MYP by Concept
2

Sciences

Paul Morris
Patricia Deo

DYNAMIC LEARNING
HODDER EDUCATION

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Series editor: Paul Morris

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Contents

How to use this book

Welcome to Hodder Education's *MYP by Concept* series! Each chapter is designed to lead you through an inquiry into the concepts of MYP Sciences, and how they interact in real-life global contexts.

Each chapter is framed with a *Key concept* and a *Related concept* and is set in a *Global context*.

The *Statement of Inquiry* provides the framework for this inquiry, and the *Inquiry questions* then lead us through the exploration as they are developed through each chapter.


Relationships

Form, energy

Personal and cultural expression

4 What does a wave tell us?

Understanding the relationships between different forms of wave energy helps us better communicate and express our thoughts.

CONSIDER THESE QUESTIONS:

Factual: What is a wave? What is light? What kinds of energy travel as waves? How are we sensitive to energy that travels as waves? What other kinds of electromagnetic radiation are there? How are we sensitive to sound waves?

Conceptual: How does understanding waves help us to better express ourselves?

Debatable: Do artists and scientists have anything to say to each other?

Now share and compare your thoughts and ideas with your partner, or with the whole class.

■ Figure 4.1 Where is the wave? (a) The 'Mexican Wave' or 'Ola mexicana' (b) 'Krazy' George Henderson claims he invented the 'Mexican Wave'

IN THIS CHAPTER, WE WILL ...

- **Find out** how waves carry energy through oscillation, and what different kinds of wave there are.
- **Explore** how light and sound are used to communicate and to help us to express ourselves.
- **Take action** to protect ourselves from harmful waves, and investigate how to limit noise pollution.

KEY WORDS

balance medium transmit vibration wave

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KEY WORDS

Key words are included to give you access to vocabulary for the topic. Glossary terms are highlighted and where applicable, search terms are given to encourage independent learning and research skills.

As you explore, activities suggest ways to learn through *action*.

ATL

- Activities are designed to develop your *Approaches to Learning* (ATL) skills.

EXTENSION

Extension activities allow you to explore a topic further.

◆ Assessment opportunities in this chapter:

Some activities are *formative* as they allow you to practise certain parts of the MYP Sciences *Assessment Objectives*. Other activities can be used by you or your teachers to assess your achievement against all parts of an assessment objective.

Key *Approaches to Learning* skills for MYP Sciences are highlighted whenever we encounter them.

Hint

In some of the Activities, we provide Hints to help you work on the assignment. This also introduces you to the new Hint feature in the on-screen assessment.

Information boxes are included to give more detail and explanation.

SEE-THINK-WONDER: Comparing waves

- Search video: Tsunami climbing or go to https://youtu.be/OdhfV-8dbCE to watch footage of a boat riding over a tsunami at sea.
- Search video: gentle wave motion boat to find footage of boats rocking on smaller waves.
- Search video: mexican wave to find footage of a Mexican Wave at a sports event.

Individually, make notes. What do you see? What does it make you think? What does it make you wonder?

Write down descriptive words for the motion in each case.

Figure 4.2 The energy of a tsunami can cause massive destruction

These Approaches to Learning (ATL) skills will be useful …

- Collaboration skills
- Communication skills
- Information literacy skills
- Creative-thinking skills
- Critical-thinking skills

We will reflect on this learner profile attribute …

- Inquirer – we will apply new knowledge to ask new questions and carry out investigations to find the answers.

Assessment opportunities in this chapter:

- Criterion A: Knowing and understanding
- Criterion B: Inquiring and designing
- Criterion C: Processing and evaluating
- Criterion D: Reflecting on the impacts of science

Figure 4.1 shows a stadium wave or 'Mexican Wave' at a sports event. Have you ever seen this, or taken part in one? 'Krazy' George Henderson was a professional cheerleader for an American football team called the Oakland A's, and claims that he started the first 'wave' in October 1981 – in the USA, not in Mexico (in the USA, it is called simply 'the wave'). Others have claimed it really was invented in Mexico – in Monterrey, during a soccer match. The wave certainly gained international recognition during the 1986 World Cup in Mexico.

In this chapter we will explore how important kinds of energy are transferred by waves, and we will consider how waves allow us to communicate our thoughts to each other. But what is a wave? Are all waves like the 'Mexican Wave'?

A tsunami is another kind of wave. It is a very destructive wave created at sea by seismic activity such as an earthquake (see *MYP Sciences by Concept 1*, Chapter 6 for more detail). While far out at sea, the energy of the wave is spread over a very large area and so boats can ride over the wave. When the tsunami hits shallower water, however, its energy becomes concentrated and on hitting land has devastating effects.

4 What does a wave tell us? 87

We have incorporated Visible Thinking – ideas, framework, protocol and thinking routines – from Project Zero at the Harvard Graduate School of Education into many of our activities.

You are prompted to consider your conceptual understanding in a variety of activities throughout each chapter.

Finally, at the end of the chapter you are asked to reflect back on what you have learned with our *Reflection table*, maybe to think of new questions brought to light by your learning.

Use this table to evaluate and reflect on your own learning in this chapter.					
Questions we asked	Answers we found	Any further questions now?			
Factual					
Conceptual					
Debatable					
Approaches to learning you used in this chapter	Description – what new skills did you learn?	How well did you master the skills?			
		Novice	Learner	Practitioner	Expert
Learner profile attribute(s)	Reflect on the importance of the attribute for your learning in this chapter.				

! Take action

! Guidance is given throughout the book about how to apply your knowledge of the scientific process to real-life situations. While the book provides many opportunities to apply the knowledge you have learned in practical ways, you must be an active part in this process. Activities help you explain the ways in which science can be applied and used, and also to discuss and evaluate the implications of using scientific principles to address specific issues. This should give you a better understanding of the issues facing scientists in the twenty-first century. By engaging in these activities, you will also learn the value of consistently applying scientific language to communicate understanding clearly and precisely.

We will reflect on this learner profile attribute …

- Each chapter has an *IB learner profile* attribute as its theme, and you are encouraged to reflect on these too.

Links to:

Like any other subject, MYP Sciences is just one part of our bigger picture of the world. Links to other subjects are discussed.

1 Where are we now and where might we be going?

Through making **models** of the world we have understood how **place and time relate to motion** and we have made the world seem a smaller place.

CONSIDER THESE QUESTIONS:

Factual: Where did we come from? How did we get here? How do we determine distance and location? What are coordinates? How can we measure speed? What is the greatest known speed? What is a force? What can cause a force? How do forces affect motion? What happens when forces balance?

Conceptual: How can we represent motion? What is gravity?

Debatable: Should we all be able to travel wherever we like, whenever we like, however we like?

Now **share and compare** your thoughts and ideas with your partner, or with the whole class.

IN THIS CHAPTER, WE WILL …

- **Find out** how humans have travelled over time, and how they have represented their place in space.
- **Explore** the effects of forces on motion, and how we have learned to travel faster.
- **Take action** to investigate the consequences of mass transportation by motor vehicles on local and global environments, and communicate your scientific opinions on the impact of measures to limit pollution from cars.

These Approaches to Learning (ATL) skills will be useful …

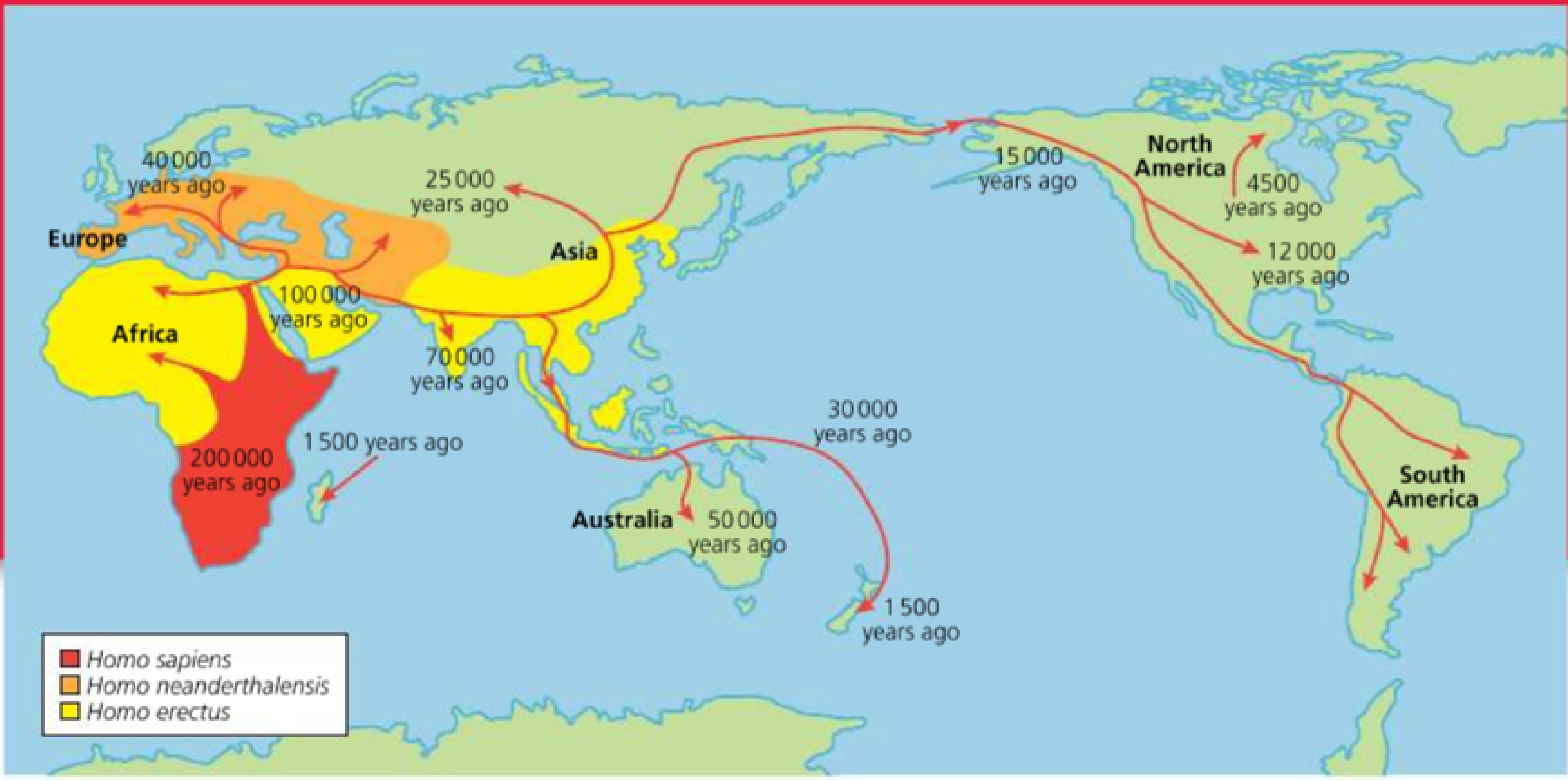
- Collaboration skills
- Information literacy skills
- Media literacy skills
- Critical-thinking skills
- Creative-thinking skills

Assessment opportunities in this chapter …

- **Criterion A:** Knowing and understanding
- **Criterion C:** Processing and evaluating
- **Criterion D:** Reflecting on the impacts of science

We will reflect on this learner profile attribute …

- Reflective – we will reflect on the impacts, advantages and disadvantages of greater human movement.



■ **Figure 1.1a** Early humans travelled by foot to spread across the whole of the planet

■ **Figure 1.1b** Modern humans are beginning to spread beyond the planet

Figure 1.1a shows how scientists believe early human beings travelled to spread across the planet. Scientific research from fossil remains (see *MYP Sciences by Concept 1*, Chapter 6) has shown that our first ape-like ancestors originated in East Africa over 7 million years ago. They began to evolve on a pathway that distinguished them from other apes – who later evolved to become chimpanzees or bonobos. At first our ancestors, such as the *Ardipithecus* family, could walk for short distances only and lived much of the time in trees, while around 4 million years ago *Australopithecus* had enlarged jaws and teeth that suggested a diet that was becoming more **omnivorous**.

KEY WORDS

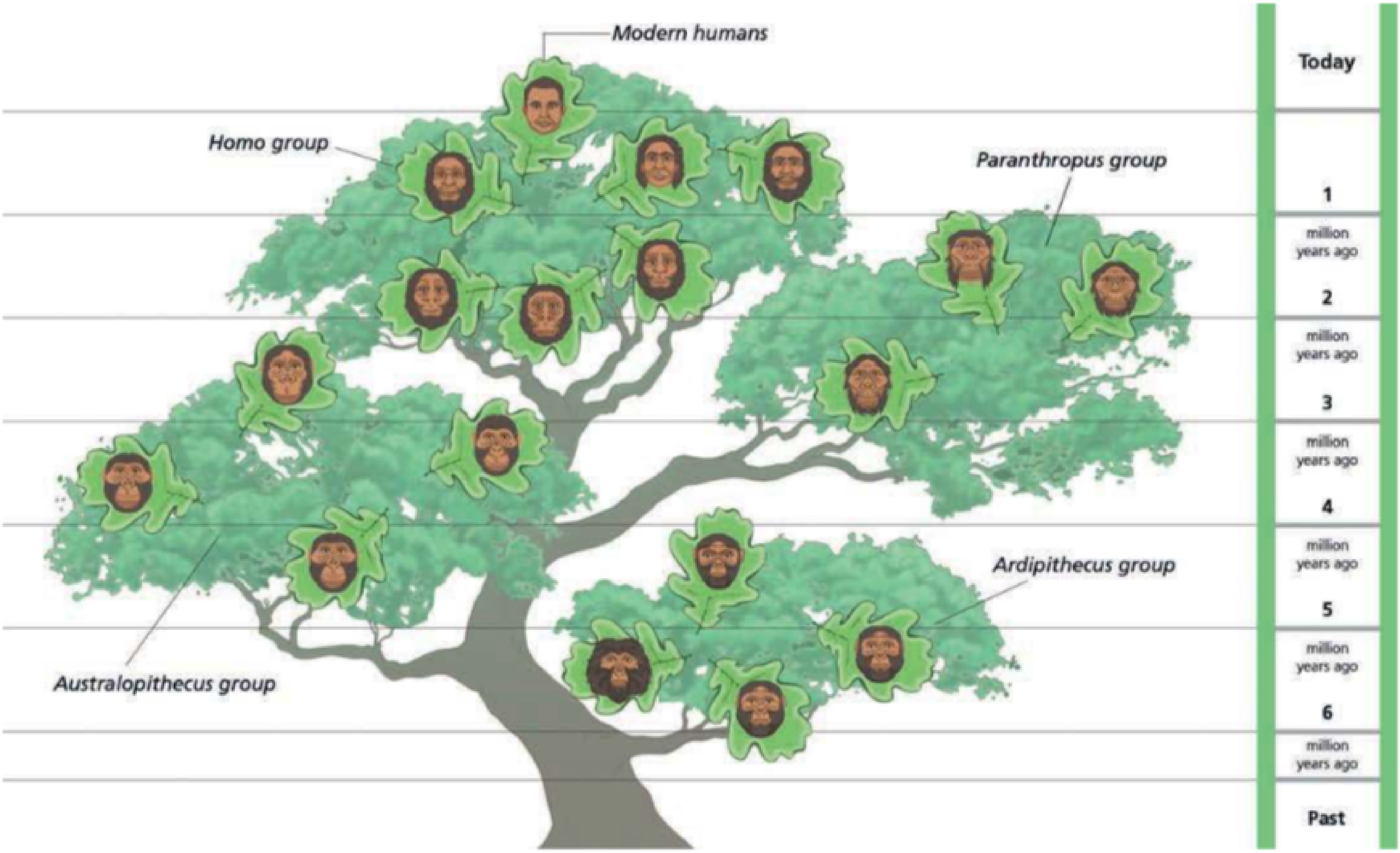
balance
force
gradient
motion
pollution
slope
transport

Where did we come from? How did we get here?

■ **Figure 1.2** Cousins: *Homo neanderthalensis* and *Homo sapiens*

Between two and three million years ago the first members of the human family, called by scientists the *Homo* **genus**, appear in the fossil record. Our first real human ancestors, called *Homo habilis*, had fingers that were nimble enough to fashion tools. In a few hundred thousand years *Homo erectus* was able to walk and run long distances. *Homo erectus* later became extinct, but (fortunately for us) not before a branch of the family evolved along a different pathway again. *Homo neanderthalensis* and *Homo sapiens* both evolved around the same time, one million years ago. Both could make relatively delicate and sophisticated tools such as arrow heads from flaked flint.

Homo sapiens – our **species** – had a brain capacity of around 1400 cm^3 and developed the capacity to think in symbols, which gave rise to language and art. Scientists are not sure about what happened to our cousin *Homo neanderthalensis*, but 'Neanderthal man' seems to have become extinct sometime between 40 000 and 12 000 years ago – although many scientists believe there is genetic evidence to show that Neanderthals and *Homo sapiens* in fact bred together.



■ **Figure 1.3** The human family tree

■ **Figure 1.4** Paintings found in caves in Altamira show that early *Homo sapiens* had the capacity for symbolic thought, and so art

■ **Figure 1.5** Would early humans have understood passport controls?

The first humans that were anatomically identical to us, called *Homo sapiens sapiens*, appeared in East Africa some 200 000 years ago, and migrated north into Eurasia perhaps 100 000 years ago – although *Homo erectus* had already migrated as far east as China, as far south as Indonesia and into the Iberian peninsula (modern Spain and Portugal) at least 600 000 years before us!

After this first breakout from our common African origin, *Homo sapiens* went on to wander the world – steadily eastward through modern Russia, and crossing a land bridge with Alaska into the American continent. Fossils in Chile show that humans were there around 18 000 years ago. It took *Homo sapiens* perhaps 190 000 years or more to colonize planet Earth! Still, it seems clear that from the earliest times to be human has meant to travel.

THINK-PAIR-SHARE

Think of three reasons why early humans might have migrated from their origin.

Classify your ideas into:

- **push factors – negative factors that pushed early humans away from their first home**
- **pull factors – factors that attracted early humans to new places.**

Note down your ideas.

Now pair with a partner and compare your answers. Share your ideas with the whole class, and see if you can agree on a consensus view.

Links to: Individuals and societies

Scientists who study the history and behaviour of human beings are known as anthropologists. The evidence for early human history is gathered using scientific techniques by archeologists.

How do we determine distance and location?

WHERE ARE WE NOW?

Have you ever daydreamed and doodled? It isn't necessarily a bad thing – although it might not be such a good idea to daydream when you are supposed to be paying attention in class! Daydreaming and doodling sometimes can allow us to think creatively, and generate new ideas. Have you ever doodled like the person in Figure 1.6?

■ **Figure 1.6** Doodling about your location in the universe

People often wonder about our place in time and space, and the distances between things. The first recorded forms of measurement were probably based on the size of parts of the human body. Evidence from prehistoric settlements in China and in central Europe show that both Neanderthals and other early humans who lived in the same places cut axes to the same length, and defined weight using stones of the same type and size – even though they probably could not

■ **Figure 1.7** (a) Ancient Egyptian measures (b) The great pyramid of Khufu at Gizeh

count. By 2600 BCE, a civilization of the Indus Valley (now in modern India) used ivory scales to define lengths as small as 1.7 mm.

In ancient Egypt around the same time, the civilization of the pharaohs devised a complex system of measurements that was based on the distance from the elbow to the tip of the middle finger. This distance was known as the **cubit**, and was further divided into smaller units such as the **hand**, which was the width of a palm – the height of a horse is still measured in 'hands' today. This system of measurement was reliable enough for these peoples to build with such accuracy that the length of the sides of the great pyramid of Khufu at Gizeh in Egypt are accurate to within 1.5 mm!

ACTIVITY: Humans as the measure

ATL

- Critical-thinking skills: Revise understanding based on new information; Identify obstacles and challenges

In this activity we will **investigate** how to measure distance in terms of the human body.

1. As a class, decide on a suitable distance in your classroom or school. Make sure it is a fairly long distance that allows for multiple measurements with a 'human ruler'.
2. In pairs, choose who will be the 'human ruler' and who will be the 'measurement taker'. Now choose a part of the body that you can easily use to measure distance – such as an arm, leg or foot.
3. **Measure** your distance with the help of the 'measurement taker', whose job is to ensure that the measurements are as accurate as possible, and to make a note of the measurement when it is made.
4. As a class, **compare** your measurements.

Discuss:

- Did you choose the same part of the body to measure with? If not, team up with other groups to **calculate** how to convert one measurement to another, in order to compare them.
- How closely did each pair's different measurements of your common distance agree?
- With reference to your comparison of class results, **summarize** the difficulties and challenges you encountered in using the human body as a **measurement standard**.

Another division of the cubit was the **foot**, which – as you might expect – represented the length of a human foot. This measurement was inherited by the Greeks and Romans through trading with Egypt (and later invasion). The Roman Empire in particular extended these measurements across Europe and into Asia, and a Roman foot was divided into 12 *unciae* or, in English, **inches** – where an inch was thought to derive indirectly from the length of a finger from the first joint to the end.

When the Romans invaded the islands of Great Britain they brought their measurement system with them. With time and some adjustments and standardizations – especially during the medieval and early renaissance periods – this became the 'common' or (from 1824) the British 'imperial' unit system. Imperial units are still in use today in some parts of the world such as the United States of America, and to some extent in the United Kingdom too, where traffic signs are marked in miles, for example.

Look again at the list of common or imperial measurements above. Can you see any other difficulties with this system of measurement? How easy would it be to convert one measurement to another?

Links to: Language acquisition

In many modern languages that originate from Latin, the word for *inch* derives from the word for 'thumb' – for example, *pouce* in French, or *pulgada* in Spanish.

Units of length in the common or imperial measurement system

Most common units:

- 12 lines = 1 inch
- 12 inches = 1 foot
- 3 feet = 1 yard
- 1760 yards = 1 mile

Some other units still in use:

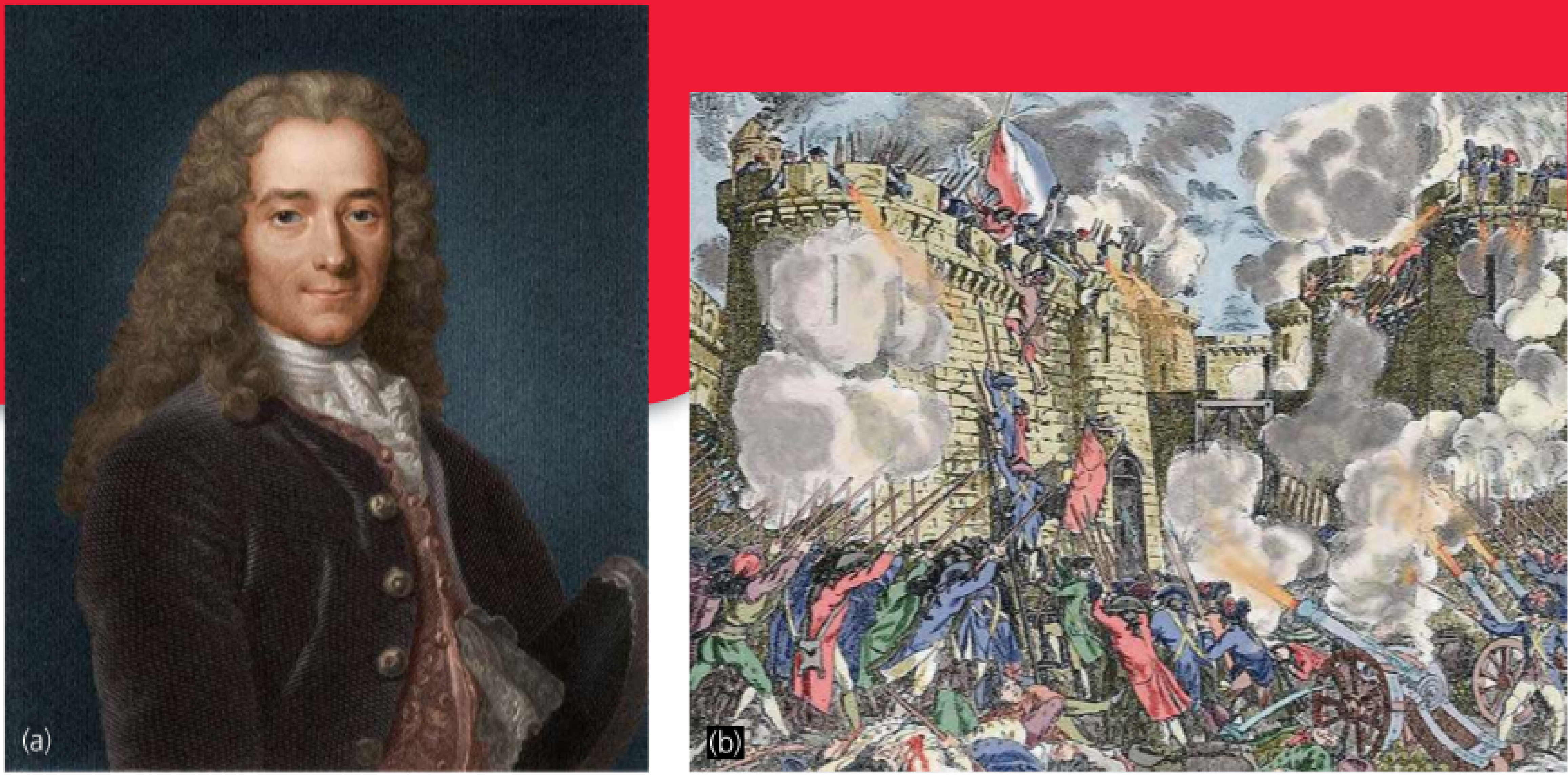
- 22 yards = 1 chain
- 10 chains = 1 furlong
- 8 furlongs = 1 mile
- 4 inches = 1 hand

Accuracy and precision

When scientists make measurements, they need to be sure that the measurements are **reliable**. This means that whoever makes the measurement, wherever they are made and under whatever conditions, the answer obtained will always be the same.

If a number of measurements are **precise**, they will be in close agreement with each other.

If a measurement is **accurate**, it will be close to an expected value.



■ **Figure 1.8** The French writer and philosopher Voltaire (1694–1778) was an important thinker in the 'Enlightenment' that led to the French Revolution (a) Voltaire, (b) the French Revolution of 1789

The French Revolution was another period in history that saw the development of new forms of measurement. The revolution in France from 1789 not only sought to change the way society was organized and who was in charge, but also to reorganize the way humanity thought about time and space. The revolutionaries introduced a new calendar based on 10 months a year rather than the 12 inherited from ancient times, and in 1799 the revolutionary government created new standards of measurement for length and mass, called the **metre** and the **kilogram**. These in turn were divided logically into units of 10, 100 or 1000, in the **metric** system. The measurements were standardized using a platinum rod and a mass, which were kept in the *Archives de la République* in Paris.

In Britain in 1860 the physicists James Clerk Maxwell (1831–1879) and William Thomson (Lord Kelvin) (1824–1907) developed a system of units that aimed to derive all measurements from a small number of basic, metric units. This was the basis of the metric *Système International* (SI) units – although the system wasn't given this name until as late as 1960!

THINK-PAIR-SHARE

Look at Table 1.1. What do you notice about the definitions of the units in the table? What has changed since the first definitions of the metre and kilogram in France in 1799?

Discuss your thoughts with a partner. Why do you think some definitions have been changed?

Now share your ideas with the rest of the class.

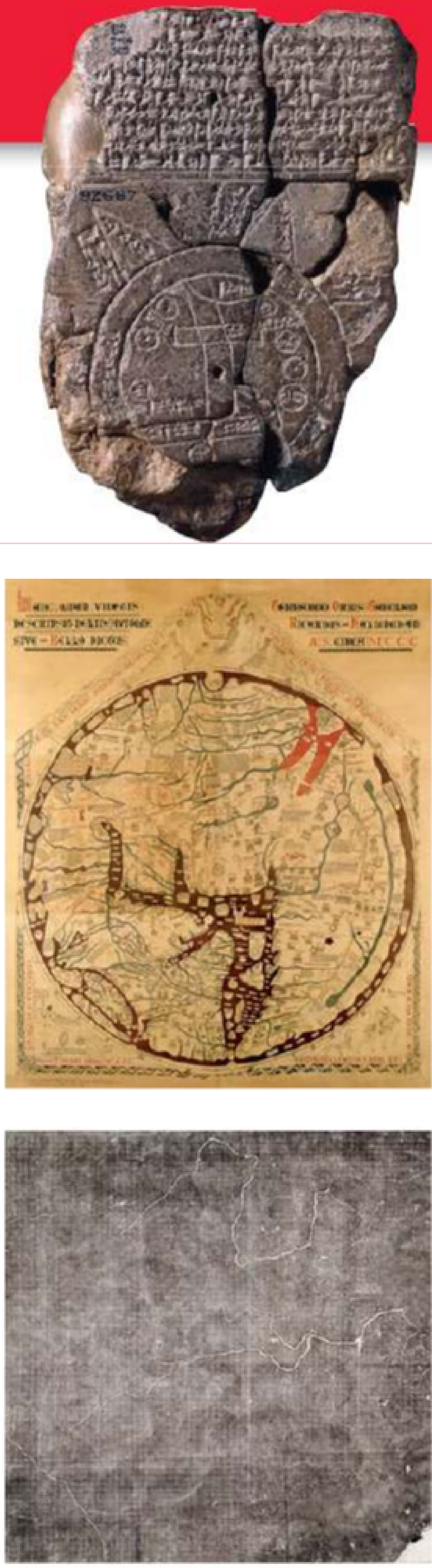
Quantity	SI Unit of measurement	Definition
Length	Metre	The length of the path travelled by light in a vacuum during a time interval of $\frac{1}{299\,792\,458}$ of a second
Mass	Kilogram	The mass of the international prototype of the kilogram **http://physics.nist.gov/cuu/Units/kilogram.html**
Time	Second	The duration of 9 192 631 770 periods of the radiation corresponding to the transition between the two hyperfine levels of the ground state of the Caesium-133 atom **http://physics.nist.gov/cuu/Units/second.html**

■ **Table 1.1** Definitions of some of the SI base 'mechanical' units (there are seven base units in total)

What are coordinates?

If we are to locate objects precisely, in addition to standardized units of distance we also need to have an agreed way to specify their position. If you have ever tried to find somewhere you have never been before by following a list of directions alone, you may already know what the problem can be. First of all, directions only work when you know where to begin. Secondly, one wrong turn and you find the directions no longer make any sense and you are lost!

The easiest way to solve this problem is to draw a map. There is evidence that humans have been making maps for over 2500 years.

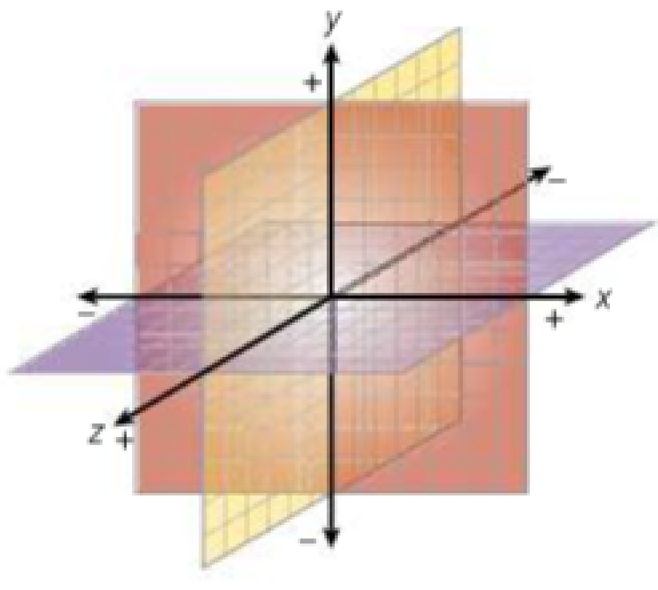


■ **Figure 1.9** (a) Babylonian map from 500 BCE, (b) Hereford *mappa mundi* created around 1300 CE, (c) Chinese Song Dynasty map drawn to a scaled grid, dating from around 1100 CE

The use of a grid system to define location in space is often called a Cartesian system after the French philosopher René Descartes (1596–1650). Descartes described how the relationship between mathematical variables could be shown on a graph. In a Cartesian system (Figure 1.10) space is divided using three dimensions or directions, each of which is then measured using a line called an axis. You will have used a coordinate system like this before to produce graphs or bar charts.

Each of the directions or axes is given a letter: *x*, *y* or *z*. Most commonly maps or graphs use only two dimensions to show position, where *x* is used for the horizontal and *y* for the vertical direction.

In order to locate something in space, we use the Cartesian grid to work out coordinates. Coordinates tell us how far along each axis the position falls, counting from the zero point where all the axes cross each other. This zero point is called the origin. Coordinates are written starting with *x*, then with *y* (and indeed in three dimensions, with *z*). So an object that is 4 units across from the origin and 5 units up from it has coordinates (4,5).



■ **Figure 1.10** Cartesian coordinates

▼ Links to: History, Mathematics

For centuries sailors have known how to estimate their position north or south by measuring the height or elevation of stars such as Polaris (the pole star) above the horizon at midnight. Finding position east or west is a different matter. Search **longitude John Harrison** to discover the story of how the problem of longitude was solved.

ACTIVITY: Knowing your position

ATL

- Critical-thinking skills: Interpret data; Evaluate evidence and arguments

In this activity we will use a coordinate system to locate objects on a map.

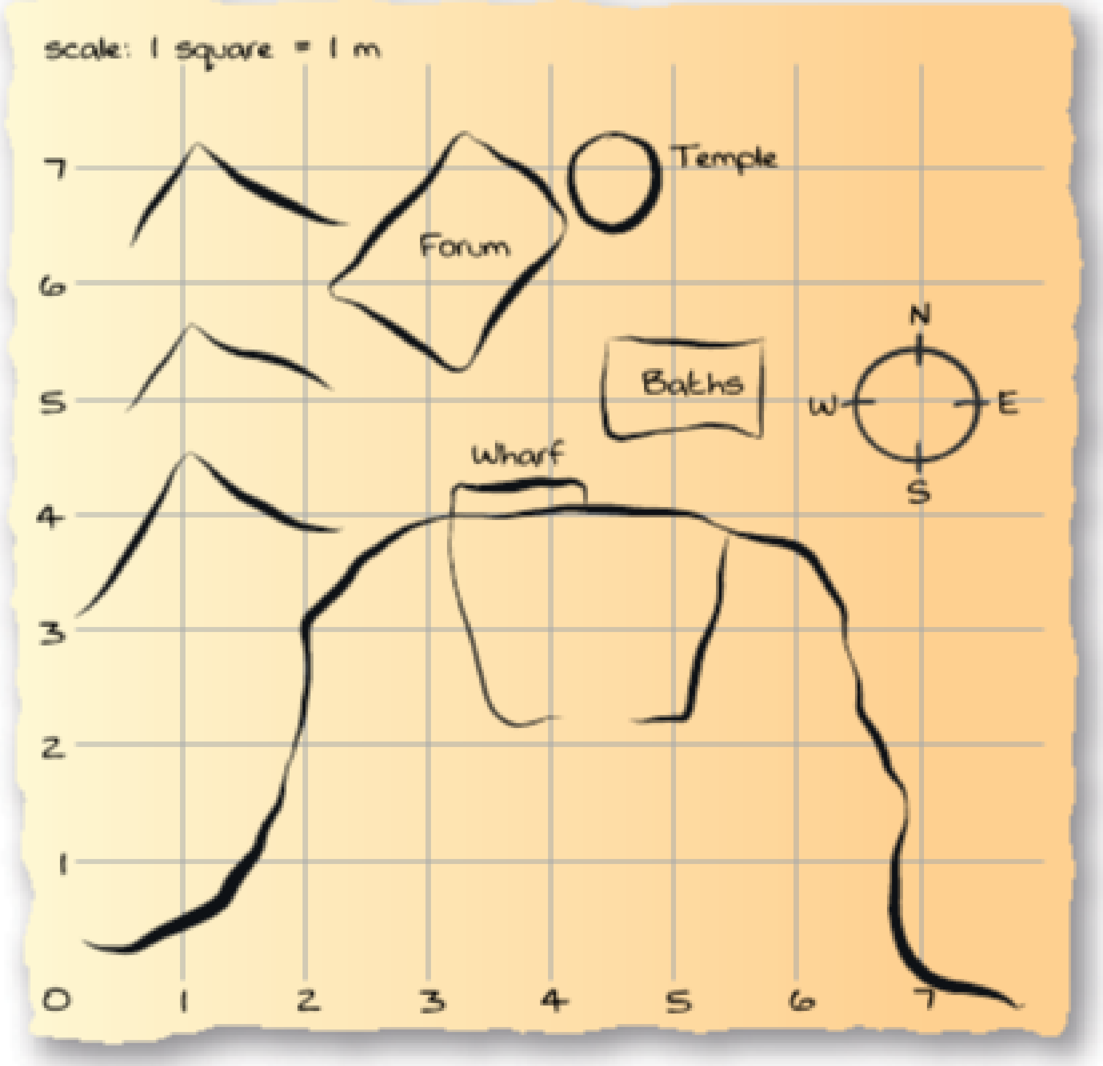
Some archeologists are researching and excavating in an old port known to have been used by merchants in the time of the Roman Empire. During their excavations, they discover a dried clay tablet with some directions scratched into it in Latin (Figure 1.11).

> From the wharf, walk 1 along the sea front to the end of the wharf.
> Then turn and take the via Thermae north.
> Pause and freshen your feet if you will, that you may be pure on arrival.
> Then walk 1 further along via Forum to the north and west.
> Purchase here your devotional offering.
> Then walk 1 further north and east across the forum.
> Search now at the feet of the vestal virgin and you will find your heaven on earth.

■ **Figure 1.11** Directions translated from the clay tablet

The archeologists think that the directions tell where to find a horde of valuable artifacts from the merchants' ship. The archeologists have drawn a map of the excavation site (Figure 1.12).

Unfortunately, it is not clear from the clay tablet what unit is being used for the directions. One of the archeologists, Dr Boulos, thinks that the unit must have been the *passus* or 'pace'. Another archeologist, Professor Li, believes that the unit must have been the *gradus* or 'step'.



■ **Figure 1.12** Map of the port excavation

1. **Individually or in groups, search** Roman measurement units **to find out the length of each of the Roman units: the pace or the step.**
2. **Calculate the distance in metres for each of the Roman measurement units suggested.**
3. **Using the scale of the map in Figure 1.12, determine the coordinates for each of the points on the route given by the clay tablet directions, depending on whether you use paces or steps. Record your findings in a suitable table.**
4. **Suggest the predicted location of the horde, according to Dr Boulos or Professor Li.**
5. **After further excavation, the archeologists find another fragment from the clay tablet with an inscription on it. They translate the inscription to read:**

   'These directions are given for every five Roman feet (*pedes*).'

   Using your research on Roman measurement units, deduce what unit the directions are actually using, and state which of the archeologists was right!

Assessment opportunities

In this activity you have practised skills that are assessed using Criterion A: Knowing and understanding.

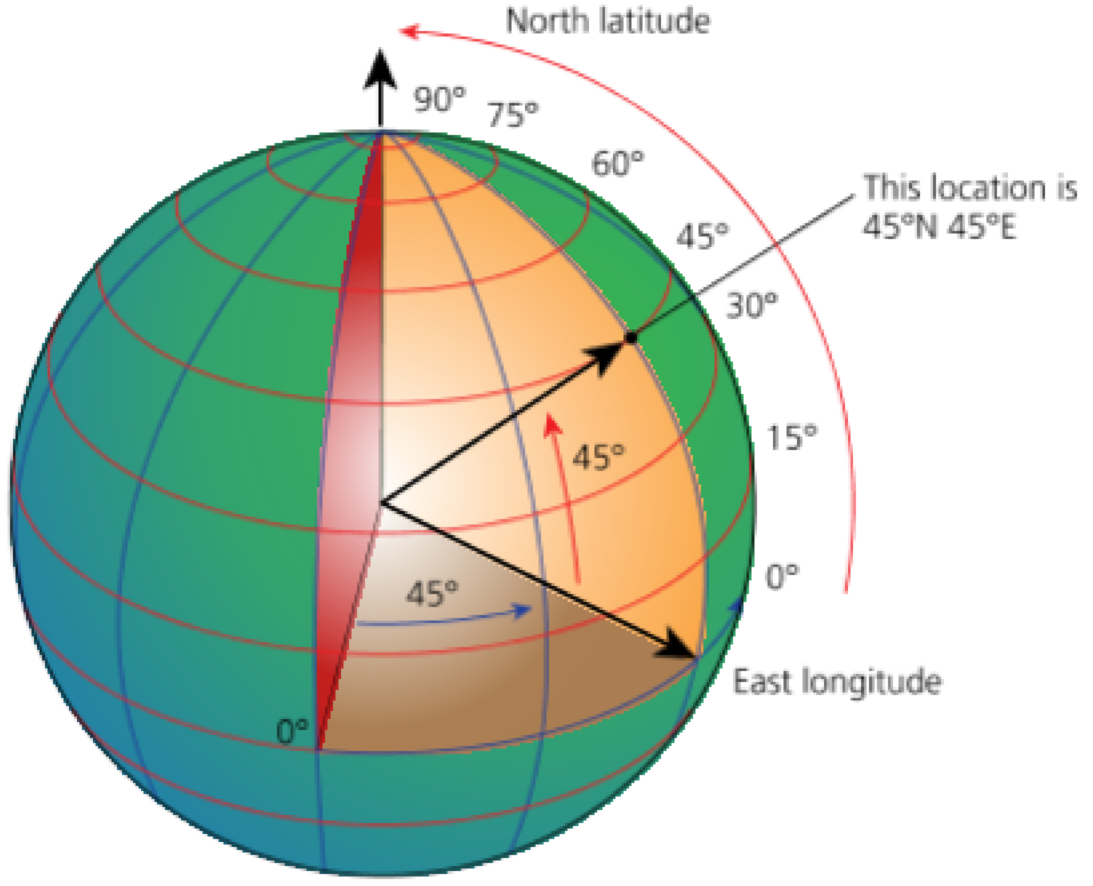


Figure 1.13 Spherical or 'geographical' coordinates map the Earth's surface in angular distances

Cartesian coordinates work well enough to describe location over relatively small areas such as our Roman port. However the Cartesian system defines location according to position on a flat grid or plane surface. If the world were indeed flat, this would be fine. However, if you try to fold a sheet of paper over the surface of a globe you will soon find that you cannot cover the globe with paper unless you start tearing the paper into strips. A map drawn on a plane surface cannot accurately represent the real distances between places on the curved surface of the Earth's sphere.

On flat maps we show the angular distance between points on the Earth's sphere in the form of lines of **longitude** and **latitude** (Figure 1.13). The line around the circumference of the Earth midway between the poles is defined as 0° latitude, while the poles have a latitude of 90°. Similarly, a line tracing the circumference of the Earth passing through each of the poles is defined as 0° longitude. This line is called the **prime meridian** and it passes by definition through the Royal Observatory at Greenwich in London, England. In fact, other places have claimed their own prime meridian at different times, and have calculated their distances accordingly – the choice of the Greenwich meridian was in the end a consequence of historical events, rather than of any scientific reasoning.

Time and position have always been closely related, as we will explore further at the end of this chapter.

ACTIVITY: All the time in the world

ATL

- Information literacy skills: Collect and analyse data to identify solutions

Global communications mean that it is possible for those who have the technology to contact anyone at any time instantaneously. We can also travel to almost anywhere in the globe, provided we can afford the expense.

Use an online world clock to answer the following questions:

- **What time do you get up in the morning? Determine where in the world people are just now getting up at that same time.**
- **Imagine you take a flight two hours from now from your nearest airport and travel for eight hours to the east. Calculate what time it will be for you when you land in the new place. If the aircraft travels through an angular distance of 90° during the flight, determine what time it will be at your destination.**
- **It is possible to take a flight and arrive the day before you left! Determine where this could happen and explain your answer.**

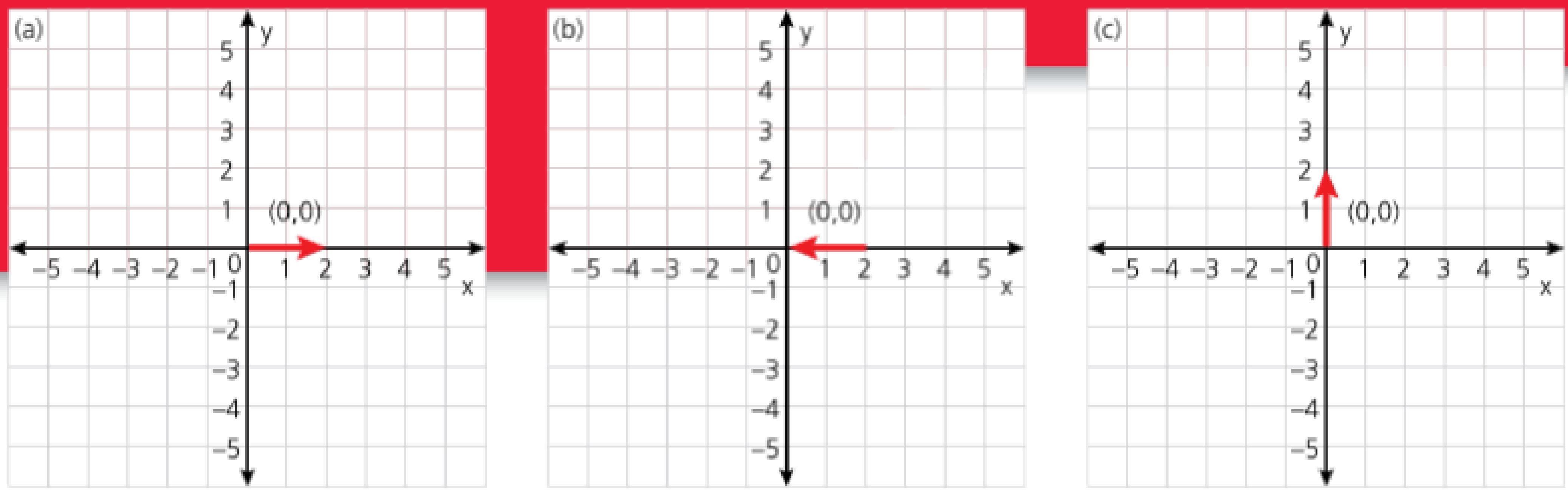
Assessment opportunities

- In this activity you have practised skills that are assessed using Criterion A: Knowing and understanding.

As the Earth rotates on its axis and carries us towards the east, we travel through time. Our longitude defines the **time zone** we are in, measured relative to **Greenwich Mean Time (GMT)**.

EXTENSION

Search Global Positioning System to find out how we can now know our exact position at any time using even a small handheld or wearable device.



■ **Figure 1.14** Displacement includes information about the direction of travel. (a) Displacement +2 m in the *x*-axis, total displacement = +2 m, (b) Displacement −2 m in the *x*-axis, total displacement = 0 m, (c) Displacement +2 m in the *y*-axis

Did you notice in the *All the time in the world* activity that, if we travel east, we move to time zones that are *earlier* than where we are, and when travelling west the opposite happens? Of course we are not really travelling in time – for our bodies, time continues to move forward at the same pace (as far as we can tell), relative to us. It is only 'clock time' that changes. Writers of science fiction have speculated for many years about the possibility of actually travelling in time. We'll come back to this later!

In order to account for not only the distance, but also the direction we travel relative to our starting point, we can include a '+' or a '–' sign, depending on whether we move in the positive direction of an axis or in the negative. When we do this, the distance we travel is called the **displacement**.

Notice that when we return to the starting point again, our displacement is zero – because our journey has not actually taken us anywhere. However, the distance travelled is the total distance, ignoring the signs. In Figure 1.14a and b:

Displacement = + 2 – 2 = 0 m

Distance = 2 + 2 = 4 m

The arrows in Figure 1.14 represent the displacement. Arrows are used to indicate the direction, and their length gives us the amount of movement. In mathematics, these arrows are called **vectors**.

We can combine the information about a journey in a graph.

Place	Map coordinates	Time to travel there (days)	Mode of transport	Distance (km)
London, UK				
Suez, Egypt		7	Railway and steamship	
Mumbai (Bombay), India		13	Steamship	
Kolkata (Calcutta), India		3	Railway	
Victoria, Hong Kong		13	Steamship	
Yokohama, Japan		6	Steamship	
San Francisco, USA		22	Steamship	
New York City, USA		7	Railway	
Liverpool, UK		7	Steamship	
London, UK		1	Railway	
Total:		79		

■ **Table 1.2** Around the world in eighty days

ACTIVITY: Around the world in eighty days

ATL

- Information literacy skills: Collect and analyse data to identify solutions
- Critical-thinking skills: Interpret data

In French writer Jules Verne's novel *Around the World in Eighty Days* (first published 1873) the Englishman Phileas Fogg and his assistant Passepartout embark on an adventure to win a wager (a bet) that it is possible to circumnavigate the Earth in eighty days. This might seem quite a long time to us, but at the time of writing the world was just beginning to be connected by new transportation systems such as railways, steamships or balloons.

A journey graph can be used to show the change of position with time of an object. Table 1.2 shows some distances, times and locations for journeys made by Phileas Fogg and Passepartout.

1. **Individually, complete the blank columns in Table 1.2.**
2. **Use an online or other world map to determine the coordinates of all the places listed.**
3. **Now use an online route planner or map app to estimate the distances between the places.**
4. **By hand with millimetric graph paper, or using a spreadsheet (see below!), draw two axes:**
   - **the *x*-axis showing time in days**
   - **the *y*-axis showing distance in kilometres (km).**

   The origin of the graph will be the starting point for Phileas and Passepartout's adventure.
5. **Plot the different destinations on the graph for their journey around the world. Remember that each new destination becomes the starting point for the next journey! Figure 1.15 shows how to begin this.**

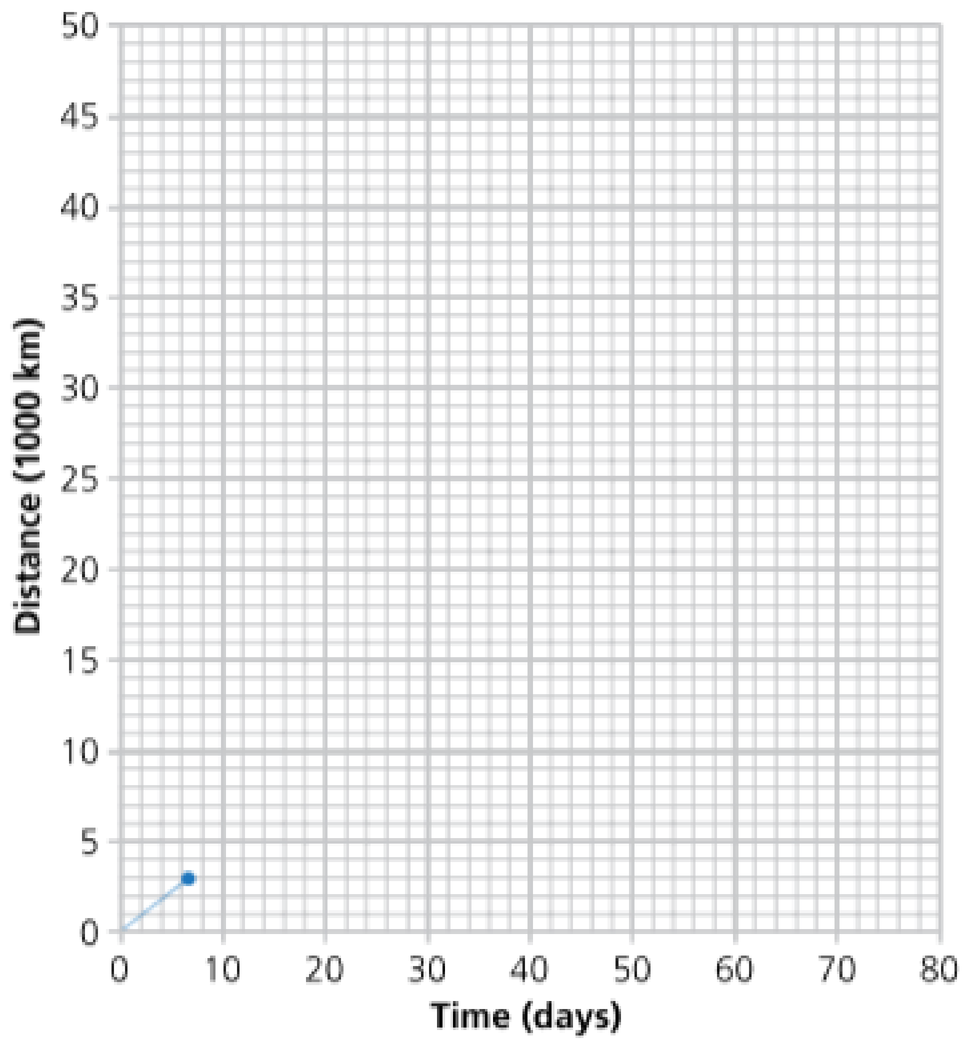


Figure 1.15 Journey graph

Now **interpret** the graph and **summarize** your answers in a paragraph:

- **What was the total distance travelled by Fogg and Passepartout?**
- **Which part of their journey took the longest time?**
- **What was the total displacement of Fogg and Passepartout at the end of their journey?**
- **Which part of the journey was the fastest? Explain how you can deduce this from the graph.**
- **Which part of the journey was the slowest? Explain how you can deduce this from the graph.**
- **How accurate is our graph as a representation of Fogg and Passepartout's journey? Outline any factors it might ignore.**

Assessment opportunities

- In this activity you have practised skills that are assessed using Criterion C: Processing and evaluating.

Links to: History, Language and literature

Why do you think that Jules Verne chose to write about a journey around the world in the late nineteenth century? What changes might have inspired him? Thinking about the context of fiction can tell us a great deal about how people thought at the time, and how they saw the world around them.

What do science fiction writers write about now, in our time?

ATL

In the *Around the world in eighty days* activity we represented information using a journey graph. It is often a good idea to do this by hand, because working this way encourages you to think about what the information in the graph means. However, we can also use software such as a spreadsheet to make a graph.

The exact procedure for doing this will depend on the spreadsheet app that you use, but the main steps will be the same in all spreadsheet apps.

Step 1

Each 'box' on the spreadsheet is called a cell and is used to hold a **datum**, most often a number value. Enter your data into cells in the spreadsheet in the form of a table. You can type the column headings in the first row on the spreadsheet.

	A	B	C
1	Time (s)	Distance (m)	
2	0	0	
3	1	3	
4	2	6	
5	3	9	
6	4	12	
7	5	15	
8	6		
9	7		
10	8		
11	9		
12	10		
13			

■ **Figure 1.16** Step 1 – enter your data as a table

Step 2

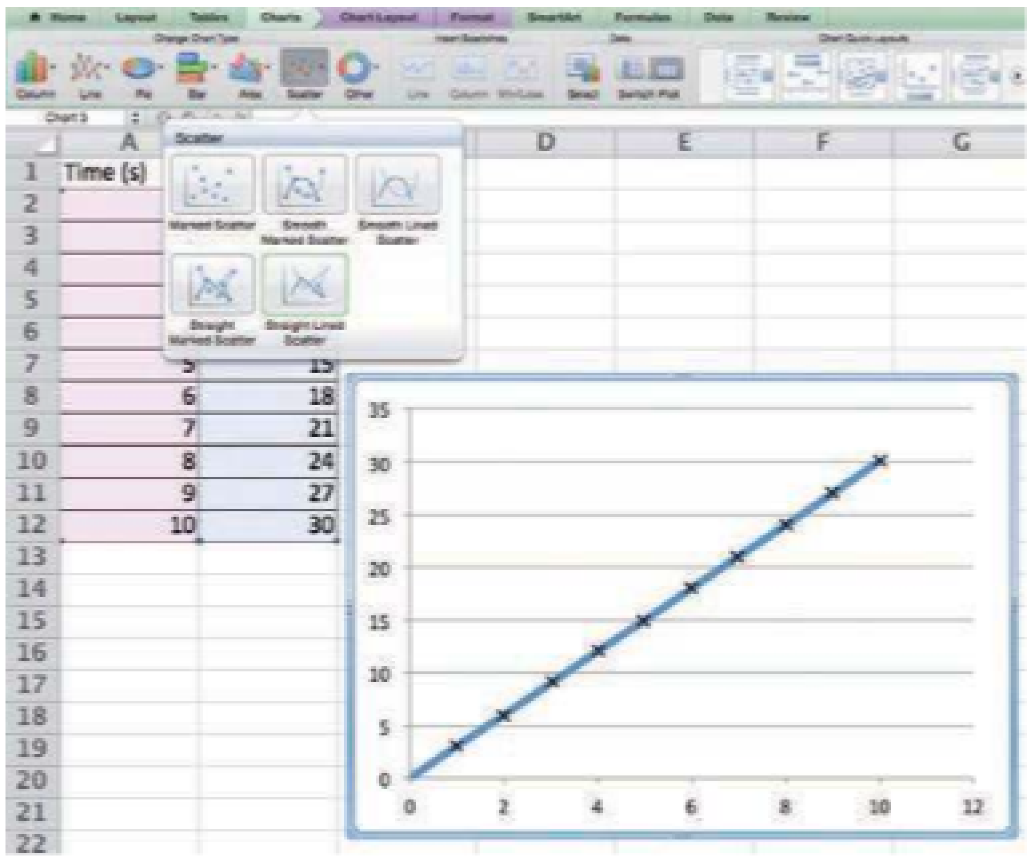
Highlight the cells that you wish to plot as a graph. Usually it is best not to include the column headings (although some spreadsheet apps will recognize these as labels). To highlight multiple columns, on a PC you can hold down the CTRL key while dragging with your mouse or finger. On a Mac, use the COMMAND key.

	A	B	C
1	Time (s)	Distance (m)	
2	0	0	
3	1	3	
4	2	6	
5	3	9	
6	4	12	
7	5	15	
8	6	18	
9	7	21	
10	8	24	
11	9	27	
12	10	30	
13			

■ **Figure 1.17** Step 2 – highlight the data you want to plot

Step 3

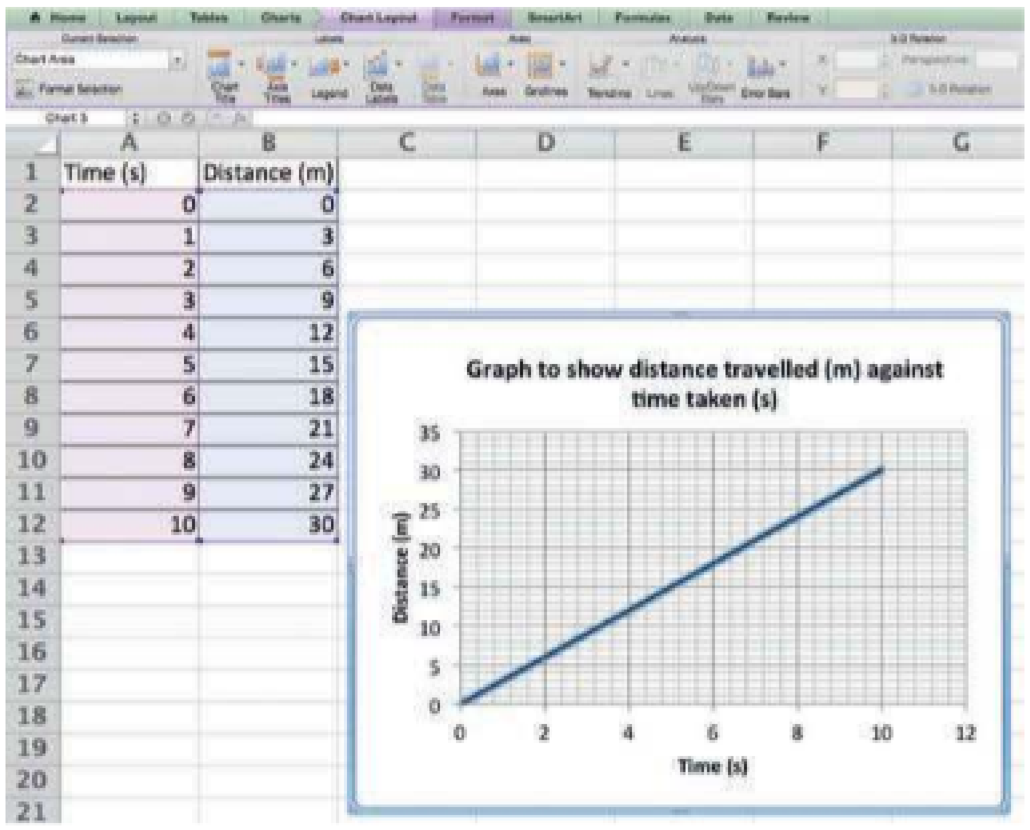
Select the kind of graph you wish to plot from the relevant tools menu. For our journey graph, we will select a line graph, where all the points plotted are connected with straight lines. You can usually position the graph on the same sheet, or in a new worksheet.



■ **Figure 1.18** Step 3 – choose the type of graph you want

Step 4

Now we need to give the graph a title, and label the axes! Different apps will do this in different ways so you may need to consult the 'help' function in your program.



■ **Figure 1.19** Step 4 – make sure your graph is labelled

ACTIVITY: Everyday journeys

■ ATL

■ Critical-thinking skills: Practise observing carefully; Gather and organize relevant information

Choose a journey you make regularly – maybe the journey to school each day, or to somewhere you stay during the school holidays.

Using a timer (such as your phone or a watch), **measure** the time taken for each stage of the journey. Include all the stages – even walking to the car, waiting at the traffic signals on your bicycle, or waiting in the airport!

Using an online route planner or a journey app on your portable device, **estimate** the distance you travel in each of the stages of your journey. (Think! What distance do you travel while you are waiting?)

Plot a journey graph for your journey and **interpret** it using these guiding questions:

- What was the total distance you travelled?
- Which part of your journey took the longest time?
- What was the total displacement at the end of your journey?
- Which part of the journey was the fastest? **Explain** how you can **deduce** this from the graph.
- Which part of the journey was the slowest? **Explain** how you can **deduce** this from the graph.
- What happens on the journey graph when you are waiting, stationary?
- **Evaluate** your journey graph – how accurate is it as a representation of your journey? Is there anything it misses out?

How can we measure speed?

WHERE ARE WE GOING?

We have seen from our journey graphs that greater speed of travel means the line has a steeper slope, since we cover distance in a shorter time. We can represent this using an equation:

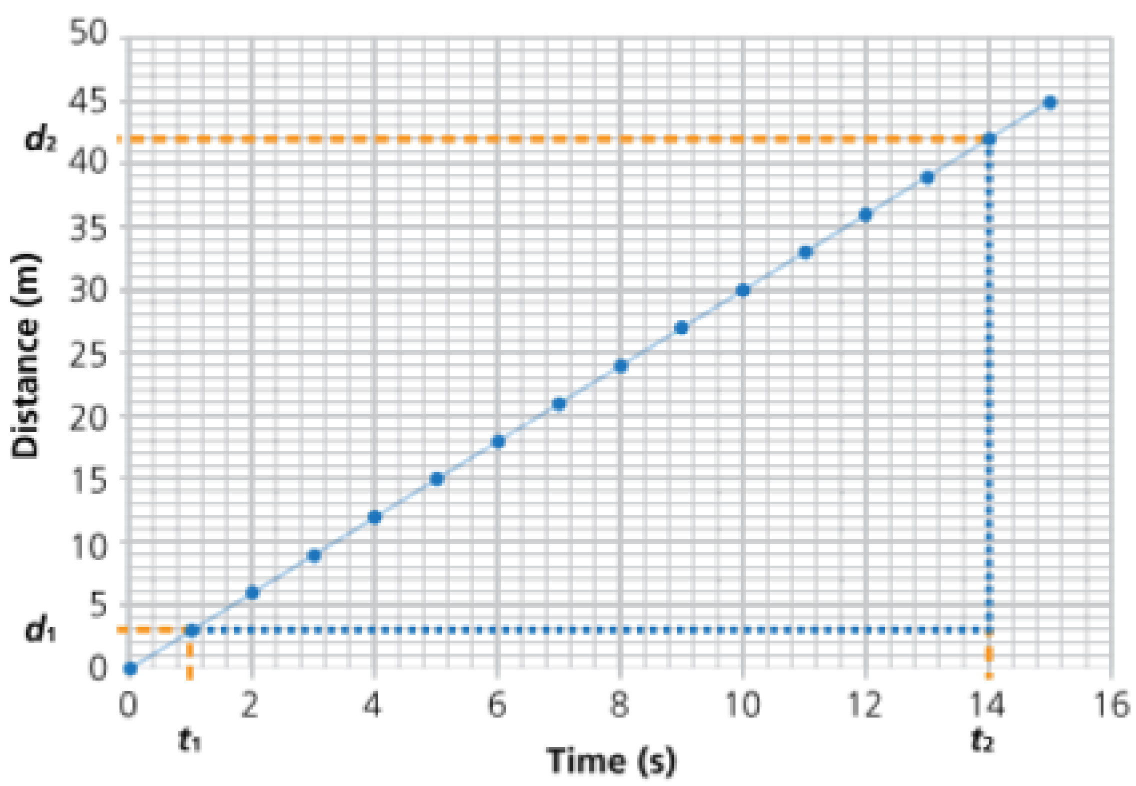
$$\text{Speed } v = \frac{\text{Distance}}{\text{Time}}$$

Where distance is measured in metres (m) and time is measured in seconds (s), so speed is measured in metres per second, which is written $m\,s^{-1}$.

We can see from our graphs that this also represents the **gradient** of the journey line, since it is the ratio of units in *y* (distance) to units in *x* (time):

$$\text{Gradient} = \frac{\text{Change in } y}{\text{Change in } x} = \frac{d_2 - d_1}{t_2 - t_1}$$

Where d_2 = distance travelled at end of the journey, d_1 = distance travelled at start of the journey, t_2 = time at end of the journey, t_1 = time at start of the journey.



■ **Figure 1.20** The gradient of a distance–time graph is speed

HOW CAN WE REPRESENT MOTION?

Because it is a ratio, the gradient is the same for any part of a straight line. Notice though that the equation ignores the sign of distance – whether we are travelling towards or away from the origin, the answer for the speed will be the same. If we want to account for the direction of travel, we will need to use the displacement as before. The speed in a given direction is then called the **velocity**:

$$\text{Velocity } \boldsymbol{v} = \frac{\text{Displacement}}{\text{Time}}$$

Again, velocity is measured in metres per second $m\,s^{-1}$ because we haven't changed the units of measurement, only the direction. Because velocity has a sign, it is therefore a vector.

Example: (a) A cyclist in the *Tour de France* race travels 2 km in 2 minutes. What is the velocity, in $m\,s^{-1}$?

$$\boldsymbol{v} = \frac{d}{t}$$

Displacement d = 2 km = 2000 m.

Time t = 2 minutes = 2 × 60 s = 120 s.

So

$$\text{Velocity, } \boldsymbol{v} = \frac{2000}{120}$$

$= 17\ m\,s^{-1}$

(b) A cameraman is chasing the cyclist in a van at $50\ km\,h^{-1}$. Will the cameraman be able to catch the cyclist?

$50\ km\,h^{-1} = 50 \times 1000\ m\,h^{-1}$

$= 50\,000\ m\,h^{-1}$

$= \frac{50\,000}{3600}\ m\,s^{-1}$

$= 14\ m\,s^{-1}$

The cameraman will not be able to catch the cyclist at this speed.

Just as we can use a journey graph to show how distance or displacement changes with time, we can also present information about speeds and velocities graphically.

Figure 1.21 The fastest mass transport system available to date. In our century, spacecraft would be the fastest transportation, but they are not available to many people – yet!

ACTIVITY: Getting there ...

ATL

- Critical-thinking skills: Interpret data

Table 1.3 shows the time to travel 10 km by the fastest available mass transport system in different time periods. (By 'mass transport system' we mean a form of transportation that is readily available to many people.)

- **Interpret** the data in the table to **calculate** the average speeds of the different transportation systems.
- With reference to your calculations, **outline** how times of travel have changed over the ages.

Hint

Take care to account for units! Remember that 1 kilometre (km) = 1000 metres, and to convert hours and minutes to seconds.

Time period	Mode of transport	Average time to travel 10 km	Average speed ($m\,s^{-1}$)
Prehistoric times	By foot	2 hours	
5000 BCE – 1800 CE	Horse	40 minutes	
Nineteenth century	Steam train	9 minutes	
	Motor vehicle	12 minutes	
Mid twentieth century	Propeller aircraft	4 minutes	
Late twentieth century	Jet aircraft	1 minute	

Table 1.3 Fastest times of mass transport through the ages

Assessment opportunities

- In this activity you have practised skills that are assessed using Criterion A: Knowing and understanding.

ACTIVITY: Hare and tortoise race

ATL

- Creative-thinking skills: Apply existing knowledge to generate new ideas.

Figure 1.22 The hare and the tortoise … but speed is not the only thing that counts in winning the race!

Have you ever run a 100 m race? How about a 2000 m race? You may know the old fable by Aesop about the hare and the tortoise who have a race. In this activity we will compare the journeys of two people running the same length of track at two different speeds.

You will need to work in groups of at least 12 people. Organize your groups as follow:

- 1 jogger
- 1 sprinter
- 9 timers
- 1 starter

You will need the following equipment:

- 10 stopwatches
- 1 long measuring tape
- Notepads or paper on clipboards, and pens or pencils

1. Outside your classroom, find a space that you can run in safely to use as your 'track'. The ideal length to run is around 100 m, but it can be shorter. Make a note of the length.
2. Now position the starter at the beginning of the track. Divide the length of the track by 10, and position a timer at 9 equal intervals along the track. (For example, if your track is 100 m long, the starter will be at 0 m, the first timer at 10 m, the second timer at 20 m, and so on.)
3. The jogger and sprinter now take their positions at the start of the track.
4. The starter shouts 'go!' At this first shout:
   - the jogger runs at a steady jogging pace down the track, without changing speed
   - the timers all start their stopwatches as soon as they hear 'go!'
   - the starter also starts the stopwatch.

No doubt you can see from your speed–time graphs in the *Hare and tortoise race* activity that speed can change during a journey. A change in speed or direction is called **acceleration**, and can be calculated using this equation:

$$\text{Acceleration } \boldsymbol{a} = \frac{\text{Change in velocity}}{\text{Time taken for the change}}$$

As we are dealing with a change in velocity over a certain amount of time, we have to find the change by subtracting values from the start and end of the part of the journey concerned:

$$\boldsymbol{a} = \frac{\boldsymbol{v}_2 - \boldsymbol{v}_1}{t_2 - t_1}$$

Velocity $\boldsymbol{v}$ is measured in metres per second ($m\,s^{-1}$), and time is taken in seconds (s), so the unit for acceleration is metres per second changed per second, written as $m\,s^{-2}$ – 'metres per second squared'.

Since the acceleration represents how much the speed is changing in a certain amount of time, it can be seen on a velocity–time graph as a change in gradient of the line (Figure 1.23).

Example: A skier starts her run from standstill at the top of a mountain. She accelerates down the mountainside at $0.25\,m\,s^{-2}$ for 20 s, and then she reaches the valley bottom. What is her velocity at the bottom of the mountain?

5 A little after the first shout (you can decide when), the starter shouts 'go!' a second time. At the second shout:
- the sprinter run as fast as possible down the track
- the starter notes the time on the stopwatch.

6 As the jogger and the sprinter pass each of the timers, the timers write down the time on their notepad or clipboard.

Results

Collect and **organize** all your timings. **Present** the timings in a suitable table.

Plot your data on a distance–time graph. Show two different lines, one for the jogger and the other for the sprinter, on the same axes.

Now create a second table. In this table **calculate** the average speed of each of the runners at each point in the race. Use these headings:

Distance (m)	Time for jogger (s)	Speed of jogger ($m\,s^{-1}$)	Time for sprinter (s)	Speed of sprinter ($m\,s^{-1}$)
First 10 m				
Second 10 m …				

Using the data in this table, **plot** a speed–time graph showing two lines, one for each of the runners.

Conclusion

Interpret your data and **summarize** your ideas in the form of a conclusion, using these guiding questions:
- How did the speed of each runner change during the 'race'? **Explain** your answer with reference to the lines you have drawn.
- Did the sprinter catch up with the jogger? **Determine** when this happened, and **show** this on both your graphs.

Evaluation

Discuss how accurate your graphs are as a representation of the journey of each runner during the race. **Describe** how the graphs would be different if you doubled the number of timers.

What if you could know the exact speed every second, or even every thousandth of a second, of either runner? **Describe** how your speed–time graph would look if you plotted these data.

Assessment opportunities

- This activity can be assessed using Criterion C: Processing and evaluating.

$$a = \frac{(v_2 - v_1)}{(t_2 - t_1)}$$

The skier starts from a standstill, so $v_1 = 0\,m\,s^{-1}$.

Time taken for acceleration = 20 s.

So

$$a = \frac{(v_2 - 0)}{(20 - 0)}$$

Rearranging the equation,

$$v_2 = 20 \times a$$

So

$$v_2 = 20 \times 0.25 = 5\,m\,s^{-1}$$

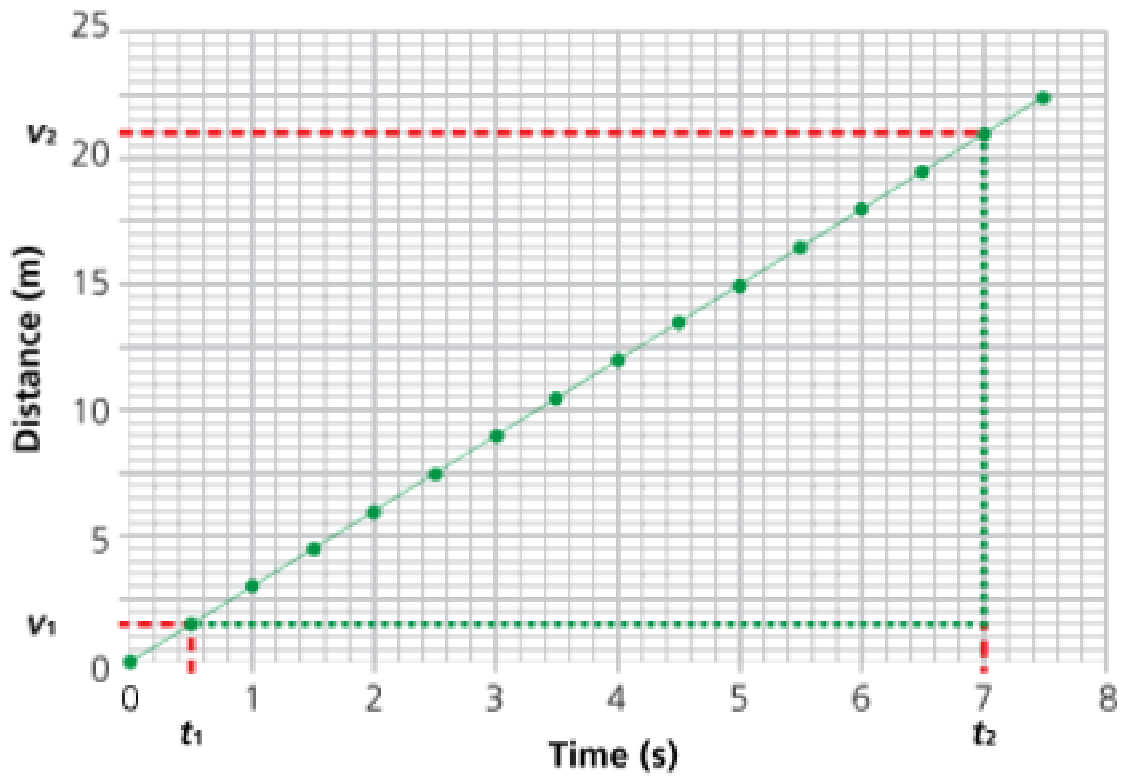


Figure 1.23 Calculating acceleration from the gradient on a velocity–time graph

What is the greatest known speed?

ACTIVITY: Hare and tortoise accelerated

ATL

- Critical-thinking skills: Interpret data; Revise understanding based on new information and evidence

Look again at your speed–time data and graphs from the *Hare and tortoise race* activity. **Interpret** the data and graphs to solve these questions.

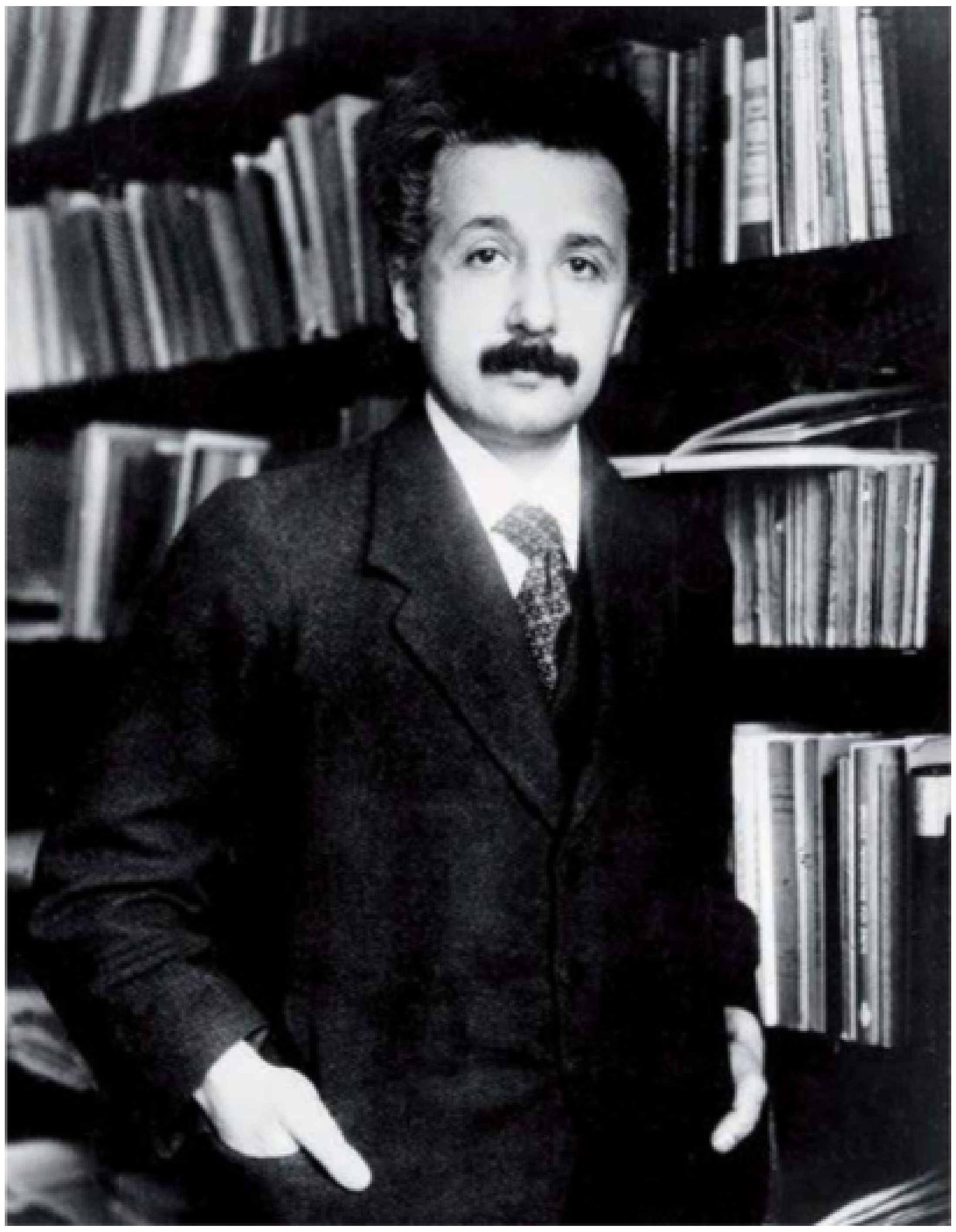
- **Determine** which runner had the greatest acceleration. **State** the times between which this acceleration occurred. **Explain** how you determined this from your speed–time graph.
- **State** whether the acceleration was ever zero for either runner in the race. If so, between which times did this occur? **Explain** how you determined this information from your speed–time graph.
- **Calculate** the greatest acceleration in the race.
- **State** whether the acceleration was ever negative in the race. **Describe** the motion of the runners when this happens. **Outline** how this looked – or, if it did not occur, how it might look – on your speed–time graph.

Assessment opportunities

- This activity can be assessed using Criterion A: Knowing and understanding.

EXTENSION

What is the greatest known speed?



■ **Figure 1.24** Albert Einstein (1879–1955)

When you turn on an electric light in a dark room, how long does the light take to fill the room? Of course, the light seems to fill the room instantly – after flicking the switch, we do not have to wait in the darkness until the light reaches our eyes! As we will see in Chapter 4, light is a form of energy.

The astronomer Ole Roemer (1644–1710) showed in the seventeenth century that light did not move infinitely fast but had a fixed speed: although by 1907 we had a fairly accurate idea that this speed was very fast indeed (see *MYP Physics by Concept 4&5*, Chapter 7, for details as to how). The speed of light in a vacuum (called *c*) is measured to be close to 300 000 000 $m\,s^{-1}$.

The great physicist Albert Einstein (1879–1955) told a story that when he was 16 years old, he asked himself the question, what would the universe look like if we could travel on a beam of light? What would light then *look* like? Would we be able to see other beams of light travelling towards us? And what speed would *those* beams of light seem to be travelling at? (Some historians have disputed that Einstein could have used his 'thought experiment' in this way, but for the purposes of this explanation we'll give Einstein the benefit of the doubt!)

If two vehicles move towards each other, one with a velocity ***v*** and the other with velocity −***v***, then the speed of one vehicle as measured by the other is the sum (addition) of the two velocities, 2***v***. This is called their **relative velocity**. In the case of light, there is a **paradox**: if two beams of light approach each other, since the speed of light is fixed, they must *both* still measure the speed of the other beam as the same value – the speed of light!

Einstein uses the story to describe the leap of imagination he made in 1905 when elaborating the *special theory of relativity*. He deduced that two things must happen when something approaches the speed of light. Since

$$\text{Speed of light } c = \frac{\text{(Distance travelled)}}{\text{(Time taken)}}$$

in order for the value of *c* to remain constant, the distance travelled by the two beams of light must become shorter, and time must run slower (and so the time taken for the light to travel be greater). Einstein deduced that space and time were in fact related to each other. From this insight he developed first his *special theory of relativity* and later his *general theory of relativity*, which incorporated the phenomenon of gravity as a force that affects space–time.

If time could be made to run slower, could it be made to run in reverse? Could we then travel backwards in time? This could only ever happen if we were able to travel faster than the speed of light – and would create further complications, as described in thought experiments such as the so-called **grandfather paradox** or the **twin paradox**.

How do forces affect motion?

What makes things move? What stops them from moving? In this section we will explore how forces change motion.

For most of recorded human civilization, people believed that movement was something 'contained' in any object that moved – rather like a sort of energy or fuel that was used up as the object moved. This was how the classical Greek thinker Aristotle (384–322 BCE) understood motion, for example. After all, don't moving objects always slow down and stop in the end? It is true that when an object moves, it gains energy – and one way to understand forces is that they are what changes energy. We will look more closely at the relationship between forces and energy in *MYP Sciences by Concept 3*.

Galileo Galilei (1564–1642) first suggested that maybe things slowed down on Earth because something was actually slowing them down. The slowing effect is caused by forces of **friction** – whether due to physical contact or rubbing between materials, or by the air. If left alone, with no forces acting, objects tend to continue to do what they are already doing – whether sitting stationary or moving at a constant velocity. This concept that things are reluctant to change their state of motion is called **inertia**. Galileo figured that an object's inertia had something to do with the amount of material in an object – since it was very difficult to change the motion of more massive objects.

ACTIVITY: Motion tricks

ATL

- Critical-thinking skills: Practise observing carefully in order to recognize problems

When do objects move, and when do they not?

Trick 1

A famous 'magic trick' involves a magician pulling a table cloth out from a fully set table, without any of the cups, glasses or plates getting smashed. We can re-create the trick!

You will need:

- **Some coins of different sizes**
- **A sheet of paper**

Method

1. **Position the paper so that its edge protrudes from the edge of the table.**
2. **Now balance coins on top of the paper that lies on the table.**
3. **Pull the edge of the paper very quickly so that the paper is pulled from under the coins.**

Discuss: What did you see? What does this make you think about the coins and the paper? What does this make you wonder about motion?

Experiment with different sizes of coins to see how this affects the trick.

Trick 2

How long do objects continue to move? We can test this using:

- **1 raw egg (in its shell!)**
- **1 hard-boiled egg**

Method

1. **Place the eggs side-by-side on a table. Give each of them a spin around its axis.**
2. **Observe the motion of the eggs as they spin.**

Discuss: What difference do you see between the motions of the eggs? What does this make you think about the effect of motion on each? What does this make you wonder?

■ **Figure 1.25** Inertia means that it is much easier to change the motion of a floating feather, with just a breath of air, than it is a supertanker at sea, which can take many kilometres to stop or turn

Galileo was the first person to claim to have proved his ideas using experiments – there has been plenty of experimental evidence since to show that inertia is real.

While Galileo Galilei was able to refute the incorrect assumptions of centuries, it was not until Isaac Newton (1642–1727) began to consider the motion of objects that a full scientific theory was elaborated, which made predictions that could be measured and tested.

ACTIVITY: Inertia explanations

■ ATL

- Critical-thinking skills: Revise understanding based on new information

Think again about your observations in the *Motion tricks* activity. Use the concept of inertia to **explain** your observations.

◆ Assessment opportunities

- In this activity you have practised skills that are assessed using Criterion A: Knowing and understanding.

■ **Figure 1.26** Spacecraft in deep space, such as NASA's Pluto mission New Horizons, a long way from significant gravitational forces, continue to move at a constant velocity

Newton's breakthrough was to describe the physics of motion using a complete mathematical system – along the way inventing a mathematical method for describing continuous changes such as velocity or acceleration, called **calculus**. Newton's ideas on motion are summarized in his three laws of motion.

1. Newton's first law states that an object will remain at rest or continue in a state of steady motion unless acted on by an unbalanced force. This is Galileo's idea of inertia, and the first law is often called the *law of inertia*.
2. Newton's second law states that when a force acts on a mass, an acceleration occurs. The acceleration is proportional to the force acting, but inversely proportional to the mass it acts on.

   Newton used a concept called **momentum** to derive an equation for his second law:

   Force $\boldsymbol{F}$ = Mass m × Acceleration $\boldsymbol{a}$

   where the SI unit of force is called the newton (N), mass is measured in kilograms (kg) and acceleration is in metres per second squared ($m\,s^{-2}$).

Example: A spacecraft of mass 10 tonnes requires an acceleration of 11 $m\,s^{-2}$ to reach a space station. What force must the rockets produce on the spacecraft?

Mass m = 10 tonnes

1 tonne = 1000 kg, so mass m = 10 000 kg

$$\boldsymbol{F} = m\boldsymbol{a}$$

So

$$F = 10\,000 \times 11$$

$$= 110\,000\,\text{N or } 110\,\text{kN}$$

ACTIVITY: Catapulting trolleys

ATL

- Information literacy skills: Collect, record and verify data

Here we will investigate how force or mass affects the motion of a vehicle.

You will need:

- A dynamics trolley (any trolley or toy vehicle with low-friction wheels)
- A metre ruler
- A lab mat
- A long, smooth surface such as a dynamics ramp, or a long laboratory table
- Some laboratory masses, or lumps of putty of measured mass
- A thick elastic band
- Two laboratory clamps
- A sheet of white card

Method

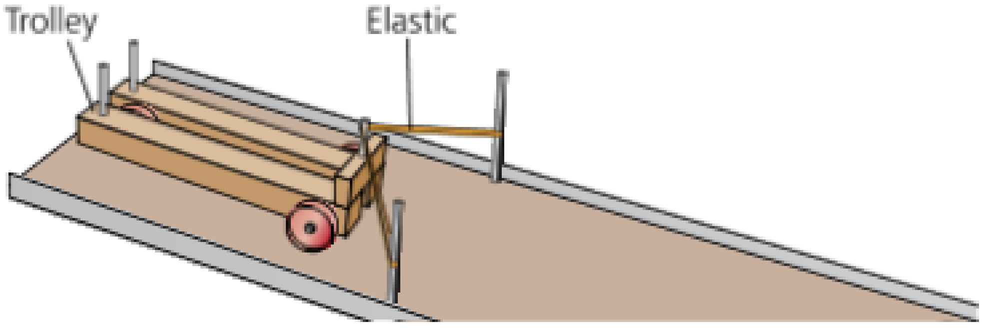


Figure 1.27 Experimental setup for 'catapulting trolleys'

1. Fix the clamps to either side of the table or ramp. Stretch the elastic band between them.
2. Tape the white card to the ramp between the clamps, extending back behind the elastic band.
3. Tape the metre ruler along the table or ramp, ahead of the trolley but to one side (so that the trolley will not run into it).
4. Position your trolley against the elastic band. Roll the trolley back so that it stretches the elastic band to a certain point on the white card – for example, to a line drawn 10 cm from the edge of the card.
5. Release the trolley!

Identify what variables the experiment setup allows you to change and control.

In pairs, **discuss** the following:

- **Describe** the motion of the trolley after it is no longer being propelled by the elastic band. **Explain** why this will occur.
- **Predict** how the motion of the trolley will change when you change your independent variable (force or mass).
- **Suggest** what other factors might change when you change the independent variable, and how they might affect the results.
- **Summarize** the ideas from your discussion.

Results

Discuss how you might make measurements to **compare** the motion of the trolley when you change the independent variable (force or mass). Use the apparatus to take readings for the effect of each of the variables, force or mass.

Hint
Remember to only change one variable at a time!

Organize your results and **present** them in tables, with clear headings and units of measurement.

Plot your results on graphs to show the effect of the independent variables on the motion of the trolley.

Conclusion

Interpret your graphs and **summarize** your findings. **Explain** your findings with reference to what you know about force, inertia and acceleration. **State** whether your prediction was correct.

Evaluation

Describe whether your results give the expected outcome. **Discuss** assumptions you made in the experiment.

Hint
Think – what is slowing the trolley down? What are you assuming about this? How reliable is your assumption?

Outline improvements you could make to the experiment.

Suggest what further experiments you could carry out with this or similar apparatus.

Assessment opportunities

- In this activity you have practised skills that are assessed using Criterion B: Inquiring and designing. This activity can be assessed using Criterion C: Processing and evaluating.

ACTIVITY: Rockets and reactions

ATL

- Critical-thinking skills: Practise observing carefully in order to recognize problems; Draw reasonable conclusions and generalizations

Try these demonstrations to explore how Newton's third law of motion predicts that motion must be conserved.

Skateboard reaction

In pairs, you will need:

- **A skateboard, roller skates or blades**
- **A large, heavy ball such as a basketball or medicine ball**

Figure 1.28 Newton gets his skates on!

Method

1. **One person stands on the skateboard or skates. The other person throws the ball to the skater. What happens when the skater catches the ball?**
2. **Now try again, but this time the skater pushes the ball away instead of catching it. What happens this time?**

Discuss your observations. **Explain** how the motion of the skater is affected by the ball in each case.

Vinegar rocket

You will need:

- **150 ml malt vinegar or similar**
- **Two tablespoons of baking soda (sodium bicarbonate)**
- **An empty plastic bottle (330 ml volume approximately)**
- **Some drinking straws**
- **Thin tissue paper**
- **A rubber stopper to fit the bottleneck**

SAFETY: This experiment is messy and should be carried out in a large area that can be easily cleaned. All observers and participants should wear safety glasses, and stand in front of the bottle, not behind it!

Method

If carrying out this experiment indoors, cover the floor with plastic or similar to protect it.

As a class demonstration:

1. **Place the drinking straws beside each other and a few centimetres apart on the floor, to the total length of the bottle. These will act as rollers.**
2. **Now turn the bottle upright and pour 150 ml vinegar into it.**
3. **Put two tablespoons of baking soda in the tissue paper, and twist to form a packet.**
4. **Drop the tissue packet into the bottle.**
5. **Quickly push the stopper loosely into the bottle.**
6. **Lay the bottle on the straws and stand back!**
7. **Now clean up!**

Discuss your observations. **Describe** how the bottle's motion has changed. **Explain** your observations with reference to action and reaction.

Assessment opportunities

- In this activity you have practised skills that are assessed using Criterion A: Knowing and understanding.

Newton's third law of motion concerns the action of forces on different objects, and states that *'for every action there is an equal and opposite reaction'*. Newton's idea was that the motion that objects experience – *momentum* – must stay the same unless a force acts on them (which gives us the first and second laws). He reasoned this meant that when an object ejects some mass in one direction, the force caused by the ejected mass must accelerate the object in the opposite direction.

ACTIVITY: Newton's law problems

ATL

- Information literacy skills: Make connections between various sources of information
- Critical-thinking skills: Evaluate evidence and arguments

Individually, try to solve these problems.

Figure 1.29 shows some examples of Newton's third law in action.

- **Use Newton's third law to describe how Newton's laws can be used to explain the motion of the objects in the pictures. Use the words in the box below to help:**

inertia	action	reaction	force
acceleration	mass		

- **The world land-speed record is held by ThrustSSC, a jet-powered car that achieved a top speed of 1228 km h^{-1} in 1997 (Figure 1.29a) The car has a total mass, including fuel, of 11 tonnes, and the engine produces a thrust force of 223 kN. Use this information to estimate the maximum acceleration achieved by ThrustSSC during its record-breaking run.**
- **As ThrustSSC made its high-speed run, it burned up 18 litres of fuel per second from its tanks. Outline how this information would affect the calculation you made above.**
- **The bullet in Figure 1.29b is fired with a velocity of 500 m s^{-1}. If the amount of explosive in the bullet is increased, the firing velocity would increase. Outline how this would affect the motion of the gun and the bullet after firing.**

Assessment opportunities

- This activity can be assessed using Criterion A: Knowing and understanding.

Figure 1.29 (a) World land-speed record holding jet car ThrustSSC, (b) a gun firing a bullet, (c) a rocket launch

What happens when forces balance?

BATTLING FORCES

We have seen how forces cause changes in motion – *accelerations* – when they act on masses. Sometimes forces don't seem to cause a change in motion at all. In fact, this is a very important idea in engineering – the key to making buildings and other structures stable is to keep the forces in them balanced, so that they don't move!

ACTIVITY: Skater tug-of-war

ATL

- Critical-thinking skills: Practise observing carefully in order to recognize problems; Draw reasonable conclusions and generalizations

For this activity you will need:

- **Two skateboards, or two pairs of skates or roller blades**
- **A strong rope**
- **Helmets, elbow pads, crash mats**

SAFETY: In case of falling, carry out this demonstration in a clear space with no nearby objects you could hit. Skaters should wear helmets and other protective gear, and be surrounded with crash mats.

Method

1. **Work in pairs. Both people stand on a skateboard, skates or roller blades, facing each other.**
2. **Take one end of the rope each. Now gently lean backwards. Describe what happens to both of you!**
3. **After a count of three, one person releases the rope. Describe what happens this time!**
4. **Individually, explain what happened in each of the trials with reference to what you know about forces.**

In the *Skater tug-of-war* activity, while at first the two people are not moving, we can see that there must be a force in the rope which is pulling in both directions to try to bring them closer together. If they are standing on the floor, the force of friction between their feet and the floor prevents them from accelerating towards each other. If the force in the rope – usually called **tension** – and the friction on their feet are the same in size (but opposite in direction), the forces are said to be **balanced**. We can show this using a force diagram.

Figure 1.30 Balancing forces in a tug-of-war

The force arrows in Figure 1.30 have direction and size and so can be thought of as vectors. We can add the forces to work out the total force acting, overall, on the two participants:

Total force $\boldsymbol{F} = \boldsymbol{F}_1 + \boldsymbol{F}_2$

$\boldsymbol{F}_1 = 10\,\text{N}$, $\boldsymbol{F}_2 = -10\,\text{N}$. So

$$\boldsymbol{F} = 10 + (-10)$$

$$= 10 - 10$$

$$= 0\,\text{N}$$

So the forces overall are balanced, and no change in motion occurs.

What is gravity?

FEELING GRAVITY'S PULL

There is one very important force we need to consider in any situation on Earth (or indeed on, or near to, any other large mass for that matter!) The force of **gravity** acts on all masses, causing them to **attract** each other. We will look at attractive and repulsive forces in more detail in *MYP Sciences by Concept 3*, Chapter 4, and in *MYP Physics by Concept 4&5*, Chapter 2.

Newton realised that gravity was an important kind of force in explaining the way the universe works. He thought that the force of gravity accelerated masses towards each other in just the same way as any other force. The special name we give to gravitational forces is 'weight'. We can then use Newton's second law to write an equation for weight:

Weight W = Mass $m \times g$

where weight is measured in newtons (N), and mass is measured in kilograms (kg).

Hint

Note that while it is quite common for us to talk about weight in 'kilos' or 'pounds', this is inaccurate since these are units of *mass* or the amount of matter in an object.

The letter g in the equation above is called the *gravitational acceleration* and its value depends on the size of the masses causing the attraction. On Earth, gravitational acceleration is overwhelmingly affected by the huge size of the Earth's mass – which is 6 trillion trillion kilograms (that's a 6 with 24 zeroes after it)! This means that the value of g is more or less the same wherever we are on Earth:

$g = 9.81\,\text{m}\,\text{s}^{-2}$

(In fact, the value of g does vary in different places on the Earth due to factors such as the Earth's rotation, and the density of the rock under our feet – see *MYP Physics by Concept 4&5*, Chapter 2, for more on this!)

This means that every 1 kg of mass causes a weight (on Earth) of 9.81 N. We can usually approximate this to 10 N. On other planets, however, it is a different story.

ACTIVITY: Extra-terrestrial weigh-in

ATL

- Critical-thinking skills: Interpret data

Individually, try to solve these problems.

Table 1.4 shows the gravitational acceleration on some different objects in our Solar System.

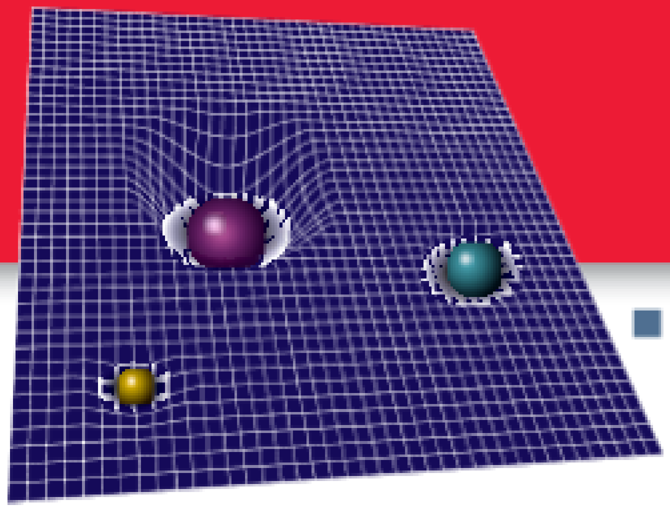
Place	Gravitational acceleration g ($\text{m}\,\text{s}^{-2}$)
Moon	1.62
Mars	3.73
Jupiter	25.94
Asteroid Ceres	0.26

Table 1.4 Gravitational acceleration in different places in our Solar System

- **Describe** how our weight depends on our mass and on the gravitational acceleration.
- **State** your mass on Earth, and on each of the places in the table.
- **Calculate** your weight for each of the places in the table.
- **Suggest** what would happen if you played basketball on the Moon, and what would happen if you approached the core of Jupiter.

Assessment opportunities

- This activity can be assessed using Criterion A: Knowing and understanding.



■ **Figure 1.31** Einstein interpreted gravity as the effect of distortions in space–time

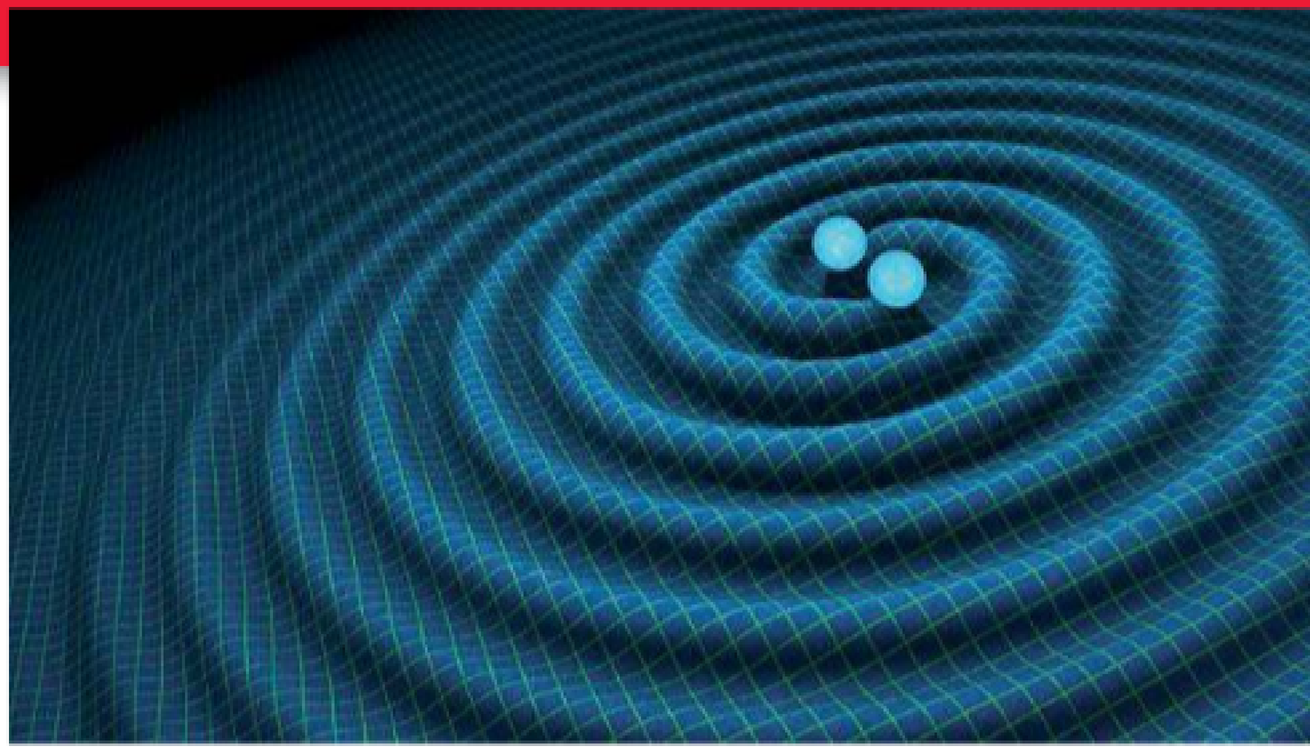
It is important to recognize that *all* masses will fall to Earth with the same acceleration – *g*. A larger mass will require a bigger force to do so – but this is what we mean by its *weight*. In other words, the gravitational force on a larger mass is proportionately greater, and produces the same acceleration on a cannonball as it does on a pebble. It *does* seem that less massive objects fall more slowly than more massive ones, but this is usually because the **air resistance** – the friction on the objects caused by the air – is different.

EXTENSION

Find out how Galileo is reputed to have demonstrated that the acceleration of different masses is the same by searching Galileo Pisa gravity. Explore further how Galileo's prediction was tested 400 years later by NASA astronauts on the Moon during the Apollo 15 Galileo experiment.

Actually, gravity is still quite mysterious. Our inquiry question 'What is gravity?' is really conceptual, because there is no single straightforward answer. Einstein incorporated the effect of gravity into his *general theory of relativity*, and interpreted gravitational acceleration as caused by the 'bending' of space–time, as though space were like a sheet of rubber that was distorted and bent by masses.

Very recent research has aimed to identify a particle that 'carries' the force of gravity between masses. Scientists have given this hypothetical particle the name 'graviton'. Similarly, recent measurements by astronomers have attempted to demonstrate the existence of 'waves' of gravity across the universe, remnants of the huge distortions in space–time caused by the Big Bang at the beginning of time!



■ **Figure 1.32** Evidence of waves in gravity across space–time?

■ **Figure 1.33** Gymnastics at the Concurs de Castells festival at Tarragona in Spain. Can they balance the forces?

ACTIVITY: Some balancing force examples

ATL

- Information literacy skills: Make connections between various sources of information
- Critical-thinking skills: Evaluate evidence and arguments

Individually, test your understanding by trying to solve these problems.

1 Two explorers have come across an old rope bridge across a river. The first explorer reaches the centre of the bridge safely. The second explorer then starts to cross the bridge. Disaster! As soon as she stands on the bridge the rope snaps and they fall into the river.

Figure 1.34 Rope bridge

- **Draw** a diagram to show the forces acting on the bridge when the first explorer has reached the centre. **Label** all your forces with their correct names (but not their sizes).
- **Explain** what happened in terms of the forces acting on the bridge when the first, and then the second, explorer tried to cross.

2 Alfonso is trying to move a new sofa into his apartment. Unfortunately, he forgot to measure the size of his doors and it turns out the sofa won't fit through! He must therefore lift the sofa from the street and bring it into the apartment through his window.

The sofa has a mass of 160 kg. With a rope, Alfonso can pull upwards with a force of 400 N.

- **Calculate** how much mass Alfonso can lift alone. **State** whether he will need to ask for help from his friends, and if so, how many friends will he need to ask?

3 Yoshihiro is working on a sculpture for his art project. The sculpture consists of an empty picture frame that appears to be floating in mid-air. In fact, Yoshihiro wants to use very thin wires to suspend the sculpture from two fixed points on the ceiling.

The diagram in Figure 1.35 shows the position for the picture frame and the two points where he has fixed hooks.

- **Determine** where the wires should be and draw them in a diagram of your own. **Deduce** the probable relative sizes of the tension forces in each of the wires, and draw force arrows on the diagram to show these.

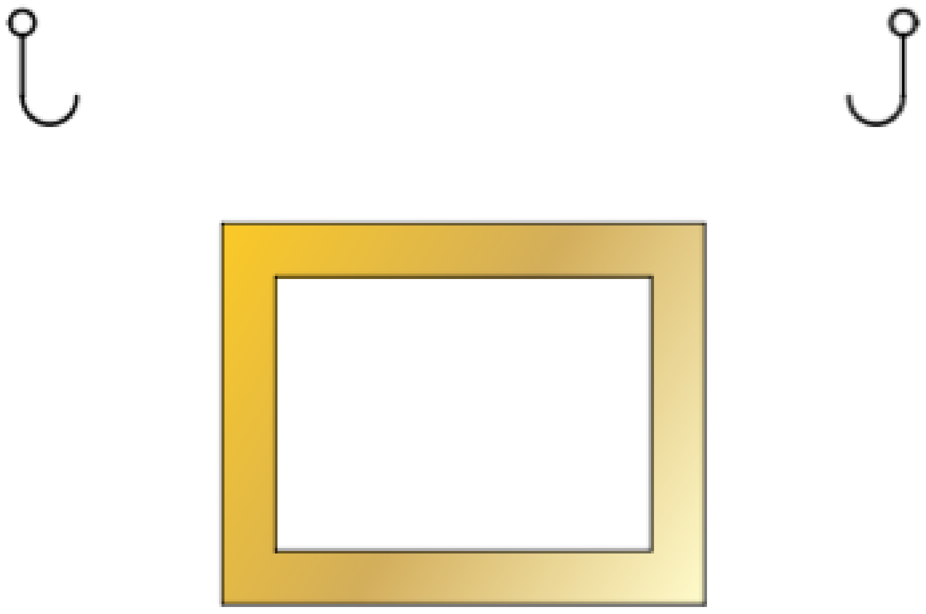


Figure 1.35 Yoshihiro's design for a sculpture

Assessment opportunities

- This activity can be assessed using Criterion A: Knowing and understanding.

Take action! The invisible cost of mass transportation

ATL

- Information literacy skills: Access information to be informed and inform others; Present information in a variety of formats
- Media literacy skills: Locate, organize, analyse, evaluate, synthesize and ethically use information from a variety of sources of media
- Critical-thinking skills: Recognize unstated assumptions and bias

! There is no doubt that the invention of the automobile has revolutionized human life across the globe. It is estimated that there are more than 1.2 billion cars in the world, consuming 90 million barrels of crude oil as fuels such as petroleum daily (source: BP Energy Statistics, 2015; US Energy Information Administration, 2013).

! In this activity, your task is to find out about the impact of automobile use on local and global environments. Your product will be an information resource of any kind to advise motorists on how best to minimize the impact of their vehicles. You can choose to present your information as a slide show, as a leaflet or magazine article, or in an online form.

Research

! **Source A:** Open the article and look at the data on oil consumption by clicking on the graphic:

www.theguardian.com/news/datablog/2010/jun/09/bp-energy-statistics-consumption-reserves-energy

! **Source B:** Review the data from the US Energy Information Administration at:

www.eia.gov/cfapps/ipdbproject

! **Source C:** Read the following extract from an article on an English language online news site about recent action in Mexico City.

Mexico City is taking drastic measures to tackle an environmental emergency. Smog levels in the city have risen to dangerous levels and the government has decided to take action.

Private cars in the capital must now remain off the roads for one day every week, according to the numbers on their registration plate, and one Saturday each month.

The real problem …

But environmental campaign groups such as Greenpeace say that such a programme is not a long-term solution to peak levels of pollution not seen in the city since the 1980s. They criticize the car-limiting programme since it does not address other major contributors to the pollution, such as factories on the outskirts of the city.

Environmental scientists at the National Autonomous University of Mexico (UNAM) meanwhile have suggested that the real causes of pollution are old, inefficient and poorly maintained vehicles, and the congestion of city traffic. "Engines are designed to run with maximum efficiency around $70\,km\,h^{-1}$. Speeding can increase pollution, but that is not really the issue in Mexico City. The real problem is hundreds of thousands of dirty, badly maintained engines overheating while crawling through heavy traffic," stated Dr Humberto Ayala from the university's department of mechanical engineering.

… maximum efficiency …

Meanwhile, motoring organizations in Mexico such as the taxi drivers' and bus drivers' unions have pointed out that the city's economy relies on them to transport millions in and out of the megacity every day.

! Carry out your own **research** into other methods for reducing the exhaust emissions from motor vehicles.

! **Describe** how science is used to reduce the emissions from motor vehicles in this way.

! With reference to the sources above, and your own research, **discuss** and **analyse** the implications of seeking to reduce pollution in this way. How effective will these methods be in reducing pollution? What other impacts (positive or negative) might these methods have?

! Remember to use **scientific language** you have learned clearly and correctly. Document all sources, using the referencing and citation standard recommended by your school.

Assessment opportunities

- This activity can be assessed using Criterion D: Reflecting on the impacts of science.

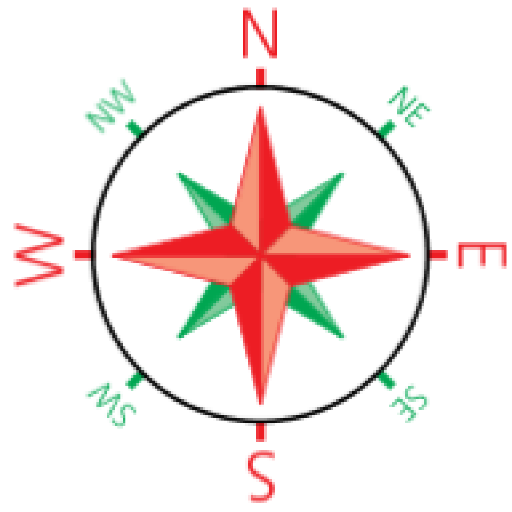
Compass points

When you have finished your project, explore the debatable question for this chapter using the Compass Points Routine.

ATL

- Critical-thinking skills: Consider ideas from multiple perspectives
- Creative-thinking skills: Practise visible thinking strategies

The proposition to debate is:
'Anyone should be able to travel and live wherever they like'.



In groups, take a large sheet of poster paper. Around the edges of the paper, write the compass points:

- **E Excited** – What excites you about this proposition?
- **W Worrisome** – What do you find worrisome about this proposition?
- **N Need to know** – What else do you need to know to help you evaluate the proposition?
- **S Suggestions** – What suggestions would you make about this proposition? What should or could be done?

Start by choosing any one of the compass points and **discuss** your ideas as a group. Write down the ideas next to the compass points. When you have finished, try to agree a group consensus 'stance' on the proposition. Write your group stance in the middle of the compass.

Share your ideas in class!

Reflection

In this chapter we have **described** how early humans travelled across the Earth, and **summarized** the ways in which human civilization developed measurements. We have **constructed** charts and graphs to **present** information on motion in space and time, and **determined** speeds, velocities and accelerations from those charts. We have **described** how forces affect motion, and **demonstrated** what happens when forces balance. We have **described** how transportation systems have developed in time, and **evaluated** the impacts of mass transportation on local and global environments.

Use this table to reflect on your own learning in this chapter.					
Questions we asked	Answers we found	Any further questions now?			
Factual: Where did we come from? How did we get here? How do we determine distance and location? What are coordinates? How can we measure speed? What is the greatest known speed? What is a force? What can cause a force? How do forces affect motion? What happens when forces balance?					
Conceptual: How can we represent motion? What is gravity?					
Debatable: Should we all be able to travel wherever we like, whenever we like, however we like?					
Approaches to learning you used in this chapter:	Description – what new skills did you learn?	How well did you master the skills?			
		Novice	Learner	Practitioner	Expert
Collaboration skills					
Information literacy skills					
Media literacy skills					
Critical-thinking skills					
Creative-thinking skills					
Learner profile attribute(s)	Reflect on the importance of reflection for your learning in this chapter.				
Reflective					

Change | Models, patterns | Scientific and technical innovation

2 How do we map matter?

By **changing matter** we can identify **patterns** in properties that help us to make **models**, and the models help us **invent new kinds of material**.

■ **Figure 2.1** Material problems, material solutions?

CONSIDER THESE QUESTIONS:

Factual: What substances are pure, what substances are impure? How do pure substances combine? What's in an atom?

Conceptual: How can patterns of properties be used to organize elements? What kinds of chemical reaction can take place? How can we represent chemical change? How do we exploit properties of chemicals?

Debatable: To what extent can science be used to fix the problems science creates?

Now **share and compare** your thoughts and ideas with your neighbour, or with the whole class.

IN THIS CHAPTER, WE WILL …

- **Find out** how patterns in the properties of substances can help us to manipulate them chemically and make new materials.
- **Explore** the structure of atoms, and the kind of chemical reactions that can take place.
- **Take action** to consider the impact of electronic waste materials and their recycling.

These Approaches to Learning (ATL) skills will be useful …

- Information literacy skills
- Critical-thinking skills
- Creative-thinking skills
- Transfer skills

We will reflect on this learner profile attribute …

- Knowledgeable – we will use knowledge of material properties to make models that help us to acquire new knowledge.

Assessment opportunities in this chapter …

- **Criterion A:** Knowing and understanding
- **Criterion B:** Inquiring and designing
- **Criterion C:** Processing and evaluating
- **Criterion D:** Reflecting on the impacts of science

KEY WORDS

chemical property	metal
displace	product
extract	react

SEE-THINK-WONDER

Look at the images in Figure 2.1. In groups, discuss the following questions:

- **What do you see?**
- **What do you think about the images?**
- **What do the images make you wonder?**

The images in Figure 2.1 show different kinds of chemical change. In *MYP Sciences by Concept 1*, Chapter 2, we explored different kinds of change, and how we might exploit physical and chemical properties to improve people's lives. In this chapter we will explore further, considering how looking at patterns in chemical properties has allowed us to better understand chemical changes, and then to use our understanding to innovate and create new solutions to the problems we encounter.

ACTIVITY: Classifying properties

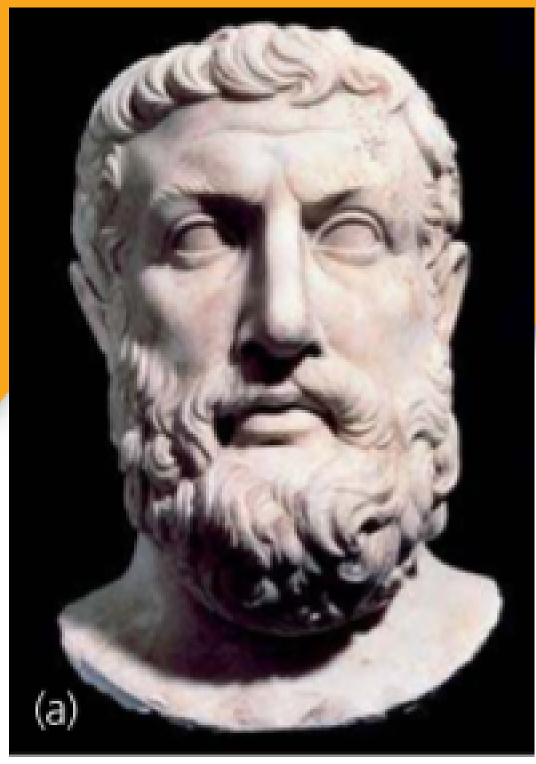
Look again at the images in Figure 2.1.

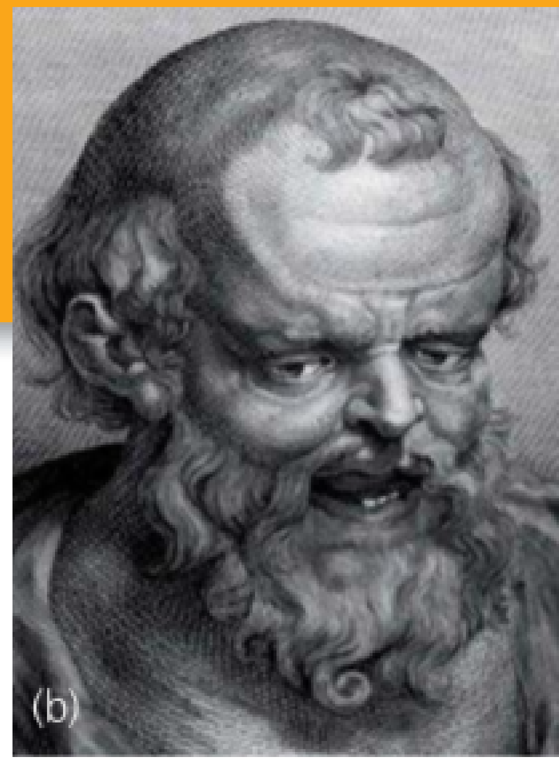
Classify the images according to whether they show a problem or a solution.

Discuss: can you match the problems and solutions?

Present your ideas in a visual organizer or table.

What substances are pure, what substances are impure?





■ **Figure 2.2** (a) Parmenides believed matter went on forever and filled all space, but (b) Democritus hypothesized tiny, indivisible 'atoms'

NO NEED TO BE MIXED UP, IT'S ELEMENTARY!

If we could look at the world around us with fresh eyes, we would see bewildering variety. The world is full of materials of different kinds, with different properties. Perhaps it is something in human nature that led us to try to classify and categorize, to analyse all of these different materials and try to understand whether they all had something in common.

Some of the earliest thinkers on the nature of matter lived in Greece in Mediterranean Europe, during a time we now refer to as the 'classical' period. The philosopher Parmenides, who lived around 500 BCE, asked the question, 'Is it possible to have a space filled with nothing?' He thought it impossible that such a space should exist, and from this **deduced** that matter must be everywhere, filling space even down to the tiniest scales. Parmenides thought that if we cut a piece of matter over and again we would just obtain smaller and smaller pieces forever – matter was continuous. A little later, Democritus (c. 460–370 BCE) pointed out that all things start and end somewhere, so Parmenides couldn't be correct. Surely if we cut matter into smaller and smaller pieces we would eventually come to a single, un-cuttable piece? Democritus used the Greek word *atomos* for these tiny objects, which means 'un-cuttable'. From this, we get the word 'atom'.

For much of the Middle Ages in Europe and Asia, people known as alchemists continued to inquire into the physical world. These early inquirers understood the world in terms of closely related material and spiritual realms, and their work was often thought of as magic. Alchemists sought ways to change or transmute matter from one substance to another, and believed that a 'philosopher's stone' existed that could turn base metals such as lead into gold. One of the earliest alchemical texts was written by an Egyptian-born Greek named Zosimus (c. 250 CE), but he refers to an earlier alchemist Mary (or Miriam) the Jewess, who experimented with distillation (see *MYP Sciences by Concept 1*, Chapter 2) and after whom the method of warming substances in a water bath is still named (*bain-marie* in French or *baño maria* in Spanish). While alchemists were often secretive about their 'esoteric' research, the influence of alchemy extended into the modern age.

Today Chinese Taoists practise an 'external alchemy' (wai-dan), which involves diet and the use of minerals and herbs to promote long life.

In Chapter 1 we discussed how great changes in the way humans thought about the world happened in Europe during the period from the sixteenth to eighteenth centuries – and onward! During the period known as the 'renaissance', some philosophers began to argue that all knowledge should be tested against reality

THINK-PAIR-SHARE

Think, individually – why did Democritus and Parmenides think what they did about matter? Identify what they didn't know that we know now.

Pair – share your ideas with a partner.

Share – discuss your ideas as a class. How did Parmenides and Democritus carry out their inquiries? How were their inquiries different to those of modern science?

Links to: Language and literature

The story of science is often inextricably bound up with the language of ideas. The word 'alchemy' can be traced back to the Old French *alquemie*, which in turn derives from the medieval Latin *alkimia*. This is thought to come from the Arabic *al-kīmiyā*, which is again borrowed from the Greek *chēmeía* (χημεία) meaning 'black magic' – and this again possibly comes from the ancient Egyptian *kēme* or *khmi*, derived from a name for Egypt, where alchemy originated. The journey of the word reflects the journey of ideas – right up to our modern word *chemistry*.

using experiments. Later, in the eighteenth century, the French aristocrat Antoine Lavoisier (1743–1794) was charged by the King of France with investigating the minerals available in France at the time. Lavoisier carried out his experiments with the aid of his wife, Marie-Anne Pierrette Paulze, who recorded many of his results and translated recent scientific papers from English. Lavoisier was able to show that combustion involved the combination of a gas, oxygen, with other substances and he identified 55 'elements' – although some of these we now know to be compounds, such as acids. Lavoisier established the principle of naming chemical substances in terms of their composition.

Meanwhile, the Industrial Revolution was in full force in Britain. British 'natural philosophers' such as Joseph Priestley (1733–1804) and Henry Cavendish (1731–1810) were also inquiring into the nature of combustion, which was of great interest as inventors explored the possibilities of powering steam engines with coal. Lavoisier's work helped to make a new theory that explained combustion in terms of chemical change. A British man called John Dalton (1766–1844) was fascinated by the weather, and from the age of 21 for 57 years he kept a 'meteorological diary', which recorded over 200 000 observations. Dalton elaborated a theory of matter which, like Lavoisier's, proposed that substances could be formed through different combinations of elementary, basic units of matter. Dalton drew symbols to represent different elements, and the way they combined to form molecules.

By the nineteenth century in Europe the idea that matter consisted of fundamental, 'elementary' substances, which were themselves comprised of different kinds of 'atoms', was firmly established.

Figure 2.3 In a book published in 1840, called *Seimi Kaisō* ('Science of Chemistry'), a Japanese scholar, Udagawa Yoan, describes the findings of Lavoisier for the first time in Japan. This drawing includes an alembic or still of the type used by Lavoisier, consisting of two vessels connected by a tube. According to the alchemist Zosimos, the alembic was first invented by Mary the Jewess

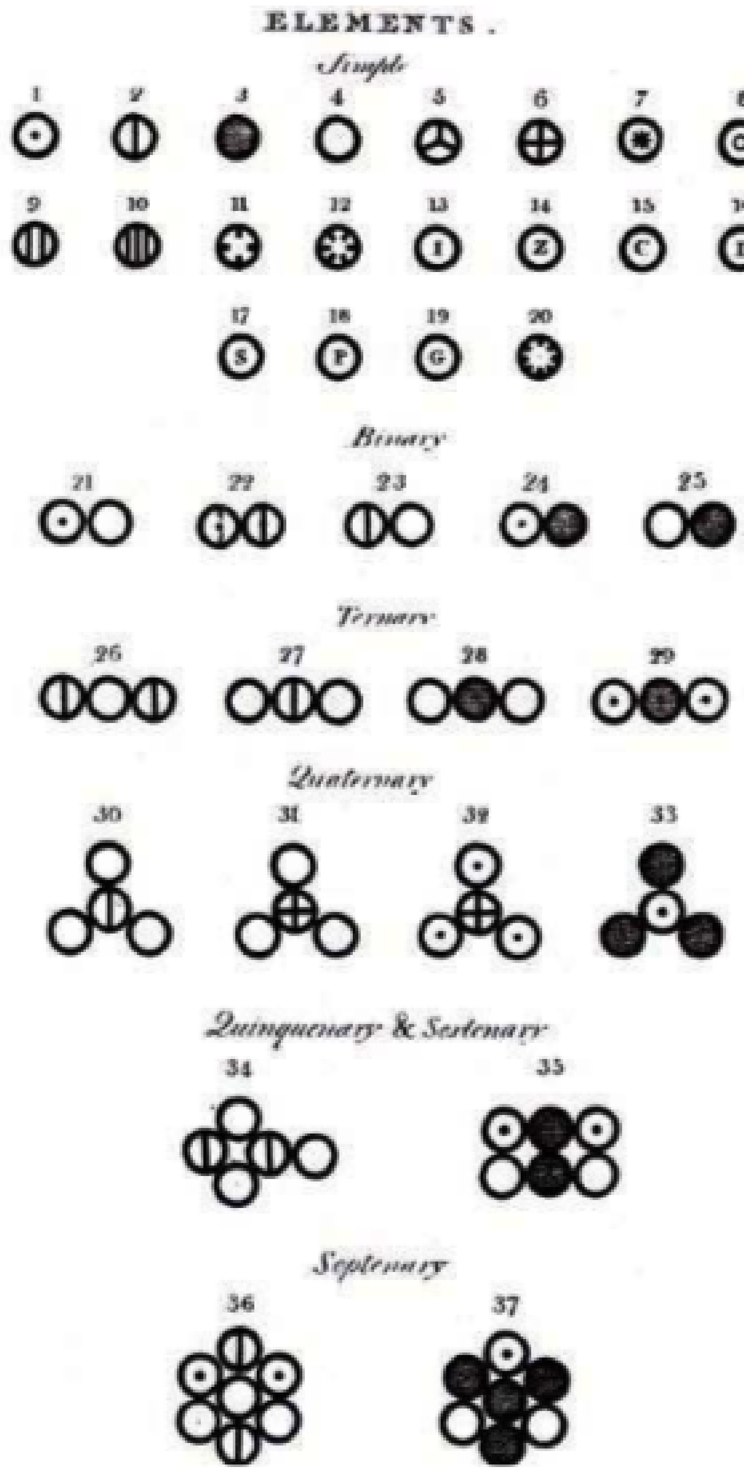


Figure 2.4 Dalton's symbols for chemical elements and sketches of molecules

How do pure substances combine?

WHAT'S IN A NAME?

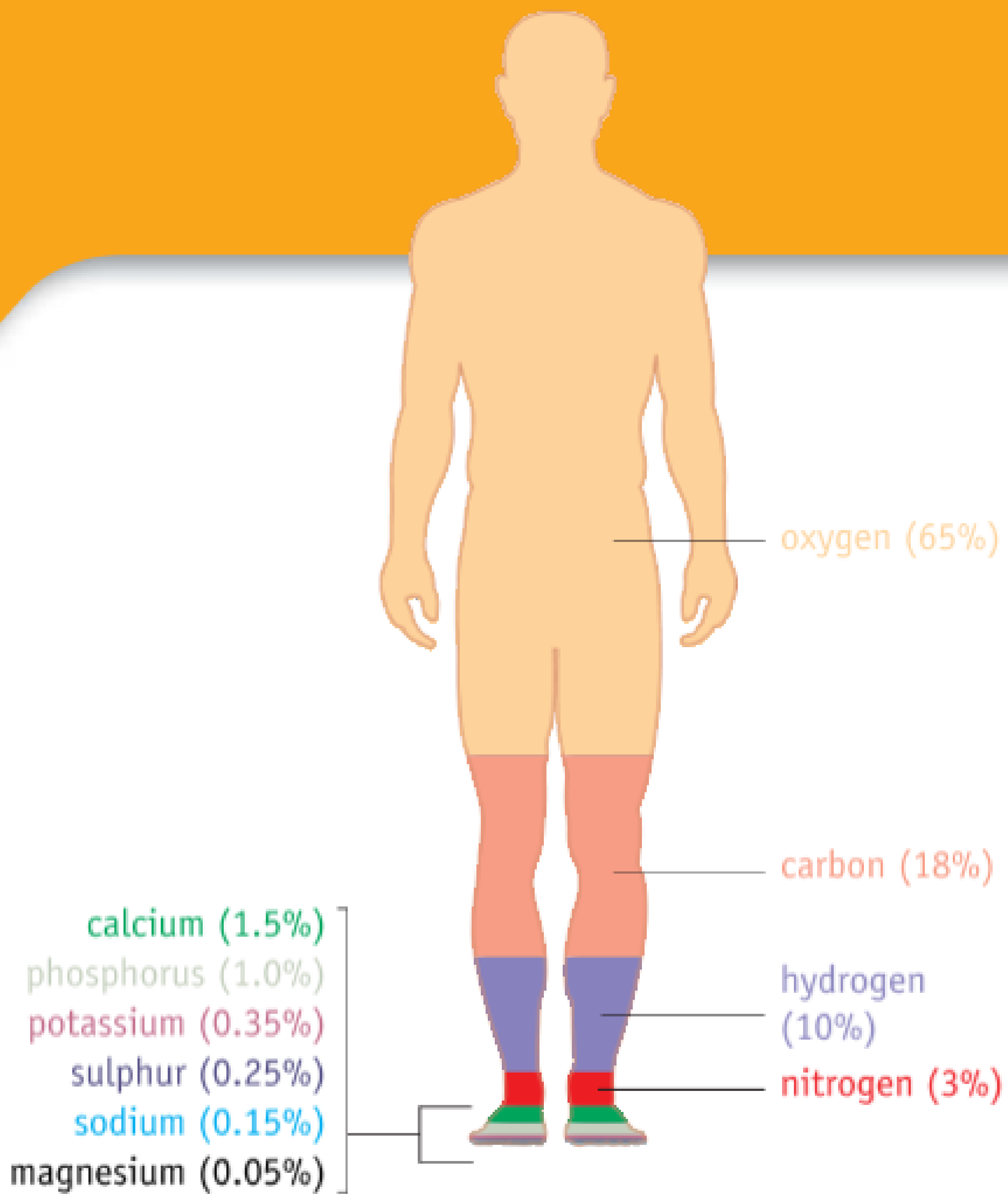
The mixtures, solutions and suspensions we explored in *MYP Sciences by Concept 1*, Chapter 2, can be separated using the different **physical properties** of their constituents. However, the materials we separated may not themselves have been 'pure' substances.

Elements contain only one kind of substance. Elements cannot be 'turned into' anything else by chemical processes alone (although more recently we have learned to change elements using nuclear processes – more on this in *MYP Physics by Concept 4–5*!). Elements can exist as collections of single atoms (monatomic), in pairs with another atom of the same element (diatomic) or – more rarely – as threes (triatomic). The state in which the element occurs depends on conditions such as the temperature of the material.

Compounds are formed when elements combine in various ways. Unlike in a mixture, the elements are **bonded** together with relatively strong forces between their atoms. Compounds can be changed into different compounds, or even reduced to their component elements, using **chemical reactions** or by electrical means such as **electrolysis**.

When a substance consists of multiple atoms joined together it is called a **molecule** – whether a compound or an element.

Many compounds consist of two, three or four elements bonded together, but some compounds can be much larger. Carbon and silicon are elements that are particularly good at forming very large molecules with chains of tens or hundreds of molecules bonded together. When these long molecules consist of smaller 'unit molecules' of the same kind joined together, the longer molecules are called **polymers** (see *MYP Sciences by Concept 3*, Chapter 2, for more information on carbon molecules).



■ **Figure 2.5** The human body mostly consists of 10 elements combined in various compounds

> **DISCUSS**
>
> What do the symbols in Figure 2.6 mean to you?

Symbols are a quick way to communicate information. In order for symbols to work, everyone needs to agree on their meaning. In Figure 2.4 we can see how Dalton chose symbols to represent the different chemical elements – he probably derived these from earlier symbols used by alchemists. To make it easier to quickly write down the atomic arrangements of substances, we use a letter symbol for each element. The symbols can then be written together to give a **chemical formula**. The symbols are sometimes just the first letter of the name of the chemical in English, but not always – the symbols for some elements come from the Latin names for their ores. Because the symbols are also names, chemical symbols always begin with a capital letter (H), never a lower-case letter.

ACTIVITY: What's my name?

ATL

- Information literacy skills: Access information to be informed and inform others

Copy and complete Table 2.1 below by stating the missing names and symbols. Search online or use a chemical table to help you.

Name	Symbol
Hydrogen	
	Fe
Sodium	
	Cl
Potassium	
	W
Gold	
	Ag

Table 2.1 Chemical substance names and symbols

Assessment opportunities

- In this activity you have practised skills that are assessed using Criterion A: Knowing and understanding.

Figure 2.6 What information do these symbols communicate?

ACTIVITY: My word is my bond

ATL

- Critical-thinking skills: Interpret data

Table 2.2 shows the atomic arrangements for different substances. Different kinds of atoms are shown as circles of different colours.

Analyse the diagrams, and then copy and complete the table to state:

- **whether the substance is a molecule or not**
- **whether the substance is an element or a compound.**

Use the key to write a chemical formula for each substance, with subscripts to give the numbers of each element present. One example has been done for you.

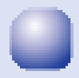
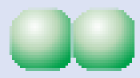
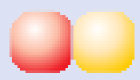
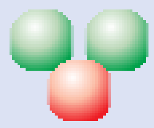
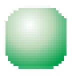
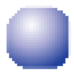
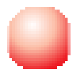
Atomic diagram	Molecule? (Yes or no)	Element or compound?	Chemical formula
			
			$_2$
			
			

Table 2.2 Atomic arrangements for substances

Key:  =  =
 = =

Assessment opportunities

- In this activity you have practised skills that are assessed using Criterion A: Knowing and understanding.

We show the number of elements in a compound using numbers in 'subscript' like this:

- H_2 means two hydrogen atoms bonded together (diatomic hydrogen)
- O_2 means two oxygen atoms bonded together (diatomic oxygen)
- SO_4 means one sulphur (S) atom bonded to four oxygen atoms (O) (this molecule is also called a sulphate **ion**).

ACTIVITY: The right stuff for the job

ATL

- Information literacy skills: Access information to be informed and inform others
- Critical-thinking skills: Gather and organize information to formulate an argument

Look at the objects in Figure 2.7.

Figure 2.7

Use online research or books to:

- **state what elements these objects might contain, and in which parts of the objects you would find these elements**
- **state whether the objects are formed from elements, compounds, polymers or a combination of these**
- **write chemical formulae for the elements, compounds or polymer substances in the objects**
- **describe the physical properties of each substance (see *MYP Sciences by Concept 1*, Chapter 2, for ideas!)**

Use the properties of the materials you have found to explain why these substances might be used for the different objects in Figure 2.7.

Assessment opportunities

- In this activity you have practised skills that are assessed using Criterion A: Knowing and understanding.

What's in an atom?

For Dalton, atoms were simple, indivisible, tiny spheres. We have seen that to understand the way matter is made, we need to consider the way in which atoms are bonded together. Dalton did not have any explanation for this, and so work went on to try to understand better how atoms could join together. The first clue came in 1897 when British scientist Joseph John Thomson (1856–1940) experimented with a new discovery called cathode rays. Cathode rays were mysterious energy that seemed to be emitted from some metals when they were heated and electrically charged (see *MYP Sciences by Concept 3* for more on electric charge). At first, many thought the rays were pure energy like light, but Thomson had the idea that they might be caused by particles, and that these particles streamed away from the electrically charged metal because they also had an electric charge.

Thomson was able to use measurements from his experiments to estimate the size of these particles, and to his surprise they turned out to be very small indeed – smaller even than the best estimates at the time for the size of an atom. Thomson was the first to discover a **subatomic particle**, which he called the **electron**.

Thomson reasoned that atoms should not have an electrical charge overall, otherwise matter would be affected by **electric fields**. Consequently, he hypothesized that the atom was like a 'plum pudding' – which in Britain was a kind of dessert made from sponge cake with plums scattered inside. A plum pudding is rather like a blueberry or chocolate-chip muffin.

ACTIVITY: The chemical body

ATL

- Information literacy skills: Access information to be informed and inform others

Refer to Figure 2.5. Choose *one* of the elements in the human body. Research to **describe**:

- **what this element does in the human body**
- **where this element might be found**
- **where we obtain this element from.**

Choose appropriate words from the box below to describe the properties of this element, and the form in which it is found.

element	molecule	compound

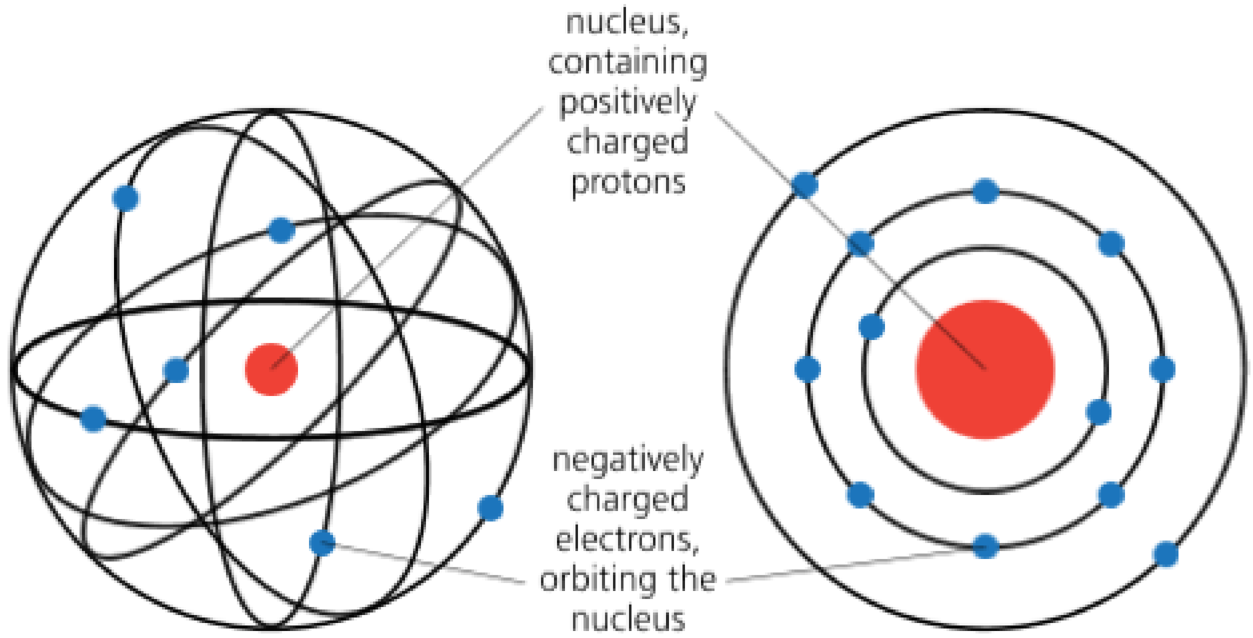
Assessment opportunities

- In this activity you have practised skills that are assessed using Criterion A: Knowing and understanding.

It seemed that atoms were not, after all, 'uncuttable'. Proof of the hypothesis came in 1911 when New Zealander Ernest Rutherford (1871–1937) asked his research assistants Geiger and Marsden to carry out an experiment. The experiment was intended to estimate the thickness of a piece of **gold leaf** by firing another new kind of ray consisting of 'alpha particles' at the gold. Rutherford was expecting that the 'plum-pudding' atoms of gold would cause the rays to deflect away, like two balls in a game of pool. When **calibrating** their equipment one day, Geiger and Marsden noticed that some of the alpha rays were being bounced right back in their paths. Rutherford realised this meant there must be a very strong force between the alpha particles and the atoms of gold. The only force known to be capable of doing this at the time was the electric force. Rutherford deduced that there must be a very strong electrical charge inside the atoms. When he carried out his calculations Rutherford saw that the electrical charge of the atom would have to be condensed into a very small area – much smaller even than the overall size of the atom. Rutherford called this the **nucleus**, and the atomic model was revised again!

Figure 2.8 Cathode rays are streams of electrons, produced in a glass tube like this containing a vacuum, from charged metal electrodes. Cathode rays are invisible, but they cause a phosphorescent screen to glow so we can see their path. They are deflected by a magnet, which tells us that they are electrically charged.

Figure 2.9 Thomson's 'plum pudding' atom was like a blueberry muffin!



■ **Figure 2.10** Models of the atom: (a) Rutherford's nuclear model, (b) Bohr's electron orbits

In Rutherford's atom, the nucleus is surrounded by space. The electrons **orbit** around the nucleus in this space. The overall size of the atom depends on the orbits of the electrons, which in turn depend on the strength of the electrical forces between electrons and the nucleus. In 1913, Danish physicist Niels Bohr (1885–1962) modified Rutherford's atom to explain how atoms in gases could both **absorb** and **emit** light. Bohr suggested that the electrons were not orbiting anyhow around the nucleus, but must be fixed into certain 'allowed' orbits, and no others.

Now the race was on to see if the atom could be cut further and further! In 1932 another British physicist, James Chadwick (1891–1974), discovered another particle inside the nucleus. This particle had no electrical charge at all, and so was called the **neutron**. The positive charge in the nucleus was thought to come from **protons** that were about the same size and mass as neutrons. The nucleus had now itself been 'split' into two subatomic particles.

Today scientists understand that these different 'pictures' of atoms are really just different 'models' that we can use to explain different properties. Scientists have gone still further to hypothesize that protons and neutrons themselves contain unimaginably tiny particles of different types called **quarks** in various combinations.

So what do atoms really look like? The truth is that it is hard to know – we can't 'see' atoms using our own eyes because they are simply too small – about the same size as the light waves we would use to see them. A single human hair is about 40 000 atoms wide! We have to use very sophisticated quantum microscopes, such as scanning tunneling microscopes (STM), to give us an idea what an atom might 'look' like.

Name	Mass (kg)	Mass (relative to proton)	Electric charge
Proton	1.6726×10^{-27}	1	+ (positive)
Neutron	1.6749×10^{-27}	1 approximately	0 (zero)
Electron	9.1094×10^{-31}	$\frac{1}{1800}$	– (negative)

■ **Table 2.3** Parts of the atom

Models in science

The story of the atom tells us something important about the way science works. Models in science work like pictures or stories that help us visualize the objects we are trying to explain. As new discoveries are made, the models are changed. This doesn't mean the previous model was wrong, as it helped explain what was known at the time. Different models are useful in different ways.

EXTENSION

Find out how we might 'see' atoms and what they look like. Search **Nature video: Have you ever seen an atom** or go to https://youtu.be/yqLlgIaz1L0

Search **Video: Scanning Tunnelling Microscope** to find out how an STM enables us to 'see' atoms.

How can patterns of properties be used to organize elements?

PATTERNS IN MATTER

In the *Element card games* activity below, you will carry out a similar task to scientists like Dalton, the Russian chemist Dmitri Mendeleev (1834–1907), and German chemist Julius Meyer (1830–1895). Meyer and Mendeleev both independently worked to identify common properties of the 60 or so elements known at the time. Mendeleev was quoted as claiming that his table came to him in a dream, and he is commonly credited with devising the first version of the periodic table, although Meyer published a less sophisticated version five years earlier.

Element	Melting point (°C)	Boiling point (°C)	Appearance at room temperature	Reactivity with cold water	Conductivity of heat and electricity at room temperature
Argon	–189	–186	Colourless gas	No reaction	Does not conduct
Bromine	–7	58	Red-brown liquid	Dissolves	Does not conduct
Chlorine	–101	–34	Green-yellow gas	Dissolves	Does not conduct
Copper	1083	2595	Shiny brown solid	Very slow reaction	Very good
Fluorine	–220	–188	Pale yellow gas	Dissolves	Does not conduct
Gold	1063	2966	Shiny yellow solid	No reaction	Very good
Helium	–270	–269	Colourless gas	No reaction	Does not conduct
Lithium	181	1330	Silver-grey solid	Rapid reaction	Good
Neon	–250	–246	Colourless gas	No reaction	Does not conduct
Potassium	63	765	Silver-grey solid	Very rapid reaction	Good
Silver	960	2212	Shiny silver solid	No reaction	Good
Sodium	98	890	Silver-grey solid	Very rapid reaction	Good

■ **Table 2.4** Properties of elements

ACTIVITY: Element card games

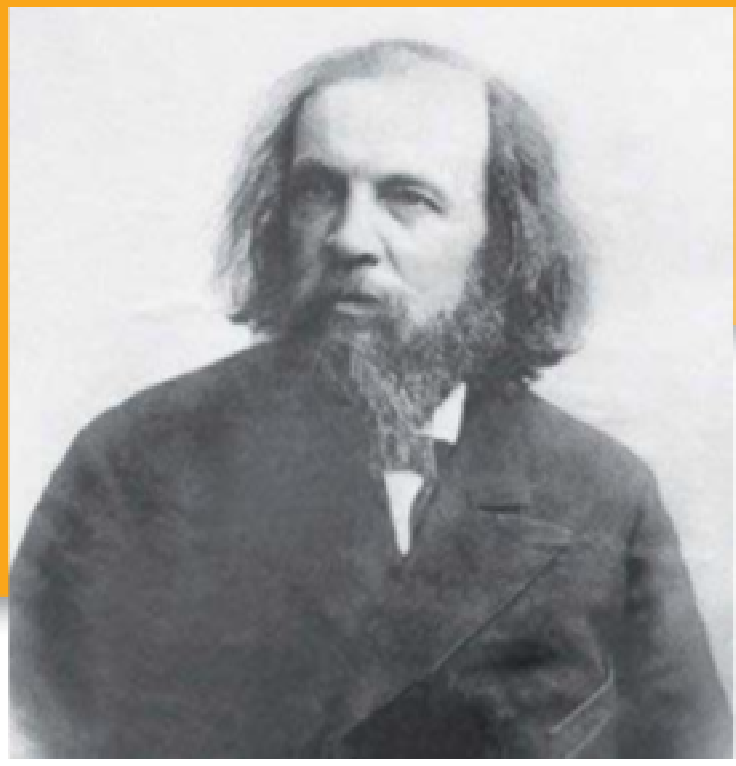
ATL

- Critical-thinking skills: Interpret data; Draw reasonable conclusions and generalizations; Analyse complex concepts and synthesize to create new understanding

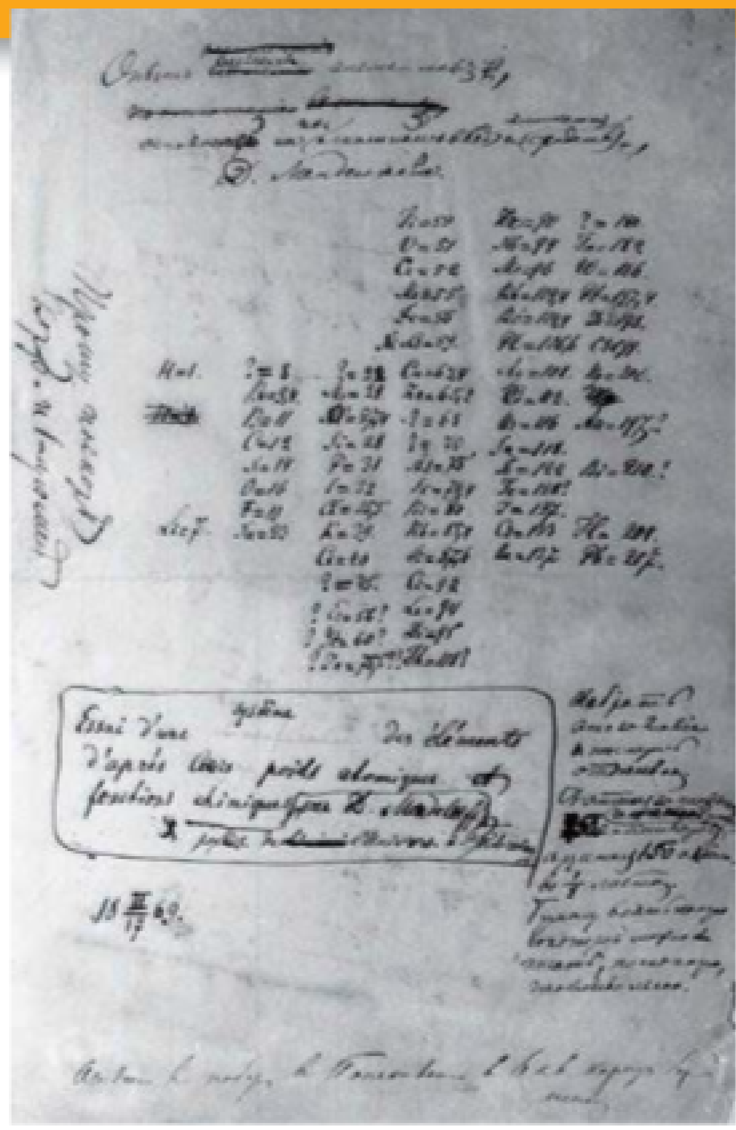
1. In pairs, research to find out what the different properties in Table 2.4 mean.
2. For each of the elements in the table, make a small playing card. On the cards, write each of the properties and the chemical symbol for each of the elements.
3. Carry out an image search to find images of the elements, and paste onto your cards.
4. Now spread out all the cards on the table in front of you. Then group the cards according to similar properties or rank the cards according to the properties.
5. Take a photo of your cards, and **present** your information in a chart or diagram.
6. **Outline** how you grouped the cards together, and **explain** how you ordered or ranked them.

Assessment opportunities

- In this activity you have practised skills that are assessed using Criterion A: Knowing and understanding.



■ **Figure 2.11** Dmitri Mendeleev



■ **Figure 2.12** A hand draft of Mendeleev's periodic table from 1869

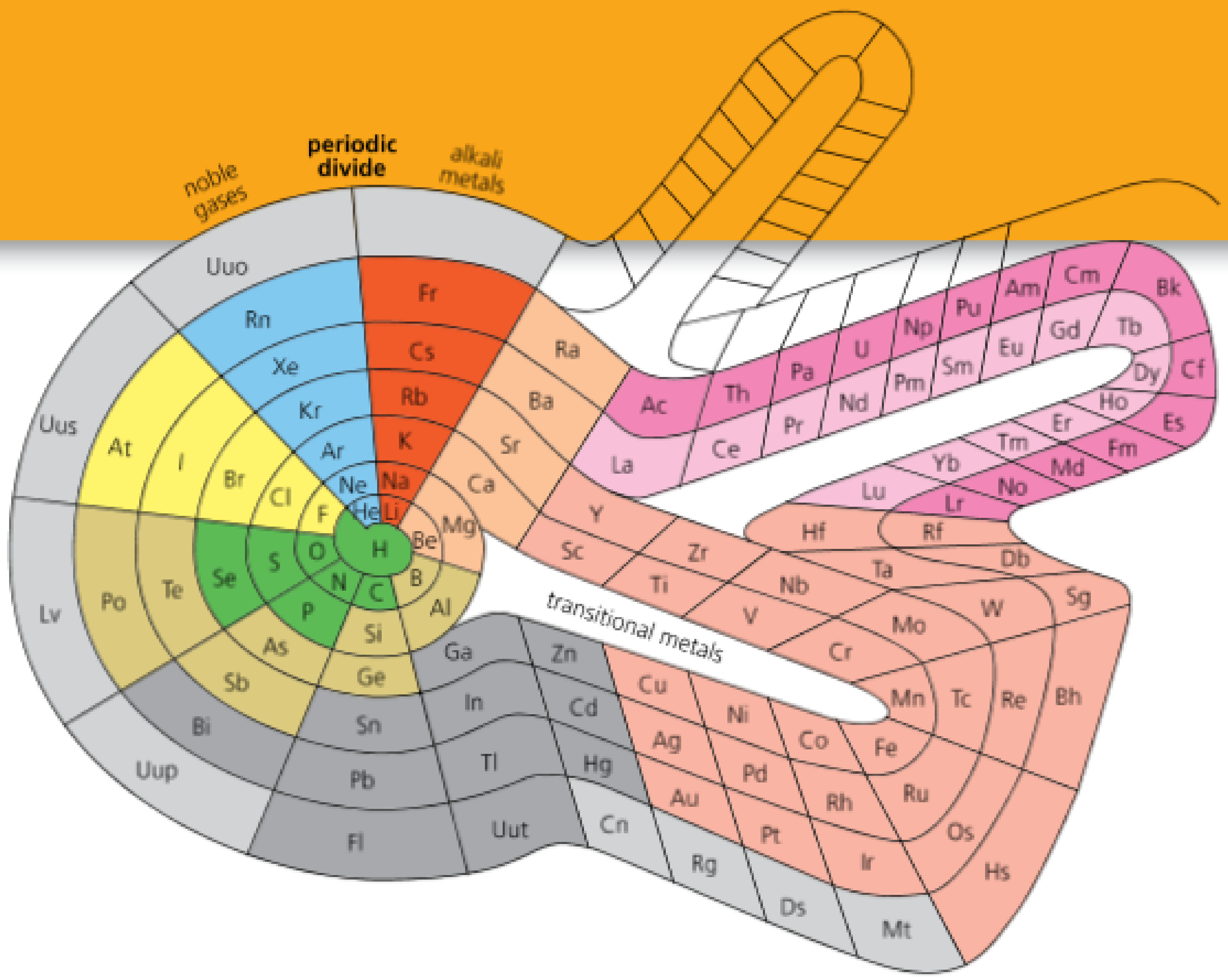
Mendeleev's table was particularly successful as it predicted the existence of elements that had not yet been discovered – especially the elements gallium (Ga), germanium (Ge) and scandium (Sc). Gallium and germanium were both discovered shortly afterwards.

There are a number of different ways of grouping and arranging the elements according to their properties, as Figure 2.13 and Figure 2.14 show.

The position of the elements in the periodic table gives us valuable information about the properties of the elements. Vertical columns in the table are called **groups**, while horizontal rows are called **periods**. We can investigate the way that element properties change experimentally, and by using simulations and models of the periodic table online.

Group	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Period	alkali metals																	noble gases
1	1 H																	2 He
2	3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne
3	11 Na	12 Mg					transition metals						13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
4	19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
5	37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
6	55 Cs	56 Ba		72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
7	87 Fr	88 Ra		104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Ds	111 Rg	112 Cn	113 Uut	114 Fl	115 Uup	116 Lv	117 Uus	118 Uuo
			57 La	58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb	71 Lu	
			89 Ac	90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lr	

■ **Figure 2.13** The International Union of Pure and Applied Chemistry (IUPAC) periodic table of the elements is the standard version used by most chemists globally



■ **Figure 2.14** This version of the periodic table devised by Theodor Benfey (1964) shows how the elements can be arranged in a continuous spiral

ACTIVITY: Periodic table models

ATL

- Information literacy skills: Access information to be informed and inform others; Process data and report results

Search **interactive periodic table** or go to the Royal Society of Chemistry's website at www.rsc.org/periodic-table to find some online interactive versions.

Use online periodic tables to find out the locations of these types of element:

- **Metals**
- **Non-metals**
- **Diatomic elements**
- **Solids at 20 °C**
- **Gases at 20 °C**

On your own version of the periodic table, show the locations of these types of element using a colour code.

Did you note anything about hydrogen? What are the properties of hydrogen? Do these properties suggest to you that it is a metal, or a non-metal? What does this make you think about its location in the periodic table?

Assessment opportunities

- In this activity you have practised skills that are assessed using Criterion C: Processing and evaluating.

Links to: Language and literature

The Italian writer Primo Levi (1919–1987) began his career as a chemist. Levi was Jewish, and when Nazi Germany took control of Italy in 1943 he was captured and deported ultimately to the Auschwitz concentration camp. Of the 650 Italians deported with Levi, he was one of only 20 to survive. As a chemist, he had learned some German and was given a job as an assistant in a factory for producing synthetic rubber, enabling Levi to avoid the fate of some of his co-prisoners. After the second world war, Levi wrote a collection of short, poetical essays – some autobiographical – each of which is inspired by an element taken from the periodic table.

Levi's idea of using the elements as inspiration perhaps reflects the more ancient, alchemical belief that elements have certain spirits or characters. What elements would you choose to represent how you are feeling today?

Take action! Periodic poetry

ATL

- Creative-thinking skills: Create original works and ideas

! For an end-of-term celebration, your class has been asked to present your learning in this chapter so far in the form of a performance.

! Devise a performance – a play, poem, dance or song – about one of the topics you have explored. Here are some ideas!

- Reactivity of different metals
- Properties of elements in the periodic table
- Different models of the atom

What kinds of chemical reaction can take place?

REACTING METALS

■ **Figure 2.15** Metals are used in many contexts

Figure 2.15 shows some different metals in use. The different ways a metal is used can tell us something about the way it reacts with other elements found in the environment. The Earth's atmosphere is abundant in oxygen and nitrogen, and in most places also contains quantities of water vapour. Moreover, any metal that comes into contact with humans will also have to contend with the moisture in sweat, salt and slightly acidic oils produced by our skin.

GENERATE-CONNECT-ELABORATE

1. In pairs, think about and then **discuss** the uses of metals shown in Figure 2.15. Write the names of the metals in a list.
2. **Generate** a separate list of other substances that each of the metals will come into contact with when it is used in the context shown.
3. **Connect** the names of the metals to the substances they will come into contact with, using arrows.
4. **Elaborate** the connections between metals and substances – write on the arrows to say how they might interact or react.

Would you say that the metals in Figure 2.15 are likely to be relatively reactive, or relatively unreactive? What makes you say that?

How can we represent chemical change?

At normal temperatures (around 20 °C) the metals in Figure 2.15 do not react very readily with oxygen or water in the air, and so they have been commonly used for centuries or more.

When a metal reacts with oxygen it forms an **oxide**. This is an example of a chemical reaction. To help represent chemical reactions clearly, we can use **word equations** to show the changes taking place. In the equation, we always show what we start with – the **reactants** – on the left-hand side. On the right-hand side we show what we finish with – the **products**.

$$\text{Reactant} + \text{Reactant} \rightarrow \text{Product(s)}$$

It may be that the product on the right-hand side of the equation is a single new substance, or multiple new substances – but the principle of **conservation of mass** is always obeyed! For example, the iron nails in Figure 2.15 slowly rust in contact with both water and oxygen. The chemical equation for this reaction is:

$$\text{Iron} + \text{Oxygen} \xrightarrow{\text{water}} \text{Iron oxide}$$

Note that the water is not itself used up in the reaction – it just helps the reaction to occur – and so it is not placed in the reactants, nor in the products. Since the product of this reaction is formed when oxygen is added to iron, this is an example of an **oxidation reaction**. The new substance, iron oxide, is not very reactive, but forms a reddish-brown powder that tends to fall apart and crumble because it requires more space than the iron atoms. Not all metals have this problem: aluminium oxide, for example, 'seals' the surface of the aluminium metal and so prevents it from oxidizing any further. Aluminium is a more **durable** metal to use as a result.

Similarly, lead can be dissolved by weak acids present in some drinking water. Lead is a very soft metal found easily in the earth, and has for millennia been used to make water pipes. When lead dissolves in this way and is ingested it becomes poisonous to the human body, and so whenever lead piping is found in older buildings it should be replaced.

Other metals do react readily with water.

Links to: Mathematics

In mathematics, you will know that an equation means that the left-hand side must always have the same value as the right-hand side. In a chemical equation this is true for the mass of the chemicals present. We must account for all of the substances present on both sides of the equation. The principle that the total mass of substance in a chemical process remains the same before and after is called the principle of conservation of mass. (Lavoisier established this in his experiments on combustion.)

ACTIVITY: Reactive metals

ATL

- Information literacy skills: Collect, record and verify data
- Critical-thinking skills: Interpret data; gather and organize information to formulate an argument

In this activity, you will **compare** the reactivity of metals within a group, and in different periods. Part of the investigation will be demonstrated by your teacher, and part you will carry out yourself.

You need to **write** an inquiry question or aim for your investigation.

Refer to the inquiries you carried out in the *Element card game* and *Periodic table models* activities. Use your conclusions from those activities to **predict** the order of reactivity for the metals in the list.

The metals we will compare are:

- **potassium**
- **sodium**
- **magnesium**
- **zinc**
- **copper.**

Part 1: Metals reacting with water

SAFETY: Some metals react violently with water. Your teacher should demonstrate these reactions, using a safety screen and wearing safety glasses. Only small quantities (a few grams) of the metals should be used.

When a metal reacts with water it forms hydrogen gas. We can write this reaction as a word equation like this:

Metal (solid) + Water (liquid) → Metal hydroxide (solid) + Hydrogen (gas)

Equipment:

- **Large water bath (containing at least 3 litres of water)**
- **Safety screen**
- **Heatproof mat**
- **Tongs**
- **3 boiling tubes**
- **Boiling tube rack**
- **Small pieces of potassium, sodium, magnesium, copper, zinc**

As a class: discuss and agree a **prediction** for what you might observe when the metals are dropped into water.

Observe what happens as your teacher drops potassium and sodium into the water bath. **Record** your observations in your notes.

Observe what happens when your teacher drops magnesium, copper and zinc into different boiling tubes. (Your teacher may pass the boiling tubes around for you to observe the reactions more closely.) **Record** your observations in your notes.

Results analysis

Describe what happened in the reactions. **Explain** the difference between the reactions with reference to the reactivity of the metals.

Part 2: Metal displacement reactions

A **displacement reaction** occurs because a more reactive metal can 'displace' a less reactive metal from a solution of a **salt** of that metal. We will investigate two reactions:

Zinc (s) + Copper Sulphate (aq)

Copper (s) + Zinc Sulphate (aq)

Notice that we can use symbols to show the states of the different reactants:

(s) = solid, (l) = liquid, (g) = gas, (aq) = 'aqueous' solution.

Predict and **summarize** using word equations what you expect to happen in the reactions.

SAFETY: The dissolved metal salts in this experiment can be poisonous if ingested in large quantities. If you spill any solution or touch directly, clean immediately and do not ingest.

Equipment:

- **2 boiling tubes in a boiling-tube rack**
- **Beaker containing no more than 50 ml of copper sulphate solution**
- **Beaker containing no more than 50 ml of zinc sulphate solution**
- **Copper shavings**
- **Zinc granules**
- **2 spatulas**

Method

1. Pour copper sulphate solution into a boiling tube until it is half full. **Record** the appearance of the solution and of the zinc granules.
2. Using the spatula, tip one spatula-full of zinc granules into the solution.
3. Agitate the solution by gently shaking the boiling tube, and place into the rack.
4. **Observe** what happens to the solution. **Record** your observations.
5. Now pour zinc sulphate solution into a clean boiling tube. **Record** the appearance of the solution and of the copper shavings.
6. Using the spatula, tip one spatula-full of copper shavings into the solution. Gently agitate the solution as before.
7. **Observe** what happens to the solution and **record** your observations.

Results analysis

Describe what happened in the two reactions.

Conclusion

Summarize the results of both parts of your investigation. What can you **conclude** about the reactivity of the five metals tested? **Organize** your findings and **present** them as a ranking of reactivity.

Evaluation

Outline whether your observations were reliable. What other measurements or observations could you have made to improve the validity of the experiments?

Assessment opportunities

- This activity can be assessed using Criterion C: Processing and evaluating.

■ **Figure 2.16** Reactivity series of metals

We can present the reactivity of different metals as a **reactivity series** (Figure 2.16). This shows us the order of the reactivity of the metals.

ACTIVITY: Relating reactivity to the periodic table

ATL

- Critical-thinking skills: Gather and organize relevant information to formulate an argument

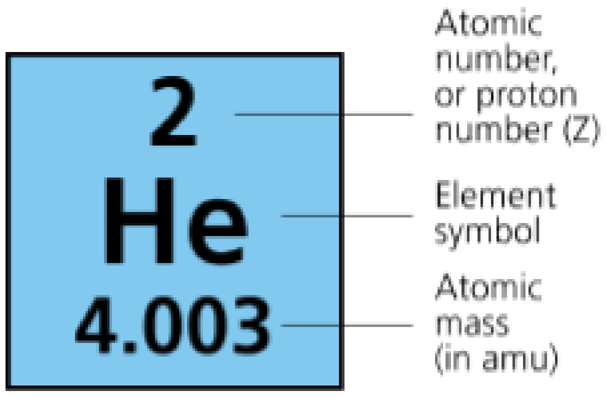
Using a periodic table, highlight the metals in the reactivity series in Figure 2.16.

Interpret your findings, and try to **summarize** in the form of a sentence. You may find these sentence starters helpful:

- **Vertical columns in the periodic table are called groups. The metals in our experiments were in these groups:**
- **Metals that are lower down a group …**
- **Horizontal rows in the periodic table are called periods. The evidence from our experiments suggest that the more reactive metals are …**

Assessment opportunities

- In this activity you have practised skills that are assessed using Criterion A: Knowing and understanding.



■ **Figure 2.17** Atomic number and atomic mass

EXTENSION

The atomic mass is often shown as a decimal. Research isotopes to find out why.

You may have noticed that elements in the periodic table are shown with two numbers (Figure 2.17). The numbers are sometimes shown in different positions.

The smaller number is called the **atomic number** and it tells us the number of protons in the nucleus of the atom. This is also equal to the number of electrons around the atom, provided the atom has not gained or lost any electrons to become an **ion**. The larger number is called the **atomic mass** and represents the average mass of the element, accounting for the different forms in which it is found.

ACTIVITY: Metal detectives

ATL

- Information literacy skills: Collect, record and verify data
- Critical-thinking skills: Interpret data; Gather and organize information to formulate an argument; Draw reasonable conclusions and generalizations

Different metals can have very similar appearances – shiny and silvery, for example. Can we use the different reactivity of metals to help identify them?

■ **Figure 2.18** Metal coins found in the ground

The archeologists we met in Chapter 1 have been digging at their site and have found a collection of metal artifacts in the ground. Unfortunately, once again Dr Boulos and Professor Li are disagreeing about their find! They cannot agree what metals the artifacts are made from, whether they are from the original Roman site, or whether they were left there much later.

Table 2.5 shows some of their initial observations for the two types of artifacts they have found.

Artifact	Appearance in ground	Appearance when cleaned
Bracelet	Greenish, corroded	Brownish, shiny
Ring	Whitish, corroded	Silver colour, shiny

■ **Table 2.5** Summary of archeologists' observations

Dr Boulos thinks that the bracelet may be made from copper, and the ring may be made from magnesium.

Prof Li thinks that the bracelet may be made from iron, and the ring may be made from silver.

Research these different metals to find out what salts they might form if corroded in the ground. **Describe** what you would expect to see when the metals had been underground for some time and **compare** to the archeologists' observations.

Suggest what chemical tests the archeologists could try on the artifacts to find out what metals they are made from. **Outline** the procedure for these tests, and **describe** what you would expect to observe in each case.

Assessment opportunities

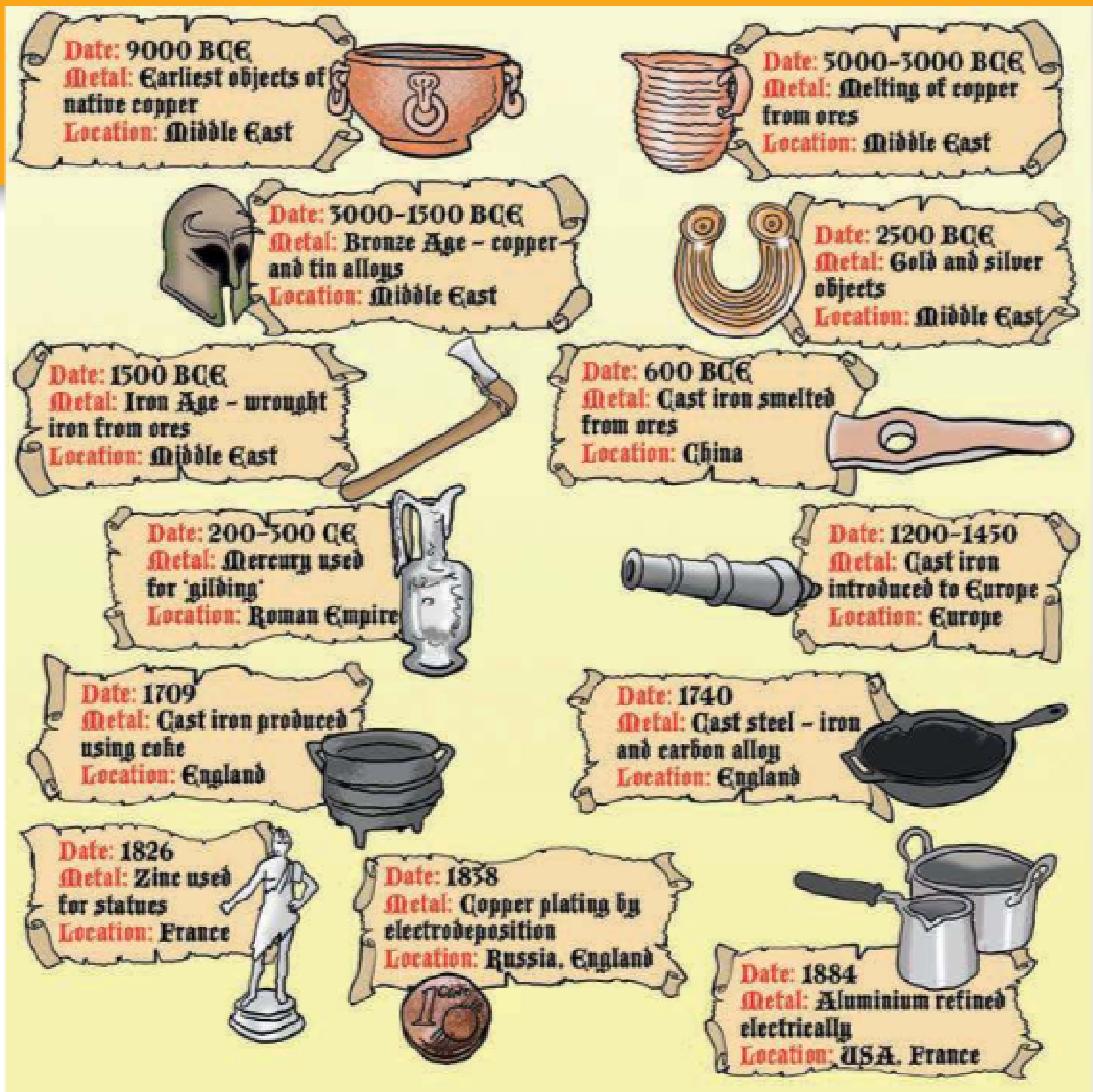
- This activity can be assessed using Criterion A: Knowing and understanding.

EXTENSION

Search metal ores to find out which metals are extracted from the ores in Figure 2.21.

BREAKING IT DOWN: DECOMPOSITION, OXIDATION AND REDUCTION

Figure 2.19 shows the metals that humanity has used throughout the ages, organized by the time of their discovery. Why do you think that some metals were used earlier than others?

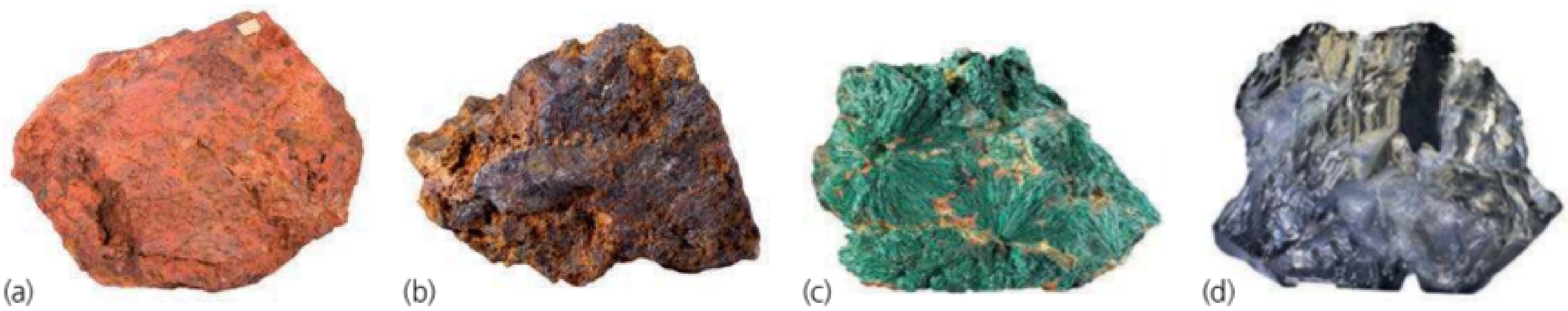


■ **Figure 2.19** Metals through the ages

Any metal lower than hydrogen in the reactivity series is found in a pure, elemental form in the ground as **native deposits**. These metals would have been very obvious to our ancestors, and to extract them would simply have been a question of removing them from the surrounding rock or dirt. Gold is one such metal. Gold is quite often found in small particles or 'nuggets' in rivers, since groundwater washes it out of the surrounding earth and downriver.

■ **Figure 2.20** Panning for gold in river water

Many metals are found in compounds they form with other substances as **ores**. Figure 2.21 shows some examples of common metal ores. If we are to use these metals, we must extract them from their compounds.



■ **Figure 2.21** Some important metal ores: (a) bauxite (b) haematite (c) malachite (d) galena

How do we exploit properties of chemicals?

ACTIVITY: Heavy metals

ATL

- Critical-thinking skills: Gather and organize relevant information to formulate an argument

1. **Compare the order of discovery of metals in Figure 2.19 to the metal reactivity series in Figure 2.16.**
2. **Describe the properties of metals that were first extracted and used by humans.**
3. **Compare these metals to those metals used later on. How are these extracted?**
4. **With reference to the reactivity series, suggest why the metals were discovered and extracted in this chronological order.**
5. **Using your knowledge of the extraction of iron from its ores to justify the position of carbon in the reactivity series.**

Assessment opportunities

- In this activity you have practised skills that are assessed using Criterion A: Knowing and understanding.

We saw earlier how the Industrial Revolution in Europe depended on scientific discoveries about the properties of metals, and one very important metal both then and now is iron. Iron was first extracted and smelted in 1709 and used as a construction material in its elemental form. In 1740 it was combined with small quantities of carbon as an **alloy** to form **steel**. Iron ores are forms of iron oxide. Iron is extracted from its ore in a blast furnace, which uses very high temperatures and carbon in the form of a fuel called **coke** to remove the oxygen from the iron ore (Figure 2.22). In a blast furnace, the coke first burns to form a gas called carbon monoxide CO. As the process of burning, called **combustion**, involves the addition of oxygen to a material it is another example of an oxidation reaction, as we saw earlier with the rusting of iron.

Carbon (s) + Oxygen (g) → Carbon monoxide (g)

The hot carbon monoxide then reacts with the iron oxide from the ore. Carbon is more reactive than iron, and so it displaces the iron from the iron oxide to form the gas carbon dioxide CO_2.

Iron oxide (s) + Carbon monoxide (g) → Iron (l) + Carbon dioxide (g)

The iron is now in elemental form. We say that it has been **reduced** because it has lost its oxygen to the carbon monoxide in the reaction. Since the blast furnace is very hot, the iron is formed in a molten liquid state, and can be poured out of the furnace to cool.

The iron ore found in the earth usually contains other materials as impurities, which are not useful. In order to remove these impurities from the iron, another reactive metal is introduced to the blast furnace. Calcium carbonate $CaCO_3$ is an insoluble, white substance that is available as a cheap, abundant material because it is found in **limestone** (see *MYP Sciences by Concept 1*, Chapter 6) and we can see from the reactivity series (Figure 2.16) that calcium is relatively reactive. When calcium carbonate is heated it breaks down, or **decomposes**, to form calcium oxide and more carbon dioxide gas.

Calcium carbonate (s) $\xrightarrow{\text{heat}}$ Calcium oxide (s) + Carbon dioxide (g)

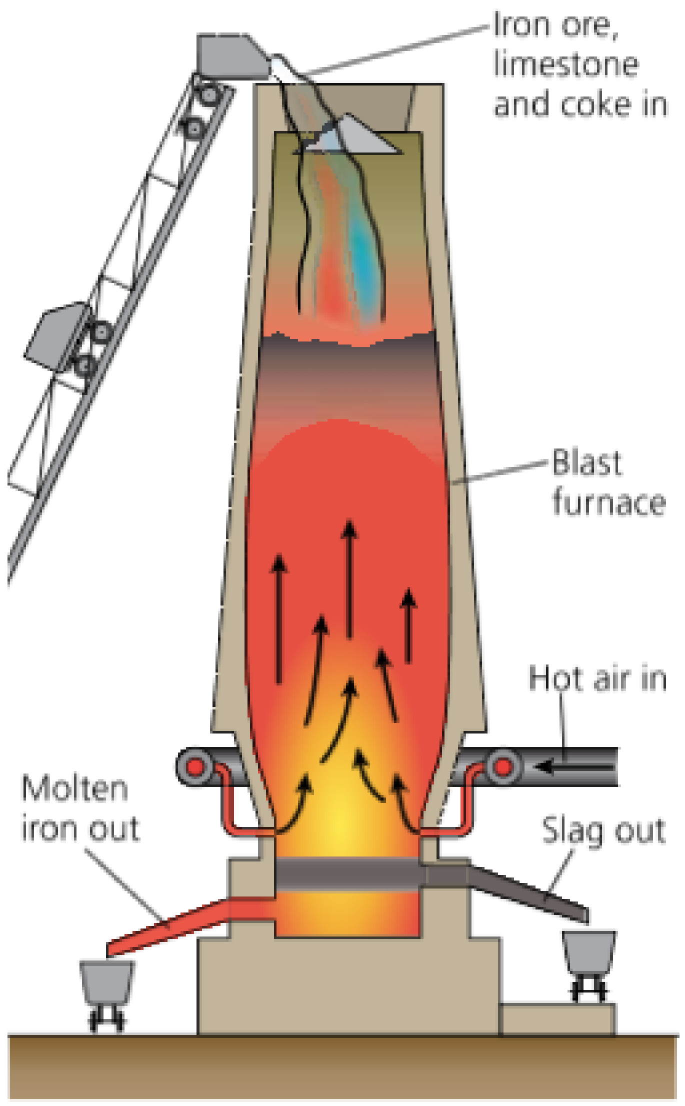


Figure 2.22 A blast furnace is used to extract iron from its ore

ACTIVITY: Decomposing limestone

ATL

- Critical-thinking skills: Interpret data

Inquiry question: How can we detect the products of heating limestone?

SAFETY: This experiment involves directly heating a boiling tube containing calcium carbonate. Handle equipment with care, using gloves and tongs at all times. Wear safety clothing, safety glasses and use heatproof mats.

In pairs, you will use a solution of calcium hydroxide $Ca(OH)_2$ to detect carbon dioxide CO_2 produced in the reaction. Calcium hydroxide solution is known as **limewater**. This will be prepared for you by your teacher.

Equipment:

- **2 boiling tubes**
- **Bung and delivery tube**
- **Stand and clamp**
- **Heatproof mat**
- **Tongs**
- **Spatula**
- **Bunsen burner**
- **Limestone powder (calcium carbonate $CaCO_3$)**
- **Limewater solution**

Method

1. **Place five spatulas of limestone powder into one of the boiling tubes. Seal the end of this tube carefully with the bung and delivery tube.**
2. **Position this tube in the clamp carefully. Position the Bunsen burner beneath the end of the tube, so that it can be gently heated.**
3. **Half fill a second boiling tube with limewater. Position this over the end of the delivery tube.**
4. **Now light the Bunsen burner so that the limestone is heated gently by a small blue flame.**
5. **Heat until the limestone has reacted. You should see bubbles of gas in the limewater.**

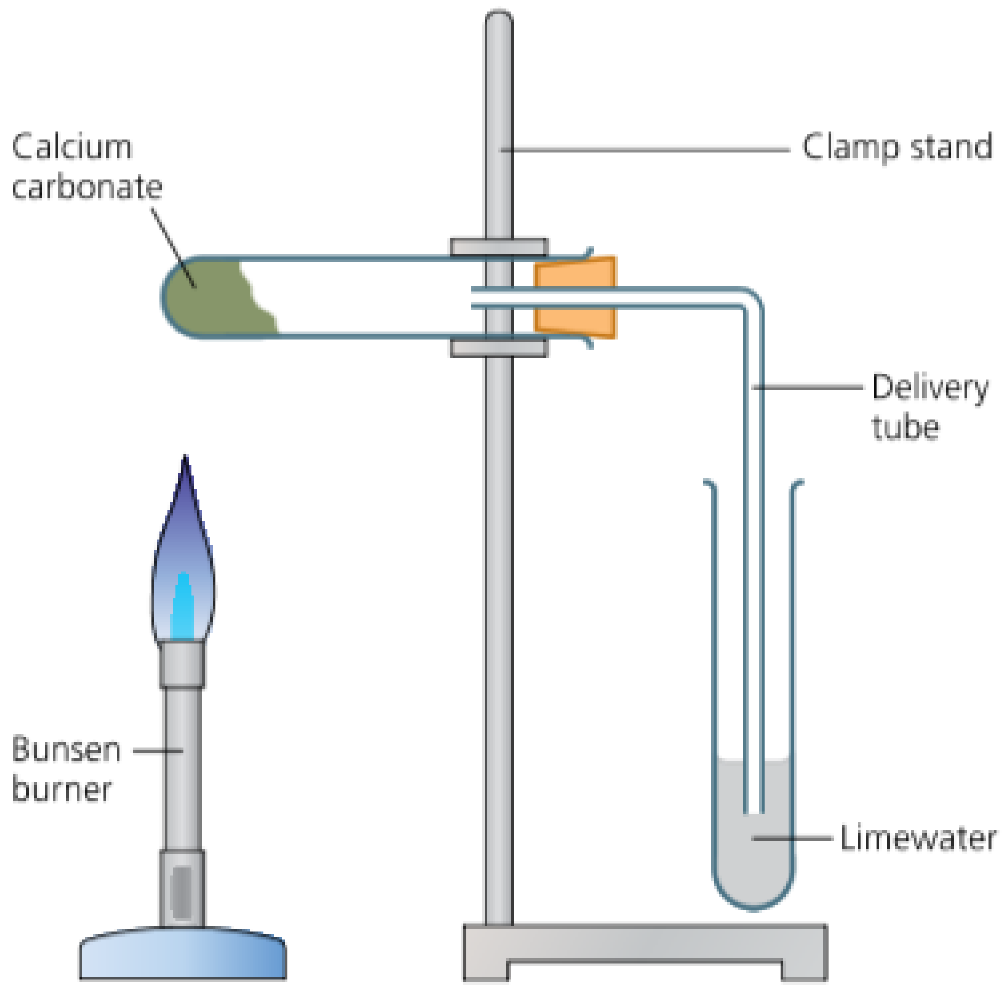


Figure 2.23 Apparatus for decomposing limestone

6. **Remove the boiling tube containing the limewater from the delivery tube *before* you stop heating the limestone. (This is to prevent the limewater being sucked back into the hot tube as the tube cools down.)**

Observe the changes in the reactant and in the limewater. **Record** your observations.

Interpret your observations. What changes have occurred?

Conclusion

When carbon dioxide enters the limewater this reaction takes place:

$$Ca(OH)_2(aq) + CO_2(g) \rightarrow CaCO_3(s) + H_2O(l)$$

Use what you have learned about the properties of calcium carbonate $CaCO_3$ to **interpret** this formula equation and so **explain** the change you observed in the limewater.

Assessment opportunities

- In this activity you have practised skills that are assessed using Criterion C: Processing and evaluating.

This is just one example of a way in which chemical reactions can be used to extract a metal from its ore. Another common way to do this – particularly for metals such as aluminium – is to pass electricity through a solution or through the molten ore. This process is known as electrolysis – you can find out more about electrolysis in *MYP Chemistry by Concept 4&5*, Chapter 8.

■ **Figure 2.24** (a) An ancient limestone structure (b) Tooth decay (c) Ingredients from a soft drink

ACIDS AND ALKALIS

The images in Figures 2.24a and 2.24b show effects of a class of chemicals called **acids**. Acids are compounds that produce hydrogen ions when put in solution. We saw earlier that hydrogen is a little unusual in the periodic table – although not found as a metal, it is placed in the periodic table with metals. When acids react with metals, the metals displace the hydrogen to produce a chemical salt. The limestone structure in Figure 2.24a has been corroded by the action of acid formed when carbon dioxide CO_2 is dissolved in rain, to form carbonic acid H_2CO_3. Similarly, tooth decay is caused in two ways by acids. Firstly, sugar in our food causes bacteria on our teeth to produce acid as a waste product, and this acid reacts with our teeth. Secondly, if we ingest drinks that themselves already contain acid, this acid acts directly on our teeth (Figure 2.24c).

Acids react in different ways with different substances, and their reactivity depends on their **dilution** in water and on their strength. Carbonic acid in rain is relatively weak because it does not easily produce hydrogen ions, which is why we don't need to worry about getting acid burns when it rains. On the other hand – as we will see at the end of this chapter – other chemical pollutants in the atmosphere and earth can cause stronger acids to be formed. All acids can be dangerous if not handled with care.

Three common acids found in school laboratories are:

- hydrochloric acid HCl
- sulphuric acid H_2SO_4
- nitric acid HNO_3.

EXTENSION

When acids are dissolved in water, the hydrogen separates from the other compound or element to form ions, which are very reactive. Ions are reactive because – unlike the balanced, neutral elements we looked at in the periodic table – they have an electrical charge, because the atoms that form them have gained or lost some electrons. Note that the hydrogen remains in the solution in this ionic form, not as hydrogen gas molecules H_2 – unless a reaction causes hydrogen gas to be produced.

Hydrochloric acid in solution forms hydrogen ions and chloride ions:

$$HCl\ (aq) \rightarrow H^+ + Cl^-$$

Sulphuric acid in solution forms hydrogen ions and hydrogen sulphate ions:

$$H_2SO_4\ (aq) \rightarrow H^+ + HSO_4^-$$

Nitric acid in solution forms hydrogen ions and nitrate ions:

$$HNO_3\ (aq) \rightarrow H^+ + NO_3^-$$

When other reactants are added to the acid solution, they may react with the ions.

In each of the acids, hydrogen is combined with another compound. Can you identify the elements that form these compounds?

In this section we will explore some of the reactions of acids.

Acids may sound like exotic chemicals, but in fact they are everywhere! Figure 2.26 shows some everyday acids in different foodstuffs. Anything that tastes spicy or sour is slightly acidic. (How acidic? We will explore this in the next section.) Our bodies contain strong acids – for example, hydrochloric acid is produced in our digestive tract.

Food acids are based on carbon. Citrus fruits contain citric acid $C_6H_8O_7$, while vinegar is dilute acetic acid CH_3COOH. Artificial sweeteners often contain a complex amino acid called aspartic acid $C_4H_7NO_4$.

ACTIVITY: Acidic spices

ATL

- Information literacy skills: Collect and analyse data to identify solutions and make informed decisions
- Critical-thinking skills: Interpret data; Evaluate evidence and arguments

Inquiry question: Which metal is best for cooking acidic foods?

SAFETY: In this experiment you will be using diluted hydrochloric acid. Like all acids, this must be handled with care. If you spill any acid, clean it up immediately with plenty of water. Wash your hands after doing the experiment. Wear safety glasses at all times and do not put your fingers in your eyes at any time. You will also be testing for an explosive gas. Do not touch hot splints with your hand, even after they have gone out. Make sure the end of the test tube you are using is pointing away from anyone else before lighting.

Acidic foods tend to react with the utensils used for cooking them – especially when heated. In this experiment you will investigate the way metals react with an acid.

In pairs, you will investigate the reaction of these metals with hydrochloric acid HCl:

Mg Zn Fe Sn Cu

State the names of the metals with these symbols.

Predict which of the metals you think will be most reactive with an acid. **Explain** your prediction.

We can write a general word equation for the reaction like this:

$$\text{metal} + \text{hydrochloric acid} \rightarrow \text{metal} + \text{hydrogen chloride}$$

With reference to the word equation, **predict** the products of each of the metals used.

Equipment:

- **5 test tubes**
- **5 small test tube bungs**
- **Test-tube rack**
- **Wooden splint**
- **Matches**
- **Dropper pipette**
- **Small pieces of metals**

Method

1. **Put the five test tubes in the rack.**
2. **With the dropper pipette, add acid to each tube until it is about half full.**
3. **Drop a piece of each of the five metals into the five different tubes.**

Observe what happens in the tubes. **Record** your observations.

Now test the gas you can see being produced in some of the tubes. Do this by taking one of the bungs and placing it in the top of the tube for a few seconds. Take a wooden splint and light it with a match. Carefully remove the bung and then hold the lit splint over the top of the tube.

Interpret your observations. **State** the properties of the gas produced and **suggest** what gas this is.

Conclusion

State a formula equation for the reaction with each of the metals if you can.

State whether your prediction was correct. **Explain** any differences between your prediction and your observations.

With reference to your observations, **justify** the position of hydrogen in the reactivity series. **Explain** your reasoning.

Suggest which metal might be best for pans used to cook acidic foods. **Explain** your answer.

Evaluation

Suggest what you might have done to make your experimental model more realistic. What other tests could you carry out on these reactions? What other variables could you change in the experiment? What additional reactions could you try?

The metal chloride is an example of a chemical salt. **Suggest** what other metal salts might be produced with the different acids mentioned earlier.

Assessment opportunities

- This activity can be assessed using Criterion C: Processing and evaluating.

ACTIVITY: Dissolving buildings

ATL

- Information literacy skills: Collect, record and verify data
- Critical-thinking skills: Interpret data

Inquiry question: How does acid cause buildings to corrode?

SAFETY: In this experiment you will use dilute sulphuric acid. Like all acids, this must be handled with care. If you spill any acid, clean immediately with plenty of water. Wash your hands after doing the experiment. Wear safety glasses at all times and do not put your fingers in your eyes at any time.

In Figure 2.24 we can see how acid has caused the limestone structure to dissolve and corrode. We know that limestone is formed from calcium carbonate $CaCO_3$. How does acid react with a metal carbonate?

While carbonic acid in the rain can cause corrosion, another form of pollution occurs when sulphur compounds in the atmosphere dissolve in rain to form sulphuric acid H_2SO_4. The sulphur compounds are commonly produced from combustion of coal containing sulphur. Could acid rain of this kind corrode other materials, too?

In pairs, you will investigate the reaction of sulphuric acid H_2SO_4 with copper carbonate $CuCO_3$.

Describe the reactants. **Identify** the ions present in our two reactants. **Predict** what may be formed in the reaction.

Equipment:

- **Flask**
- **Bung with delivery tube**
- **Boiling tube**
- **Spatula**
- **Limewater**
- **Dilute sulphuric acid**
- **Copper carbonate powder**

Method

1. **Pour limewater into the boiling tube until it is about half full.**
2. **Pour approximately 100 ml of dilute sulphuric acid into the bottom of the flask.**
3. **Add two or three spatulas of copper carbonate to the flask. Gently agitate (shake) the flask to mix the reactants.**
4. **Put the bung in the top of the flask.**
5. **Position the delivery tube in the boiling tube with the limewater so that any gas produced bubbles into the limewater.**

Observe what happens in the flask and in the boiling tube. **Record** your observations.

Interpret your observations. **State** the properties of the gas produced and **suggest** what gas this is.

Conclusion

State a word equation or formula equation for the reaction. Where is the gas coming from?

State whether your **prediction** was correct. **Explain** any differences between your prediction and your observations.

Evaluation

Suggest what other tests you could carry out on these reactants. What other variables could you change in the experiment? What additional reactions could you try?

Assessment opportunities

- This activity can be assessed using Criterion C: Processing and evaluating.

DETECTING IT

In the experiments earlier in this chapter, you used limewater to detect the presence of carbon dioxide gas, because limewater produces a visible change when carbon dioxide is bubbled through it. Limewater is a kind of **indicator** – a chemical that can be used to detect another chemical property. Similarly, we can use some chemical substances to act as indicators for the acidity of a solution. Many plants contain complex **dye** compounds that change colour when an acid is present.

ACTIVITY: Plant detectives

ATL

- Critical-thinking skills: Gather and organize information to formulate an argument; interpret data

Inquiry question: How can plants be used to detect acidity?

SAFETY: In this experiment you will be cutting plants into fine pieces with a scalpel. Take care not to cut your fingers and always cut onto a cutting tile or mat. You may also use methylated spirits (ethanol) as a solvent. Take care not to inhale fumes from the ethanol. Ethanol is highly flammable – keep away from any naked flame.

In pairs, research plant indicators, with the search term **using plants to make indicator**. You may wish to try some of these:

red cabbage   blackberries   beets   blueberries
cumin powder   horse chestnut leaves

Note that horse chestnut leaves produce a very special kind of dye that requires an ultra-violet ('black') light to observe it. Ask your teacher about this.

Your teacher may provide you with a range of possible chemicals to test with your plant indicator.

Select the chemicals to test with your plant indicator. **Explain** why you selected these chemicals.

Predict what changes you expect to see for your dye with each of the different chemicals.

Equipment:

- **Mortar and pestle**
- **Scalpel**
- **Cutting tile**
- **Methylated spirit or warm water as solvent**
- **Dropper pipette**

Method

To carry out your investigation, you will need to extract the dye from the plant so that it can be added to a solution (Figure 2.25).

When you have prepared your indicator dye, **describe** how you will use it to test the substances you selected.

Observe any changes and **record** your observations.

As a class, compare different dyes. Did they give the same results for each substance?

Assessment opportunities

- In this activity you have practised skills that are assessed using Criterion B: Inquiring and designing.

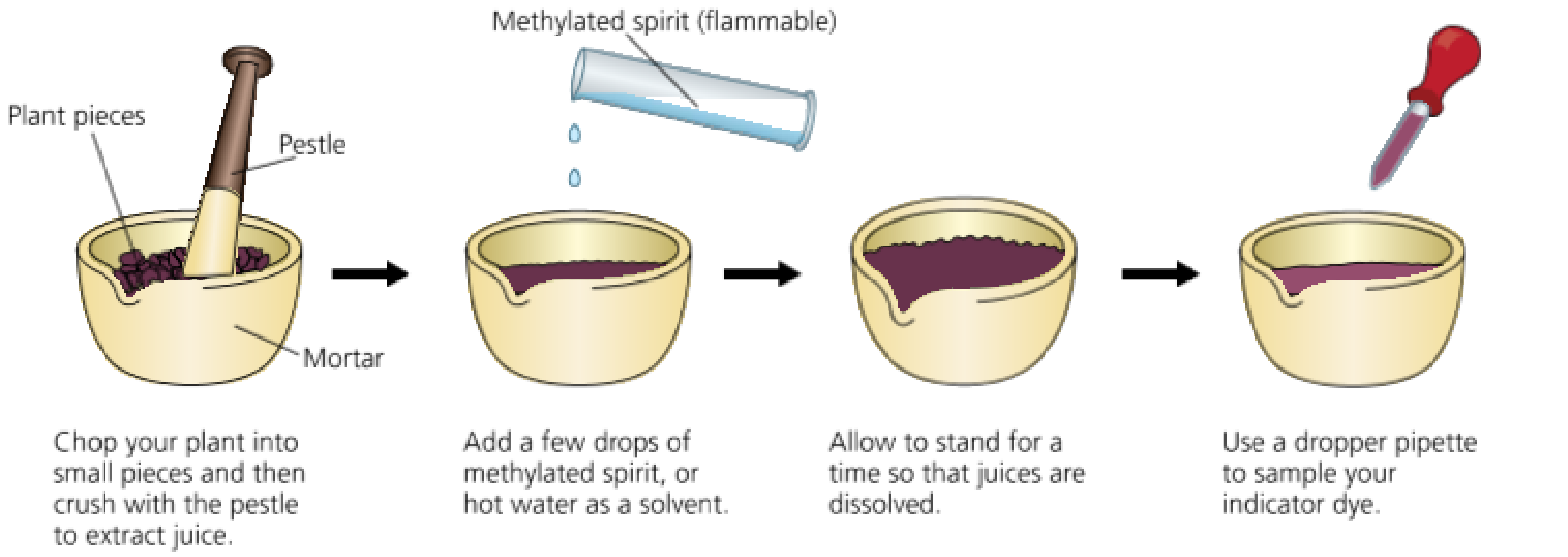


Figure 2.25 Extracting dye from plants

Different plant dyes react in different ways to the same acids, and do not react to all acidities in the same way. For this reason, chemists have created a blend of indicators that provides a standard colour change for certain acidities, called **universal indicator**.

We saw earlier how acids react because in solution they release hydrogen ions, and the acidity of a solution is measured using the relative proportion of hydrogen ions available. This scale is called the pH scale.

	pH	Examples
acidic	0	Battery acid
	1	Sulphuric acid
	2	Lemon juice, vinegar
	3	Orange juice, soda
	4	Acid rain
	5	Bananas
	6	Clean rain, milk
neutral	7	Pure water
	8	Sea water, eggs
	9	Baking soda
	10	Milk of magnesia
	11	Ammonia
	12	Soapy water
	13	Bleach
basic	14	Liquid drain cleaner

■ **Figure 2.26** The pH scale and universal indicator colour changes

We can use the pH scale to compare acidities. Earlier we discussed the acids that are present in the human body. In fact, the hydrochloric acid made in our digestive system has a pH around 2, so it is very acidic indeed. The pH in our stomach is between 4 and 6. However, blood has a pH of 7.4. Notice that distilled (pure) water is in the middle of the scale with a pH of 7.0. This is said to be **neutral**. Anything with a pH greater than water (above 7.0) is not acidic, but is said to be **alkali**. Alkalis are like 'chemical opposites' of acids. Instead of producing (positively charged) hydrogen ions H^+ in solution, they release (negatively charged) hydroxide ions OH^-.

When acids and alkalis react together, the hydrogen ions produced by the acid combine with the hydroxide ions to produce water. If the number of hydrogen and hydroxide ions available is equal, then the final product of the reaction will be neutral.

Acid + Alkali → Salt + Water

EXTENSION

Research to find out more:

- Search **plant indicators** to find out how plants can be used as indicators for environmental changes.
- Find out how **hydrangeas** can be used to indicate soil acidity.
- Find out how **fertilizers** can be used in agriculture to control soil conditions.

■ **Figure 2.27** Universal indicator in acid, alkali and water

Example:

Nitric acid (aq) + Sodium hydroxide (aq) → Sodium nitrate (aq) + Water (l)

HNO_3 (aq) + NaOH (aq) → $NaNO_3$ (aq) + H_2O (l)

ACTIVITY: Neutralize it!

ATL

- Transfer skills: Apply skills and knowledge in unfamiliar situations

State word equations or formula equations for reactions of these reactants:

- **hydrochloric acid and sodium hydroxide**
- **sulphuric acid and calcium hydroxide.**

The dilution of an acid or alkali is measured using its concentration in solution. If the quantities and concentrations of the acids and alkalis in these reactions is equal, the reaction will complete and the products will be neutral.

State the pH of a complete reaction between acids and alkalis.

The concentration of acid is now doubled. **Describe** what will happen in the reaction and **suggest** the pH of the reaction products.

If we now double the concentration of alkali and repeat with the same quantities, **describe** what will happen in the reaction and **state** the pH of the reaction products.

Assessment opportunities

- This activity can be assessed using Criterion A: Knowing and understanding.

ACTIVITY: Stomach ache

ATL

- Critical-thinking skills: Gather and organize relevant information to formulate an argument; Interpret data

Some foods cause our digestive system to produce excess acid, and this can lead to discomfort as indigestion. One way to control this is to use an alkali to neutralize the excess stomach acid produced.

Work in pairs.

You are food scientists working for a public health agency whose job is to test the effectiveness of different indigestion products being sold.

Your teacher will present you with a range of chemical substances that might be used as indigestion remedies.

Describe the problem you are going to investigate and write an inquiry question for your investigation.

Predict what you expect to see happening for the experiment. **Explain** your prediction using word or formula equations.

Design an investigation that allows you to test the products. **Describe** the measurements you will make and the quantities of substance that you will use. (Use the scientific experiment cycle to help you structure your investigation design – see Figure 4.26.)

Before you begin, make sure that your teacher checks your investigation design.

Carry out your investigation. **Record** your observations, **organize** and **present** them in a clear form. **Present** your findings in a way that allows the results for different substances to be compared.

Interpret your observations and **explain** them in your own words. **State** whether or not your prediction was correct.

Evaluate your investigation. Did you answer the inquiry question you wrote? How could you have improved your investigation? What additional measurements could you have made?

Assessment opportunities

- This activity can be assessed using Criterion B: Inquiring and designing and Criterion C: Processing and evaluating.

The Dark Side of Moore's Law

Scientific and technical innovation has led to rapid improvements in the technology we have at our disposal. In the 1970s, a computer scientist called Gordon E. Moore (1929–) suggested that the computing power of microprocessors would double every two years – this is sometimes known as Moore's Law. Just think about the way mobile phones (cell phones) have developed within your own lifetime. How many phones have you owned?

While this rapid technological change is exciting, and arguably is in the process of revolutionizing our lives, there is a dark side. Have you ever considered what happens to all those out-of-date, obsolete devices?

The construction of any digital device – a computer, laptop, tablet computer or mobile phone – utilizes a variety of plastics and metals. Gold is used for circuit interconnects, copper for connection tracks on the printed circuit boards (PCBs), and tin for the solder that joins the components together. Rapid technological change brings with it rapid obsolescence, and so rapid growth in waste. These metals are expensive to extract from the Earth, and sometimes – as in the case of gold – very rare.

Take copper, for example. Forty-one per cent of the copper used in manufacturing in Europe is now obtained from recycling waste material. If copper waste is relatively bulky, it can be recycled mechanically – by simply separating it out from the rest of the waste and melting down. The copper obtained is just as pure and of equivalent quality to copper obtained from ore. Recycling copper from PCBs, however, is more complex, since the copper tracks are very thin and embedded in the plastic substrate of the PCB.

One way to extract copper from discarded PCBs is through the process of 'leaching' with acids. Sulphuric acid, hydrochloric acid and nitric acid can all be used in concentrated form to dissolve copper away from the PCB and then precipitate copper in the form of copper salts. The salts can then be reduced to extract the metal.

■ **Figure 2.28** Printed circuit boards (PCBs) contain many valuable metals, including gold and copper

As copper collection for recycling becomes more widespread, the costs of this recycling process become viable. While demand for copper remains high, the price obtained for the copper produced makes this an economically attractive investment. And it seems likely that the technological change that has created the problem of waste metal in the first place will continue to keep the demand for copper high.

■ **Figure 2.29** Computer waste in a plant, Wuhan, China

! Take action! E-cycling

ATL

- Information literacy skills: Access information to be informed and inform others
- Critical-thinking skills: Gather and organize relevant information to formulate an argument
- Creative-thinking skills: Create novel solutions to authentic problems
- Transfer skills: Apply skills and knowledge in unfamiliar situations

! **Analyse** the text and make notes on these guiding questions:

- What positive and negative consequences of rapid technological change are described in the article?
- What solutions are suggested to the negative consequences?

! Write a letter to the magazine giving your own point of view. In your letter:

! **Outline** how acid leaching can be used to extract copper from PCBs. **Describe** how the copper metal can then be obtained from the products of acid leaching. **Describe** what positive opportunities this kind of recycling might offer. **Describe** what negative problems this kind of recycling might present. **Consider** – what environmental issues might there be? What economic factors might be involved? **Suggest** how these negative problems could be solved. **Summarize** your views in a **conclusion**.

Assessment opportunities

- This activity can be assessed using Criterion D: Reflecting on the impacts of science.

Reflection

In this chapter we have **classified** materials as elements, compounds and molecules. We have **outlined** different models for the atom, and **described** how the patterns in properties of different elements can be used to **organize** the elements in the periodic table. We have **described** chemical changes in the form of equations that conserve mass. We have extended this understanding to **determine** the chemical formulae of reactants and products. We have **distinguished** metals and non-metals in terms of their properties, and **identified** patterns in reactivity for elemental metals, carbon and hydrogen. We have **outlined** some important kinds of chemical reaction such as combustion, thermal decomposition, oxidation (and reduction), displacement, and neutralization of acids and alkalis. We have **described** how chemical processes can be used to extract a metal from its ore. We have **described** the properties of acids and alkalis in terms of the ions they produce in solution, and **outlined** how acidity and alkalinity can be measured using the pH scale.

Use this table to evaluate and reflect on your own learning in this chapter.					
Questions we asked	Answers we found	Any further questions now?			
Factual: What substances are pure, what substances are impure? How do pure substances combine? What's in an atom?					
Conceptual: How can patterns of properties be used to organize elements? What kinds of chemical reaction can take place? How can we represent chemical change? How do we exploit properties of chemicals?					
Debatable: To what extent can science be used to fix the problems science creates?					
Approaches to learning you used in this chapter:	Description – what new skills did you learn?	How well did you master the skills?			
		Novice	Learner	Practitioner	Expert
Information literacy skills					
Critical-thinking skills					
Creative-thinking skills					
Transfer skills					
Learner profile attribute	Reflect on the importance of being knowledgeable for your learning in this chapter.				
Knowledgeable					

3 Who are we?

Because scientists understand the **relationships** between genes and inherited characteristics, we can use genetic **patterns** as **evidence** for **identification and decision-making**.

CONSIDER THESE QUESTIONS:

Factual: What is DNA? What are genes? What is the relationship between DNA, genes, and inherited characteristics? How do we grow and develop?

Conceptual: How are genetic patterns identified and used? How can individuals be identified through inherited characteristics and genetic patterns?

Debatable: To what extent should legal cases depend on identifying people through DNA?

Now **share and compare** your thoughts and ideas with your partner, or with the whole class.

Figure 3.1 What makes you, you?

IN THIS CHAPTER, WE WILL …

- **Find out** about the function and inheritance of genes.
- **Explore** how individuals get their unique and common traits.
- **Take action** by using an understanding of genetics to write scientifically supported judgments about using DNA in legal matters.

So, I guess we are who we are for a lot of reasons. And maybe we'll never know most of them. But even if we don't have the power to choose where we come from, we can still choose where we go from there. We can still do things. And we can try to feel okay about them.

The Perks of Being a Wallflower, *Stephen Chbosky*

■ **Figure 3.2** Where do our physical characteristics come from?

These Approaches to Learning (ATL) skills will be useful …

- Reflection skills
- Information literacy skills
- Critical-thinking skills
- Creative-thinking skills

We will reflect on this learner profile attribute …

- Principled

Assessment opportunities in this chapter …

- **Criterion A:** Knowing and understanding
- **Criterion D:** Reflecting on the impacts of science

KEY WORDS

characteristic	inherit
heredity	trait

THINK-PAIR-SHARE

Read the quote by Stephen Chbosky. The quote brings up some points to consider about our individual identities. Think about the following questions:

- **What makes you, you?**
- **Is it the way you look, or feel, or think?**
- **Do we 'create' ourselves, or are we the products of those around us?**
- **Can we change our identity, or are we always the same person?**

With a partner, **reflect** on different aspects of 'self' and then **share** your reflections with your classmates.

In this chapter, you will take on the role of a forensic DNA analyst. You will analyse evidence collected at a crime scene and make decisions to identify the person who committed the crime. You will also write or record an 'op-ed' for a news broadcast or newspaper, to share, supporting your opinion about using DNA evidence to make legal decisions.

What is DNA?

I AM WHO I AM

As you may have seen in the news or from watching crime shows or movies, police often use DNA to identify suspects involved in a crime. But why is this? What actually is DNA? Why is DNA so valuable for isolating a person's identity? And how reliable is DNA analysis – should we really be using it to make legal judgments about a person?

In this chapter, we will explore these ideas and more. To begin, it is important to understand the origin of our physical characteristics and how the body functions. If someone asked you to describe yourself, you might refer to the colour of your eyes, hair and skin; whether your hair is straight or curly; whether you are tall or short or somewhere in between; or whether or not you are good at sports. But what if the person, instead of asking how you look or what you are good at, asked *why* do you look the way you do and *why* do you have certain skills or interests?

You might now answer something like, 'Because my dad has the same colour eyes, and my mum also has brown hair like mine. And my mum is a good runner, like me.'

But, once again – *why*? Why do we have a combination of the characteristics of our parents (and other relatives)? At this point, maybe you and your classmates are saying, 'It's because of our **genes**. We get our genes from our parents, who get them from their parents.'

So, in order to answer all of these questions about why we are the way we are, we must first understand what genes are, and why they give us our characteristics.

ACTIVITY: Face it

ATL

- Creative-thinking skills: Use brainstorming and visual diagrams to generate new ideas and inquiries

For this activity, you will determine some physical characteristics of a 'child'. The characteristics that you give the 'child' will be according to specific instructions that you receive during the activity, and will depend on the combination of letters you select at random for the eye colour, hair type, hair colour and the presence or absence of freckles.

Before you begin, you must prepare the materials.

1. **On a blank piece of paper, sketch the outline of a person's face.**
2. **Get another blank piece of paper and cut it into quarters.**
3. **On one of the quarters, write the letter A. On another, write B. On the third, write C, and on the fourth, write D.**
4. **Fold each quarter over so the letter cannot be seen.**
5. **Put the quarters in a bowl, cup, or bag.**

Once you have the materials prepared, you are ready to create the face of the next 'child' that will be born in a family.

	Possible characteristics			
	Round 1:	Round 2:	Round 3:	Round 4:
'Genes'	Eye colour	Hair type	Hair colour	Freckles
AB	Brown	Straight	Brown	With freckles
AC	Brown	Curly	Brown	No freckles
AD	Brown	Straight	Brown	No freckles
BC	Blue	Curly	Blond	With freckles
BD	Blue	Curly	Blond	With freckles
CD	Green	Wavy	Red	No freckles

■ **Table 3.1** Possible characteristics for creating the 'child'

Round 1 – Pick the genes for eye colour

- **Pick two pieces of paper from the container. Open them to see which letters you have chosen at random.**
- **Match the letters of the 'genes' to the eye colour listed in the 'Round 1' column of Table 3.1.**
- **On the face outline, draw and colour eyes according to the colour indicated by the genes you chose. For example, if you picked one piece of paper with 'A' and one with 'D', you would draw brown eyes on the face outline.**
- **Fold the papers again and return them to the container.**

Round 2 – Pick the genes for hair type

Repeat the steps for round 1, but now match the letters of the chosen 'genes' to the corresponding hair type in the 'Round 2' column.

Round 3 – Pick the genes for hair colour

Repeat the steps from round 1, but now match the letters of the chosen 'genes' to the corresponding hair colour in the 'Round 3' column.

Round 4 – Pick the genes for freckles or no freckles

Finally, repeat the steps from round 1, but now match the letters of the chosen 'genes' to whether or not there will be freckles, in the 'Round 4' column.

Compare the face you have created with those of your classmates. What do you notice?

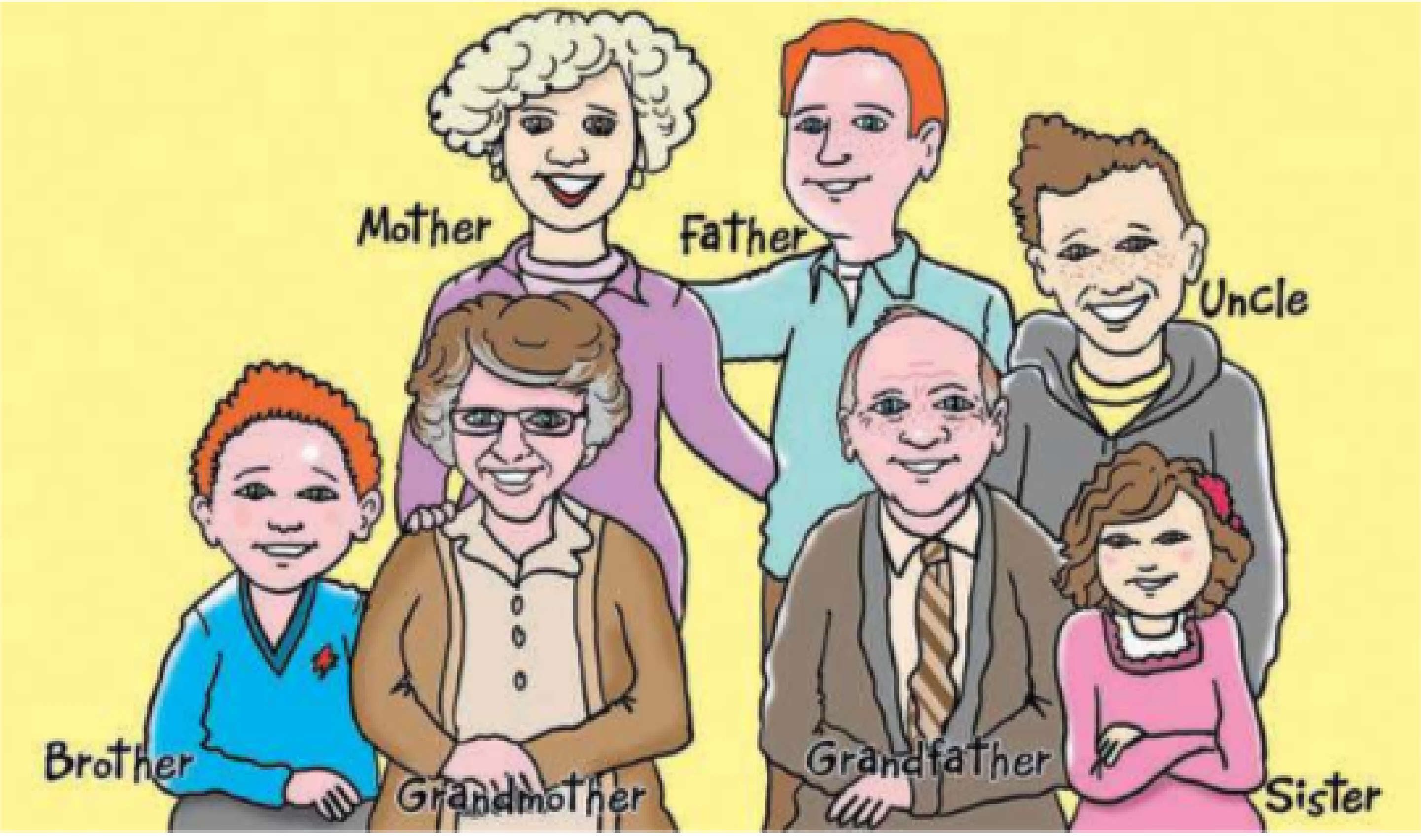
Now, look at the faces of the relatives of the 'child' you have just created (Figure 3.3). Compare the characteristics of the relatives with the characteristics of the 'child' you created as well as the possible characteristics from Table 3.1. What do you notice?

With your partner, **discuss** your thoughts on the following questions:

- **What were the 'genes' made up of?**
- **What was the purpose of the 'genes' in this activity?**
- **What are some other things you noticed about the genes and characteristics?**
- **What are some things that you wonder about genes now that you have done this activity?**

◆ Assessment opportunities

- ◆ In this activity, you have practised skills that are assessed using Criterion A: Knowing and understanding.



■ **Figure 3.3** Genes and characteristics of the relatives of the 'child'.

ACTIVITY: Genes and characteristics

ATL

- Critical-thinking skills: Gather and organize relevant information; Analyse complex concepts and synthesize them to create new understanding

Copy and complete Table 3.2. Fill in the first two columns using information from the *Face it* activity, your class discussions, and the information in the previous paragraph. As you continue with the chapter, you will complete the third column with scientific information that you read and learn about. An example for the first two columns has been done for you.

Basic information about genes and characteristics	Example from the *Face it* activity	Scientific information and example
Genes are made up of smaller components.	Each gene was made up of two letters from A, B, C or D.	

Table 3.2 Summary of basic information about genes and characteristics

Assessment opportunities

- In this activity, you have practised skills that are assessed using Criterion A: Knowing and understanding, and Criterion C Processing and evaluating.

From the *Face it* activity, you could see that genes are made up of smaller components, represented in this activity by the letters A, B, C, and D; and that genes function to provide 'instructions' for the characteristics – such as whether to draw in blue, brown, or green eyes, or whether the hair is curly, wavy, or straight. You could also see by comparing the relatives in Figure 3.3 with the child you created that characteristics and genes are shared within a family.

Some combinations of letters in the genes result in the same characteristics, while other combinations of letters result in different characteristics. For example, in the *Face it* activity both AB and BC result in freckles, while AC results in no freckles. Some characteristics are more common or more likely than others. For example, in the activity, brown hair results from three possible combinations of letters, so it is more likely and common than red hair. Furthermore, from the activity you probably noticed that the genes and the resulting characteristics of your 'child' were determined in a random way from the genetic options that were available. In other words, because you were selecting the pieces of paper without knowing which paper was which, the genes that the 'child' ended up with were down to chance. However, the 'child' did not end up with some characteristics – like black coloured hair – because they were not part of the available **gene pool**.

Now that we have identified some basic information about genes and characteristics, we will get deeper into the scientific information and explanations for these patterns.

Genes are made of DNA. Inside the nucleus of each cell, long strands of DNA are wound around each other, in a structure known as a **double helix**. The two DNA strands of each double helix twist tightly around each other to form a **chromosome**.

Each strand of DNA is made up of molecules called nucleotides, which are strung together like 'beads' in a DNA 'necklace'. Each nucleotide is itself composed of smaller molecules, including a sugar that has five carbon atoms, phosphate, and a **nitrogenous base**. There are four different kinds of bases in DNA. Just as we used letters to represent the components of the genes in the *Face it* activity, the bases are often referred to by the first letter of their chemical names – A for adenine, T for thymine, C for cytosine and G for guanine.

A gene is a sequence of nucleotides – some genes consist of a 'short' sequence of a few hundred nucleotides, while others are long sequences of thousands and thousands. Just as we saw in the *Face it* activity, different genes give instructions – or code – for different characteristics.

Genes give us our characteristics because they give the instructions for creating substances called proteins inside our cells. Proteins are very important for all cells, because they are like the 'workers' for the cell and organism. Every characteristic that we have – from the colour of our hair and eyes to whether or not we like certain foods – and every function of our cells and bodies is a result of the presence (or absence) and 'work' of proteins. And, because every protein that 'works' inside our cells is created from the instructions of a specific gene, we can say that our genes are responsible for our characteristics.

Because each gene is a different set of instructions, each gene results in the production of a different protein, and each protein does a different job in the cell. For example, some genes give the instructions for producing a protein called melanin, which is a dark-coloured **pigment** that gives eyes, hair, and skin a dark colour or tone.

DISCUSS

One way to think of genes and proteins is to compare them to the director and actors of a movie.

Discuss with a partner how the director and actors in a movie are like genes and proteins in a living organism.

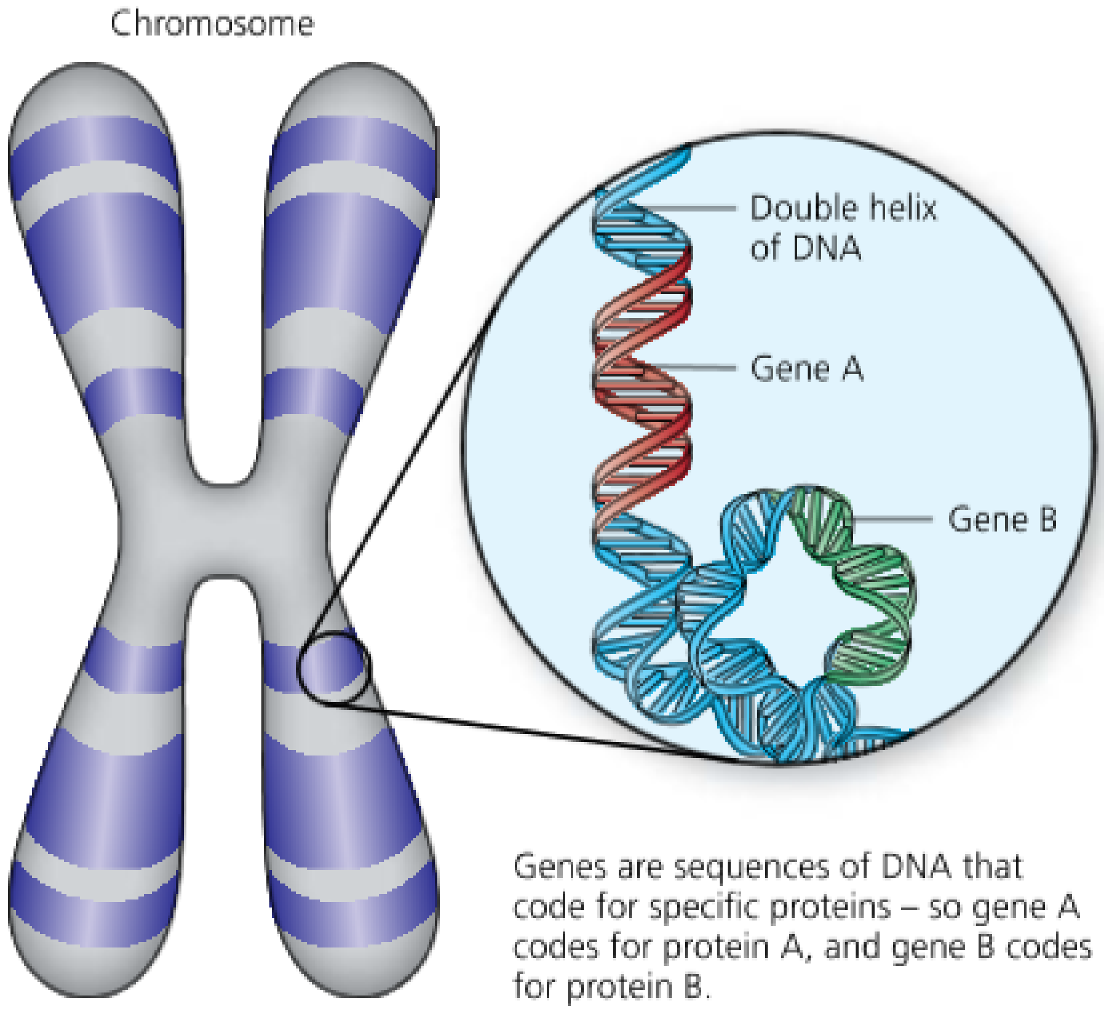


Figure 3.4 A gene is a sequence of nucleotides in the DNA of a chromosome, which instructs the cell to make a particular protein

Figure 3.5 People's hair, eyes, and skin colour are related to whether or not their genes give the instructions to produce a protein called melanin

What is the relationship between DNA, genes, and inherited characteristics?

DISCUSS

With a partner, or as a class, **discuss** the following questions:

- **What colour eyes would a person have if they have genes that give the instructions to produce a lot of melanin in eye cells?**
- **What about a person who has genes that do not give the instructions to produce melanin in eye cells?**
- **What would the skin look like of a person who has genes that give the instructions to produce a small amount of melanin in skin cells?**
- **How about a person whose genes give the instructions to produce a medium or large amount of melanin in the cells?**

Other genes give the instructions for proteins called **enzymes**. Enzymes are proteins that speed up chemical reactions in cells, so that the organism can break down or create the molecules that are necessary for survival. Some genes give the instructions *not* to produce certain enzymes, which could cause health problems for that person.

Now that we have information about what genes are and how and why they give us our characteristics, we need to understand how our genes and therefore our characteristics are inherited.

As you read, DNA (and therefore our genes) is packaged in structures called chromosomes inside the nucleus of each cell. Different species have different numbers of chromosomes in their cells – humans have two sets of 23 chromosomes, for a total of 46 chromosomes, in all cells (except for one special cell type that you will read about shortly). Each chromosome in a set contains different DNA (and therefore different genes), and together the different chromosomes contain the 'instructions' for all the different characteristics in our cells and body.

CONNECT-EXTEND-CHALLENGE

With a partner or as a class, **discuss** the following:

- **Connect: What connections can you make between what you have just read and what you already knew, either from an earlier section in the chapter or from something you learned in another class or outside school?**

Hint

This might be a good time to add to your copy of Table 3.2.

- **Extend: What extensions or new ideas did you get from what you have read? How did these new ideas push your understanding in a new direction?**
- **Challenge: What is challenging for you to understand about this topic? What questions do you have or what puzzles you? What would you like to know more about?**

In your journal or on a class chart, record the connections, extensions, and challenges that come from this information – add to your personal or class chart as you continue with the chapter.

Twenty-two of the 23 human chromosomes are numbered from 1 to 22. Then, instead of having a number, the 23rd chromosome is either an X chromosome or a Y chromosome (Figure 3.6). The X and Y chromosomes are known as the sex chromosomes because they contain the genes that give the instructions for the biological characteristics associated with females and males. A person who has two copies of the X chromosome in each cell has the biological characteristics associated with females; a person who has one copy of an X chromosome and one copy of a Y chromosome in each cell has the biological characteristics associated with males.

Sometimes, the genes on one or more chromosomes may be irregular, or **mutated**, and give instructions that result in diseases. For example, Type 1 diabetes results from mutations in genes that are on chromosomes 11 and 7, and Alzheimer's disease is most strongly associated with mutations, or accidental errors, in genes on chromosomes 14 and 1. Because these diseases are associated with genes, they are known as **inheritable diseases**.

All of the human chromosomes and genes – known as the human genome – have been mapped. This human genome map was the result of a large-scale effort of scientists from around the world, working together for 10 years to identify the genes found on each human chromosome. As a result of mapping of the human genome, during what is known as the Human Genome Project (HGP), we now know there are approximately 20 500 human genes. As technology improves and research continues, scientists and doctors are learning more and more about human chromosomes, genes, and the characteristics that are associated with each of those genes.

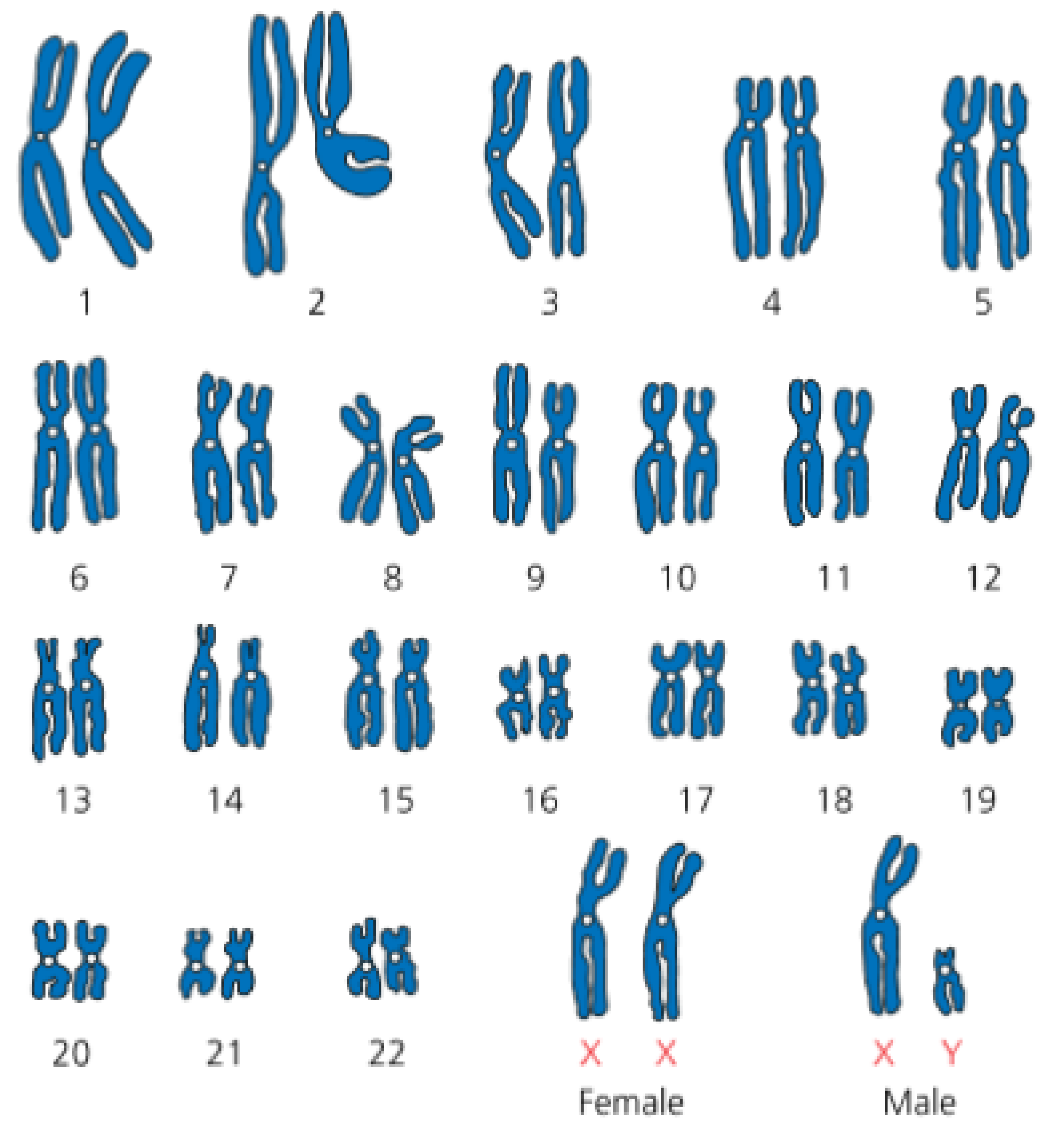


Figure 3.6 A karyotype contains pictures of a person's chromosomes. We can see that humans have 23 different pairs of chromosomes, for a total of 46

Figure 3.7 The human genome is the sequence of all of the nucleotides that make up all of the genes in all of our chromosomes. What are all the letters in this photo?

ACTIVITY: Knowledge is power

ATL

- Reflection skills: Consider ethical, cultural and environmental implications

Knowing the location of each gene in the human genome has the potential to give scientists and doctors a great amount of power in identifying and even modifying the genes and possible characteristics of a person.

With your partner or as class, **create** a chart of the 'pros' and 'cons' associated with the knowledge of, and ability to modify, the genes that make up the human genome. Under what circumstances might the ability to identify and modify a person's genes be a good thing? Under what circumstances might this cause problems?

You might want to think about the following factors:

- **cultural**
- **economical**
- **environmental**
- **ethical**
- **moral**
- **political**
- **social**

Assessment opportunities

- In this activity, you have practised skills that are assessed using Criterion D: Reflecting on the impacts of science.

EXTENSION

What genes does each of the human chromosomes contain? And what diseases are associated with the genes on the different chromosomes?

The National Center for Biotechnology Information (or NCBI) in the United States of America has created an online resource for learning more about human chromosomes and human genetics.

Try searching for NCBI chromosome map viewer to find a 'map' of each of the 23 different human chromosomes. When you get to the page, **discuss** the following with your classmates:

- What do you notice about the genes?
- In what ways are they similar? In what ways are they different?
- Which contains the largest number of genes? Which contains the smallest number of genes?
- What are some other inheritable diseases that you recognize?

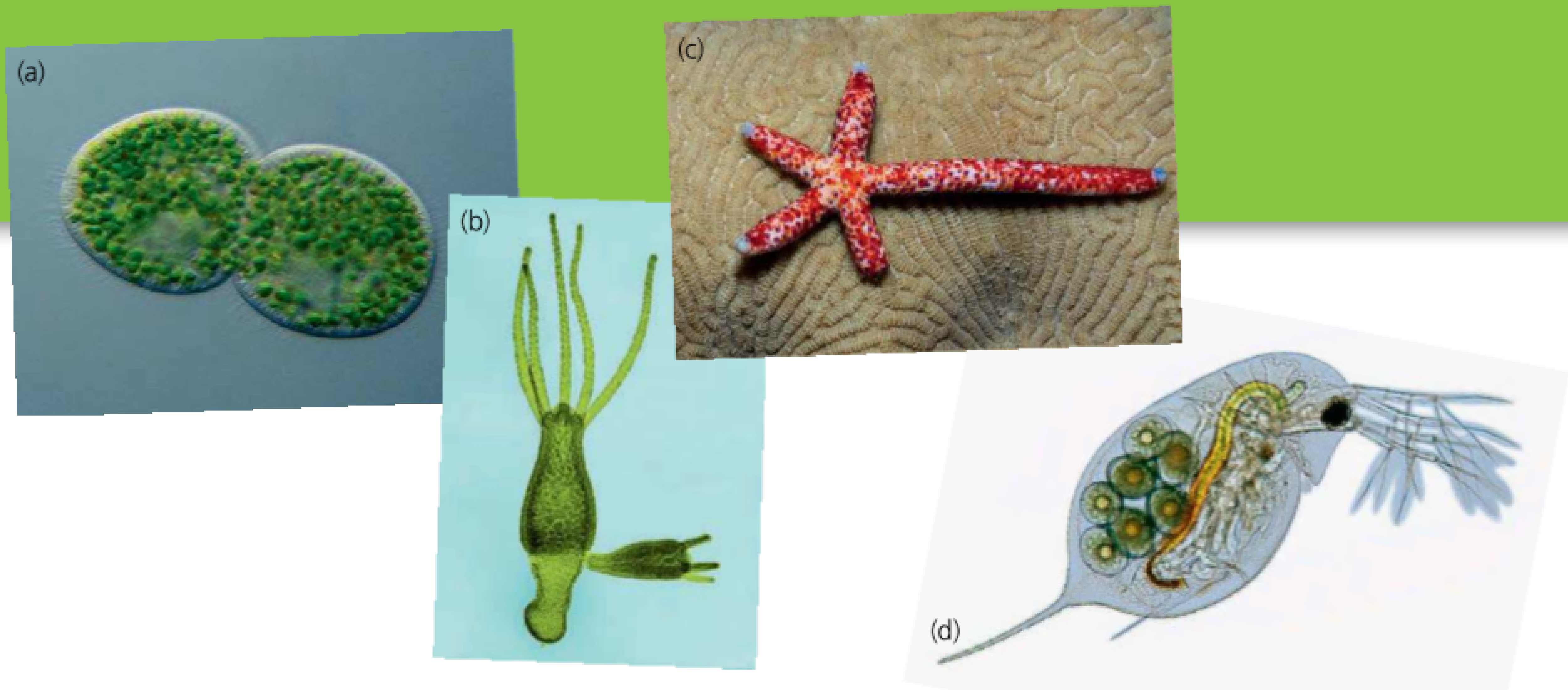
You might want to explore further by doing some research on one or more of the inheritable diseases – start by clicking on the name of the disease in the chromosome map.

As we have discussed throughout the chapter, genes and characteristics are inherited, or passed along, each time reproduction occurs. But how does that happen?

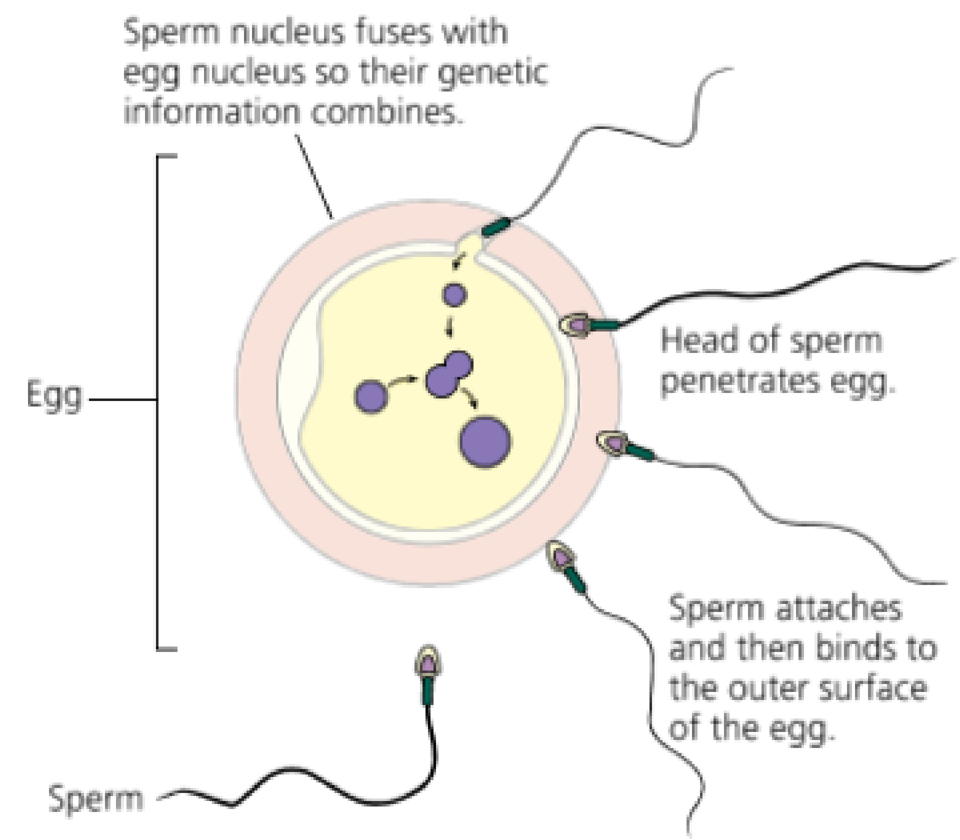
First, as you may remember, there are two types of reproduction: **sexual reproduction** and **asexual reproduction**. During asexual reproduction, the parent organism passes along its genes to its **offspring** without combining its genes with those of another individual. In single-celled organisms such as bacteria, this occurs in a process known as **binary fission**. In other organisms – including fungi such as yeasts, plants such as strawberries, and some animals such as corals, worms and starfish – this occurs through the processes of **budding**, **fragmentation**, or **parthenogenesis**. However, no matter the specific process, asexual reproduction always results in new individuals that have exactly the same genetic information as the parent.

During sexual reproduction, male and female sex cells, or **gametes**, combine. When this happens, the genes from the male sex cells, or **sperm**, combine with the genes from the female sex cell, or **egg**. This is true for all organisms that reproduce sexually, such as insects, fish, humans, and some types of plant.

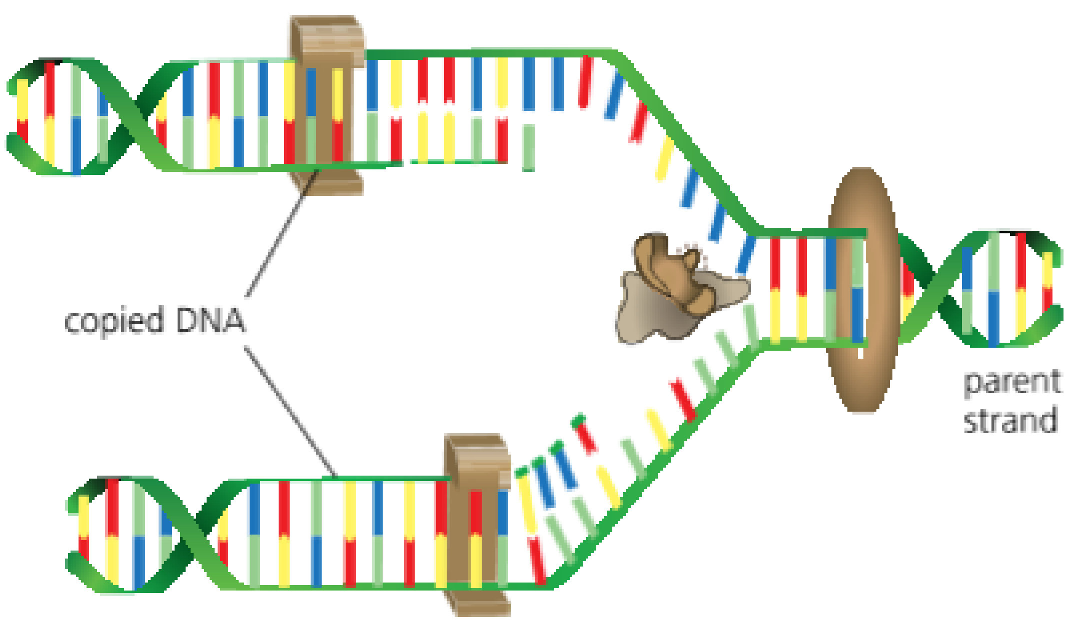
You might be wondering at this point how a parent organism can 'pass along' its genetic information, or DNA, without losing DNA from its own cells. In fact, an organism can 'pass along' its genetic information because DNA is capable of copying itself in a process called **DNA replication**. After DNA replication occurs, and all of the other cell components are also copied, the parent organism can create a new cell or cells with the same genetic information as the parent.



■ **Figure 3.8** Asexual reproduction by (a) binary fission, (b) budding, (c) fragmentation and (d) parthenogenesis



■ **Figure 3.9** In sexual reproduction, the genetic information from the sperm cell combines with the genetic information from the egg cell at fertilization



■ **Figure 3.10** DNA replicates so that a copy of the DNA can go to the 'daughter cells' during cell division or reproduction

What makes you say that?

Earlier in the chapter, we learned that almost all human cells contain two sets of 23 different chromosomes (Figure 3.6), for a total of 46 chromosomes. The only exceptions to this are the male and female sex cells – sperm and egg cells – which are called gametes.

Knowing that during sexual reproduction the genes of the DNA from the sperm cell and from the egg cell combine to form a complete set of genetic information (two sets of 23 chromosomes) in the cells of the offspring, **discuss** the following:

- **How many chromosomes must be in a human sperm cell and in a human egg cell so that the cells of the offspring have the correct number of chromosomes? What makes you say that?**
- **Is it possible for the offspring of sexual reproduction to have all of the characteristics of only one parent? What makes you say that?**

You also learned that during asexual reproduction, there is one parent that passes all its genetic information to its offspring.

- **How do the characteristics of the offspring compare to those of the parent, in asexual reproduction? What makes you say that?**
- **How do the characteristics of all of the offspring from one parent compare to each other, in asexual reproduction? What makes you say that?**

How do we grow and develop?

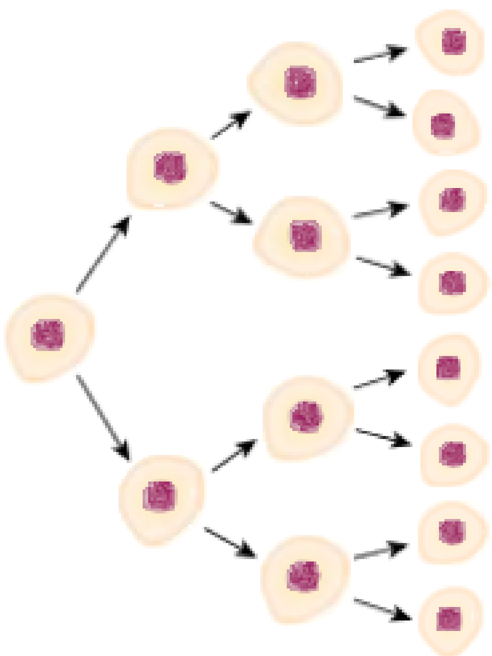
■ **Figure 3.12** Onion root tips are the very bottom portions of the onion root in a region where there is a lot of cell division and growth

GROWING UP

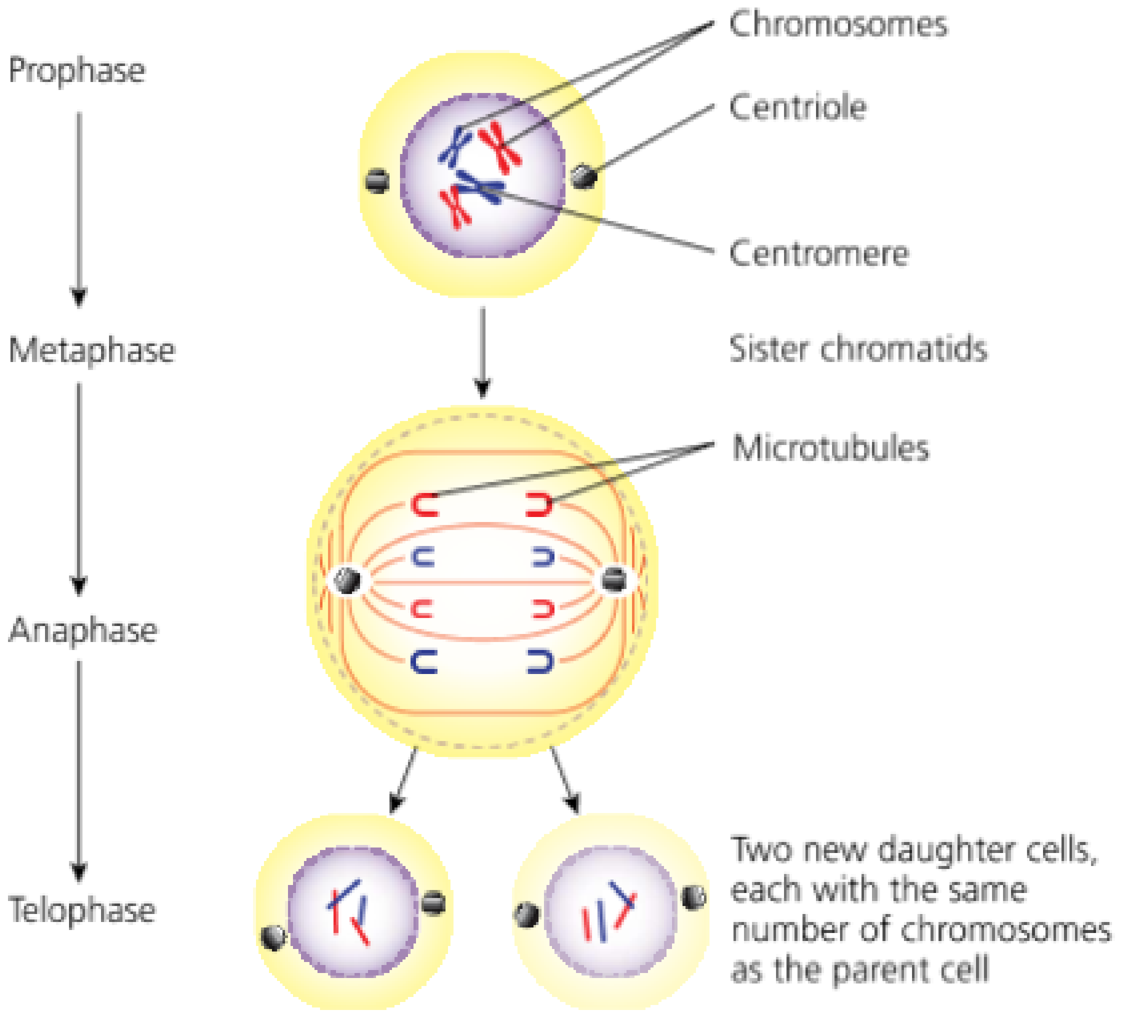
In the previous section, you learned that living things pass along their genes through the processes of asexual and sexual reproduction. You read about DNA replication, and how the copied DNA is passed along to the 'daughter cells' when cell division occurs. But, how do we go from a tiny, single cell to a whole, full-sized human with trillions and trillions of cells?

Multicellular organisms start off as a single cell, and grow into many cells as a result of cell division – a process called **mitosis**. Before mitosis occurs, the DNA replicates and cell structures such as mitochondria and ribosomes are duplicated, so that when the cell divides the copies are divided up into two cells with identical genetic information. The resulting cells are called **daughter cells**. With each round of mitosis, where there was once just one cell, there is now two.

Mitosis occurs in several steps, or phases, as outlined in Table 3.3. As a result of the events in each phase, the resulting daughter cells have the same genetic information as the original cell.

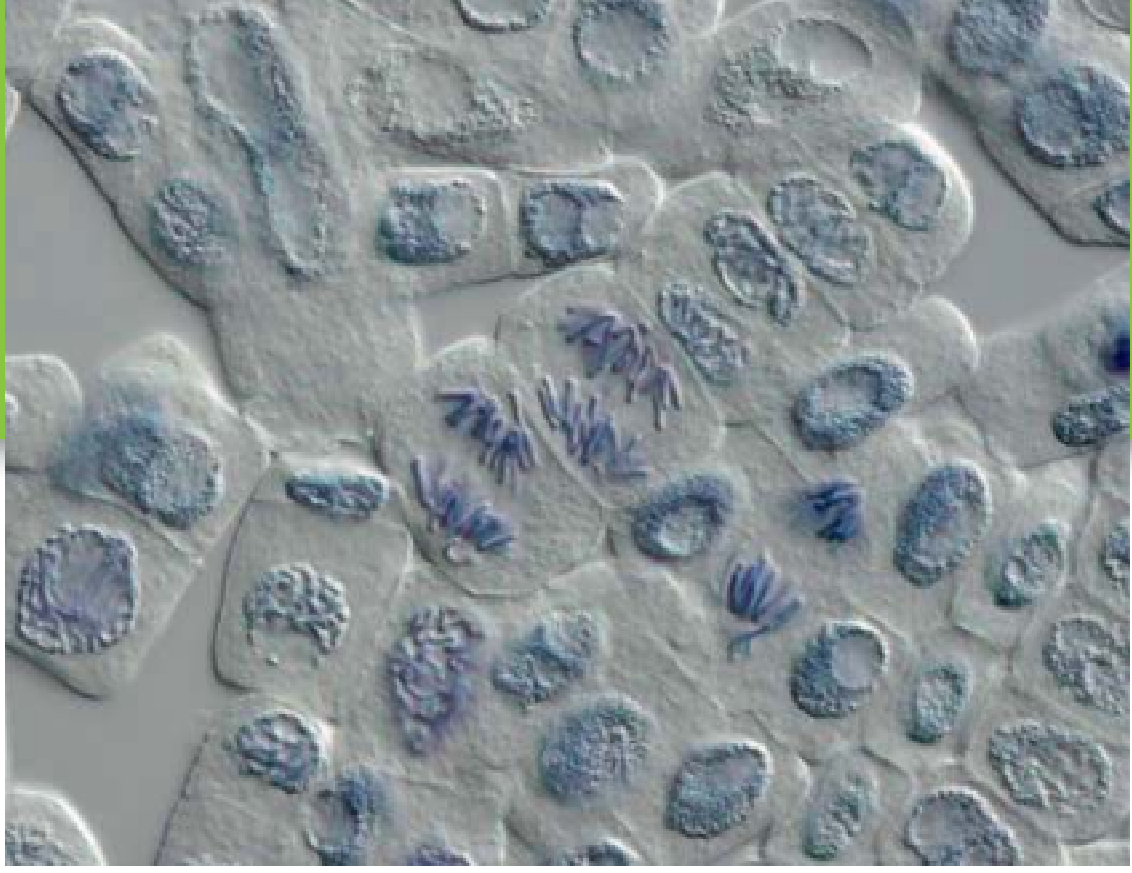


■ **Figure 3.11** As a result of cell division, a single cell can give rise to many cells that can form a multicellular organism



■ **Figure 3.13** During mitosis, replicated DNA and other cell structures are divided to create two genetically identical daughter cells

As a result of mitosis, living things can get bigger, as the number of cells continues to increase. It also allows cells that get damaged in injury, or that get old as part of the regular cell life cycle, to be replaced.



■ **Figure 3.14** This micrograph shows onion root tip cells at different phases in mitosis

Phase of mitosis	What happens
Prophase	**The DNA sends a signal that it is almost time for the cell to divide.** The replicated DNA condenses and chromosomes become visible under the microscope. Each chromosome contains two identical DNA copies joined in the middle, at a structure called a **centromere**. The two copies are called **sister chromatids**. Structures called **centrioles** form and line up at two opposite ends of the cell.
Metaphase	**The chromosomes line up in the middle of the cell, like an equator.** The centrioles form **microtubules**, which attach to the chromosomes at the centromeres.
Anaphase	**Separation begins!** One sister chromatid from each chromosome gets pulled along a microtubule toward one centriole, and the other sister chromatid gets pulled along a microtubule toward the other centriole.
Telophase	**Division occurs.** The sister chromatids have all reached opposite ends of the cell. A nuclear membrane forms around the DNA in each new cell. The cell structures get divided up. A cell membrane begins to form down the middle of the cell, dividing it in two. Two separate cells are formed.
Interphase	**Cell life carries on as usual!** Each cell performs its usual processes. The DNA is replicated ready for the next cell division.

■ **Table 3.3** Summary of mitosis

ACTIVITY: Taking a closer look

■ ATL

- Critical-thinking skills: Practise observing carefully; Interpret data

Did you know that you can actually see the phases of mitosis as they occur inside different cells? One of the most popular ways to see mitosis happening is to look at onion root tip cells under the microscope.

For this activity, you may either look at prepared slides of onion root tip cells, if they are available in your school, or you can use Figure 3.14, which shows a photograph of onion root tip cells under a microscope.

Working with a partner, **identify** the phase of mitosis in each cell.

Then, **discuss** why you think onion root tip cells are so popular for viewing mitosis. What are the characteristics of onion root tips that make them ideal for visualizing mitosis?

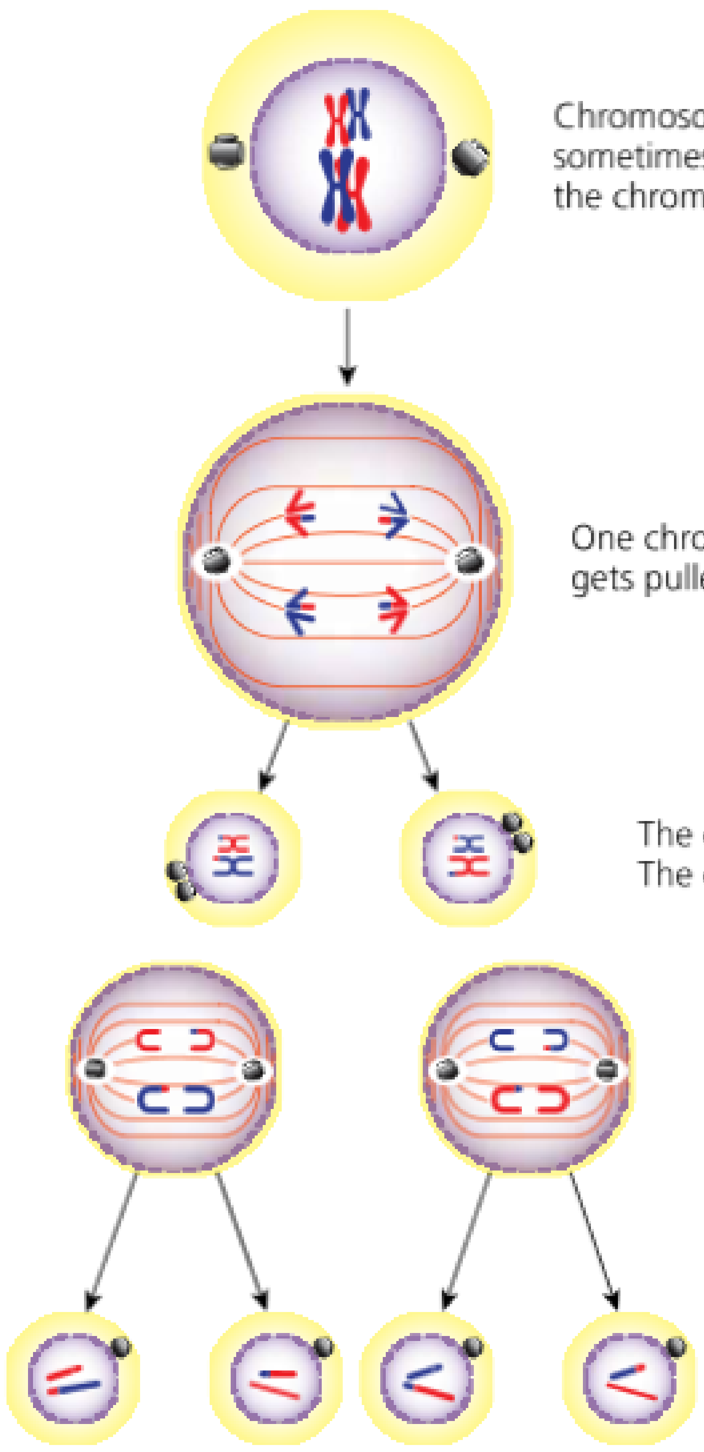
EXTENSION

Can you find mitosis in action? Go to youtube.com and search for real cell mitosis or real cell division. You could also try searching for observing mitosis in a living cell. Check out some of the videos to see how mitosis actually occurs!

◆ Assessment opportunities

- In this activity, you have practised skills that are assessed using Criterion A: Knowing and understanding.

There is one more process related to cell division and the creation of new cells. It is called **meiosis**, and it is how the sex cells (egg and sperm cells) are formed. The process of meiosis is very similar to mitosis, except that there are actually two rounds of prophase (prophase I and II), metaphase (metaphase I and II), anaphase (anaphase I and II), and telophase (telophase I and II). Another important difference between mitosis and meiosis is that the DNA does not replicate before prophase II.



■ **Figure 3.15** Meiosis is a special kind of cell division. Sex cells are formed by meiosis

ACTIVITY: Comparing mitosis and meiosis

■ ATL

■ Creative-thinking skills: Use brainstorming and visual diagrams to generate new ideas and inquiries

What similarities and differences do you notice between mitosis and meiosis? Copy Table 3.4 in your notes and use the diagrams of mitosis and meiosis in Figures 3.13 and 3.15, as well as Table 3.3 and other information in this section, to **compare and contrast** the two processes. Feel free to add some sketches to your comparison table. If you create the table on a computer, you could also find some images online to include in your comparison.

Mitosis	Meiosis

■ **Table 3.4**

◆ Assessment opportunities

◆ In this activity, you have practised skills that are assessed using Criterion A: Knowing and understanding.

As you have read, the DNA – and therefore the set of genes – in every cell of your body is the same. But, as you know, your body is not made up of just one type of cell.

DISCUSS

What are some examples of different types of cell in the human body? For example, our bodies are covered by skin cells. What other types of cells can you and your partner think of? What makes the cells different? What is the same about all the different types of cell?

There are many different types of cell in the human body. There are heart muscle cells that contract to move blood throughout the body, and the skeletal muscle cells that contract to make our arms or legs move. There are stomach cells that produce acid to help digest food, brain cells that send signals so we can respond to our surroundings, lung cells that exchange oxygen and carbon dioxide with the air, and many others that you may have discussed. Even though these cells contain many of the same cell structures and perform some of the same cell processes, such as cellular respiration, each type is different from the other.

If all of the cells in the human body have the same genetic information, and we know that genetic information gives the characteristics of a cell and the 'instructions' for how it should function, why isn't there just one type of 'human cell'? Why don't all cells in the body do the same thing?

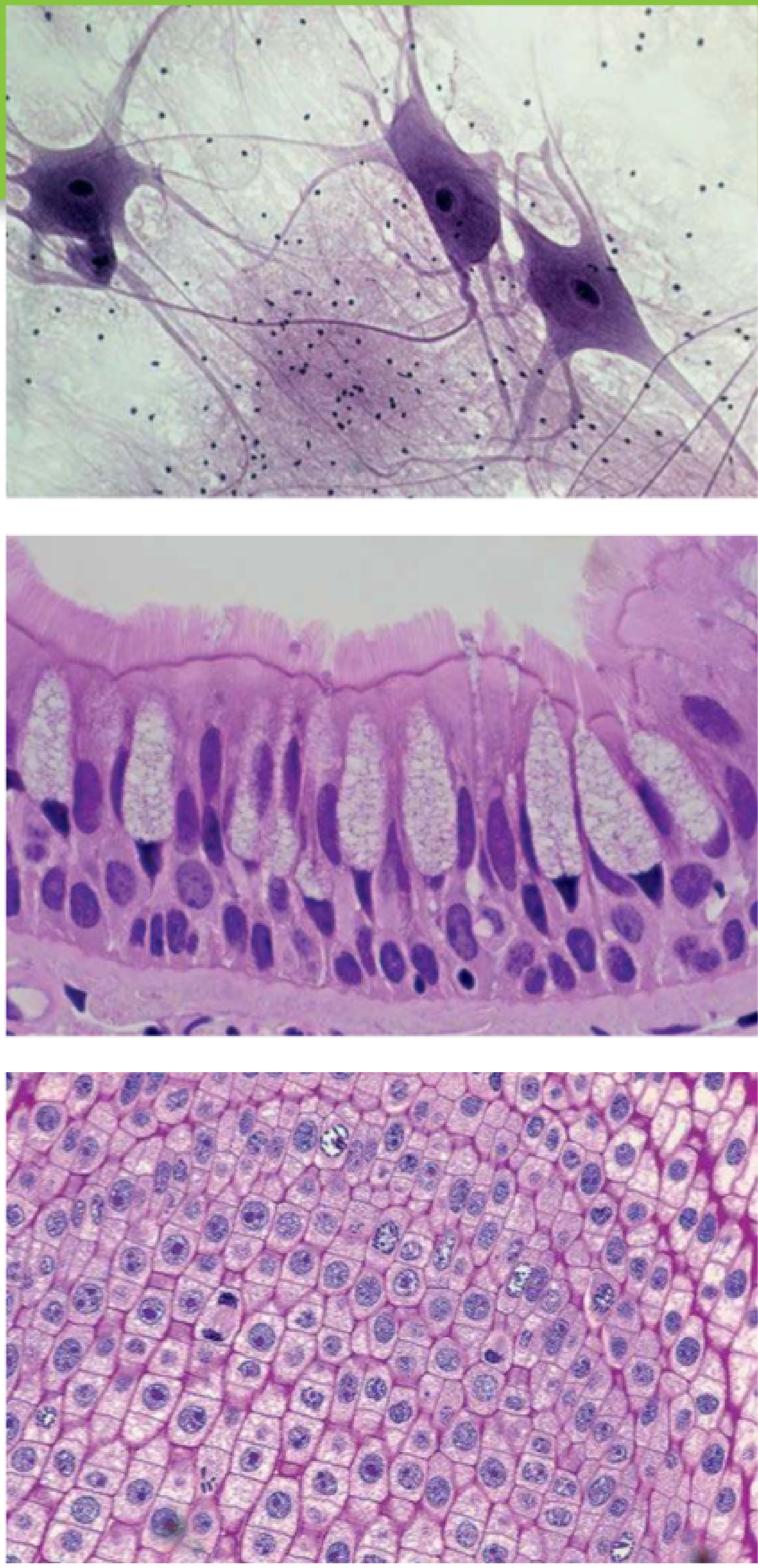


Figure 3.16 Our bodies are made up of different kinds of cell. What similarities and differences do you notice between these cells?

DISCUSS

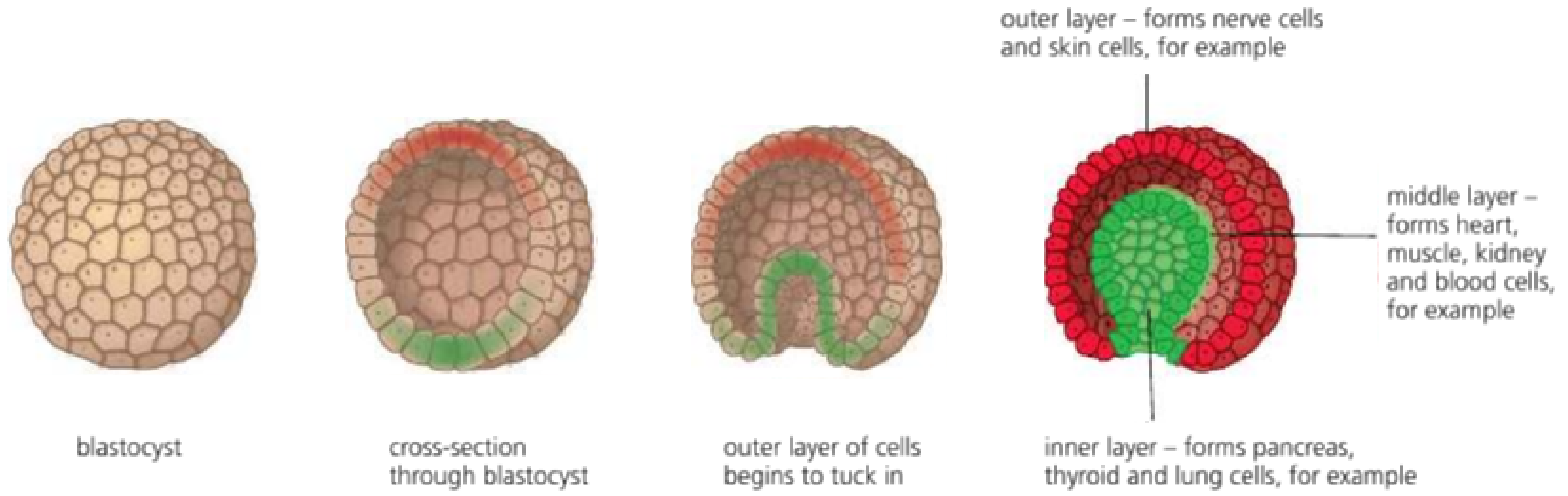
How do you think it is possible that there are different types of cell in the human body, with different characteristics and functions, even though they all have the same genetic information?

After the genetic information from the male sperm cell and female egg cell combine, there is a series of rapid cell divisions (by mitosis). For each cell division, the genetic information that came from the male and female sex cells is replicated and then divided between the daughter cells. Eventually, the cells have divided enough to create a 'ball' of 32 cells, called the **blastocyst**. The blastocyst cells continue to divide until there is a compact mass of about 100 cells.

Then, amazingly, as the cells continue to divide they begin to **differentiate** into different types of cell. Depending on the location of the cells in the blastocyst, external conditions around them cause certain genes to be activated (or not activated) within the cells. The activation of different genes means that the cells produce different proteins. And, as proteins are the 'workers' of the cells, different proteins mean different characteristics and functions of the cells. As these differentiated cells continue to divide, they eventually form a **fetus** with the different **tissues** and organs that we are familiar with in our own bodies.

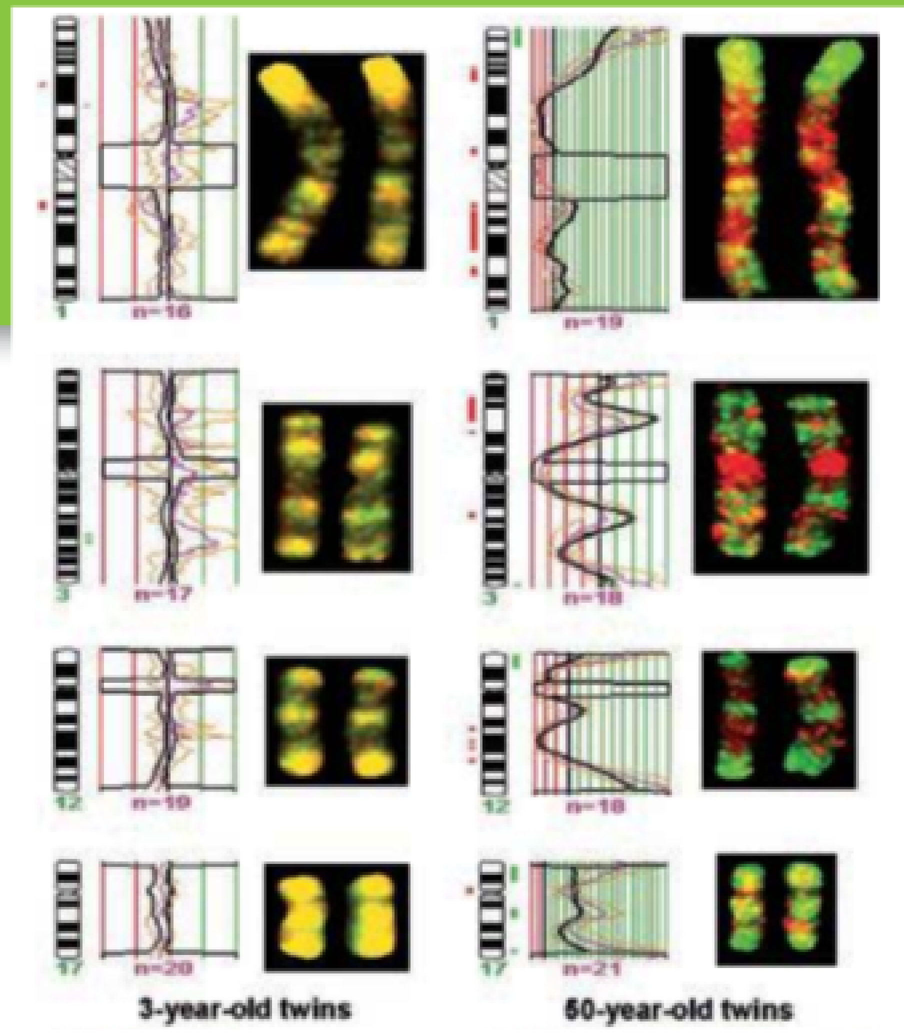
The importance of external conditions in determining differences in the characteristics and functions of cells that have the same genetic information is not limited to what happens during the early stages of the development of the fetus. External conditions also affect genes and resulting characteristics after birth – that is why identical twins (who have identical genetic information) do not have 100% of the same characteristics (Figure 3.18). Depending on different life experiences, and different places or substances each twin was exposed to, different genes inside their cells can be turned on or off – resulting in different protein production and different cellular characteristics and functions.

The effect of environmental conditions on our genes and characteristics is called **epigenetics** (*epi* means 'around' or 'above' in Greek). As a result of epigenetics, scientists know it is not just our genes that give us our characteristics – it is the combination of our genes plus external or environmental conditions that control gene expression, or the characteristics that result from turning on or off certain genes.



■ **Figure 3.17** The location of the cells in the blastocyst corresponds to the development of different types of cells in the body

■ **Figure 3.18** Even though identical twins have identical DNA, they do not have perfectly identical characteristics. What differences do you notice?



■ **Figure 3.19** In this image, we can see where twins have epigenetic 'tags' that are the same (everything in yellow) and epigenetic tags that are different (areas that are red or green) in the same chromosome. What do you notice about the chromosomes for the three-year old identical twins compared to the 50-year-old identical twins?

DISCUSS

What are some human characteristics that are determined by epigenetics?

Begin your **discussion** by first talking about general, common characteristics shared by everyone in your class. For example, everyone likes certain foods and doesn't like other foods. Or, everyone gets ill at some point.

Then, for each of the common characteristics, **identify** some specifics that vary between you and your classmates. So, even though everyone likes certain foods and doesn't like other foods, there are some people who like broccoli and others who don't; some who like salty foods, and those who prefer sweet things.

You might want to start your discussion in small groups, and then share with the whole class. What do you notice? What are some life experiences or environmental conditions that might cause these examples of differentiated genetic expression?

EXTENSION

Are you interested in learning more about how external conditions can affect how genes function? Search **twin epigenetics** or **epigenetics inheritance**. Remember to search for images as well!

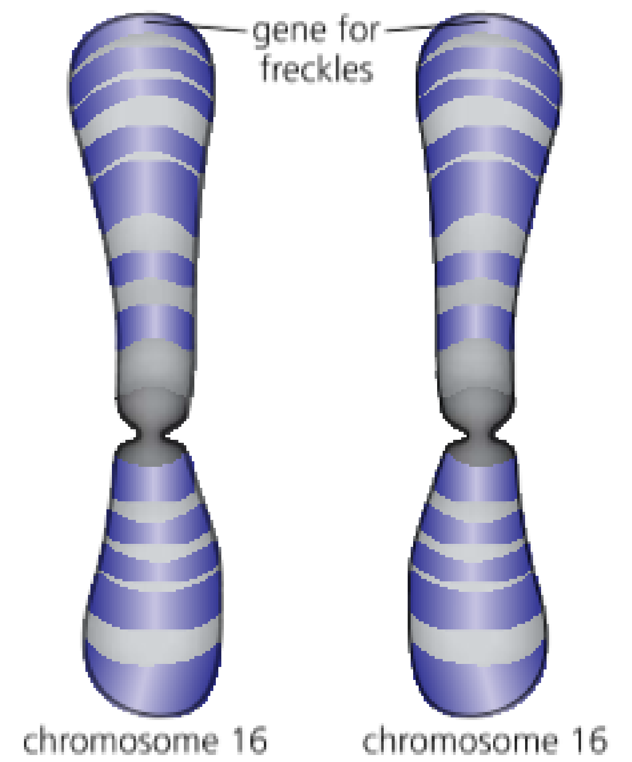
VISIBLE THINKING: Tweet it!

Think about what you have learned about cell division and the growth and development of living things.

If you were to write a tweet that **summarizes** and captures the most important thing about what you have learned and what everyone should remember, what would that tweet be? Type or write it down – remember, you can only use a maximum of 140 characters!

Once you have your tweet ready, share it with your partners and the class. What do you notice about the tweets? Have you and your classmates created similar tweets, or is there a variety of 'big ideas' to remember? Perhaps use your classmates' tweets as important information to include in your notes.

How are genetic patterns identified and used?



■ **Figure 3.20** The alleles for genes associated with freckles are located at the same place on each copy of chromosome 16

WE ARE ALL CONNECTED – AND UNIQUE

In the previous section, we learned that, during the process of sexual reproduction, half of an organism's genes come from the female parent and half from the male parent, so that it has a combination of the two parents' characteristics. But how do the genes combine?

Humans have 23 pairs of chromosomes in each body cell. This means we have two copies of each chromosome – and therefore two copies of each gene, in the same position on each chromosome of a pair. Many genes have different versions, or **alleles** – one allele is found on one chromosome of a pair, and the other allele is found on the other chromosome. Different alleles can result in a different version of a characteristic, or **trait**.

An allele can be **dominant** or **recessive**. When an allele is recessive, it means that two recessive alleles are necessary in order for the person to have the characteristic associated with the recessive trait. When an allele is dominant, it means that a person can have the trait associated with the allele if there are two dominant alleles, or if there is one dominant allele and one recessive allele. In other words, the trait from the dominant allele can 'block' or 'cover' the trait from the recessive allele. The characteristics associated with an allele are often represented by a letter. A capital letter represents the dominant form of the allele, and a lowercase letter represents the recessive form of the allele. For example, the alleles that code for freckles may be represented by the letter F or f.

The presence of freckles is a dominant trait (Figure 3.21a). This means that anyone who has freckles (You? Your classmates? Look around …) has, in all of their cells, either a dominant 'freckle' allele on *both* of their chromosome 16s, or one dominant 'freckle' allele on one chromosome 16 and one recessive 'no freckle' allele on the other chromosome 16.

Unlike the presence of freckles, the presence of 'hitchhiker's thumb' is thought to be a recessive trait. That means anyone with a hitchhiker's thumb (Figure 3.21b) has two copies of the recessive 'hitchhiker's thumb' allele, and no copies of the dominant 'no hitchhiker's thumb' allele.

(a)

(b)

■ **Figure 3.21** (a) The presence of freckles is a dominant trait, (b) while 'hitchhiker's thumb' may be a recessive trait

ACTIVITY: Tracking your traits

ATL

- Critical-thinking skills: Gather and organize relevant information; Interpret data; Draw reasonable conclusions and generalizations

Take a quick visual survey in your class to identify who has which of the traits described in Table 3.5. Make a copy of the table and write in your findings.

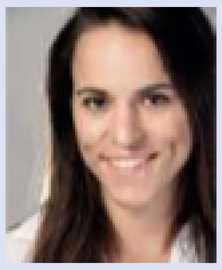
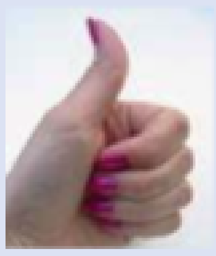
Trait	Is trait thought to be dominant or recessive?	Who has the trait?	Possible alleles of students who have it
Freckles 	Dominant		
Cleft chin 	Dominant		
Dimples 	Dominant		
Widow's peak 	Dominant		
Hitchhiker's thumb 	Recessive		
Left thumb crosses on top when hands are clasped 	Dominant		

Table 3.5 Some characteristics that may be due to dominant or recessive traits

Assessment opportunities

- In this activity, you have practised skills that are assessed using Criterion A: Knowing and understanding.

What makes you say that?

Answer these questions.

- **Is it necessary that both biological parents of someone who has freckles also have freckles? What makes you say that?**
- **If someone has a hitchhiker's thumb, do one or both parents also have hitchhiker's thumb? What makes you say that?**

EXTENSION

Autosomal dominant compelling helio-opthalmic outburst (ACHOO) syndrome is an unusual genetic trait.

Search ACHOO syndrome. What does your research tell you about the syndrome? What happens to people who have this syndrome? Is it a dominant or recessive trait? What are some other names for the syndrome?

How can individuals be identified through inherited characteristics and genetic patterns?

It is possible to make predictions about the genetic traits of an unborn child based on the genetic traits of their parents. In the same way, we can make predictions about whether or not people are related. One of the ways that this can be done is by using a system called a Punnett square.

For example, is it possible for a man with freckles and a woman without freckles to have a child who has freckles? Let's use a Punnett square to figure it out. Here's how it works.

1 Choose a letter to represent the trait. For example, we can use **F** to represent the 'freckles trait':
   F represents the dominant allele (with freckles)
   f represents the recessive allele (no freckles)

2 Create a square that is divided into nine boxes, like this:

3 To the left of the middle column, write the alleles of the mother. Since the mother does not have freckles, we know she has the recessive trait. We learned that to show the recessive trait, it is necessary to have two recessive alleles. In this case, it means the mother has two **f** alleles (**f** and **f**). Since the mother has two copies of the recessive allele, we say that she is **homozygous** recessive for the trait (remember that *homo* means 'same' in Greek, so homozygous recessive just means the same recessive allele). Another way of saying this is that she has the homozygous recessive **genotype**.

f		
f		

4 Above the middle row, write the alleles of the father. Since the father has freckles, we know he has the dominant trait. This means he can have either a dominant allele and a recessive allele (**F** and **f**) or two dominant alleles (**F** and **F**). If the father has the **Ff** alleles, we say that he has the **heterozygous** genotype for the trait (*hetero* means 'different' in Greek, so heterozygous means different alleles). If he has the **FF** alleles, we say that he has the **homozygous** dominant genotype (the same dominant allele).

With no further information than what we have, we will have to look at both possibilities (**Ff** and **FF**) in order to see if the couple could have a child who has freckles.

- **Possibility 1** – if the father has the heterozygous genotype for the freckle trait:

	F	**f**
f		
f		

- **Possibility 2** – if the father has the homozygous dominant genotype for the freckle trait:

	F	**F**
f		
f		

5 Now, copy the mother's alleles (**f**) in both boxes that are to the right of each allele, like this:

- **Possibility 1** – if the father has the heterozygous genotype for the freckle trait:

	F	**f**
f	f	f
f	f	f

- **Possibility 2** – if the father has the homozygous dominant genotype for the freckle trait:

	F	**F**
f	f	f
f	f	f

6 Next, copy the father's alleles in both boxes that are below it, like this:

- **Possibility 1** – if the father has the heterozygous genotype for the freckle trait:

	F	f
f	Ff	ff
f	Ff	ff

- **Possibility 2** – if the father has the homozygous dominant genotype for the freckle trait:

	F	F
f	Ff	Ff
f	Ff	Ff

Note that, usually, if there is a dominant allele, it is listed first (**Ff** instead of **fF**).

7 Now, identify which of the boxes contains alleles for 'freckles'. Remember, because freckles is a dominant trait, a person will have freckles if they are heterozygous (**Ff**) or homozygous dominant (**FF**).

- **Possibility 1** – if the father has the heterozygous genotype for the freckle trait:

	F	f
f	Ff	ff
f	Ff	ff

- **Possibility 2** – if the father has the homozygous dominant genotype for the freckle trait:

	F	F
f	Ff	Ff
f	Ff	Ff

Using a Punnett square

Scientists use systems like the Punnett square to identify patterns and make predictions about inheritance. Using a Punnett square is a good way to keep information organized and find potential genetic combinations in a systematic way – two important features of any type of genetic analysis.

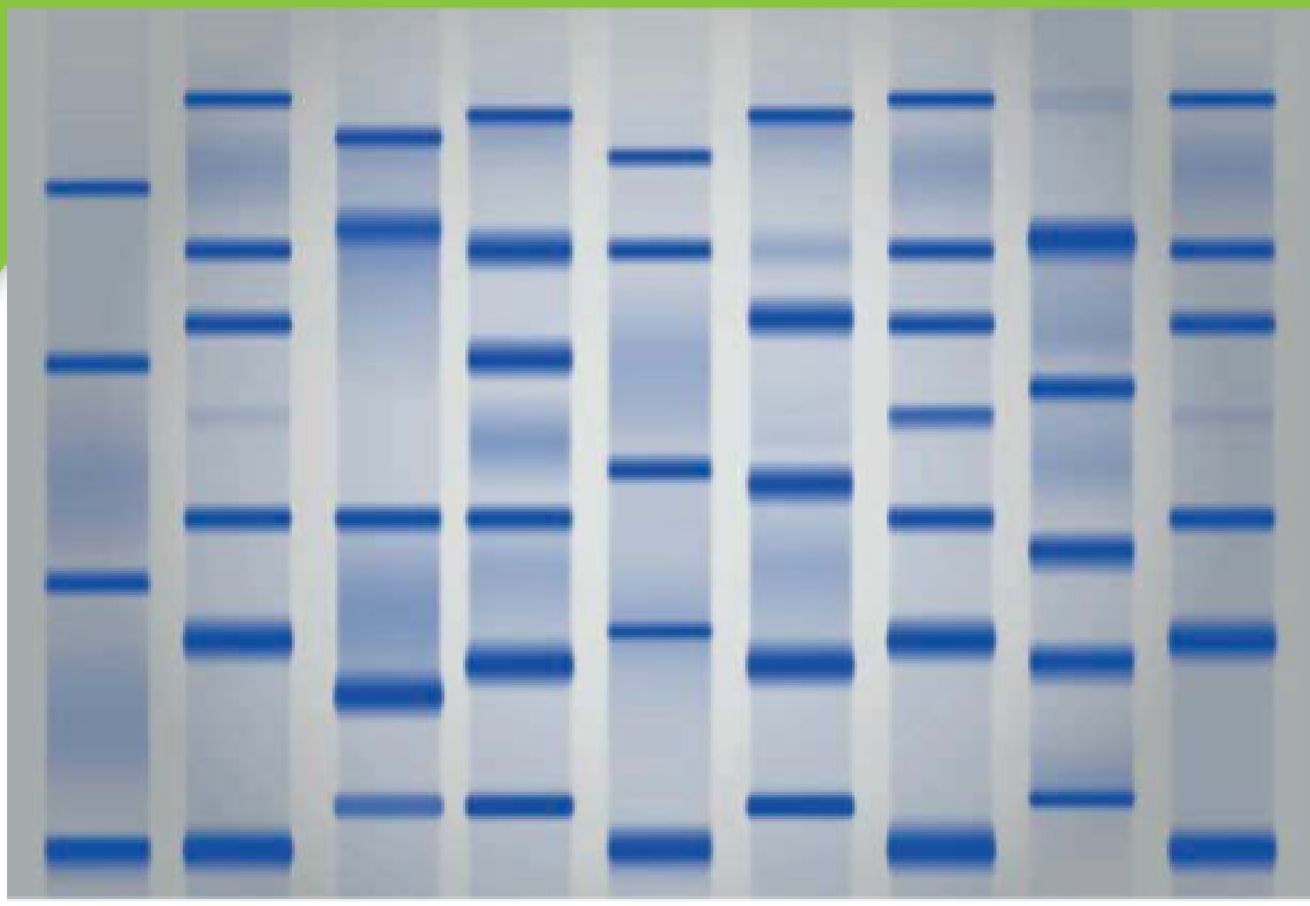
8 The alleles in the boxes represent the possible combinations of alleles – and therefore the possible traits – of the child. So, you can approximate the 'chances' of these parents having a child with freckles.

- **Possibility 1** – if the father has the heterozygous genotype for the freckle trait:
  2 out of the 4 boxes have the alleles for freckles, so there is a 50% chance the child will have freckles.
- **Possibility 2** – if the father has the homozygous dominant genotype for the freckle trait:
  4 out of the 4 boxes have the alleles for freckles, so there is a 100% chance the child will have freckles.

DISCUSS

- **Imagine the parents from the example have a child who does not have freckles. Can you identify what the father's genotype is? Why or why not? If yes, what is it?**
- **What if the parents had a child who *does* have freckles. Can you identify what the father's genotype is? Why or why not? If yes, what is it?**
- **If the parents have two children, one with freckles and then one without freckles, can you identify what the father's genotype is? Why or why not? If yes, what is it?**
- **If the parents have two children, both without freckles, can you identify what the father's genotype is? Why or why not? If yes, what is it?**

■ **Figure 3.22** A scientist is loading DNA fragments and dye into the gel, to carry out gel electrophoresis



■ **Figure 3.23** Results from gel electrophoresis

A Punnett square can help us identify some basic patterns or possibilities of inheritance, but it cannot tell us much about a person's actual genetic make-up. For that, scientists use a process called **gel electrophoresis**.

For gel electrophoresis, a sample of DNA is taken from some cells, such as cells in saliva, blood, or hair. A process called **PCR** is used to make many, many copies of the DNA. Then, different chemicals are used to cut up the DNA into pieces called gene fragments. Some of the gene fragments are big, some are small, and some are medium-sized. Not all people will have the same big, small, or medium-sized fragments – according to your individualized, unique combination of alleles, your DNA gets cut in different places.

Then, the DNA fragments are mixed with a special blue-coloured dye and put into a small square gel that is floating in a special solution in a small chamber, or container. An electric potential is applied across the chamber – at the end where the DNA is, there is a negative charge, while at the opposite end there is a positive charge.

Because DNA has a small negative charge, it will be attracted to the positive charge at the opposite end of the chamber. The DNA fragments will travel through the gel (since gel is not a completely solid substance) toward the positive charge.

The larger fragments of DNA will have a more difficult time moving through the gel, so they will not travel so far, whereas the smaller fragments will be able to move easily through the gel. After the DNA fragments have had a chance to travel through the gel and separate, it is possible to see where the different sized fragments are, because of the dye that was mixed with the DNA. The gel can be viewed on a special lighted table or under a special kind of light to get a clearer picture.

Depending on the exact chemicals used to cut up the DNA, the results may look something like Figure 3.23. You can see that the DNA fragments travelled different distances in the gel, which means there were fragments of different sizes.

This distribution of DNA fragments by gel electrophoresis is called a DNA fingerprint, because, like a regular fingerprint, each person's DNA fingerprint is unique.

DISCUSS

DNA has a small negative charge. What will happen to the DNA because the opposite end of the chamber has a positive charge? What makes you say that?

Take action! DNA evidence on trial

ATL

- Reflection skills: Consider ethical, cultural and environmental implications

- Imagine you are a journalist for a newspaper or news show. Once every week, one of the journalists in your organization writes an opinion-based article related to a current event.
- Recently, a court case has begun in which DNA evidence is going to be used against the suspect.
- Because you have been reporting on the trial, your boss has asked you to write the opinion piece in response to the debatable question:

  'To what extent should legal cases depend on identifying people through DNA?'

- Even though it is an opinion piece, you must support your opinion with scientific evidence and reasoning. Therefore, you must be sure to:
  - **describe** how science is used and applied when trying to identify a person in legal cases
  - **discuss and analyse** the various implication of using science in legal cases – the implications should be related to cultural, ethical, economic, or political factors
  - **apply** scientific language effectively
  - **document** the work of others and sources of information used.
- You may either write your opinion piece or make a short video broadcast.
- After you have finished, share your work with your classmates. **Discuss** the opinions and points of view. Do your classmates' opinions and evidence have any impact on your original perspective?

Assessment opportunities

- This activity can be assessed using Criterion D: Reflecting on the impacts of science.

Take action! Catch the robber

ATL

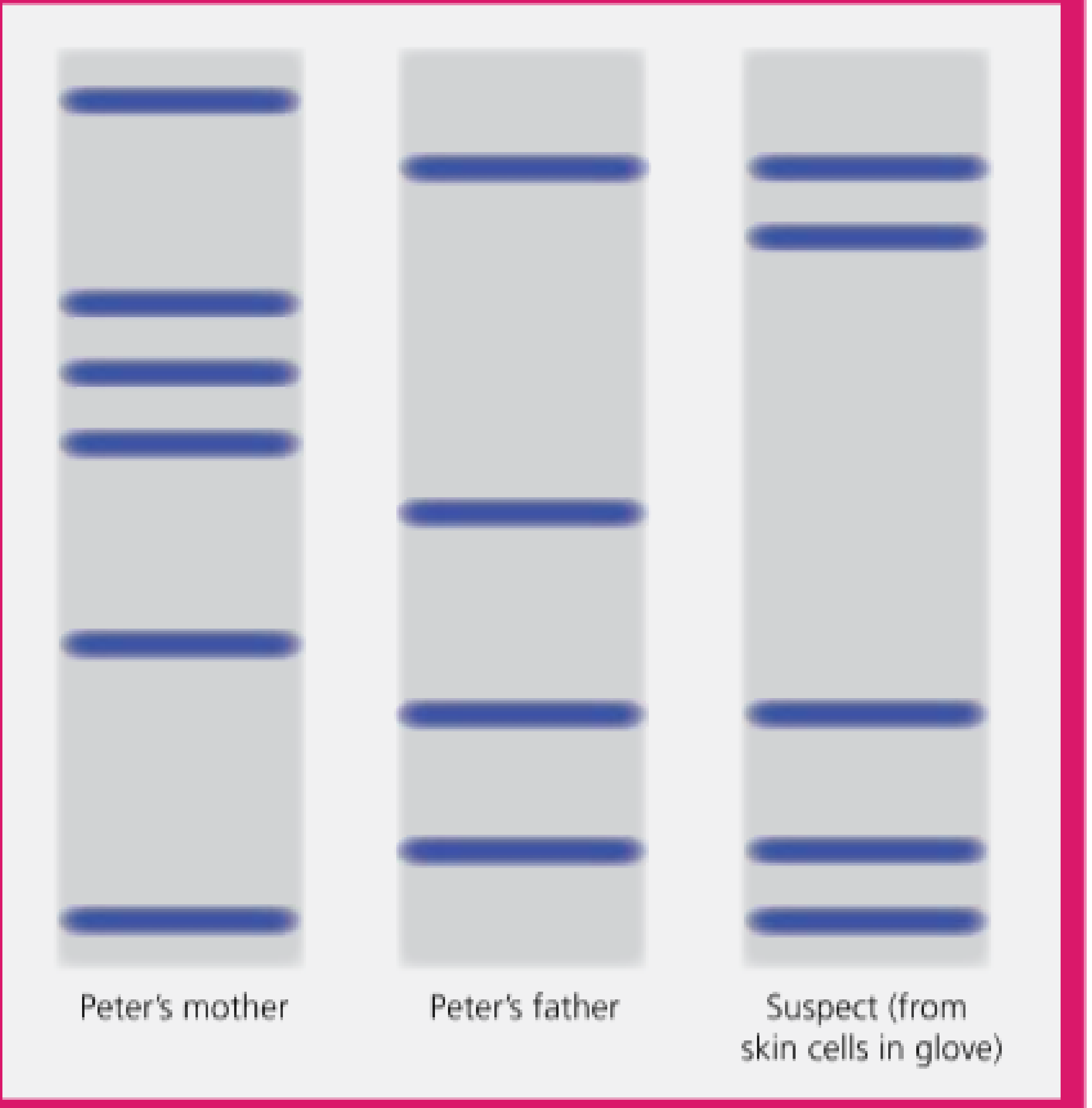
- Information literacy skills: Collect and analyse data to identify solutions and make informed decisions; Process data and report results
- Critical-thinking skills: Gather and organize relevant information to formulate an argument; Use models and simulations to explore complex systems and issues; Consider ideas from multiple perspectives

- You are a forensic DNA analyst. Your job is to analyse DNA evidence in order to make judgments about a person's identity. Below is a description of a case you are working on.
- There's been a bank robbery. Apparently, the robber was not very careful because the police not only found a dropped glove, which had skin cells inside, they also discovered a credit card by the counter. The name on the card was Peter Walker.
- Having questioned everyone in the bank at the time of the robbery, the police found that the credit card did not belong to any of them. No-one had seen the suspect's face, as he was wearing a mask, but a few people remembered that as soon as he ran outside into the daylight, he sneezed three times before he disappeared.
- The police went to the address listed for the credit card. The suspect, Peter, had lived there with his parents and brother, but had moved out two days earlier. Peter was on a four-day road trip to his new town; he had taken everything except his mobile phone, which he had accidentally left behind. His parents were not expecting to hear from him until he got to his new place in two days.
- When asked why the credit card might be at the bank, Peter's father suggested that maybe Peter had dropped it there a few days before when he withdrew some money from his account, and the police just happened to find it on the day of the robbery. The family was very confident that Peter had not committed the robbery. The parents agreed to give a saliva sample so their DNA could be compared to the DNA from the skin cells in the glove.

Take action! Catch the robber (continued)

- As the police were leaving, the family walked with them. As he stepped into the daylight, Peter's father sneezed three times, but his mother and brother did not.
- Back at the station, a woman was waiting who said she had seen a man running from the bank on the day of the robbery. As he took off his mask, she saw that he had brown, straight hair, with a widow's peak. She could not see his face completely, but noticed his skin tone was fair.
- Your task, as a forensic DNA analyst, is to analyse the genetic evidence you have been given, including Figures 3.24 and 3.25, and make a scientifically supported judgment about Peter's guilt or innocence.

1. Using what you have learned in this chapter about some different genetic traits, make a list of traits of Peter, his family, and the man seen running from the bank that could be used as evidence linking Peter to the robbery.
2. **Analyse** the information you have been given and make a scientifically supported judgment about Peter and his connection to the bank robbery.
3. **Present** your findings and opinions to your class in either a persuasive essay, slide show presentation, or video recording. Remember to do the following in your findings:
   - **describe** scientific knowledge about genetics and the inheritance of traits
   - **apply** scientific knowledge and understanding to solve this problem, which is in an unfamiliar situation
   - **analyse** information about Peter, his family, and the man seen running from the bank to make a scientifically supported judgment about Peter and whether he was involved in the bank robbery.



■ **Figure 3.25** DNA fingerprints from the skin cells inside the suspect's glove, from Peter's father and from Peter's mother

■ **Figure 3.24** Peter's mother, father and brother

Assessment opportunities

- This activity can be assessed using Criterion A: Knowing and understanding.

Links to: Mathematics

Identifying patterns and using evidence in the justification of statements are important concepts in both mathematics and science. What are some connections you can make between patterns and justification from your maths class and using genetic information to identify individuals?

Reflection

In this chapter, we have learned how and why genes are responsible for our characteristics. We have learned about the connection between genes, proteins, and our traits. We **inquired** into how genetic traits are passed from parents to offspring, and the cellular processes that make reproduction possible. We learned how to make **predictions** about some genetic traits using Punnett squares, and **explored** how scientists use technology to create DNA fingerprints to identify individuals.

We have **described** the function of genes and how genetic characteristics are inherited, **applied** our understanding of genetics to support judgments about the use of genetic information, **analysed** evidence and data to make scientifically supported judgments, **discussed** whether or not DNA evidence should be used in legal decisions, and **documented** the resources used to support our judgments.

<table>
<tr><th colspan="6">Use this table to evaluate and reflect on your learning in this chapter.</th></tr>
<tr><td>Questions we asked</td><td>Answers we found</td><td colspan="4">Any further questions now?</td></tr>
<tr><td>Factual: What is DNA? What are genes? What is the relationship between DNA, genes, and inherited characteristics? How do we grow and develop?</td><td></td><td colspan="4"></td></tr>
<tr><td>Conceptual: How are genetic patterns identified and used? How can individuals be identified through inherited characteristics and genetic patterns?</td><td></td><td colspan="4"></td></tr>
<tr><td>Debatable: To what extent should legal cases depend on identifying people through DNA?</td><td></td><td colspan="4"></td></tr>
<tr><td rowspan="2">Approaches to learning you used in this chapter:</td><td rowspan="2">Description – what new skills did you learn?</td><td colspan="4">How well did you master the skills?</td></tr>
<tr><td>Novice</td><td>Learner</td><td>Practitioner</td><td>Expert</td></tr>
<tr><td>Reflection skills</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Information literacy skills</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Critical-thinking skills</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Creative-thinking skills</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Learner profile attribute(s)</td><td colspan="5">Reflect on the importance of being principled for our learning in this chapter.</td></tr>
<tr><td>Principled</td><td colspan="5"></td></tr>
</table>

4 What does a wave tell us?

Understanding the **relationships** between different **forms** of wave **energy** helps us better **communicate and express our thoughts**.

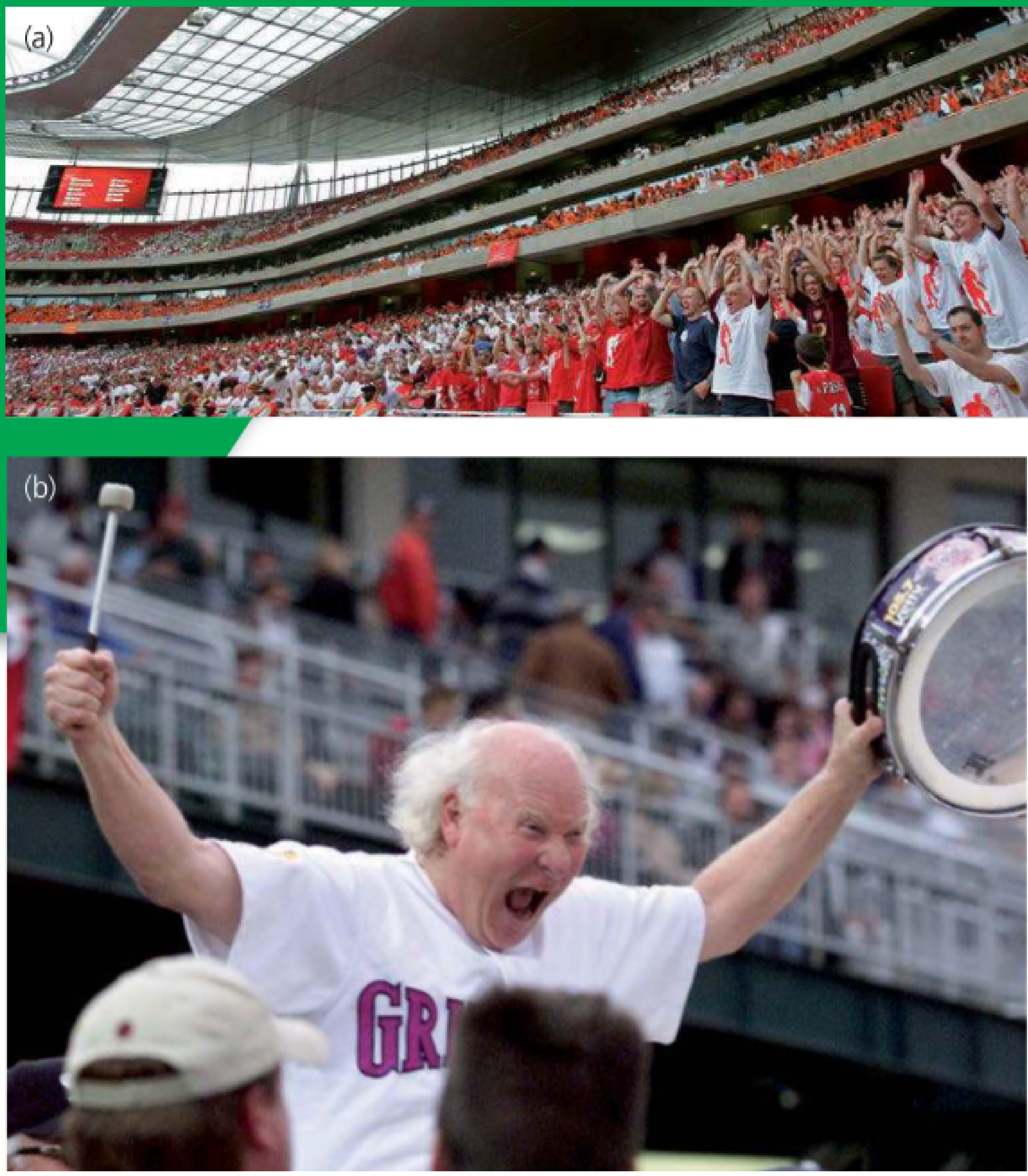


Figure 4.1 Where is the wave? (a) The 'Mexican Wave' or 'Ola mexicana' (b) 'Krazy' George Henderson claims he invented the 'Mexican Wave'

CONSIDER THESE QUESTIONS:

Factual: What is a wave? What is light? What kinds of energy travel as waves? How are we sensitive to energy that travels as waves? What other kinds of electromagnetic radiation are there? How are we sensitive to sound waves?

Conceptual: How does understanding waves help us to better express ourselves?

Debatable: Do artists and scientists have anything to say to each other?

Now **share and compare** your thoughts and ideas with your partner, or with the whole class.

IN THIS CHAPTER, WE WILL …

- **Find out** how waves carry energy through oscillation, and what different kinds of wave there are.
- **Explore** how light and sound are used to communicate and to help us to express ourselves.
- **Take action** to protect ourselves from harmful waves, and investigate how to limit noise pollution.

KEY WORDS

balance medium transmit vibration wave

■ **Figure 4.2** The energy of a tsunami can cause massive destruction

SEE-THINK-WONDER: Comparing waves

- **Search video: Tsunami climbing or go to https://youtu.be/OdhfV-8dbCE to watch footage of a boat riding over a tsunami at sea.**
- **Search video: gentle wave motion boat to find footage of boats rocking on smaller waves.**
- **Search video: mexican wave to find footage of a Mexican Wave at a sports event.**

Individually, make notes. What do you see? What does it make you think? What does it make you wonder?

Write down descriptive words for the motion in each case.

These Approaches to Learning (ATL) skills will be useful …

- Collaboration skills
- Communication skills
- Information literacy skills
- Creative-thinking skills
- Critical-thinking skills

We will reflect on this learner profile attribute …

- Inquirer – we will apply new knowledge to ask new questions and carry out investigations to find the answers.

Assessment opportunities in this chapter:

- **Criterion A:** Knowing and understanding
- **Criterion B:** Inquiring and designing
- **Criterion C:** Processing and evaluating
- **Criterion D:** Reflecting on the impacts of science

Figure 4.1 shows a stadium wave or 'Mexican Wave' at a sports event. Have you ever seen this, or taken part in one? 'Krazy' George Henderson was a professional cheerleader for an American football team called the Oakland A's, and claims that he started the first 'wave' in October 1981 – in the USA, not in Mexico (in the USA, it is called simply 'the wave'). Others have claimed it really was invented in Mexico – in Monterrey, during a soccer match. The wave certainly gained international recognition during the 1986 World Cup in Mexico.

In this chapter we will explore how important kinds of energy are transferred by waves, and we will consider how waves allow us to communicate our thoughts to each other. But what is a wave? Are all waves like the 'Mexican Wave'?

A tsunami is another kind of wave. It is a very destructive wave created at sea by **seismic activity** such as an earthquake (see *MYP Sciences by Concept 1*, Chapter 6 for more detail). While far out at sea, the energy of the wave is spread over a very large area and so boats can ride over the wave. When the tsunami hits shallower water, however, its energy becomes concentrated and on hitting land has devastating effects.

What is a wave? What kinds of energy travel as waves?

GOOD VIBRATIONS

In the *See-Think-Wonder* activity on the previous page, you will have noticed some similarities in the different waves you observed. All waves involve a motion back and forward around a certain point. This kind of motion is called **oscillation**. Waves can occur in all kinds of material, and in all states of matter. The material through which the wave is travelling is called the **medium** (the plural of this is **media**). The point around which the oscillation occurs is the place where the medium would be if there was no wave passing by. This point is called the **equilibrium position**, because equilibrium means 'balance'. We can see therefore that a wave is caused whenever a medium is moved away from its equilibrium. The kind of wave that is produced depends on the properties of the medium and the direction of motion.

THINK-PAIR-SHARE

Individually, brainstorm all the properties of a medium that might affect the way a wave travels through it.

Hint

If you are not sure what properties to consider, you may like to review MYP Sciences by Concept 1, Chapter 1.

In pairs, **discuss** the properties, and **explain** to your partner how you think the property would affect the wave.

Now share your ideas as a class. Agree on which properties of media are likely to be the most important in determining how a wave travels.

ACTIVITY: Different waves, different media

ATL

- Communication skills: Negotiate ideas and knowledge with peers; Share ideas
- Collaboration skills: Listen actively to other perspectives and ideas
- Critical-thinking skills: Practise observing carefully

Work in groups. In this activity you will learn about waves in different media and then teach what you have learned to your classmates.

Carry out the demonstration assigned to you by your teacher. For each demonstration, make a note of what you will need to say to explain to your classmates. When you have finished, present your demonstration to the rest of the class!

Demonstration 1: Body waves

For this demonstration, you will need:

- **One presenter**
- **Six demonstrators**

You will demonstrate two ways in which waves can move through a medium using your bodies.

Type 1: Longitudinal body waves

For this type of wave, the six demonstrators should stand in a line, front to back, and then place their hands carefully on the back of the person in front of them (Figure 4.3).

Figure 4.3 Longitudinal body wave

Now, the presenter should gently push on the person at the back of the line. This person then passes the push down the line, before returning to their place.

Type 2: Transverse body waves

For this type of wave, the six demonstrators should stand side by side and put their hands around the wrists of the people either side of them (Figure 4.4).

Figure 4.4 Transverse body wave

Now, the presenter should take the wrist of the first person in the line and pull them forward. This person should then pass the pull on down the line and return to their place.

Describe the wave motion in each case. In which direction does the medium move? In which direction does the wave move? **State** the medium for the wave.

Demonstration 2: Waves in water

If your school has a ripple tank, this may be used for the demonstration. You may also wish to search video: ripple tank. Alternatively, a very simple demonstration can be made as described below.

Equipment:

- **Large, transparent bowl at least 30 cm diameter**
- **Dropper pipette**
- **Positionable light source**

1. **Pour water into the large bowl until it is half full. Take a little of the water in the dropper pipette.**
2. **Position the light source so that it illuminates the transparent bowl from beneath. For best effects, you should darken the room.**
3. **Now slowly drip water into the centre of the bowl. Watch the ripples produced in the surface of the water spread out, and change the pattern of light cast on the ceiling.**

Describe the motion of the water as a ripple passes by. What is causing the water to move away from its equilibrium position? **State** the medium for the wave.

Demonstration 3: Waves in the air

SAFETY: Loud sounds experienced for a long time can damage your hearing. In this experiment, do not place your ear directly over the loudspeaker at any time, and if the sound becomes unpleasant, turn down the amplitude setting on the signal generator.

For this demonstration, you will need:

- **Large loudspeaker cone**
- **AC signal generator**
- **Fine sand**

Your teacher will connect the AC signal generator to the loudspeaker cone.

1 **Look carefully at the AC generator. Identify the controls for the amplitude and frequency.**

2 **Use a spatula to finely sprinkle sand over the loudspeaker cone. Turn on the AC generator.**

4 **Slowly change the frequency setting on the AC generator. Take care! If the sound becomes unpleasant, turn down the amplitude!**

Describe what you see and hear. What is causing the sound you hear? **State** the medium for the wave.

Demonstration 4: Waves in a wire

For this demonstration you will need:

- **A hand-cranked AC generator**
- **A cathode ray oscilloscope (CRO) or voltage datalogging equipment and software**

Your teacher will connect the AC generator to the CRO or datalogger. The CRO or datalogger is a device that can measure the electric current flowing in a wire, and then display these measurements in the form of a graph against time.

1. **Slowly turn the crank on the AC generator. Observe what happens to the trace on the screen**
2. **Now turn the AC generator at a constant speed, but much faster. Observe the trace.**

Describe how the speed of the crank affects the trace you observe. What shape is the graph? Where is the wave occurring? **State** the medium for the wave.

Assessment opportunities

- In this activity, you have practising skills that are assessed using Criterion A: Knowing and understanding.

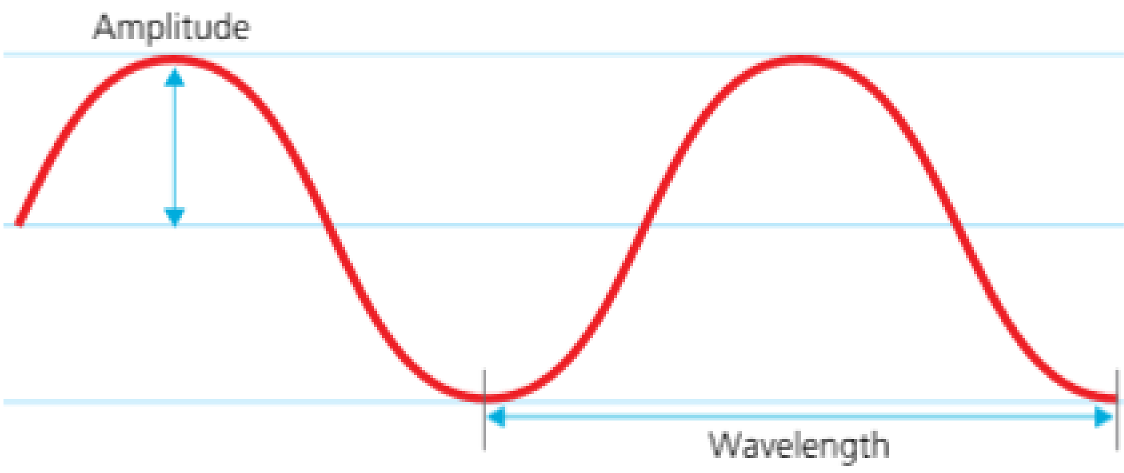
In each of the demonstrations in the *Different waves, different media* activity, a wave is produced in a different medium. In the first demonstration, we also saw that the medium can oscillate in different ways. In the **longitudinal oscillation**, the medium (the bodies, in our demonstration) moved back and forth in the same direction as the direction that the wave was moving. In the **transverse oscillation**, the medium moved at ninety degrees to the direction that the wave was moving.

We need to describe waves of different kinds so that we can better understand them. Three variables are used for this: **wavelength**, **frequency** and **amplitude**. We will look at frequency in the context of light and sound waves in the rest of this chapter.

The wavelength is defined as the distance between one point in a wave and the same point in the next wave that comes along. To put it another way, the wavelength is the distance taken for the oscillation to return to a particular point.

The amplitude of the wave is the distance from the equilibrium position to the point of maximum disturbance – from the middle of the wave to the top (sometimes called the **crest** or **peak** of the wave) or to the bottom (sometimes called the **trough** of the wave). Note that the amplitude is measured from the equilibrium position – the middle line through a symmetrical wave – and not from the highest to the lowest point.

We can imagine how these measurements are used in the example of a boat bobbing gently up and down on the water. If the boat is moored or anchored to the sea bottom, then it cannot move forwards or backwards.



■ **Figure 4.5** Wavelength and amplitude

If the sea is perfectly still, the boat will rest at the equilibrium position – that is, on the surface of the still seawater (of course, this never happens). When a wave passes by, the boat moves up to the peak, back down through the equilibrium position to the trough, then back up to equilibrium position again. The motion will repeat as a series of waves pass by.

At a swimming pool, you may have experienced an artificial wave machine. On the surface of the water, waves are transverse because the water is moving up and down as the wave moves forward across the water. In reality though, sea waves are more complex than this – underneath the surface, water exhibits a rolling motion that means the medium is oscillating both longitudinally and transversally.

DISCUSS

In demonstrations 2, 3 and 4, in the *Different waves, different media* activity, two of the oscillations were longitudinal and one of the oscillations was transverse. Can you work out which was which?

ACTIVITY: Seismic waves

ATL

- Critical-thinking skills: Gather and organize information to formulate an argument; draw reasonable conclusions and generalizations

Search **video: Smithsonian Seismic Waves shake L.A.** to watch a simulation by the United States Geological Survey of a major earthquake as it passes through the city of Los Angeles.

In pairs, **discuss**:

- **What does the left-hand panel of the simulation show?**
- **What does the colour-coded scale in the top right-hand side of the main panel show?**
- **What is the long, red line shown on the left-hand panel?**

Hint

Refer to MYP Sciences by Concept 1, Chapter 6, for a reminder!

The simulation shows the earthquake starting in the Salton Sea in California. Research using a distance calculator and **interpret** the information in the simulation to:

1. **describe the wave motion you observe during the whole of the earthquake, using the scientific terms for waves you have learned in this section**
2. **estimate the speed of the first waves to arrive in Los Angeles**
3. **analyse the way the earthquake travels out from the epicentre and so summarize the effect of the San Andreas fault on the strength of the earthquake when it hits Los Angeles.**

Assessment opportunities

- This activity can be assessed using Criterion A: Knowing and understanding.

When we want to show how waves travel, the easiest method is to use a line or arrow that points in the direction the wave travels. This line is called a **ray**. For transverse waves, a ray is drawn at 90° to the wave peaks. For a longitudinal wave, the ray shows us the direction in which the medium is oscillating back and forth.

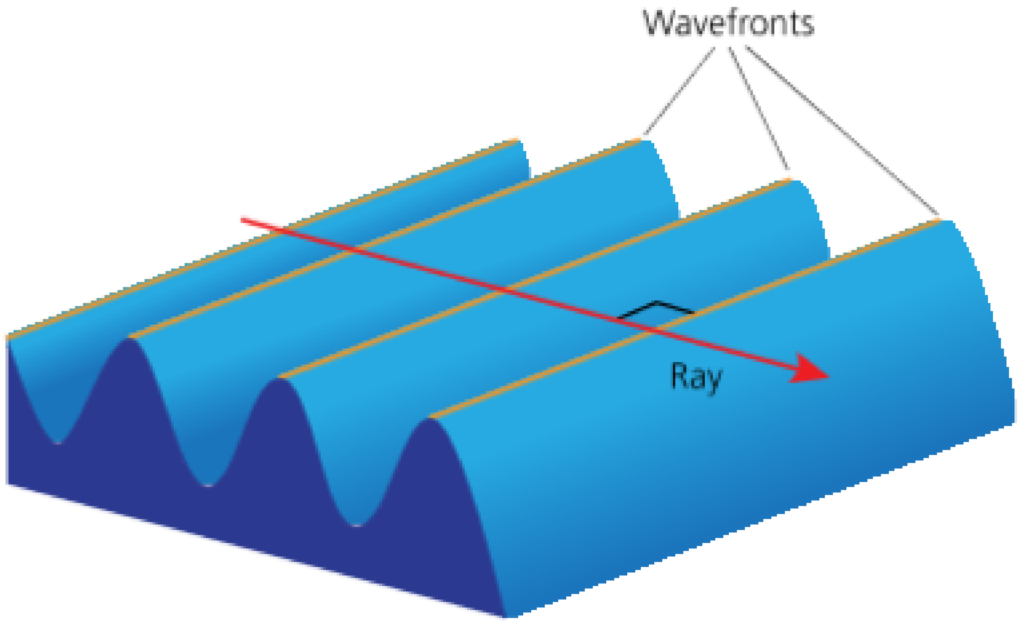


Figure 4.6 Rays can be used to show the direction of travel of waves

What is light?

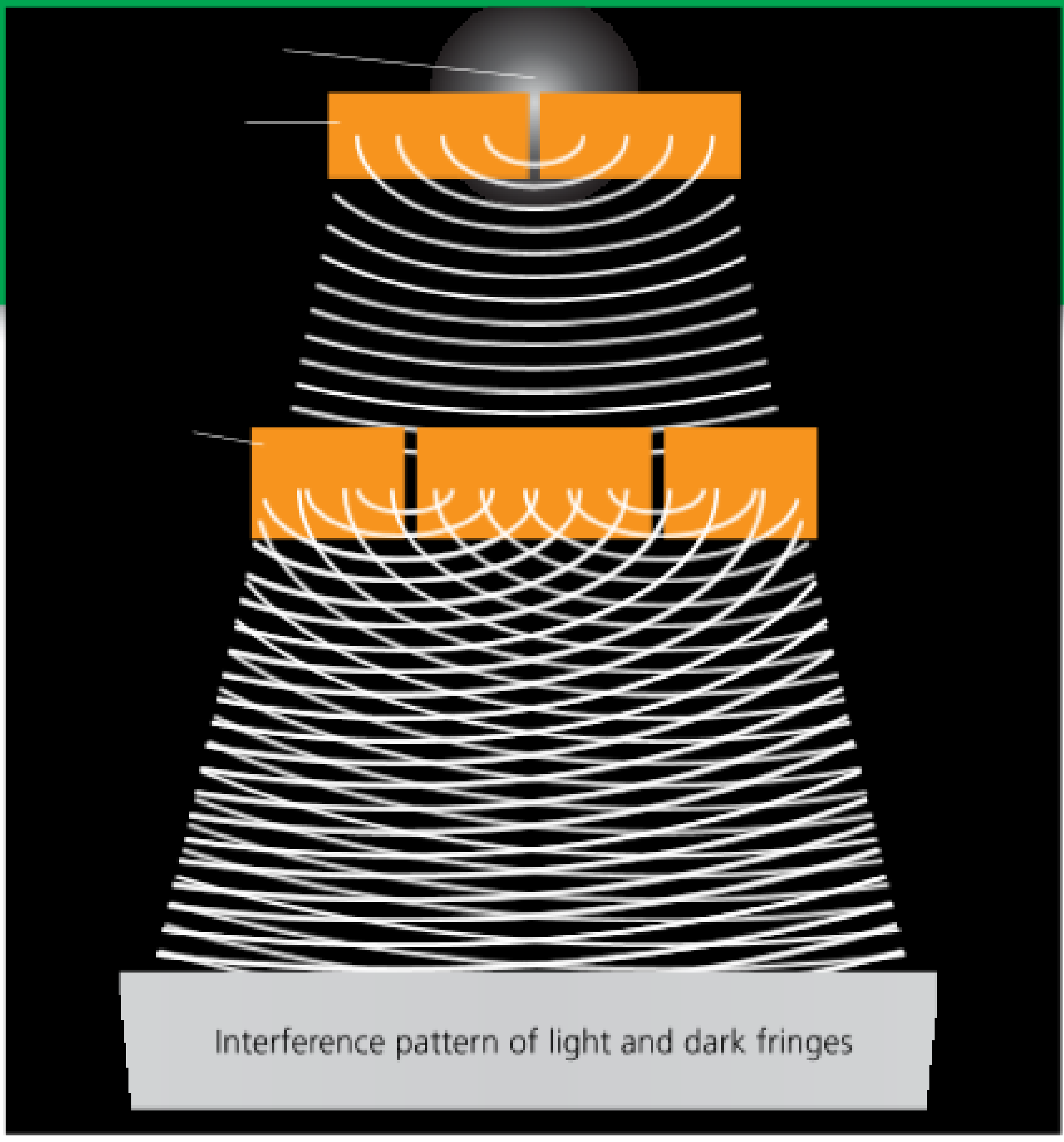
■ **Figure 4.7** Different creatures' eyes. (a) Nautilus has a simple eye like a pinhole with no lens. (b) Insects have compound eyes made from many light detectors but the eye cannot move. (c) Goats' eyes have a horizontal pupil so that their vision is not affected by bright sunlight overhead. (d) The mantis shrimp has an eye that can see across a very wide range of colours. (e) Some cave-dwelling creatures have evolved to lose the eyes their ancestors originally had.

SHEDDING LIGHT ON IT

It is sometimes said that 'the eyes are the windows to the soul'. Perhaps this expression reflects the importance to humanity of the relationship between what we see, and who we are. Figure 4.7 shows how other creatures, too, have evolved different kinds of eye, each adapted to their living conditions and so their ecological function. The simple eye of the nautilus is a pinhole over some light-sensitive cells. In Europe in the eighteenth century CE it became quite popular in wealthier households to entertain one's guests by creating a **camera obscura**, a device which operates on the same principle as the nautilus' eye.

Light is an important kind of energy to life on Earth, but have you ever wondered exactly what light is? If so, you are in good company – humans in all cultures over many centuries have pondered the same question. The Greek philosopher Empedocles (495–430 BCE) thought that light was caused by a small fire in the eye, and shone out in rays that illuminated the world around us. Others, such as the Roman philosopher Lucretius (99–55 BCE), thought that light was made from atoms which shot across space in straight lines. The idea of light as an atom persisted – Isaac Newton developed his 'corpuscular theory' around the idea that light was made of small particles whose behaviour could be explained just like the motion of masses. Still others thought light behaved more like waves in water. French philosopher René Descartes (1596–1650) described light as waves of pressure that passed through an invisible medium, and the eye was a sort of pressure sensor. Either way, it was accepted that light travelled very quickly – as we saw in Chapter 1.

The argument seemed to have been resolved when a British doctor, Thomas Young (1773–1829), carried out an experiment in which he shone the yellow light made by burning sodium in a lamp through two very narrow, very close slits. Young observed a surprising pattern on the screen beyond the slits – instead of seeing two bright lines as he expected he saw a series of light and dark lines. Young deduced that this pattern

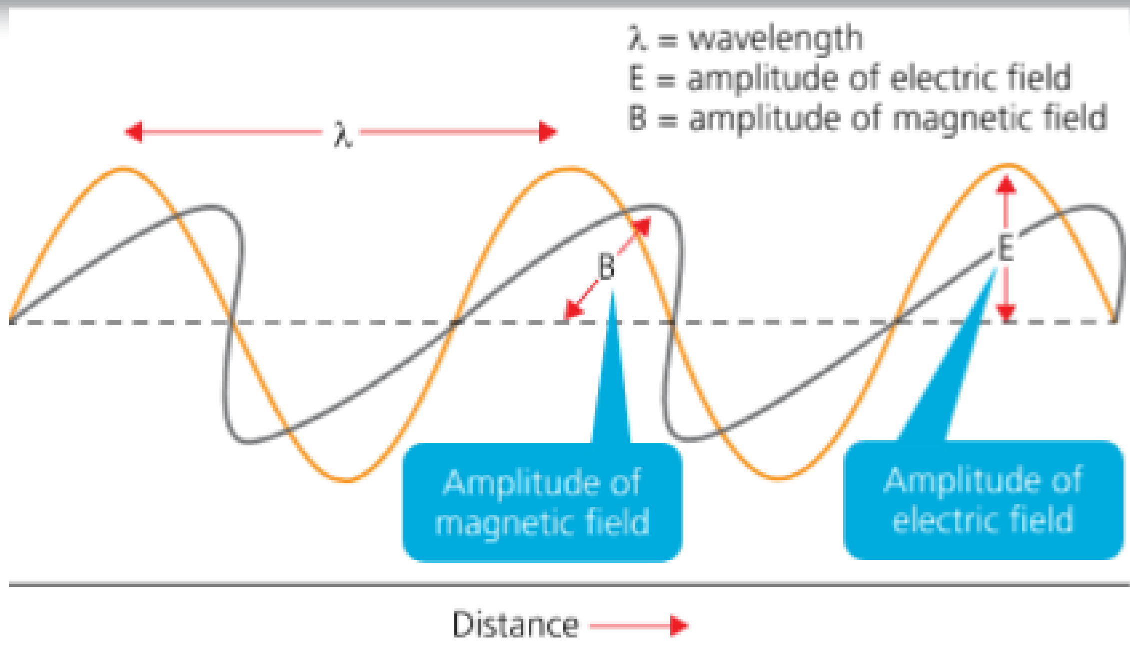


■ **Figure 4.8** Young's double slit interference experiment provides evidence that light is a wave

could be explained if we thought of the light passing through each of the slits as a wave that spreads out. The waves from each of the slits overlap and **interference** is produced, so that in some places on the screen the waves cancel each other out to produce a dark region, and in others they add together to make a bright region.

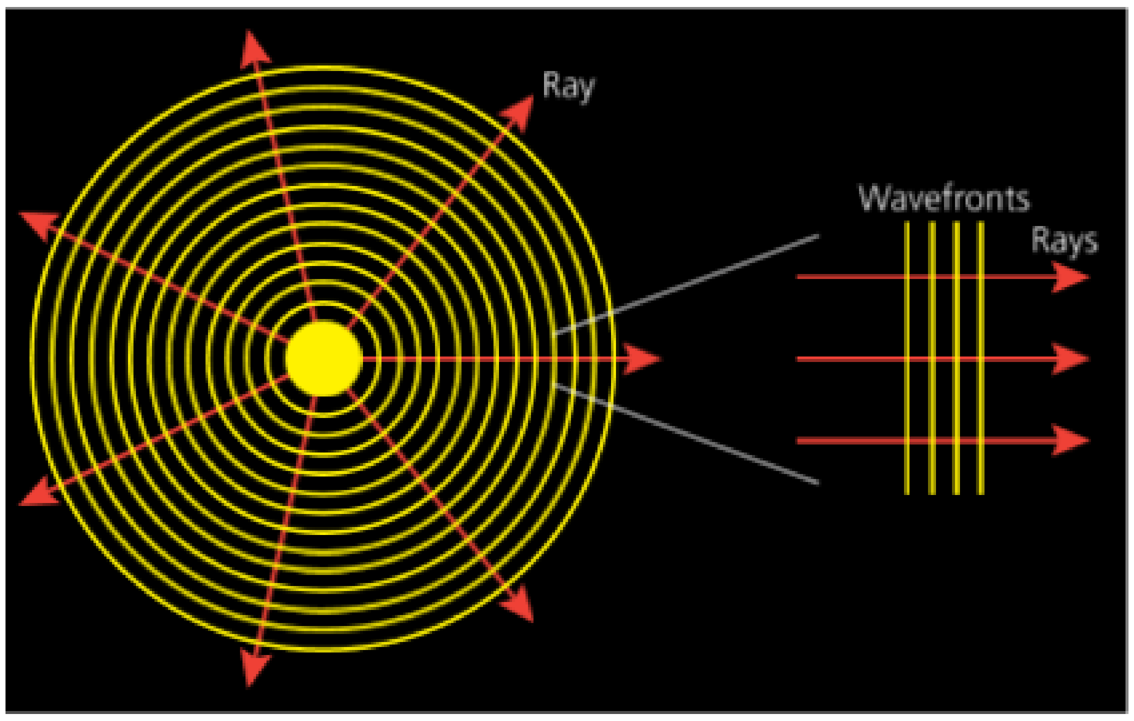
Later, James Clerk Maxwell (1831–1879) realised that different colours of light, and indeed different kinds of **electromagnetic radiation**, all travelled at the same speed in a vacuum. From this he made the leap of imagination to deduce that light was itself a kind of electromagnetic wave travelling through space.

In Maxwell's model, light consists of electrical and magnetic energy whose strength oscillates as it travels. Different kinds of electromagnetic energy oscillate at different rates. When we draw rays for light, we are drawing the direction of travel or **propagation** of the light through space. For a very large or very distant object such as the Sun, the rays that reach us are spreading out over a very small fraction of the total angle of 360°. For this reason, we can think of the rays as being almost parallel to each other. This is a useful **approximation** when we consider how light rays produce an image in optical devices like the pinhole camera.

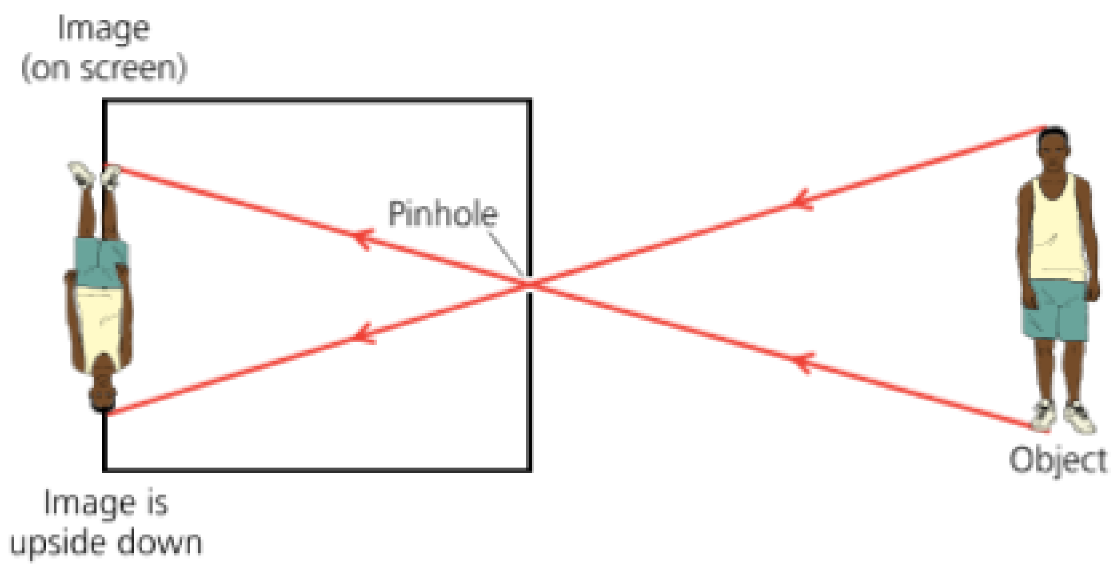


■ **Figure 4.9** Maxwell deduced that light is a wave of electromagnetic energy travelling through space

The image in the pinhole camera appears upside down or inverted because the light rays from the distant object cross over in the pinhole or **aperture** (Figure 4.11).



■ **Figure 4.10** Ray diagram for a spherical light source like the Sun – at very large distances, the rays spread out over a small angle and appear close to parallel



■ **Figure 4.11** Ray diagram of a pinhole camera or camera obscura

ACTIVITY: Making a pinhole camera

ATL

- Critical-thinking skills: Revise understanding based on new information and evidence

Work in pairs. In this activity you will make a simple camera, called a pinhole camera. If you have sheet ('Polaroid') film or photographic paper available, you can even use the camera to take pictures. Alternatively, you can use the device as a camera obscura.

You will need:

- A light-tight container – anything will do, but an empty paint can (with lid), cylindrical gravy granule container or a coffee can will work well
- A very fine screwdriver or awl for making a hole
- Matt black paint
- Thin black card
- For a camera obscura, translucent paper such as tracing paper or greaseproof paper
- For a pinhole camera, sheet film or photographic paper, and photographic printing facilities
- Sticky tape

Method

1. Paint the inside of the container and lid with matt black paint. This will prevent any light entering the camera from reflecting and spoiling the image.
2. Make sure the lid fits well onto the container.
3. Using the screwdriver or awl, make a small hole no more than 0.5 mm in diameter in the centre of the bottom of the container. (Take care!)

   Alternatively, if the bottom of the container is too thick to make a neat hole easily, then use aluminium foil to cover the end of your camera and make a small hole in that.
4. Make a 'shutter' for your camera by bending the black card to form a hinge along one end. Tape the hinge to the container so that the shutter covers the hole. Tape down the other side of the card to keep the shutter closed for the moment.
5. **For a camera obscura**, tape the translucent paper over the open end of the camera.

   To test your camera, try pointing it at a bright object such as a TV or monitor screen in a dark room. Observe the image produced on the 'screen'.

   For a pinhole camera, remove the lid and take your camera to a darkened room. Tape the film or photographic paper on the inside of the lid, so that the light-sensitive surface is facing the pinhole. The light-sensitive surface will feel a little sticky to the touch.

   Replace the lid, with the film or paper inside.

   To take a photo, position your camera so that it can lie still pointing at the object you wish to photograph. Lift the shutter and keep it open to expose the paper or film inside the camera as follows:

   - photographic paper – expose for up to 2 minutes
   - photographic film – expose for 1–2 seconds on a bright, sunny day; 4–8 seconds on a cloudy day.

   To 'fix' the image you have made, you will need to take the pinhole camera to a darkroom and have the photograph printed.

Results

Record your observations for the image produced by the camera obscura or pinhole camera.

Search for definitions to the words in the box below:

Upright   Inverted   Magnified
Diminished   Focused

State the meaning of each of the words. Using these words, **interpret** and **describe** the images from your camera and compare to the real objects.

Assessment opportunities

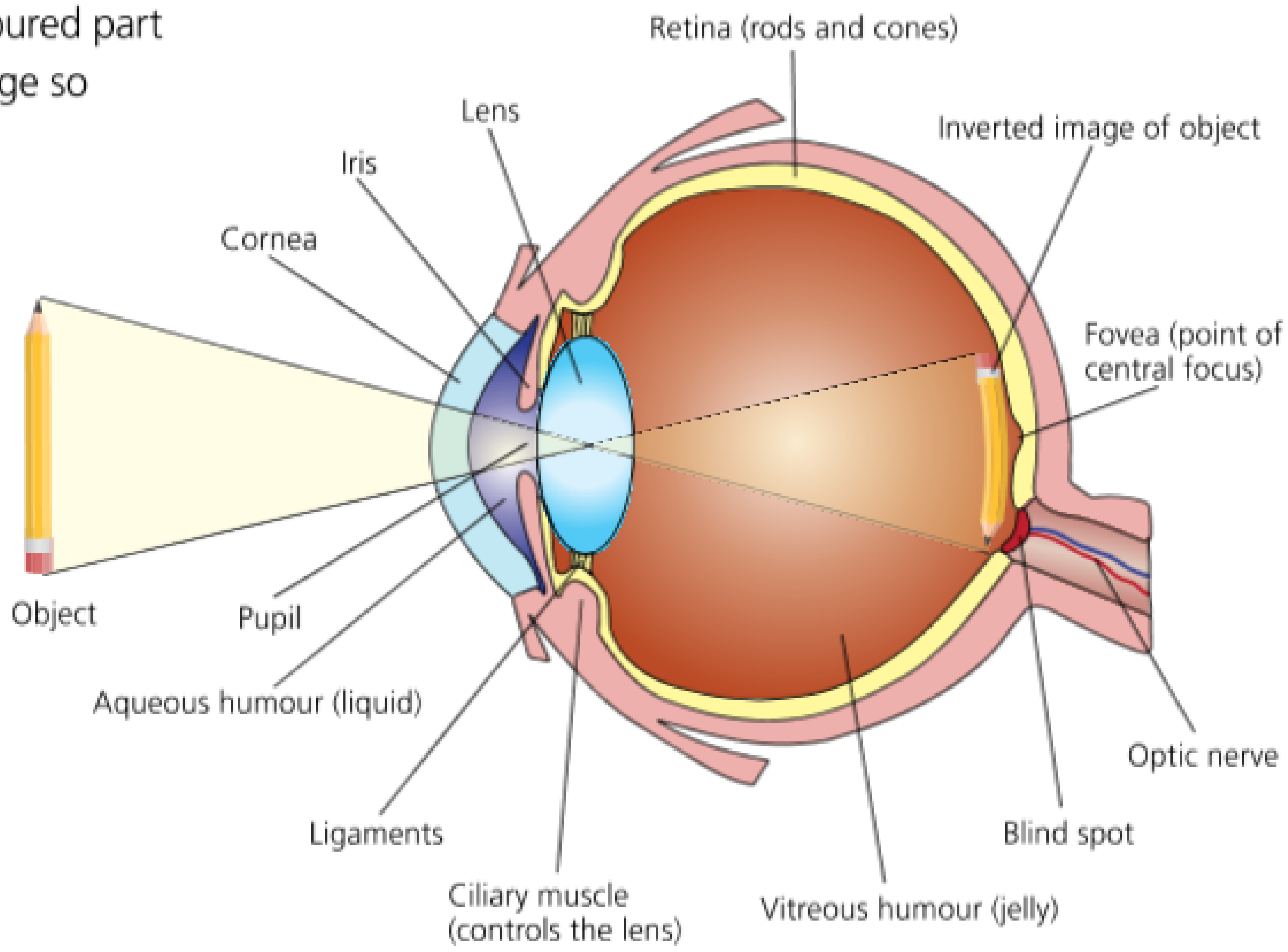
- In this activity, you have practised skills that can be assessed using Criterion A: Knowing and understanding.

How are we sensitive to energy that travels as waves?

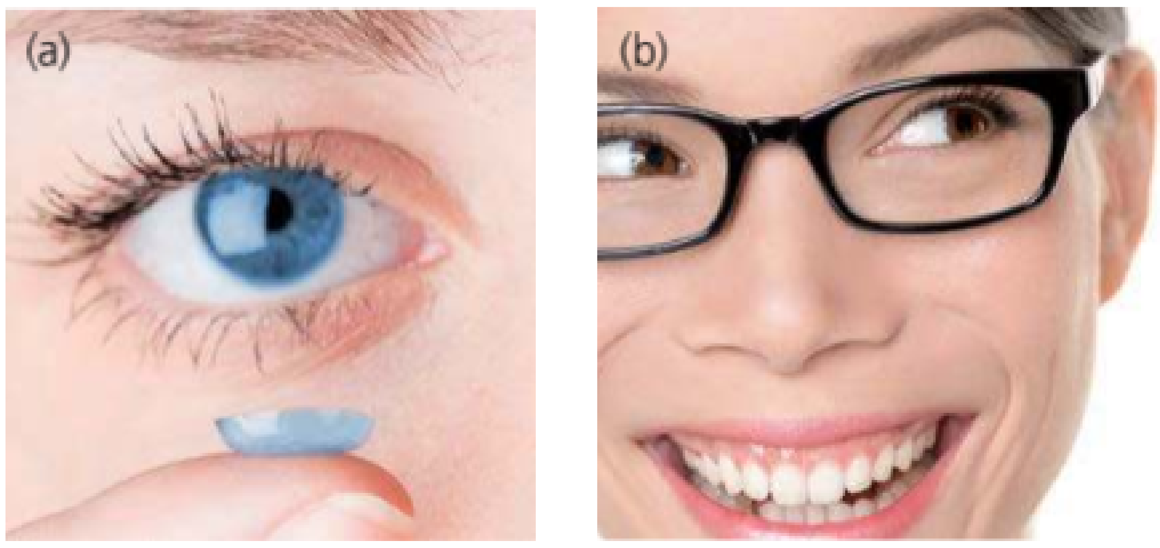
■ **Figure 4.12** Opticians measure the performance of our eyes to see if they need help. Ophthalmologists are eye doctors who diagnose problems with our sight

The eye is our body's light-sensitive equipment, but it does very much more than simply tell us whether it is light or dark around us (Figure 4.12). In the eye, light is collected through an aperture at the front called the **pupil**. Unlike the pinhole camera, the pupil is not an open aperture because it is covered by a layer of relatively stiff, transparent tissue called the **cornea**. The cornea not only protects the eye, but also holds a liquid called the **aqueous humour** over the pupil and helps to direct light into the pupil, acting as a lens. The pupil is surrounded by the **iris**, which is the coloured part of our eyes. The size of the iris can change so that we can control the amount of light entering the eye – this is an example of a **reflex**, because we cannot consciously control the iris muscles.

Once it has entered the eye through the pupil, light is then further directed by another **lens**. The lens can be stretched by the **ciliary muscles** so that it can **focus** light rays onto the **retina**. If the light rays are correctly focused, we see a clear image. If the light rays do not focus on the retina correctly, we see a blurred image instead. The retina is a layer of tissue that is covered with special light-sensitive cells. The greatest density of these cells is around a small depression in the retina called the **fovea**, which contains the cells that allow us to see colour. The information gathered by the retina is then transmitted to the brain by nerve cells, which collect at the optic nerve at the back of the eye. The area over the optic nerve does not have any light-sensitive cells, and so is a 'blind spot' where we cannot 'see'. However, the brain manages to compensate for this by piecing together the missing information, so we don't usually notice the blind spot.



■ **Figure 4.13** The human eye, seen in cross-section from above



■ **Figure 4.14** (a) Contact lenses sit on the cornea and provide an extra lens to help the eye focus. (b) Alternatively, spectacles can be cool!

ACTIVITY: Eye test

ATL

- Critical-thinking skills: Practise observing carefully

Work in pairs. In this activity you will carry out some eye tests in order to observe how the human eye works.

Test 1: Iris adaptation

Discuss: what is the function of the iris?

To observe the iris in action, you will need:

- **A magnifying glass**
- **A small flashlight**

1. **Your partner should close both eyes for about a minute.**
2. **Position the magnifying glass over one of your partner's closed eyes.**
3. **When ready, turn on the flashlight and point it at the same eye.**

SAFETY: Hold the torch no closer than about 10 cm from the eye as the bright light can be unpleasant.

4. **Ask your partner to open their eyes.**

Observe what happens to the iris! **Describe** what you saw and **explain** why the iris responds in this way.

Switch roles and repeat the test, so your partner observes your iris adaptation.

Test 2: Lens accommodation

1. **Take a piece of paper or a page in your notebook. In the centre, write a message in your normal handwriting. Keep the message secret from your partner.**
2. **Now cover one eye with your hand, and then stare at something around 25 cm from your eye – such as the top of the table.**
3. **Your partner should take the page with their message on it and hold it up about 3 m away or more.**
4. **After staring at the table for a minute or so, look up at the page.**
5. **Time how long it takes before you can read the image.**

Explain what happens in this test with reference to what you have learned about the function of the lens in the eye.

Switch roles and repeat the test, so your partner reads your message.

Test 3: Blind spot

Look at the image in Figure 4.15. Close your right eye, and stare at the red spot with your left eye. Now slowly move your head closer to the page.

Figure 4.15 Blind spot testing

At one point, the blue line will no longer appear broken – the 'gap' will disappear.

Explain why this occurs, with reference to what you have learned about the blind spot. Why does the gap disappear?

Assessment opportunities

- This activity can be assessed using Criterion A: Knowing and understanding.

Figure 4.16 'Seeing-eye' or 'guide' dogs lend their eyes to help blind or partially sighted people

What other kinds of electromagnetic radiation are there?

THE HIDDEN RAINBOW

When we say that something looks 'light,' we tend to think of bright colours, or white. The world we see is full of colour – even if we may not always agree on what those colours are. Early thinkers thought that colour was something that matter 'gave' to pure, white light – just as a blob of red paint 'taints' white paint, so colour could 'dye' light. It was Isaac Newton (busy man!) who first showed that the opposite was the case: in fact, white light contained many different colours.

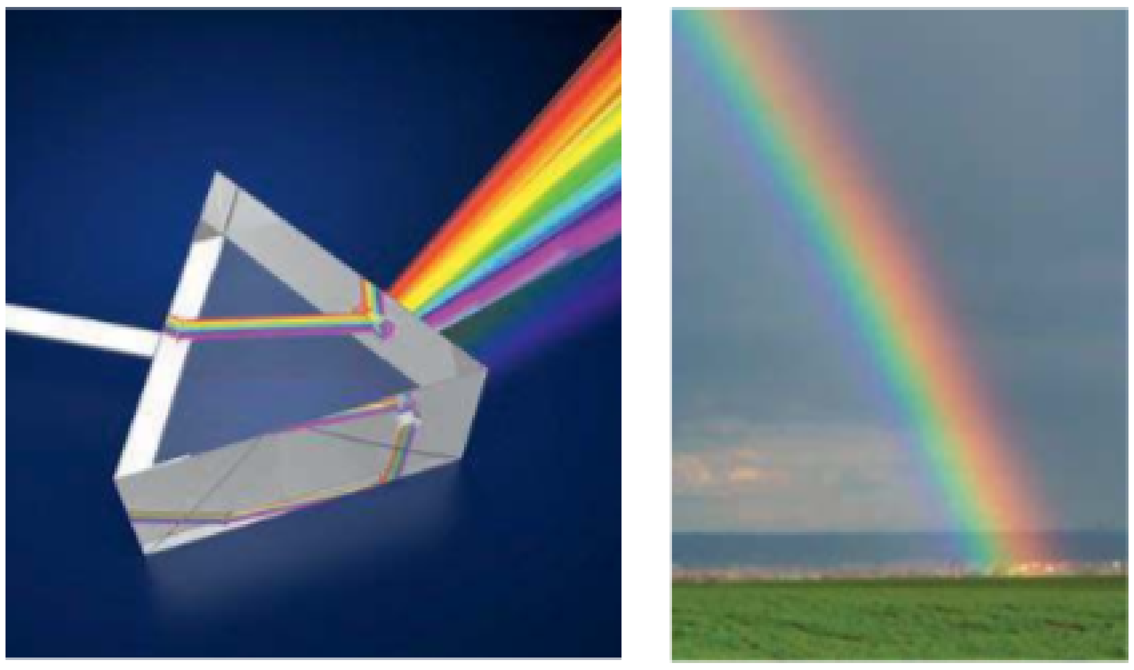
As we can see in Figure 4.17, the white light entering a glass **prism** is 'split' into different colours. The different colours we see are in fact different kinds of light wave, of different frequency. Frequency is the number of wave oscillations that happen every second. The **time period** of a wave is how long it takes for each oscillation to occur, so

Frequency = Number of oscillations per second

$$f = \frac{1}{T}$$

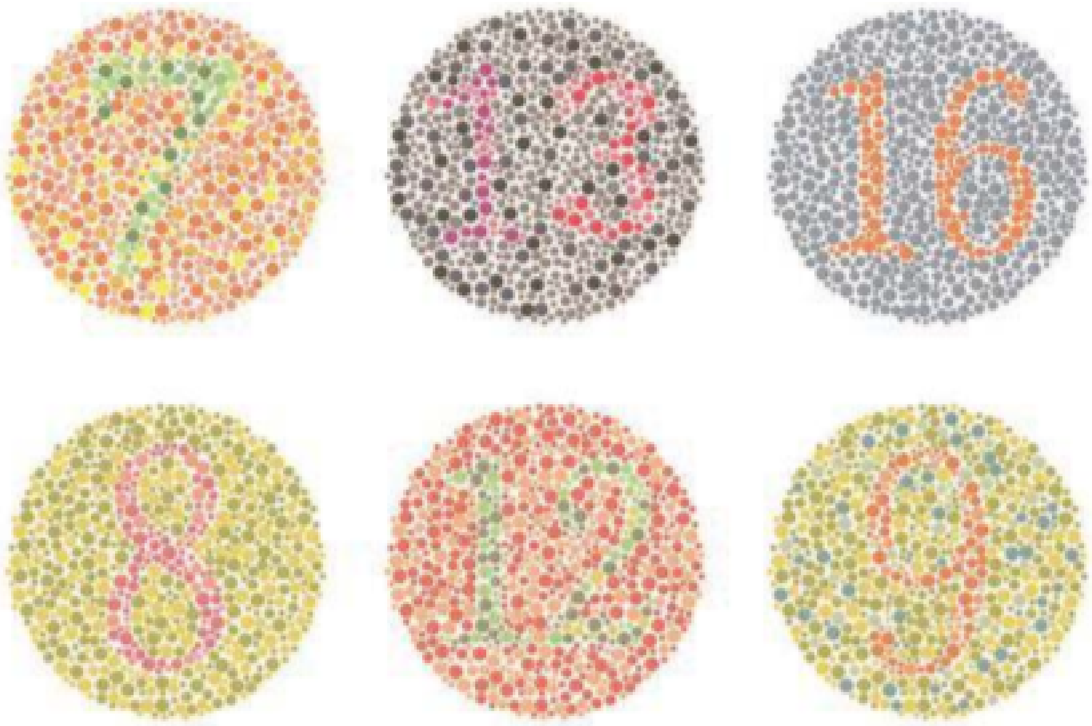
where frequency f is measured in Hertz (Hz), and time period T in seconds (s).

Colour is the way that we 'see' light of different frequencies. Colour vision is provided by special light-sensitive cells in the retina called **cones** (because they are shaped a little that way). Cone cells have frequency-sensitive parts that send a different signal to the brain when light of different frequencies falls on them. The cone cells respond to light that is red, green or blue: these are then the **primary colours** that form the basis of all other colours when mixed together. Cone cells are crowded in around the fovea, and they only work well in bright conditions. For conditions of lower brightness, we have cells called **rods** which are very sensitive to low light levels, but cannot distinguish between different frequencies.



■ **Figure 4.17** Where does colour come from?

Not everyone can see colour in the same way – our colour vision depends on the way that the cones operate. Problems with colour vision are often inherited from our parents, and are caused by cone cells that do not respond to one particular colour (Figure 4.18). One very common type of 'colour blindness' is the inability to distinguish between red and green – this is called **deuteranopia**.



■ **Figure 4.18** 'Colour blindness' tests: can you see the numbers in these patterns?

EXTENSION

Find out more about 'colour blindness' by researching online. You may wish to start here: www.colourblindawareness.org

ACTIVITY: Bending light

ATL

- Critical-thinking skills: Evaluate evidence and arguments

Earlier in this chapter, we discussed how thinkers about light realised that light rays travel in straight lines. But is this always true?

Figure 4.19 Observing light bending

1. **Take a ruler or pencil and place it inside a small glass beaker, half-full of water. Look at the beaker from the side, as shown in Figure 4.19. State what appears to be happening to the ruler as it enters the water.**

This optical illusion is caused by the bending of light as it passes from the air into the water. This effect is known as **refraction**.

2. **Now drop a coin into the bottom of the beaker. Position your head so that you are looking down into the beaker from above. Describe how deep the water appears to be.**
3. **Juan wants to dive into a deep swimming pool, in order to reach the bottom. But when he dives into the water, he is surprised to find that it takes him much longer than he thought to reach the bottom.**

   With reference to your answers in 1 and 2 above, explain why it might take Juan a longer time than he expects to reach the bottom of the pool.
4. **Look again and analyse the prism and spectrum shown in Figure 4.17. Describe what is happening to the light as it enters the prism. What is happening to the light as it leaves the prism?**

   State which colour appears to be affected least. Which colour appears to be affected most?
5. **Juan makes a prediction: 'The refraction of light depends on the frequency of the light waves'. With reference to your answers above, evaluate Juan's prediction. What evidence is there that he is correct?**

Assessment opportunities

- This activity can be assessed using Criterion A: Knowing and understanding.

In the *Three Colours* activity we saw how primary colours can be used to form all colours when mixed. Notice that when we added together coloured light, the colours mixed to become 'lighter' or more white. This is just the reverse process to the 'splitting' of a spectrum from white light discussed earlier. It is also the basis of colour reproduction in cinema and electronic devices (Figure 4.20).

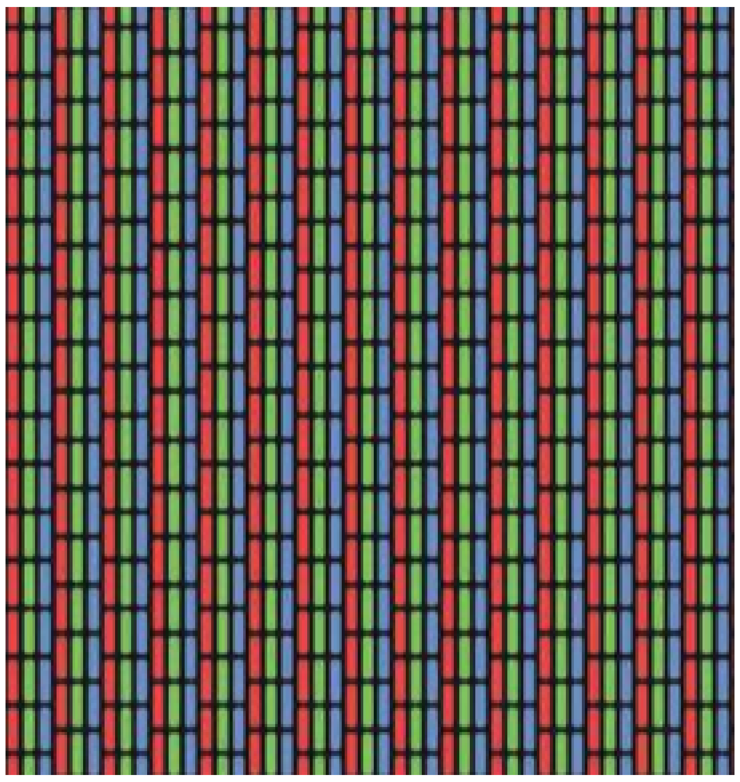


Figure 4.20 Electronic screens reproduce colour using illuminated dots called 'pixels' in primary colours

On the other hand, when we placed coloured filters in front of each other in the third experiment, the brightness of the light reduced and became darker. Colour subtraction of this kind explains the way that surfaces – such as paint – can appear different colours. When white light falls onto a surface covered with coloured paint, only some frequencies reflect back. These frequencies then correspond to the colour we perceive in that surface. Painters achieve a range of different colours by mixing 'subtractive' primary colours. These can be red, yellow and blue, or cyan (blue-green), magenta (red-blue) and yellow.

ACTIVITY: Three colours

■ ATL

- Critical-thinking skills: Draw reasonable conclusions and generalizations

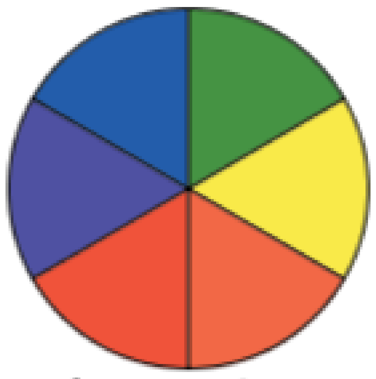
Work in pairs. In these activities, you will explore the way that we perceive colour.

Experiment 1: Spin the colour wheel

For this experiment, you will need:

- **1 white paper plate**
- **1 protractor**
- **1 pencil**
- **Sticky-tac**
- **Felt tip pens, markers or paints: red, orange, yellow, green, blue, violet**
- **A piece of string**

1. **Use the protractor and pencil to divide the paper plate into six equal sectors. Colour the sectors using the different coloured pens, to make a colour wheel as shown in Figure 4.21.**



■ **Figure 4.21** Colour wheel

2. **Make a small hole in the centre of the wheel. Make the string into a loop, and pass the loop through the hole in the centre of the wheel.**
3. **Use the sticky-tac to hold the string in the hole at the centre of the plate.**
4. **Now pick up the ends of the string with two hands and twist the string. Pull on the ends of the string to make the colour wheel spin!**

Observe the effect of spinning the wheel on your perception of the colours. **Record** your observations.

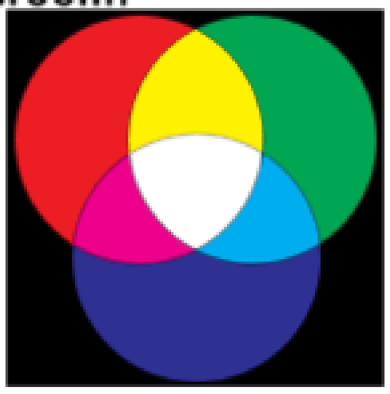
Experiment 2: Pixel dots

For this experiment you will need:

- **3 ray boxes, and suitable power supply**
- **3 pieces of card to fit the end of the ray box**
- **3 pieces of coloured plastic or acetate: 1 red, 1 blue, 1 green**
- **White wall, or a white screen**

SAFETY: Be careful not to touch the light bulb inside. Take care not to look directly at the bulb when switched on.

1. **Cut the pieces of card to fit the aperture in the ray box. Make a small hole in the centre of each card, about 1 cm in diameter.**
2. **Cut the pieces of coloured plastic to fit the aperture of the ray box.**
3. **Slot the card into the aperture of the ray box, and slot the plastic behind the card.**
4. **Connect the ray boxes to the power supplies.**
5. **Turn out the lights in your classroom!**
6. **Turn on the first ray box (any one will do). Position the ray box so that the light projected from the box appears on the screen.**
7. **Now position the other ray boxes so that they project their light overlapping each other as shown in Figure 4.22.**



■ **Figure 4.22** Colour spots from ray boxes

Observe the effect where the light spots overlap. **Record** your observations.

Experiment 3: Subtracting colour

1. **Take one of the ray boxes from experiment 2. This time, take the card out of the ray box. Turn it on to project the coloured light on the screen.**
2. **Now take one of the coloured plastic squares from another ray box and slot this into the ray box, behind the square that is already in there.**
3. **Repeat for the third coloured square.**

Observe the effect on the projected light of adding each of the coloured squares. **Record** your observations.

Conclusion

Explain the colour effects you observed when the colours were mixed. **Outline** how the effects observed in experiments 1 and 2 are different to the effect observed in experiment 3. **Summarize** how different colours are formed.

Evaluation

Was the experiment valid? What other observations could you have made to extend the investigation? Was the experiment reliable? What could you have done to make the observations more reliable?

◆ Assessment opportunities

- In this activity, you have practised skills that are assessed using Criterion C: Processing and evaluating.

Do artists and scientists have anything to say to each other?

■ **Figure 4.23** (a) Pointillist painting by Georges Seurat (1859–1891) (b) *The Sower* by Vincent van Gogh (1853–1890) – van Gogh was fascinated by the effect of light on colour (c) Piet Mondrian (1872–1944) reduced his use of colour to three primary colours

SEE-THINK- WONDER

Look at the paintings in Figure 4.23.

What do you see? What do you think about these images? What do they make you wonder?

Discuss: Why do you think the artists chose to use colour in these ways? What effect does their use of colour have on the impact of their art?

To what extent do you think that understanding the science of colour helps us to appreciate these paintings?

▼ Links to: Arts

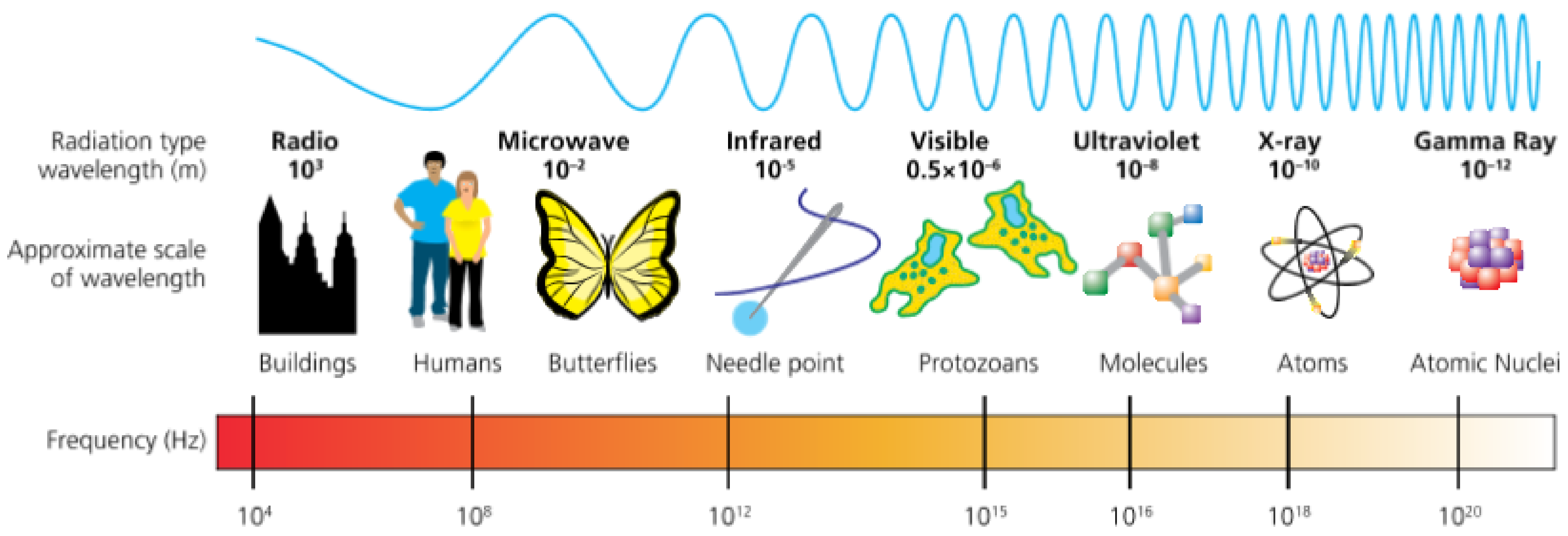
Artists make choices about the way they represent images so that they have a particular impact on the viewer. Understanding the way colour vision works has influenced artists in many media, from painting to photography to cinema.

Do we see all the light there is to see? In fact, the energy we call 'light' is just a part of the picture. We saw earlier that light is a form of wave energy called electromagnetic radiation, and it isn't limited to the frequencies our eyes can perceive. Some living creatures 'see' the world very differently to us because their eyes are sensitive to different frequencies.

The eyes of birds and insects are more sensitive to blue-violet light and so they see flowers differently to us – using what is known as 'ultra-violet'. Similarly, many snakes have special receptors on their snouts that enable them to 'see' beyond the red region of the spectrum, into 'infrared'. Digital cameras (such as those built into mobile phones) use a special microchip called a charge couple device (CCD) to collect light.

EXTENSION

In *The Sower*, van Gogh has chosen colours to suggest the end of the day. At the beginning and the end of the day – if the sky is clear – the Sun's light becomes reddish in the sky. At midday however, the sky appears to be clear blue. Research **atmospheric scattering** to find out why the sky changes colour throughout the day.



■ **Figure 4.24** The electromagnetic spectrum

Most of the time the images they form are like those we 'see' with our eyes. But if you point your phone camera at a TV remote control and press any button on the remote, you will see something surprising.

The flashing light you see in the image is invisible to our eyes normally. It is infrared radiation used by the remote to transmit information to the TV. The CCD in the camera is sensitive to infrared that we cannot see.

All the different varieties of electromagnetic wave are shown by the **electromagnetic spectrum** (Figure 4.24). The spectrum also shows the effect that these different waves have on matter.

ACTIVITY: Wave scare stories

ATL

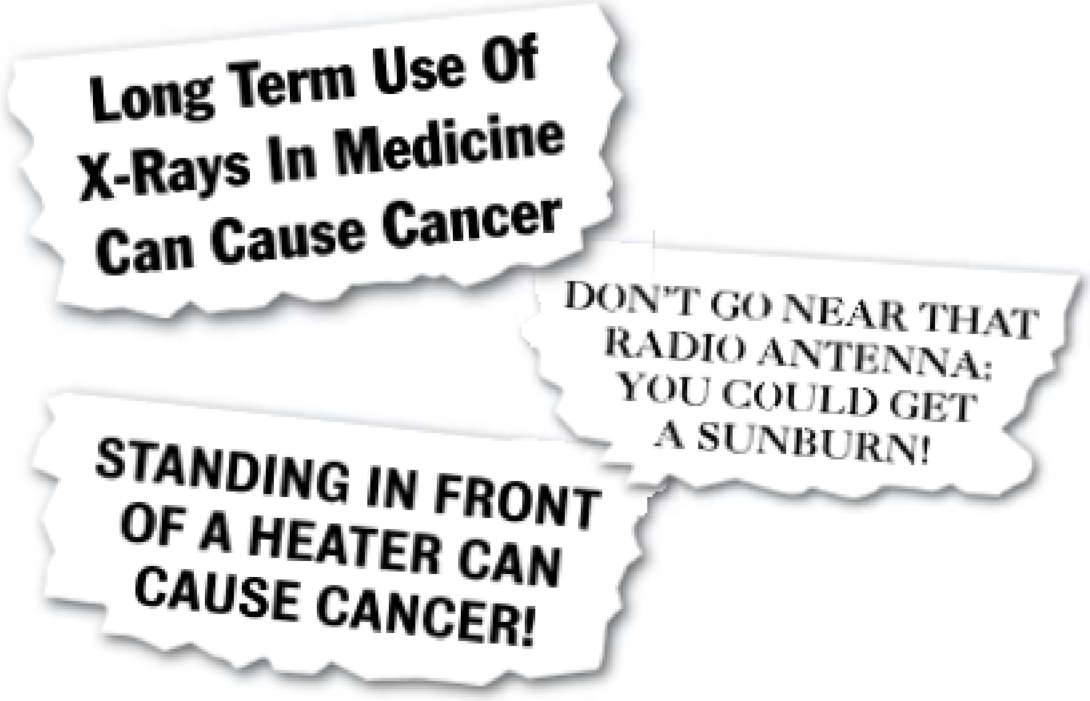
- Critical-thinking skills: Evaluate evidence and arguments; Develop contrary or opposing arguments

Electromagnetic waves are properly referred to as 'radiation' because they are a form of energy that travels through space. However, the word 'radiation' is also associated for many people with the radiation produced by isotopes (see Chapter 2). This can be confusing and lead to mistaken ideas.

Look at the claims in Figure 4.25, taken from some websites.

With reference to the electromagnetic spectrum in Figure 4.24:

- **Outline** the main regions of the electromagnetic spectrum.
- **State** which frequencies might cause cancer or sunburn.
- **Research** using the search term biological effects of radiation and **describe** how some kinds of electromagnetic radiation can cause damage to biological cells.



■ **Figure 4.25**

- **Evaluate** the claims in the websites. **Summarize** the arguments they make, and **state** whether or not you think they are true.
- **Discuss** why we must be careful to check the information we can find on internet websites. Use your findings to **outline** ways to be sure that information we research online is scientifically valid and reliable.

Assessment opportunities

- This activity can be assessed using Criterion A: Knowing and understanding.

ACTIVITY: Protecting ourselves from the Sun

ATL

- Critical-thinking skills: Interpret data
- Creative-thinking skills: Apply existing knowledge to generate new ideas

Look back at Figure 4.24. Can you identify the ultra-violet region of the spectrum? Electromagnetic waves with these frequencies can cause damage to our skin. At the least, they can cause sunburn; at worst, with long and frequent exposure times, they can cause skin cancer.

Sun screen is 'rated' according to the amount of protection it provides. However, in different parts of the world, different ratings are used, so it can be difficult to make comparisons. In this investigation, you will be a research scientist. You have been asked by the World Health Organization (WHO) to compare the effects of different kinds of sun screen. You must report your findings to the WHO in the form of a scientific report.

Research ultra violet harmful effects to find out about the effects of ultra-violet radiation on our skin.

Individually or in pairs, carry out an investigation to find out how different materials might protect us from the effects of ultra-violet radiation in the Sun's rays.

To give you some ideas, you might wish to think about how some of this equipment could be used in your investigation, if available:

- **Acetate or plastic sheets**
- **Clingfilm**
- **Sun screen of different sun protection factors (SPF) or similar**
- **Ultra-violet source ('black light')**
- **Ultra-violet sensor**
- **Ultra-violet colour beads**

Select an independent variable to change and a dependent variable to measure for your experiment.

Formulate an inquiry question for your experiment.

Use the scientific experiment cycle in Figure 4.26 to help design your investigation.

Report your findings in the form of a full scientific investigation report, with a presentation of your conclusions.

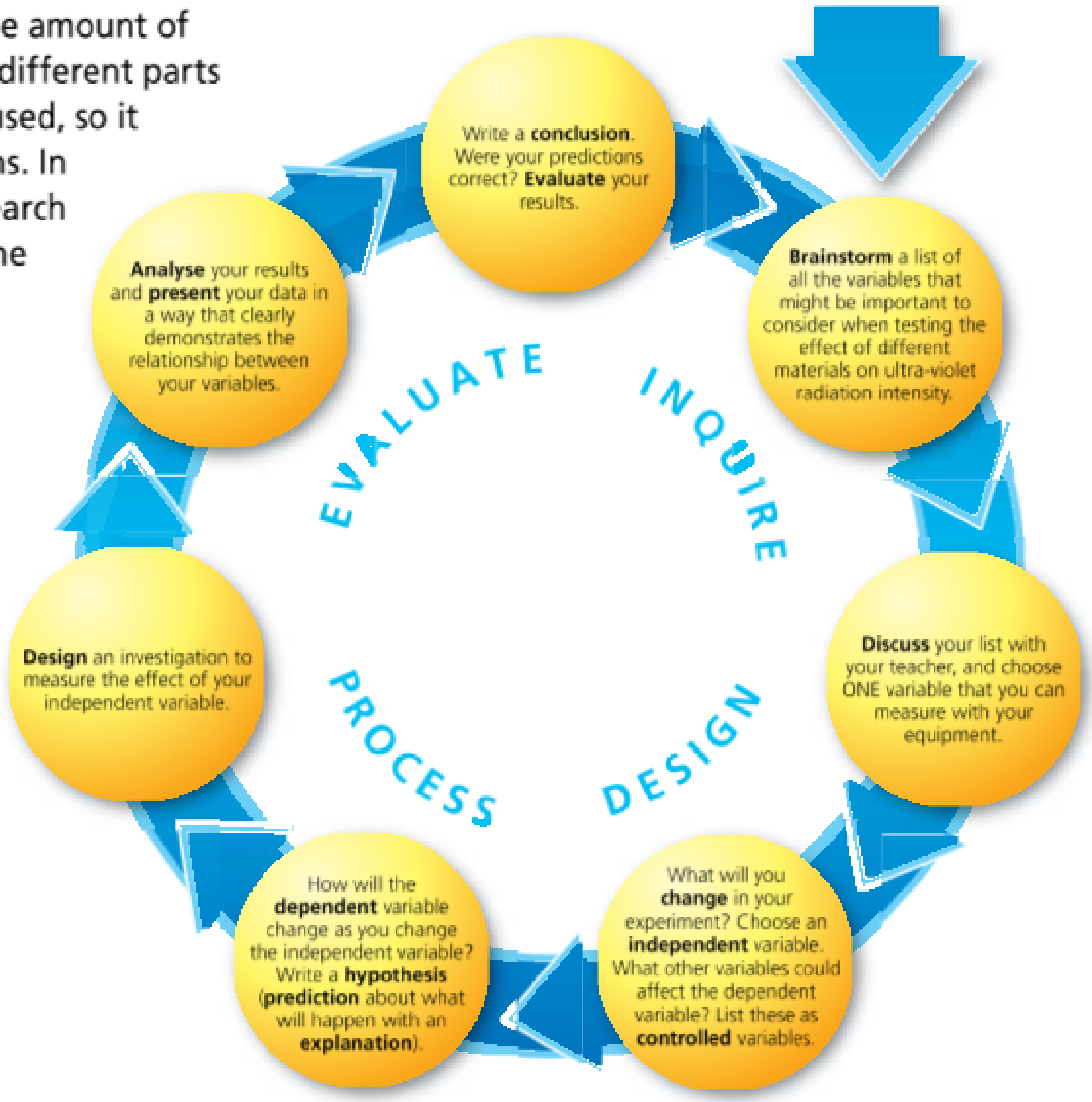


Figure 4.26 Scientific experiment cycle

Assessment opportunities

- This activity can be assessed using Criterion B: Inquiring and designing, and Criterion C: Processing and evaluating.

How are we sensitive to sound waves?

SOUNDS LIKE FUN

In the *Different waves, different media* activity earlier, we saw how a loudspeaker produces sound waves through vibration. How do we experience these waves as sound? How are sound waves transmitted?

Sound is the effect of a medium – such as air – being compressed periodically, and the **compressions** spread out from the source as sound waves. The oscillations are longitudinal because the air molecules oscillate backwards and forwards in the same direction in which the wave travels.

SEE-THINK-WONDER

Watch a video online by searching **video: sound wave fire extinguisher** or going to https://youtu.be/uPVQMZ4ikvM.

What do you see in the video? What does it make you think? What does it make you wonder?

ACTIVITY: Flaming noise!

ATL

- Critical-thinking skills: Draw reasonable conclusions and generalizations

Work in pairs or carry out as a demonstration. In this activity you will observe sound waves travelling through the air from a loudspeaker.

You will need:

- **Up to 10 small 'night-light' candles**
- **A powerful loudspeaker, such as that used in a stereo system or for a computer**
- **A signal generator and amplifier**

Method

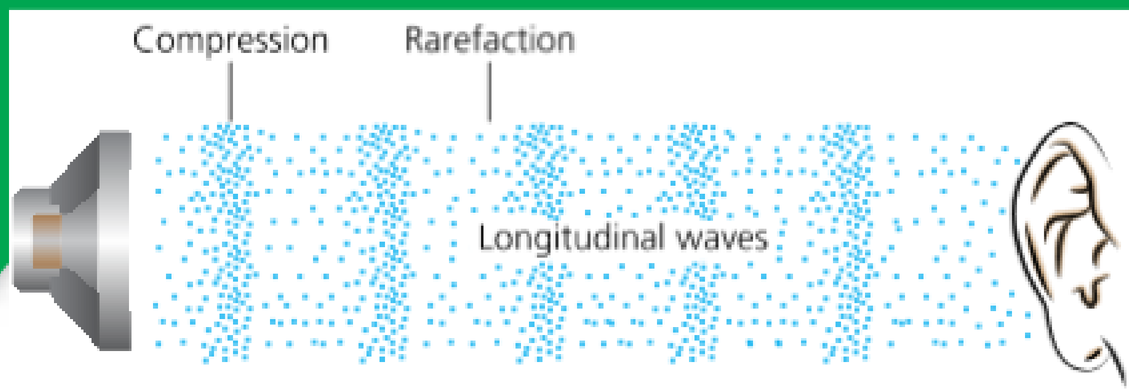
1. **Place the loudspeaker on a surface and connect to the amplifier output (your teacher may need to help you do this).**
2. **Identify the amplitude control and the frequency control on the signal generator. Turn these to their lowest settings.**
3. **Turn on the signal generator. Turn up the frequency to around 100 Hz. Now turn up the amplitude as loud as you can without the sound becoming uncomfortable.**
4. **Now turn off the signal generator.**
5. **Position the night-light candles in a row from the base front of the speaker. Alternatively, if the loudspeaker has a 'bass port' or hole at the back for low frequency (bass) sounds, position the candles in front of this.**
6. **Use a lighted splint to light the night-lights.**
7. **Turn the frequency control on the loudspeaker down to 1 Hz.**
8. **Turn the loudspeaker on and observe the effect on the candle flames. (If you don't see an effect, you may need to turn up the amplitude.)**
9. **Change the frequency of the signal. Observe the effect on the flames at different frequencies.**
10. **Change the amplitude of the signal. Observe the effect on the flames.**

Interpret your **observations** to **outline** the effect on the flames of changing amplitude and frequency.

Search **video: audio speaker slow motion** to watch video of a loudspeaker producing sound. **Explain** your observations with reference to the video and to what you know about longitudinal wave motion (Figure 4.27, on the next page).

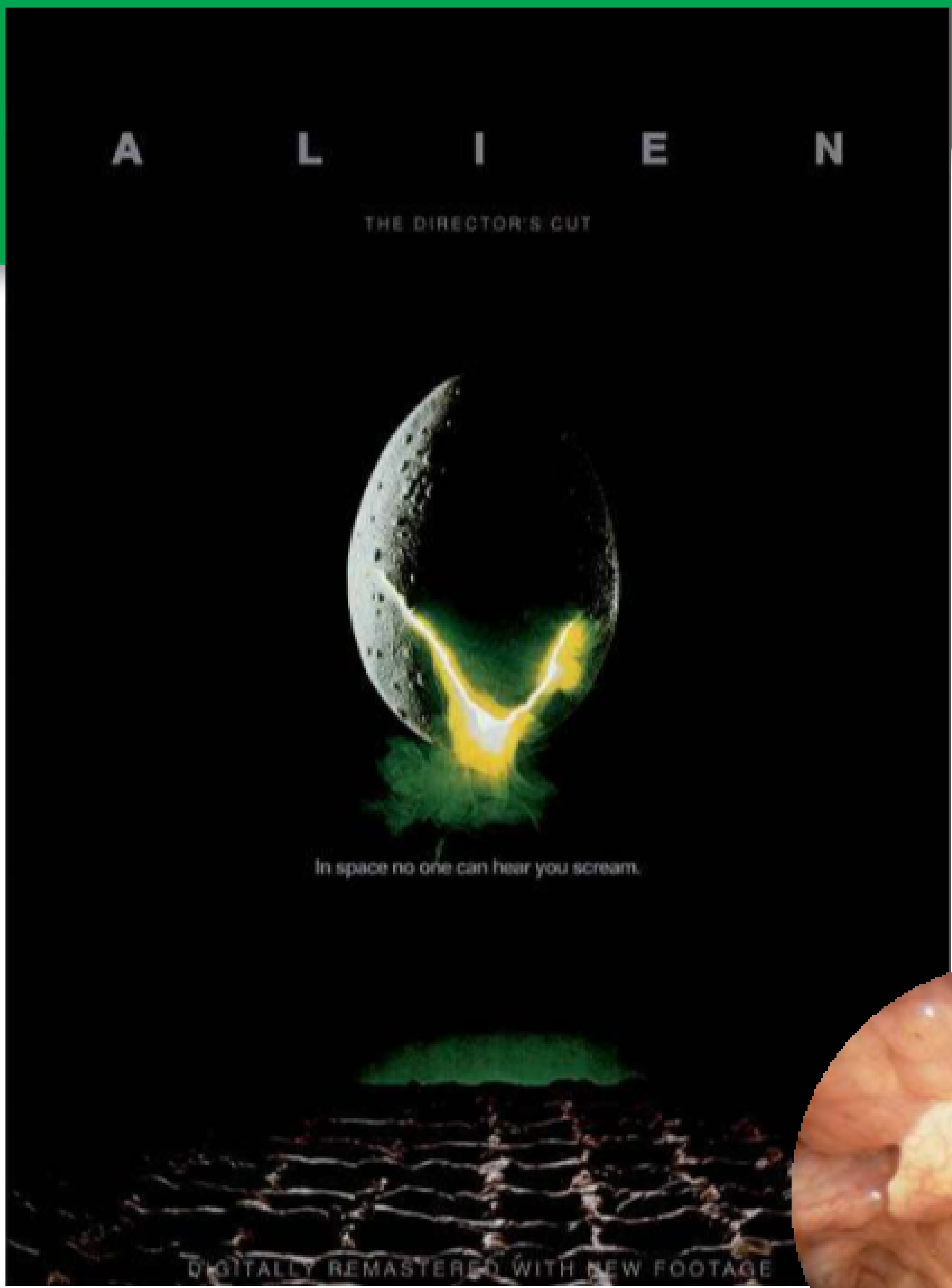
Assessment opportunities

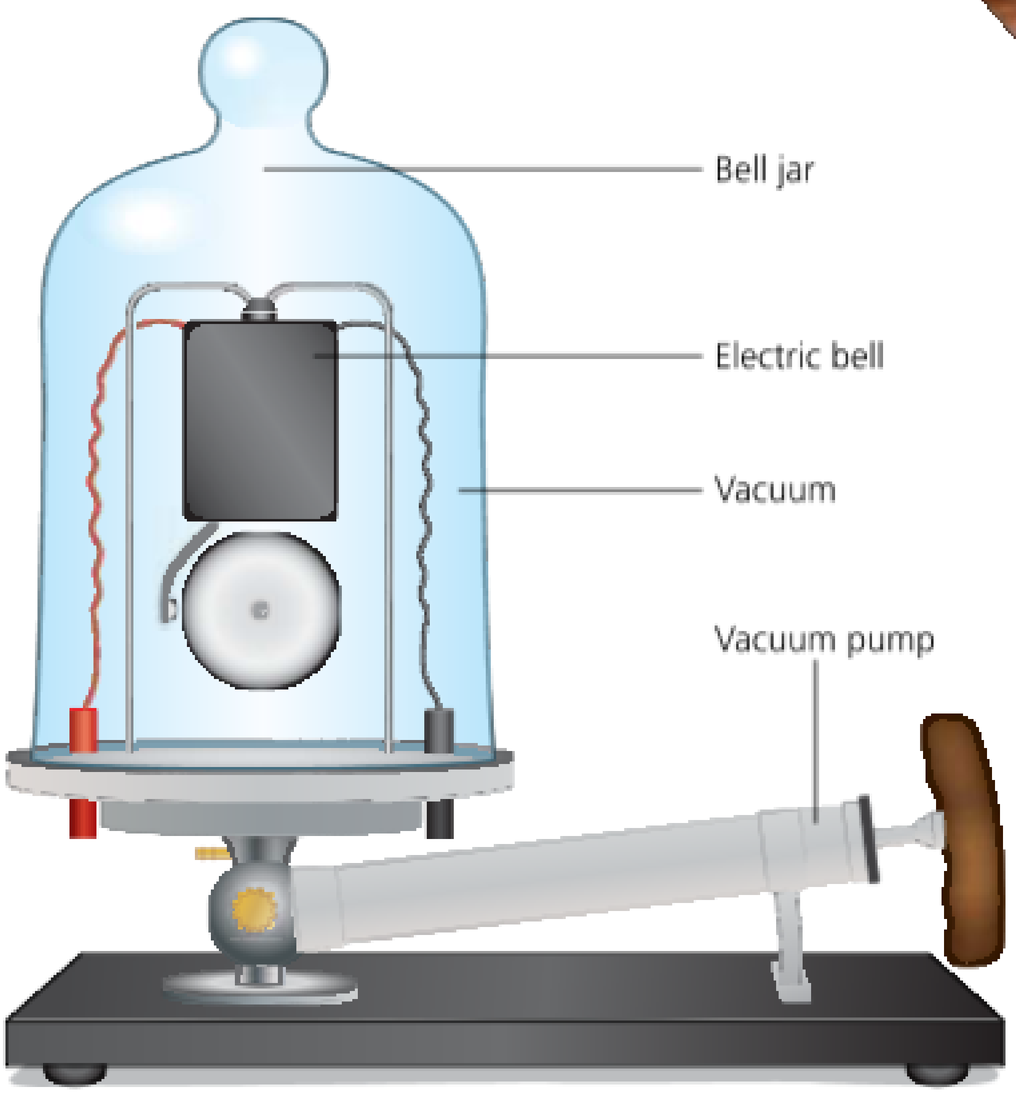
- In this activity, you have practised skills that are assessed using Criterion C: Processing and evaluating.



■ **Figure 4.27** Sound waves are compressions in a medium and oscillate longitudinally

All objects that oscillate mechanically in a medium produce sound waves in this way. Since sound is a form of mechanical oscillation, it requires a medium through which to travel: in a vacuum, there is no sound – space is completely silent! This can be demonstrated by placing a source of sound such as an electric bell or buzzer inside a bell jar, and then using a vacuum pump to remove the air: your teacher may demonstrate this, or you can see a video of the experiment by searching **video: bell in a bell jar.**





■ **Figure 4.28** Does the bell jar experiment confirm the slogan for the movie *Alien*?

■ **Figure 4.29** Our voices are produced by oscillating tissue in our throats called vocal cords. How do these musical instruments produce their sound?

DISCUSS

ATL

- Critical-thinking skills: Draw reasonable conclusions and generalizations

For each of the instruments shown in Figure 4.29, **discuss**:

- **What is the source of vibration?**
- **How is the amplification achieved?**

All musical instruments produce sound through mechanical oscillation in some way (Figure 4.29). In addition to a source of vibration, a sound producer usually also needs some way to make the sound louder – an **amplifier**. Most often this is achieved by using a hollow space or cavity, which makes sound louder through a process called **resonance**.

Of course there would not be much point in our making sound with our vocal cords if we could not also hear it! Figure 4.30 shows how our ears help us do this.

Sound enters the ear through the **ear canal**. The fleshy part on the outside of the head is called the **pinna**, and this allows us to locate the direction and so the origin of the sounds we hear. The tissues of the **outer ear** also produce a waxy substance that – along with fine hairs – traps anything entering the ear that we don't want in there. At the end of the ear canal there is a fine, drum-like membrane called the **ear drum**. When sound waves hit the ear drum it begins to oscillate with them, just like a drum-skin, but in reverse. The ear drum is connected to three tiny bones known as the malleus, incus and stapes – collectively called the **ossicles** – that behave as a system of levers to transfer oscillations to a second membrane called the **oval window**. This covers the opening to a spiral-shaped bony tube called the **cochlea**. The cochlea contains a fluid that transmits the oscillation and the vibrations are then detected by tiny hair cells connected to nerve cells. The hair cells convert the mechanical vibration into an electrical signal in the nerve cells, and this is transmitted to the brain along the **auditory** or **vestibulocochlear nerve**.

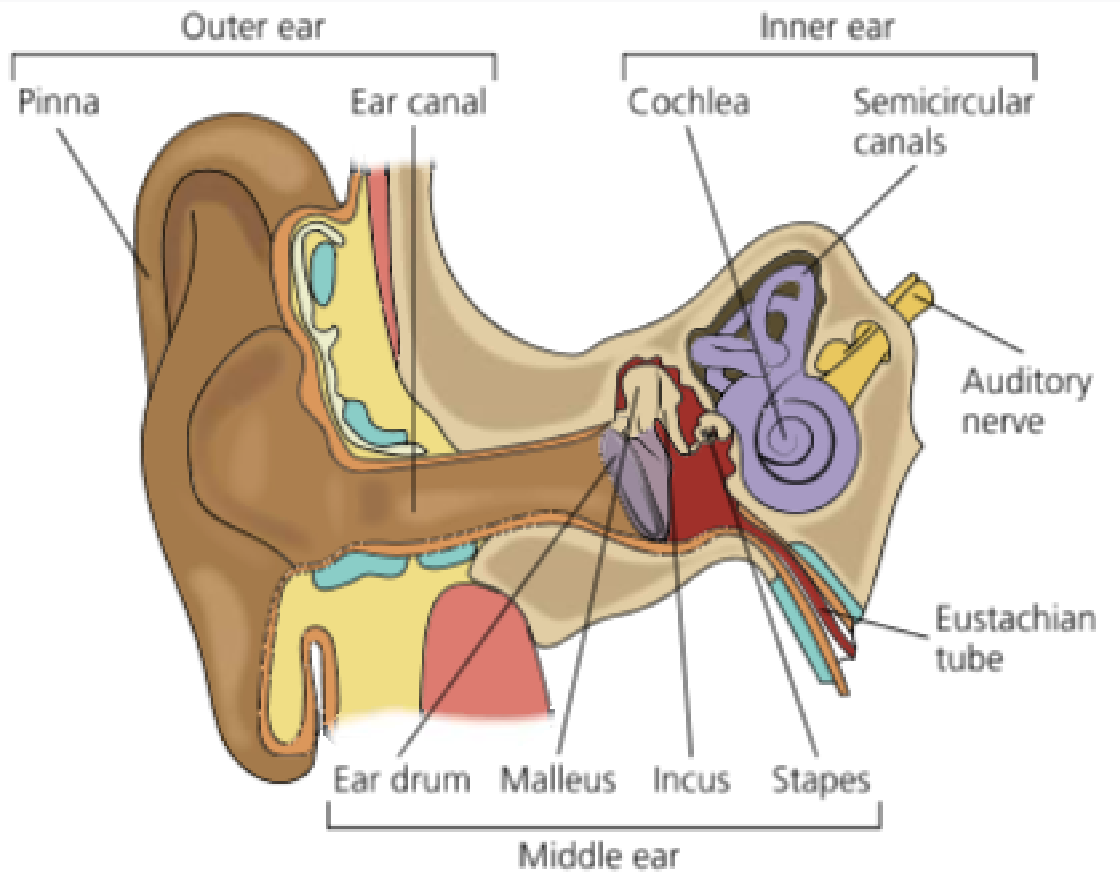


Figure 4.30 The human ear

It's interesting to note that each ear also contains three semicircular canals at 90° to each other responsible for our sense of balance.

Find out more about how the ear works by searching **video: vibration ear sound** or **www.webmd.com/cold-and-flu/ear-infection/video/ear-anatomy**.

Human ears are sensitive to sounds over a wide range of frequencies and amplitudes. While the ear detects vibrations, once they have been converted into electrical signals the brain interprets them as sound. We experience different amplitudes as **volume**, while different frequencies of sound are experienced by us as **pitch**. Furthermore, just as we saw how other living things can see different frequencies of light, so too many animals can perceive different frequencies of sound – see *MYP 4–5 Physics by Concept*, Chapter 7 for more details!

ACTIVITY: Seeing with sound

ATL

- Information literacy skills: Make connections between various sources of information
- Critical-thinking skills: Gather and organize relevant information to formulate an argument

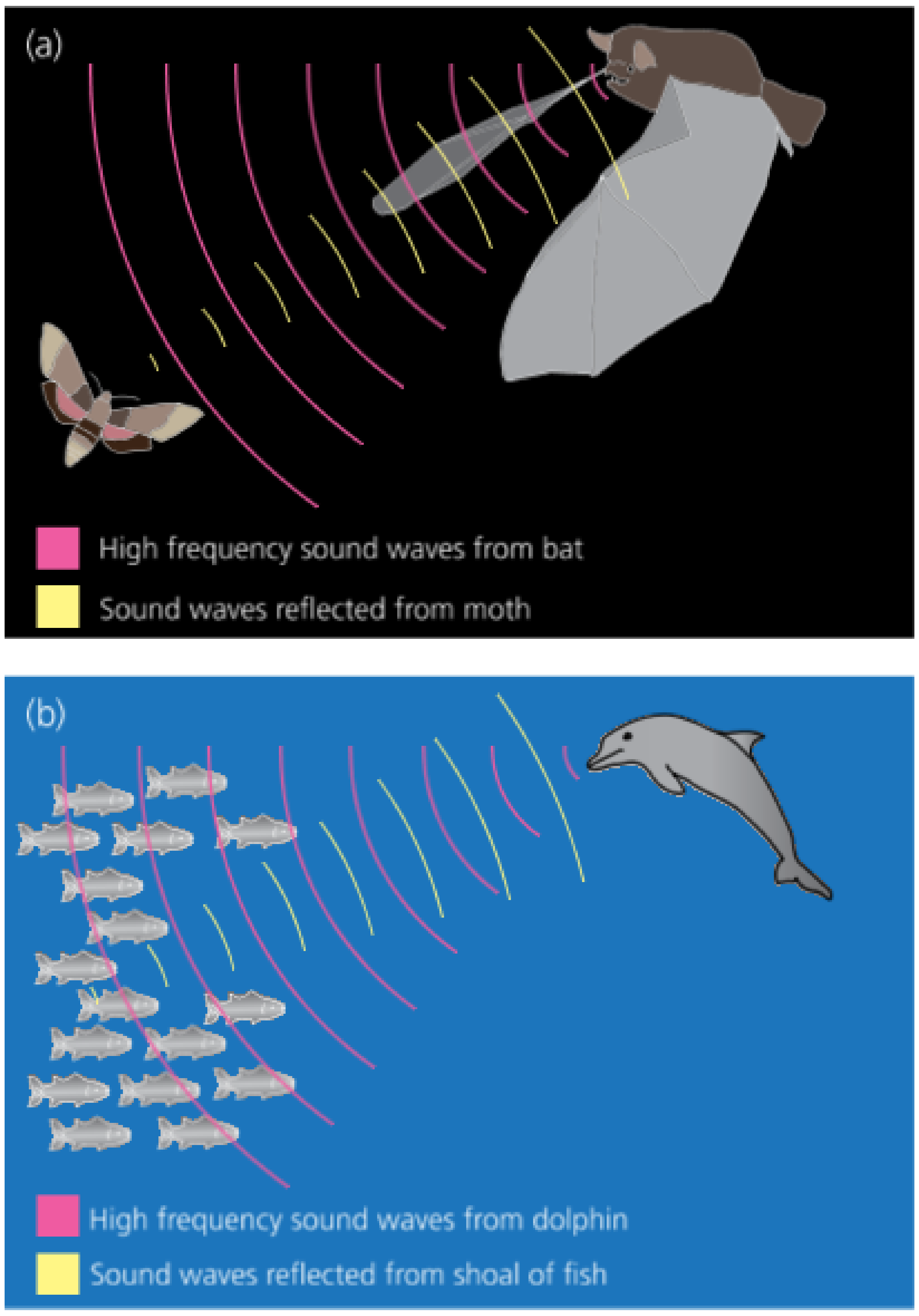


Figure 4.31 Bats 'see' using reflected sound waves (a), as do dolphins and other marine mammals (b)

Figure 4.31 shows how bats and dolphins use high-frequency sound waves to detect objects when it is difficult to see using light alone. This technique has been adapted by humans as **sonar**, which is used by ships and submarines to detect objects beneath the water.

Figure 4.32 shows the equipment used to make an **ultrasound** scan of a fetus inside a womb.

Figure 4.32 (a) Ultrasound scan of a fetus in the womb (b) ultrasound equipment

Individually, **interpret** the images to answer these questions.

- **Describe how bats and dolphins use sound waves to detect objects in the dark.**
- **The speed of sound in air is around 330 m s^{-1}. If a bat emits a single high-pitched 'click' of sound in a cave that is 20 m wide, calculate the time taken for the echo of the sound to return to the bat.**
- **Dolphins use seawater to transmit their high-frequency 'clicks'. If a dolphin is 20 m away from an underwater object, deduce whether it will 'see' the object sooner or later than the bat.**

Hint
Research the speed of sound in water!

- **Suggest how an ultrasound scan can produce an image of an object within the human body.**

Assessment opportunities

- This activity can be assessed using Criterion A: Knowing and understanding.

Figure 4.33 Sound waveforms for music are very complex

Not all sound is welcome – if you have ever stood outside at an airport or next to a building site, you will know how disruptive very loud sounds like those from aircraft taking off or from heavy machinery can be. Our sensitivity to different amplitudes is measured using a scale called the **decibel scale**.

Loudness (dB)	Example	Effect	Relative amplitude
140	Jet taking off 50m away	Threshold of pain	10,000,000
120	Jackhammer nearby/loud car horn	Extreme discomfort	1,000,000
100	Disco or rock concert 1m from speaker.MP3 player with earphones, maximum volume	Very loud	100,000
80	Hairdryer - busy city traffic	Loud	10,000
60	Normal conversation	Moderate	1000
40	Raindrops	Faint	100
20	Whisper	Very faint	10
10	Tree leaves in wind		3.162
1	Shallow breathing		1.122
0		Threshold of hearing	1

Figure 4.34 The decibel scale

ACTIVITY: Different pitches, different volumes

ATL

- Information literacy skills: Make connections between various sources of information

Individually, look at the decibel scale in Figure 4.34.

- **State the information given on the scale.**
- **Interpret the scale and state the ratio of the amplitudes between two sounds that are 0 dB and 60 dB, respectively.**

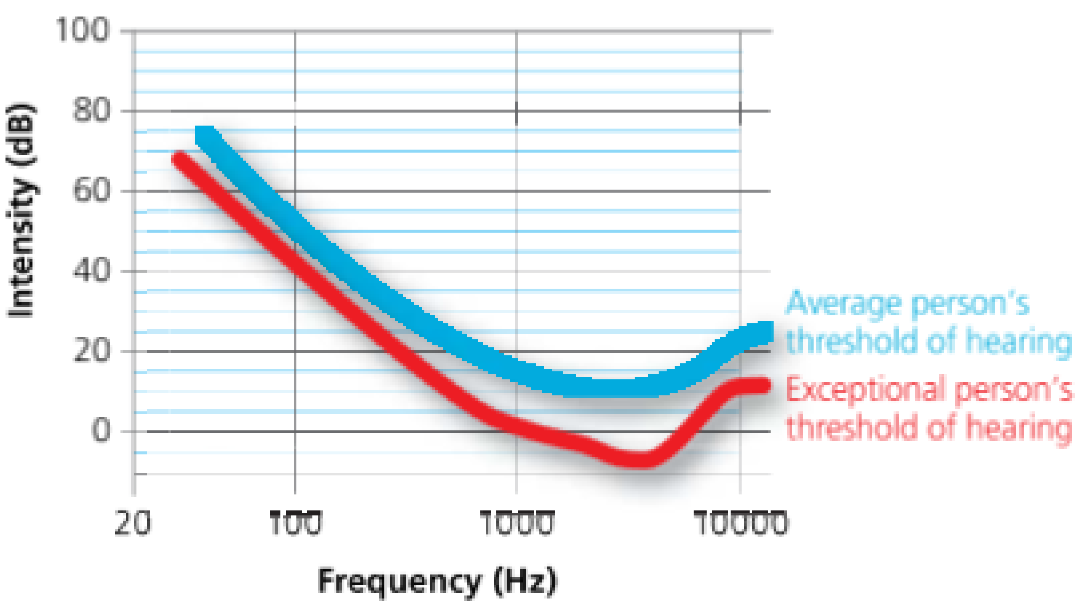


Figure 4.35 Human auditory response frequency

Figure 4.35 shows the way that the sensitivity of our hearing changes at different frequencies for a person between 10 and 20 years old. **Interpret** the information in Figure 4.35 to answer these questions.

- **Outline** the way that our hearing sensitivity changes for different frequencies.
- **Analyse** the information in the graph and suggest the range of frequencies for which our hearing is most sensitive.
- As we get older, the sensitivity of our hearing decreases for higher frequencies. Sketch the graph shown in Figure 4.35 and then **sketch** a similar curve for the hearing of someone who is between 50 and 60 years old.
- **Describe** the second curve you have sketched, and so **outline** how an older person would experience sound differently to a younger person.

Assessment opportunities

- This activity can be assessed using Criterion A: Knowing and understanding.

! Take action! Cut the noise!

ATL

- Information literacy skills: Access information to be informed and inform others; Present information in a variety of formats
- Critical-thinking skills: Interpret data
- Creative-thinking skills: Apply existing knowledge to generate new ideas

! Work individually or in pairs.

! Unwanted sound can be a real nuisance, particularly if you live near to a busy airport or road intersection.

Figure 4.36 Jet aircraft produce large amounts of noise

! In this activity, you will work as an acoustic engineer who has been commissioned to investigate the way materials can be used to reduce noise levels. Your audience is a local authority who are considering the impact of a new airport runway on the people who live locally. You will need to produce scientific data to describe the ways in which materials can be used to better insulate homes against unwanted sound. The local authority believes that the two key problems they face with the airport are the volume of sound produced by jets taking off, and the range of frequencies produced by the engines.

! Work individually or in pairs. Carry out some background **research** to find out what materials are used to reduce sound levels. **Identify** some suitable laboratory materials that you can use to 'model' sound absorbers.

SAFETY: Very large amplitude (loud) sounds can damage your hearing, especially for long periods of time. Control the volume in your experiment to make sure it is not unpleasantly loud, and **never** place your ear next to the cone of the loudspeaker.

! Use either of these pieces of equipment for your investigation:

- Sound producer – loudspeaker, signal generator
- Sound detector – microphone, sound intensity sensor, oscilloscope

! **Identify** the dependent variable you can measure in your investigation.

! **Brainstorm** what independent variables you could change in your investigation.

! Write down the aim of your investigation as an **inquiry question**.

! Now use the scientific experiment cycle to make a hypothesis, a prediction and to design your investigation. Be sure to clearly **describe** how you will control other variables that might affect the results. Ask your teacher to check your design before you begin.

! **Present** your results in tables and graphs, and **interpret** them in order to answer your inquiry question. **State** whether your prediction was correct.

! Write your final recommendation to the local authority in the form of a full report or online presentation.

! In your report, **outline** the research you did on sound reduction techniques. **Describe** the impact of aircraft take-off sound, with reference to what you have learned in this chapter about sound waves. **Discuss** some of the pros and cons (advantages and disadvantages) of easily accessible air travel. (Be sure to correctly **document** all your sources of information!)

! **Summarize** the results from your investigation. **Evaluate** your findings, **explaining** whether they were valid. **Suggest** ways in which further experimentation could increase the reliability of your results.

! **Explain** how your findings might be used to help the local authority decide whether to allow the new runway to be built at the airport.

Assessment opportunities

- This activity can be assessed using Criteria B: Inquiring and designing, C: Processing and evaluating, and D: Reflecting on the impacts of science.

Reflection

In this chapter, we have **outlined** how energy is transferred as waves that are caused by oscillations. We have **described** longitudinal and transverse wave motion, and **described** waves in terms of their wavelength, amplitude and frequency. We have **outlined** how the properties of different media affect the transmission of energy by waves of different kinds, such as water waves or seismic waves. We have **described** light waves in terms of transverse wave motion and **summarized** how we experience brightness and colour. We have used a ray model to **analyse** the way that devices such as cameras and the eye manipulate light to form images, and the way that changing the medium of light can make the light ray change direction. We have **summarized** different kinds of electromagnetic radiation in terms of their frequency and **described** their effects on matter. We have **explained** the transmission of sound through media as a longitudinal vibration of compression and rarefaction, and how sound is produced by mechanical oscillations. We have **outlined** how the human ear detects sounds and how we experience sound as volume and pitch. Finally, we have **explained** how sound volume can be reduced using different materials.

<table>
<tr><th colspan="6">Use this table to evaluate and reflect on your learning in this chapter.</th></tr>
<tr><td>Questions we asked</td><td>Answers we found</td><td colspan="4">Any further questions now?</td></tr>
<tr><td>Factual: What is a wave? What is light? What kinds of energy travel as waves? How are we sensitive to energy that travels as waves? What other kinds of electromagnetic radiation are there? How are we sensitive to sound waves?</td><td></td><td colspan="4"></td></tr>
<tr><td>Conceptual: How does understanding waves help us to better express ourselves?</td><td></td><td colspan="4"></td></tr>
<tr><td>Debatable: Do artists and scientists have anything to say to each other?</td><td></td><td colspan="4"></td></tr>
<tr><td rowspan="2">Approaches to learning you used in this chapter:</td><td rowspan="2">Description – what new skills did you learn?</td><td colspan="4">How well did you master the skills?</td></tr>
<tr><td>Novice</td><td>Learner</td><td>Practitioner</td><td>Expert</td></tr>
<tr><td>Collaboration skills</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Communication skills</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Information literacy skills</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Creative-thinking skills</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Critical-thinking skills</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Learner profile attribute(s)</td><td colspan="5">Reflect on the importance of being an inquirer for your learning in this chapter.</td></tr>
<tr><td>Inquirers</td><td colspan="5"></td></tr>
</table>

5 How does our planet work?

Modelling interactions between Earth's systems allows us to understand patterns that we can use to secure or improve human experiences.

■ **Figure 5.1** Life on Earth results from the complex interactions of different systems. How can we understand them to improve our lives?

CONSIDER THESE QUESTIONS:

Factual: What natural systems are necessary to maintain life on Earth? In what ways do the systems on Earth interact? What processes and events have contributed to local and global conditions on Earth?

Conceptual: How do the interactions between Earth's systems influence our living conditions?

Debatable: To what extent is it possible to use science to prevent, or reduce the damage from, natural disasters?

Now **share and compare** your thoughts and ideas with your partner, or with the whole class.

IN THIS CHAPTER, WE WILL ...

- **Find out** about the different systems that make up the Earth.
- **Explore** the interactions of the different systems and their effects on human life.
- **Take action** by using models and data to identify patterns that help us make decisions to support human lifestyles.

These Approaches to Learning (ATL) skills will be useful …

- Organization skills
- Critical-thinking skills
- Creative-thinking skills

We will reflect on this learner profile attribute …

- Thinker

Assessment opportunities in this chapter …

- **Criterion A:** Knowing and understanding
- **Criterion B:** Inquiring and designing
- **Criterion C:** Processing and evaluating
- **Criterion D:** Reflecting on the impacts of science

KEY WORDS

climate
cycle
earthquake
flow
properties
tsunami
weather

WHAT'S OUT THERE?

Look out of the window – what do you see? Are you surrounded by buildings or nature? What are the buildings like? What kinds of plants are there? How is the land? How is the weather – sunny or cloudy, rainy or dry, hot or cold? Is the air clean or polluted?

No matter where you are, or what it is like there, you can be sure of one thing: the conditions for human life that surround you are the result of energy and matter interacting and cycling around and throughout the world. So, whether you are in China or Chile, Austria or Australia – or anywhere else – we are all part of the same interconnected systems that have formed and will continue to transform our Earth.

For this chapter, you will be part of an urban development team that is tasked with identifying an ideal location to build a new city for people who have lost their homes due to a recent natural disaster. You will use models and evidence of climate and geography in order to decide on and support your proposed location for the city. You, and the other members of the urban development planning team, will present your proposals to a board of directors, who will decide which proposal offers the most successful option for designing a successful, sustainable new city.

What natural systems are necessary to maintain life on Earth?

HERE ON EARTH

The Earth itself is a system. But it is made up of many different systems that are interconnected and yet independent from each other. As you may recall from what you learned in MYP 1, these systems are part of the ecospheres, which include the atmosphere, hydrosphere, biosphere, and geosphere (Figure 5.2).

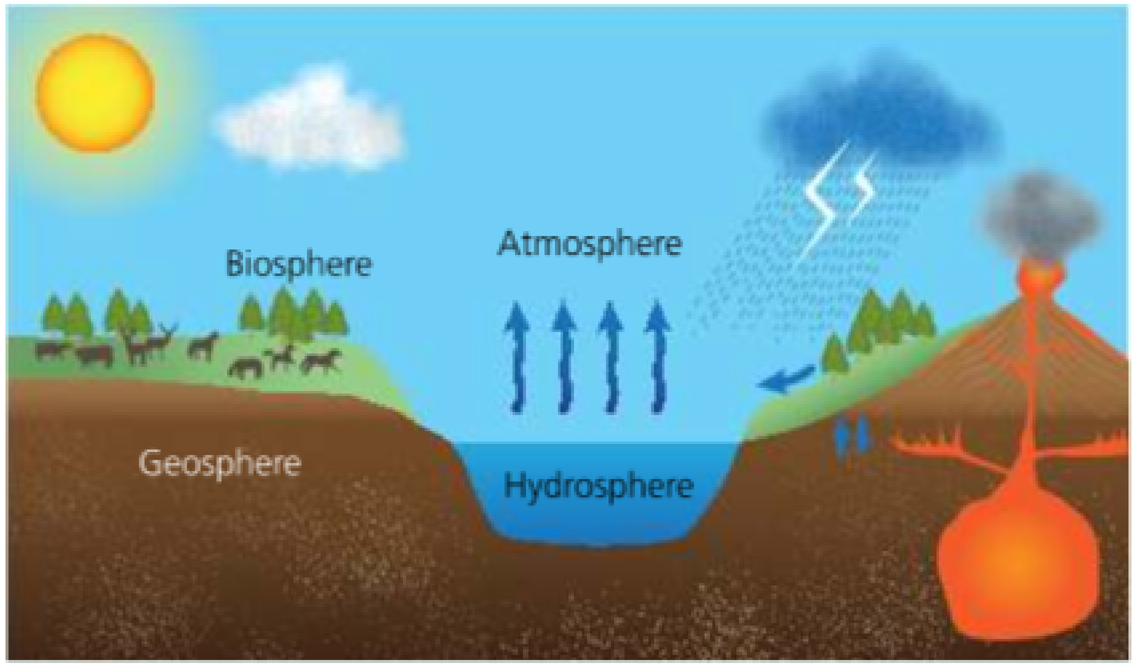


Figure 5.2 Earth's ecospheres

DISCUSS

- **What is a system? What are the characteristics of a system?**
- **What are some systems that you are part of in school? What about at home?**
- **What are the benefits of systems? What are challenges with systems?**
- **What would school, home, sports, or nature be like if there were no systems in each one?**

ACTIVITY: Ecospheres of influence

ATL

- Critical-thinking skills: Evaluate evidence and arguments; Draw reasonable conclusions and generalizations; Revise understanding based on new information and evidence

By carefully observing the diagram in Figure 5.2 and applying your background and prior knowledge from what you learned in MYP 1, you can develop an understanding of the systems that make up the ecospheres.

Working with a partner, consider carefully each ecosphere shown in Figure 5.2. Make a copy of the table, and fill it in with your answers to these questions:

- **What are the components of each ecosphere?**
- **What processes occur in each ecosphere?**
- **What is the relationship between each ecosphere and one or more of the others?**
- **Why is each ecosphere important for Earth to function?**

Share your work with the class, and add in any new ideas from your classmates or teacher.

Assessment opportunities

- In this activity, you have practised skills that are assessed using Criterion A: Knowing and understanding.

■ **Figure 5.3** The energy that powers all of Earth's systems comes either from the Sun, or from inside the Earth

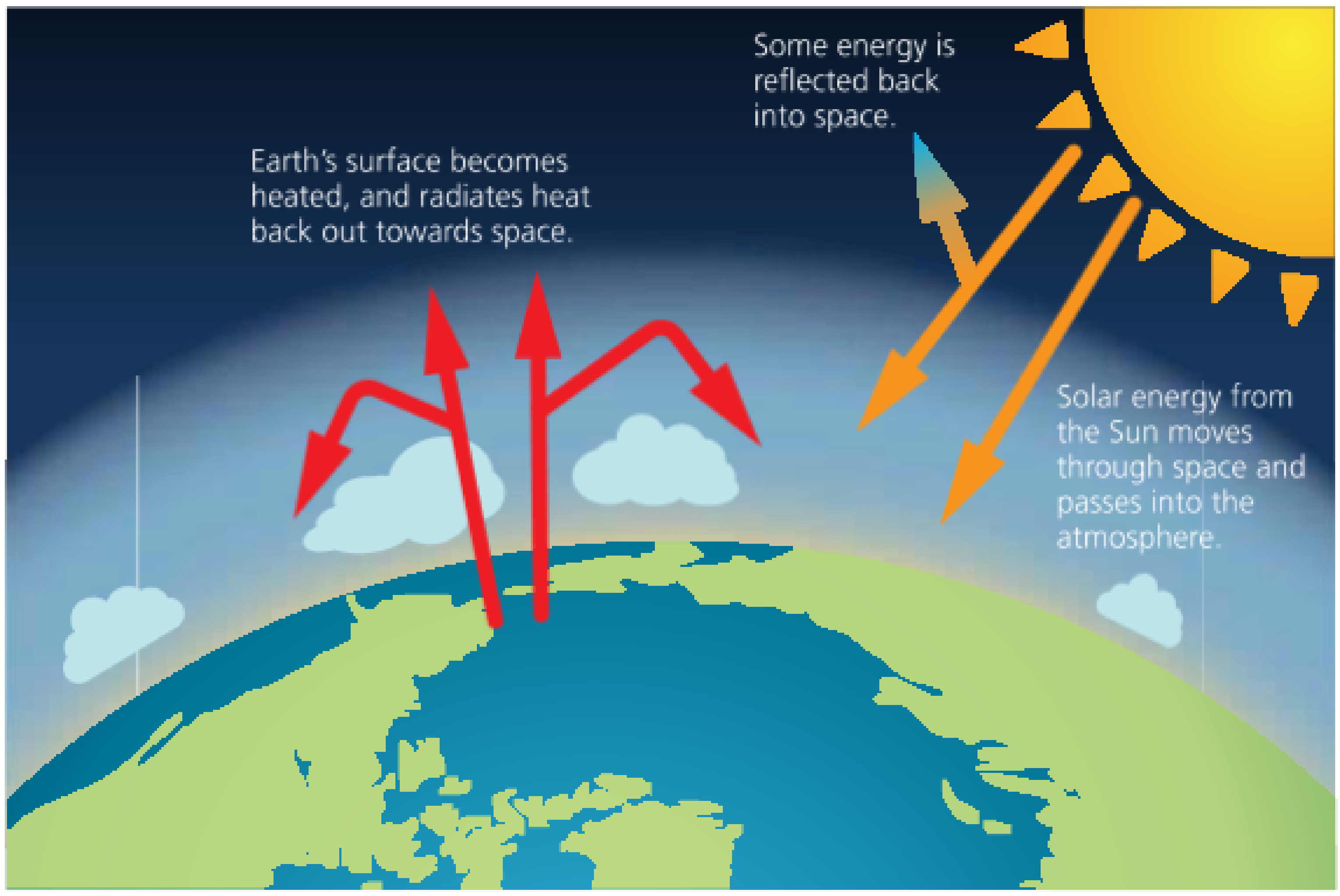
There are many different processes that you may have written and talked about in the *Ecospheres of influence* activity: anything from precipitation in the hydrosphere, to the rock cycle in the geosphere, to reproduction in the biosphere, to melting frozen lakes in the hydrosphere. No matter what the process or system is, and 'who' or what is involved, each process requires energy (Figure 5.3).

DISCUSS

How do we know that energy comes from the Sun and from inside the Earth? What is the 'evidence' that there is energy that comes from the Sun and from inside the Earth?

The energy that comes from the Sun, also known as solar energy, is used for photosynthesis and to heat the land and oceans of Earth. And, as we will soon learn, the different patterns of heating help to determine weather and climates around the world. Some of this energy that originates from the Sun is transformed to heat energy and is reflected back into space.

You may recall from your studies in MYP 1 that the energy that is inside the Earth is witnessed when hot **magma** from deep inside the **core** is released as **lava** during volcanic eruptions, or when hot water comes exploding from a geyser. But it is also seen during earthquakes and in the small movements of the **plates** that make up the surface of the Earth.



■ **Figure 5.4** Energy from the Sun flows to Earth and then back into the atmosphere towards space

DISCUSS

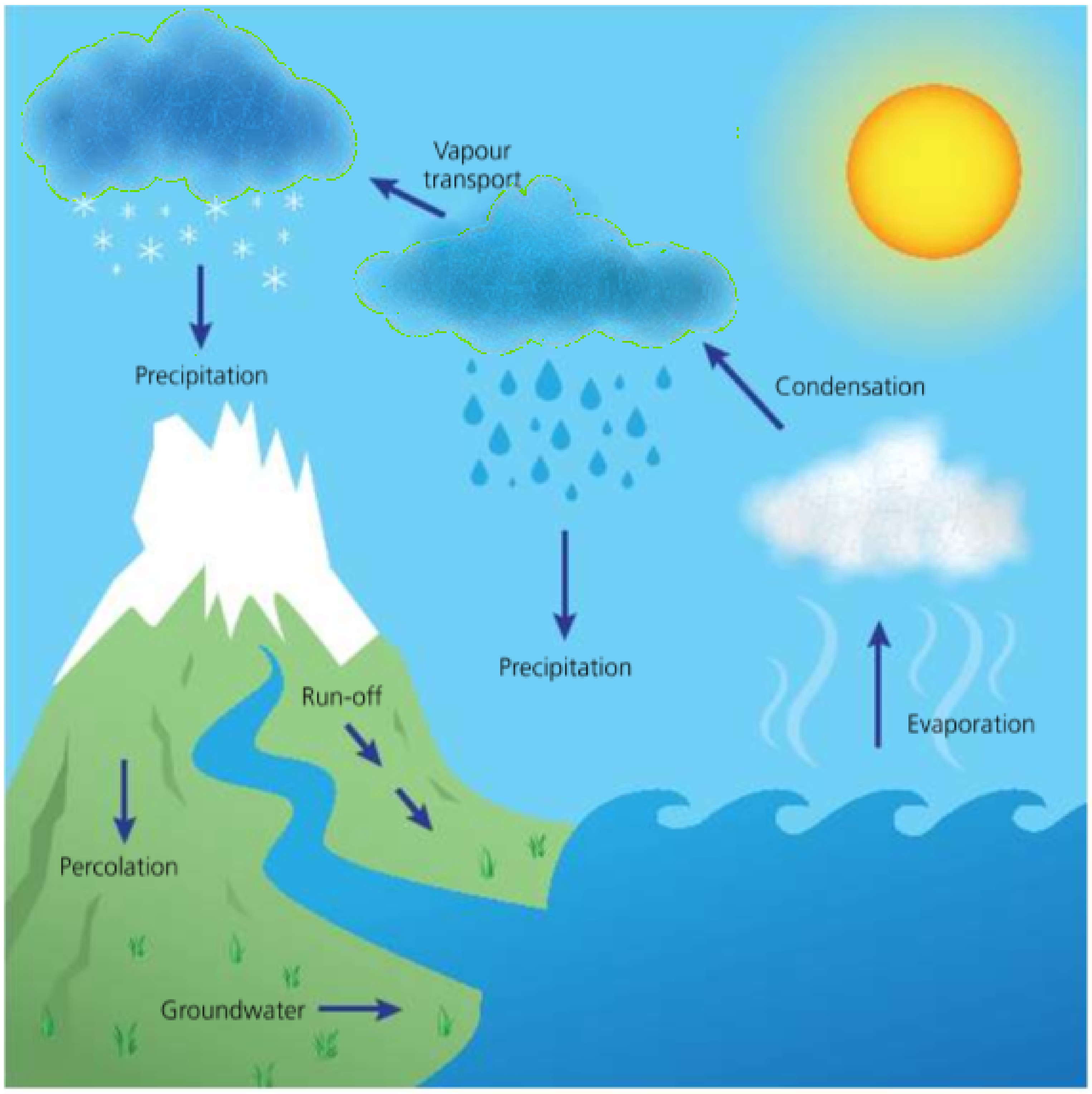
How does energy 'flow' from the Sun into animals and other living things? How does energy flow through each of the ecospheres?

In what ways do the systems on Earth interact?

DISCUSS

What are some examples of physical changes that occur because of energy flowing and matter cycling? What are some examples of chemical changes?

The flow of energy is not the only thing that all Earth systems have in common – there are also different kinds of **matter** that cycle through all systems. For example, water in the hydrosphere evaporates (with the help of energy from the Sun) into water vapour and rises into the atmosphere, where it cools and condenses to form liquid water again, which falls back to the hydrosphere and the biosphere (as a result of gravity) as **precipitation**, which flows back to the hydrosphere as **run-off** or soaks into the geosphere (again, as a result of gravity). If we use a finger to trace this process in Figure 5.5, we can see that water – as an example of a type of matter – never leaves the ecospheres completely. Instead, it cycles through again and again.



■ **Figure 5.5** Matter, such as water, cycles through the ecospheres

ACTIVITY: Water, water everywhere

■ ATL

- Critical-thinking skills: Use models and simulations to explore complex systems and issues

Work with a partner to **design** and construct a model of the Earth to provide evidence that the water cycle occurs. You should model each of the ecospheres. Decide what you will use to represent each ecosphere and what your evidence will be that the water cycle is occurring.

Instead of writing a description of your model and the evidence of the water cycle, make a short video of the process and results. You might leave your computer or camera to record your model Earth overnight and then watch it in fast motion to witness the cycle in action.

◆ Assessment opportunities

- In this activity, you have practised skills that are assessed using Criterion A: Knowing and understanding.

In addition to being necessary for life to exist, the flow of energy and cycles of matter have the ability to cause both chemical and physical changes throughout the ecospheres.

ACTIVITY: Cycles of matter

ATL

- Organization skills: Use appropriate strategies for organizing complex information

Other types of matter cycle through the ecospheres of the Earth, not just water. Carry out an image search for **cycles of matter**. Find four other cycles of matter that occur on Earth. Ask your teacher to check the cycles that you have chosen, and then research each one.

Compare and **contrast** the four cycles you research, plus the water cycle. In what ways are the cycles similar? In what ways are they different? In which ecospheres does each cycle occur?

Assessment opportunities

- In this activity, you have practised skills that are assessed using Criterion A: Knowing and understanding.

EXTENSION

What are some other examples of the movement of water transforming the Earth? You could do an image search for **water erosion**, or perhaps conduct a more targeted search of a specific event like a flood or tsunami. Put the images you find into a short slide show to share with the class.

You may have discussed the power of water to smooth rocks in a river or in the ocean, or to carve the Earth into deep canyons (Figure 5.6a). These are examples of physical changes that occur as a result of matter – in this case, water – cycling through the hydrosphere, geosphere and atmosphere.

An example of a chemical change is the process of photosynthesis, which can only occur as a result of the carbon dioxide and water cycles, as well as the flow of energy of the Sun. In this chemical change, a plant uses energy from the Sun to transform carbon dioxide and water into glucose and oxygen (Figure 5.6b).

An example of both physical and chemical changes occurring together is the formation of new islands from the lava of underwater volcanoes. For example, the state of Hawaii in the United States and the Galapagos Islands in Ecuador formed from the solidification of lava and volcanic rocks that erupted from volcanoes under water in the Pacific Ocean (Figure 5.6c)

These interactions between the ecospheres, which occur as matter cycles and energy flows through them, result in changes that occur on a small, local scale – such as plants growing in a vegetable garden – and on a global scale – such as the formation of volcanic islands. The interactions might be fast and short-lived – like a rain shower percolating into the soil – or slow, lasting millions or billions of years – like the creation of the Grand Canyon. No matter the scale or time frame, we can understand that the interactions of the ecospheres have shaped the Earth in the past, and will continue to do so in the future.

Figure 5.6 (a) The Grand Canyon was eroded by water over millions of years (b) Photosynthesis occurs on a daily basis (c) The Galapagos Islands were produced by volcanic activity

What processes and events have contributed to local and global conditions on Earth?

In the previous section, you learned about the water cycle, and how – through the processes of evaporation, condensation (or crystallization when snow or ice form), precipitation, and downward flow (run-off) – water is able to move in its various states between the geosphere, biosphere, hydrosphere, and atmosphere. In addition to making liquid water available to all living things for their survival, this cycling has the ability to physically transform ecosystems and contribute to local weather patterns.

We have already looked at one example of how the movement of water results in physical transformation – through the processes of **weathering** and **erosion**, the Grand Canyon formed over millions years. But we can also see evidence of the power of water after a flood or tsunami when homes, cities, and land are destroyed or swept away by the power of water.

■ **Figure 5.7** The power of water is witnessed in the damage caused by Hurricane Katrina in the United States in 2005 and the 2004 tsunami in the Indian Ocean (Figure 5.21)

Water and the movement of water also affect climate and local weather. In the following activity, *How's the weather?*, you will use average weather data for various cities around the world to identify a pattern that will help you understand the impact of water on climate and weather.

ACTIVITY: How's the weather?

ATL

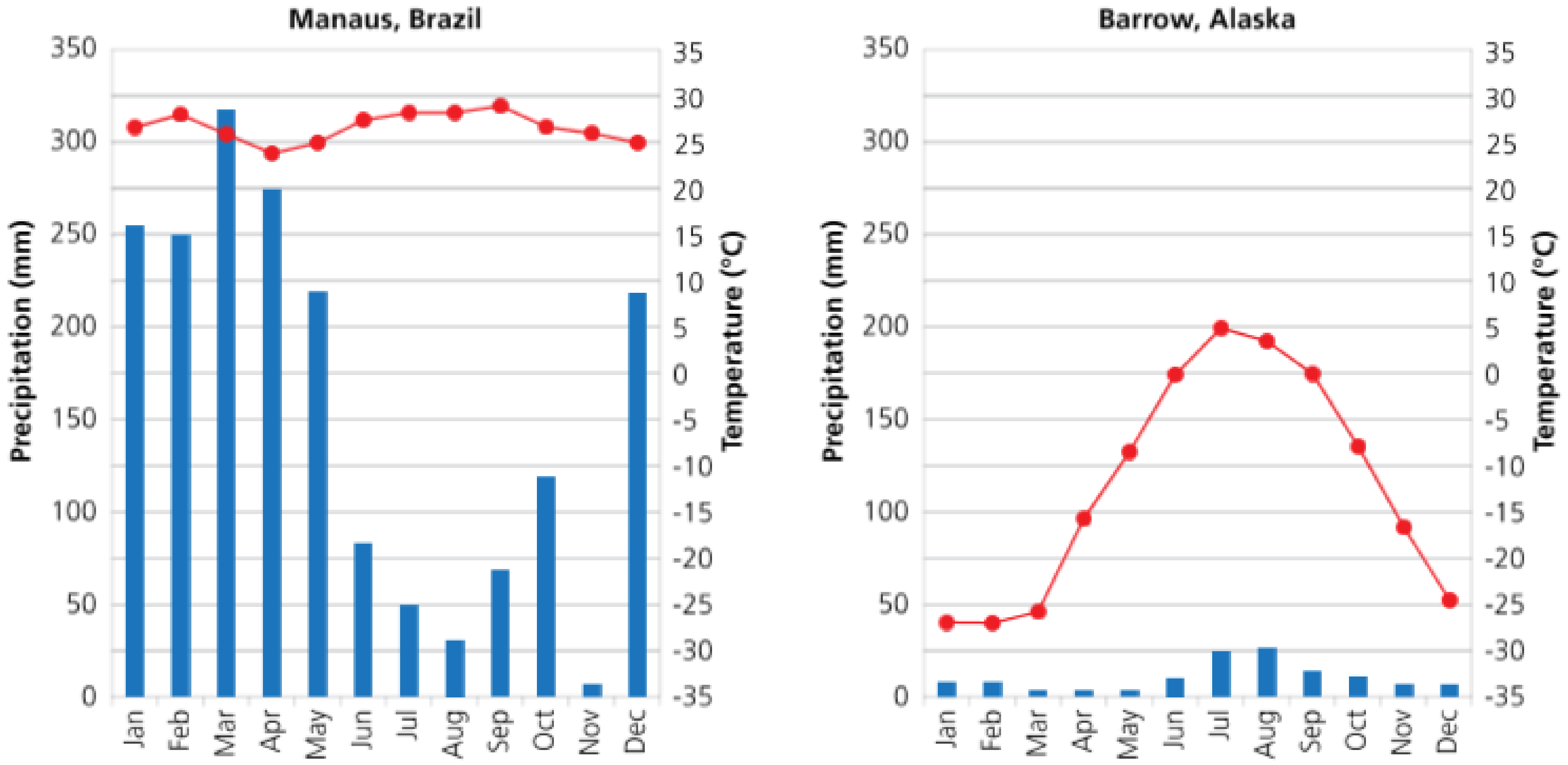
- Critical-thinking skills: Identify trends and forecast possibilities
- Creative-thinking skills: Use brainstorming and visual diagrams to generate new ideas and inquiries

In this activity, you will work with your entire class to map the location of several cities around the world and create a **climatograph** (also called a **climograph** or **climogram**) for each city. You will then identify trends in the climate data, and use these trends to identify the effect of water on climate and weather.

Before you begin, you must understand what a climatograph contains, and what you must include in your own climatographs. Figure 5.8 shows examples of climatographs for Manaus, in the Brazilian rainforest, and Barrow, in Alaska.

Discuss and complete the following prompts with your partner according to what you see in the climatographs. Use your responses as a guideline or 'checklist' when making your own climatographs.

- **The title of the climatograph should contain …**
- **The *x*-axis is …**
- **The *y*-axis on the left is …**
- **The *y*-axis on the right is …**
- **Precipitation is shown using …**
- **Temperature is shown using …**
- **In Manaus, the range of temperatures is from … to …**
- **In Barrow, the range of temperatures is from … to …**
- **The difference in the ranges of temperatures is because …**
- **The climatograph helps us know …**



■ **Figure 5.8** Climatographs for Manaus, Brazil and Barrow, Alaska

Now, look at the cities (Table 5.1) that the class will study. Using a world map or an internet search, find where in the world each city is located. Then, copy and complete Table 5.1 using your background knowledge about climate and weather. An example has been done for you. (Note that all these cities are at or near sea level.)

City	General description of location	My prediction of what the weather will be like	Reasoning for my prediction
Fairbanks, Alaska	Fairbanks is in the United States of America. It is far north. It is in the middle of the state. It is not close to the ocean or sea.	I think it is going to be really cold there in the winter, and not very warm in the summer. I don't think there will be too much precipitation.	I think it is going to be pretty cold because it is so far north, and I have learned that the more north you go, the colder it is. I don't think there will be too much precipitation because it is not near the water, and I usually think of wet places being close to the water.
London, England			
Winnipeg, Canada			
Trondheim, Norway			
Goa, India			
Niamey, Niger			

■ **Table 5.1**

City climates

Once you have made your predictions in Table 5.1, you are ready to go on. For this activity, you will need:

- **Graph paper or graphing software**
- **A world map – either electronic or paper**
- **A place to write down your observations and responses to the questions – this could be either done as a class or individually**

Your teacher will divide the class into six groups and assign each group a city.

1. **Mark each city on one class map of the world.**
2. **Calculate the average yearly temperature for your city (Table 5.2).**
3. **Calculate the average yearly precipitation for your city (Table 5.3).**

Hint

If you use graphing software such as Microsoft Excel or Google Sheets, you can 'plug in' values and use the 'average' function to quickly get the average values for both the temperature and precipitation.

4. **Using either graphing software, or graph paper, graph both the average monthly temperature and average monthly precipitation, in a climatograph for your city.**

Hint

Remember to use the checklist that you identified above when making your own climatograph.

Note that, because you will be comparing the climate data for each city, it is important that all of the graphs use the same scale for precipitation and temperatures. Discuss with your class what the range for each of these variables should be. In other words, what will be the maximum and minimum temperature on everyone's graph? What will be the maximum and minimum precipitation, in millimetres?

Graph scales

Scientists purposefully and carefully identify the most useful scale when making graphs. When comparing data in different graphs, it is important that all of the graphs be on the same scale so that similarities and differences can be accurately portrayed. Otherwise, people might observe similarities and differences that do not really exist.

When all of the groups have finished their calculations and climatographs, share the yearly averages with the whole class and put all the climatographs together so that the entire class can make observations of the climate patterns in the different cities. Go back to your predictions (Table 5.1) – how well do they match the actual climate for each city? Does anything surprise you?

Use the visible thinking routine of See-Think-Wonder when observing the graphs. You could set up a three-column chart to organize your responses.

- **See: What do you notice about the climate of each city? What patterns or relationships do you notice about the location of each city and its climate?**
- **Think: Using your observations and what you noticed, what do you think might be the reason for these patterns? What do you think might be the reason why your predictions about climate did not fit the actual climate?**
- **Wonder: What do you wonder about the climate patterns you noticed? What do you wonder about the reasons for the climate patterns?**

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Year
Fairbanks, Alaska	−23	−20	−12	−1	9	15	17	14	8	−4	−16	−21	
London, England	6	6	8	10	13	16	18	18	15	12	8	6	
Winnipeg, Canada	−16	−11	−5	3	10	15	17	18	11	3	−6	−13	
Trondheim, Norway	−1	0	3	7	12	15	19	17	13	8	4	1	
Goa, India	26	26	28	29	30	28	27	27	27	28	28	27	
Niamey, Niger	24	27	31	34	34	32	28	28	29	31	28	25	

■ **Table 5.2** Average monthly temperatures (°C) of different cities (data from climatemps.com)

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Year
Fairbanks, Alaska	15	13	1	1	2	5	6	5	3	2	2	2	
London, England	52	39	35	43	50	43	41	48	49	71	63	53	
Saskatoon, Canada	16	13	16	20	44	63	58	37	32	17	14	17	
Trondheim, Norway	68	67	67	60	48	66	70	78	92	98	67	76	
Goa, India	0	0	1	5	56	891	853	622	237	111	35	2	
Niamey, Niger	0	0	4	6	35	69	154	171	92	10	1	0	

■ **Table 5.3** Average monthly precipitation (mm) of different cities (data from climatemps.com)

Now, look at Table 5.4. Calculate the difference in the average yearly high temperature and low temperature for each city. (Note: the high temperatures are usually sometime in the afternoon, and the low temperatures are usually at some point during the night.)

Add your observations of the differences in high and low temperatures for each city to your See-Think-Wonder chart.

	Average high (°C)	Average low (°C)	Difference (°C)
Fairbanks, Alaska	3	−8	
London, England	14	7	
Winnipeg, Canada	8	−4	
Trondheim, Norway	8	2	
Goa, India	32	23	
Niamey, Niger	36	22	

■ **Table 5.4** Average yearly high temperatures and average yearly low temperatures

Finally, with your group or on your own, write one sentence to summarize the pattern or relationship between location in the world and climate. Share your 'big idea' with the class.

◆ Assessment opportunities

- In this activity, you have practised skills that are assessed using Criterion C: Processing and evaluating.

DISCUSS

What do you think the reasons for the patterns you noticed in the *How's the weather?* activity might be? Use Figure 5.9 to help.

DISCUSS

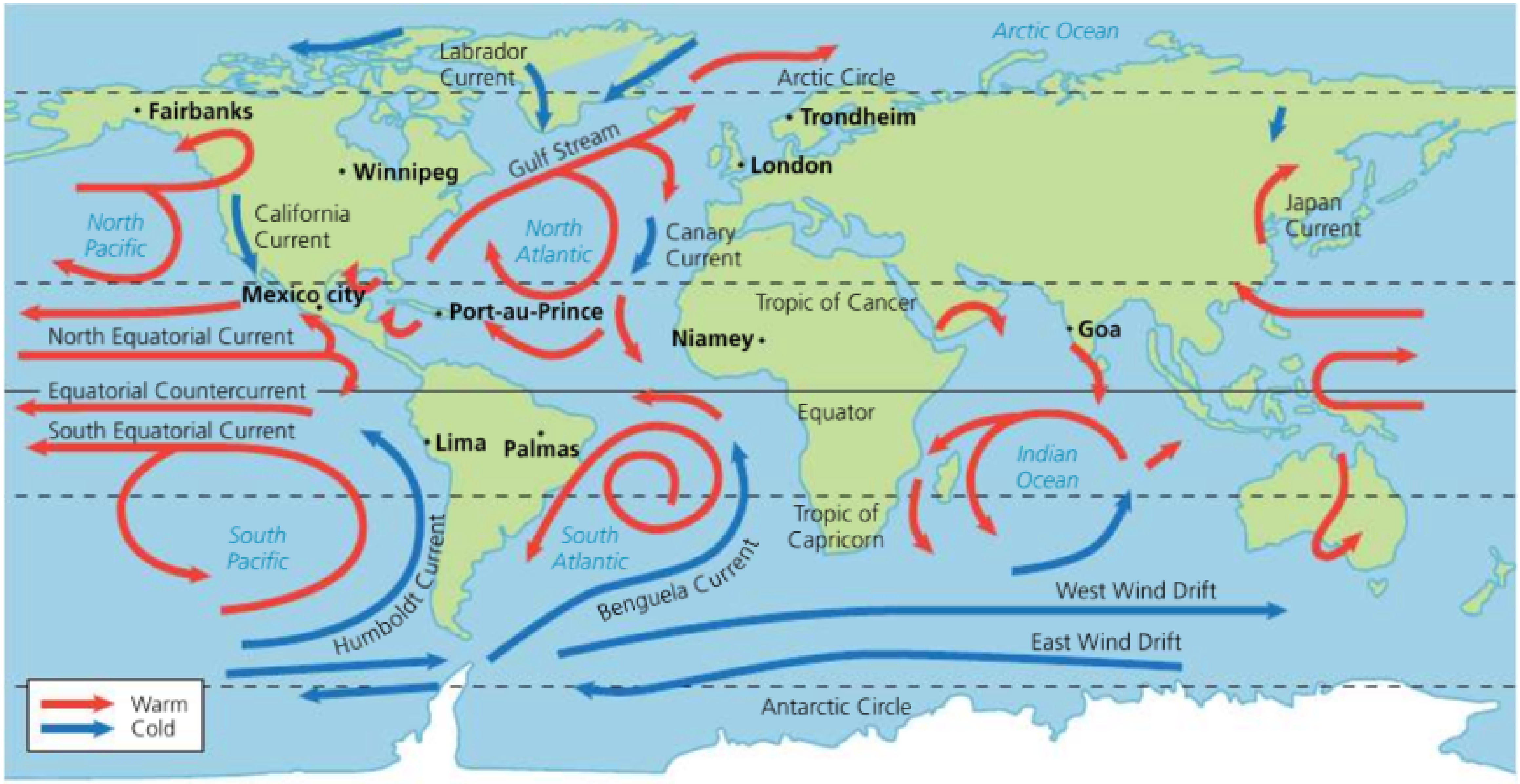
Which other cities in coastal Western Europe also have a climate affected by the Gulf Stream current? You can use your personal experience with visiting or living in that part of the world, or you can search for climate data on the internet.

In the *How's the weather?* activity, you probably noticed some interesting – and sometimes unexpected – patterns in climates around the world. For example, you probably noticed that even though Trondheim is very far north in Norway, its climate is much more mild and much wetter compared to Fairbanks, Alaska, which is on approximately the same line of latitude. Similarly, the climate in London is much warmer and wetter than that in Winnipeg, which is also more or less at the same latitude. Did you notice that there is a smaller range or difference in temperatures in Goa, India, compared to Niamey, Niger, even though they are also at similar latitudes? Perhaps you noticed that in general, the temperatures in Fairbanks, Winnipeg, and Niamey are more extreme or have a bigger range than those in Trondheim, London, and Goa.

The reason for the climate patterns has to do with the behaviours, or **properties**, of water and the cyclical movement, or **currents**, of water around the world.

Water, due to the way the hydrogen and oxygen atoms bind together, has some special properties. One is that it tends to 'hold on' to heat energy, which means that the temperature of water does not change very quickly – especially when compared to that of air. This means that, when the water in the oceans around the equator gets heated up by solar energy, it 'holds on' to that heat energy, and slowly releases it over distance and time. Air gets heated up and cooled down much more quickly and easily.

The Gulf Stream is a warm current that originates in the tropical regions of the Gulf of Mexico and Atlantic Ocean in North and Central America. The strong sunlight of the tropics heats the water, and causes differences in the temperatures and densities of the water at the surface and deep underwater.



■ **Figure 5.9** Cold and warm currents around the world

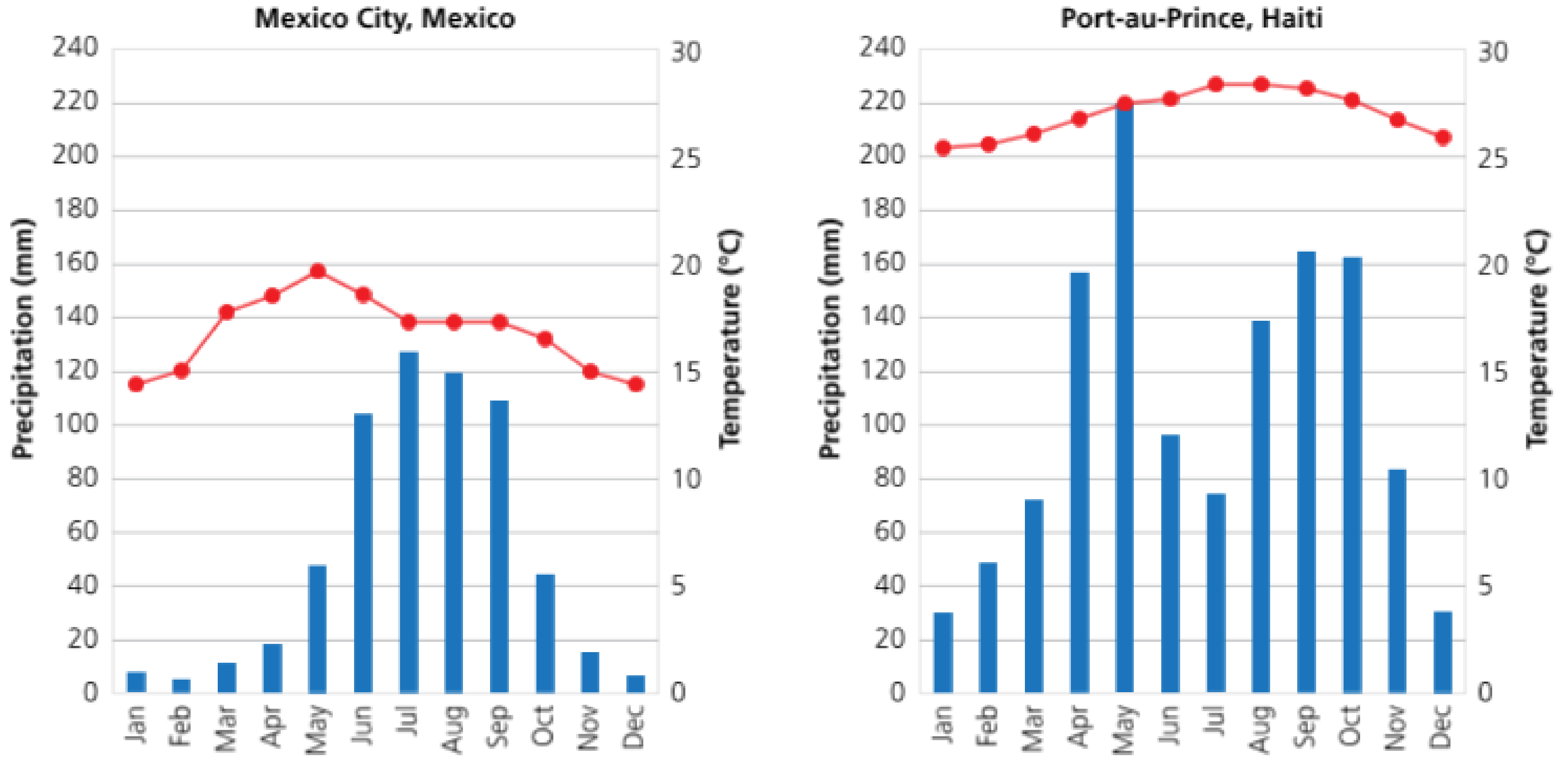


Figure 5.10 The climate for Mexico City, Mexico and Port-au-Prince, Haiti

This, together with the effects of the wind, means the warm water is able to circulate and flow from the Gulf of Mexico, northward though the Atlantic ocean, past the East coast of the United States, and then westward toward the United Kingdom and continental Europe.

Because of water's tendency to 'hold on' to heat energy, the temperature of the ocean currents that make it to the UK and coastal Western Europe are relatively high. As the water 'releases' its heat energy to the air around the UK and coastal Western Europe, the air temperatures are also higher in comparison to those places where there is not a warm water current to be a source of heat energy. And, because warmer air holds onto more moisture than cooler air, that means the UK and coastal Western Europe tend to have wetter weather than areas of the world that are at a similar latitude but not near a warm water current.

Just as the water from the tropics is heated by the abundant solar energy, water from the polar regions, such as the Arctic Ocean, is cool from the lack of solar energy. Furthermore, just as the water from the tropics stays warm over long distances and time, the water from the polar regions stays cool over long distances and time. This is because, as we have learned, one of the properties of water is that its temperature does not change very easily or quickly. Therefore, the areas of the world that are near cold water currents, such as the Benguela Current, have climates that are cooler and drier than would otherwise be expected.

Another implication of water's ability to 'hold on' to heat energy is that the temperature of places located near the coast tend to be more consistent, and have less extreme differences between the highs and lows. Which cities from the *How's the weather?* activity exemplify this pattern?

EXTENSION

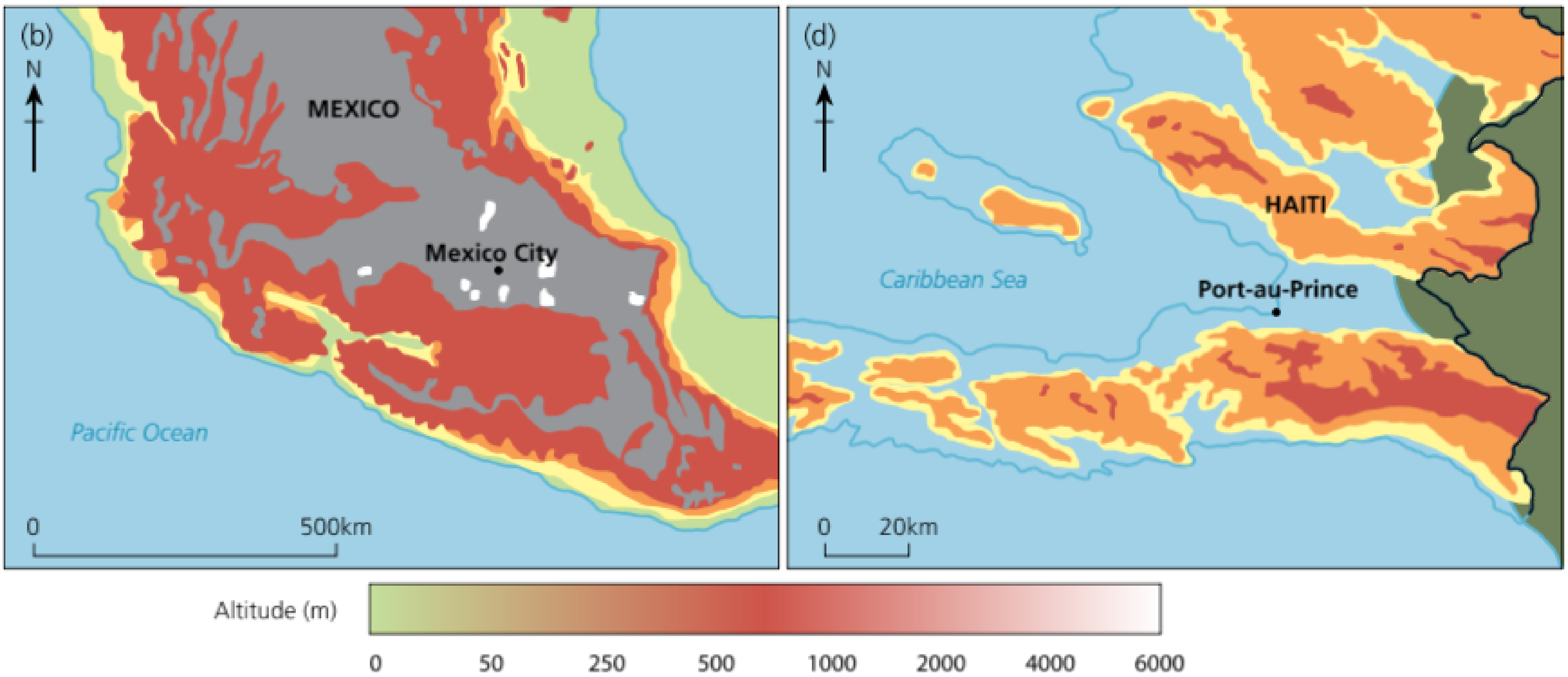
Using the map of currents in Figure 5.9, make some predictions about the climate of regions in the world that we have not yet looked at. Pick a city or region, make a prediction about the climate based on the ocean currents that are near it, and search for a climatograph to confirm or contradict your prediction. Try it with some cities you are interested in and share your findings with the class.

Depending on which cities you searched for, you may have noticed that some places do not fit the pattern expected due to ocean currents. Perhaps you noticed that Mexico City, Mexico, is 'sandwiched' between two warm water currents: the Equatorial Countercurrent and Gulf Stream current, which would make you think that Mexico City has a very warm climate. However, after a bit of research, you would have found that actually the climate of Mexico City is cool compared to Port-au-Prince, Haiti, which is at a similar latitude and similarly surrounded by warm water currents (Figure 5.10).

What is the reason for that? The answer is revealed in these **topographic** maps and photos of Mexico City and Port-au-Prince (Figure 5.11). What do you notice when you look at the photos and the maps?

From the maps and photos, you will notice that Mexico City is in the mountains, at a high **altitude**, or **elevation**, of 2500 metres above sea level, while Port-Au-Prince is close to sea level, with an average elevation of just 41 metres. Therefore, we can understand that, in addition to the impacts of warm or cool water currents, altitude also has an important impact on climate.

Another example of how **topography** interacts with the movement of air and water to affect local weather is found when we consider islands like Hawaii.



■ **Figure 5.11** Photos and topographic maps of Mexico City (a and b) and Port-au-Prince (c and d). Topographic maps help us see the geographic features, such as mountains or rivers

SEE-THINK-WONDER

To start, make a three-column See-Think-Wonder chart.

Then, search and observe maps of Hawaii and photos of the plant life that grows on one island, Oahu.

- **Working with your partner, write all of your observations in the 'See' column of your chart. Even if you are not sure of what the terms mean, use them in your chart. For example, you might start one of your observations like this: 'I notice that on the *windward* side of Oahu …'**
  Now, go back to Figure 5.9 showing the ocean currents. Use the maps you found to find the approximate location of Hawaii. What do you observe about the location of Hawaii? Add your observations to the 'See' column.
- **Once you have your list of observations, use your background knowledge to suggest possible reasons for what you have noticed. Write your suggestions or possible reasons in the 'Think' column.**
- **Finally, in the 'Wonder' column, add questions concerning what you would like to know more about.**

Share ideas from your See-Think-Wonder chart with your class. Can you add anything more? Are any of your 'wonderings' answered by your classmates' ideas?

DISCUSS

For the Hawaiian Islands, the eastern side is the windward side, and the south-eastern side is the leeward side. However, that is not the case for every place – the windward or leeward sides could be on any side.

What determines which side is windward and which side is leeward? Use evidence and diagrams from this chapter to support your answer.

In the *See-Think-Wonder* activity, you probably observed that one side of Oahu in Hawaii, the northern and western side, is greener, while the southern and eastern side is more brown. In addition, you may have noticed there are mountains on the islands, and the currents are moving from east to west around the islands. Furthermore, we can see that there are more plants growing on the 'windward' side of the islands in comparison to the 'leeward' side.

The equatorial current has the greatest amount of contact with the eastern (and some of the northern) coast of Oahu. The warm, moist air of that current is carried by the wind towards the western side of the island. Because the eastern side is the one that receives the wind from the currents, it is called the **windward** side of the island.

As we can see represented in Figure 5.12, as the warm, moist air 'hits' the mountains that are on the east (and northern) coast, it rises because warm air is less dense than cool air. However, as the warm air rises, it cools so that the water vapour condenses to form liquid water, which falls as rain (take a look back at the water cycle in Figure 5.5). Because there is so much rain, many plants can grow, resulting in the green appearance of the eastern side in satellite images of Hawaii.

The air that continues to travel over the mountain is now cool and dry (because the moisture 'left' the air as rain). That cool and dry air sinks, because cool air is more dense. As the air is so dry, there is not much rain. Because there is not much rain, few plants can grow. This side of the mountain is known as the **leeward** side – the side that does not get the direct wind from the sea.

EXTENSION

Which other places in the world have weather influenced by the rain shadow effect? Try searching **rain shadow effect examples**. You might also search **windward leeward examples**.

You could also look at a map of the world and try to determine which places are likely to be influenced by the rain shadow effect. You could then search for images or climate data for these places to check your predictions.

Links to: Mathematics

The factors and patterns that result in daily weather and long-term climate are complex. When you identify patterns in mathematics and determine the probability of different events occurring, you are practising the same skills that meteorologists use to predict the weather for daily or long-term forecasts.

This process of warm, moist air resulting in rainy, warmer weather on one side of a mountain and dry, cooler weather on the other side is known as the **rain shadow effect**. This is another example of how the systems of the ecospheres interact to affect where and how people live.

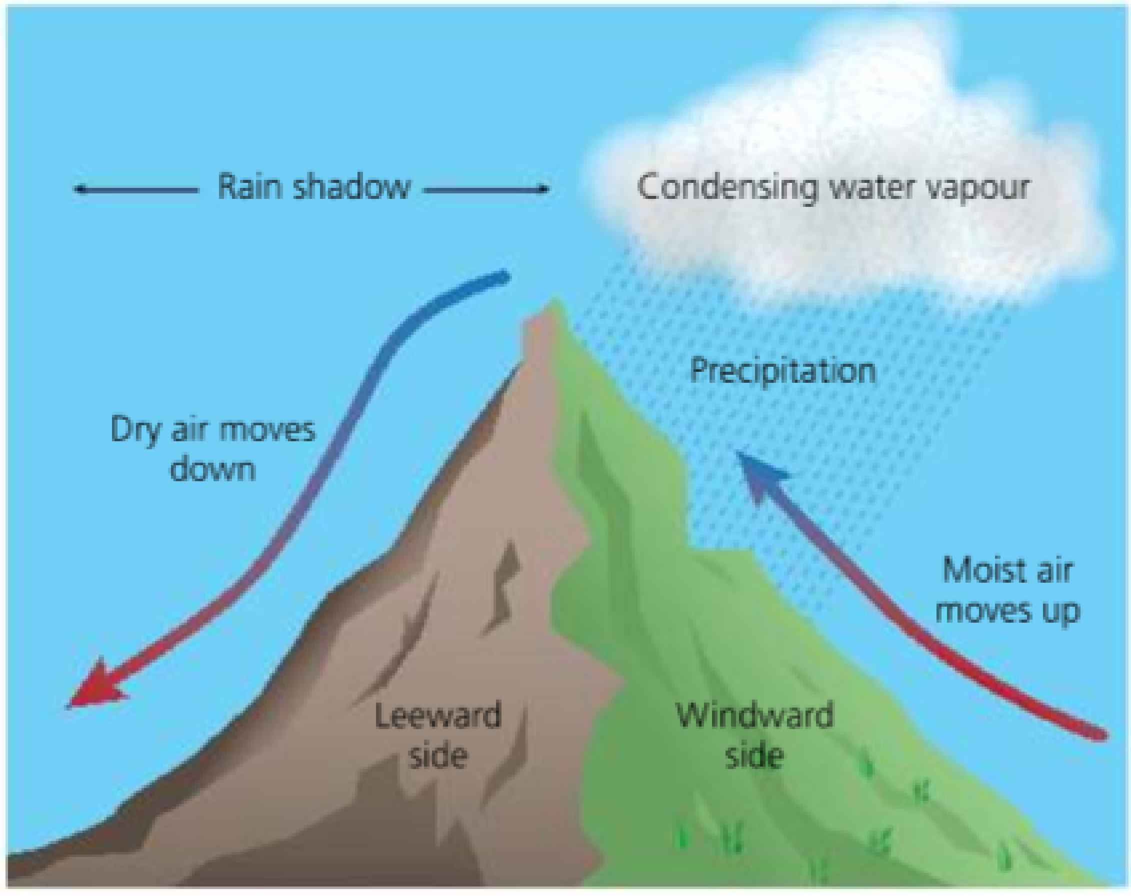


Figure 5.12 The rain shadow effect results in the differences in local weather on the windward and leeward sides of a mountain

ACTIVITY: Water, air, and earth

ATL

- Critical-thinking skills: Use models and simulations to explore complex systems and issues
- Creative-thinking skills: Use brainstorming and visual diagrams to generate new ideas and inquiries

How does the presence of water, air, or earth really affect the temperature and how temperature changes? To understand the impacts these different types of matter have on temperature, and therefore on climate, you can create an experiment to model and measure temperature changes in temperature in the air, in the sea, and on land. You will come up with your own experimental question, materials, and methods. Then, you will collect and process your data, make conclusions about the different ways in which water, air, and earth vary in temperature; and then you will evaluate your investigation and results.

Use the checklist in Table 5.5 to help you complete all of the steps and learning objectives for a scientific investigation.

Models

Scientists use models, such as the one you probably created in this investigation, to identify patterns and make predictions. Scientists use models to help visualize or confirm scientific principles that people are already familiar with, or to try to understand principles we are just discovering.

Assessment opportunities

- This activity can be assessed using Criterion B: Inquiring and designing, and Criterion C: Processing and evaluating.

Step	Things to consider	Criterion B or C	Learning objective
Explain the question or problem to be tested	To write a question, use this format: 'How does _____ affect _____?' To describe a problem, use some version of the word 'effect' or 'affect'.	B	**i** outline a problem or question to be tested by a scientific investigation
Formulate and explain a testable hypothesis	Write in a short way what you will do in your experiment, what you think the results will be, and the scientific reason why you think this will happen.	B	**ii** outline a testable prediction using scientific reasoning
Explain how to manipulate the variables, and how to collect the data	**Independent variable:** what you will change in each 'trial' or test group **Dependent variable:** what you will measure, count, or calculate **Controlled variables:** what you will keep the same in each 'trial' or test group		
Design a complete, logical, and safe method	Include the independent, dependent and controlled variables. (Underline or highlight the variables so that you are sure you included them.) What safety considerations, if any, might you need to make in doing this experiment?		
Collect and organize data	Remember to include appropriate titles, headings, and units.		
Transform, and present data	What mathematical calculations will you do with your data? What type of graph is most appropriate to give a visual summary of your results? What will you put on your *x*-axis? (This is the variable you changed in your experiment.) What will you put on your *y*-axis? (This is the variable you measured or counted in your experiment.) Remember to include the units!		
Interpret and explain results	What are your conclusions from the experiment? What is the 'answer' to your question? What are the results from the investigation that support your conclusion or 'answer' to your question?		
Evaluate the hypothesis	In what way(s) did the results of the experiment support or not support your hypothesis?		
Evaluate the method	Which step(s) of the method could have been the source of an error or inaccurate results? Why?		
Discuss improvements and extensions to the method	Considering the steps that were possible sources of error, what could you do differently in order to avoid errors or inaccurate results in a future experiment? What do you still wonder about your problem or research question? What would you do in order to investigate the thing you are still wondering about?		
Document your sources	Use **easybib.com** or another website to help	D	**iv** document sources completely

■ **Table 5.5** Checklist for planning and carrying out an investigation

How do the interactions between Earth's systems influence our living conditions?

In addition to the effects of the interacting systems of the hydrosphere, atmosphere, and geosphere that we saw in the ocean currents and climate patterns around the world, there is another factor which plays a huge role in our physical location and the geography of our surroundings: the movement of **plates** of the Earth.

The movement of the plates of the Earth is described by the **plate tectonic theory**. The plate tectonic theory provides an explanation for how the surface of the Earth moved in the past and continues to move in the present. It gives us a framework to understand how and why the geographical features that surround us – such as mountains, volcanoes, and valleys – formed and why geographical events such as earthquakes, tsunamis, and volcanic eruptions occur. The plate tectonic theory helps us understand how land formed in the past, and predict how land might form or be destroyed in the future.

But what exactly occurs between the plates that has had such a powerful effect on life on Earth? The next activity will help you visualize what occurs beneath our feet every day.

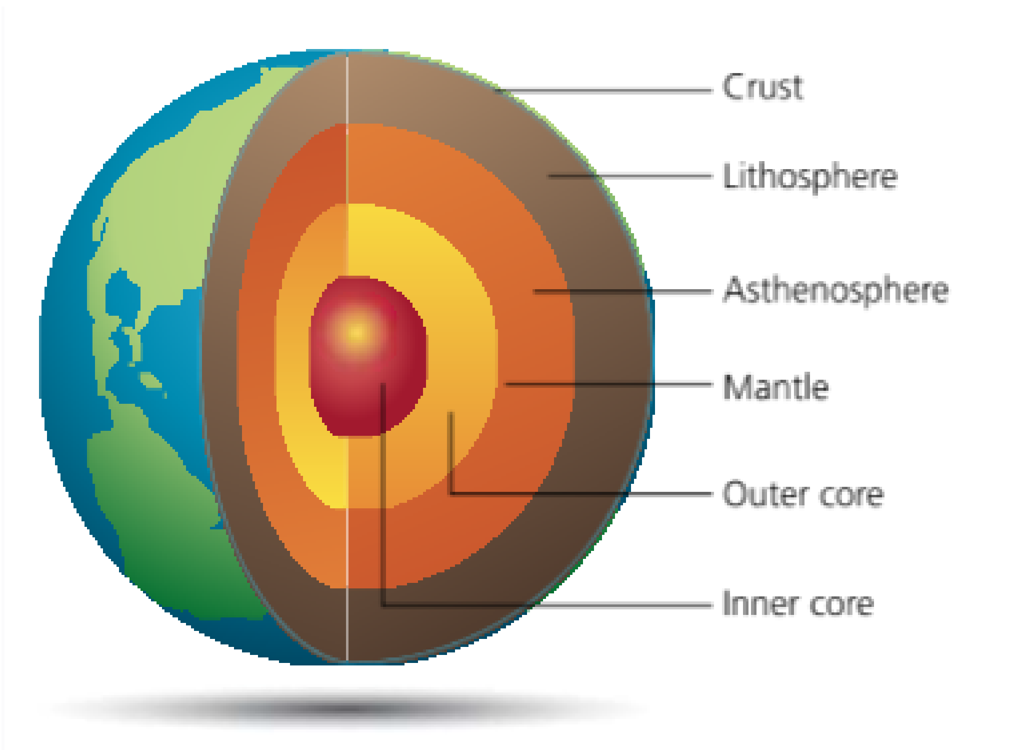


Figure 5.13 The layered structure of the Earth

ACTIVITY: Tasty plate tectonics

ATL

- Creative-thinking skills: Apply existing knowledge to generate new ideas, products or processes

In this activity, which builds on a similar one you may have done in MYP 1, you will use candy bars to model the Earth and the different types of movement that occur between the plates.

SAFETY: Remember, you should never eat in a science lab. Let your teacher know if you should not personally handle the chocolate bars due to food allergies; if you are allergic to any of the ingredients in the candy bars, you may be able to work with your partner to take notes and pictures.

Here are the materials you will need for this activity:

- **1 chocolate-covered candy bar that has at least two layers, such as a layer of caramel and a layer of nougat (Figure 5.14).**
- **Several paper towels**
- **1 plastic knife**
- **1 paper plate**

Before you begin, you must first recognize the features of the Earth that the candy bar models. To do this, make a copy of the diagram of the candy bar as in Figure 5.14, either a hand-coloured sketch or a computer drawing. Label each section with the corresponding layer of the Earth.

(Note that our candy bar models the first four layers of the Earth, in order from the outside of the Earth toward the centre.)

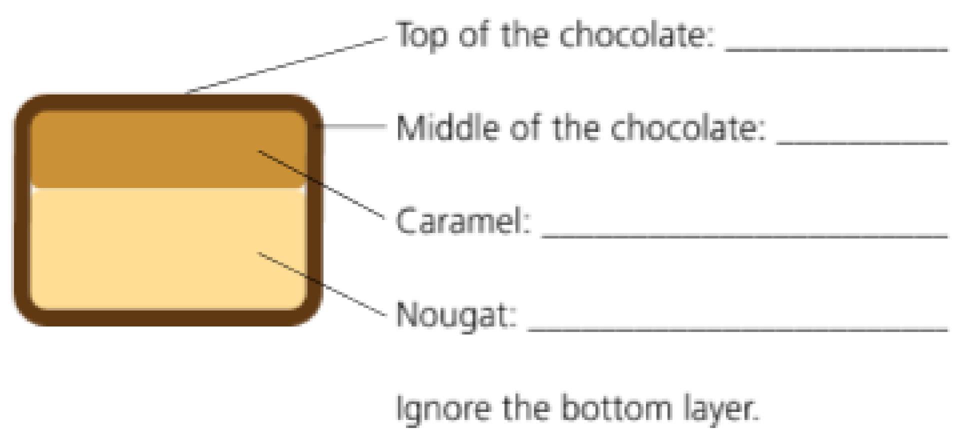


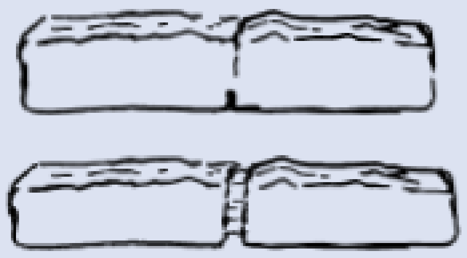
Figure 5.14 Diagram of a candy bar labelled to show the layers of the Earth it represents

Once you have identified the layers of your candy bar 'Earth' and your teacher checks them, you are ready to begin.

1 **Make a copy of Table 5.6 on paper or on a computer. If you are using your computer, you can take a picture of each step and upload it for the 'Illustration' column. If you are writing by hand, you should make a coloured sketch.**
2 **Put the candy bar on the paper plate or on a paper towel so that it is horizontal in front of you.**
3 **Follow each of the steps listed in Table 5.6, and fill in each section for columns B and C. The first one has been done for you as an example. You will fill in Column D later in the activity. Be sure to use the appropriate names of the layers of the Earth in your descriptions.**

Consider the following when making and writing your observations:

- **What happens to the overall length of the candy bar (plate)?**
- **Does the surface (crust, lithosphere) of the candy bar get higher or go lower?**
- **What happens to the inner layers (asthenosphere, mantle) – do they get thicker or thinner?**

Column A: Actions → plate activity	Column B: Illustration	Column C: Description of the results of the plate activity	Column D: Scientific description
Draw a crack in the 'crust' from top to bottom, and start to pull the two halves away from each other – only pull them a few millimetres apart.		The crust and lithosphere start to crack open. The crust gets lower at the crack as the two sides pull apart. The candy bar gets longer. The asthenosphere and some of the mantle are visible. The asthenosphere gets thinner.	
Gently push the two halves of the 'plate' back to the original shape – do not smash them together!			
Now use more force to push the two halves very firmly into each other.			
Carefully pull the two halves back to the original position. Push them together again so that the right half is a bit higher than the left half.			

■ **Table 5.6** Steps for modelling plate tectonics

Read the scientific explanation of what happens during plate activity. Use the explanation to complete Column D in your copy of Table 5.6. Be sure to include all of the bold words in your description, but do not copy the paragraphs word for word. Instead of writing long sentences, write short, bulleted phrases.

◆ Assessment opportunities

- In this activity, you have practised skills that are assessed using Criterion A: Knowing and understanding.

To what extent is it possible to use science to prevent or reduce natural disasters?

From the *Tasty plate tectonics* activity, you learned that there are different types of interactions and boundaries between the plates of the Earth. The type of boundary – either divergent, convergent, or transform – creates the physical features that make up the Earth and forms the characteristics of the land where we live. Not only does the activity between the plates create the physical features where we live, it also impacts how we live our lives and whether or not we have to be prepared for and deal with the consequences of earthquakes, volcanoes, or tsunamis.

DISCUSS

What are some ways in which plate boundaries impact life for those living near them? Here are some questions to guide your discussion:

- **What do people who live on a plate boundary have to consider in their daily lives?**
- **How might a person's life change as a result of living in an area where there is a plate boundary?**
- **What do the governments of cities that are on plate boundaries have to plan for and manage?**

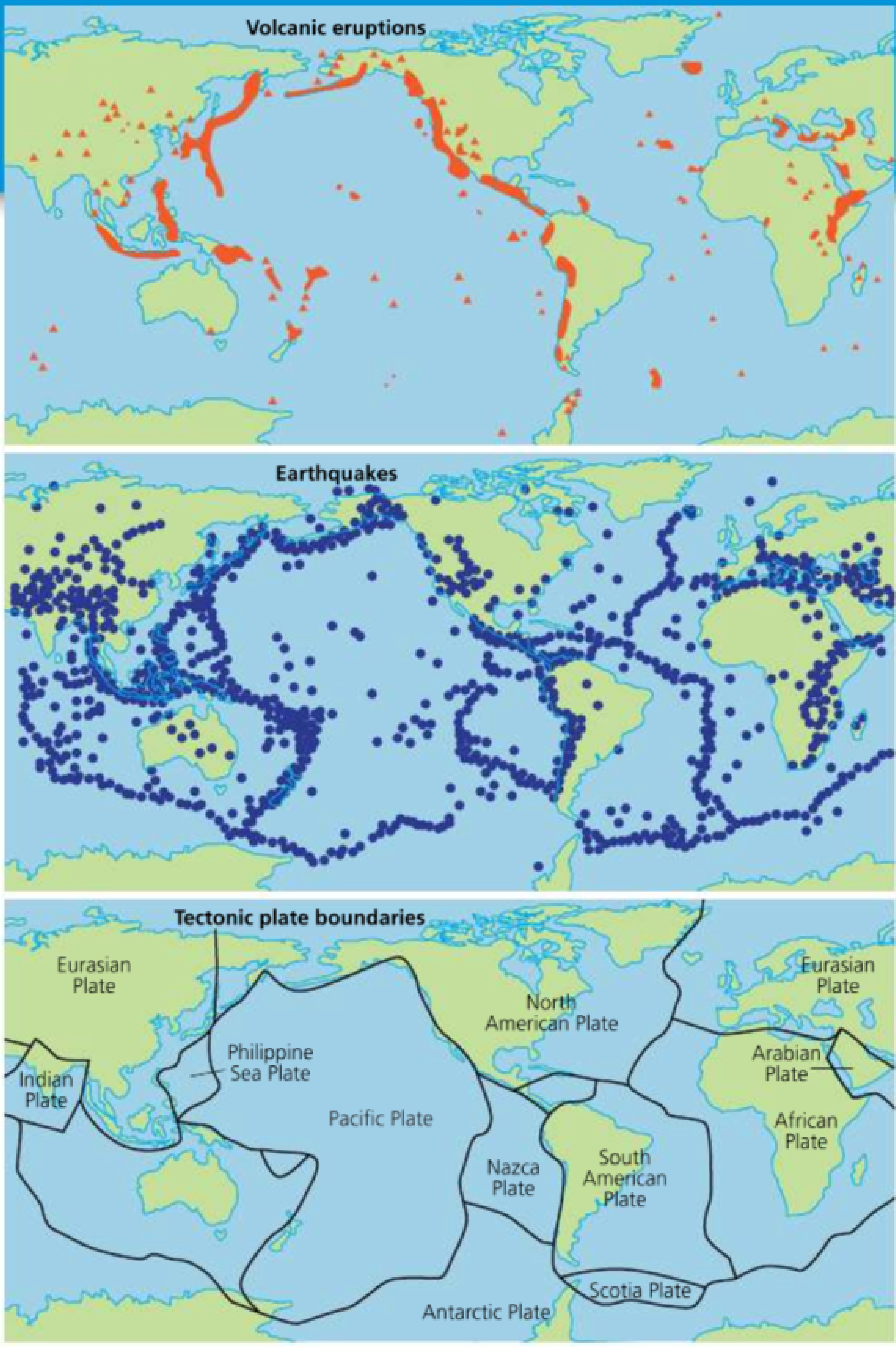
When **plates** move apart, the **crust** sinks and forms a **rift valley**. If this **diverging** movement continues, the surface of the Earth can separate enough so that the **magma**, or melted rock, from the centre of the Earth can come to the surface, forming the opening of a **volcano**. The magma that rises to the surface can also result in the formation of new crust as it cools. When this occurs in the ocean, new land can form as volcanic islands (like Hawaii and the Galapagos islands). Diverging movement occurs at a **divergent boundary** between plates.

The opposite of diverging movement is **converging** movement. As a result of converging movement, plates **collide** into each other, and the crust rises up to form mountain ranges. When plates collide, one plate slides below the other plate, forming a **trench**. As the lower plate moves down toward the centre of the Earth in a process called **subduction**, the rocks that make up the crust melt. The melted rocks can be pushed upward toward the surface. This forms volcanoes in the mountain range that was formed by the converging plates. Converging movement occurs at a **convergent boundary** between plates, and it forms an area known as a **subduction zone**.

Horizontal movement from side to side occurs at a **transform boundary**. This forms **fault lines**, or cracks in the crust, where **earthquakes** occur. Transform boundaries can also result in the bends or 'kinks' of rivers.

Now that we are familiar with the different types of plate activity and plate boundaries, you might wonder how much these plates actually move. How do earthquakes and volcanic eruptions really relate to plate boundaries?

Look at the maps in Figure 5.15. What do you notice about the occurrences of earthquakes, the locations of volcanoes, and the positions of the plates around the world?



■ **Figure 5.15** Maps showing the worldwide occurrences of earthquakes, locations of volcanoes, and positions of plates

EXTENSION

If you would like to learn more about volcanoes, search on youtube.com for how to understand volcanoes. You might also go to www.volcano.si.edu, which is a website dedicated to volcanoes from the Smithsonian museum in the United States.

Using some further research, determine what volcanic hotspots are. Where are hotspots found? What happens at hotspots to give them this name?

ACTIVITY: Identifying boundaries

ATL

- Critical-thinking skills: Identify trends and forecast possibilities; Draw reasonable conclusions and generalizations

Use what you have read about the different types of plates and plate activity, Figure 5.15, and background knowledge of the geography, to make predictions about a few different plate boundaries. For the boundaries between the Nazca and South American plates, the North American and Pacific plates, the Pacific and Australian plates, and the Eurasian and Indian plates, list:

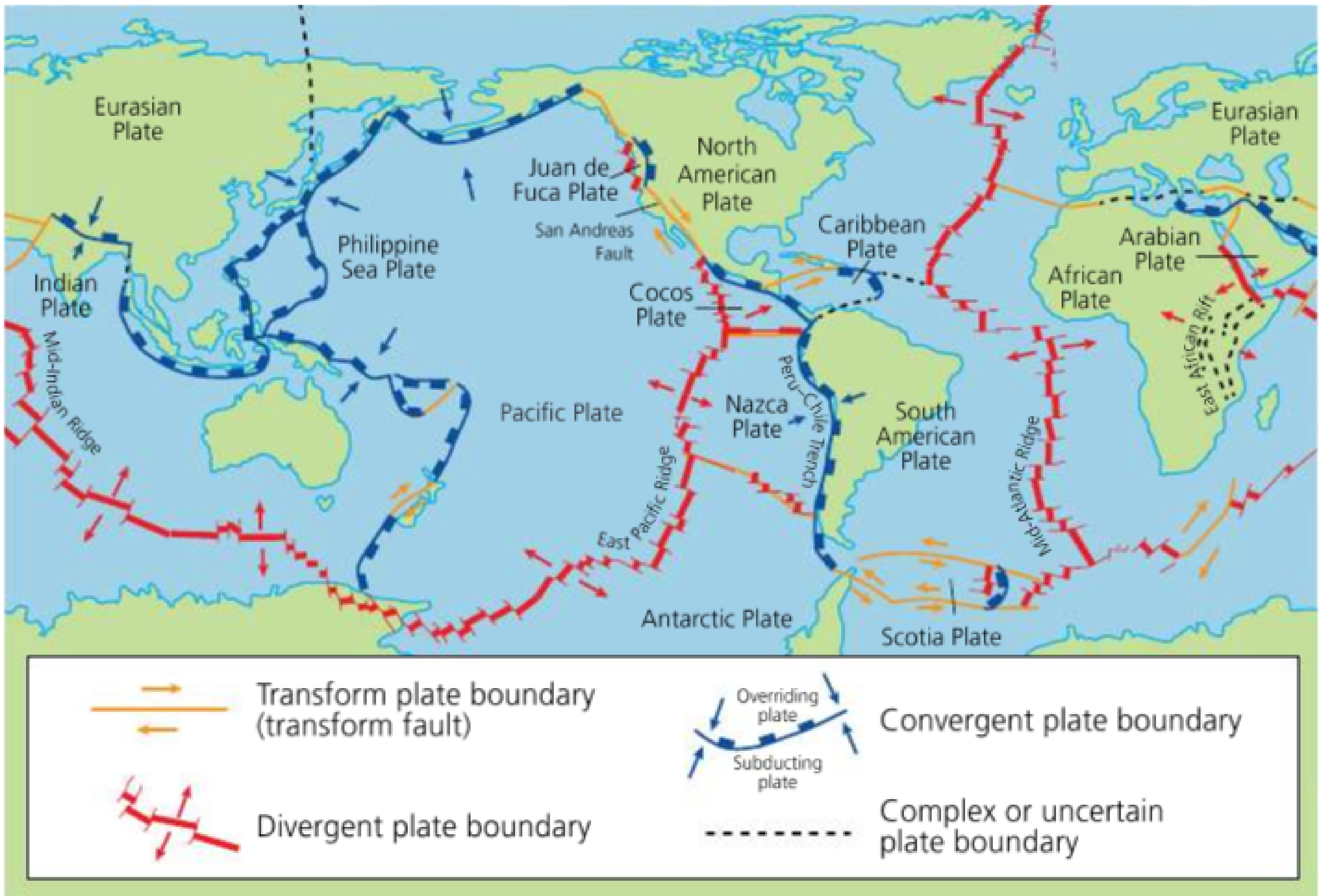
- **Type of boundary**
- **Direction of plate movement (What makes you say that?)**

Now use the internet to search for geographic evidence to support your reasoning. For example, when you look at the map of where the Eurasian and Indian plates touch, you can see it is in north India. So, you can try an image search for North India geography or North India topography.

Assessment opportunities

- In this activity, you have practised skills that are assessed using Criterion A: Knowing and understanding.

Figure 5.16 shows the types of plate boundary that are found around the world. How do your responses in the *Identifying boundaries* activity compare to the types of boundaries that actually exist?



■ **Figure 5.16** Tectonic plate boundaries and movement

DISCUSS

What plate do you live on? Are you close to a plate boundary? If yes, have you experienced the effects of plate movement? If you have lived in other places, what plates were you living on then?

In addition to determining the geographic features and **seismic activity** of a region, plate tectonic theory also explains why some parts of the world are rich in certain minerals, metals, or types of rocks, and why other areas have little. Gems, like diamonds, topaz, and garnets, form as a result of the high pressure and high temperature conditions that occur during the movement of plates. They are brought to the surface (and into human possession) through natural processes that occur at plate boundaries, or through mining. We can see evidence of the influence of plate activity on the formation of gems by looking at a world map of some gemstone resources (Figure 5.17) and comparing them to the locations of plate boundaries (Figures 5.16).

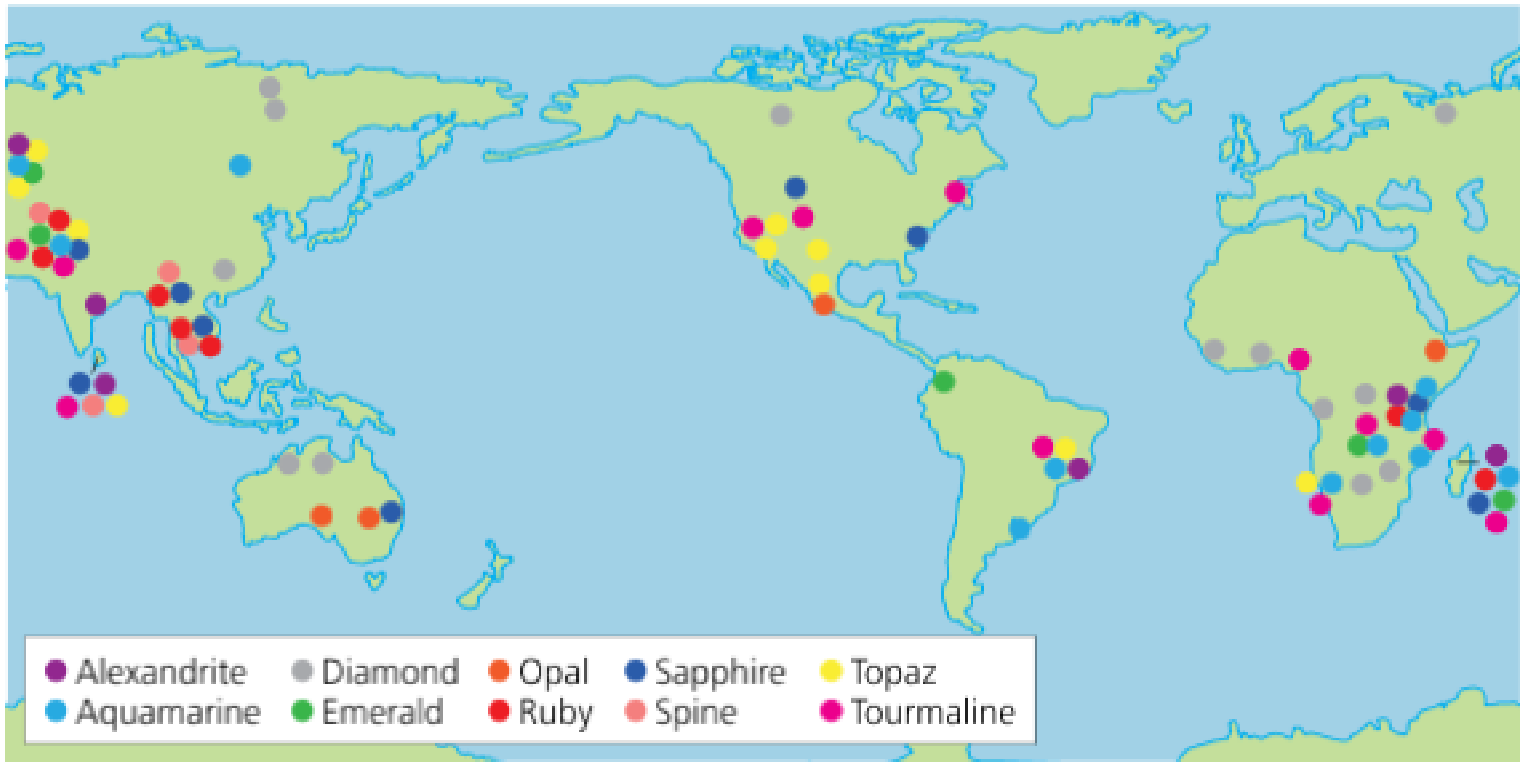


Figure 5.17 Gemstone resources are found in certain areas of the world

The formation of base metals, such as copper, and precious metals, such as gold, is also related to plate activity in parts of the world that have certain types of minerals. These types of metals are found along the plate boundaries where there is a large quantity of minerals in the rocks and where sufficient pressure is created through the process of subduction. In which areas of the world do you predict there might be a large supply of metals?

By measuring seismic activity (the vibrations resulting from plate movement), scientists are able to create models and maps of volcanic activity and earthquakes, and learn about the location and movement of plates. Importantly, they can also see where there is an increase in plate activity, and share this information with local governments to warn them to take precautionary measures to help reduce the damage from impending earthquakes, tsunamis, or volcanic eruptions.

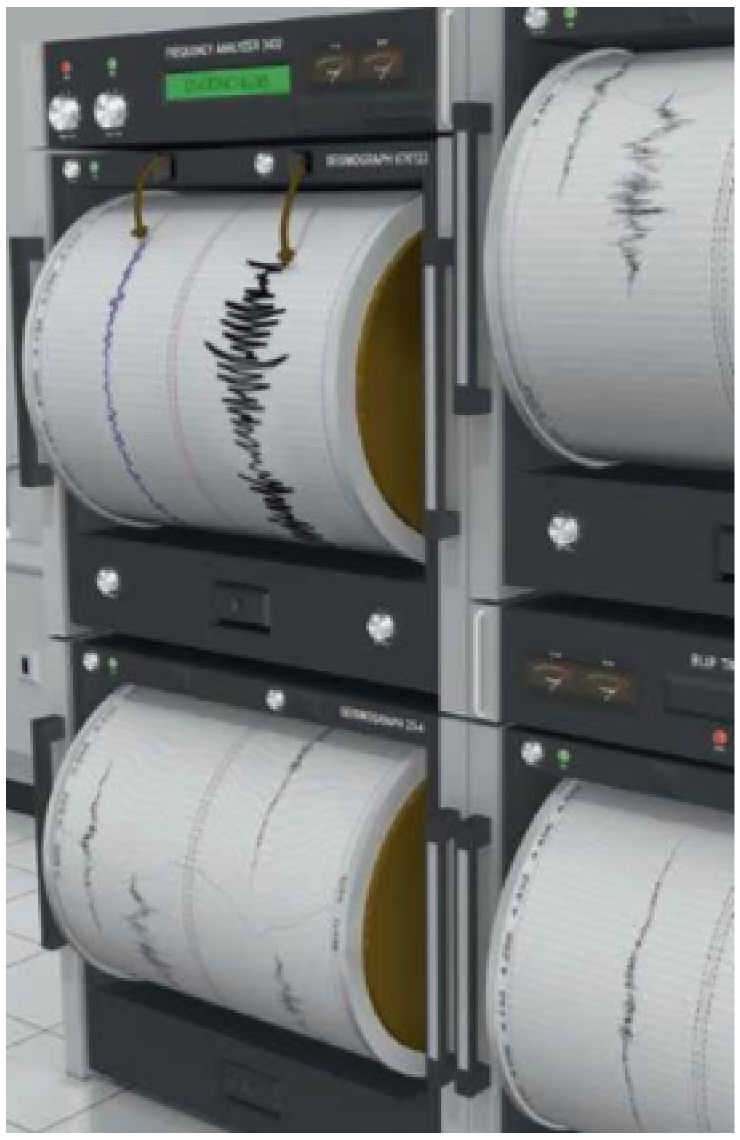


Figure 5.18 Seismograms buried in the ground record the vibrations from plate activity, and can provide early warning of earthquakes and volcanic eruptions

ACTIVITY: Early warning?

ATL

- Critical-thinking skills: Gather and organize relevant information to formulate an argument; Consider ideas from multiple perspectives; Develop contrary or opposing arguments

On December 26, 2004, an earthquake in the floor of the Indian Ocean resulted in a devastating tsunami that hit many countries in the coastal regions of Thailand, Sri Lanka, Indonesia, and India.

Scientists monitoring seismic activity in a tsunami monitoring centre in the Pacific basin were alerted to the increased vibrations and movement in the plates. They identified that a powerful earthquake had occurred in the Indian Ocean, at the boundary of the Indian and Burma plates. According to the information that they received from their seismograms, they issued the message shown in Figure 5.19.

TSUNAMI BULLETIN NUMBER 001
PACIFIC TSUNAMI WARNING CENTER/NOAA/NWS
ISSUED AT 0114Z 26 DEC 2004

THIS BULLETIN IS FOR ALL AREAS OF THE PACIFIC BASIN EXCEPT ALASKA – BRITISH COLUMBIA – WASHINGTON – OREGON – CALIFORNIA.

........TSUNAMI INFORMATION BULLETIN........

THIS MESSAGE IS FOR INFORMATION ONLY. THERE IS NO TSUNAMI WARNING OR WATCH IN EFFECT.

AN EARTHQUAKE HAS OCCURRED WITH THESE PRELIMINARY PARAMETERS

ORIGIN TIME – 0059Z 26 DEC 2004
COORDINATES – 3.4 NORTH 95.7 EAST
LOCATION – OFF W COAST OF NORTHERN SUMATERA
MAGNITUDE – 8.0

EVALUATION

THIS EARTHQUAKE IS LOCATED OUTSIDE THE PACIFIC. NO DESTRUCTIVE TSUNAMI THREAT EXISTS BASED ON HISTORICAL EARTHQUAKE AND TSUNAMI DATA.

THIS WILL BE THE ONLY BULLETIN ISSUED FOR THIS EVENT UNLESS ADDITIONAL INFORMATION BECOMES AVAILABLE.

THE WEST COAST/ALASKA TSUNAMI WARNING CENTER WILL ISSUE BULLETINS FOR ALASKA – BRITISH COLUMBIA – WASHINGTON – OREGON – CALIFORNIA.

Figure 5.19 A bulletin from a tsunami monitoring centre in the Pacific basin

However, without the scientists' knowledge, a large amount of ocean water was moved as a result of the earthquake, and travelled in huge waves toward Thailand, Sri Lanka, India, Indonesia, and other islands and coastal regions in the area. About four hours after the earthquake, a huge tsunami hit these countries, resulting in the kind of damage we can see in Figure 5.20.

After the tsunami occurred, the scientists who were responsible for monitoring seismic activity and the potential of tsunamis evaluated their alert system in order to find out what had gone wrong. They realised that because they had no 'real-time data' of what occurred in the ocean (that is, the movement of water) and their data for the magnitude, or strength, of the earthquake indicated that it was smaller than it actually was, they did not put enough emphasis on the true potential of a tsunami. In addition, even if they had had enough information at the right time to make an accurate prediction, the countries that were in the 'danger zone' did not have any system to receive warning messages from the tsunami monitoring centre.

For this assessment, you will respond to the debatable question: To what extent is it possible to use science to prevent, or reduce the damage from, natural disasters?

Figure 5.20 The Indian Ocean tsunami resulted in devastating damage and loss of life

In other words, you will reflect on the impacts of science – in this case, the ability of experts to use scientific technology, such as seismograms, to learn and warn people about potential natural disasters. For a complete reflection, you must:

- **describe** how science is used to address the problem of natural disasters
- **discuss** and **analyse** how cultural, economic, environmental, political, ethical, moral, or social factors might impact the effectiveness of using science to warn people of natural disasters
- **apply** scientific language consistently and effectively
- appropriately and completely **document** the work of others.

To develop your response, you can research different types of monitoring systems that scientists use to understand and make predictions about large changes in the ecospheres. For example, you might want to research monitoring systems for hurricanes, tornadoes, earthquakes, volcanoes, or tsunamis.

Decide with your teacher what will be the best way for you to **present** your response. Perhaps you would like to make a persuasive speech or documentary; maybe you would like to set up an interview with a classmate; or maybe you'd prefer to write an article or essay. In any case, be sure to use the descriptions for *Criterion D: Reflecting on the impacts of science* to guide you.

Assessment opportunities

- This activity can be assessed using Criterion D: Reflecting on the impacts of science.

Knowledge of plate tectonics not only helps scientists understand the condition of the present Earth and make predictions about the future; it also helps them understand our past. Through the analysis of fossil records of plants and animals and the types and formations of rocks on different continents, scientists understand that at one time, all of the continents, which are today separated by thousands of miles of ocean and sea, were once joined together in a massive 'supercontinent' called **Pangaea**. Our understanding of the movement of plates and the fossil evidence that was left behind has helped to provide evidence for the process of evolution and the development of new species.

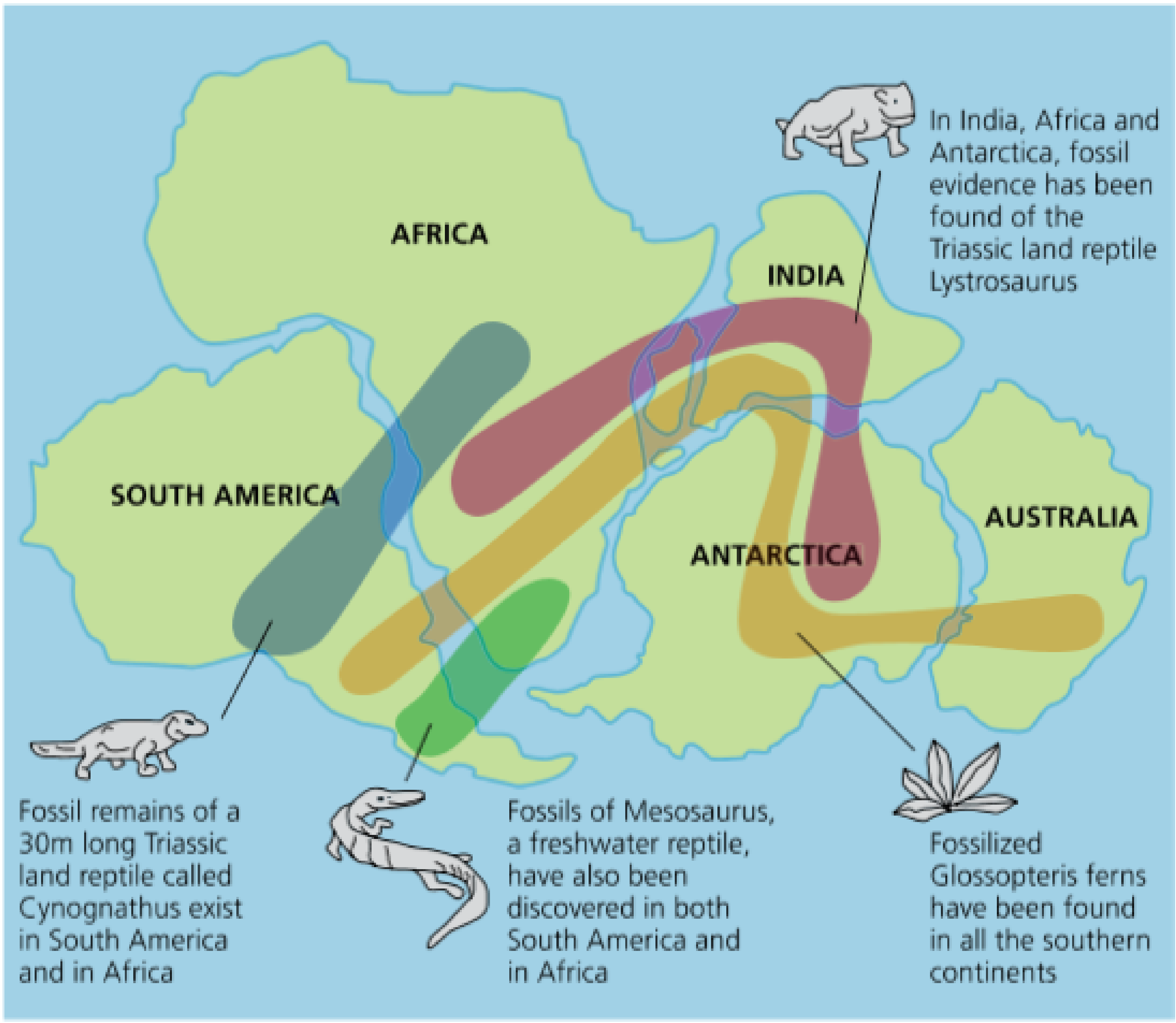


Figure 5.21 Fossil records of the plants and animals that lived millions of years ago provides evidence that the supercontinent Pangaea existed

Links to: Individuals and societies

Our exploration of models and patterns for understanding the systems of the Earth and how they impact human life offers an important perspective for an inquiry into the concept of orientation of space and time as it relates to Individuals and societies.

! Take action! Finding a new home

ATL

- Critical-thinking skills: Gather and organize relevant information to formulate an argument; Interpret data; Evaluate evidence and arguments; Recognize and evaluate propositions; Consider ideas from multiple perspectives; Identify trends and forecast possibilities
- Creative-thinking skills: Consider multiple alternatives; Create novel solutions to authentic problems

! Imagine you are part of an urban development team. You have been hired to identify an ideal location to build a new city for people who have lost their homes due to a recent natural disaster.

! You must make a proposal of where the new city should be to the city government that has hired you. To make your proposal, you must first identify the characteristics of a region that would be ideal for developing a comfortable and sustainable city. For example, you might inquire into the climate and the geography of your proposed region. In addition, you might identify other factors that you learned about in this chapter to help you determine the natural characteristics that would contribute to a successful settlement.

! To support your proposed location for the new city, research models and evidence of climate and geography. You, and the other members of the urban development planning team (your classmates!), will present your proposals to the board of directors (teachers from your school) who will decide which proposal offers the most successful option for designing a successful, sustainable new city.

! For this assessment, you will demonstrate what you know and understand about science by:

- **describing** scientific knowledge about the ecospheres and systems of the Earth
- **applying** this scientific knowledge and understanding to solve the problem of designing a new city
- **analysing** information about the region you have chosen to **identify** patterns that provide scientific support for your proposal.

Assessment opportunities

- This activity can be assessed using Criterion A: Knowing and understanding.

Reflection

In this chapter, we have learned about the different ecospheres of the Earth and the systems that occur within and between those ecospheres. We have learned how the flow of energy and cycling of matter through the atmosphere, hydrosphere, biosphere and geosphere impact human life. We have **inquired** into the properties of water, and how it interacts with air and land to create different climates around the world. We have also **explored** the movement of plates, and how this movement determines not only the physical characteristics of where we live, but also the chances of being confronted with natural disasters such as volcanic eruptions or earthquakes.

<table>
<tr><th colspan="6">Use this table to to evaluate and reflect on your learning in this chapter.</th></tr>
<tr><td>Questions we asked</td><td>Answers we found</td><td colspan="4">Any further questions now?</td></tr>
<tr><td>Factual: What natural systems are necessary to maintain life on Earth? In what ways do the systems on Earth interact? What processes and events have contributed to local and global conditions on Earth?</td><td></td><td colspan="4"></td></tr>
<tr><td>Conceptual: How do the interactions between Earth's systems influence our living conditions?</td><td></td><td colspan="4"></td></tr>
<tr><td>Debatable: To what extent is it possible to use science to prevent, or reduce the damage from, natural disasters?</td><td></td><td colspan="4"></td></tr>
<tr><td rowspan="2">Approaches to learning you used in this chapter:</td><td rowspan="2">Description – what new skills did you learn?</td><td colspan="4">How well did you master the skills?</td></tr>
<tr><td>Novice</td><td>Learner</td><td>Practitioner</td><td>Expert</td></tr>
<tr><td>Organization skills</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Critical-thinking skills</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Creative-thinking skills</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Learner profile attribute(s)</td><td colspan="5">Reflect on the importance of being a thinker for your learning in this chapter.</td></tr>
<tr><td>Thinker</td><td colspan="5"></td></tr>
</table>

6 How do we respond to our world?

Scientific innovations designed to enhance our ability to perceive and respond to change in our surroundings have consequences on our survival.

■ **Figure 6.1** Our success – both on the court and in our daily lives – requires that we can respond to change in our surroundings.

CONSIDER THESE QUESTIONS:

Factual: How do organisms perceive and respond to change in their surroundings?

Conceptual: How does survival depend on organisms' ability to perceive and respond to change in their surroundings? How do species become adapted, over the long term, to conditions in their environment?

Debatable: To what extent should we continue to develop products that impact the way people or other living things perceive and respond to their surroundings? To what extent is the use of sense-enhancing technology a responsible and ethical choice?

Now **share and compare** your thoughts and ideas with your partner, or with the whole class.

IN THIS CHAPTER, WE WILL ...

- **Find out** the systems and mechanisms that allow organisms to respond to their surroundings.
- **Explore** the scientific innovations that have altered our ability to respond and adapt to our surroundings.
- **Take action** by producing a mini-documentary about scientific innovations that enhance our perception of and response to stimuli.

These Approaches to Learning (ATL) kills will be useful …

- Critical-thinking skills
- Creative-thinking skills

We will reflect on this learner profile attribute …

- Thinker

Assessment opportunities in this chapter:

- **Criterion A:** Knowing and understanding
- **Criterion D:** Reflecting on the impacts of science

KEY WORDS

perceive
stimulus (stimuli)
survive

The survival of living things depends on their ability to modify their behaviours according to the conditions in their surroundings. In humans, sometimes these modified behaviours come from conscious, active decisions, but usually they are the result of automatic, uncontrollable responses.

In this chapter, we will explore how living things are able to perceive and respond to the conditions that are in their surroundings. We will consider how the ability to perceive and respond to the environment impacts not only the immediate survival of individuals but also the long-term evolution of species. We will also inquire into how responding, or not responding, to environmental conditions can give rise to new species. Finally, we will consider people's ability to perceive conditions in the environment, and how scientific innovations have changed those abilities.

How do organisms perceive and respond to change in their surroundings?

PERFECT SENSE!

How do we become aware of our surroundings? How do we know what is around us so that we don't walk into things? How do we know there is something is happening behind us that we need to move for? How do we avoid burning ourselves when we are cooking? How do we know what we can eat or drink?

Of course, we use our eyes, ears, skin, nose, and mouth – our **sense organs** – in order to sense the things that are all around us. In other words, we use our senses of sight, hearing, touch, smell, and taste to perceive the things we come in contact with. In addition to our sense organs, we also use our brain and spinal cord, which make up the **central nervous system**, to process and understand what the **stimulus** is and how to respond.

But how does this actually happen? What is it about our eyes, ears, skin, nose, and mouth that makes it possible for us to be aware of what is around us – and then for us to take action or make decisions as a result?

Figure 6.2 To safely cross the street, we use many of our senses: we see and hear the cars passing by so we know when is a good time to cross, and we see and feel the street under our feet so we don't trip on something. What senses do we use when we are eating something?

ACTIVITY: Seeing (and smelling, feeling, hearing, and tasting) is believing

ATL

- Critical-thinking skills: Gather and organize relevant information to formulate an argument

In this activity, you will consider the adaptations we have as humans to perceive different things in our environment.

Work with a partner to copy and complete Table 6.1. Make your responses as detailed as possible – take the time to really think deeply about each of the questions and go beyond an immediate, superficial response. What can you think of that is less obvious, but also relevant, for each question?

Because you must not eat in the science lab, some of the first row has been done for you as an example.

Way to perceive	What do you perceive right now?	How can you perceive these things?	Why is it important to perceive these things?	What would happen if you could not perceive these things?	What do we use to better perceive things in this way?
Tasting	When I eat an orange, it tastes sweet, and sour. A bit of the skin is on the fruit, and it tastes bitter.	When I put food in my mouth and chew, I can taste it, using my sense of taste.			
Smelling					
Hearing					
Feeling					
Seeing					

■ **Table 6.1** Perceiving our environment

Now, consider which of the senses you think is least important to survival. If humans had to 'lose' one of these senses, which one would have the least negative impact on survival?

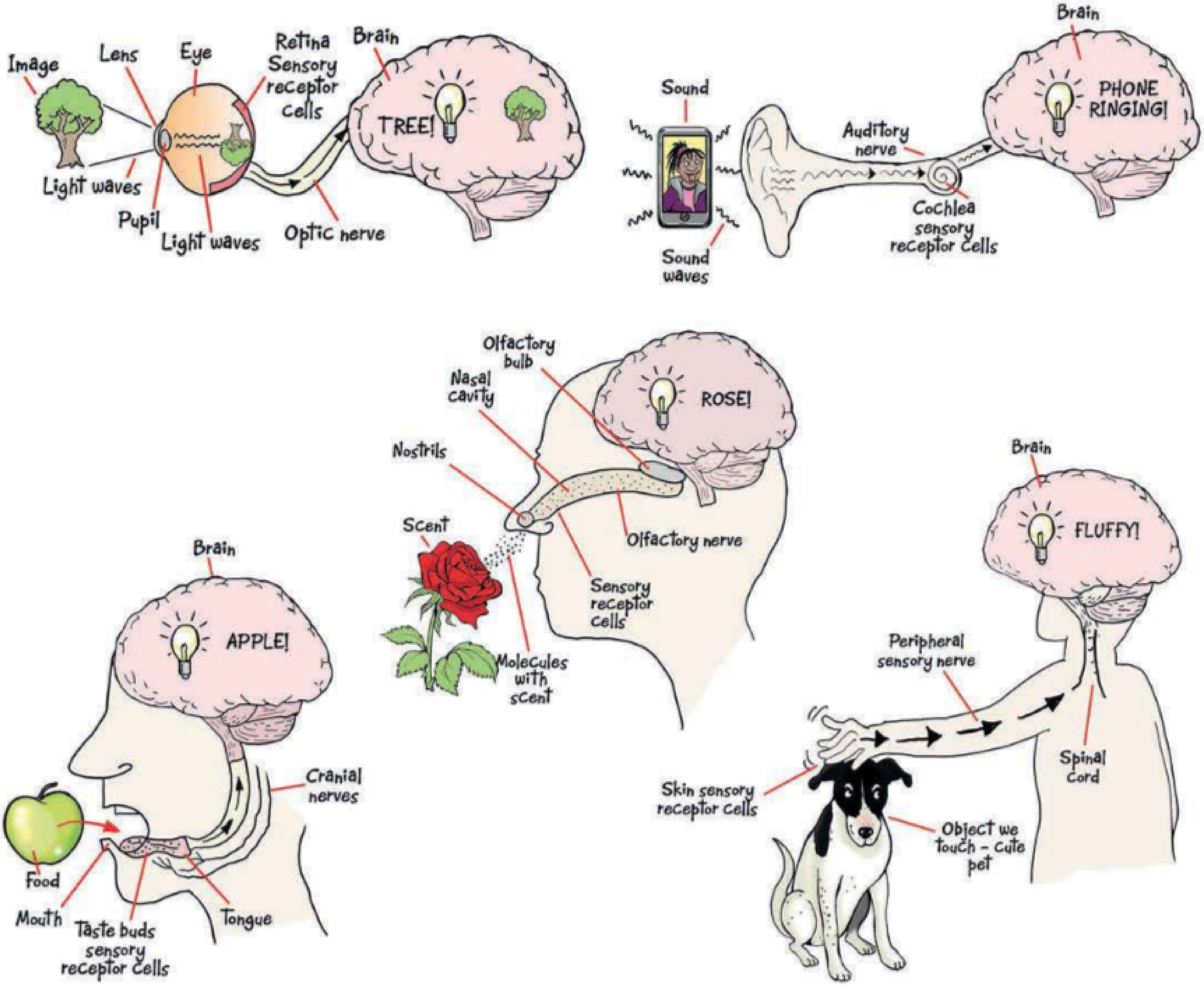
Make a mini-presentation of your argument. Be sure to use scientific reasoning to support your point of view.

Share your mini-presentation with the class. How does your argument compare with your classmates' ideas? **Discuss**: can you come to an agreement?

Assessment opportunities

- In this activity, you have practised skills that are assessed using Criterion A: Knowing and understanding.

Each of our sense organs has specialized cells that are activated by stimuli. (Remember in Chapter 3, we learned that different genes are activated in different types of cells so that they can perform special functions.) Now, we will explore the special functions of these cells in order to understand how each of the sense organs works.



■ **Figure 6.3** Summary of sense organs and their functions

SEE-THINK-WONDER

Working with a partner, copy the See-Think-Wonder chart below.

When we look carefully at Figure 6.3, we ...		
See	**Think**	**Wonder**

Now, look carefully at each sense organ illustrated in Figure 6.3. Read the key words that are included with each illustration. Then, fill in each column of the chart, using these questions to guide your work:

- **See: What are some patterns that you notice in the illustrations? What similarities do you notice between all the sense organs? What differences do you notice between the sense organs?**
- **Think: Based on your prior learning or what you observe in the illustrations, what do you think you know about how our sense organs work? Based on your prior learning or what you observe in the illustrations, how do you think the sense organs work?**
- **Wonder: What do you wonder about sense organs and how they work? What questions do you have about how sense organs work? What puzzles you about how sense organs work?**

Share your responses in your See-Think-Wonder chart with the class. Add new ideas to your chart as you listen to your classmates' responses.

You may have noticed that all of the sense organs are connected to **nerves**, and that nerves are connected to the brain. You might also have noticed that each sense organ has different, specialized structures, and different kinds of nerves.

ACTIVITY: What is a nerve?

ATL

- Critical-thinking skills: Gather and organize relevant information; Interpret data

With your class or a partner, read the definitions related to nerves in Table 6.2, and then make a connection for each to the illustrations in Figure 6.3. In a copy of Table 6.2, write in the key term that is related to each definition.

Each sense organ is able to sense a different stimulus using its specialized sensory receptor cells. Copy and complete Table 6.3.

Nerve	A cluster or group of specialized cells, called **neurons**, that function to send signals to and from the brain so that the organism can recognize and respond to stimuli
Neuron	A specialized cell that can receive and send signals about the things we sense in our surroundings
	Part of the central nervous system that connects the brain with some nerves, like the peripheral nerves
	A nerve that is specialized to send information from the nose to the brain about things that we smell
	A nerve that is specialized to send information from the eyes to the brain about things that we see
	A nerve that is specialized to send information from the mouth to the brain about things that we taste
	A nerve that is specialized to send information from the skin and other parts of the body to the spinal cord

Table 6.2 Definitions related to nerves and nerve cells

Sense organ	Related stimulus
Mouth	
	Something that comes in contact with the skin
	Sound waves
Nose	
Eye	

Table 6.3 Sense organs and the related stimulus for each

Assessment opportunities

- In this activity, you have practised skills that are assessed using Criterion A: Knowing and understanding.

ACTIVITY: Perception pathway

ATL

- Critical-thinking skills: Use models and simulations to explore complex systems and issues

Using your ideas from the *See-Think-Wonder* activity on the previous page, the types of nerves from Table 6.2, and the sense organs and their related stimuli from Table 6.3, describe how each sense organ in Figure 6.3 works. Be sure to use, and **describe**, all of the key words that are noted in the illustrations.

You may choose to make a numbered or bulleted list of steps or write a short paragraph for your description.

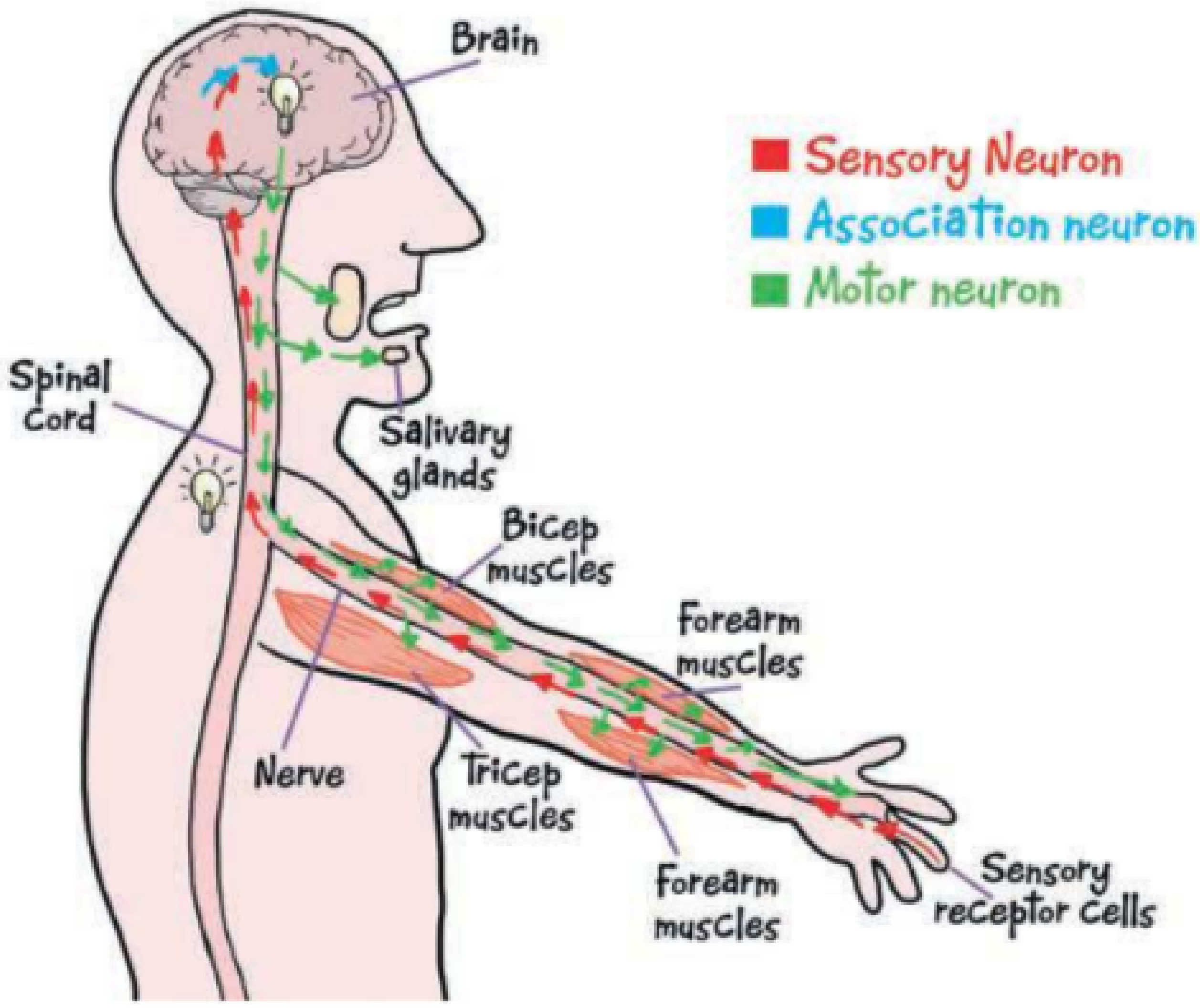
Share your ideas with your class. Add to or modify what you have written according to feedback from your classmates and teacher.

Assessment opportunities

- In this activity, you have practised skills that are assessed using Criterion A: Knowing and understanding.

From the thinking and activities you have done, you have developed an understanding of how we are able to perceive stimuli that surround us. Here is a brief summary for all sense organs in general:

1 A stimulus comes in contact with the sensory receptor cells of a sense organ.
2 The sensory receptor cells send a signal through a nerve.
3 The signal travels along the nerve to the brain or spinal cord.
4 The brain or spinal cord processes the signal and identifies what the stimulus is.



■ **Figure 6.4** Summary of how we respond to stimuli

We know, however, that in order for our sense organs to really fulfil their purpose, it is not enough just to perceive stimuli – we also need to be able to respond to what we perceive around us.

The central nervous system (CNS) – the brain and spinal cord – not only processes signals from sensory nerves and perceives what the stimulus is, it also determines and coordinates a response that will be beneficial for the person's well-being or survival (Figure 6.4).

But what does this mean, exactly? In some cases, it is obvious – if you pick up something hot, your spinal cord sends a signal to your arm and hand muscles so that you drop the hot object and you do not get burned. But what about responses that are less-obviously beneficial or advantageous to our well-being or survival?

ACTIVITY: What's the advantage of that?

ATL

- Creative-thinking skills: Apply existing knowledge to generate new ideas; Practise visible thinking strategies and techniques

In pairs or as a class, consider the possible advantages of some typical responses that come from the CNS (Table 6.4). Write down what you think the advantage of the response is – in other words, write down in what way(s) the response is favourable, beneficial or advantageous for survival. Then use the visible thinking strategy of 'What makes you say that?' to **explain** your thinking. The first one has been done as an example.

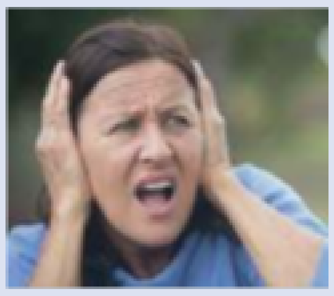
Stimulus	Typical responses	Advantage of the response	Explanation of the advantage (What makes you say that?)
Sunlight shines into your eyes. 	Circular muscles in the iris around each pupil contract so that your pupil gets smaller.	When the pupil is smaller, less sunlight will go into your eyes.	Sunlight can cause 'sunburn' and damage cells. Less sunlight entering the eyes means less risk of damage to cells in the eye. Also, it is not necessary for the pupils to be large because there is enough light to see clearly.
You smell or taste something sweet. 	Glands in your mouth produce more saliva and you feel like you want to eat more of the sweet food.		
You see a large dog off its leash running toward you. 	Radial muscles in the iris around each pupil contract so the pupils get bigger to let more light waves into your eye.		
You feel the cold air when you don't wear your jacket. 	The muscles around the hairs on your arms contract so that the hairs stand up.		
You smell or taste something very sour. 	The muscles in your nose contract so that you 'crinkle' your nose; the muscles in your tongue contract so you force the food out of your mouth.		
The fire alarm in your school suddenly goes off for a fire drill. 	The muscles throughout your body contract so that you 'jump' and the muscles in your heart begin to beat faster.		

Table 6.4 Advantages of typical responses to stimuli

Assessment opportunities

- In this activity, you have practised skills that are assessed using Criterion A: Knowing and understanding.

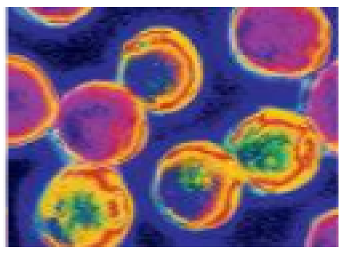
DISCUSS

One of the conceptual questions for this chapter is, 'How does survival depend on organisms' ability to perceive and respond to change in their surroundings?'

Using your knowledge and understanding of how different organisms respond to their surroundings, **discuss** your response to this question. **Share** your ideas with a partner, in a small group, or as a whole class.

Homo sapiens is not the only species that is capable of and depends on perceiving changes in the environment and then responding to the change. In fact, all other species can and do – in their own ways – detect and respond to stimuli. Just like humans, other species have specialized cells (or specialized portions of the cell in the case of single-celled organisms) that detect stimuli, and that also create a response. Just as for humans, these responses are advantageous to the organism's well-being or survival.

Table 6.5 gives some examples from each **kingdom** of living things.

Kingdom	Example species	Stimulus	Response
Archaebacteria 	*Euryarchaeota* – single-celled organism that needs a lot of salt to survive	Salt-detecting proteins in the cell identify a concentration of salt in one area of its habitat.	Cell moves itself toward the area of high salt concentration.
Eubacteria 	*Escherichia coli* – single-celled bacterium that gets most of its nutrients from glucose, a simple sugar	Glucose-detecting proteins in the cell identify a concentration of glucose in one area of its habitat.	Cell moves its flagella so it goes toward the area of high glucose concentration.
Protista 	*Amoeba* – a single-celled organism that mostly uses bacteria as its food source	*Amoeba* cell detects the chemicals that bacterial cells produce.	*Amoeba* uses its pseudopodia to move in the direction of and consume the bacteria.
Fungi 	Mushrooms – multicellular organisms that reproduce in humid, well-lit conditions with low levels of carbon dioxide	Specialized cells detect low levels of carbon dioxide.	A signal is sent to the reproductive cells so they start dividing.
Plant 	Bean sprouts – require sunlight to produce their own food	Specialized cells in the bean sprout leaves detect sunlight from one area of the habitat.	A signal is sent to cells in the stem so the plant grows and bends toward the sunlight.
Animal 	Rabbits – small mammals that live in grasslands and forests and are the prey of larger meat-eating animals	Through its senses of smell or hearing, the rabbit identifies that a fox is nearby.	The CNS determines that danger is near and sends signals to the rabbit's muscles so they contract but stay very still.

■ **Table 6.5** Examples of stimuli and associated responses in all kingdoms of life

ACTIVITY: How will it respond?

ATL

- Creative-thinking skills: Make guesses, ask 'what if' questions and generate testable hypotheses

In this activity you will design and carry out some simple investigations to identify stimuli and responses for different organisms. You can use plants and some types of invertebrate animals – such as worms, pill bugs, or woolly bear caterpillars – for your mini investigation.

First, decide what organism you are going to investigate.

SAFETY: If you choose to use an animal, your teacher must approve the species selected to ensure that is not dangerous for humans and that it can be safely removed from its environment. It is also extremely important that you do not harm or cause stress to any animals during your investigation.

Now, observe your chosen organism in its natural habitat to determine which stimuli you are going to investigate. What conditions seem beneficial to or advantageous for the organism's well-being or survival? For example, is there a lot of moisture or sunlight where your chosen organism lives? Or is it dark or dry? How does it get its food or nutrients for survival?

Once you have decided on the stimuli you are going to inquire into, think of how you would like to identify or test the organism's response. For example, we learned that bean plants detect and grow toward the light, so you could set up different plants with light coming from different directions to see how the plant grows.

Then you need to design your investigation. **Discuss** and write down:

- **'What-if' questions – for example, 'What if I put a light underneath the pot where bean sprouts are growing?'**
- **Guesses in response to your question – for example, 'I think the bean sprout stems will curve and start to grow down towards the light.'**
- **A testable hypothesis – for example, 'If I put a light underneath a pot where bean sprouts are growing, the bean sprout stems will curve and start to grow down towards the light because the leaves need sunlight to grow.'**

When you do your mini investigation, be sure to carefully observe and record the results. Take pictures or videos or make sketches in addition to writing a verbal description of what you see.

At the end, what can you conclude? How does the organism respond to the chosen stimuli? How well did your experiment work? Would you do anything different if you did the experiment again?

EXTENSION

Are you interested in learning more about how organisms other than humans respond to stimuli? You could start by searching for the organisms listed in Table 6.5. For example, you could do a web or video search for ***Euglena* response to stimuli**.

You could also search for a more specific response, such as **plant response to heat**.

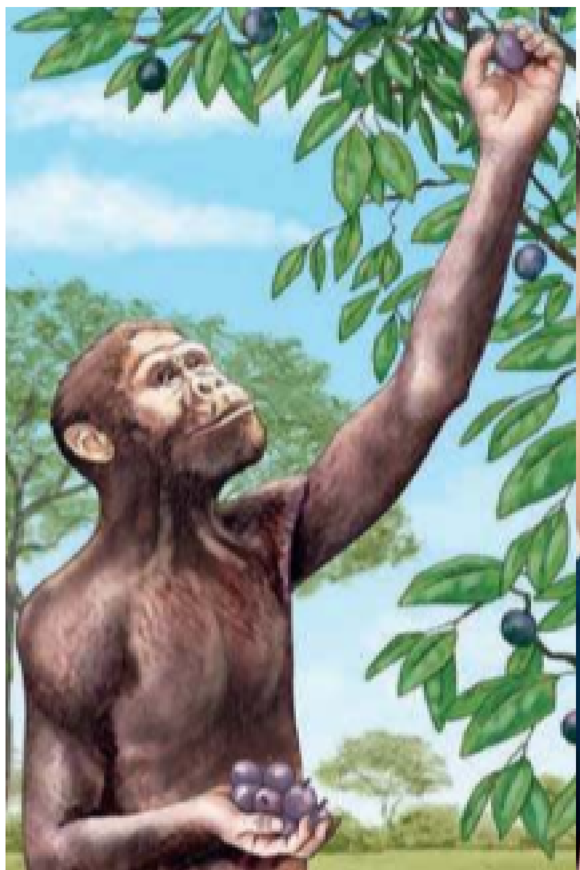
Assessment opportunities

- In this activity, you have practised skills that are assessed using Criterion B: Inquiring and designing, and Criterion C: Processing and evaluating.

How do species become adapted, over the long term, to conditions in their environment?

In the previous section, we focused mainly on how individual organisms – mostly humans – detect changes in their surroundings and then respond in a way that is beneficial or advantageous to the survival of the individual at that moment or in the near future.

Now, we are going to focus on how those responses by individuals can lead to the development – over a long period of time – of characteristics that are beneficial or advantageous for the survival or development of a species. In other words, we are going to explore how, through the process of **natural selection**, species **evolve** so they are adapted, or well-suited, to respond to changes and survive in their habitat.



■ **Figure 6.5**

■ **Figure 6.6** Even though eating too many sweets can have a negative effect on our health, we have a positive response to sweet foods and want to eat more. Why is that?

ACTIVITY: That's sweet!

ATL

- Critical-thinking skills: Analyse complex concepts and projects into their constituent parts and synthesize them to create new understanding
- Creative-thinking skills: Use brainstorming and visual diagrams to generate new ideas

For this activity, we are going to do what is known as a 'thought experiment'. We can think of this as a type of 'experiment modelling' (see Figure 6.7).

For the thought experiment, we 'experiment on' our early human ancestors. Our early human ancestors would hunt and gather any available food from the wild as their only source of food – they did not farm, and of course there were no stores or other places to get food. Therefore, their way to get the nutrients they needed for energy and survival was mostly from the edible plants they were able to collect from the wild, and partly from the animals they were sometimes able to hunt.

Thought experiments

In this activity we have used a 'thought experiment' to model a process that is difficult to create or observe in a real laboratory setting. Scientists often create models to better understand processes that occurred long ago, and make predictions about processes that are too time consuming, expensive, or dangerous to do an actual experiment on.

Your teacher will explain how to conduct the thought experiment but you should think about and discuss the following:

■ **Figure 6.7** How to set up the paper, with your 'population' of early humans

Method

1. **What would happen to our early human ancestors who did not like the taste of sweet foods (fruits, in this case) and would not eat them?**
2. **If some of our early ancestors had 'genetic instructions' that made them have a positive response to sweet foods, and those early ancestors survived and reproduced, what can we predict about the genes and preference for sweet foods of their children? What about those early ancestors whose 'genetic instructions' were for a negative response to sweet foods? What would happen to their 'genetic instructions'?**
3. **How did the early human ancestors' response to the stimulus of 'sweet food' affect their survival? How did this response contribute to their being adapted, or well-suited, for survival in their habitat?**

Although this 'thought experiment' presents a greatly simplified version of how and why modern humans have a positive response to sweet foods, we can use the patterns from the process to gain an understanding of how more and more members of a population become better able to survive as a result of the way they respond to different stimuli in their environment.

We started this thought experiment with the question: 'Why do we respond to the stimulus of a sweet taste by feeling happy and eating more?' Now, using the results from the thought experiment and scientific reasoning about responding to stimuli and how genetic characteristics are passed along, write an argument for why modern humans have a positive response to sweet foods, even though that response can have negative impacts on our well-being and survival. In your response, you might also consider the difference in the modern source of sweet foods compared to the source of sweet foods for our early human ancestors.

Share your argument with your class. What do others think?

◆ Assessment opportunities

- This activity can be assessed using Criterion A: Knowing and understanding.

DISCUSS

Identify each of the three factors on which natural selection relies. In other words:

- **What were the variations in the genes and genetic traits within the species?**
- **In what way did the rate of reproduction differ?**
- **Where did we see evidence that genes were inherited?**

NATURAL SELECTION

In the *That's sweet!* activity, you have learned about one of the most fundamental principles of biology and the natural world: the process of natural selection.

Natural selection occurs as a result of three factors:

- variations in genes and genetic traits within a species
- different rates of reproduction
- the ability for genes to be inherited.

Some individuals in a population have a genetic trait that allows them to be well-suited for their habitat. Because these individuals are well-suited for their habitat, they are more likely to outcompete other, poorly suited individuals. This means the well-suited individuals have access to more resources like food, living space, mates, or water than the poorly suited ones. Because the well-suited individuals have access to more resources, they are more likely to survive and reproduce than the poorly suited individuals.

As the well-suited individuals reproduce, they pass along their genes to their offspring, so that their offspring are also well-suited for survival in their habitat. With each generation, more and more of the well-suited individuals will outcompete the poorly suited individuals, so that, eventually, the population will consist of individuals that have the genes and characteristics of the well-suited individuals.

At that point – when a population of organisms has an inheritable genetic trait that makes them well-suited for survival in their habitat – we say that they have **adapted**, or have an **adaptation**, to their habitat. If, through the process of natural selection, the genetic make-up of the population becomes very different from the original genetic make-up, we can say that a new species has evolved.

DISCUSS

Each of the three factors necessary for natural selection to occur is represented in the previous three paragraphs.

Discuss with your partner or as a class where each factor is described.

I used to think, now I think …

We have learned a lot about how and why we perceive and respond to different stimuli, as well as how those responses contribute to the development of adaptations that are advantageous for survival.

Take a moment to reflect on what you used to think about what it meant for organisms to be 'adapted' to their environment, and what you now think it really means when organisms are 'adapted' to their environment.

EXTENSION

What are some other adaptations that have resulted from the process of natural selection? Try doing a web or image search for interesting adaptations and share your results with your classmates. In what ways do you think the adaptations make the organisms better suited to perceive and respond to changes in their environment?

Links to: Individuals and societies

The topics, activities and discussion in the chapter have required you to test hypotheses and interpret increasingly complex information, two skills that are also a key component of Individuals and societies. In addition, in Individuals and societies, you also explore the concept of causality (cause and consequence), which is related to the scientific concepts of change and consequence in this chapter.

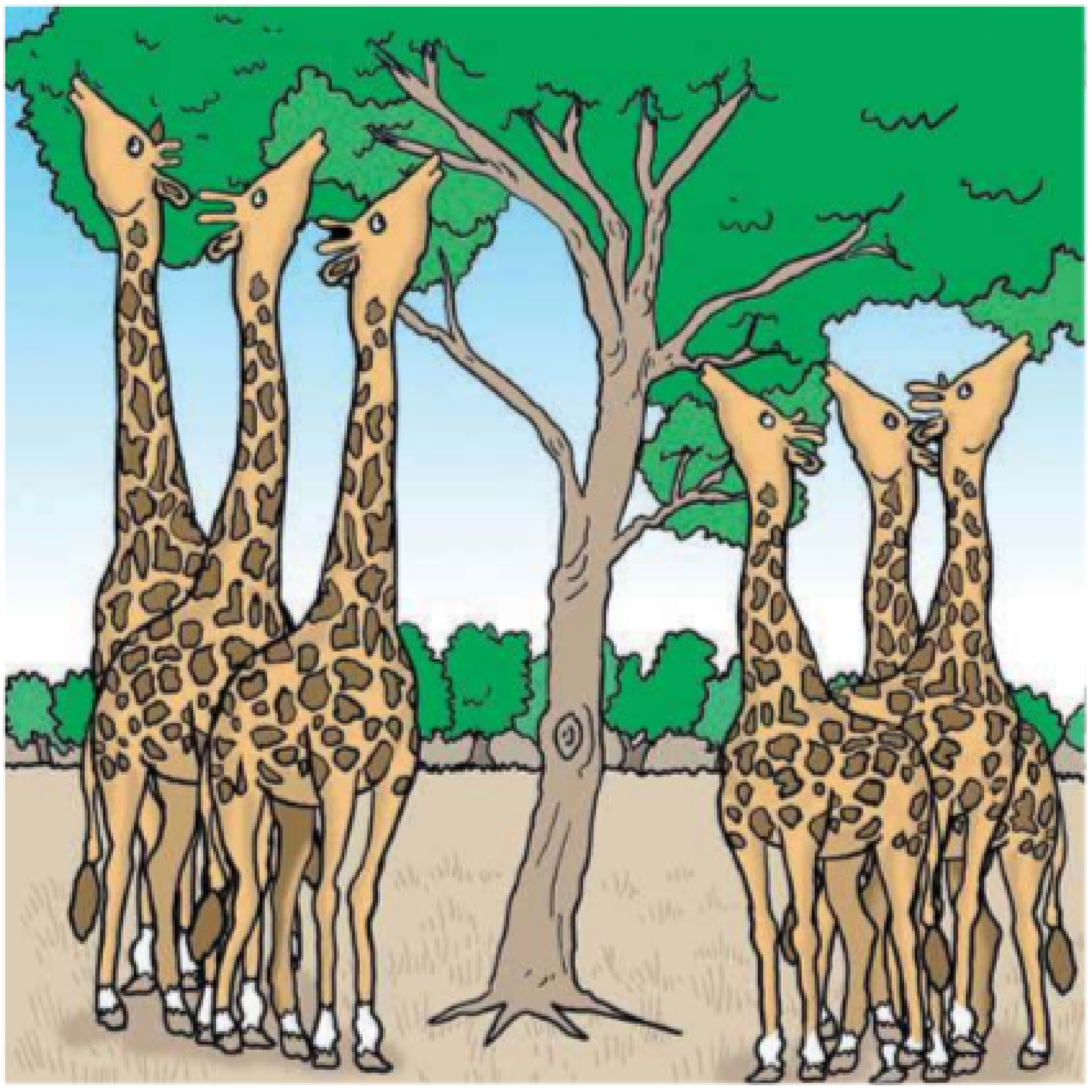


Figure 6.8 Some individuals have genetic characteristics that make them well-suited for survival in their habitat

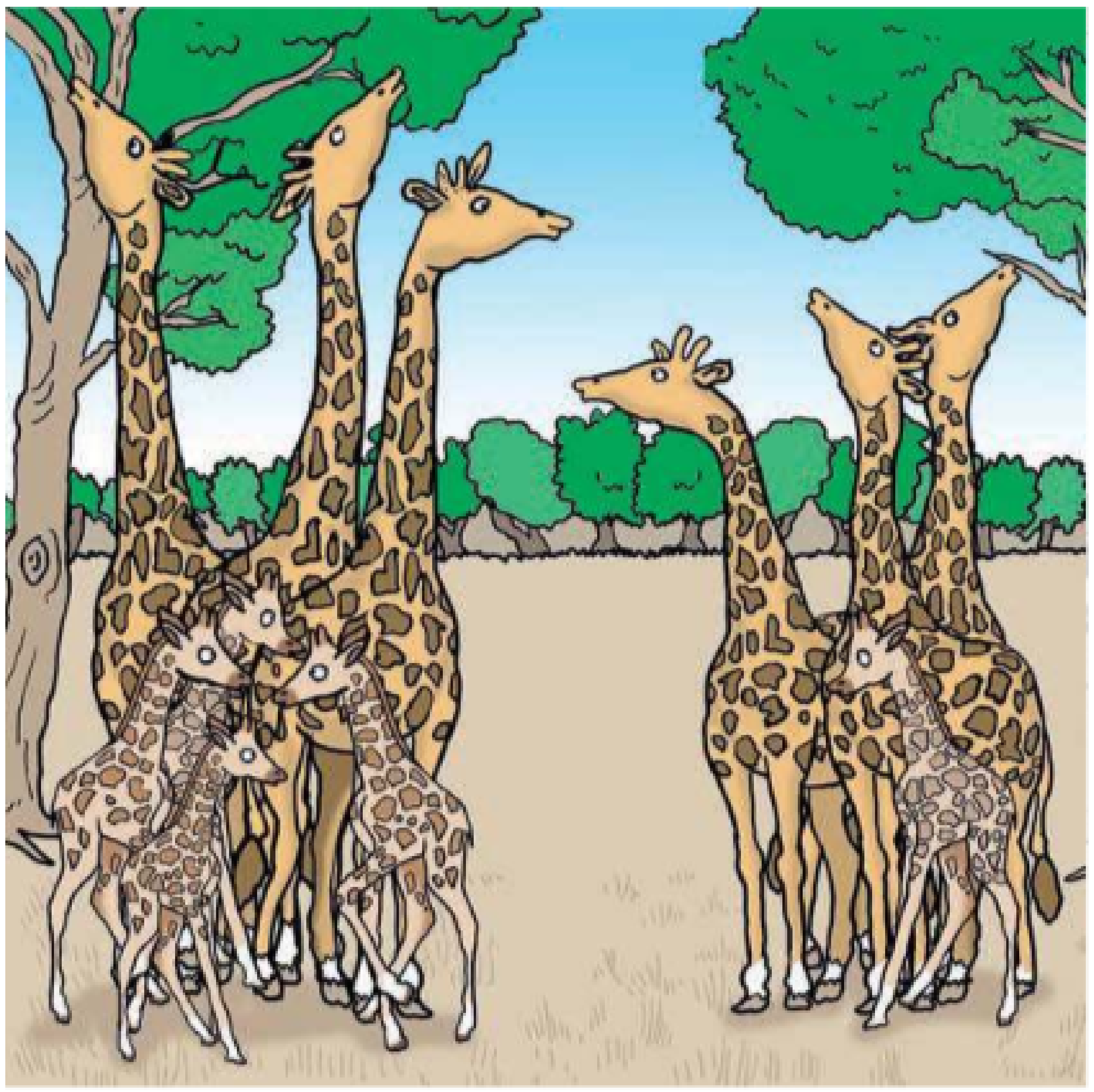


Figure 6.9 Individuals that are well-suited are more likely to reproduce and pass along their genetic characteristics to their offspring

! Take action!
Opportunity to apply learning through action … Major summative project

ATL

- Critical-thinking skills: Gather and organize relevant information to formulate an argument; Draw reasonable conclusions and generalizations
- Creative-thinking skills: Make unexpected or unusual connections between objects and/or ideas; Apply existing knowledge to generate new ideas

! You are a movie producer. You are going to produce a mini-documentary about technology that enhances the way in which people can perceive or sense different stimuli. Earlier in the chapter, you began your research to learn about different types of technology that exist to help people better perceive and respond to their surroundings.

! Perhaps in your research you read about some common, day-to-day forms of technology that we use to enhance our senses, such as eyeglasses or hearing aids. Perhaps you found more high-tech examples, such as night-vision goggles. Before you begin the production of your video, take the time to research, think, and talk about technology that has enhanced all of our senses. Think creatively! How, for example, has technology enhanced our sense of taste?

! In any case, the goal for your mini-documentary is to reflect on the impact of using science to enhance the way in which we perceive or sense different stimuli. In addition, in your mini-documentary, you must include your response to and ideas about the debatable questions for this chapter:

> To what extent should we continue to develop products that impact the way people or other living things perceive and respond to their surroundings?
>
> To what extent is the use of sense-enhancing technology a responsible and ethical choice?

! Your mini-documentary can take many forms – perhaps you will interview an expert, such as an eye doctor, as a primary source of information about your topic. If you are uncomfortable being recorded, you may write a script that you give to one or more of your classmates so that you are the producer, writer, and director. Or maybe you prefer to do an animation! There are many options, so be sure to create a step-by-step plan and discuss it with your teacher before you begin.

! In the production of your mini-documentary, be sure you:

- **describe** the ways in which science is applied and used to enhance people's perception of stimuli
- **discuss** and **analyse** the cultural, economic, ethical, environmental, moral, political, or social implications of using science to enhance people's perception of stimuli
- **apply** scientific language effectively
- **document** the work of others and sources of information used.

Assessment opportunities

- This activity can be assessed using Criterion D: Reflecting on the impacts of science.

Reflection

In this chapter, we have learned how humans and other organisms are able to perceive and respond to changes in their environment. We have **inquired** into the human nervous system and sense organs, and how they function to support our survival. We have also **explored** the process of natural selection, and its relationship to perceiving and responding to stimuli, as well as the development of adaptations within a species. We have grown as '**thinkers**' by practising critical- and creative-thinking skills, and we have practised our scientific skills by using a 'thought experiment' to model a complex, long-term process.

<table>
<tr><th colspan="6">Use this table to evaluate and reflect on your learning in this chapter.</th></tr>
<tr><td>Questions we asked</td><td>Answers we found</td><td colspan="4">Any further questions now?</td></tr>
<tr><td>Factual: How do organisms perceive and respond to change in their surroundings?</td><td></td><td colspan="4"></td></tr>
<tr><td>Conceptual: How does survival depend on organisms' ability to perceive and respond to change in their surroundings? How do species become adapted, over the long term, to conditions in their environment?</td><td></td><td colspan="4"></td></tr>
<tr><td>Debatable: To what extent should we continue to develop products that impact the way people or other living things perceive and respond to their surroundings? To what extent is the use of sense-enhancing technology a responsible and ethical choice?</td><td></td><td colspan="4"></td></tr>
<tr><td rowspan="2">Approaches to learning you used in this chapter:</td><td rowspan="2">Description – what new skills did you learn?</td><td colspan="4">How well did you master the skills?</td></tr>
<tr><td>Novice</td><td>Learner</td><td>Practitioner</td><td>Expert</td></tr>
<tr><td>Critical-thinking skills</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Creative-thinking skills</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Learner profile attribute(s)</td><td colspan="5">Reflect on the importance of being a thinker for your learning in this chapter.</td></tr>
<tr><td>Thinker</td><td colspan="5"></td></tr>
</table>

Glossary

absorb take in energy, or a fluid substance

acceleration rate of change of velocity; change of velocity in a certain time

accurate close to an expected value

acids substances producing hydrogen ions in solution; substances that produce a solution with pH value less than 7

acoustics the branch of physics concerned with the properties of sound

adaptation a characteristic or trait that helps an organism survive in its habitat

adapted when an organism or trait has modified or become better suited for its surroundings

air resistance force of resistance produced by the action of air particles on a moving object

alkali substances producing hydroxide ions in solution; substances that produce a solution with pH value greater than 7

alleles alternative forms of a gene

alloy a mixture of metals

altitude distance above sea level

amplifier any device that increases the amplitude of a signal; electronic device that increases amplitude of electrical signals

amplitude distance from the equilibrium (midpoint) of an oscillation to the point of maximum displacement

aperture an opening or gap through which light passes in an optical instrument

approximation a value that is nearly the same as another, but not exactly correct

aqueous humour the clear fluid filling the space in the front of the eyeball between the lens and the cornea

asexual reproduction reproduction by cloning of a single parent organism, without the combination of genetic information

atomic mass the measured mass of a chemical element expressed in atomic mass units. Approximately equal to the number of protons and neutrons in the nucleus, or to their average number when relative abundancies of isotopes are included

atomic number number of protons in the nucleus of an atom, defining the place of an element in the periodic table

attract action of a force that tends to bring two objects closer together

auditory relating to hearing

axis a line of reference for measuring coordinates

balanced equal on both sides

bases building blocks for DNA; either adenine, cytosine, guanine, or thymine

binary fission a type of asexual reproduction that usually occurs in prokaryotes (like bacteria) and other single-celled organisms

blastocyst a group of cells that forms in the early stages of the development of an embryo

bonded joined chemically

budding a type of asexual reproduction in which a 'bud' or small outgrowth grows off the parent organism before breaking off into an independent organism

calculus mathematical method to express the properties of functions through infinitesimally small differences

calibrating adjusting an instrument or reading to an expected value or to a standard reference point

camera obscura a darkened room with a small aperture to produce a projected image of the outside

central nervous system (CNS) the part of the nervous system that is composed of the brain and spinal cord and is responsible for controlling the functions and actions of the body

centrioles small organelles that help with the production of the spindle fibers for cell division

centromeres the place on a chromosome where the spindle fibers attach during cell division

chemical formula symbolic expression of the atomic composition of a substance

chemical reaction any process where particles are exchanged between reactants to produce products with new chemical properties

chromosome thread-like structures in the nucleus of cells that contain the genetic information for the organism

ciliary muscles muscles that stretch the lens in the eye to change its curvature

climatograph (climograph, climogram) graphic representation of the average monthly temperature and precipitation in a given area during a year

cochlea spiral tube in the inner ear that converts physical vibrations of sound to nerve impulses

coke a fuel made by heating coal to purify it

combustion process of burning something; the rapid exothermic oxidation of a substance

compressions regions of relatively higher pressure

cones in the eye, light sensitive cells that respond to different wavelengths, giving the perception of colour

conservation of mass law stating that mass is never created or destroyed in a chemical process, but only reorganised

coordinates a group of numbers used to indicate a position in a geometric space, such as on a line or plane

core the innermost layer of the Earth

cornea transparent tissue that covers the front of the eye

crest in a wave, the point of greatest positive displacement

cubit ancient length measurement, thought to be equivalent to the length of a man's forearm

currents air or water that moves in a particular direction

datum a single point of information (plural: *data*)

daughter cells the cells that result from cell division

decibel scale scale for measuring the loudness of sound or other signals

decompose in chemistry, to break down a compound to simpler components, or elements

deduced work out a conclusion by logical processes

deuteranopia defect of colour vision caused by insensitivity to green light, resulting in confusion of greens and reds

differentiate the process of cells becoming specialized to make up different tissues and organs and to perform specific functions

dilution reducing concentration of a solution by adding more solvent

displacement moving something from its usual position; in chemistry, the replacement of a compound or substance with another

displacement reaction reaction in which chemical displacement occurs

DNA replication the process of making an exact copy of DNA

dominant the genetic characteristic that appears in the offspring as long as the offspring inherited one allele of the trait from its parents

double helix the shape of a molecule of DNA, in which the two strands that make up the DNA are wound together

durable hardwearing, able to withstand sustained use

dye a chemical substance that adds colour

ear canal the channel leading from the outer to the middle ear

ear drum the tympanic membrane; thin tissue across the ear canal in the middle ear which vibrates in response to sound waves

egg female gamete (sex cell)

electric field a volume of space in which electrical charges exert forces on other electrical charges

electrolysis chemical decomposition produced by passing an electric current through a liquid or solution containing ions

electromagnetic radiation energy produced by varying electrical and magnetic fields of different frequencies, including visible light, ultraviolet radiation and gamma rays

electromagnetic spectrum the range of electromagnetic fields organised in terms of wavelength and categorised in terms of their effect on matter

electron an elementary particle with a negative electrical charge, usually found outside the nucleus within atoms

elevation height above sea level

emit give out, especially energy or waves

enzymes biological catalysts that speed up chemical reactions in a living organism

epigenetics the non-genetic factors that influence an organism's characteristics

equilibrium position point of rest for an object or a medium when no resultant force is acting

erosion the process of breaking down or destroying a surface or substance

evolve the process of changing over time

fetus unborn offspring of a mammal

focus point of convergence of rays, for example light rays

foot a unit of measurement in the 'British Imperial' measurement system equal to twelve inches

fovea a small depression in the retina of the eye where visual sensitivity is highest and where retinal cones are particularly concentrated

fragmentation breaking DNA into pieces

frequency the number of oscillations per second

friction retarding force resulting from the physical interaction of two objects in physical contact, always acting against the direction of motion

gametes male or female sex cells that combine in the process of sexual reproduction

gel electrophoresis laboratory procedure that allows DNA fragments to be separated and visualized according to the molecular size of the fragments

gene pool all of the possible genes present in a population

gene a section of DNA that codes for characteristics of the organism; genes are inheritable and passed from parents to offspring

gene expression when the information contained within a gene is observable

genotype the genetic makeup of an organism

genus a taxonomic category, higher than species but lower then family, for example *Homo*

gland an organ that produces chemical substances, such as hormones

gold leaf very thin sheet of gold

gradient slope or incline, especially of a line or curve on a graph

gravity attractive force acting between all masses

Greenwich Mean Time a time standard, where midday is defined when the Sun passes its zenith over a meridian through Greenwich in East London, UK

groups in the periodic table, elements arranged in a vertical column

hand an ancient unit of length, based on the breadth of the palm

heterozygous a pair of genes in which one gene is dominant and one gene is recessive

homozygous when both alleles are matching

inch a unit of length in the British Imperial measurement system, equal to 2.54cm

indicator any chemical substance whose change of property can be used to detect the presence of other substances, especially colour changes in the presence of acids and alkalis

inertia the resistance of a mass to any change in its state of motion

inheritable diseases diseases that are passed from parent to offspring through genes

interference effect of combination of two waves to make a resultant wave

ion a charged atom, resulting in the gain or loss of electrons

iris the coloured part of the eye surrounding the pupil

kilogram standard unit of mass in the SI unit system

kingdom largest taxonomic category according to common fundamental characteristics

latitude angular distance of a place north or south of the equator

lava melted rock that erupts from a volcano or crack in the Earth

leeward the side that is sheltered or away from the wind

lens a prism whose shape causes rays to converge or diverge to a point

limestone sedimentary rock formed from the shells of prehistoric sea creatures

limewater a solution of calcium hydroxide

longitude angular distance of a place east or west of the Greenwich Meridian

longitudinal oscillation an oscillation in which the medium moves to and fro in the same axis along which energy is transferred

magma melted rock that is still contained within the Earth

matter physical substance that has mass or takes up space

measurement standard a physical reference used to define units of measurement, such as length, mass or time

medium (media) any material through which energy travels in the form of a wave

meiosis type of cell division that results in the production of gametes

metre Système Internationale (SI) fundamental unit of length

metric any unit of measurement deriving from the metre in the Systeme Internationale (SI) standard

microtubules small tube-like structures that are found in the cytoplasm of cells

mitosis cell division

molecule a group of atoms bonded together, representing the smallest fundamental unit of a chemical compound that can take part in a chemical reaction

momentum a quantity related to inertia found by multiplying the mass by the velocity of an object

motor nerves nerves that carry impulses from the central nervous system to muscles

mutated genetic information that has been changed or modified from its original form

native deposits metals found in their metallic form in rock, either elemental (pure) or as an alloy

natural selection the process through which organisms better suited for survival in a habitat give rise to more offspring that are also better suited, and that can eventually lead to evolution of new species

nerves a bundle or group of neurons

neurons nerve cells

neutral devoid of a certain property, for example, without electrical charge, or without acidity or alkilinity

neutron nuclear particle with mass slightly greater than a proton but with no overall electrical charge

nitrogenous base one of the nitrogen containing molecules (adenine, cytosine, guanine, thymine) that make up DNA

nucleus massive central part of an atom, containing protons and neutrons

offspring the young organism that results from reproduction

omnivorous living thing that eats both animal and plant matter

optic related to light, and instruments that are used to manipulate light

orbit a closed trajectory (circular or elliptical) around another object, such as a planet or an atomic nucleus

ore a naturally occurring solid material from which a metal or mineral can be extracted

origin in Cartesian coordinates, the point of intersection of axes, from which coordinates are numbered

oscillation any vibration or movement back and forward

ossicles tiny bones of the middle ear

outer ear the part of the ear including the pinna or auricle and the auditory canal

oval window aperture at the innermost end of the auditory canal

oxidation reaction a chemical reaction in which oxygen is added to a reactant by addition or displacement

oxide a chemical compound consisting of a metal and oxygen

Pangaea the supercontinent that was made up of all the current continents before the occurrence of continental drift

paradox a seemingly contradictory statement which may nevertheless be true

parthenogenesis reproduction from a female organism even though fertilization has not occurred

PCR polymerase chain reaction laboratory procedure to rapidly make multiple copies of a fragment of DNA

peak in oscillations and waves, the point of maximum positive displacement from equilibrium

periods in the periodic table, elements arranged in a horizontal row

physical properties a property that is measurable, defining the physical or mechanical state of an object

pigment compound that gives colour to an organism or parts of an organism

pinna the outer ear visible outside the skull, also called the auricle

pitch the perceived property of a sound wave that relates to frequency

plate tectonic theory the theory that the surface of the Earth is covered by land masses that move slowly over the surface of the Earth

plates land masses that make up the surface of the Earth

polymers a substance whose molecular structure consists of a number of smaller, similar units bonded together

precipitation rain, snow, sleet, or hail that falls to the earth during the water cycle

precise in measurement, results or measurements that are in close agreement with each other (without necessarily being correct)

primary colours a group of colours from which all other colours can be obtained by mixing

prime meridian the line of longitude defined as zero degrees for any planet

prism a transparent object whose shape is used to control light by refraction

products what is produced in a chemical reaction

propagation reproduction, or spreading out of an effect or energy

protons nuclear particles with significant mass and carrying a positive electrical charge

pull factors any factor which attracts, particularly for human migration

pupil the aperture at the front of the eye through which light passes

push factors any factor which repels, particularly for human migration

quark theoretical elementary particle which in groups form larger, massive particles called hadrons

rain shadow effect when a geographic feature, such as a mountain range, blocks the moist air that leads to precipitation, leading to a relatively dry area

reactants substances that undergo a chemical reaction

reactivity series hierarchy of metals and other elements in terms of their chemical reactivity

recessive the genetic characteristic that appears in the offspring only if the offspring has inherited the same allele of the trait from both of its parents

reduced to have lost oxygen, gained hydrogen or gained electrons through a chemical reaction

reflex involuntary muscular response

refraction change of direction of propagation of light or other waves as they pass from one medium to another

relative velocity velocity of an object relative to another moving object

reliable replicable results that can be reproduced in subsequent experiments

resonance constructive interference of vibrations / sound waves to produce much larger vibrations

retina tissue at the back of the eye containing light-sensitive cells

rods light-sensitive cells in the eye that respond to brightness only

run-off water that drains away, down the surface of the Earth

salt a chemical compound formed by the reaction of an acid with a base (alkali)

seismic relating to movement of the Earth and the Earth's crust

seismic activity vibrations caused by movement of tectonic plates

sense organs organs, such as eyes, nose, mouth, ears, and skin, that are capable of perceiving different stimuli

sexual reproduction production of new organisms through the combination of male and female genetic information

sister chromatids the identical strands of genetic information that are produced during the process of mitosis

sonar detection system that uses reflection of sound waves

species taxonomic category of living things that can reproduce together, for example *Homo sapiens*

sperm male gamete (sex cell)

steel an alloy of iron and carbon

stimulus (stimuli) a substance or event that causes a reaction

subatomic particle any particle smaller than an atom, principally protons, neutrons and electrons

subduction zone boundary of two plates that have collided, when one plate slides under the other

tension a stretching force

time period time taken for one oscillation to complete

time zone range of longitudes on the Earth where the clock time is adjusted to the same value

tissues groups of cells of the same type

topographic graphic representation of the features of the surface of the Earth

topography the features of the surface of the Earth

trait characteristic

transverse oscillation oscillation in which the medium is moving at right angles to the direction of propagation of energy

trough in waves, the point of maximum minimum displacement of a medium

ultrasound high frequency sound used for echolocation, especially in medicine

universal indicator a mixture of indicators to provide a colour spectrum relating to the acidity and alkalinity of a solution

vectors arrows indicating direction and magnitude

velocity the speed in a certain direction, displacement per unit time

vestibulocochlear nerve also called the auditory nerve, nerve responsible for transmitting signals from the inner ear to the brain

volume the perceived property of a sound wave related to its amplitude

wavelength the distance from a point in an oscillation to the same point in the next oscillation

weathering the process of erosion that occurs from the exposure to different weather conditions, such as rain and wind

windward the side that is exposed to or in the direction of the wind

word equation representation of chemical reactions using the names of compounds

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