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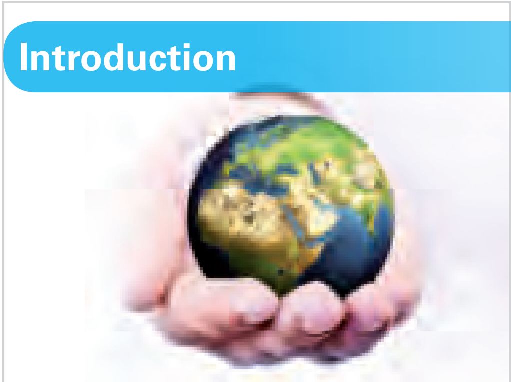

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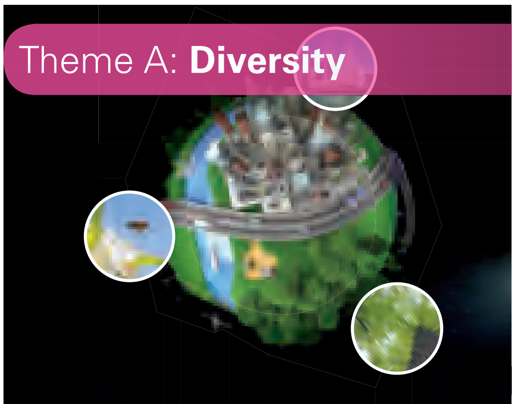

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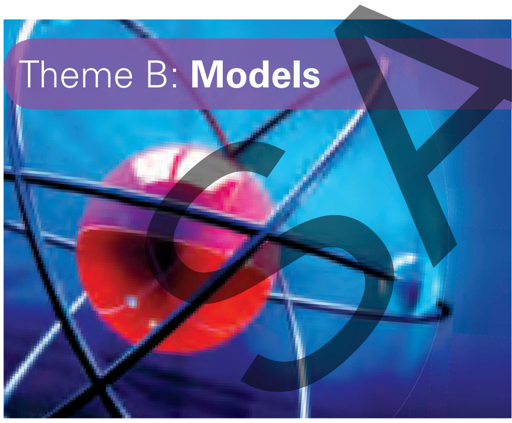

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1 The Scientific Endeavour

- What is science?
- How does science explain things that occur around us?
- How does science affect our lives?

What do we know about our planet? How do we find out more about our world?

Science tries to find out about the world. Scientists study the world through **scientific inquiry**. They use methods such as observing, doing experiments and solving problems. They also use imagination and creativity. The scientific knowledge gained not only helps us understand our world, but it can also be applied to many aspects of our lives.

LEARNING OUTCOMES

You will learn to:

- show an awareness that science is not confined to the laboratory, but is manifested in all aspects of our lives
- show a healthy curiosity about the natural and physical world
- show an appreciation of science being a human endeavour, with scientific knowledge contributed by different civilisations over the centuries
- understand how scientific knowledge is built from systematic collection and analyses of evidence, and rigorous reasoning based on the evidence
- show an awareness that scientific evidence is subject to multiple interpretations
- recognise that scientific evidence can be quantitative or qualitative, and can be gathered through one's senses or instruments as extensions of one's senses
- use a variety of scientific inquiry skills and processes
- show attitudes such as creativity, objectivity, integrity, open-mindedness and perseverance in carrying out scientific inquiry
- discuss the uses and benefits of science and technology to society
- relate applications of science to some social and ethical issues
- state some limitations of science and technology in solving problems
- recognise the need to be responsible towards society and the environment in using technology and scientific knowledge
- demonstrate safety consciousness and adopt safe practices when carrying out investigations

Science Mystery...

Before you begin, look through this chapter and write down questions about what you want to find out. Here are some examples:

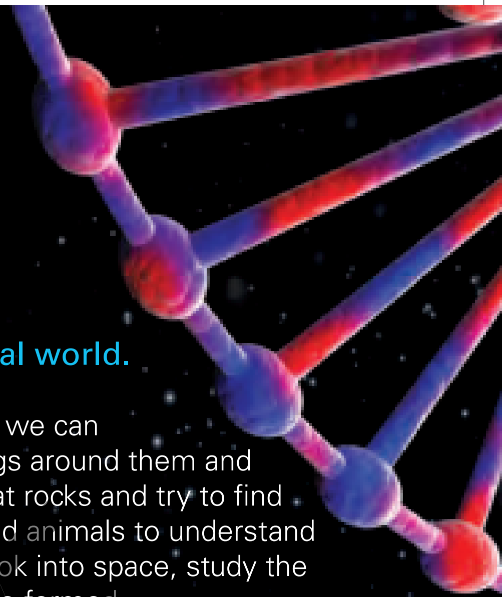
1. *How do I use science?*
2. *What are the best or worst effects of science?*
3. *How has science benefited my life?*

Where did the bacteria come from?

Several years ago, a city in the United States of America faced a problem.

Many children became sick from bacteria which are sometimes found in food. At first it was thought that the children had eaten contaminated food. However, there was no single place where all the children had eaten from. Then, it was found that all the children had visited a zoo to look at some baby Komodo dragons.

What caused the children to become sick? In order to find the answer, the city asked Cindy, a scientist, to help. How did she solve the mystery? As you read this chapter, look for clues on how Cindy and other scientists work. Then, find out how the mystery was solved at the end of the chapter.



1.1 What Is Science?

Science is the study of the natural and physical world.

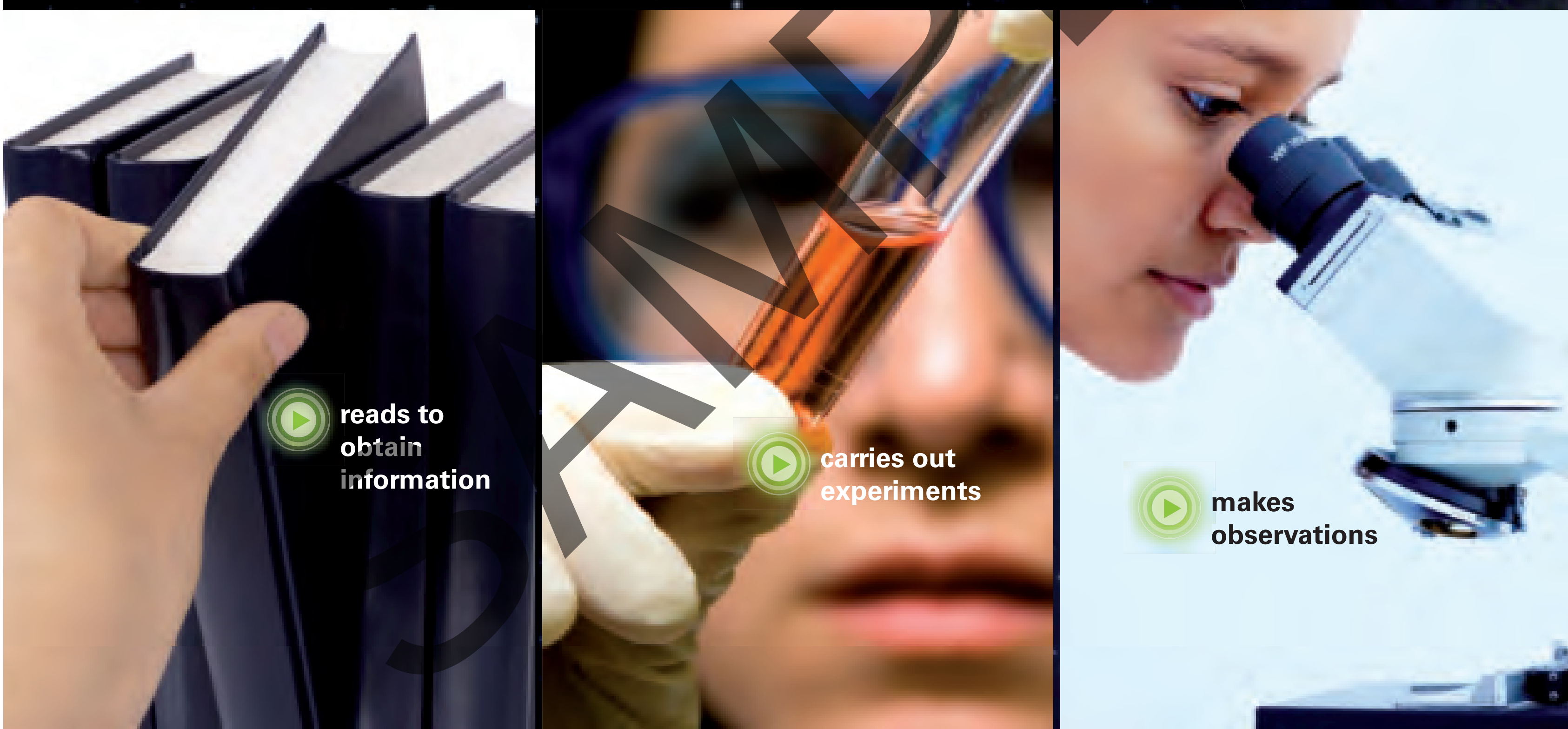
The natural and physical world includes all the things we can observe. For a long time, people have observed things around them and tried to understand them. For example, people look at rocks and try to find out what they are made of. People observe plants and animals to understand how they behave and where they live. People also look into space, study the sun, planets and stars to try to explain how they were formed.

A person who studies and practises science is called a **scientist**. In studying and practising science, scientists read, observe and carry out experiments to try and uncover the secrets of the world.

Know it!

The word 'science' comes from the Latin word 'scientia', which means **knowledge**.

A scientist…



In this course, you will behave like a scientist. You will observe things around you. You will also see how scientific knowledge can be used to benefit society and to solve problems we may encounter in our daily lives.

You will also be introduced to some famous scientists and learn more about their discoveries.

What are the different branches of science?

Science is divided into many branches. Each branch finds out about a different part of the world around us. For example, in biology, we can find out how a caterpillar turns into a butterfly. Figure 1.1 shows some examples of the different branches of science.

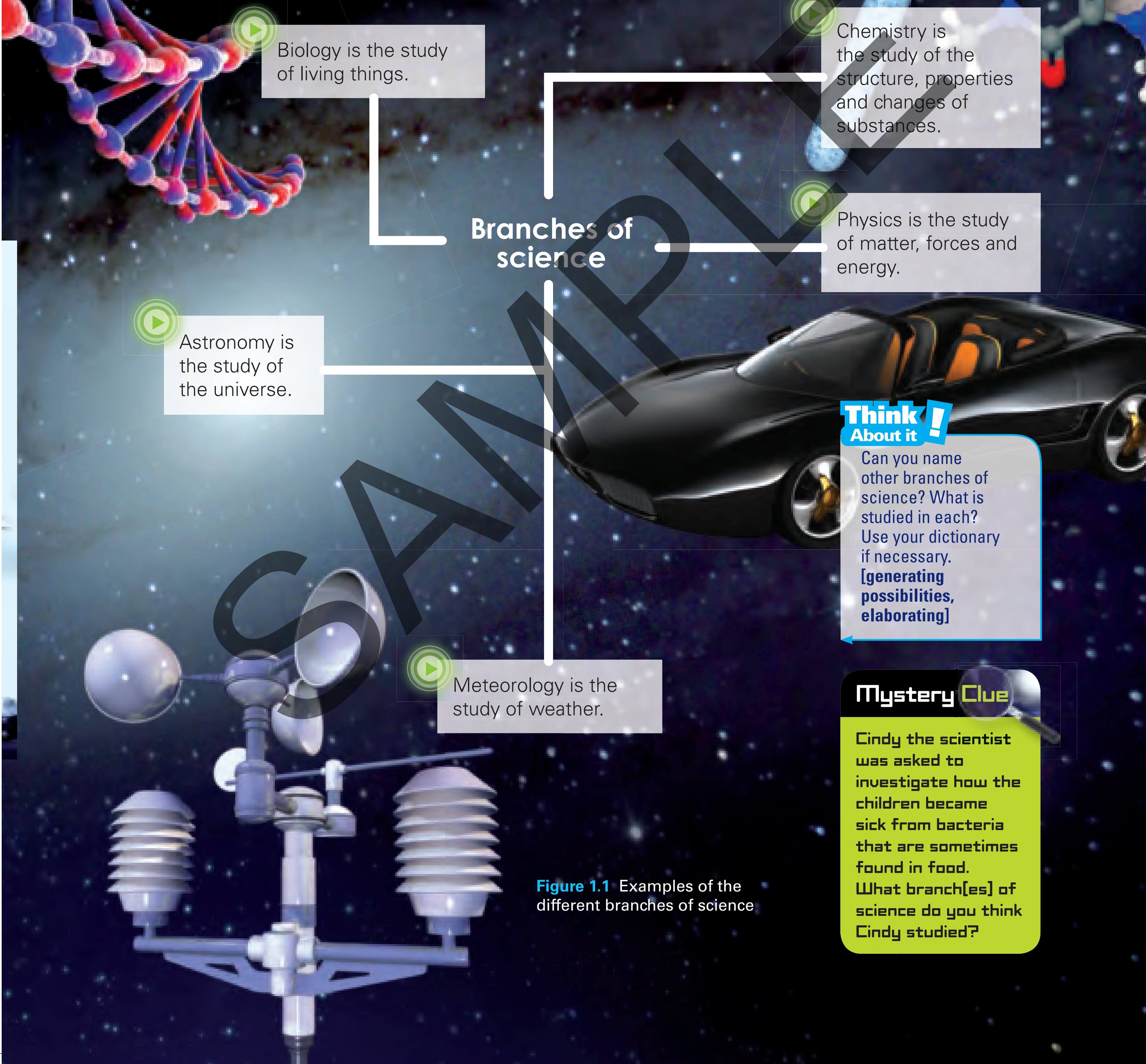


Figure 1.1 Examples of the different branches of science

Think About it!

Can you name other branches of science? What is studied in each? Use your dictionary if necessary. **[generating possibilities, elaborating]**

Mystery Clue

Cindy the scientist was asked to investigate how the children became sick from bacteria that are sometimes found in food. What branch[es] of science do you think Cindy studied?

Science is everywhere

We often see science at work in a **laboratory**, where scientists carry out experiments to find out about the world. Some scientists, such as environmental scientists, even go outdoors to collect data and carry out research.

Figure 1.2 A scientist carries out experiments and analyses results in a laboratory.

Figure 1.3 An environmental scientist collects water samples to analyse water quality.

However, these are not the only ways in which we see science at work. Science can be found in all aspects of our everyday lives! Here are some examples.

Science is at work when…

We cook our food to kill germs.

We place water in the freezer to get ice.

We use a Global Positioning System (GPS) to find our way.

We take medicine to help us recover from illnesses.

Figure 1.4 Science can be found in all aspects of our everyday lives.

1.2 Who Were Some Famous Scientists?

The following is an account of three famous scientists and their discoveries.

Louis Pasteur (1822–1895)

Figure 1.5 Louis Pasteur

Louis Pasteur lived and worked in France. He studied **biology** and **chemistry**. He is famous for his discovery that germs, such as bacteria, make food go bad.

Pasteur was asked to find out why beer turned sour. Using the work of Anton van Leeuwenhoek, who did research using the microscope, he observed bacteria in beer that had gone sour. He then carried out experiments to show that it was the bacteria that made the beer turn sour. Later, he showed that bacteria also made milk turn sour.

Marie Curie (1867–1934)

Figure 1.6 Marie Curie

Marie Curie was born in Poland. Because girls in Poland could not enter university, she went to France to study and work. In 1898, Marie and her husband, Pierre Curie, discovered a new metal called radium that gives off rays. These rays, known as X-rays, were discovered by Henri Becquerel.

Marie discovered that these rays could kill body cells. She was curious to know if they would also kill diseased cells. They did and so she used the rays from radium to kill cancer cells.

Marie always worked with patience and perseverance. She often got results only after years of careful work. Her work with radium was important in both **chemistry** and **medicine**.

Daniel Tsui Chyu (1939–)

Figure 1.7 Daniel Tsui Chyu

Daniel Tsui was born to a poor family in China. Later, he was educated in a Middle School in Hong Kong. He is now in the United States of America where he teaches and carries out research in electrical engineering.

In 1998, Tsui, along with two other scientists, won the Nobel Prize in physics for their contributions to our understanding of electricity. Their discoveries resulted in the development of new but very small transistors that are used in mobile phones today. These may help in the development of even more advanced computers.

Mystery Clue

Scientists often build on discoveries of others. Which of Pasteur's discoveries might help Cindy to solve the mystery as to why the children became sick?

The examples of Louis Pasteur, Marie Curie and Daniel Tsui show three important things about science:

1. Discoveries made by scientists **build on the work of others**. For example, Pasteur used a microscope, building on the work of Anton van Leeuwenhoek, who had also discovered bacteria (see page 137). He also built on the work of a doctor in Vienna who suggested that bacteria cause diseases. Marie Curie depended on the work of Henri Becquerel who had discovered X-rays a few years earlier.
2. Science is a human endeavour with **contributions being made by many people** in different countries.
3. Science is a **part of our everyday lives**. For example, when we cook food at home, we are applying Pasteur's discovery of how heating kills bacteria.

Investigate it!

Life of a scientist [ICS: management of information]

Search the library or the Internet for the life story of one of the following scientists: John Dalton, Gregor Mendel, Thomas Edison, Al Kindi, James Watson, Yang Chen Ning. What are some of their achievements? What qualities did they have? Present the information you find in the form of a poster to your class.

To make a good poster, keep the following points in mind:

- Include pictures.
- Use text but not too much — let the pictures tell the story.
- Use a large font size so that people can read from at least 1 m away easily.
- Focus on the main points — in the title, the pictures and the main headings.

GOT it?

1. (a) What is science?
   (b) What is a person who studies and practises science called?
2. (a) Biology is a branch of science. What does it involve?
   (b) Name some other branches of science.
   (c) Name some famous scientists.

1.3 Attitudes Needed in Science

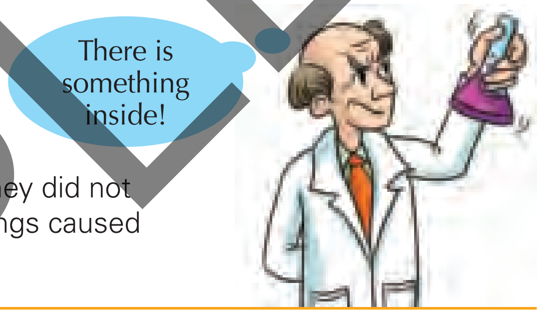
In February 2004, a scientist in South Korea, Hwang Woo-Suk, announced that he had cloned a human embryo. Cloning involves producing an exact copy of an animal using one cell of that animal. Hwang's feat was important as cells taken from human embryos could, in the future, lead to the cure of many diseases. However, Hwang's claim turned out to be false; he had faked his results!

An important attitude in science is being truthful and not faking results of experiments. When this happens, people can lose their trust in scientists. Thus, scientists need to have positive attitudes.

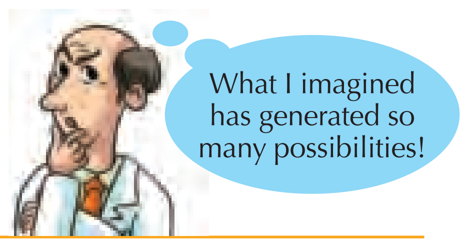
Louis Pasteur, Marie Curie and Daniel Tsui (Section 1.2) showed several positive attitudes. These included being curious, creative, imaginative and showing perseverance. These, and other positive attitudes needed for scientific inquiry, are described below.

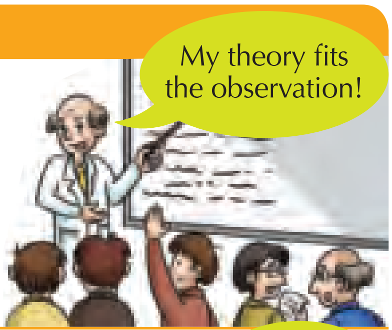
Link it
TW: Exercise 1.1

<table>
<tr><th>Attitude</th><th>Example</th></tr>
<tr><td>Being curious
Wanting to explore and find out</td><td>Louis Pasteur (page 7) observed that sometimes food went bad and was curious to find out why.

</td></tr>
<tr><td>Being open-minded
Willing to accept new ideas but at the same time not believing that all you read or find out is true or correct</td><td>Pasteur's results showed that bacteria made food go bad. He was willing to accept this result. However, other scientists were not; they did not at first believe that living things caused food to go bad.

</td></tr>
<tr><td>Being humble
Not being too proud of what you have discovered; a willingness to say "I am wrong" and to change your ideas when new evidence is presented</td><td>Harold Urey, who published a theory on the origin of the moon's surface, immediately admitted he was wrong when he examined some rocks brought back from a mission on the moon.

</td></tr>
<tr><td>Being creative
Looking for new ways to solve problems</td><td>Pasteur's method to solve the problem of how to stop milk from going bad was new and effective.

</td></tr>
<tr><td>Being imaginative
Being able to think of and make mental pictures of things we cannot see or do not know</td><td>In 1543, the Polish astronomer, Nicolaus Copernicus, imagined that the planets moved around the sun. Until then, people believed that the planets revolved around the earth.

</td></tr>
</table>

<table>
<tr><th>Attitude</th><th>Example</th></tr>
<tr><td>Being objective
Being fair and not letting opinions or beliefs affect your work</td><td>In 1803, John Dalton, an English school teacher, proposed a new theory about matter. He did this despite the fact that for 2 000 years, many people had believed that all matter was made up of fire, air, earth and water.

</td></tr>
<tr><td>Being truthful
Being honest and not changing the results of experiments</td><td>When you make measurements in an experiment, record these even if you think they may be wrong.

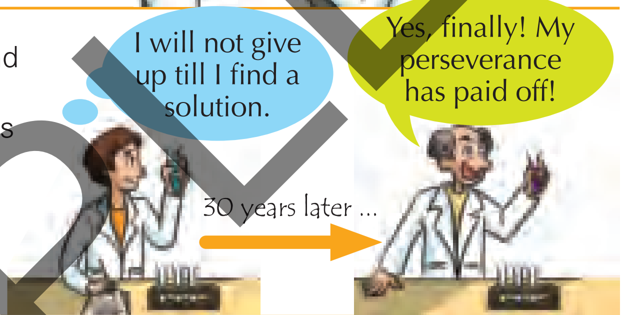
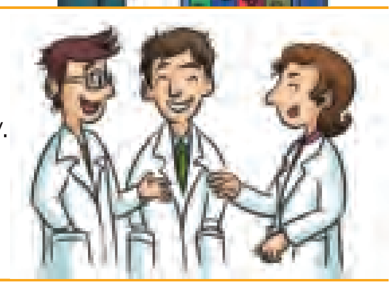
</td></tr>
<tr><td>Showing perseverance
Working on a problem until a solution is found</td><td>Both Louis Pasteur and Marie Curie (page 7) worked for many years on problems before they found solutions.

</td></tr>
<tr><td>Being responsible
Showing care and concern for living things and the environment</td><td>Many plants and animals are endangered. We need to be concerned and ensure that our actions do not harm or destroy these plants and animals.
</td></tr>
<tr><td>Working in a team
Sharing information with other scientists</td><td>Governments of many countries have signed agreements with one another to co-operate in science and technology. Co-operation among scientists is especially important during times like the bird flu crisis.
</td></tr>
</table>

Table 1.1

Mystery Clue

Scientists need good attitudes. Suggest attitudes Cindy would need in her investigation to find out how the children became sick.

Investigate it!

Negative attitudes **[observing, analysing]**

On the Internet, carry out a search to find out about one or more scientists who did not show positive attitudes when carrying out their work.

(a) What was the field of work of the scientist(s)?

(b) In what way did they not show positive attitudes?

(c) How would such actions affect others?

Search terms: *scientist faking data*

1.4 How Does Science Affect Our Lives?

Scientific knowledge can be used to **benefit mankind**, but it **can also cause harm**. Here are some examples.

How does science benefit our lives?

Scientific knowledge gained from discoveries made by scientists has been used in many areas of our lives. This application of scientific knowledge is called **technology**. We use technology to benefit our daily lives.

Investigate it!

Benefits of science [CIT: manages complexities and ambiguities]

(a) In small groups, suggest how science has benefited the following people: a cook, an artist, a photographer, a nurse, an office worker.
(b) Select one of these people and present your ideas to the rest of the class.

Think About it!

The typewriter has become obsolete nowadays with the use of computers as a means of writing documents. Thumb drives have replaced floppy disks as a means to store digital information.

Why do you think technology has changed over time? **[formulating hypotheses]**

Figure 1.8 Technology is used in many areas at the Marina Bay to make it an exciting place with various purposes.

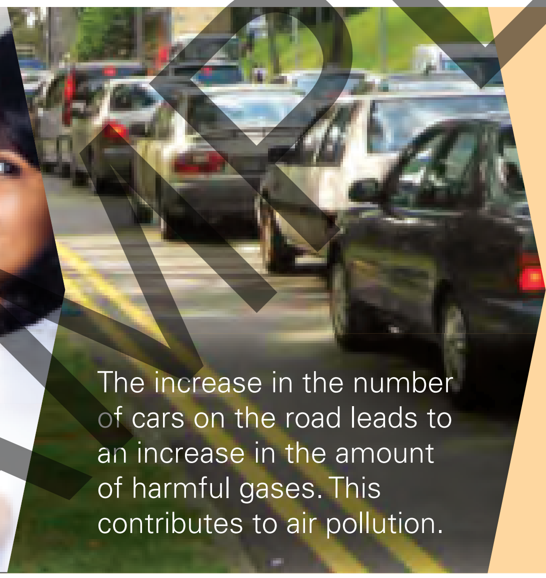
Can science bring harm to our lives?

Although scientific knowledge and technology are used to benefit our lives, there can be harmful effects on society and the environment when they are misused.

For example, scientific knowledge has been used to make chemical and biological weapons for war. Although these weapons may be used for defence, their destructive nature causes more harm.

In order to prevent such harmful effects on our society and environment, we need to use scientific knowledge and technology responsibly. Here are some examples.

Useful effects of technology	Harmful effects of technology	What we can do
The development of plastics has provided us with many lightweight and waterproof materials.	Plastic products are not biodegradable. When not disposed of properly, they can cause pollution of land and water.	We can do our part by reducing or reusing our plastic waste. We can also choose to use more biodegradable products instead of plastic products.
The development of mobile phones gives us the convenience of communicating anytime and anywhere.	Our ability to communicate with others anywhere may cause disturbance to others when we use our mobile phones at inappropriate places or times.	We can do our part by being considerate when using our mobile phones. For example, putting our phones on the silent mode when in libraries or theatres will help us avoid annoying others.

Useful effects of technology	Harmful effects of technology	What we can do
 Advancements in technology allow us to share information, personal ideas and thoughts through the Internet and social media.	 The freedom with which we express ourselves through social media can be abused. We can easily harm or hurt others if we are not careful with what we say.	We can do our part by being sensitive to the feelings of others when we share thoughts or make comments via social media. We can also protect ourselves by not putting too much personal information on the Internet.
 The development of cars allows us to travel faster and over longer distances.	 The increase in the number of cars on the road leads to an increase in the amount of harmful gases. This contributes to air pollution.	We can do our part by walking or cycling when travelling over short distances. This will reduce the production of harmful gases, and conserve natural resources such as oil and natural gas.

GOT it?

1. What is technology?
2. Give examples of how technology has:
   (a) benefited society, and
   (b) caused harm.

Think About it!

Science has given us electricity, cars and jet aircraft, and pesticides.

(a) Suggest benefits of each of these to society.
(b) Suggest some harm that each one may bring to society (if any).
(c) Do you think we should still use these things even if they cause some harm? Discuss this question in a group.

[elaborating]

Link it

Section 18.9: Burning fuels and air pollution

TW: Exercise 1.2

1.5 How Do We Find Out in Science?

In order to find out about things, scientists read books to know what other scientists have discovered. They also carry out experiments and think about the results they obtain.

Carrying out experiments and thinking about the results require scientists to use many skills. These skills include:

- **Posing questions**
- **Observing**
- **Measuring** (using apparatus and equipment)
- **Communicating**
- **Inferring** (including drawing conclusions)
- **Predicting**
- **Formulating hypotheses** (singular: hypothesis)
- **Thinking skills** (including analysing data, organising and communicating results)

Scientists also carry out more complex tasks, called **processes**, that use several skills. Two important processes are:

- **Planning and carrying out investigations**
- **Creative problem-solving**

When you carry out experiments, you will use these skills and processes. You will also need important attitudes for scientific inquiry (Section 1.3).

The above skills and processes are elaborated and described in greater detail in Sections 1.6 and 1.7.

1.6 Skills Needed in Science

Posing questions

In science, we often start by asking questions about things around us. You have probably asked these questions: *How does this work? What would happen if…?* and *Why is this so?* In doing so, you have already been doing what scientists do!

Many questions begin with these six words: *why*, *what*, *where*, *which*, *when* and *how*. We should use these words whenever we ask questions.

Mystery Clue

Scientists ask questions. "How did the children get infected?" is one question Cindy might ask. Can you think of other questions?

Observing

Observing is an important skill. It helps us to collect information about the world around us. Observing requires us to use our five senses — sight, hearing, smell, taste and touch.

The information (or data) collected from observing is either **qualitative** or **quantitative**. Qualitative information is obtained using our senses, such as the loudness of a sound or the taste of food. Quantitative data is obtained through using instruments as extensions of our senses. For example, describing that sugar makes water taste sweet when it dissolves is qualitative. Measuring the amount of sugar that dissolves in the water is quantitative.

When scientists observe, they look for patterns. For example, all lemons taste sour, the sun always rises in the east, and pure water always boils at 100 °C at sea level.

Important patterns that are accepted by scientists are called laws. Here are two examples of laws that you may be familiar with:

- All metals expand when heated.
- Like poles of magnets repel; unlike poles attract.

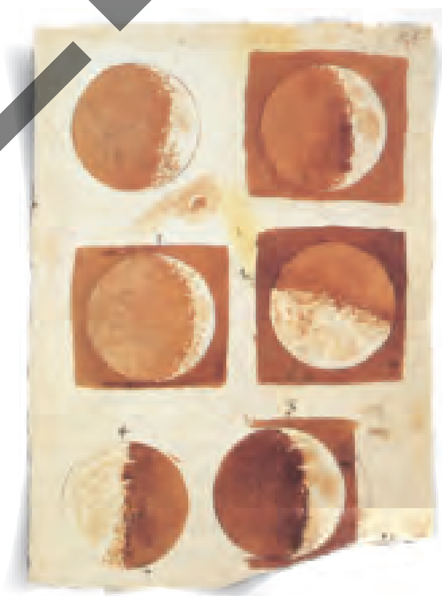


Figure 1.9 Early sketches of the moon's phases by Galileo Galilei

Investigate it!

Do you see what I see?
[observing, communicating]

Look around your school. Tell your class about something in your school that you have observed, but which may not be that obvious to everyone.

Think About it!

Look at Figure 1.10. Make one observation about the frog. Then pose one question about your observation that you can study. **[observing, posing questions]**

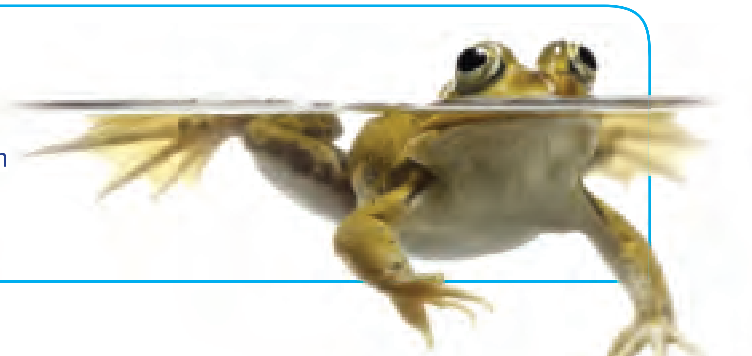


Figure 1.10 A frog in water

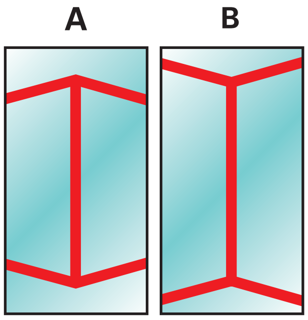


Figure 1.11 Which line is longer, A or B?

Think About it!

What are other measuring instruments that you know? What are they used to measure? **[elaborating]**

Measuring

How accurate are our senses? Figure 1.11 is a simple test to answer this question. Which line, **A** or **B**, is longer? Now, use a ruler to measure the length of the two lines. Were you correct?

In this test, your observation was probably incorrect. Our senses are limited and can be unreliable sometimes. In order to make accurate measurements, we use **instruments** (also called measuring instruments). Some common measuring instruments are shown in Figure 1.12.

In science, making accurate measurements is important. You will learn how to use some of these measuring instruments in the later part of the course.

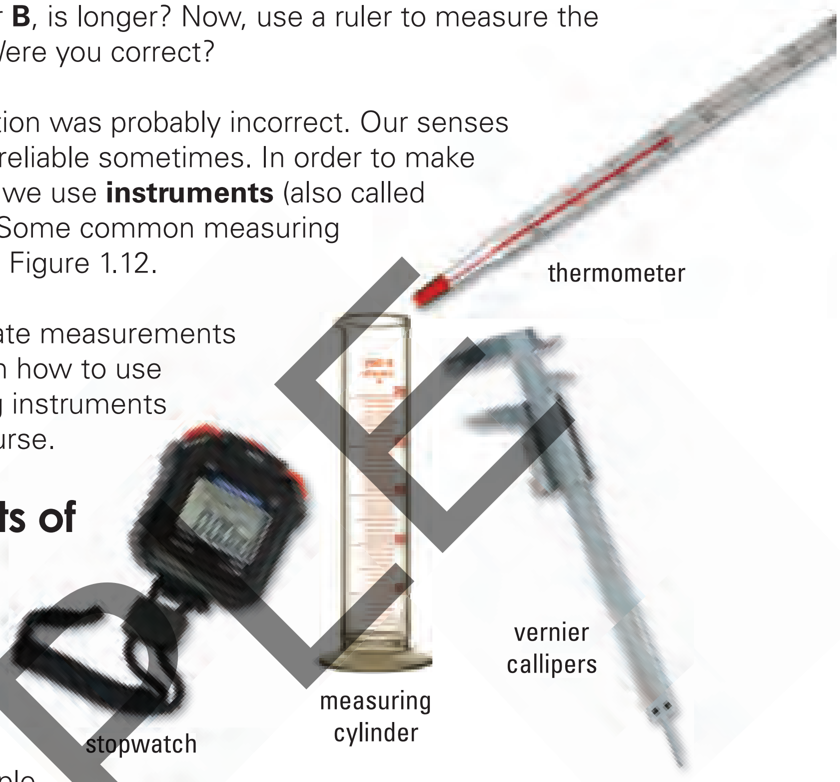


Figure 1.12 Some measuring instruments

What are the units of measurement?

When we measure physical quantities, the amount used for each measurement must be fixed. This fixed amount is called a **unit**. For example, a unit we use to measure length is the **centimetre**.

In the past, the length of an object was measured by comparing it with a part of the body. For example, in ancient Egypt, a cubit was the unit of length. One cubit was the length from the elbow to the tip of the middle finger of a person's hand. What kind of problems did this method result in?


Measuring using the arm was confusing as one person may have a shorter or longer arm than another person. In order to overcome such problems, scientists have been using a system of units called **SI units** since the 1960s.

SI stands for *Systeme International d'Unites* (in French) or International System of Units (in English). This system ensures that a standard set of units is used in scientific measurement. In this course, you will learn the SI units for some common measurements.

Figure 1.13 A scientist must be able to share ideas and results of experiments with others.

Communicating

Whenever we talk, listen or write, we are **communicating**. When we communicate, we share ideas, thoughts and reasoning with other people. Scientists communicate with others to share their ideas and the results of their experiments. Here are some ways we can communicate in science:

- Write statements about what we observe.
- Draw diagrams of what we see.
- For measurements, we can use tables, graphs or charts to record our observations.
- For a project, we may keep a diary, log book or journal.
- We can also use tapes and photographs to record our observations.

Inferring

An **inference** is something new that we have to work out based on information (observations or measurements) that we already have.

Here is an example. Look at Figure 1.14.

Observation: We can see two people together, one of them holding a basketball.

Inference: The two people want to have a basketball match with each other.

Try not to confuse observations with inferences. In the above example, the observation is what we see, while the inference is what we say or claim based on our observation.

Figure 1.14 What can we infer from this picture?

Link it

TW: Exercise 1.3

Things to note when making inferences:

1. We can often make different inferences from the same observation or measurement. From the example above, another inference could be: 'The two people's favourite pastime is playing basketball'.
2. Inferences may turn out to be wrong. For example, the two people's favourite pastime may not be playing basketball, but playing soccer.
3. Experiments usually end with a **conclusion**. A conclusion is also an inference.

Think About it!

Look at Figure 1.15.

(a) Write down your observations.

(b) Write down some inferences from these observations.

[inferring]

Figure 1.15 Marks in sand

Predicting

From observations, we can often make predictions. When we make a **prediction**, we say what will happen in the future. For example, 'The taller player will win the match'. A prediction is also an inference.

Formulating hypotheses

In order to explain observations, we sometimes make guesses. A smart guess is called a **hypothesis** (plural: **hypotheses**).

Lee observes that his torch stopped working. In order to explain this observation, he says:

"The battery has run out of energy."

This is Lee's hypothesis. A hypothesis needs to be tested. You will learn how to test a hypothesis in the next section.

Mystery Clue

Cindy suggested that the baby Komodo dragons carried the bacteria. She also suggested that there might be bacteria on the fence around the Komodo dragons' house and the children were infected by touching the fence. What do we call suggestions like this in science?

Investigate it!

Why is this so? [formulating hypotheses]

Suggest a hypothesis to explain each of the following observations:

(a) Ice left on the bench turns to water.
(b) Many fish in a river have died.
(c) Milk goes bad quickly if it is not kept in a refrigerator.

GOT it?

1. Without looking at the previous pages, try to name some important skills in science.
2. Name some measuring instruments used in science.
3. Name some ways scientists use to communicate observations and the results of experiments.
4. What is the meaning of (a) an inference and (b) a hypothesis?
5. Ros heated some water in a beaker. She measured the temperature of the water every minute for seven minutes. In her lab notebook she wrote, "As I heated the water, it became hot very quickly." She also recorded a table of her observations as shown below.

Time (minutes)	0	1	2	3	4	5	6	7
Temperature (°C)	20	28	36	44	52	60	68	76

(a) Which of her observations are (i) qualitative and (ii) quantitative? Explain.
(b) Suggest what Ros might do using her quantitative observations.

1.7 Processes in Science

In Section 1.6, you learnt that hypotheses need to be tested.

Note Lee's hypothesis on page 18. He can use his hypothesis to make a prediction, and then test his prediction by carrying out experiments.

The overall steps that Lee can take in formulating and then testing his hypothesis are shown below. These steps involve key elements of a **scientific method**.

Formulating and testing a hypothesis	Step 1	Step 2	Step 3	Step 4
	Making an observation The torch is not working.	**Formulating a hypothesis** The battery has run out of energy.	**Making a prediction** The torch will work if the battery is replaced.	**Testing the prediction** An experiment is designed to test the prediction.

In science, hypotheses that have been tested and can explain many things are called theories.

Planning and carrying out investigations

When we plan something, we think of the important things we need to do. When we plan an experiment, we have to decide what apparatus to use and what observations or measurements to make. We also have to think of how we can conduct the experiment to make it a **fair test**.

In many experiments, there are factors that can affect the result of the experiment. These are called **variables**. For example, if we want to find out how temperature affects the amount of sugar that dissolves in tea, this is what we do to conduct a fair test:

- Identify the variable we want to change, e.g. temperature. This is called the **independent variable**.
- Identify the variable to measure and see what happens, e.g. the amount of sugar dissolved. This is called the **dependent variable**.
- Keep all other variables constant (the same), e.g. the amount of tea used and the location where the experiment is conducted.

Carrying out these steps is called **controlling the variables** and will help us to conduct a fair test.

The following flow chart shows the important steps to take when planning and carrying out an investigation.

1. **Purpose**
   This is the question or hypothesis you are investigating.

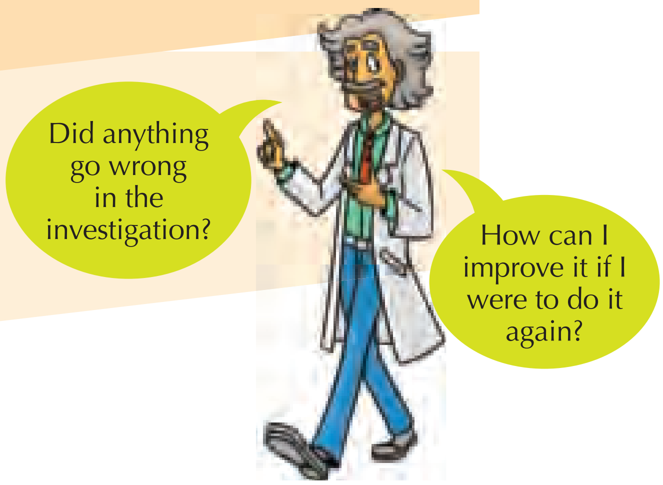
2. **Planning**
   - Identify the variables in the experiment. Decide which variable you will observe and which you will change.
   - When necessary, make the experiment a fair test by controlling other variables.
   - Choose suitable apparatus and materials for the experiment.
   - Decide how to record the observations or measurements.

3. **Method**
   Describe how you will conduct the experiment. You can also include diagrams of apparatus.

4. **Results**
   - Record your observations and measurements.
   - For quantitative data, repeat the experiment at least three times. By taking the average of the readings, the results will be more accurate.

5. **Conclusion**
   Draw a conclusion which answers the question being investigated.

6. **Evaluation**
   It is sometimes good to evaluate the investigation and suggest improvements.



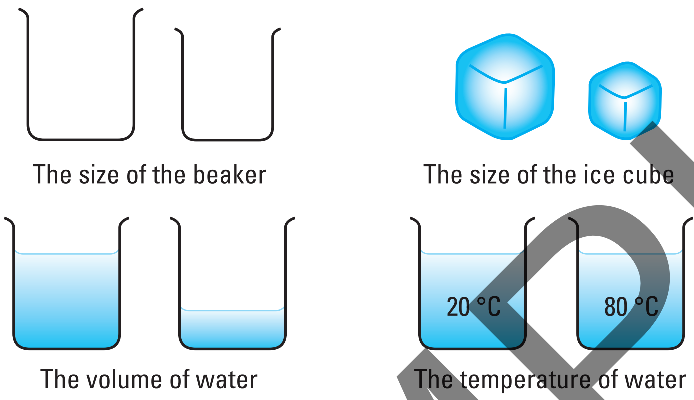
Here is an example of planning and carrying out a scientific investigation.

1. **Purpose**
   Suppose you want to investigate this question:
   Does an ice cube melt faster in hot water or cool water?

State the purpose of the experiment.

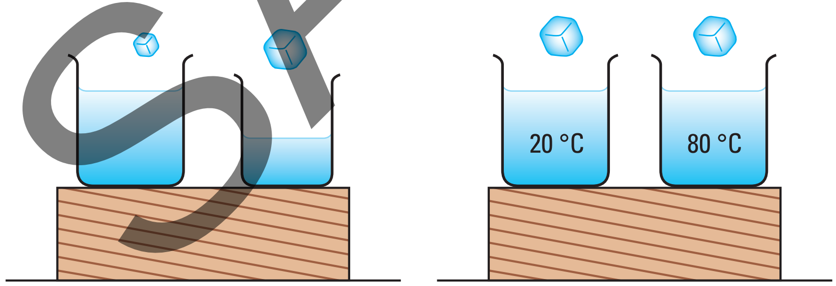
2. **Planning**
   There are several variables that might affect the melting of an ice cube in water. Here are four of them:

Identify the variables.



In this experiment, we want to investigate how **temperature** affects the **time taken** for an ice cube to melt. Hence, we will **measure** the **time taken** (**dependent variable**) for ice cubes to melt in water at **different temperatures** (**independent variable**). Besides temperature, other variables may affect the time taken for ice to melt. For example, a small ice cube will melt faster than a large ice cube.

Control the variables to make the experiment a fair test.



This test is not fair. More than one variable is different.

This test is fair. Only the temperature of the water in the two beakers is different.

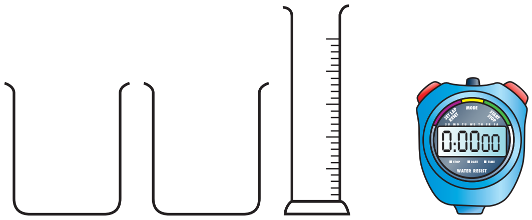
In order to conduct a fair test, we control all other variables except the temperature of water.

Mystery Clue

This section is about something Cindy and other scientists do to test their hypotheses. What is this?

For this experiment, we need two beakers of the same size, a measuring cylinder, a stopwatch, cool water (tap water), hot water and two ice cubes of the same size.

Apparatus required



Choose suitable apparatus and materials.

Decide how to record observations and measurements.

3. **Method**

❶ Add 50 cm^3 of tap water to a measuring cylinder.
❷ Pour the water into a beaker.
❸ Add one ice cube to the beaker of water.
❹ Using the stopwatch, measure the time taken for the ice cube to melt completely.
❺ Repeat steps 1 to 4 using 50 cm^3 of hot water.
❻ Repeat the whole experiment to obtain at least three sets of readings. Take the average of these readings to obtain a more accurate result.

Describe how to conduct the experiment.

4. **Results**

- Record your observations and measurements.
- For quantitative data, repeat the experiment at least three times. By taking the average of the readings, the results will be more accurate.
- We will record the results in a table.

Time taken for ice to melt completely

	1st reading	2nd reading	3rd reading	Average
Cool water	5 min 30 s	5 min 45 s	5 min 20 s	5 min 32 s
Hot water	2 min 10 s	2 min 0 s	2 min 20 s	2 min 10 s

Record the observations or measurements.

5. **Conclusion**
An ice cube melts faster in hot water than in cool water.

6. **Evaluation**
Instead of just using hot water and cool water, we might use water at several different temperatures, for example, 30 °C, 40 °C and 60 °C.

From the results, draw a conclusion which answers the question being investigated.

Evaluate your investigation and suggest improvements.

Obtaining scientific knowledge

The above investigation shows how scientific knowledge is obtained. It comes from:

- making careful observations (qualitative or quantitative),
- doing experiments,
- analysing the results of the experiments to obtain useful conclusions, and
- using imagination and creativity.

Think About it!

Suggest any other ways to improve the investigation on pages 21–23. **[elaborating]**

GOT it?

Wen Hui wanted to find out if more jelly powder dissolves in hotter water than in cooler water. She found that 5 g of jelly powder dissolved in water at 20 °C, 6.5 g in water at 40 °C and 9.2 g in water at 60 °C.

(a) In her experiment, what is
  (i) the independent variable, and
  (ii) the dependent variable?
(b) How will Wen Hui set up her experiment to ensure that the experiment is fair?
(c) (i) Put her results into a table, using 'water temperature' and 'weight of jelly powder that dissolved' as column headings.
  (ii) To ensure that her results are accurate, what should Wen Hui do?
(d) Draw a conclusion from her results.
(e) For successful scientific inquiry, scientists need positive attitudes. List some attitudes Wen Hui would need while carrying out her investigation.

Link it
TW: Exercise 1.4
PW: Activity 1.5

Creative problem-solving

A **problem** is a statement or question that needs to be solved or answered.

When we ask questions, every question we ask is actually a problem. However, a question such as "What is the meaning of photosynthesis?" is a simple problem that can be answered by using a dictionary. On the other hand, "How can we show that light is necessary for photosynthesis?" is a more difficult problem. This is because if we do not know the answer to the above question, we have to design an experiment to get the answer.

As scientists often ask difficult questions about things, they have to be creative to find ways to answer the question or solve the problem. Creative problem-solving requires us to think of and imagine solutions. Often, the solutions may not have been thought of before.

Creative problem-solving involves the following steps:

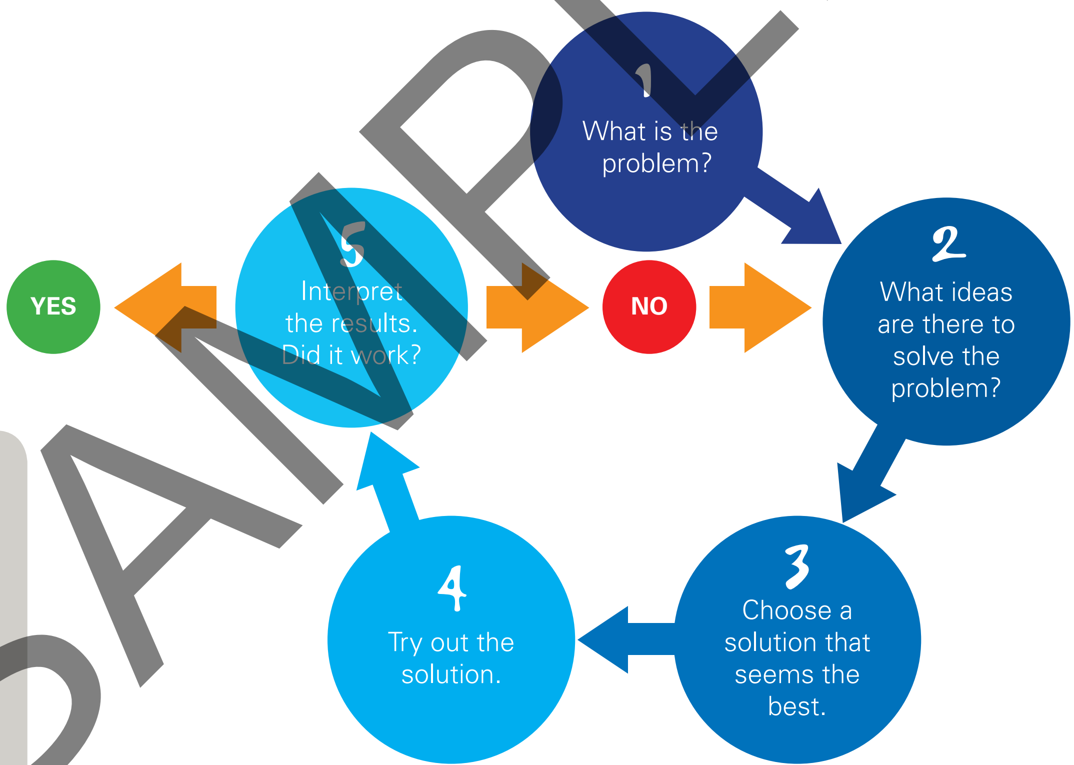


Figure 1.16 Steps in creative problem-solving

Investigate it!

An egg container
[CIT: explores possibilities and generates ideas]

Imagine you want to post an egg to a friend overseas. Design a container which will hold the egg without causing it to break. Draw a diagram of your container and label it to show its features.

Here are examples of where creative problem-solving is needed:

- When we are **planning a scientific investigation**
- When we are **designing a device** such as a machine or a piece of apparatus
- When we are **thinking of a scheme or a plan** to overcome a problem

Redi's Experiment

Francesco Redi was an Italian doctor and poet. He was one of the first to design fair experiments. In this experiment, Redi showed that flies do not come from rotting meat as people thought.

Figure 1.17 Francesco Redi (1626–1697)

Figure 1.18 Maggots were thought to have come from rotting meat.

1 Redi placed meat in two identical jars. He left one uncovered. He covered the other with a cloth.

2 After a few days, Redi saw maggots (young flies) on the rotting meat in the uncovered jar. There were no maggots on the meat in the covered jar.

3 Redi inferred that flies had laid eggs on the meat in the uncovered jar. The eggs hatched into maggots. Because flies could not lay eggs in the covered jar, there were no maggots there. Redi concluded that rotting meat could not produce maggots.

Think About it!

Answer the following questions:

(a) What was Redi's hypothesis?

(b) In his experiment, what was one factor that was different in the two jars?

(c) Explain why Redi's experiment was fair.

[elaborating, verifying]

1.8 Limitations of Science

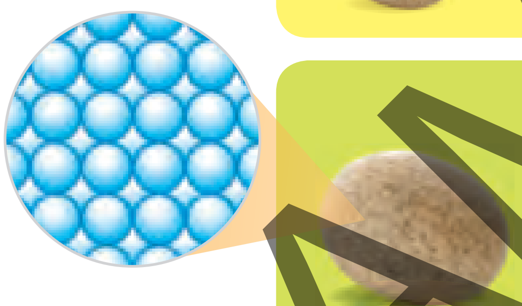
Through science, we explore and understand our world. However, science has **limitations**. Here are some of them.

Link it
Section 3.1: Elements
Section 7.2: Particles in solids, liquids and gases
Section 8.1: Atoms

Scientific knowledge always changes

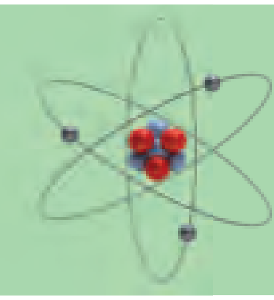
We only accept scientific knowledge if it can explain observations and answer questions. Later, if there are new observations that scientific knowledge cannot explain or questions that it cannot answer, we look for new and better explanations. Here is an example.

First, we did not know what objects, such as stones, were made of. About 2 500 years ago, a Greek philosopher and scientist said that everything is made of four elements — fire, air, water and earth.



Next, another Greek said that things are made up of small particles called *atomos* (or atoms). A stone is made up of many small 'stone' atoms. 2 000 years later, John Dalton, an English schoolteacher and scientist, also said that everything is made of atoms. He believed atoms were like small solid balls.

Now, we know that atoms are not small solid balls; they consist of even smaller particles.



In future, what will scientists discover about atoms

Mystery Clue

Many years ago, scientists thought we got sick by breathing bad-smelling air. Then Pasteur showed it was not air but bacteria in food and water that cause disease. What does this tell us about scientific knowledge?

This example also shows that many people contribute to scientific knowledge. Scientific knowledge is never fixed but could change and possibly improve over time. As you study the chapters in this book, you will see more examples of this, including our understanding of what things are made of.

Link it
Sections 13.10 & 17.6: Global warming

Scientific evidence can be interpreted differently

Scientists often disagree with one another. They can interpret the same observations and data in different ways. This leads to a lot of discussion and debate among scientists.

One example is vitamin C and colds. An experiment showed that people who took vitamin C tablets had fewer colds than people who did not take the tablets. Some scientists say this suggests that a lack of vitamin C causes people to get colds. Other scientists interpret the results differently. They suggest that it was not a lack of vitamin C that caused more colds, but other factors such as living conditions or even food that people in the study had eaten.

In cases such as this, more evidence is needed so that more reliable conclusions can be obtained.

Science cannot answer all questions

Although scientists have made many discoveries, they cannot answer all questions or solve all of our problems. Here are some examples.

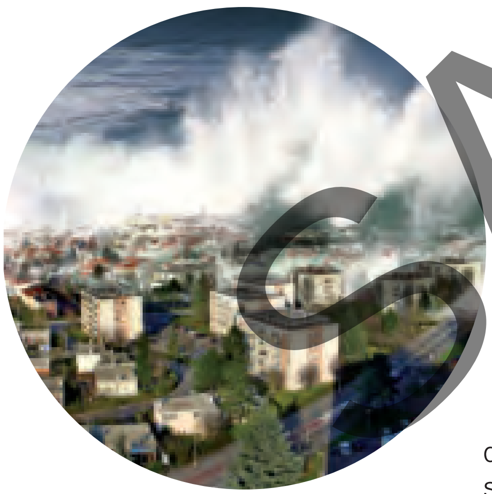


Figure 1.19 Science cannot prevent the occurrence of natural disasters.

Scientists can accurately measure the strength of typhoons and earthquakes. However, they cannot prevent them from happening.

Scientists know the causes of many diseases. However, they cannot always stop diseases from spreading from one person to another. Often, it is we who must do this.

Figure 1.20 Science cannot always prevent the spread of diseases.

Science does not answer ethical and social issues

Link it
TW: Exercise 1.5

Ethics deals with what is right and wrong, or good and bad. Scientific knowledge cannot decide what is right and wrong or good and bad. People in society, not scientists, have to decide how scientific knowledge is used, or even not to use it at all.

Surrogacy

Sometimes, a married couple is unable to have a baby. So, they get another woman (called a surrogate mother) to have a child for them. Scientists have discovered ways to do this using eggs and sperm from the couple or from other people. This may raise issues such as who the baby's true parents are.

Human genetic engineering

Human genetic engineering is the alteration of a person's genes. It may allow us to cure genetic diseases, or change the characteristics of a newborn or adult. The idea of genetically engineering a human has raised many ethical arguments. Some believe that every child has the right to be cured from genetic diseases; some feel that parents have no right to genetically modify their children.

Scientific knowledge also cannot be applied to solve societal problems. In such situations, people need to consider other factors before making decisions.

Care for our parents

Advancements in technology and medicine, and the availability of healthcare services allow us to adequately care for elderly folk in Singapore. Thus, some people bring their parents to nursing homes. Although we have such facilities, the decision of how and whether we should care for our parents is something that lies with us.

Poverty

The problem of poverty exists in many countries. In Singapore, for example, we can find people who are very poor, some even homeless. Who should help them? How should they be helped? Scientific knowledge cannot be applied to answer these questions.

Solving the Mystery...

Where did the bacteria come from?

Science is the study of the natural and physical world. It has many branches. The branches that Cindy studies are biology and medicine.

In order to solve the mystery, she used many scientific skills, such as posing questions, observing, making hypotheses and doing experiments to test her hypotheses. In her work, she also needed positive attitudes, such as being curious and creative.

In order to solve the mystery, Cindy observed that the Komodo dragons would stand up and touch the fence around their site. Her experiments then showed that there were bacteria on the fence. Cindy concluded that when the Komodo dragons touched the fence, they would leave behind bacteria that infected the children who touched the fence.

Further thought

Scientific knowledge is never permanent but is always changing and improving to give a better understanding of our world. Scientific knowledge can be used to improve our lives but can also cause harm. Give examples that show this.

Chapter Review

Map it!

Scientific endeavour

→ **Science**
- Study of the physical and natural world
- Scientific knowledge comes from:
  - observations and experiments
  - human imagination and creativity
- Scientific knowledge is subject to change

→ **Scientific inquiry**

→ **Technology**
- Application of scientific knowledge
- Can be used to bring benefits and/or harm

Scientific inquiry →

Skills

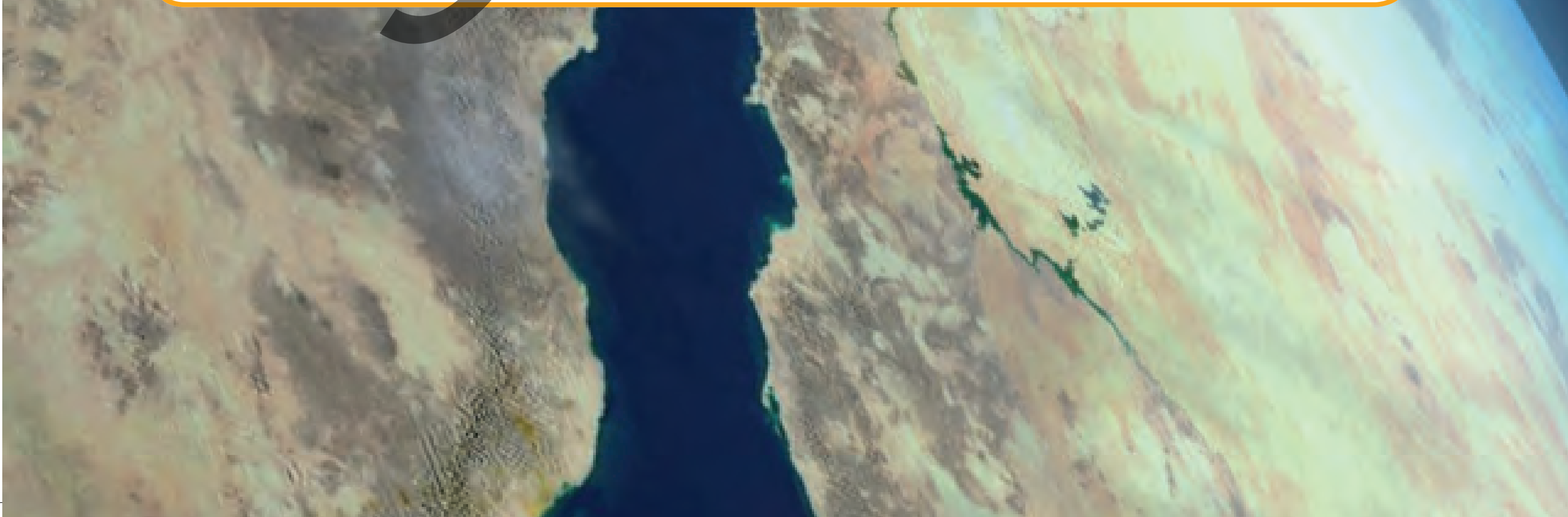
Examples
- Posing questions
- Observing
- Inferring
- Formulating hypotheses

Processes

Examples
- Creative problem-solving
- Planning and carrying out experiments

Attitudes

Examples
- Curiosity
- Open-mindedness
- Perseverance



Apply it!

1. Scientific knowledge has been used to benefit our lives. To show this, give examples of what people used in the past and what we use today for each of the following:
(a) Cooking
(b) Cleaning the house
(c) Communicating with friends overseas
(d) Travelling
(e) Receiving news on current affairs
(f) Keeping rooms cool on hot days
[elaborating]

2. Science is seen in many aspects of our lives. Look at the list below and classify them into two groups — situations where science can be applied and situations where it cannot be applied.

Finding the weight of a car	Deciding if we should explore outer space
Finding the atmosphere on Mars	Choosing clothes for a cold day
Finding the value of a painting	Deciding if we should build a new school
Cleaning a cut from a fall	Finding out how high an aeroplane can fly

[classifying]

3. You see an advertisement on television which says that 'CleanO' is the best washing powder.
(a) Write a suitable question that can be tested by an experiment.
(b) Describe an experiment you could do to answer your question in (a).
[posing questions, planning investigation]

4. Su Ling observed how a flat piece of paper fell slowly to the ground. She suggested this hypothesis:

'Surface area affects how fast the paper falls.'

How can you test her hypothesis? Challenge **[planning investigation]**