical experiments running together or performing the experiment on a large number of subjects at the same time. Both repetition and replication help to demonstrate that results are consistent. If results are different each time an experiment is performed, they are of little value.

Repetition and replication can also help to overcome the effects of uncontrolled variables. For example, if 10 subjects are used in an experiment and one of them is unusual in some way, it will have a big effect on the overall result. If 100 subjects were used, one unusual subject in 100 would not have much effect on the average result.

In designing any experiment, plan for as much repetition or replication as time and resources will allow.

Validity, accuracy and reliability of results

When an experiment tests what it is supposed to test, it has **validity**. Some scientists were testing the hypothesis that 'consumption of junk food affects people's memory'. They fed one group of young rats on fatty food for 12 weeks, and fed another group of older rats a low-fat diet. The rats' memories were then tested using an activity that involved pressing a lever. The rats fed on junk food were more forgetful, so it was concluded that the hypothesis was supported. This experiment did not test what it was supposed to test, for two reasons.

- Testing one species, rats, will only demonstrate the effect on the memory of rats, not any other species.
- Rats' memories may be affected by age. The two groups of rats should have been of the same age.

Experiments can also be invalid if there are uncontrolled variables – that is, if there are factors that could affect the result of an experiment that are not kept the same for the experimental and the control set-ups. When experimenting with humans, it is often very difficult to design a valid experiment because it is hard to control all the variables.

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FIGURE 1.6 Where possible, design an experiment so that the results are expressed as measurements. Measuring height in millimetres is much more meaningful than observations such as 'tall' or 'short'

The **accuracy** of data refers to how close the data is to the exact value. Accuracy is dependent on the equipment used, which needs to be calibrated correctly. For example, if an investigation involved measuring the mass is eaten, it would be more accurate to weigh the food with a laboratory balance than with bathroom scales. The balance would also need to be zeroed prior to weighing the food, for the mass to be accurate.

Reliability is the extent to which an experiment gives the same result each time it is performed. The measuring instruments used in the experiment must also be reliable; that is, they must give the same measurement each time they are used. For example, you may have a set of bathroom scales that give three different weights when you step on them three separate times. Those scales are unreliable, and if used in an experiment would make the results unreliable. The bathroom scales may give the same reading every time but it may be consistently higher or lower than the actual weight. In that case, the scales are reliable, but inaccurate.

Repetition and replication are used to identify that results are reliable, but they do not improve the accuracy of the experiment.

Key concept

During a controlled experiment the independent variable is changed to determine its effect on the dependent variable. All other variables are controlled so that the investigation is valid. The correct equipment is chosen and calibrated to ensure accuracy, and the experiment is repeated and replicated to ensure the data is reliable.

Types of data

Data from an investigation can be one of two types:

- **quantitative data** – expressed in numbers and usually involving measurement; for example, 'the students are 174 and 176 cm in height'
- **qualitative data** – observations that do not involve numbers or measurement; for example, 'student A is taller than student B'.

Wherever possible, you should design an investigation so that the results are quantifiable. Numerical results can be ranked, averaged and manipulated in other ways. They can also be summarised using graphs.

Sometimes it is possible to quantify qualitative data. For example, if asking people's opinions on something, they can be asked 'Do you disagree strongly, disagree, agree or agree strongly?' or asked to answer using a numerical value such as 1 for 'disagree strongly' to 4 for 'agree strongly'.

Secondary data

Secondary data is data that has been collected by someone other than the people who are using the data. For example, earlier in this chapter we quoted the rate of growth of Dr William Bean's fingernails. This is secondary data – fingernail growth was measured by Dr Bean, not by the authors of this book.

Errors and limitations in data

It is important that data is checked carefully for errors. In science, an error is not necessarily a mistake. Rather, it is any deviation from the result that should have been obtained. One of the reasons why scientists provide comprehensive reports on their investigations is so that others can check their data for errors.

Measurements made with any measuring instrument are approximate. For example, if you measure a person's height at several different times, the measurements are unlikely to be the same every time. This may be because there is natural variation in the subject, variation in the measurement process, or both. This uncertainty in measurement is called **measurement error**. In this case the word 'error' does not mean the same as 'mistake'. Your measurements are not wrong; the measurement error is the difference between the measurements you made and the true value of what you were measuring. Repetition can help to reduce measurement error, but it cannot overcome error caused by the limitations or deficiencies of the measuring instrument.

It is also important to understand the limitations of data obtained from an investigation. You must not draw conclusions that go beyond the data. Sometimes it is difficult to look objectively at data, and even experienced scientists can draw conclusions that are not necessarily supported by their data.

One example of reading too much into the data obtained in an investigation arose from a report by Norwegian scientists on the incidence of breast cancer in 25 624 women. Published in the *New England Journal of Medicine* (1997, vol. 336, no. 18, p. 1269), a prestigious medical journal, the results of the scientists' survey showed that the incidence of breast cancer in women who exercise regularly

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was reduced by 37%. The media reported on the investigation with headlines stating that 'exercise prevents breast cancer'.

Other scientists pointed out that women who exercise regularly are also likely to be non-smokers, drink less alcohol, have healthier diets, and have higher levels of education and higher incomes than women who do not exercise. Which of these variables was actually contributing to the reduction in breast cancer? Was it really exercise, or could it be having a healthier diet, being a non-smoker, having a better education, and so on? Could it be a combination of some of these factors? Each factor and combination of factors would have to be investigated before arriving at a firm conclusion. This example illustrates some of the pitfalls in analysing data.

Data may sometimes include a *confidence interval*. A confidence interval is used to indicate the reliability of data. It is the range of values above and below a result in which the actual value is likely to fall. For example, opinion polls published in the media may say that 53% plus or minus 1.5% of people will vote for Party X. The confidence interval is 51.5% to 54.5%. A confidence *interval* should be quoted along with a confidence *level*. The *confidence level* most commonly used in research is 95%. This means that if the research were repeated a number of times, the range of values obtained would contain the true value 95% of the time. In the survey of voters, if the survey were repeated many times, the proportion of people who intend to vote for Party X would be between 51.5% and 54.5%, 95% of the time.

Another example may help to clarify this concept. Suppose you wanted to find the average height of Year 12 students in Western Australia. You could measure the height of every Year 12 student in the state and then calculate the average height. This would give you an accurate result (the true value), but it would be impractical. A more practical method would be to measure a sample of Year 12 students. If you took a sample of 20 Year 12 students and calculated their average height it would give you an estimated result, but it would not tell you how certain you could be that your result was correct. Using a mathematical formula, a confidence interval could be calculated that would indicate the reliability of your estimate. The calculated confidence interval may show, for example, that using the same sampling method, the average height of Year 12 students will be between 167 and 179 cm, 95% of the time.

Processing data

If you have designed an experiment to give quantitative data, you will end up with a mass of figures that you must interpret. In a controlled experiment you will have to compare the control and the experimental results. There are some simple calculations that you can do to make the numbers more meaningful.

Average

In science a description of a set of numbers almost always includes a measure of its centre, or its **average**. Averages are a very common and simple way of handling sets of numerical data. The average that is most often calculated is the **arithmetic mean**, often just called the **mean**. To calculate the mean of a group of measurements, you add up all the measurements in the group and divide by the total number of measurements.

Sometimes in a set of measurements there will be values that are well beyond the range of the rest of the measurements. These are called **outliers**. The mean is affected by outliers, because a very high or very low outlier value will make the mean higher or lower than it would be without the outlier included. Outliers may result from mistakes in measurement, the failure of equipment or other errors. If the outliers clearly result from an error, they may be excluded when the mean is calculated.

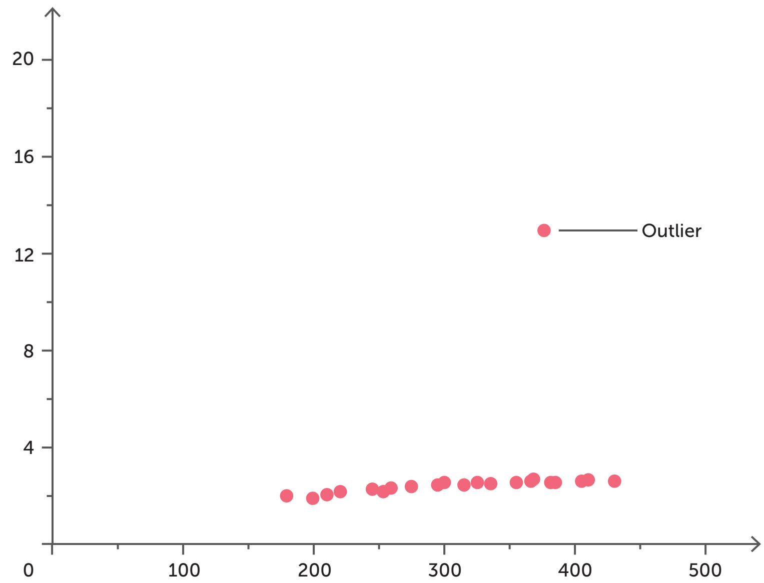

FIGURE 1.7 An outlier is beyond the range of the rest of the data

Median

The **median** is the middle of a set of numbers. It divides the lower set of numbers from the upper set. For example, the heights of the members of a cricket team were measured and (in centimetres) they were: 164, 176, 177, 177, 178, 181, 182, 182, 183, 185, 191.

The median height of the team was 181 cm; that is, 181 is the middle value – there are five team members with heights lower than 181 cm and five with heights higher. If there is an even number of measurements, then the median is taken as the mean of the two values in the middle of the set of numbers.

Using the median of a set of numbers reduces the influence of outliers. Outliers due to measurement error could have a significant effect on the mean of a set of numbers, but would have much less effect on the median.

Range

A measure of the centre of a group of numbers can be misleading. The mean, or the median, gives us no idea about whether all the values are clustered around the centre or whether there is a very wide spread from highest to lowest value. Any description of a set of numbers should therefore include both a measure of centre and a measure of spread.

The simplest way to indicate the spread is to quote the **range** – that is, the highest and lowest measurements in the group. For example, we could say that the heights of students in a Year 12 class ranged from 151 to 183 cm, with a mean of 171 cm.

Ratios and rates

A **ratio** is a numerical statement of how one variable relates to another. That is, it is a comparison of two numbers. Ratios are written as two numbers separated by a colon. For example, on older TV screens the ratio of width to height was 4:3. If the width is 40 cm, the height is 30 cm; if the width is 60 cm, the height is 45 cm; and so on. Modern, widescreen TVs have a ratio of 16:9.

A **rate** is a special kind of ratio that shows how long it takes to do something. For example, a very good athlete can run 10 000 m (10 km) in around 30 minutes. This is a rate of 1 km per 3 minutes, or 20 km per hour. Rate is much more meaningful than a simple count of how often something occurs. If you were investigating the effect of exercise on breathing, counting a person's breaths would be meaningless unless you knew how many breaths there were in a given time. That is, you need to know the rate in breaths per minute.

Percentages

'Per cent' means 'per hundred'. Percentages are used to express how large one variable is in relation to another. For example, if a breakfast cereal is labelled as containing 1.5% fat, it means that 100 g of the cereal contains 1.5 g of fat.

In Western Australia in 2011, males aged 15 to 19 years made up 6.7% of the population; females of the same age made up 6.4%. This means that for every 100 people in the population, 6.7 (or 67 per thousand) are 15 to 19 year-old males and 6.4 (64 per thousand) are 15 to 19 year-old females.

Percentage change

Calculating a percentage increase or decrease is often a good way to understand changes in a variable over time. For example, if a person weighing 100 kg lost 10 kg after dieting for six months, we could say that the person had lost 10% of their body weight as a result of the diet. If another person weighing 120 kg lost 13 kg after six months on the same diet, the percentage decrease would be 10.8%. Percentage change is helpful in making such comparisons.

To calculate percentage change:

1 *subtract* the old value (120 kg) from the new value (107 kg)
2 *divide* by the old value (120 kg)
3 *multiply* the result by 100 and add a per cent sign (%) to it.

This can be written as a formula:

$$\text{Percentage change} = \frac{\text{New value} - \text{Old value}}{\text{Old value}} \times 100$$

If the percentage change is positive, it indicates an increase; if the change is negative, it indicates a decrease.

Frequency

Frequency is the number of times an event occurs. For example, some students conducted a survey to find out how many drinks containing caffeine were consumed by the members of their class in a two-day period. The table of data they collected is called a **frequency distribution** or **frequency table**. A frequency table summarises the data by showing how often the variable in question occurs (Table 1.1). Frequencies can also be presented graphically as a **histogram** (Figure 1.8).

TABLE 1.1 Frequency table showing number of caffeine drinks consumed by students in a Year 12 class over a two-day period

NUMBER OF DRINKS CONSUMED	NUMBER OF STUDENTS
0	3
1	0
2	3
3	7
4	6
5	3
6	1
7	2

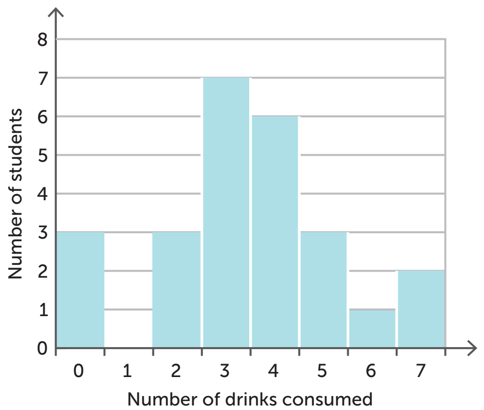

FIGURE 1.8 Histogram showing number of caffeine drinks consumed by students in a Year 12 class over a two-day period

Presentation of data

Tables

A convenient way to present numerical data is in the form of a table. The table of results for the students' survey of the number of caffeine drinks consumed in a Year 12 class over a two-day period could look something like Table 1.1.

Notice that the table follows these guidelines:

- It has a title. The title should state the variables represented by the data; in this case, the number of drinks consumed and the number of students are the two variables.
- The data is presented in columns. Usually the independent variable (in this case, the number of drinks consumed) is in the left column and the dependent variable (number of students) is in the right column. This rule is not always applied – it is more important that the table be easily understood.
- Each column has a heading and, where appropriate, the heading must state the units in which the data has been measured.

Graphs

Graphs are a pictorial way of presenting numerical data. A graph shows how changes in one variable affect another variable. From a graph it is easy to see any trends in the data. It is also possible to predict what the values would have been between the points plotted (**interpolation**), or the trend beyond the data shown in the graph (**extrapolation**).

Types of graphs

When drawing any graph, the following rules must be observed.

- The graph should have a title that states the two variables shown on the graph.
- The independent variable is plotted on the horizontal axis and the dependent variable is plotted on the vertical axis.
- Each axis is labelled with one of the variables and the units in which it is measured.
- Equal intervals of units are used on each axis.

The most commonly used graphs are line graphs (for continuous data), histograms (for frequencies) and, column graphs and bar graphs (for discrete data).

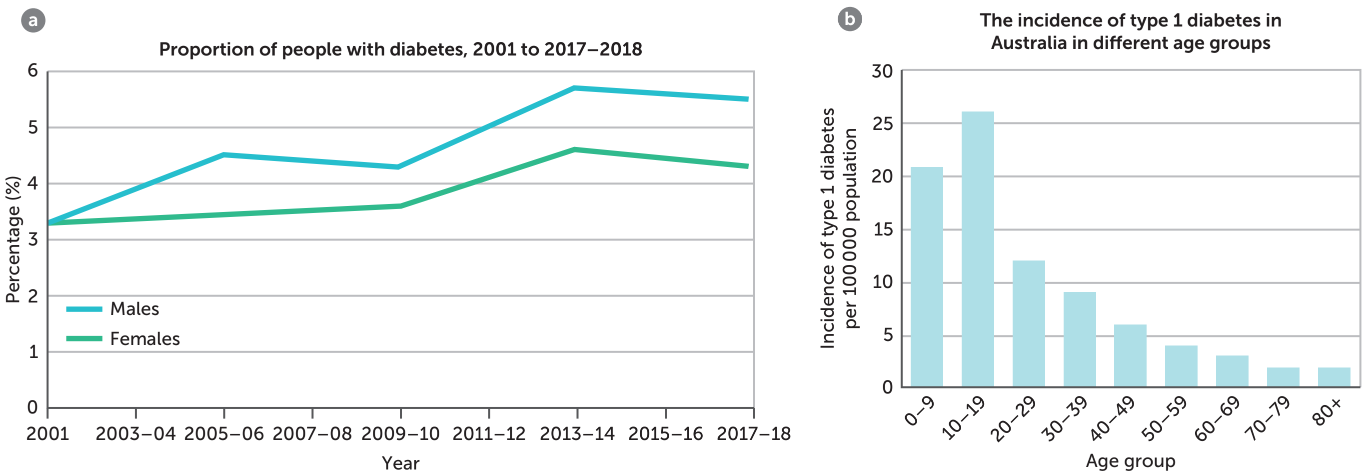

FIGURE 1.9 a Line graph; **b** Column graph. Data source a: Australian Bureau of Statistics, 4364.0.55.001 – National Health Survey: First Results, 2017–18. CC-BY 4.0 (https://creativecommons.org/licenses/by/4.0/); Data source b: Australian Institute of Health and Welfare (AIHW) CC-BY 3.0 (https://creativecommons.org/licenses/by/3.0/au/)

Key concept

Data is represented in tables and graphs and analysed to identify trends and patterns.

Models

In science, a **model** is a simplified representation of an idea or process. Figure 1.5 (page 7) is a model of the scientific method, where it is being applied to the steps a doctor may take in trying to diagnose an illness. Once a model has been developed it can be applied to a number of situations. The model for the scientific method can be applied to most scientific investigations.

Figure 2.2, in Chapter 2 (page 30), is a model showing in simple diagram form how hormones may affect the functioning of a cell. The stimulus–response–feedback model shown in Figure 5.3, in Chapter 5 (page 106), is a model that can be applied to the regulation of body temperature, blood glucose and many other situations.

A model may be a diagram, a flow chart or a physical model such as a model of the atoms in a protein. Scientific models often have to be modified as new data is collected.

Flow charts

A flow chart is a diagram that shows the steps involved in a process. The steps are usually shown in boxes and the sequence of steps is indicated by arrows. Flow charts are very useful in summarising and visualising the steps in a complex process.

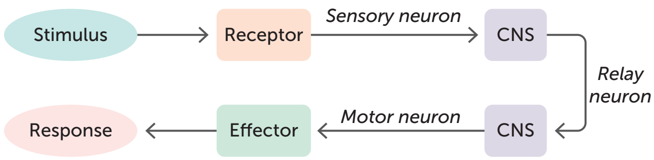

FIGURE 1.10 Flow chart for a reflex

Reference to the work of others

WS
1.1 Scientific investigations

An extensive examination of the literature at the start of an investigation allows the researcher to fully grasp the available information relating to the problem under consideration. This review also allows the results to be seen in the context of what is already known. Research done by others can also be used to support or confirm what has been discovered in the investigation. Demonstrating how your findings relate to what is already known will give credibility to your research and will add to the body of knowledge on the subject under review.

Questions 1.2

RECALL KNOWLEDGE

1. Arrange the steps of the scientific method in the correct order.
   - Report on the investigation.
   - Recognise a problem and define a question.
   - Draw conclusions about whether the hypothesis was supported or disproved.
   - Test the hypothesis using an experiment.
   - Analyse and interpret the data collected from the experiment.
   - Propose a hypothesis – a possible explanation for the problem.
   - Collect as much information as possible relating to the problem.
2. List four procedures or devices that increase safety during an investigation. For each one, describe a risk that it would be used for.
3. Define 'ethics'.
4. Describe the principle of informed consent with regards to investigations involving humans.
5. Match the description with the relevant term.

REPETITION	During an experiment, the scientist completed five trials for each variation of the independent variable.
REPLICATION	Five different scientists followed the same method to test the same hypothesis.

APPLY KNOWLEDGE

6 Explain why an investigation may disprove a hypothesis but not prove it.

7 Literature review is an important component of a scientific investigation, as it allows scientists to assess methods used by others. Explain why this improves an investigation.

8 A group of students was testing the following hypothesis: 'Drinking caffeine increases focus while studying.' The students tested 20 Year 12 students, with five girls and five boys drinking a can of cola prior to studying and five girls and five boys drinking the same volume of water prior to studying. The time each student remained focused during their study was recorded.
   - a State the independent variable for the investigation.
   - b State the dependent variable for the investigation.
   - c Describe the control group.
   - d Rewrite the hypothesis to better reflect what was tested.
   - e Was the investigation valid? Justify your answer.

9 During an investigation about the effect of different types of exercise, the following pulse rates, in beats per minute, were recorded prior to exercise.

54 65 62 58 60 66 84 57 61 65 59 63
   - a Calculate the mean for the data.
   - b Identify any outliers in the data.
   - c State the median pulse rate.
   - d State the range for the data.
   - e During exercise, the mean pulse rate was 96 beats per minute. Calculate the percentage increase in pulse rate due to exercise.

10 The average heights of males of different ages are shown in the table.

AGE	AVERAGE HEIGHT (MALE) (CM)
20–24	164.44
25–29	164.32
30–34	163.59
35–39	163.59
40–44	163.31
45–49	163.50
50–54	162.93
55–59	162.16
60–64	161.21
65–69	160.46
> 70	158.30

Construct an appropriate graph to represent the data.

1.3 REPORTING ON SCIENTIFIC INVESTIGATIONS

When an investigation has been completed, the findings need to be made known to others. This is usually done by a written report. Reports are a very important part of communication in science. Scientists inform others of their research by publishing a report in a scientific journal. There are thousands of scientific journals, some of which deal with a very narrow field of science. Examples are *Nature, Science, Journal of Musculoskeletal Research* and *Journal of Genetics*.

The editors of scientific journals use a process called **peer review** to make sure that the report is worthy of publication. A submitted report is sent to one or more scientists who are experts in the field and who may or may not recommend publication. This process is important as it helps to keep scientific literature free of incorrect, bogus or misleading information.

A scientific report includes a description of an investigation, the results that were obtained and any conclusions that can be drawn from the results. The description of how the investigation was done must be sufficiently detailed to allow other scientists to repeat the experiment. It is common practice for scientists to repeat experiments that others have performed. If the results obtained are not the same as those for the original experiment, any conclusions that may have been drawn are questionable.

Scientific report format

Scientific reports generally follow a fairly standard format, as follows:

- title of the report and name of the author or authors
- introduction, stating the nature of the problem investigated and the hypothesis tested
- materials and equipment, listing the apparatus used, particularly any specialised items of equipment
- method, describing the exact method used to carry out the investigation
- results, often presented as tables, graphs, diagrams or photographs
- discussion, including comments about the results and the way they relate to the hypothesis that was tested as well as an evaluation of the investigation
- conclusion, summarising the most important parts of the discussion and stating whether or not the hypothesis was supported
- further research, as scientific investigations often raise more questions than they answer – many reports suggest areas that need further investigation
- references, which list any reports, books, journal articles, websites or other sources of information referred to in the report
- acknowledgements, of people who helped with the investigation or of organisations that provided funds for the research.

The discussion

Report writing
This Monash University website gives detailed advice on report writing for scientific investigations.

Report writing FAQ
This University of New South Wales website gives advice on report writing and links to other useful sites.

The most important, and longest, part of a report is usually the discussion. The discussion is about the results and the method used to obtain the results. The discussion needs to be very thorough and to address all aspects of the research.

A checklist of questions that could be answered in the discussion section is as follows.

- Were there any defects in the design of the investigation or in the procedure?
- Were any results different from those expected?
- How do the results fit into the broader context of what is already known about the topic?
- Are there any practical applications for the results?
- Do the findings relate to any earlier work in the same area?
- Did the results support the hypothesis, or did they indicate that the hypothesis was incorrect?
- Were there any limitations in the research?
- Could the investigation have been improved in any way?
- Were there any variables that could not be controlled?
- Was there any bias in the results?
- Is there any information available from other reliable sources that would support the results?
- Is there a need for further research to clarify any of the results?

This is not an exhaustive list of questions. When writing a report, you will be able to think of other points that need to be discussed.

Key concept

Scientific reports are used to communicate information about investigations. These reports undergo peer reviews to ensure the validity of the processes and results.

Case study of a scientific investigation

French scientist Louis Pasteur (1822–95) conducted hundreds of investigations. His achievements include showing that micro-organisms cause disease, developing vaccines for rabies and some animal diseases, showing that micro-organisms are responsible for fermentation, and showing how the development of micro-organisms could be prevented by boiling and then cooling a liquid. This last process became known as pasteurisation.


Alamy Stock Photo/Science history images

FIGURE 1.11 Louis Pasteur

Activity 1.1
Researching for Mightypharm

Pasteur's investigations followed the scientific method. We can use aspects of his work as examples of many of the points discussed here. We will focus on Pasteur's demonstration that spontaneous generation does not occur. Spontaneous generation is the idea that living organisms can develop spontaneously from non-living matter.

Italian physician Francesco Redi had shown in 1668 that maggots develop from eggs laid by flies. Until then it was believed that maggots formed naturally from rotting meat. Another Italian, Lazzaro Spallanzani, demonstrated 100 years later that micro-organisms come from the air and that boiling can kill them.

Despite the work of Redi and Spallanzani, the belief persisted that micro-organisms could spontaneously develop in decaying organic matter. The French Academy of Sciences arranged a contest for scientists to disprove the idea of spontaneous generation. Pasteur took up the challenge in 1859. This is a good example of how scientific knowledge builds over time. First Redi, then Spallanzani and later Pasteur and many others were involved in debunking the idea of spontaneous generation.

Pasteur's reports
This website has one of Pasteur's research reports on the growth of micro-organisms, published in 1860.

Pasteur had a problem to be solved and his hypothesis was 'that micro-organisms occur in sterile culture medium only when exposed to contaminated air from the outside'. To test the hypothesis he began a series of meticulous experiments. He opened flasks of sterile broth in the streets of Paris and found that after a time there was abundant growth of micro-organisms in the broth. He opened flasks high in the Alps and the broth nearly always remained sterile. Variables other than the location of exposure were kept the same: the flasks were the same size and shape, with the same volume of the same type of broth. All flasks were opened for the same period of time and kept at the same temperature, and so on. From his results Pasteur was able to conclude that the flasks exposed in Paris became infected because of the large numbers of micro-organisms in the air. The flasks exposed in the Alps remained free of micro-organisms because there are fewer micro-organisms in the air at high altitude.

Another experiment that Pasteur performed involved placing broth in flasks and heating them to kill micro-organisms. Some of the flasks then had their necks heated and drawn out into a long S-shaped curve. The necks of control flasks were heated but left straight, allowing the air to access the broth. All flasks were left in the same location with their necks open to the air. After several weeks the broth in the flasks with straight necks had gone cloudy due to the activity of micro-organisms. Broth in the curved-neck flasks remained clear; the micro-organisms and dust in the air settled in the bend of the S-shaped tube and did not reach the broth in the flasks. This experiment confirmed Pasteur's earlier conclusion that the air contains micro-organisms. Pasteur summarised his findings in a report titled 'On the Organised Bodies that Exist in the Air. Examination of the Doctrine of Spontaneous Generation'.

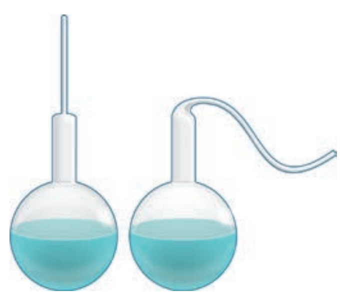

FIGURE 1.12 Types of flasks used by Pasteur in his experiment to demonstrate that spontaneous generation did not occur

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Support for Pasteur's conclusions came from English physicist John Tyndall. He showed that sterile broth exposed to air but kept in a dust-free chamber remained sterile indefinitely. Tyndall and Pasteur were aware of each other's work – an example of one scientist producing evidence that supported the findings of another.

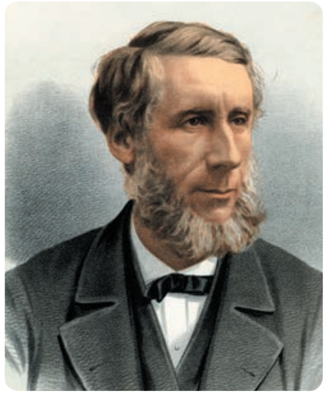


FIGURE 1.13 John Tyndall

Despite the convincing evidence, the dispute over spontaneous generation continued. Many were not convinced, and Pasteur often had to defend his research. At a lecture in 1864 he said:

> *... there is now no circumstance known in which it can be affirmed that microscopic beings came into the world without germs, without parents similar to themselves. Those who affirm it have been duped by illusions, by ill-conducted experiments, spoilt by errors that they either did not perceive or did not know how to avoid.*

This situation persists in science today. The findings of scientists are subject to intense scrutiny by others and are often the subject of criticism – sometimes warranted, sometimes not. One reason for writing reports and presenting papers at conferences is so that other experts can examine the results.

Ideas about spontaneous generation were not finally laid to rest until 1876, when Pasteur and his assistant, Charles Chamberland, discovered that some bacteria produce spores that are resistant to high temperatures. These resistant spores accounted for the development of micro-organisms in cultures that had apparently been sterile for long periods. Some scientists had claimed that such development was the result of spontaneous generation. Spontaneous generation had finally been refuted 16 years after Pasteur's first convincing experiments and more than 200 years after Redi's research on the topic.

Activity 1.2
Validating Pasteur's experiment

Questions 1.3

RECALL KNOWLEDGE

1. State the reasons that peer reviews are an important part of scientific investigations.
2. Describe what you should include in each of the following sections of a scientific report:
   - a introduction
   - b method
   - c results
   - d conclusion
   - e acknowledgements.
3. Where did people believe micro-organisms came from prior to Pasteur's investigations?

APPLY KNOWLEDGE

4. The largest part of a scientific report is the discussion. The information presented in the discussion can be classified as:
   - discussing the results and their implications
   - evaluating the results
   - evaluating the method.

   Classify each of the following according to these options.
   - a Were there any defects in the design of the investigation or in the procedure?
   - b Were any results different from those expected?
   - c How do the results fit into the broader context of what is already known about the topic?
   - d Did the results support the hypothesis, or did they indicate that the hypothesis was incorrect?
   - e Could the investigation have been improved in any way?
   - f Were there any variables that could not be controlled?
   - g Was there any bias in the results?
5. Explain how Pasteur's investigation using broth in flasks with different necks was able to support the hypothesis 'that micro-organisms occur in sterile culture medium only when exposed to contaminated air from the outside'.
6. Discuss the importance of Tyndall and Chamberland's work supporting Pasteur's in disproving the idea of spontaneous generation.

CHAPTER 1 ACTIVITIES

ACTIVITY 1.1 Researching for Mightypharm

Researchers working for the pharmaceutical company Mightypharm were extracting chemicals from a new species of toadstool discovered in the rainforests of Brazil. Several of the chemicals were compounds that had never been found before. The researchers decided that the new compounds might have the potential to be used as antibiotics in the treatment of human bacterial infections.

Imagine that you are one of the Mightypharm researchers and your task is to test the new compounds with the goal of eventually producing an antibiotic that can be used to treat bacterial infections in human patients.

- *Stage 1:* Propose a hypothesis linking the two variables (chemical compounds and effect on bacteria). Describe how you would test the hypothesis to find out whether any of the compounds are effective in killing bacteria. Make your description detailed enough for someone else to follow and carry out the same tests that you propose. Describe how you would present your results and what sort of results would indicate that a compound had potential for use as an antibiotic.
- *Stage 2:* Suppose that one of the compounds tested in stage 1 showed promise as an antibiotic. Describe how you would test that compound on animals to find out whether it worked and whether there were any side effects from use of the compound. Make your description detailed enough for someone else to follow your procedure exactly, and remember that there are ethical considerations relating to the use of animals in research.
- *Stage 3:* The promising compound has successfully passed stages 1 and 2. Describe how you would carry out human trials on the compound. Also, describe how you would deal with any ethical issues that may arise.

In writing your descriptions of stages 1, 2 and 3 you may wish, or your teacher may ask you, to present your material as a paper to be published in a scientific journal. Refer to page 18 for the format of a scientific report.

Further investigation

You may wish to investigate how a prescription drug currently in use was discovered, developed and marketed.

ACTIVITY 1.2 Validating Pasteur's experiment

You can repeat Pasteur's experiment in which he used flasks with S-shaped necks, to see whether you get the same results.

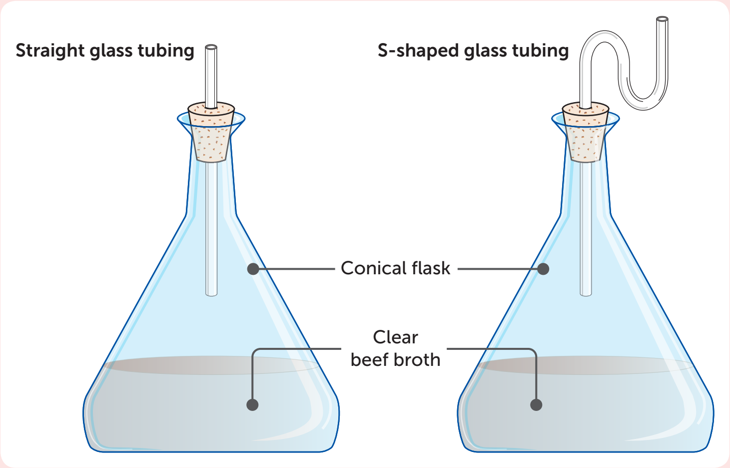
You will need

For each pair or group:

- beef stock cubes
- filter funnel and filter paper
- four 100 mL conical flasks
- four one-hole stoppers
- straight glass tubing and S-shaped glass tubing
- source of heat (hot plate or Bunsen burner)

What to do

1. Make a broth using the beef stock cubes.
2. Filter the broth so that it is clear.
3. Place equal volumes of broth in each of the four flasks.
4. In two flasks, place a stopper with straight glass tubing and in the other two flasks place a stopper with S-shaped tubing.
5. Gently boil the broth in each flask for 15 minutes.
6. Leave the flasks in a warm place and check every couple of days for evidence of the growth of micro-organisms, such as cloudiness, a scum or mould on the surface of the liquid, or bubbles. You may need to leave your flasks for several weeks before any changes are apparent.
7. At the conclusion of the investigation do not open any of the flasks. They must first be autoclaved at 120°C for 20 minutes under 100 kPa pressure to destroy any micro-organisms.



Studying your results

1. Describe your results, giving a description of the broth in each flask.
2. Combine your results with those of other groups in the class. Explain the advantage of combining results.
3. Were your results similar to Pasteur's? Were the class results similar to Pasteur's?
4. If your results were not similar to Pasteur's, can you suggest any explanation?
5. If you were to repeat the experiment, how could you improve it?

CHAPTER 1 SUMMARY

- Scientists use a range of different methods to acquire new knowledge, including observations, controlled experiments, surveys, trial and error, case studies and longitudinal studies.
- Controlled experiments involve changing one variable to identify the effect it has on the results.
- Surveys collect data from a large number of subjects to identify patterns.
- In science, trial and error involves testing a wide range of possibilities to find solutions.
- Case studies and longitudinal studies involve studying a particular person or situation. Longitudinal studies are conducted over a longer period than case studies.
- The scientific method provides a systematic approach to investigations.
- The scientific method involves identifying a problem, collecting information, proposing a hypothesis, testing the hypothesis, analysing the data and drawing a conclusion.
- Literature reviews survey material already written about the topic. This allows scientists to identify what is already known, assess research methods and relate findings to previous knowledge.
- It is always important to predict and address any safety issues for an investigation.
- Any investigations involving humans must adhere to ethical standards. This includes voluntary participation, informed consent, no risk of harm and confidentiality.
- Ethical principles must also be applied when working with animals.
- In a valid investigation, the independent variable is changed to determine its effect on the dependent variable. All other variables are controlled.
- Accurate data is close to the actual measurement. It is obtained by using the appropriate equipment, which has been calibrated correctly.
- Investigations are repeated and replicated in order to ensure the results remain the same.
- Reliable results occur when reliable measuring instruments are used and the same method is repeated.
- Data may be qualitative (descriptive) or quantitative (numerical), and can be represented in tables and graphs.
- An error, or a deviation from the correct value, is not necessarily a mistake in a scientific investigation. It can be due to a variation in the subject or measuring process.
- Data can be processed to determine the mean, outliers, median, range, ratio or rates, percentage change or frequencies.
- Models and flow charts can be used to represent ideas or processes.
- Peer reviews of scientific investigations ensure that they are valid.
- Scientific reports are used to communicate the process and findings from investigations.

CHAPTER 1 GLOSSARY

Accuracy How close a measurement is to the true value

Arithmetic mean Often called the mean; the total measurements in a group divided by the total number of measurements

Average The total measurements in a group divided by the total number of measurements

Case study An in-depth investigation of one particular person or situation

Controlled experiment An experiment in which there are two almost identical set-ups; the only difference between them is the one variable being tested

Controlled variable A factor kept the same for both the control and the experimental groups in an experiment

Dependent variable In an experiment, the factor that changes in response to changes made to the independent variable; also called the responding variable

Ethical behaviour Behaviour that follows a set of moral principles or values

Ethics A set of moral principles or values

Extrapolation An estimation beyond the range of the original data

Frequency The number of times an event occurs

Frequency distribution *see* frequency table

Frequency table A summary of the data showing how often the variable in question occurs

Graph A pictorial way of presenting numerical data; shows how changes in one variable affect another variable

Histogram A graph to represent the frequency distribution of data

Hypothesis A statement of the relationship between the independent and dependent variables that is testable

Independent variable In an experiment, the factor being investigated; the factor deliberately changed to determine its effect; also called the experimental variable or the manipulated variable

Interpolation An estimation within the range of the original data

Literature review A survey of the material that has been written about a subject under consideration

Longitudinal study A study conducted over a long period of time; may be carried out over years or even decades

Mean *see* arithmetic mean

Measurement error The difference between a measurement and the true value of what is being measured

Median The mid-point of a set of numbers

Model A simplified representation of an idea or a process; may be a diagram, a flow chart, a simplified description of a complex situation or a physical model such as a model of a cell; examples are the stimulus–response–feedback model and the lock and key model for enzyme action

Observation The process of using the senses to acquire information

Outlier A measurement well beyond the range of other measurements in a set

Peer review The evaluation of work by people with similar skills and knowledge

Qualitative data Observations that do not involve numbers or measurement

Quantitative data Data expressed in numbers; usually involves measurement

Range The difference between the highest and lowest measurements in a group

Rate A ratio that shows how long it takes to do something

Ratio A numerical statement of how one variable relates to another; written as two numbers separated by a colon

Reliability The extent to which an experiment gives the same result each time it is performed

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Repetition Doing the same experiment many times

Replication Having a number of identical experiments running together, or performing the experiment on a large number of subjects at the same time

Scientific method A process of conducting valid investigations

Secondary data Data collected by someone other than the person using the data

Survey The systematic collection, analysis and interpretation of information about a particular question or series of questions; usually designed so that data is collected from a large number of subjects

Trial and error A problem-solving method in which one attempt to solve the problem is followed by another; each trial is recorded and the results allow the investigator to gradually home in on the solution

Uncontrolled variable A variable that could not be kept the same for the control and the experimental groups in an experiment

Validity The extent to which an experiment tests what it is supposed to test

Variable Any factor that may change during an experiment

CHAPTER 1 REVIEW QUESTIONS

Recall

1 What is a controlled experiment?

2 List four principles that must be satisfied if an investigation is to be ethical.

3 What is a literature review and what are some of the reasons for carrying out such a review?

4 Describe how you would calculate the mean of a set of measurements.

5 What are outliers? Should outliers be excluded when drawing conclusions from a set of data?

6 Describe what a peer review is and why they are used.

7 Describe some of the points that should be included in the discussion section of a scientific report.

8 What is an ‘error’ when discussing a scientific investigation?

Explain

9 Explain the difference between:
  a observations and surveys
  b longitudinal studies and case studies.

10 a What is a hypothesis?
  b Can a hypothesis be proved? Explain.

11 a Explain the difference between the dependent and the independent variable in an experiment.
  b Explain the difference between controlled and uncontrolled variables.

12 Use an example to explain the difference between the validity and the reliability of an investigation.

13 Explain the difference between qualitative and quantitative data.

Apply

14 Re-read the account of Florey’s experiment in which he injected mice with penicillin (page 4). List the variables that Florey controlled in his experiment.

15 What did Albert Einstein mean when he said: ‘No amount of experimentation can ever prove me right; a single experiment can prove me wrong’?

16 Identify the type of investigation that would be the best for finding a solution to the following problems. Explain the reasons for your choice in each case.
  a Can people taste the difference between two different brands of milk chocolate?
  b What proportion of students in your school are left-handed?
  c What is the ratio of males to females in your Human Biology class?
  d How has a particular person’s growth rate changed from birth to age 15?

17 In addition to physical activity that is part of their job or daily routine, many people deliberately exercise by going to a gym or by walking or jogging. Describe how you would conduct a survey to find out the average amount of time the teachers at your school spend on deliberate exercise.

18 The table below shows the systolic blood pressure of students in a Year 12 Human Biology class.

SYSTOLIC BLOOD PRESSURE OF YEAR 12 STUDENTS (mmHg)					
109	123	141	115	131	126
144	138	106	115	49	109
125	132	128	114	116	120
195	143	132	116	13	

a Are there any obvious outliers in the data in the table? If so, which are the outliers and why should they be regarded as outliers?

b Calculate the mean systolic blood pressure for the class, excluding any outliers.

c What is the range of blood pressures in the class?

d What percentage of students had a blood pressure of 130 mmHg or higher?

e The average systolic blood pressure for adults is 120 mmHg. What proportion of students have blood pressures above this average?

19 Researchers investigating the benefits of exercise in preventing heart disease studied the health outcomes for women after participating in an exercise program. They calculated the risk of heart disease at 0.18 with a confidence interval of 0.04 to 0.80 at the 95% confidence level. Explain what the data means.

Extend

20 In 2003, a team of Australian anthropologists discovered skeletal remains on the Indonesian island of Flores. One skeleton was of a small human with a small brain, and dating showed it to be 18 000 years old. The team claimed it was a new species of human and named it *Homo floresiensis*. Experts are divided on whether the discovery is a new type of human or whether there is some other explanation for the small stature and small brain. This is a good example of scientific debate about the meaning of data.
Use the Internet to find out some of the hypotheses put forward to explain why the skeleton is really our own species, *Homo sapiens*.

21 A research method sometimes used by scientists is meta-analysis. Find out what is meant by 'meta-analysis' and give an example of an investigation that used this method of research.

22 Some controlled experiments are said to be 'double-blind' experiments. Find out what is meant by the term 'double-blind experiment' and give examples of how such experiments might be used.

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