
The world we have created is a product of our thinking; it cannot be changed without changing our thinking.
Albert Einstein

1 Science is . . .

You can increase your knowledge of science by listening to others, reading books or surfing the internet. But the best way to learn about science is to conduct your own investigations. Whether you're a professional scientist or at school or home, every investigation starts with a question.

OVERARCHING IDEAS

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

GENERAL CAPABILITIES

Literacy
Numeracy
ICT competence
Critical and creative thinking
Ethical behaviour
Personal and social competence
Intercultural understanding

SCIENCE AS A HUMAN ENDEAVOUR

Nature and development of science
Use and influence of science

SCIENCE INQUIRY SKILLS

Questioning and predicting
Planning and conducting
Processing and analysing data and information
Evaluating
Communicating

This is an extract from the Australian Curriculum.
Any elaborations may contain the work of the author.

THINK ABOUT SCIENCE

- How do all scientific investigations begin?
- Which great medical discovery was helped along by a single teardrop?
- Why is planning so important to a scientific investigation?
- Where do you go to research the topic of a scientific investigation?
- What is a controlled variable?
- How can a spreadsheet save you time in a scientific investigation?
- How does a data logger improve the gathering of data?

YOUR QUEST

It always starts with a question

Questions, questions, questions! That's what scientific research is all about — questions such as:

- How old is the universe?
- Why did dinosaurs become extinct?
- What is the smallest particle inside an atom?
- How can the common cold be cured?

Every science investigation, whether it is conducted in a government research laboratory, a hospital, a museum or a space shuttle, begins with at least one question.

Although you are unlikely to even attempt to try to answer the questions above in your school science laboratory, there are many scientific questions that you can answer. Here are some examples.

- Does an audience affect the performance of an athlete?
- What is the best shape for a boomerang?
- Which type of soil do earthworms prefer?
- How do heating and cooling affect the way that rubber stretches?

Scientific understanding, including models (like this one of DNA) and theories, is contestable and refined over time.

When do you perform at your best?

INQUIRY: INVESTIGATION 1.1

What can I investigate?

1 In groups, brainstorm a list of questions that could be answered by doing an investigation in a school science laboratory. Record all the questions that are suggested even if they seem silly or difficult. The examples above left might help you to think of some other ideas.

2 From your list, remove any questions that the group feels are not likely to be answered because of a lack of the right equipment. Keep a record of the questions that are removed for this reason to submit to your teacher. You may find that equipment you thought was unavailable can be obtained, or that the question can be answered with different equipment.

3 From your list, remove any questions that the group feels would be unsafe to try to answer, or that would be cruel to animals.

4 Submit the remaining questions to your teacher for discussion by the whole class.

1.1 SCIENCE AS A HUMAN ENDEAVOUR

In the shoes of scientists

Before you 'put on the shoes of a scientist' to design and carry out your own scientific investigation, it's worth spending some time thinking about what, or who, a scientist is. What qualities must a scientist have? It's not an easy question to answer. In fact the answers have been changing constantly for more than 2000 years.

An ancient perspective

The ancient Greek scientists, from the time of Democritus (around 500 BC) — who suggested that all matter was made of tiny particles — were called **philosophers**. They were thinkers, who tried to explain the structure of matter and creation of the sun and night sky.

The ancient Greek philosophers were curious and made accurate **observations**. They discussed their ideas with each other and with their followers and developed ideas that we would now call **hypotheses**. However, they did not perform experiments to test their ideas.

Stepping stones

Although the ideas of the ancient Greek philosophers were limited by a lack of technology, they provided a stepping stone for the more recent growth in scientific knowledge.

Aristotle, born in Greece fourteen years after the death of Democritus, reasoned that all matter was composed of four elements — earth, air, fire and water. About 2000 years later, Scottish scientist Joseph Black (1728–1798) discovered a fifth 'element'. He had discovered a new gas that he called 'fixed air'. We now call the gas carbon dioxide and know that it is not an element.

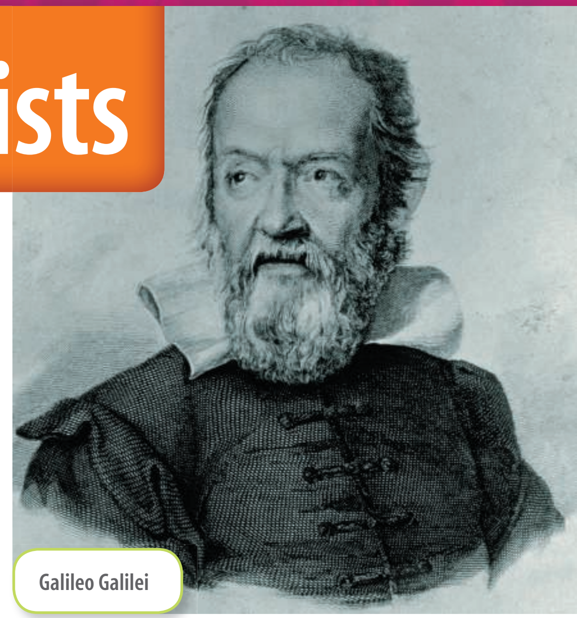
There are many other examples, including Hippocrates, born in the same year as Democritus, who taught his medical students to use observation rather than theory to diagnose illness. Hippocrates is regarded by many as the father of modern medicine.

Almost without exception, present-day scientific discoveries depend on work done previously by other scientists.

The scientific revolution

The way in which scientists worked changed greatly during the lifetime of Galileo Galilei (1564–1642), who is probably best known for being the first person to use a telescope to study the moon, planets and stars. Galileo also performed many experiments to investigate the motion of objects on the Earth's surface.

Galileo wrote about the need for controlled experiments and the importance of accurate observations and mathematical analysis. In fact, Galileo is described by many scientists and historians as the founder of the scientific method.


Galileo Galilei

eBook*plus* eLesson

Australia's top scientists
Watch an ABC Television Catalyst video about the top 20 scientific contributions made by Australian scientists.
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GALILEO'S LEGACY

Some of the great scientists of the seventeenth century who followed Galileo and used the scientific methods he wrote about were:

- Johannes Kepler (1571–1630), who developed a number of laws about the motion of planets around the sun
- William Harvey (1578–1657), who used scientific methods to discover how blood circulates through the human body
- Robert Boyle (1627–1691), who applied the scientific method in chemistry to investigate the structure of matter more than 200 years before the current model of the atom was developed
- Robert Hooke (1635–1703), who used the newly invented microscope to observe and investigate the cells that make up living organisms.

These scientists were followed by Sir Isaac Newton (1642–1727), who was born in the same year that Galileo died. Newton was able to use mathematics to describe and explain the role of gravity in the motion of the Earth and other planets around the sun. He also explained much of the behaviour of light.

The work of the scientific pioneers of this era has influenced the thinking of those that followed and continues to influence scientists in the twenty-first century.

Working in teams

Until the twentieth century, most scientists worked alone, with little or no financial support. Communication between individual scientists was difficult. Many of them wrote to each other and read the work of their fellow scientists. However, the telephone was not invented until 1876 and, of course, there were no fax machines, no computers and no overseas travel except by ship.

Since the early twentieth century, most scientists have worked in teams. Their work is almost always supported and funded by organisations, industry or governments. Communication and teamwork between scientists all over the world are easier to achieve because of phones, fax machines, the internet, email and jet aircraft.

MODELLING DNA

James Watson and Francis Crick won the Nobel Prize in 1962 for a piece of work that was a key discovery in biochemistry. In 1953 they established the structure of deoxyribonucleic acid, or DNA, the substance that makes up genes.

The model of DNA developed by Watson and Crick was based on the results of other scientists; for example:

- the work of Erwin Chargaff, who determined the basis of parts of DNA in 1951
- the X-ray diffraction photographs (taken using X-rays rather than light) developed in 1949 by Rosalind Franklin and Maurice Wilkins.

Rosalind Franklin provided an important stepping stone in the discovery of DNA.

Watson and Crick's breakthrough with DNA was possible thanks to the earlier discoveries of other scientists. Scientists today continue to build on the work of Watson and Crick. Their breakthrough has allowed other scientists to understand inherited diseases, and enabled the new field of genetic engineering to emerge.

Watson and Crick and their model of DNA

Other branches of science work in a similar way. There are many examples of scientists furthering the work done by their colleagues, such as the recent achievements of genetic researchers.

UNDERSTANDING AND INQUIRING

REMEMBER

1 Identify two aspects of what is now called 'the scientific method' that the ancient Greek philosophers practised.

2 According to Aristotle, all matter was composed of four elements. What were those elements?

3 Why was Galileo described by many as the founder of the scientific method?

THINK

4 Why was the period of the seventeenth century labelled 'the scientific revolution'?

5 Name some major technologies that were not available to the early Greeks and that have helped modern scientists to test their hypotheses.

6 Which technologies did seventeenth-century scientists have available to them that the early Greek scientists did not have?

7 List the qualities that you would expect a present-day scientist to have.

INVESTIGATE

8 Research and report on the Hippocratic Oath and its importance to medical practitioners.

9 Joseph Black made other discoveries as well as the one described here. Research some of these and find out how they have affected everyday life.

IMAGINE

10 Imagine that Galileo Galilei could return to a university in Italy today and observe the way in which scientists at the university worked. Write a one-page account of the observations that he might enter into his diary at the end of the day.

Accidents and observations

Some of the greatest scientific discoveries have been made by accident. The development of batteries, penicillin and X-rays began with 'accidents' in laboratories. However, was it all just a matter of luck?

Jumping frog's legs

The very first electric cell was created by accident over 200 years ago. Luigi Galvani, an Italian physician, was dissecting the leg of a recently killed frog. The leg was held by a brass hook. When he cut the leg with an iron knife, the leg twitched. Galvani investigated further by hanging the frog's legs on an iron railing with brass hooks. Whenever the frog's legs came into contact with the iron railing, they twitched. Galvani incorrectly proposed a theory of 'animal electricity' as the reason behind the muscle spasms.

Reports of Galvani's observations reached his friend Alessandro Volta, another Italian scientist. Volta suggested that the twitch was caused by a sudden movement of electric charge between the two different metals. The frog's flesh, he suggested, conducted the charge. Galvani had, without realising it, produced the world's first electric cell. The **galvanometer**, an instrument used to measure small electric currents, was named after Luigi Galvani.

Outside looking in

X-ray images allow doctors, dentists and veterinarians to 'see' through living flesh. The pictures taken with X-rays, called radiographs, are obtained by passing X-rays through objects onto a photographic plate. Unlike light, X-rays pass through the human body. Some parts of the body absorb more of the X-rays than others, leaving a shadow on the plate. Bones leave the sharpest shadows, making it possible to detect fractures and abnormalities.

X-rays have many other uses. They are used in metal detectors at airports and to detect weaknesses and cracks in metal objects. X-rays can be used by archaeologists to examine ancient objects (including Egyptian mummies) found under the ground or in ruins without touching and damaging them.

X-rays were discovered by accident in 1895 while German physicist Wilhelm Röntgen (pronounced 'Rentjen') was experimenting with a glass tube that glowed as electrons moved through it at high voltage. He had, by chance, left a photographic plate on a nearby bench. Röntgen noticed that whenever electrons were passing through the tube, the photographic plate glowed. This was puzzling because the glass tube was wrapped in heavy black paper and, since the room was in total darkness, there was no light to expose the photographic plates.

Röntgen investigated his puzzling observations further. He found that these mysterious rays that seemed to be coming from the tube could pass through human flesh as well as black paper. He obtained a clear image of the bones in his wife's hand as she rested it on the photographic film.

Röntgen's accidental discovery changed the face of medical practice in many ways.

X-ray pictures can reveal broken bones and disease in internal organs.

One accident after the other

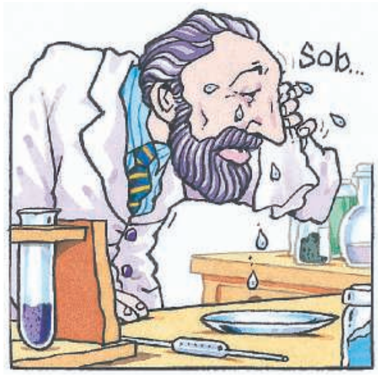
Penicillin is one of the most commonly used drugs in the treatment of diseases caused by bacteria. The discovery and production of penicillin followed a series of accidental observations. The first observation of penicillin was made in 1928 by Scottish bacteriologist Sir Alexander Fleming.

Fleming's interest in bacterial diseases intensified during World War I, when he was treating wounded soldiers. He noticed that the antiseptics used to treat wounds killed white blood cells more quickly than the harmful bacteria they were designed to kill. The white blood cells form part of the body's natural resistance to bacteria.

After the war, Fleming began searching for substances that would kill bacteria without harming the body's natural defences.

One day during his search, a teardrop fell into a dish containing a layer of bacteria. When he checked the dish the following day, he noticed a clear layer where the teardrop had fallen. Fleming then found that a chemical in human teardrops, which he named **lysozyme**, was able to kill some types of bacteria without harming the body's natural defences. Unfortunately, lysozyme was not effective against most disease-causing bacteria.

Fleming's greatest discovery occurred in 1928 when he was trying to find a cure for influenza. A tiny piece of mould had fallen into a Petri dish in which he was growing bacteria before the lid was put on. Fleming noticed that there was no further growth of bacteria around the mould. He



later admitted that if it had not been for his earlier experience with the teardrop, he may have thrown the dish away because it had been spoiled.

The mould, *Penicillium notatum*, contained a substance called **penicillin**, which kills many disease-causing bacteria without harming the body's natural defences. A new problem arose — how to separate and purify the substance. It was an Australian scientist, Howard Florey (1898–1968), who succeeded in separating and purifying the penicillin antibiotic. Together with Boris Chain, a Jewish refugee from Germany, Florey found a way of producing enough penicillin to treat a number of diseases. Their success came just in time for use in treating the many wounded in World War II. Fleming, Florey and Chain shared the Nobel Prize in Medicine in 1945.

Electron micrograph of Penicillium mould-producing spores

UNDERSTANDING AND INQUIRING

REMEMBER

1 Which modern-day device was accidentally created by Luigi Galvani?

2 What form of radiation was discovered by Wilhelm Röntgen?

3 Which drug was later produced as a result of Alexander Fleming's accidental observation?

THINK

Your answers to questions 4 and 5 could be presented in a table.

4 Consider the discoveries made by Galvani, Röntgen and Fleming. In each case, describe the skills and scientific knowledge used in making and developing their discovery.

5 Make a list of the personal qualities that enabled Galvani, Röntgen and Fleming to take advantage of their chance observations.

6 Were the discoveries of the electric cell, X-rays and penicillin really just accidents? Explain your answer.

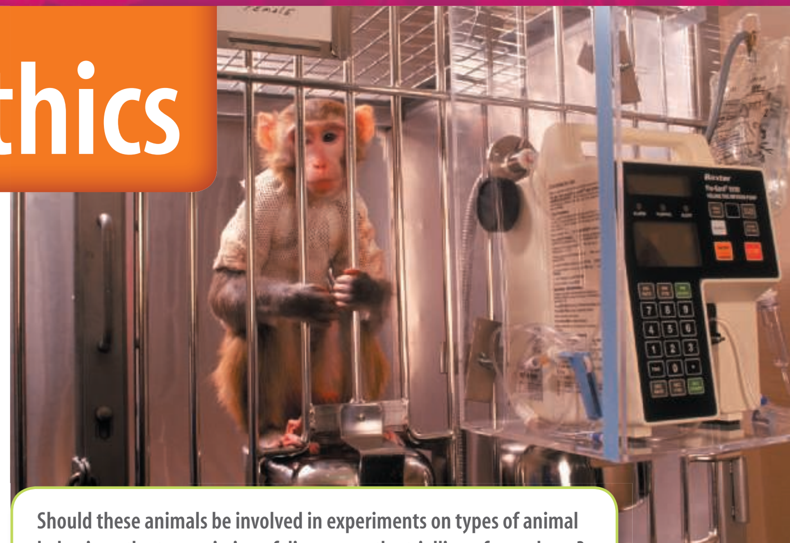
IMAGINE

7 Do you think that the electric cell, X-rays and penicillin would have been discovered if it had not been for the chance observations of Galvani, Röntgen and Fleming? Explain your answer.

INVESTIGATE

8 Find out about some other scientific discoveries that were the result of accidents or chance observations.

A question of ethics



Should these animals be involved in experiments on types of animal behaviour, the transmission of diseases or the trialling of new drugs?

Ethics is the system of moral principles on the basis of which people, communities and nations make decisions about what is right or wrong. Scientific inquiry takes place in communities that have political, social and religious views and is undertaken by people who have personal views about all sorts of issues. It is a human endeavour and therefore cannot be separated from ethics and questions about right and wrong.

Ethical values vary between countries, religions, communities and individuals — even between members of the same family. For example, capital punishment, the execution of a person for committing a crime, is considered by some to be right and by others to be wrong.

Science interacts with ethics in several ways, including:

- affecting the way in which science is conducted
- affecting the types of scientific research carried out
- in the conflict or match between scientific ideas and religious beliefs
- providing scientific community practices that act as a model for ethical behaviour.

Animal testing

Animals are used in scientific research in many ways, including: to test the effects of potential drugs; to test cosmetics for allergies; to understand the functioning of parts of the body; and to test new surgical techniques. In some research and testing, the animals die. Animals used may include monkeys, bees, mice, worms and dogs, among others.

There are ethical issues about whether animals should ever be used in scientific research, or if some types of animals shouldn't be used, or if some types of research shouldn't be carried out at all.

Medical research

Medical research is carried out partly by public institutions such as universities and specialist research departments, and partly by private companies. The main purpose of research in public institutions has been to increase understanding and to provide solutions to existing problems; while private companies aim to provide new products or services that can be sold for profit. Some research in public institutions is done with the aim of making money, and some private research aims at increasing scientific knowledge, which raises ethical questions about whether new drugs are produced more for their profitability than for the benefit of the community.

Life expectancy varies greatly around the world, as do patterns of disease. Cancer, heart disease and diabetes kill many Australians and billions of dollars are spent on researching their causes and treatment. Diarrhoeal diseases and malaria are readily treated in Australia, but kill millions of people each year in Africa, Asia and South America — sometimes because of lack of information and sometimes because of lack of low-cost products. This raises ethical and social questions, such as:

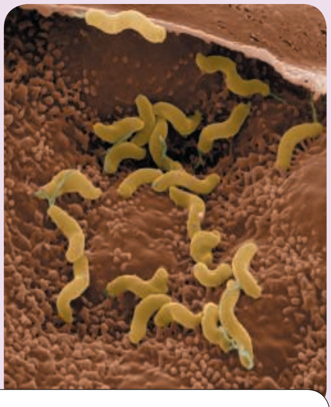
- Is it right that effective drugs are unavailable to millions because of their cost?
- What is the fundamental purpose of developing pharmaceuticals?
- Should the type of treatment be determined by the profit it generates?

Another source of ethical concern in medical research relates to the testing of new drugs. When pharmaceutical companies design new drugs, they need to test these thoroughly before being able to sell them. Some people argue that the testing regime is too lengthy and that new drugs that have the potential to treat deadly diseases should be supplied to the people dying from these diseases even if the drug has not been fully tested.

HOW ABOUT THAT!

When Barry Marshall and Robin Warren came to the conclusion that stomach ulcers were probably caused by a bacteria, they were faced with some tricky ethical and safety considerations. A stomach ulcer occurs when the lining of the walls of the stomach becomes damaged and the acid inside the stomach eats away at the stomach wall. It is a very painful condition. Previously it was thought that ulcers were caused by lifestyle factors, including stress, so it was difficult to treat ulcers. People were usually told to avoid stress, for example by changing job or cutting their work hours, and to cut out particular foods, sometimes with no improvement to their health.

Barry Marshall and Robin Warren suspected that ulcers were actually caused by bacteria called *helicobacter pylori*. They had found these bacteria in the stomachs of people suffering from stomach ulcers but not in the stomachs of healthy individuals. They had also studied the bacterium. The only way to know for sure would be to deliberately infect someone with the bacteria and find out whether they developed a painful ulcer. There were risks involved; for instance, the bacteria could cause other health problems. It could even kill the patient. There were also ethical issues associated with deliberately trying to make a healthy person sick. In the end, Barry Marshall carefully weighed up the risks involved and decided to test his hypothesis on himself. He swallowed a solution of the bacteria and soon became ill and developed the early symptoms associated with the development of stomach ulcers. He then treated himself with antibiotics. Now when a patient is diagnosed with a stomach ulcer, treatment is simple — a course of antibiotics usually fixes the problem.



Helicobacter pylori bacteria in the human stomach cause stomach ulcers. They move their hair-like structures to travel around the stomach lining.

Agriculture

Traditional plant breeding methods — manually putting pollen from one plant into the flower of another to produce a 'cross'— were once the only means of modifying plant types; a slow and laborious process. Now, using techniques for moving genes from one plant to another, it is possible to design plants that have certain characteristics. This technique of **genetic modification (GM)** is controversial. GM crops are greatly restricted in Australia. GM techniques have been used to produce crops that:

- are resistant to herbicide so that weed control is more effective (canola)
- produce their own pesticides to reduce insect attack (cotton)
- contain added nutrients (rice).

Discussion about the ethics of GM crops often focuses on the role of companies in developing GM crops for the profit they are expected to bring. Ethical issues are also raised about whether GM techniques should be used by public research laboratories and international agencies to improve food supply in regions where many people are undernourished.

UNDERSTANDING AND INQUIRING

REMEMBER

1 Explain why scientific inquiry should not take place without considering whether it is right or wrong.

2 Identify an illness that affects people worldwide and kills millions in poor countries but almost no-one in Australia.

3 Explain how GM crops are different from other crops.

THINK

4 Describe the ethical issues associated with the experiment carried out by Barry Marshall.

DISCUSS

5 In small groups, discuss the following statements.
 (a) Cosmetics should never be tested on animals.
 (b) All medical research, including research into new drugs, should be done by non-profit organisations rather than by companies aiming to make a profit.
 (c) Food made from genetically modified crops should have a special label to show that it contains GM ingredients.

INVESTIGATE

6 What does a bioethicist do? What training does a bioethicist require?

7 Research and report on alternatives to using animals in research.

8 Outline some of the arguments against using genetically modified crops.

Your own investigation

Begin with a plan

Whenever you take a trip away from home, you need to plan ahead and have some idea of where you are going. You need to know how you are going to get there, what you need to pack and have some idea of what you are going to do when you get there.

It's the same with an experimental investigation. Planning ahead increases your chances of success. It's easier if you can break an investigation down into steps as shown below.

Finding a topic

Your investigation is much more likely to be of high quality if you choose a topic that you will enjoy working on. These steps might help you choose a good topic.

1. Think about your interests and hobbies. They might give you some ideas about investigation topics.
2. Make a list of your ideas.
3. Brainstorm ideas with a partner or in a small group. You might find that exchanging ideas with others is very helpful.

Think about your interests.

Think about your hobbies.

Brainstorm your ideas with others.

4. Find out what other students have investigated in the past. Although you will not want to cover exactly the same topics, investigations performed by others might help you to think of other ideas.
5. Do a quick search in the library or at home for books or newspaper articles about topics that interest you. Search the internet. You might also find articles of interest in magazines or journals. You could use a table like the one below to organise your ideas.

Topic area	Name of book, magazine, website etc.	Chapter or article	Topic ideas

FROM OBSERVATIONS TO IDEAS

Many ideas for scientific investigations start with a simple observation. Some well-known investigations and inventions from the past started that way. Even though the discoveries by Galvani, Röntgen and Fleming described in section 1.2 were made by accident, they would not have been made without observation skills. There is also another important 'ingredient' in these discoveries — curiosity and the ability to ask questions and form ideas that can be tested by experiment and further observation.

Danish scientist Hans Oested discovered the connection between electric current and magnetism when, in 1819, he noticed that a compass needle pointed in the wrong direction every time it was placed near a wire carrying an electric current. He went on to design experiments to find out exactly how different electric currents affected compass needles. The results of his experiments started a flood of inventions, including electric generators and motors.

An investigation by 15-year-old student Catherine Pippos began with an observation that her friends seemed to perform better in track and field events when there was an audience cheering them on. You have probably seen this yourself. Her investigation

'Does an audience affect the performance of an athlete?' involved three different sporting activities and compared the performance of a large group of students under three different conditions:

- no audience
- a quiet audience
- a cheering audience.

The sporting activities were:

- goal shooting in basketball
- sit-ups
- shot-put.

What do you think she found out? Perhaps you could try a similar investigation.

Could an audience really affect this athlete's performance? To answer the question scientifically an investigation is needed.

DEFINING THE QUESTION

Once you have decided on your topic, you need to determine exactly what you want to investigate. It is better to start with a simple, very specific question than a complicated or broad question. For example, the topic 'earthworms' is very broad. There are many simple questions that could be asked about earthworms. For example:

- Which type of soil do earthworms prefer?
- How much do earthworms eat?
- Do earthworms prefer meat or vegetables?
- How fast does a population of earthworms grow?

There are many problems relating to earthworms that could be investigated.

Your question needs to be realistic. In defining the question, you need to consider whether:

- you can obtain the background information that you need
- the equipment that you need is available
- the investigation can be completed in the time you have available
- the question is safe to investigate.

Keeping records

A **logbook** is an essential part of a long scientific investigation. It provides you with a complete record of your investigation, from the time you begin to search for a topic. Your logbook will make the task of writing your report very much easier.

A logbook is just like a diary. Make an entry whenever you spend time on your investigation. Each entry should be clearly dated. It's likely that the first entry will be a mind map or list of possible topics. Other entries might include:

- notes on background research conducted in the library. Include all the details you will need for the bibliography of your report (see pages 14–15).
- a record of the people that you asked for advice (including your teacher), and their suggestions
- diagrams of equipment, and other evidence that you have planned your experiments carefully
- all of your 'raw' results, in table form where appropriate
- an outline of any problems encountered and how you solved them
- first drafts of your reports, including your thoughts about your conclusions.

AN ONLINE LOGBOOK

An exercise book can be used as a logbook, but there are several advantages in maintaining your logbook online in the form of a **blog**. There are many sites that will allow you to set up a free blog. Your teacher might be able to provide some suggestions. Once you set up a blog, every entry you make will be dated automatically. You can upload documents, diagrams, photos and short videos. You can also add links to other sites and invite friends, family and teachers to post comments about your progress.

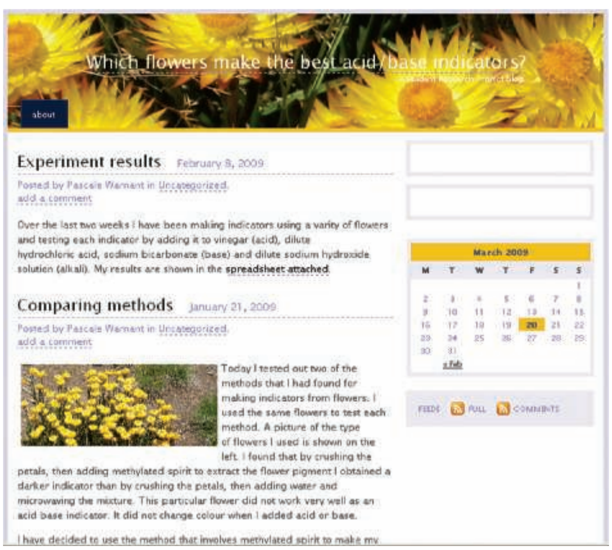
There are some precautions that you should take if you decide to use a blog as a logbook.

- Limit your posts to those related to your science investigation. Don't use your logbook blog for social networking.
- Do not include your address or phone number.

- If your blog is on the internet (rather than a school intranet):
  - do not post any photos of yourself in school uniform or any other clothing that will identify where you go to school
  - do not include your full name, address, phone number or the name of your school in the blog. Use only your first name or a nickname.
  - use privacy settings or use a password to ensure that only trusted school friends, family and your teacher have access to the blog.

WHAT DOES IT MEAN?

The word *blog* is a very recent addition to the English language. It is an abbreviation of the words *web log*.



Which flowers make the best acid/base indicators?

about

Experiment results February 8, 2009

Posted by Pascale Warnant in Uncategorized.
add a comment

Over the last two weeks I have been making indicators using a varity of flowers and testing each indicator by adding it to vinegar (acid), dilute hydrochloric acid, sodium bicarbonate (base) and dilute sodium hydroxide solution (alkali). My results are shown in the spreadsheet attached.

Comparing methods January 21, 2009

Posted by Pascale Warnant in Uncategorized.
add a comment

Today I tested out two of the methods that I had found for making indicators from flowers. I used the same flowers to test each method. A picture of the type of flowers I used is shown on the left. I found that by crushing the petals, then adding methylated spirit to extract the flower pigment I obtained a darker indicator than by crushing the petals, then adding water and microwaving the mixture. This particular flower did not work very well as an acid base indicator. It did not change colour when I added acid or base.

I have decided to use the method that involves methylated spirit to make my

March 2009

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« Feb

FEEDS FULL COMMENTS

A blog used as a logbook for a student research investigation. Use the SRP blog (Student Research Project) weblink in your eBookPLUS to access this blog.

eBook*plus* **eLesson**

Hesperides science

Watch a video about 250 scientists aboard two Spanish naval vessels assessing the effects of climate change on ocean ecosystems.

eles-1080

Designing the experiments

In order to complete a successful investigation, you need to make sure that your experiments are well designed. Once you've decided exactly what you are going to investigate, you need to be aware of:

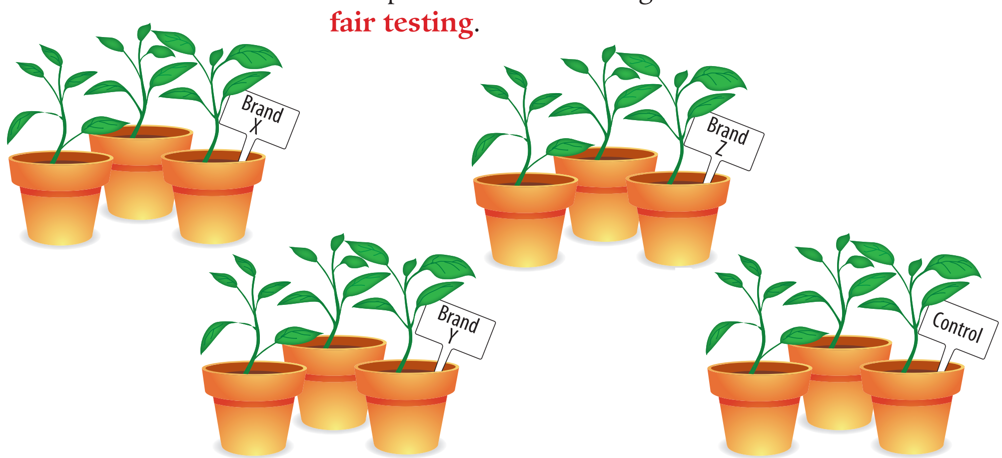
- which variables need to be controlled and which variables can be changed
- whether a control is necessary
- what observations and measurements you will make and what equipment you will need to make them
- the importance of repeating experiments (replication) to make your results more reliable
- how you will record and analyse your data.

A poorly designed investigation is likely to produce a conclusion that is not **valid**.

Controlling variables

A **variable** is an observation or measurement that can change during an experiment. You should change only one variable at a time in an experiment. The variable that you deliberately change during an experiment is called the **independent variable**. The variable that is being affected by the independent variable — that is, the variable you are measuring — is called the **dependent variable**. For example, if you were performing an experiment to find out which brand of fertiliser was best for growing a particular plant, the independent variable would be the brand of fertiliser. The dependent variable would be the heights of the plants after a chosen number of days.

When you are testing the effect of an independent variable on a dependent variable, all other variables should be kept constant. Such variables are called **controlled variables**. For example, in the fertiliser experiment, the type of plant, amount of water provided to each plant, soil type, amount of light, temperature and pot size are all controlled variables. The process of controlling variables is also known as **fair testing**.



The need for a control

Some experiments require a **control**. A control is needed in the fertiliser experiment to ensure that the result is due to the fertilisers and not something else. The control in this experiment would be a pot of plants to which no fertiliser was added. All other variables would be the same as for the other three pots.

Replication

Replication is the repeating of an experiment to make results more reliable. In the case of the fertiliser experiment, a more reliable result could be obtained by setting up two, three or four pots for each brand of fertiliser. An average result for each brand or the control could then be calculated.

Using information and communications technology

Computer hardware and software are important tools used by scientists during their investigations. For example:

- spreadsheets can be used to organise and analyse data
- data loggers can be used to collect large numbers of measurements of variables that are difficult to collect in other ways
- databases can be used to arrange data or information so that it easier to locate.

These tools are described in sections 1.6 and 1.7 in this chapter.

Getting approval

You should now be ready to write a plan for your investigation. You should not commence any experiments until your plan has been approved by your science teacher. Your plan should include the following information.

1. Title

The likely title — you may decide to change it before your work is completed.

2. The problem

A statement of the question that you intend to answer. Include a hypothesis. A hypothesis is an educated guess about the outcome of your experiments. It is usually based on observations and able to be tested by further observations or measurements.

3. Outline of your experiments

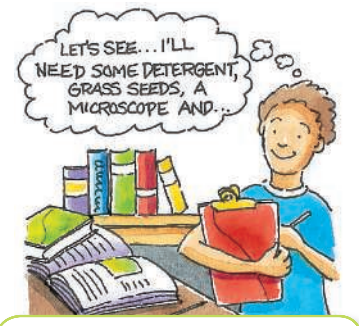
Outline how you intend to go about answering the question. This should briefly outline the experiments that you intend to conduct.

4. Equipment

List here any equipment that you think will be needed for your experiments.

5. Resources

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



Write out a plan for your investigation.

Gathering data

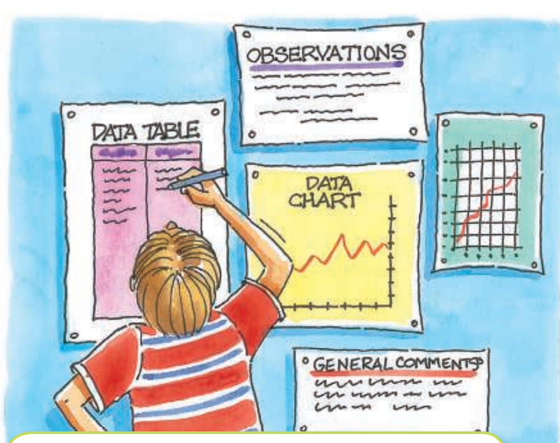
Once your plan has been approved by your teacher, you may begin your experiments.

Details of how you conducted your experiments should be recorded in your logbook. All observations and measurements should be recorded. Use tables where possible to record your data.

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

Photographs should be taken if appropriate.

You might need to change your experiments if you get results you don't expect. Any major changes should be checked with your teacher.



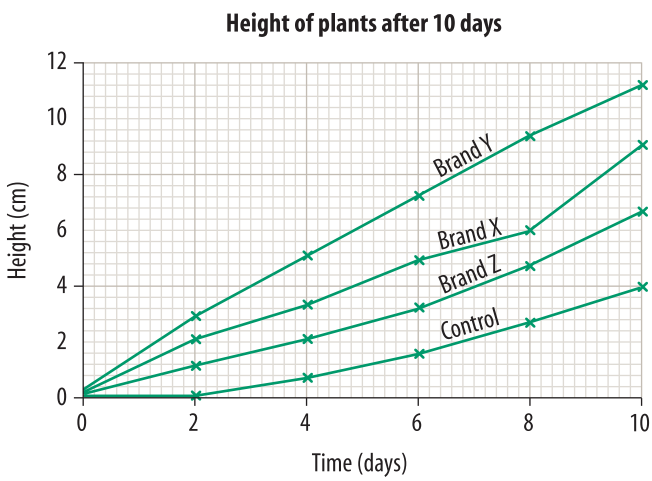
All observations and measurements should be recorded.

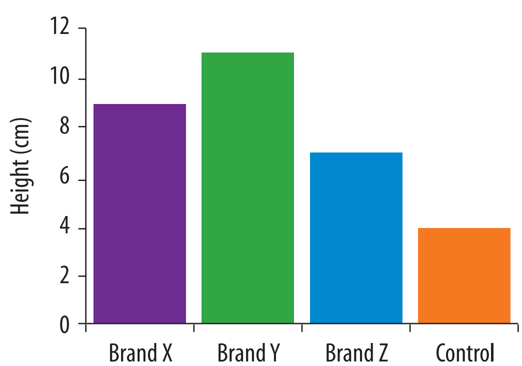
WHAT DOES IT MEAN?

The word *data* is the plural of *datum*, which means 'a piece of information'. It comes from the Latin word meaning 'something given'.

Graphing variables

If you use a graph to show your results, you would normally graph the independent variable (the one you changed) on the x-axis, and the dependent variable (the one you measured) on the y-axis. When the dependent variable changes with time, you can graph time on the x-axis and the dependent variable on the y-axis. For example, in the fertiliser experiment, two types of graphs could be used, a line graph or a column graph (bar chart).





Writing your report

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

Abstract

The abstract provides the reader with a brief summary of your whole investigation. Even though this appears at the beginning of your report, it is best not to write it until after you have completed the rest of your report.

Introduction

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

Aim

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

Materials and methods

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

Results

Observations and measurements (often referred to as data) are presented here. Data should, wherever possible, be presented in table form so that it is easy to read. Graphs can be used to help you and the reader interpret data. Each table and graph should have a title. Make sure you use the most appropriate type of graph for your data. Some examples of graphs are shown below.

Discussion

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

Conclusion

This is a brief statement of what you found out. It is a good idea to read your aim again before you write your conclusion. Your conclusion should also state whether your hypothesis was supported. You should not be disappointed if it is not supported. In fact, some scientists deliberately set out to reject hypotheses!

Bibliography

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

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

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

Some examples of different sources are listed below.

- Breidahl, H. *Australia's Southern Shores*, Lothian, Melbourne, 1997, Chapter 2.
- *World Book Encyclopaedia*, **Volume 4**, 2006, pp. 234–236.
- 'The Battle of the Bathroom', *Choice*, Sydney, November 1990, pp. 34–37.

For websites, list:

- author(s) (if known)
- URL
- date last updated (if known).

Acknowledgements

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

Everyone has talent

In most states and territories, there are competitions or events that provide opportunities for you to present reports of your own scientific research. Each year, tens of thousands of dollars in prizes are awarded to hundreds of entrants. Information about these competitions and events can be obtained from your science teacher.

UNDERSTANDING AND INQUIRING

REMEMBER

1 Construct a flowchart to show the steps that you need to take before beginning your experiments.

2 What is the advantage of repeating an experiment several times?

3 Describe how each of the following computer tools can be used in a scientific investigation.
 (a) Spreadsheets
 (b) Data loggers
 (c) Databases

4 Describe the difference between an independent and a dependent variable.

5 Outline an example of the use of a control in an experiment.

THINK

6 Outline why it is important to plan a research investigation carefully.

7 Discuss the advantages and disadvantages of using a blog as a logbook for your investigation.

8 For each problem described below, identify the independent and dependent variable and three other variables that would need to be controlled.
 (a) Josie wanted to find out whether the water in her drink bottle would stay cold for longer if she wrapped the bottle in foil or a towel.
 (b) Charlotte would like to know whether ice blocks made from green coloured water melt at the same temperature as uncoloured ice blocks.
 (c) Jayden is testing the hypothesis that tall people are faster long-distance runners than short people.
 (d) Shinji is testing the myth that plants grow faster if you play them music for at least 2 hours a day.
 (e) Nikita has heard that most people shrink slightly (in height) throughout the day and stretch out at night. She would like to know whether this is true.

9 Why is it better to write the abstract of a scientific report last, even though it appears at the beginning?

10 In which section of your report do you describe possible improvements to your experiments?

11 The television show *Mythbusters* involves a team led by Adam and Jamie carrying out investigations to test various myths. To see a list of the myths they have tested over the years and the outcomes of their tests, use the **Mythbusters** weblink in your eBookPLUS.
 (a) Define the term *myth*. (Use a dictionary if necessary.)
 (b) Look at the list of myths Adam and Jamie have investigated and pick at least three that you could test using equipment available at home or at school.
 (c) If your school has any episodes of *Mythbusters* available, watch an episode. Make a list of the myths tested in the episode and discuss the validity of the experiments carried out by Adam, Jamie and their team.

eBook*plus*

work sheets
1.1 Setting up a logbook
1.2 Variables and controls

Case study

Investigating muddy water

Sean, a Year 9 student, conducted an experimental investigation to compare the turbidity (cloudiness) of water in the following three locations:

- a creek near his school
- a creek near his home
- a river near his home.

His search for information in the library revealed that the cloudiness was caused by particles of soil (and sometimes pollution) suspended in the water. Sean chose his topic because he was interested in the environment. He felt that clean water was the right of all living things. His research and background knowledge led him to form the hypothesis that 'the clearest water will be in the river'.

Sean took water samples from each of the three locations on four days. He found a method of measuring turbidity from a library book. It involved adding a chemical called potash alum to a sample of water in a jar. The potash alum makes the particles of suspended soil clump together and fall to the bottom of the jar. A layer of mud is formed. The height of the mud at the bottom is then measured.

A summary of Sean's method, including a list of materials and equipment required, is given above right. You will notice that Sean used a fourth sample. It was needed as a control and contained distilled water. This was to ensure that there was nothing in the pure water to cause a layer at the bottom of the jar when the potash alum was added. His results are in the table below.

SEAN'S INVESTIGATION: MATERIALS AND METHODS

- 4 large jars or bottles with lids for collecting water samples (capacity of about 1 L each)
- 4 identical jam jars with lids, labelled 1, 2, 3 and 4
- metal teaspoon (not plastic, in case it breaks)
- potash alum (potassium aluminium sulfate)
- 4 water samples from different locations
- ruler with 1-millimetre graduations
- 100 mL measuring cylinder
- permanent marker

1. Water samples (about 1 litre each) were collected from a specific part of the creeks and river on the same day.
2. Each of three clean jars was filled to the same level with the water samples — a labelled jar for each location. A fourth labelled jar was filled to the same level with distilled water.
3. One level teaspoon of potash alum was added to each jar. Lids were put on the jars and the jars were shaken.
4. The jars were left for 30 minutes to allow the particles to settle.
5. The height of the layer of mud on the bottom of each jar was measured and recorded.
6. The jars were emptied and washed and the experiment was repeated three more times.
7. Water samples were collected from the same locations on three other days over a ten-day period and the entire experiment was repeated three more times.

Analysing the data

Sometimes it is necessary to refine the raw data (the data initially collected), presenting it in a different way. Sean was planning to use his average measurements to make a column graph. He decided to simplify his table so that it was easier to construct the column graph. The simplified table and column

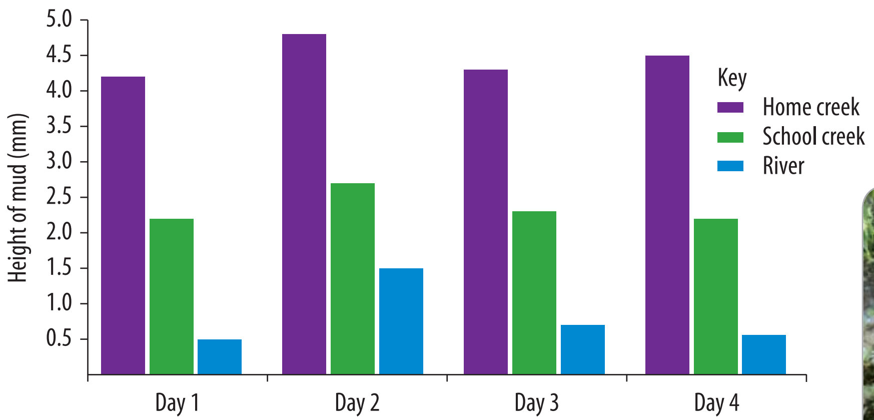
Results table measuring the levels of mud in water samples from three areas

	Height of mud (mm)															
	Day 1				Day 2				Day 3				Day 4			
	Test				Test				Test				Test			
Water sample	1	2	3	Average	1	2	3	Average	1	2	3	Average	1	2	3	Average
1. Home creek	3.5	4.0	5.0	4.2	5.0	4.5	5.0	4.8	4.5	5.0	4.5	4.3	5.0	4.5	4.0	4.5
2. School creek	2.5	2.0	2.0	2.2	3.0	2.5	2.5	2.7	2.0	2.5	2.5	2.3	2.0	2.0	2.5	2.2
3. Barnes River	1.0	0.5	0	0.5	2.0	1.0	1.5	1.5	0.5	1.0	0.5	0.7	0.5	0.5	0.5	0.5
4. Distilled water	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

graph make it easier for others to read the results, and easier for Sean to see patterns and draw conclusions.

Table showing average heights of mud in water from three different areas

Sample number and source	Height of mud (mm)			
	Day 1	Day 2	Day 3	Day 4
1. Home creek	4.2	4.8	4.3	4.5
2. School creek	2.2	2.7	2.3	2.2
3. River	0.5	1.5	0.7	0.5



Sean's graph makes it easier to see patterns and draw conclusions.

Being critical

Sean was pleased with his results and was able to draw conclusions. In the discussion section of his report, he suggested that further studies be done. The turbidity was affected by weather conditions and the sampling needed to be done over a longer period, and in different weather conditions. Sean had recorded weather details on each day that he sampled water and was able to explain the very high mud level in the river on day 2. It is almost always possible to suggest improvements to your experiments.

Drawing conclusions

Sean's hypothesis, that the clearest water would be in the river, was supported. His conclusion was written in point form.

1. The home creek has the muddiest water, with sample values ranging from heights of 4.2 to 4.8 mm of mud per 200 mL of water. The school creek has moderate amounts of mud compared to the other two samples. Sample values ranged from 2.2 to 2.7 mm of mud per 200 mL of water. The river water is the clearest, with sample values of 0.5 to 1.5 mm of mud per 200 mL of water.
2. Weather conditions can alter the amount of mud in water bodies by either adding run-off from drains or stirring up the water. This was particularly noticeable in the samples taken from the river site on day 2, which followed a period of rain.

Sean's teacher was pleased, and suggested that Sean carry out further research and rewrite his material. And what did he think about entering his project for competitions?

The last word comes from Sean. After successfully completing his student research project, he said: 'It all depends on the experimental design — get that right and the rest is likely to run smoothly.'

Chemical waste running into a river. How might you test for such materials in a water sample from this site?

UNDERSTANDING AND INQUIRING

THINK

1 For Sean's experiment, identify:
(a) the independent variable
(b) the dependent variable
(c) the variables he controlled.

2 Explain why a sample of distilled water was included in Sean's experiment.

3 Explain why Sean repeated the experiment 3 times on 4 separate days.

4 Suggest how Sean could improve the reliability and accuracy of his experiment.

5 Why did Sean use a column graph rather than another type of graph to present his results?

6 In your opinion, is Sean's conclusion valid? Give reasons for your answer.

Using spreadsheets

A spreadsheet is a computer program that can be used to organise data into columns and rows.

Once the data is entered, mathematical calculations, such as adding, multiplying and averaging, can be carried out easily using the spreadsheet functions.

If you have access to a spreadsheet program, for example Microsoft Works, Microsoft Excel or Lotus, you may find it useful to present the data from your experiments on a spreadsheet (particularly for your student research projects). Spreadsheets have many advantages over handwritten or word-processed results. For example, with spreadsheets you can:

- make calculations quickly and accurately
- change data or fix mistakes without redoing the whole spreadsheet
- use the spreadsheet's charting function to present your results in graphic form.

Elements of a spreadsheet

Although there are a number of spreadsheet programs available, they all have the same basic features and layout as shown in example 1 below. The data shown are from a student research project about the different factors on the growth of bean plants.

Entering data into cells

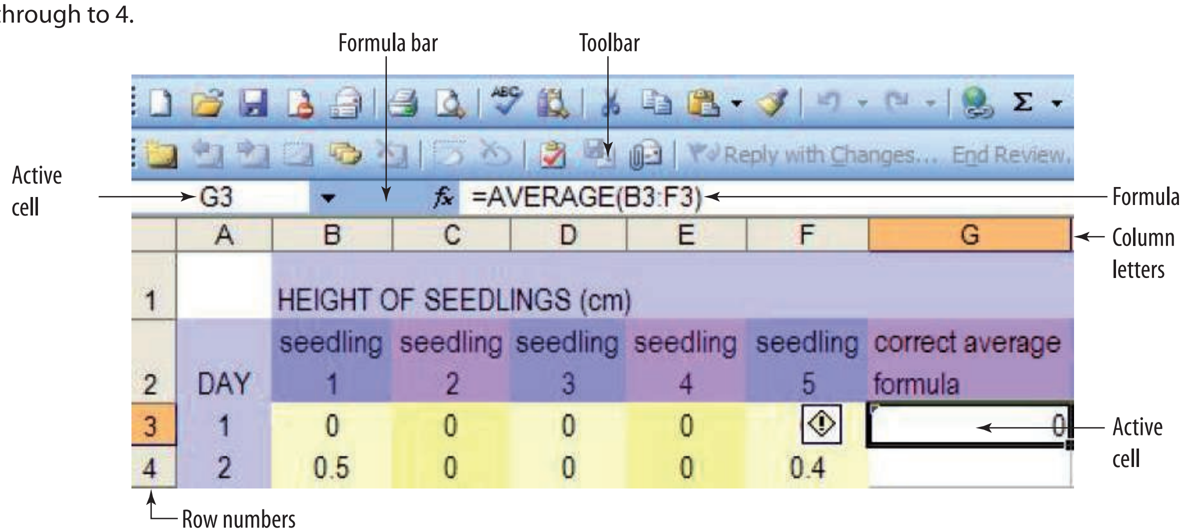
You can enter different types of data into a cell:

- a number or value
- a label, that is, text (for titles and headings)
- a formula (an instruction to make a calculation).

Decide in which cell you want to insert the data (the active cell). Type the data in the cell and press 'Enter'. To edit or change the data, simply highlight the cell and type in the new data — it will replace the old data when you press 'Enter'. Example 2 below shows a spreadsheet in which data has been entered.

EXAMPLE 1

- At the top of the spreadsheet are the toolbar and formula bar.
- A *row* is identified by a number; for example, 'row 1' or 'row 2'.
- A *column* is identified by a letter; for example, 'column A' or 'column B'.
- A *cell* is identified by its column and row address. For example, 'cell G3' refers to the cell formed by the intersection of column G with row 3. In this example, cell G3 is the active cell (shown by its heavy border). The active cell address and its contents (once data is entered) are shown to the left of the formula bar.
- A *range* is a block of cells. For example, 'range C3:F4' includes all the cells in columns C through to F and rows 3 through to 4.



Creating formulae

To create a formula, you need to start with a special character or symbol to indicate that you are keying in a formula rather than a label or value. This is usually one of the symbols =, @ or +, depending on the spreadsheet program. For example, a formula to add the contents of cell B1 to cell C1 would take one of the following forms:

=B1+C1 or @B1+C1 or +B1+C1

> The symbols used for mathematical operations in spreadsheets are:
>
> \+ for addition * for multiplication
>
> – for subtraction / for division.

Once you have entered the formula in a cell, the result of the calculation, rather than the formula, will be shown. The formula can be seen in the status bar when the cell is active. (See example 2 below.) If you subsequently needed to change the values in B1 or C1, the spreadsheet will automatically use the formula to recalculate and show the new result.

Using functions

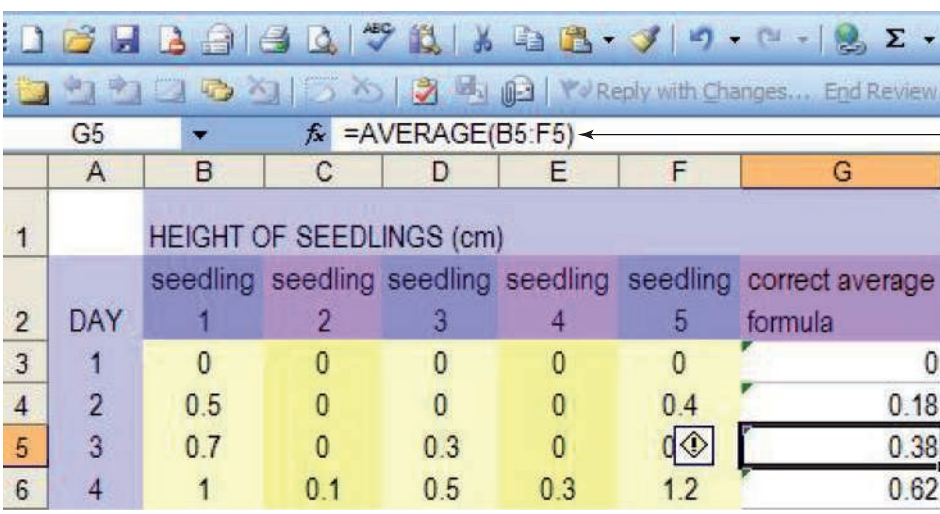
Some common types of calculations are built into the spreadsheet, so that you don't always need to type out the full formulae. These are called **functions**. All functions have two parts: the name and a value (called the **argument**) that the function will operate on. The value is normally placed in parentheses, ( ), and can be written as a set of numbers or as a range (a block of cells). For example, a function to calculate the average of the amounts entered in cells B1, B2, B3 and B4 would be written:

=AVERAGE(B1:B4)

Some of the common functions found in spreadsheets are shown in the table below.

EXAMPLE 2

The spreadsheet in example 1 has been further developed. Formulae have now been entered to average the heights of the seedlings.



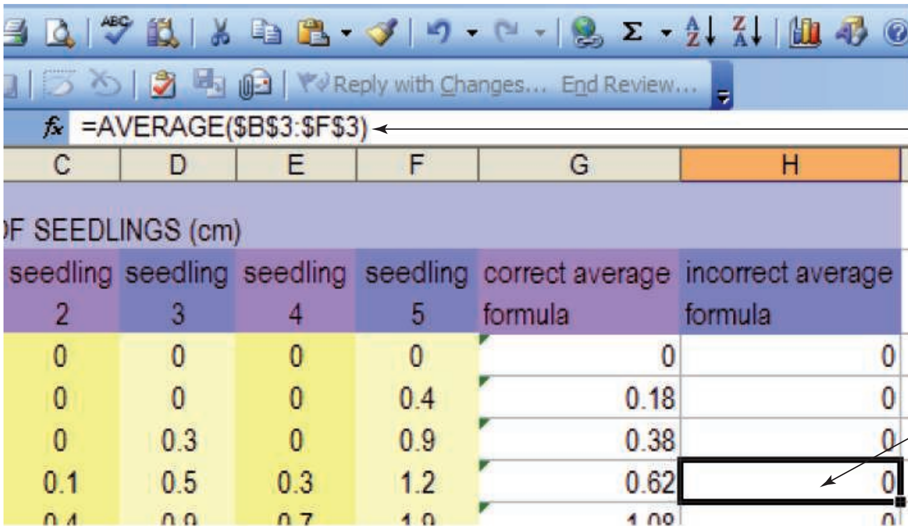
Archive cell contents

This is the active cell. The formula in the bar above is the formula for this cell.

Common spreadsheet functions

Name	Application	Example	Result
AVERAGE	calculates the average of the argument values	=AVERAGE(1,2,3,4)	2.5
COUNT	counts the number of values in the argument	=COUNT(A3:A6)	4
MAX	returns the largest value in the argument	=MAX(1,9,5)	9
MIN	returns the smallest value in the argument	=MIN(1,9,5)	1
MODE	returns the most common value in the argument	=MODE(1,1,5,5,1)	1
ROUND	rounds the argument to the number of decimal places specified	=ROUND(12.25,1)	12.3
SUM	calculates the sum of the values in the argument	=SUM(1,9,5)	15

EXAMPLE 3



The formula has a $ sign in front of the cell coordinates, so that the coordinates do not adjust automatically as the row number changes.

The formula above is the formula for this cell in row 5.

Copying cells

Spreadsheets have a command that allows you to copy a formula or value from one cell to another cell (or into a range of cells). This is usually found in the *Edit* menu (*Fill Down* or *Fill Right*). The way a formula is copied depends on whether the cell references use:

- **relative referencing**, which you use when you want the cell address in the formula to change according to the relative location of the cell that you have copied it to. Example 2 uses relative referencing. The formula AVERAGE(B5:F5) in the active cell G5 was copied downwards, so that there was no need to type the formulae in the rest of the column. The formula in the next cell (G6) is therefore AVERAGE(B6:F6) and so on.
- **absolute referencing**, which you use when you want a cell address in the formula to be constant, no matter where it is copied to. Absolute referencing is denoted by the symbol $ placed in the cell address. For example, B3 (see example 3).

Formatting cells

Investigate your spreadsheet program (most come with a tutorial) to learn how to use other useful features such as:

- adding and deleting rows or columns (useful if you have forgotten to include some calculations in your planning or decide you don't need some items)
- changing column widths (to show the full cell contents when the data is longer than the default column width) and changing row heights so that you can use larger font sizes for titles and headings
- inserting horizontal or vertical lines to improve the presentation of your spreadsheet
- changing cell formats to control how the data is to be displayed, such as using different fonts and character styles (underlining, bold, italic).

You can also format numeric values in a variety of ways. For example, the *Fixed* or *Number* format will display values to the number of specified decimal places. The *Percent* format will display values as a percentage, to the number of specified decimal places.

Once you have keyed in your data and included any necessary calculations, print out your spreadsheet and save it to a disk so that you can store the document and use it later.

Spreadsheet graphics

The three main types of graphs — pie, bar and line graphs — can usually be produced by a spreadsheet. It means that you can easily display your results graphically, but you still need to decide which is the most appropriate type of graph for your data.

The first step in producing a spreadsheet graph is to select the block of the cells that contains the data to be graphed. Use the spreadsheet's charting function, which usually brings up a window where you can indicate the type of graph, and add title and label details. When you are satisfied with the result, you can display and print out your graph.

UNDERSTANDING AND INQUIRING

USING DATA

1 Look at the spreadsheet presented in example 2 in this section and answer the following questions:
   (a) What does cell G3 contain?
   (b) Does cell E2 contain a value or a label?
   (c) If the formula in cell G4 is AVERAGE(B4:F4), what would the formula be in cells G5 and G6?

2 The following table shows the results of an experiment that tested the amount of time taken for eucalyptus oils and other substances (0.1 mL of each) to evaporate at a constant temperature. The experiment was done twice.

Substance	Time (s) Trial 1	Time (s) Trial 2
Methylated spirits	4.17	1.85
Turpentine	63.48	43.02
Water	54.42	57.05
Oil from *E. rossi*	195.92	191.23
Oil from *E. nortonii*	103.99	105.39

   (a) Enter the data into a spreadsheet.
   (b) Use the spreadsheet function to calculate the average time that each substance took to evaporate.

3 The table below shows the distance travelled by Jesse at 3-second intervals during a 100-metre sprint. The data was recorded during the sprint by attaching a paper tape to Jesse's waist. As he ran, the tape was pulled through a timer that printed a dot every 3 seconds.

Time (s)	Distance travelled in time interval (m)	Average speed for time interval (m/s)
0	0	
3	35	
6	25	
9	15	
12	15	
15	10	

   (a) Enter the data into a spreadsheet. Calculate the average speed travelled in each 3-second interval by applying a formula to the first cell in the column, and then copying it down. Remember that average speed can be calculated by dividing the distance travelled by the time taken:

$$\text{Speed} = \frac{\text{distance}}{\text{time}}$$

   (b) What was Jesse's average speed over the total time?

4 The following data were collected by two car servicing centres in Canberra in 1998, at the request of a student. The table shows the level of carbon monoxide and carbon dioxide emissions (as a percentage of total emissions) from cars of various ages.

Year car manufactured	Carbon monoxide (%)	Carbon dioxide (%)
1977	3.17	11.8
1983	2.48	13.6
1985	3.7	11.4
1987	1.6	13.1
1989	1.08	10.2
1996	0.19	15.2

   (a) Enter the data into a spreadsheet and create a graph to display these results.
   (b) Create formulae to work out the average carbon monoxide and carbon dioxide emissions for:
      (i) cars manufactured up to 1985
      (ii) cars manufactured from 1987 onwards.
   (c) Car manufacturers were required to install catalytic converters in cars made after 1986. Catalytic converters cut down carbon monoxide emissions by converting some of the carbon monoxide to carbon dioxide. What can you conclude from these data about the success of catalytic converters?

5 Find the results of a science experiment this year that required some calculations. Enter the data and use spreadsheet formulas or functions to complete the calculations. If the data is suitable, create a graph to display the results.

work sheets
1.3 Spreadsheeting and graphing
1.4 Calculating using a spreadsheet

1.7 SCIENCE INQUIRY SKILLS

Using data loggers

A data logger is a device that stores a large number of pieces of information (data) sent to it by sensors attached to it.

The data logger can transfer this data to another device, such as a graphing calculator or, more commonly, a computer, which can use data logger software or a spreadsheet program to manipulate the data (see section 1.6). Usually the computer or calculator graphs the collected data, and we can use these graphs to see patterns and trends easily.

When can a data logger be used?

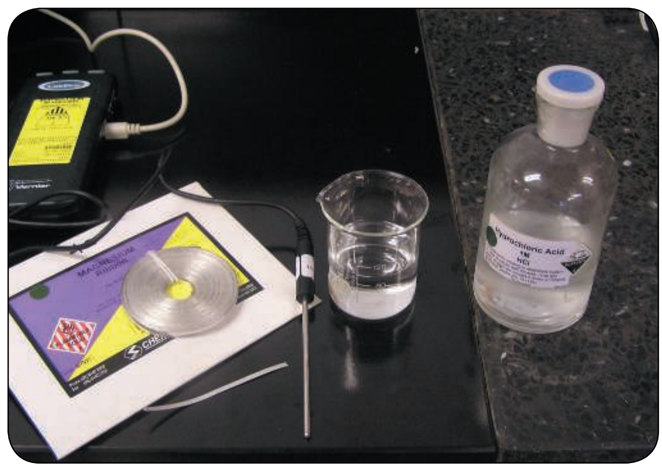
Data loggers are particularly useful whenever an experiment requires several successive measurements. Sometimes, these measurements will take place over several hours or days — such as when measuring the way air pressure varies with the weather. Sometimes, many measurements must be taken over a short time interval — such as when measuring changes in air pressure as sound waves pass by. Data loggers are very flexible and can help scientists gather and analyse data for these types of experiments, as well as many others. As an example of how a data logger might help you in your scientific investigations, let's consider the experiment *Exothermic and endothermic processes* in Investigation 7.3 in chapter 7.

Exothermic and endothermic processes

In this experiment, we investigated temperature changes in chemical processes. In part 1, we observed the reaction of magnesium metal with dilute hydrochloric acid and, in part 3, sodium thiosulfate with water. We will need a data logger with a temperature sensor attached to it, as well as the items listed in Investigation 7.3. The data logger will need to be attached to a computer on which the data logger software has been installed.

PART 1: MAGNESIUM IN HYDROCHLORIC ACID

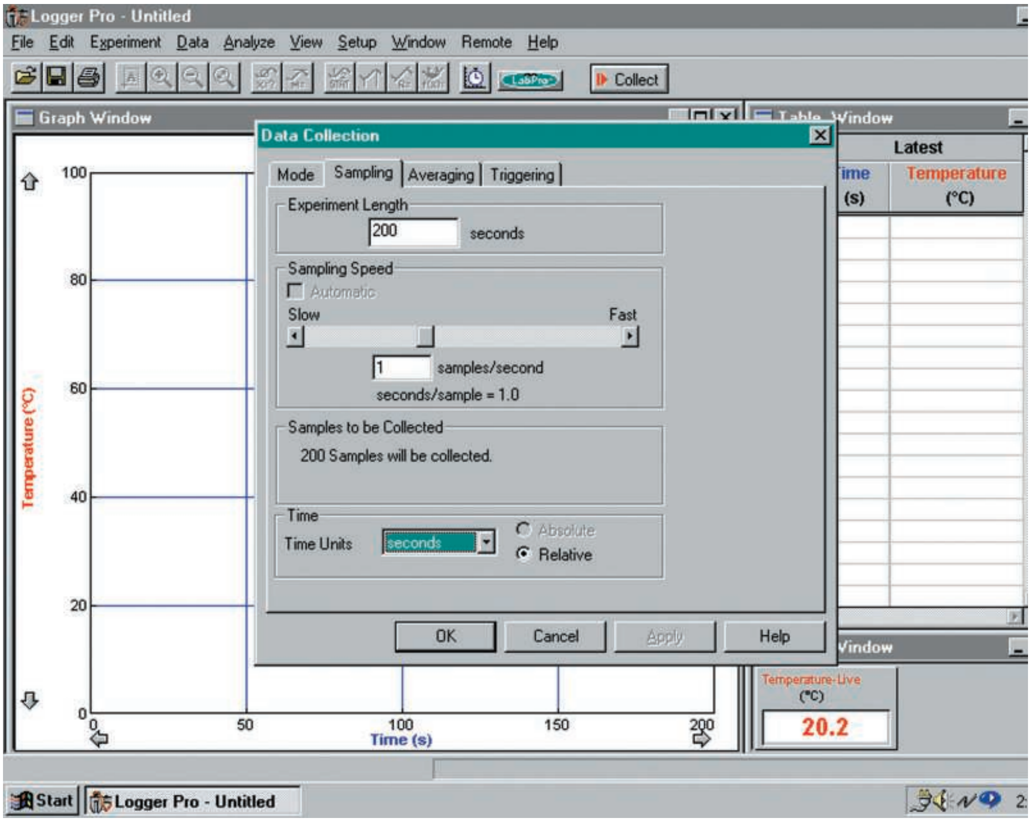
Active metals react with dilute acids to give off hydrogen gas and leave behind a salt that usually stays dissolved in the water in which the acid was dissolved. To investigate whether heat is given off or taken in during the reaction, we will need the equipment shown in the photo below. We could use a test tube or a beaker as shown in the photo. If we use a beaker, we will have to use more acid; in this case, we will use 100 mL of 1 mol/L hydrochloric acid.



The equipment required for *Part 1: Magnesium in hydrochloric acid*

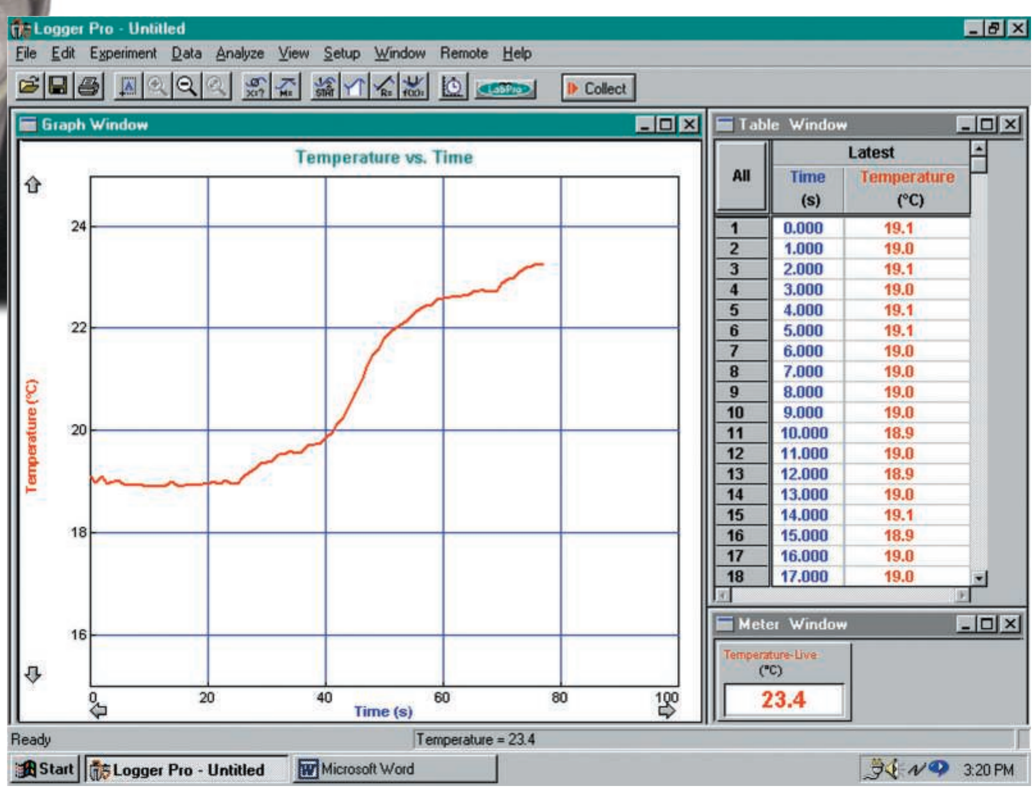
We now set up the data logger to collect data for the length of time that we need and at the rate we require. The data logger itself or its software allows us to do this. The screen at the top of the next page shows the data logger being set to collect temperature data for 200 seconds at the rate of once per second. Now it's a simple matter of putting the temperature sensor in the dilute acid, pressing the button on the data logger to start data collection and adding the magnesium.

The reaction proceeds for 200 seconds and the sensor sends a temperature measurement every second to the data logger. When the selected time has passed (that is, after 200 seconds), the data logger sends all the data to the computer, which (via the software) displays it as a graph, as shown at right.



Set the data logger to take temperature data for 200 seconds at the rate of once per second.

Place the temperature sensor into the beaker of dilute acid and add the magnesium.



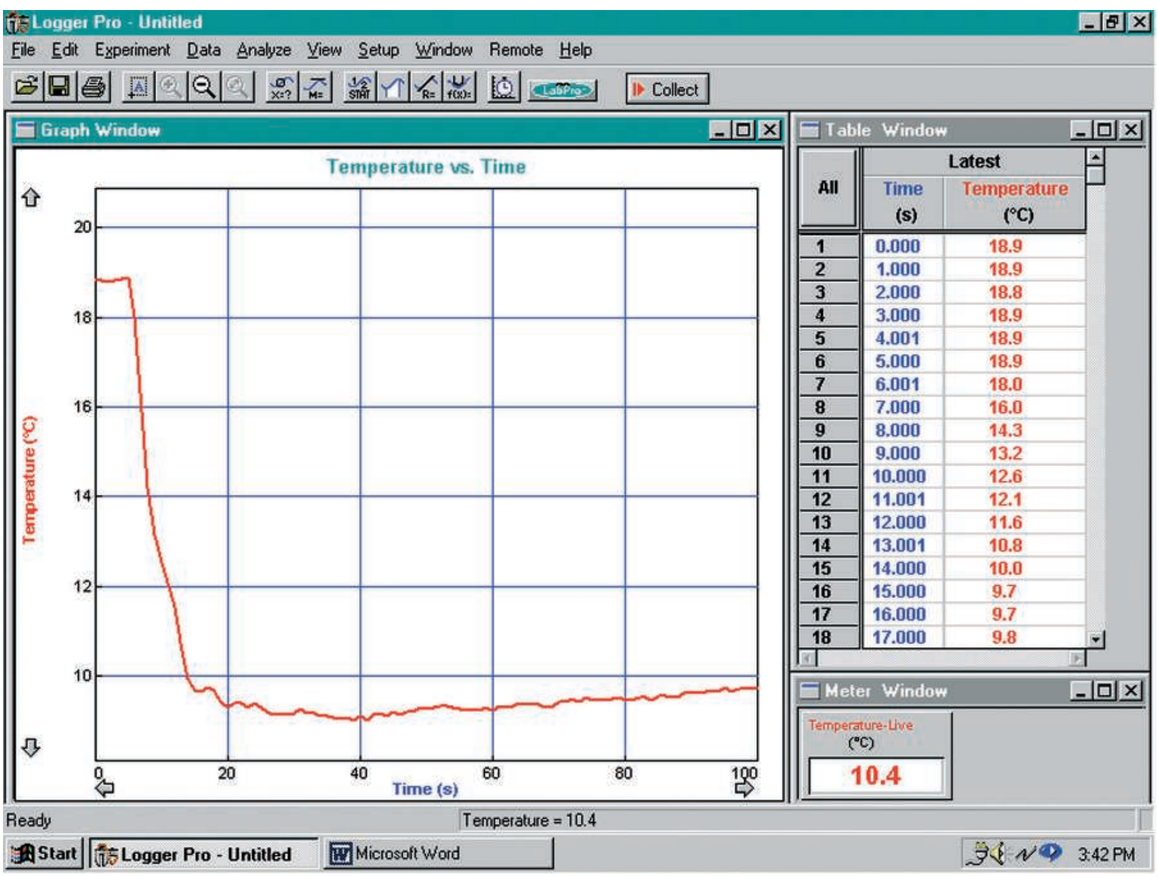
Graphed data for part 1 of the *Exothermic and endothermic processes* experiment

PART 3: SODIUM THIOSULFATE IN WATER

For this part of the experiment, we will need the items listed in Investigation 7.3, as well as a data logger and temperature sensor. Because we are using a beaker instead of a test tube, we will use 100 mL of water and 20 g of sodium thiosulfate. These items are shown in the photograph on the right.

Once again, we set the run time to 200 seconds and the data collection rate to once per second. We insert the temperature sensor into the water, press a button on the data logger to start data collection and then add the sodium thiosulfate crystals to the water. The data logger collects the data, which the computer software automatically graphs after completion of the run, as shown below.

The equipment required for *Part 3: Sodium thiosulfate in water*



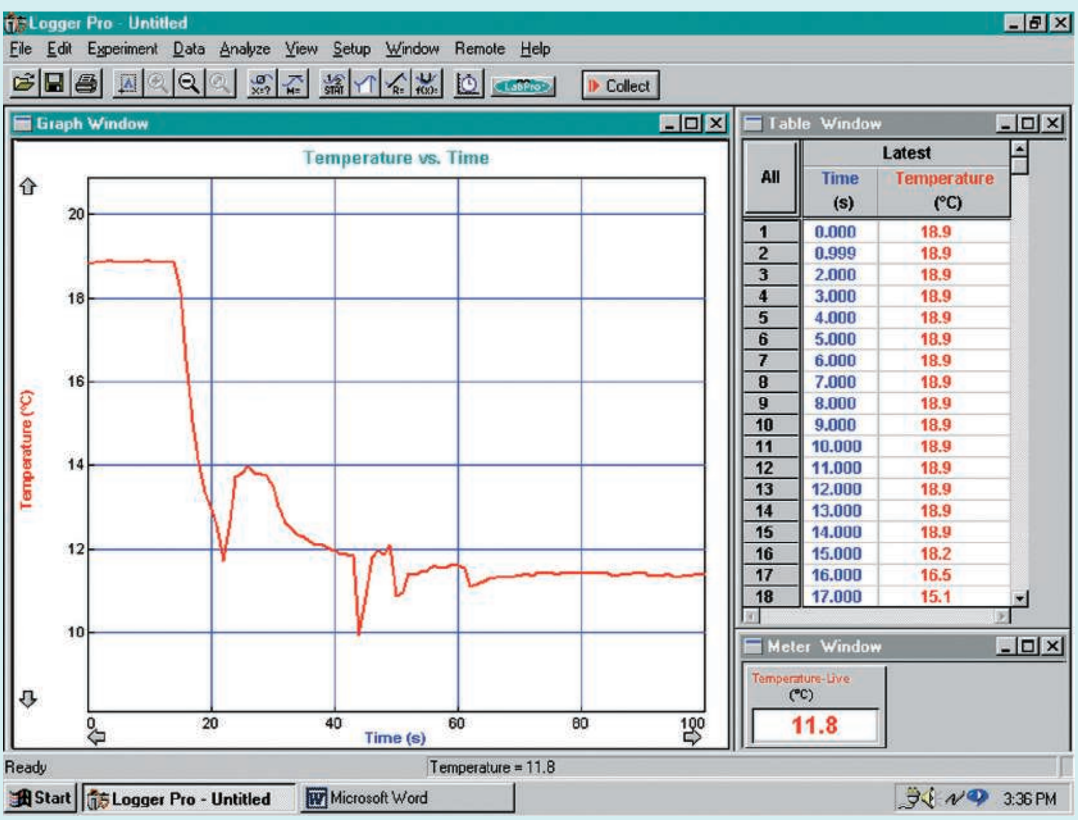
Graphed data for part 3 of the *Exothermic and endothermic processes* experiment

UNDERSTANDING AND INQUIRING

THINK

1 Look back at *Part 1: Magnesium in hydrochloric acid* in this section.
   (a) Write a word equation for the reaction that occurs.
   (b) Look at the graph of temperature vs time for this reaction. Was the reaction exothermic or endothermic? How do you know?
   (c) How long after data collection began was the magnesium ribbon added to the acid? How do you know?
   (d) The person conducting this investigation stopped the run after 77 seconds. How did they know the reaction was complete?
   (e) What was the initial temperature of the dilute acid used in this experiment?
   (f) What change in temperature did this reaction cause in the liquid in the beaker?

2 Look at the graph of the collected data produced by the computer for *Part 3: Sodium thiosulfate in water* in this section.
   (a) What was the temperature of the water at the start of the experiment?
   (b) What was the lowest temperature that the solution of sodium thiosulfate and water solution reached? How long after first adding the sodium thiosulfate crystals did this occur?
   (c) Is dissolving sodium thiosulfate in water an exothermic or endothermic process? How do you know?
   (d) At right is another graph of data logged after mixing the same amount of sodium thiosulfate in the same volume of water.



It differs from the first graph; after about 22 seconds and 44 seconds, the temperature plunged rapidly but promptly returned to the general pattern seen in the first graph. What do you think caused these anomalies (changes to the normal pattern)?

3 Sensors are the devices that take the measurements that the data logger collects. Think of scientific investigations that could use data collected by sensors that measure:
   (a) electric current
   (b) acidity of solutions
   (c) concentration of carbon dioxide in the air
   (d) total dissolved solids (salt content)
   (e) light intensity.

INVESTIGATE

4 Acids are corrosive substances; they react with most metals, such as the magnesium in part 1 of the experiment. The temperature probe is made of metal but it doesn't react with acids. What sort of metal is it and what protects it from the acid?

5 Describe a data logger and what it does in a way that a Year 7 student would understand.

6 List the advantages of using a data logger over taking the measurements manually. Describe an experiment in which using a data logger provides an advantage over manual data collection.

Using databases

Databases are simply information or data arranged in one or more tables. We use databases every day; for example, when we look up information in a phone book, a timetable or the index of a book.

Electronic databases are one of the most powerful computer applications and are important tools for businesses, organisations and scientists.

A database's design is crucial to its usefulness, so a database must be designed with ease of searching uppermost in mind. In the *Understanding and inquiring* section below, you will create a database using some of the features of Microsoft Access.

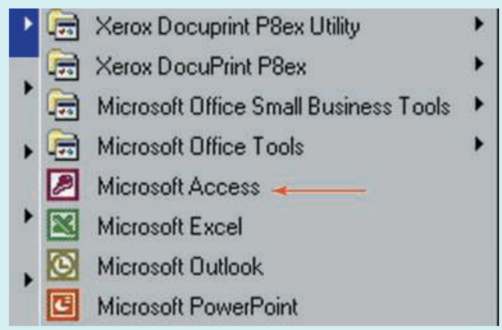
UNDERSTANDING AND INQUIRING

ANALYSE AND EVALUATE

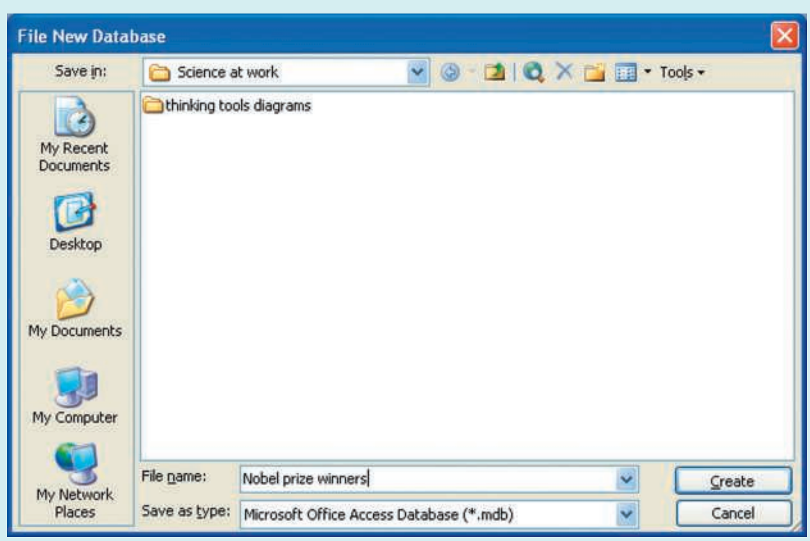
Creating a database of Nobel prize winners

Before creating your database, you will need to find some information to put in it. This is best done as a class activity with each student in the class researching one or two Nobel prize winners.

- Use the **Nobel prize** weblink in your eBookPLUS to find a list of Nobel prize winners. eBook*plus*
- Each student in the class should research one or two different Nobel prize winners. Choose people who have won a Nobel prize for work in the categories of Chemistry, Physics or Medicine.
- For each prize winner, collect the data listed below. Ideally the data should be written on cards that can be passed around the class, or it could be displayed in large writing on large sheets of paper around the room.
  - First name
  - Last name
  - Country of birth
  - Year of birth
  - Category of award (such as Chemistry, Physics and Medicine)
  - Organisation (where the person worked)
  - Nobel prize awarded for (one sentence or phrase that outlines the work for which the scientist received the award)
  - Share received (if the award was shared by a group of people)
- Microsoft Access software is commonly used to create databases. The following instructions are for the 2003 edition of thissoftware. Other editions are similar to usebut the screens are not exactly the same. You can start Access by clicking on *Start*, then *Programs* and then the Access icon shown below.

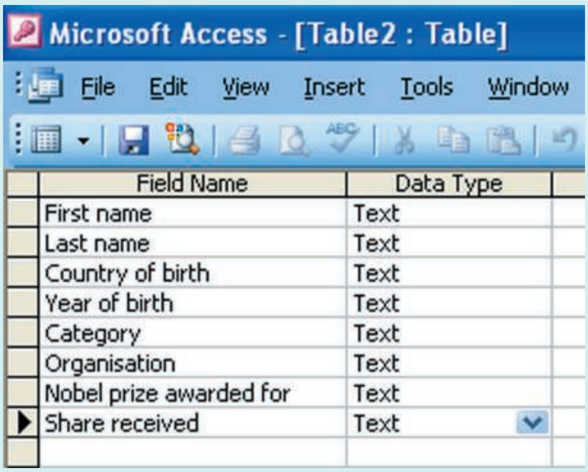


- When you open the software, click on *File* and then *New*. A list of options will appear in the task pane on the right-hand side of the screen. Choose the option *Blank database*. A dialog box will appear for you to enter a name for your database and navigate to the folder where you want to save the database. Choose a sensible name (such as 'Nobel prize winners') and save it where you normally save your science work. This is shown in the screenshot below.



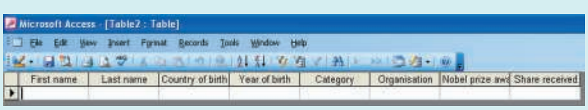
UNDERSTANDING AND INQUIRING

- A new dialog box will be displayed. Choose the option *Create table in Design view* and press [Enter]. A new screen will appear where you can enter field names, which are the column headings for the database. Enter the field names as shown below. You will note that, by default, the data type is Text even though some of the fields are numbers. This is not important for this database.



- Now that you have designed the database, it is time to change to datasheet view. Click on the Datasheet view button in the top left-hand corner of the screen. You will be prompted to save the table. Give the table a suitable name (such as 'Table 1') and click *Save*. When you are asked if you want to create a primary key, click *No*. The table shown below should appear.

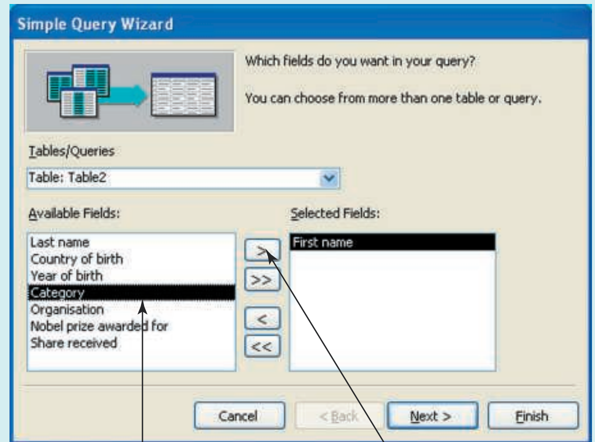
You are now in datasheet view. Note that the Design view button now appears in the left-hand corner of the screen.



- Enter the data that you and your classmates found into the table. When you have done this, save your database.

The great thing about databases is that they allow you to search for data that matches particular criteria. This is called running a *query*. We are going to create a query to find all the Nobel prize winners in our database who were awarded a prize for Medicine and were born in the United States.

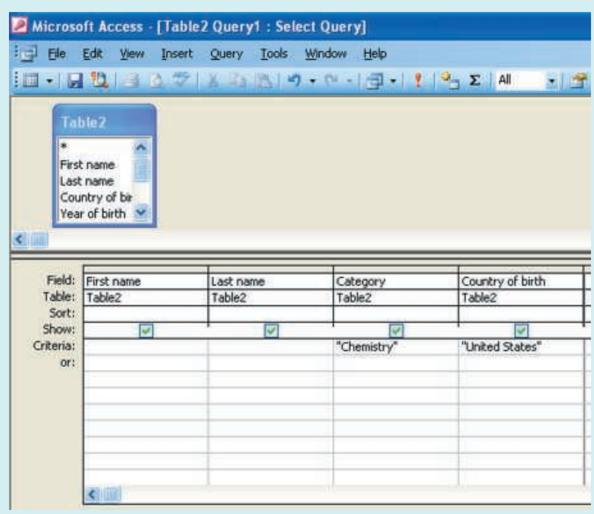
- Make sure you are in datasheet view. Click on the arrow next to the New object button. Select *Query* and then *Simple query wizard* and click *OK*. The fields in your table will be displayed; click on the ones you want to appear in the query then click on the single arrow to move them into the *Selected Fields* box. Select the following fields: first name, last name, country of birth and category. When you have done this, click *Next*. In the next dialog box, enter a name for your query, select *Modify the query design* and click on *Finish*.



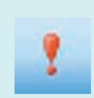
Click on a field to select it.

Click on the single arrow to move the field into the Selected Fields box.

- The screen below will appear. Now enter the criteria you want the query to look for in the appropriate boxes. In the Category column, type 'Chemistry' (without the quotation marks) in the *Criteria* row. In the Country of birth column, type 'United States' in the *Criteria* row. Quotation marks will automatically appear when you press [Enter]. This is shown below.



- Now click on the Run button in the toolbar near the top of the screen. The query will run and a table displaying the Nobel prize winners that match your criteria will appear.



- Create a new query to display the Nobel prize winners who won the Nobel prize for Physics and were born in England.

STUDY CHECKLIST

SCIENCE AS A HUMAN ENDEAVOUR

- describe the changes in the way in which scientists have worked since ancient times
- acknowledge that present-day scientists usually work in teams and that their investigations are influenced by the work done by other scientists
- describe some scientific discoveries that have been made through a combination of accidents and observation
- explain how ethical values affect scientific endeavour and discuss some examples of ethical dilemmas in scientific endeavours

CONDUCTING YOUR OWN INVESTIGATION

- identify questions to be investigated through group discussion, the internet or other resources
- recognise the importance of observations in formulating questions to investigate
- identify dependent, independent and controlled variables in an investigation
- recognise the need for a control in some investigations
- select and use appropriate equipment for the collection of data, including data loggers where appropriate
- record the progress of an investigation in a logbook
- use tables, spreadsheets and databases for the recording of data
- design and construct appropriate graphs to represent data and assist in the identification of trends and patterns and the formation of conclusions
- compare conclusions with earlier predictions or hypotheses
- evaluate the success of an investigation and suggest improvements that would make the findings more accurate or reliable
- write a scientific report using the appropriate headings, terminology, tables and graphs

ICT

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INDIVIDUAL PATHWAYS

eBook plus

Activity 1.1
Revising science

Activity 1.2
Developing science skills

Activity 1.3
Investigating science

LOOKING BACK

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

Words	Meanings
(a) Conclusion	(i) Concerns that deal with what is morally right or wrong
(b) Abstract	(ii) The variable that is deliberately changed in an experiment
(c) Discussion	(iii) The part of a journal article where a brief overview of the article is given
(d) Results	(iv) A list of steps to follow in an experiment
(e) Hypothesis	(v) The answer to the aim or the problem
(f) Ethical considerations	(vi) A list of equipment needed for the experiment
(g) Independent variable	(vii) The variable that is measured in an experiment
(h) Dependent variable	(viii) States what was seen or measured during an experiment. May be presented in the form of a table or graph.
(i) Method	(ix) A sensible guess to answer a problem
(j) Apparatus	(x) The part of a report where problems with the experiment and suggestions for improvements are discussed

2 Miranda wanted to test the following hypothesis: Hot soapy water washes out tomato sauce stains better than cold soapy water.
(a) List the equipment she will need.
(b) Identify the independent and dependent variables in this investigation.
(c) List 5 variables that will need to be controlled.
(d) Outline a method that could be used to test the hypothesis.
(e) Miranda's results are shown in the table below.

Water temperature (°C)	Observations
20	Dark stain left after washing
40	Faint stain left after washing
60	No stain left after washing
80	No stain left after washing

(f) Write a conclusion based on Miranda's results.

3 Gemina and Habib wanted to investigate whether the type of surface affects how high a ball bounces. Habib thought the ball would probably bounce the highest off a concrete floor. They dropped tennis balls from different heights onto a concrete floor, a wooden floor and carpet. Their results are shown in the table below.

Distance ball dropped (cm)	Average height of bounce (cm)		
	Concrete	Wood	Carpet
25	22	14	8
50	46	34	18
75	70	50	26
100	94	66	34
125	X	85	Z
150	128	94	48
175	129	Y	50
200	130	100	51

(a) Write a hypothesis for this experiment.
(b) Construct a line graph of Gemina and Habib's results.
(c) Use your graph to estimate the values X, Y and Z.
(d) Identify two variables that had to be kept constant in this experiment.
(e) Identify two trends in the results.
(f) Do the results support the hypothesis you wrote?
(g) Predict how high the tennis ball would bounce off each floor if it was dropped from a height of 225 cm.

4 List some of the factors affecting the decision about whether money is spent on finding a cure for a particular disease.

5 Should farmers be allowed to plant the type of crop they believe produces the best yield, irrespective of whether others object to the manner in which the crop was bred?

6 In the film *Super Size Me*, the film-maker Morgan Spurlock gains weight and suffers health problems after thirty days of eating from only one fast-food chain. The film suggests that this fast food is unhealthy.
(a) What factors should be taken into account when considering the effects of a fast-food diet compared with a broader eating pattern?
(b) Was this a controlled experiment?
(c) Is Spurlock's argument valid? Explain your answer.
(d) What type of arguments could the fast-food chain put forward in response to the film *Super Size Me*?

work sheets
1.5 Investigating
1.6 Organising and evaluating results
1.7 Drawing conclusions
1.8 Summarising
1.9 Evaluating media reports