MYP *by Concept*

3

Sciences

Paul Morris
Patricia Deo

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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.

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.

■ **Figure 1.1** Theo Jansen's Strandbeest machine

● We will reflect on this learner profile attribute…

• Thinkers – in this chapter, we will think critically and creatively to evaluate different points of view and data.

KEY WORDS

extract
exploit
mechanism
resource
transform

SEE–THINK–WONDER

Theo Jansen is an artist from the Netherlands who makes amazing machines like the one in Figure 1.1. Look at the image, and some of Theo's other machines at www.strandbeest.com.

- **What do you see?**
- **What does it make you think**
- **What does it make you wonder**

Want to find out more? Watch Theo's TED talk at www.ted.com and search for Theo Jansen

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 How do we make it work?

Machines have **revolutionized life** by making it easier to **change energy** from stored forms to **movement** and back again.

CONSIDER THESE QUESTIONS:

Factual: What is a machine? What do we mean by 'energy'? How do we measure energetic change? What is efficiency? What kinds of machines are there? What are fuels?

Conceptual: How do energy changes determine chemical change? Will energy ever run out?

Debatable: What have been the good and the bad consequences of using machines to do work?

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

IN THIS CHAPTER, WE WILL …

- **Find out** how energy changes form and type, but is never created or destroyed, and how work is done when energy changes.
- **Explore** simple machines for doing work and how they make work more efficient, the use of energy resources globally, and some of the problems with global dependency on fossil fuels.
- **Take action** to increase access to a simple machine that can make a real difference to people's lives – a water pump.

These Approaches to Learning skills will be useful…

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

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 1.1** Theo Jansen's Strandbeest machine

● We will reflect on this learner profile attribute…

- Thinkers – in this chapter, we will think critically and creatively to evaluate different points of view and data.

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What is a machine?

■ **Figure 1.2**

■ **Figure 1.3**

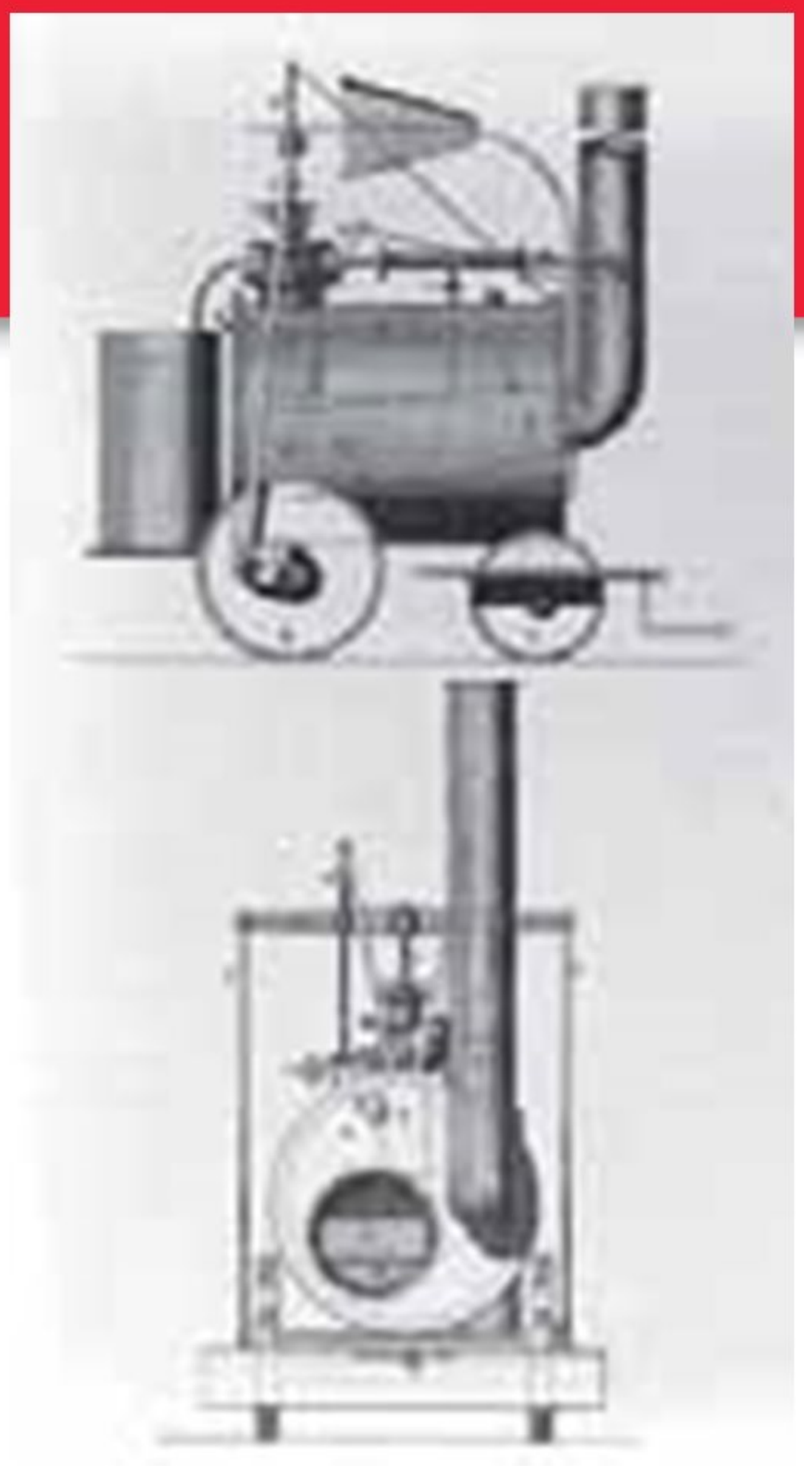
WHAT MAKES YOU SAY THAT?

On your own: Look at the images in Figure 1.2 and Figure 1.3.

As a class: Answer the following questions with reference to the pictures.

- **What is happening in the images? What is being done?**
- **What do the images have in common? What makes them different?**
- **What do you see that makes you say that?**

For most of human history, we have relied on nature to directly provide us with energy to do the work we need to do. What couldn't be done by the power of human muscles had to be done by the power of animals – for example, oxen, horses, donkeys, mules, elephants, yaks … whatever 'beast of burden' was available. Like all living things, animals require regular inputs of energy in the form of food. They also require rest after a day of work has been extracted from them. So important were these working animals that their human users often gave them a place to live that was at least as good as their own! Of course, restless humans wanted to improve on what nature has to offer, and dreamt of a 'beast of burden' that needed no rest, and whose energy input gave more and more work. The first technological solution to this problem was the steam locomotive.



Machines don't have to be as complicated as a steam engine or a solar power plant. The very first machines were made by the earliest humans in the form of tools to make the everyday work of survival more **efficient**. In fact, non-human animals such as higher primates like chimpanzees or bonobos use sticks and other natural implements to help them to do their work.

A machine is really any device or mechanism for helping us to do work more efficiently, by using the least amount of energy to do the most amount of work.

■ **Figure 1.4** This is a replica of one of the earliest steam locomotives, originally built in 1804. It was designed by Richard Trevithick, and was known as the 'Puffing Devil'

■ **Figure 1.5** These chimpanzees are using twigs as simple tools to make it quicker and easier to extract termites from the colony

What do we mean by 'energy'?

In *MYP Sciences by Concept 1*, Chapter 4, we inquired into what we mean by energy. Energy is an important concept in science, because it helps us to make sense of changes such a movement or transformation in nature – and we can see how these changes are very closely related. Because energy is an important concept, the word appears in many different contexts – and these changing contexts can make it difficult to have a clear picture of what, exactly, we mean by energy. In researching the concept of 'energy' you will discover that energy is often categorized in terms of the form in which it appears. The energy stored in a stretched spring and the energy held in the chemical bonds in a food are both forms of energy. The energy is not 'different' as such – energy is energy – the forms are just handy ways for us to visualize what is taking place and how the energy might make itself available to do work.

Energy changes form when it does work. In doing so, it will often change from a 'stored' state to an 'active' state – that is, it is 'released' from a system to cause a change of motion or form. This gives us another way to categorize or think about energy types: as 'stored' or **potential energy**, or as 'active' or kinetic energy.

Often it isn't apparent that something contains energy until the energy changes form. When we eat rice, the chemical energy stored in the rice is released through the chemical reactions of digestion and then cellular respiration to provide us with energy for movement, to keep our bodies working, and as heat. A battery is pretty boring until you connect it to something which releases the energy stored inside (in a chemical form) to make other things happen! All changes are caused by energy – or, to put it differently, all energy is potential or active change.

ACTIVITY: Making sense of energy

ATL

- Communication skills: Negotiate ideas and knowledge with peers; Organize and depict information logically

In this activity you will work individually to research uses of the word 'energy', and then work collaboratively to organize your findings according to different applications of energy as a concept.

You will need:

- **A device with an internet connection**
- **Large poster paper**
- **Marker pens**

1. **Taster: to get a quick overview of the concept of energy, watch these videos:**
   http://ed.ted.com/lessons/a-guide-to-the-energy-of-the-earth-joshua-m-sneideman
   http://energy.gov/eere/education/downloads/energy-literacy-videos
2. **In the middle of your poster paper, write the word ENERGY. Choose an icon (image) to represent what you understand by the concept and draw it in the centre.**
3. **Brainstorm in pairs all the phrases you know containing the word 'energy'. Tell each other what the phrases are and discuss what you think they mean. Write the ideas down around the middle of the paper. If you think that some of them might be connected or belong together, then write them next to each other in a cluster.**
4. **Read the energy categories below. Define what you think these categories mean. If you need clarification, search online for definitions.**

energy types	energy forms	energy sources
energy laws	energy impacts	

5. **Choose an icon to represent each of the different categories. Along the edges of your poster, draw your icons and then write down short sentences that summarize what you understand by the categories.**
6. **Classify and organize the energy phrases into groups by drawing your icons next to them on the energy word cluster you have created.**

Brainstorms, mindmaps and visual Venns

Brainstorming is a way to think creatively, whether individually or in groups. The idea is that you start with a key concept or idea and then write down *anything* that occurs to you in relation to that concept or idea. The only rules are: don't keep ideas to yourself, and don't 'block' or judge other people's ideas. Collaborative brainstorming works well when you know and trust the people you are working with – although it is sometimes equally important that you have quite different points of view! For more information, try online resources such as **www.mindtools.com/brainstm.html**.

Visual Venns are an adaptation of Venn diagrams, as used in logic and mathematics. Venn diagrams are a visual representation of the way that items are grouped by shared characteristics. Where items in a group share some properties with items in another group, the Venn circles overlap (see *MYP Sciences by* Concept 1, Chapter 6, for an example). Visual Venns can help you sort and organize ideas, without necessarily structuring them.

Mindmapping is a tool for structuring ideas. Again, start with a central concept or idea – it often works best to represent this as an icon or image of some kind. Then use 'branches' out from the central idea to introduce related concepts or ideas that are perhaps subsidiary to (less important, but related to) the central idea. You can then break these branches down again into 'twigs'. Mindmapping takes you from a big picture to details in a structured way and can be a good way to organize arguments. Find out more by searching **mindmapping** online.

ACTIVITY: Stored and active energy

ATL

- Information literacy skills: Make connections between various sources of information

Individually or in pairs: In this activity you will **describe** different forms in which energy appears, **identify** real-life objects in which energy is stored or active, and so **classify** energy as potential or kinetic.

(You may find it useful to review the activity *Energy learn and tell*, in *MYP Sciences by Concept 1*, Chapter 4.)

1 **Search online or use your own ideas to write descriptions of these different forms of energy. (The first example has been done for you.)**

Energy form	Description
Mechanical energy	Energy held in the physical bonds that hold a material together
Chemical energy	
Thermal energy	
Electrical energy	
Magnetic energy	
Nuclear energy	
Electromagnetic energy	

2 **Now identify and connect the objects shown in Figure 1.9 with the energy form(s) they suggest. You may need to connect more than one image with some energy forms. When you have done this, classify the energy forms according to whether they are potential or kinetic in the examples shown.**

Figure 1.9

Discuss: Was it difficult to decide on the energy form for any of the images? Why?

Assessment opportunities

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

ACTIVITY: Energy change matrices

ATL

- Communication skills: Organize and depict information logically

Individually: In this activity you will **identify** some machines in terms of energy changes.

We can represent energy changes using a simple matrix like the one below. One example has been completed to give you the idea. A light bulb is a device for changing electrical energy to light energy, so we begin with the row for 'electrical' energy and then move across to the column for 'light' energy, and write 'light bulb' in the corresponding square.

Notice the arrow in the top left corner of the matrix. This tells us the *direction* of the energy change.

The diagonal cells from top left are filled in, since no energy change would be achieved by objects in those boxes.

1 **Identify and complete the table by writing energy changers in the empty cells.**

	Electrical	Light	Sound
Electrical		Light bulb	
Light			
Sound			

2 **Explain why it would have been incorrect to write 'light bulb' in the first box of the second row.**

3 **Does the matrix enable us to show *all* the energy changes taking place in these machines or processes? Explain your answer. Identify and state what other energy changes might be taking place in each of the machines or processes you have selected.**

Hint

What do you feel if you put your hand near to (not on!) a light bulb that has been switched on for a while?

4 **Now design your own matrix using three different energy forms. Test your friends by asking them to identify the energy changes and complete your matrix!**

Assessment opportunities

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

How do we measure energetic change?

To make better machines, we need to understand better how energy is changed – and how to measure it. Two people who researched a solution to these problems were James Joule and James Watt – both from Scotland (UK), and both living in the nineteenth century. As perhaps you realized in the *Energy change matrices* activity, wherever energy is being changed we often feel *heat* being produced. Joule realized that heat must be a sort of energy. If only he could figure out a way to 'capture' the energy in heat, he thought, then surely there must be a way to put that energy to work. In the past, energy was measured in a unit called the calorie – for a clue as to why, find out what the word-stem *calor* means in Latin, or in languages that derive from Latin such as Spanish. In the science of nutrition, the energy content of food is still sometimes given in calories (see Chapter 3 for more on this). Now we measure quantity of energy in a unit called the **joule**

James Joule was interested in understanding better how thermal energy could be used to do useful **work**, because for some years previously engineers had been devising machines that could turn the heat released from burning coal into work. James Watt and his partner Matthew Boulton had improved the design of steam engines so that they could be used reliably to drive the machinery in factories and mills. They were interested in maximizing the amount of energy that could be gained from a machine in a certain amount of time. This is known as the **power** of a machine, and Watt's research in this area of science is acknowledged in the name of the unit for power – the **watt**.

Figure 1.10 James Watt (1736–1819) and Matthew Boulton (1728–1809) on the British £50 banknote

The power of a machine is related to the energy we gain from it by this equation:

$$\text{energy change} = \text{work done} = \text{power} \times \text{time taken}$$

or

$$\text{power} = \frac{\text{work done}}{\text{time}}$$

where power is measured in watts (W), energy changed in joules (J) and time in seconds (s).

This means that the power of a machine is related to the amount of energy it can change in a certain time.

Equations are powerful tools in sciences. They help us to **calculate** exactly how different variables are connected, and so **compare** and **evaluate** different **relationships** in science.

ACTIVITY: The broken-down car problem

ATL

- Critical-thinking skills: Evaluate evidence and arguments

Your science teacher is very fond of her old car. Unfortunately your school is at the top of a small mountain, and she has to drive her clattering old banger up that mountain to school every day! Today, the worst-case scenario actually happened: her car broke down at the bottom of the hill while you and your four friends were walking by.

Of course you volunteered to push your science teacher's car up that hill…! But how much work will you have to do? And will you be late for school?!

For this problem, you will need to know that the mass of the car = 1.5 tonnes, the mass of your teacher = 60 kg, and the height of the hill, h, = 100 m.

1 How much work will you have to do?

To calculate the work done to push the car from the bottom to the top of the hill, we need to know the energy changed. Remember that

weight = mass × gravitational acceleration

where weight is a force measured in newtons (N), mass is measured in kilograms (kg) and the gravitational acceleration on Earth has the value $g = 10\,m\,s^{-2}$.

The amount of work done in using a force to move an object a certain distance is given by

work done = force × distance moved

where work done is in joules (J), force is in newtons (N) and distance moved is in metres (m).

In our case, the object we are moving is the car, and the distance we are moving it is up the hill. In fact, if we make certain assumptions, the distance we are moving the car is the same as if we were lifting it vertically to the top of the hill. So:

work done = weight of car × height of the hill

$Wd = mgh$

- **Use this equation to calculate the work done in lifting the car up the hill while your teacher is inside steering.**

Hint

Remember that all masses must be in kg. How many kg are in a tonne?

2 How quickly can you do it?

Notice that the equation for work done above does not include the time taken. It doesn't matter how long it takes to lift the car up the hill, the amount of energy changed will be exactly the same. The time taken to do the work does become important when we consider the power we can produce. It is also important for your science teacher, since she has half an hour before her first class is due to start! Can you help her get the car to school in time?

Rearranging our equation for power above:

$$\text{time taken} = \frac{\text{work done}}{\text{power}}$$

- **If the average power produced by the muscles of an adult (student) human being is 50 W, calculate the quickest (minimum) time in which you and your friends can push the car to the top of the hill.**

Hint

Remember there are *five* people pushing the car!

- **Will your teacher (and you and your friends!) be on time?**

3 **In part 1, we made a big assumption: that the work done in pushing the car up the hill was the same as to lift it vertically. Is this true? Discuss the assumption you have made, and so evaluate the accuracy of your calculations. State whether the real values would be more or less than those you have calculated.**

Assessment opportunities

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

ACTIVITY: Feel the power!

ATL

- Critical-thinking skills: Draw reasonable conclusions and generalizations

	Horse	Steam locomotive C20th	Diesel engine from heavy truck C21st
Approximate average power output (W)	750	1.5×10	5×10^5
Average time between refuelling (h)	6	8	12

Table 1.1 Transportation power

1. **Interpret** the information in Table 1.1 to **estimate** the amount of energy changed (work done) by each machine in between energy inputs.
2. **State** any assumptions you have made in your calculations for question 1.
3. **State** whether the actual work obtained from these machines would be more or less than your calculated value. **Explain** your answer.
4. With reference to what you know about energy changes, power and work, **describe** ways in which the machines have improved over time.

Assessment opportunities

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

! Take action! Observing energy use

ATL

- Information literacy skills: Process data and report results
- Critical-thinking skills: Interpret data

! Have you ever been reminded by your parents to turn things off after you have used them at home? The energy we use every day has to be generated or extracted from energy resources in nature. In this activity, you will 'audit' the energy sources used in your home and make recommendations about how to reduce energy usage in your home.

- Carry out an energy audit of your home. Survey every room and write down all the devices or machines that use energy in some form (for example, electricity, gas, coal and so on).
- **Organize** your survey in a table that clearly shows the number of such devices, and the energy source that each uses.

Hint

Take care! Some machines use energy themselves, while others might be deceptive. A hot-water radiator in a central heating system does not use energy – it is just distributing the energy produced by the central heating boiler. An electric heater in a room, however, itself uses energy.

- Research to **find out** how much power (in watts) each of the machines in your house uses. You may be able to find this out by looking at labels on the back of the devices (see Figure 1.11, for example). Now multiply the power of each machine by the number of such machines in the house. Include this value in your energy audit table.
- Using your data, **identify** the five machines in your house that use the most energy.
- Now write a report for your parents, explaining how you carried out your energy audit. **Analyse** and **summarize** your data and **suggest** how you could minimize the energy use of your house by minimizing the use of these five machines. **Discuss** the impact this might have on the environment and on your household finances!

Figure 1.11 Power information on an electrical appliance

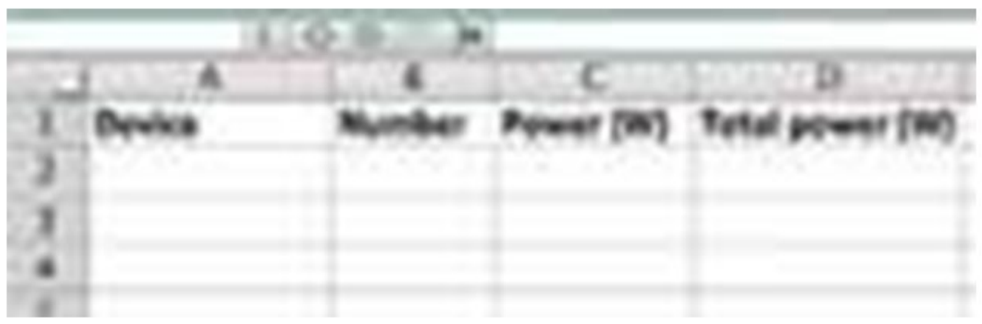
Assessment opportunities

- This activity can be assessed using Criterion A: Knowing and understanding, and Criterion D: Reflecting on the impacts of science.

Using spreadsheets

Use a spreadsheet to help organize your energy audit data and carry out the calculations.

1 **Organize** your data in columns, starting with the name of the device. You can change the width of the columns to fit the labels by dragging the borders of the columns at the top of the sheet, where you see the column labels A, B, C and so on.



2 Type a formula in column D.

'=' tells the spreadsheet that you are about to enter a formula, not a number.

3 With the pointer, select the cell for the first number you want to multiply: the number of devices.

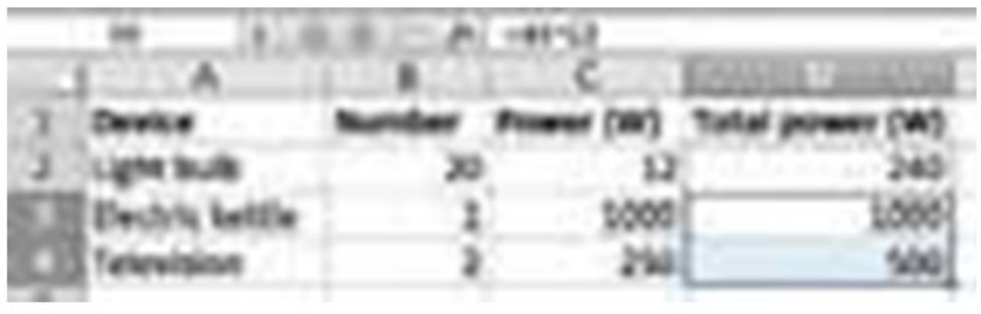
4 Type '*' – this tells the spreadsheet to multiply the numbers.

5 With the pointer, select the cell for the second number you want to multiply: the power of the device.

6 Press enter. You should see the result of the calculation appear in the spreadsheet.

7 Key in the data for the other devices.

8 To copy the formula for all the devices, select the cell containing the formula with the pointer and then select 'copy'. (On a PC, press CRTL+C; on an Apple computer, use COMMAND+C.) Highlight the cells that you wish to paste into by pointing and dragging down the column (with the mouse or tracker button held). Paste the formula into these cells (using CTRL+V on a PC or COMMAND+V on an Apple computer).



What is efficiency?

■ **Figure 1.12** A Rube Goldberg machine

Rube Goldberg was a cartoonist and inventor from the United States. In the early twentieth century he became famous for inventing and drawing crazy machines like that shown in Figure 1.12. Other cartoonists, such as Heath Robinson in the United Kingdom and Storm P in Denmark, became famous for similar ideas.

Find out more by searching online for **Video: Rube Goldberg machine**

Why would anyone make such an unnecessarily complex machine to carry out a simple task? Of course, this is the point: Rube Goldberg makes us think about what machines are, and why we might use them – or choose not to. Because Rube Goldberg machines have so many complicated stages, they would involve many energy transformations. However, as we saw in the *Energy change matrices* activity above, there is always more than one energy change going on, and not all the energy that gets changed is then used to do the job we want it to do – the work.

SEE–THINK–WONDER

Look at Figure 1.12. What do you **see**? What does it make you **think**? What does it make you **wonder**?

$$\text{efficiency} = \frac{\text{work out}}{\text{energy in}}$$

'Work out' and 'energy in' are both measured in joules (J) – since they are really just energy. Since we are usually doing work for a certain amount of time, it is more useful to write this equation in terms of the power used and the power produced by the machine, so we can substitute in our power equation above to show that

$$\text{efficiency } (e) = \frac{\text{power out}}{\text{power in}}$$

Efficiency doesn't have a unit of its own, since it is actually a **ratio** of the two values. However, it is usually given as a percentage:

$$e\ (\%) = \left(\frac{P_{\text{out}}}{P}\right) \times 100$$

In *MYP Sciences by Concept 1* Chapter 4, we inquired into the concepts of 'useful' and 'wasted' energy. For example, the heat produced by a light bulb is considered *wasted* energy, since we do not use a light bulb as a heater (although we might have to if we had no heater!). The light produced is then the *useful* work we require the light bulb, as a machine, to do. On the other hand, the heat produced by a heating element in an electric toaster is *useful* work, but the light that is produced when it glows is *wasted* energy, because we do not generally use a toaster to light the room. For more detail on this, see *MYP Physics by Concept 4&5*, Chapter 6.

ACTIVITY: Humans versus automobiles!

ATL

- Information literacy skills: Access information to be informed and inform others
- Critical-thinking skills: Interpret data

In this activity, you will carry out some calculations to compare the power and efficiency of human beings and automobiles (cars).

Table 1.2 shows some information about power output and efficiency of some different machines.

Machine or process	Power input, P_{in} (W)	Form of energy	Power output, P_{out} (W)	Form of energy	Efficiency, e (%)
Human walking			50		24
Human riding a bicycle			400		90
Internal combustion engine (petroleum)			92 000		25

Table 1.2 Typical values for power input and output

- **Interpret the data in the table. Which machine has the highest efficiency? Which has the lowest? Is this what you expected?**
- **Make your own copy of the table. In the columns headed 'Form of energy', state the form of energy input and output for each machine.**
- **Use the efficiency values in the table to calculate the power input, P_{in}, for each of the machines.**
- **Suggest the forms of wasted energy for each of the machines.**
- **Thus evaluate each of the machines in terms of their efficiency and the power they produce. Consider: why do we use expensive automobiles, when they are little more efficient than walking?**

Assessment opportunities

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

Figure 1.13 What is wasted energy, and what is useful work?

Figure 1.14 Human power has been used throughout the ages, and can still be very useful when no other power source is available – for example, to use this wind-up emergency radio

Figure 1.15 (a) An automaton, (b) a scene from the movie of Karel Čapek's play, *RUR*, (c) real robots!

Theo Jansen's Strandbeest (Figure 1.1) is fascinating to watch. His work draws on a long tradition of human fascination with machines. In the myths of ancient Greece, the god Hephaestus was said to have created mechanical people to work in his foundry, and there are stories of mechanical animals built during the middle ages in China and in the Middle East. In western Europe in the eighteenth and nineteenth centuries, it was fashionable for wealthy people to be entertained by very complex mechanical puppets called automata. The puppets were very life-like and led many to believe that they really were living things. The idea of creating a machine to do work for humans inspired Czech writer Karel Capek's 1920 play *RUR*, or *Rossum's Universal Robots*, which introduced the word 'robot' into the English language. The purpose of machines is usually to make life easier for us by enabling us to do work with greater efficiency. As our statement of inquiry suggests, machines work by transforming potential energy into movement, or the reverse.

Links to: Design

While science tries to provide answers to our questions about the universe, technology seeks to provide solutions to the problems we encounter in everyday life. A designer works out the best way to solve the problem, and engineers are the people who make those solutions a reality.

ACTIVITY: Engineering problems

ATL

- Information literacy skills: Use critical-literacy skills to analyse and interpret media
- Critical-thinking skills: Recognize and evaluate propositions

Look again at the images of machines in Figure 1.2 and Figure 1.3. For each image, **discuss** and then **outline** the following.

- **What is the problem that the machine in the picture aims to solve?**
- **How does the machine solve it?**
- **What disadvantages might the machine have?**
- **In what ways does the machine solve the problem better than the machines in some of the other pictures?**

Summarize the ways in which the machines solve the problem of work, using energy chain diagrams.

Assessment opportunities

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

What kinds of machine are there?

■ **Figure 1.16**

■ **Figure 1.17**

So what are the simplest kinds of machine? In the following activities we will investigate some fundamental kinds of machine: wedges and knives, levers and balances, gears and pulleys.

SPREADING THE LOAD

ACTIVITY: Under pressure?

■ ATL

- Critical-thinking skills: Interpret data; Test generalizations and conclusions
- Creative-thinking skills: Make guesses, ask 'what if' questions and generate testable hypotheses

Experiment inquiry question: How does shape affect the amount of force required to cut an object?

Background information: The pressure exerted on a surface is given by the equation

$$\text{pressure} = \frac{\text{force}}{\text{area}}$$

where pressure is measured in newtons per metre squared ($N\,m^{-2}$), also called a pascal (Pa), force is measured in newtons (N) and area is measured in metres squared (m^2).

1 **Design an experiment that will enable you to measure the force required to cut into some different materials with different shaped objects. You might wish to use some of the following equipment:**
   - **Masses**
   - **Blocks of wood of different shapes and sizes**
   - **Fine sand, dry rice, modelling putty**
   - **Millimetre ruler**

2 **Identify your independent (changed) and dependent (measured) variables. Suggest any other variables that must be controlled in order to ensure your experiment is valid.**

3 **Outline the expected effect of your independent variable on the dependent variable, with reference to the background information. Predict what will happen in your experiment with the equipment you have chosen to use.**

4 **Record your data and organize clearly using a table with suitable headings, and showing all measurement units.**

5 **Interpret your data. Plot a suitable graph to suggest a relationship between your independent and dependent variables, or summarize your findings with reference to your results.**

6 **In your conclusion, summarize the effect of changing shape (or the independent variable that you identified) on the force required to cut into the material. State whether or not your hypothesis was correct and valid.**

7 **Evaluate your experiment, stating any difficulties you encountered. Was the experiment valid? Suggest any improvements you could have made.**

◆ Assessment opportunities

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

THINK-PAIR-SHARE

Look at the images in Figures 1.16 and 1.17. A camel's foot and a knife have opposite functions. On your own, **think** about the function of the two objects. **In pairs**, discuss how the shape of the object improves its function. **Share** your ideas as a class.

Complete the Activity: Staying balanced on the following page to explore how different masses can be balanced around a turning point. Wedges (like knives) work by minimizing the surface area over which a force is applied, so that maximum pressure is exerted at the thin edge. Wooden wedges were used in ancient times to split rock, before humans had discovered how to extract and work hard metals such as iron. A wooden wedge or peg could be hammered into a natural fissure in the rock; if this was not enough to split the rock apart, then the wood could be soaked in water, making it expand and so breaking the rock. Another example of a wedge we still use very commonly is an axe: the blade on the axe head is actually a very heavy steel wedge for splitting wood.

BALANCING ACTS

THINK–PAIR–SHARE

Look at the images in Figure 1.18. On your own, **think** about the way forces are acting in the images. Now **share** your ideas with your **partner**. Did you agree? Discuss your ideas in class.

Figure 1.18

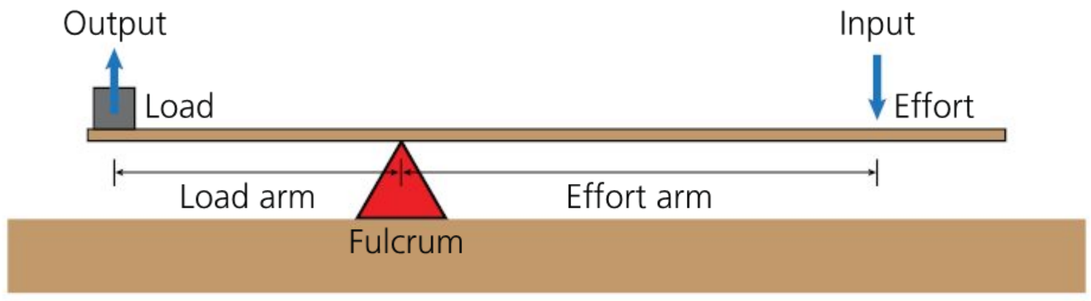


Figure 1.20

The balance in the *Staying balanced* activity is a special kind of **lever**. A lever produces a turning force by using a turning point or fulcrum (Figure 1.20).

The force that the lever is trying to lift is often called the **load**, while the force used to do the lifting is called the **effort**.

The turning effect of the different forces around the fulcrum is called the **moment** and is calculated using the distance of the force from the fulcrum:

moment = force × distance from pivot

where the moment has units of newton metres (N m), force is in newtons (N) and distance from pivot is in metres (m). In the *Staying balanced* activity, we can see from our results that it was possible for a small mass (such as 10 g or 20 g) to balance a larger mass (25 g) if the mass was positioned such that the turning force or moment was large enough. The lever was balanced when the turning force or moment on the left-hand side of the fulcrum was equal to the moment on the right-hand side. This is known as the **principle of moments**

When a smaller effort is used to lift a larger load, the moments are not balanced and so the load is accelerated or moved. This kind of lever is then known as a **force magnifier**

On the other hand, it may be necessary to use a much bigger effort applied to a small load. When this happens, the results can be spectacular! To find out how, position a pencil as a fulcrum just 10 cm from one end of a 30 cm ruler, and then place a small piece of balled-up paper on the end furthest from the fulcrum. Take care to make sure

ACTIVITY: Staying balanced

ATL

- Critical-thinking skills: Interpret data; Test generalizations and conclusions

Inquiry question: How can different masses be balanced around a turning point?

In pairs: In this activity you will investigate how forces can cause turning motion, and how turning forces can be balanced.

Equipment

- **A metre ruler**
- **Small masses (e.g. 10 g, 20 g, 25 g)**
- **A pencil**

Method

1 **Set up the metre ruler so that it balances at its centre point on the pencil, as shown in Figure 1.19. The pencil in this experiment is creating a turning point. This is called a fulcrum.**

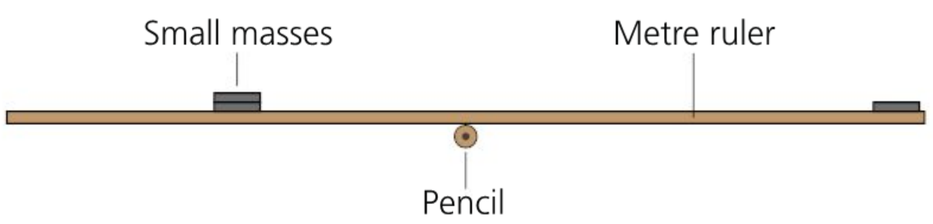


Figure 1.19

2 **Position one or more 10 g masses at different points on the ruler, as described in Table 1.3, on the left-hand side of the pencil (fulcrum).**
3 **Now find the position of a single 25 g mass on the right-hand side that just balances the ruler.**
4 **Record your observations in a copy of Table 1.3.**

Mass (g), left hand side	Distance of mass from fulcrum (m), left hand side	Distance of 25 g mass from fulcrum (m), right hand side
10	0.50	
10	0.40	
10	0.30	
10	0.20	
20	0.50	
20	0.40	
20	0.30	
20	0.20	
30	0.30	
30	0.20	
30	0.10	
40	0.20	
40	0.10	

Table 1.3 Balancing positions for different masses

5 **Interpret your data. Can you identify a pattern in the results?**
6 **Summarize your conclusions. Can you deduce a rule for balancing the masses?**
7 **Evaluate your experiment. Describe the factors affecting the accuracy of your readings. Discuss how you might have improved the accuracy.**
8 **Why was it not possible to balance 30 g at 0.50 m, or 40 g at 0.30 m? Suggest what modification to the experiment would have made this possible.**

Assessment opportunities

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

Figure 1.21 Some force-magnifier levers in action

your eyes are not in the firing-path of the ball or wear safety glasses. Now press down on the other end of the ruler. What happens to the paper ball?

In this situation, the large effort you have applied to the 'short' end of the ruler produces a moment that moves the 'long' end of the ruler very quickly and quite a large distance. This kind of lever is called a **distance magnifier.**

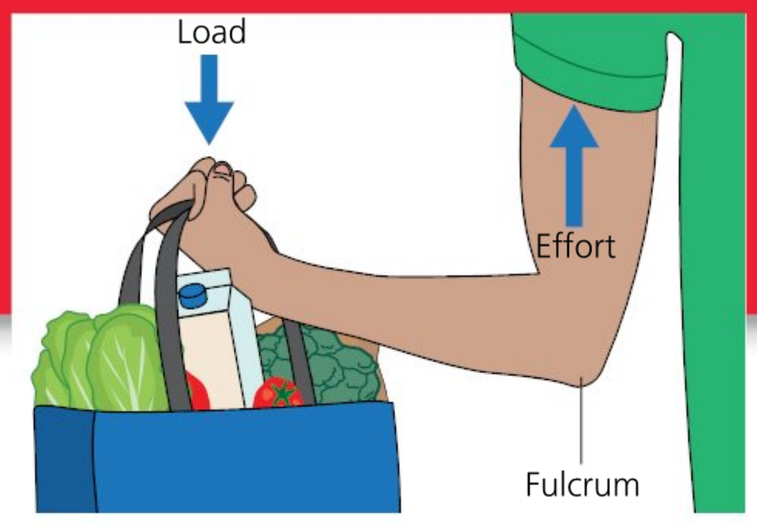


Figure 1.22 The human arm is a lever system

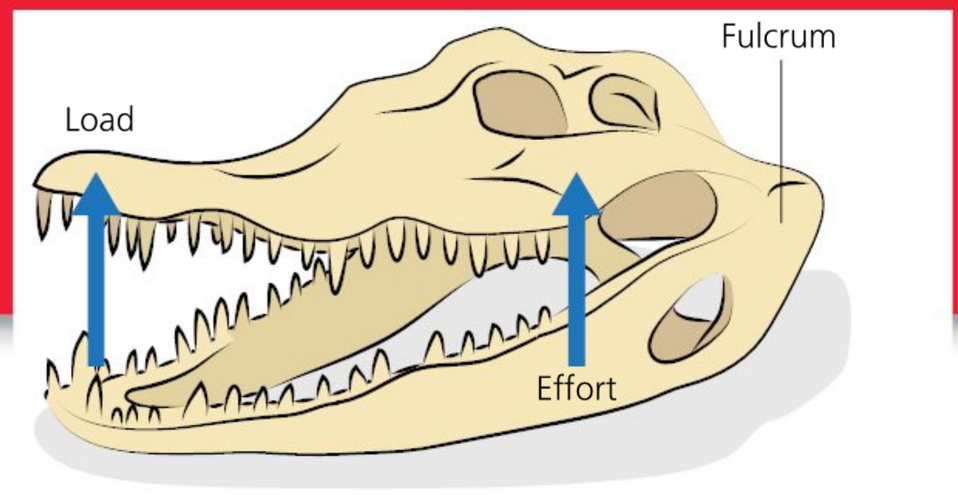


Figure 1.23 Jaws are powerful levers

EXTENSION

Search online for this video about the bite force of a piranha: river monsters piranha bite **Research** and find out how different lever systems work in different animals. **Describe** how the levers function, and **explain** why the animal needs the lever to do this.

ACTIVITY: Taking the load

ATL

- Critical-thinking skills: Analyse complex concepts into their component parts and synthesize to create new understanding

1 **A gardener is using a wheelbarrow to carry gravel for a pathway (Figure 1.24). The gravel weighs 200 N and its centre weight acts 0.5 m from the central axle of the wheel. The length of the wheelbarrow, from wheel axle to handles, is 1.5 m.**

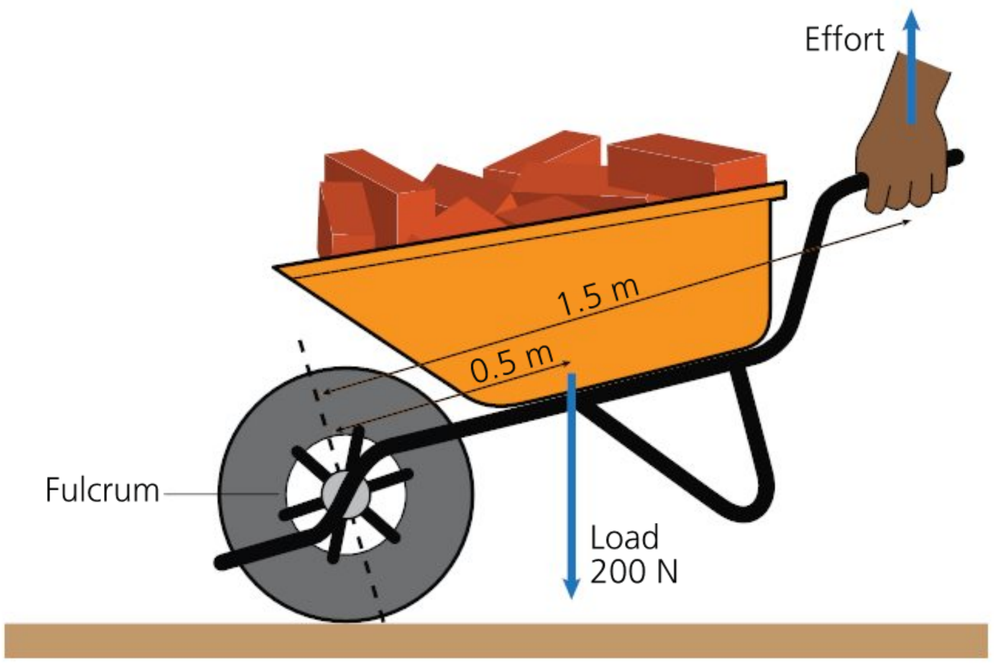


Figure 1.24 Wheelbarrow problem

a **Calculate the moment of the gravel around the wheel axle.**

b **Apply the principle of moments to calculate the size of the effort the gardener needs to make to lift the barrow handles.**

c **State whether this is a force magnifier or a distance magnifier, and explain your reasoning.**

2 **The arm of the construction crane in Figure 1.18 is 50 m long from one end to the other. The fulcrum of the crane is positioned 10 m from the counter-weight. The crane has to lift a block of concrete that weighs 25 000 N. Calculate how large the counter-weight must be.**

3 **A woman has to carry a load of grain across a creek using a bridge made from a single, narrow wooden plank. She places the grain in two separate bags, and attaches the bags to the ends of a long wooden pole. Then she lifts the pole and carries it across her shoulders.**

a **Identify the fulcrum in the lever system formed by the woman, her load and the bridge.**

b **Outline the turning forces acting on her as she crosses the bridge.**

c **A young boy follows her over the bridge with his hands in his pockets, but loses his balance and falls into the creek. Compare the turning forces on the woman and the young boy and suggest why the boy loses his balance, but the woman does not.**

Assessment opportunities

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

Figure 1.25 Maybe it wasn't so easy to invent the wheel!

GOING AROUND IN CIRCLES

One of the oldest machines invented by humans is the wheel. Certainly, wheeled vehicles have existed for millennia. It is thought that the great blocks of stone used to build the pyramids of ancient Egypt were rolled up ramps using tree-trunk rollers – a first prototype of a wheel?

The genius of the wheel is that it converts linear (straight-line) motion into continuous turning motion. The friction caused by the turning of a wheel axle in its support (or bearing) is much lower than for dragging objects along the ground, so wheels also increase efficiency.

In 1900 archeologists found the submerged wreck of an ancient Mediterranean cargo ship. The wreck contained pieces of a mysterious, corroded object made from bronze, which was called the Antikythera mechanism. Only in the 1970s did X-ray examination reveal that the object was very complicated, with many interlocking wheels and **gears**. In 2006 further **CT scans** by Cardiff University in Wales revealed that the mechanism is probably a complex mechanical computer for making astronomical calculations – the sort of machine that was not seen in the rest of the world until at least a thousand years later!

Gears work by using different radii to change the turning effect of a force applied at their circumference. When the gear has a large radius, the force has a large distance of action. When the gear has a small radius, the effort force has a smaller distance of action. When two gears are interlinked, they must turn through the same angle in a certain time – this is called the **angular speed** of a turning object. The radius of the gears affects the amount of effort required to do this, and the amount of turning force produced in the second gear.

Figure 1.26 The Antikythera mechanism

Pulleys also exploit turning force in a wheel to reduce effort. The simplest pulleys are grooved wheels fixed in place, with a rope passing around them (Figure 1.27a). This allows us to control the direction of action of the effort force, but it doesn't reduce it. A pulley that is free moving, with the string looped around it, does reduce the effort force (Figure 1.27b).

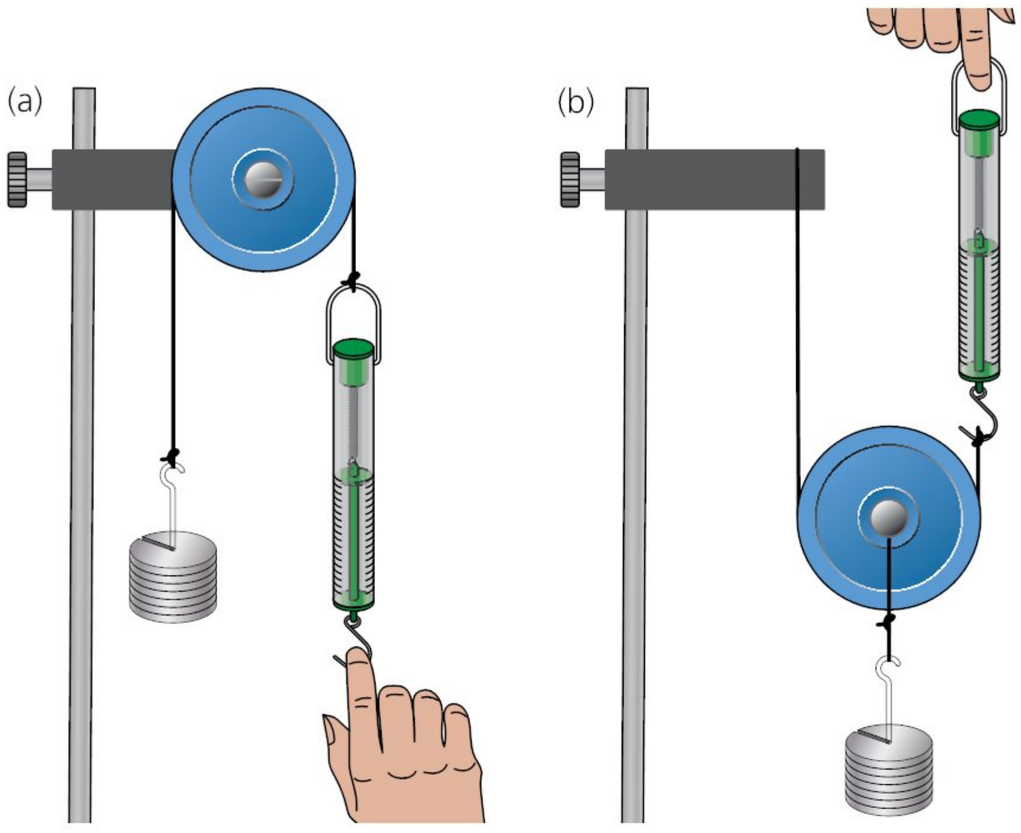


Figure 1.27 (a) A fixed pulley, (b) a movable pulley

EXTENSION

Experiment with model gears from construction sets to find out more about machines with gears, turning force and effort. Can you build a machine that converts the falling motion of a mass into a timing device? What might this kind of machine be called?

ACTIVITY: Cycle gear

ATL

- Critical-thinking skills: Interpret data; Test generalizations and conclusions
- Creative-thinking skills: Make guesses, ask 'what if?' questions and generate testable hypotheses

Inquiry question: What is the effect of gears on effort?

Bicycles have two sets of gears. The 'gear train' is attached to the pedals. The turning motion of the pedals is transmitted through the chain to the rear set, often called the 'cassette'. Most bicycles have multiple gears on the cassette, and some also have multiple gears on the gear train (especially mountain bikes).

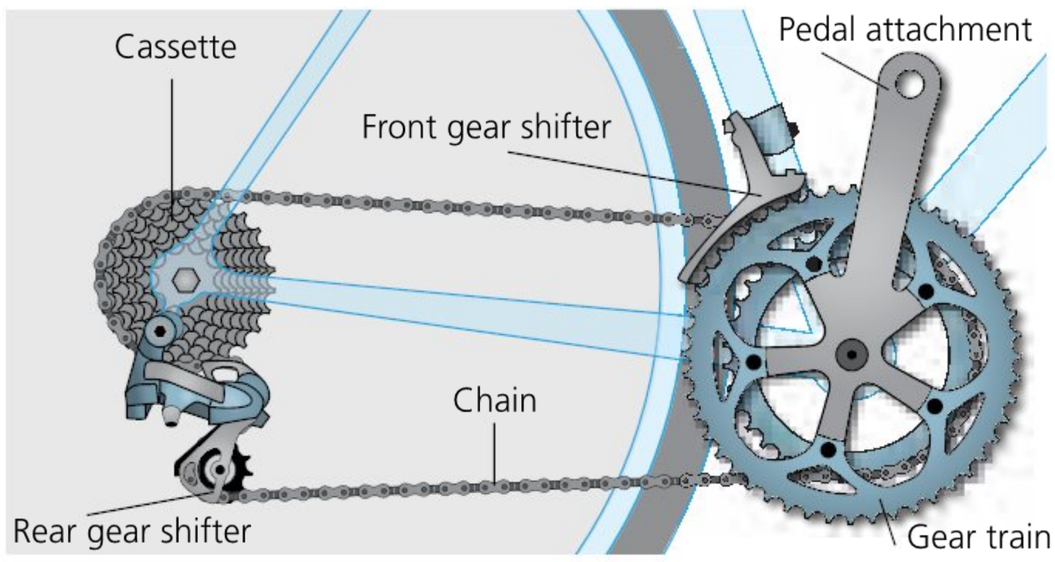


Figure 1.28 Bicycle gears

Write a **hypothesis**, **summarizing** how you think the size of the gear used will affect the motion of the bicycle. Use scientific reasoning, referring to what you have learned about turning forces. **Predict** what you expect to see when you measure the average speed of the cyclist using different gears.

Equipment

- **A bicycle with at least three gears**
- **3 stopwatches**
- **A measuring tape (25 m minimum length)**
- **A bicycle odometer (speedometer), or a smartphone cycling app with GPS location**
- **A cyclist with plenty of energy!**

Design an experiment that allows you to compare the effect on the bicycle's motion of different gear combinations. **Organize** your data and **present** it as a **graph** **Interpret** your data and so write a conclusion about the effect of the different gears. **State** whether your prediction was correct. **Evaluate** your investigation – how could it be improved?

Assessment opportunities

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

ACTIVITY: Pulling your weight

ATL

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

In groups of three: In this demonstration you will experience the effect of movable pulleys.

Equipment

- **2 broomsticks or circular-section rods, plastic piping or similar, each 1.0–1.5 m long**
- **String or thin rope, approximately 1 m long**

Method

1. **Tie one end of the rope to a broomstick. Wrap the other end once around the second broomstick.**
2. **Two of your group should hold the broomsticks vertically with both hands. The third member of your group now tries to pull the broomsticks together by pulling the free end of the rope.**
3. **Now wrap the free end of the rope around both broomsticks another time and pull.**
4. **Continue to wrap the rope around the sticks, one loop at a time, and repeat the demonstration. What do you notice about the effort required each time?**
5. **Summarize your observations. Describe how the number of 'turns' of rope around the broomstick 'pulley' affected the effort required to move the broomsticks together.**

Assessment opportunities

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

What are fuels? How do energy changes determine chemical changes?

Of course all machines need an energy input to work. In the case of our simple machines in the previous section, energy is provided by human effort – muscle power! As we saw in *MYP Sciences by Concept 1*, Chapter 4, the origin of this energy is the chemical energy stored in our foods and released through the biological processes of digestion and respiration (see also Chapter 3 of this book). In the case of electrical devices, the energy is provided from stored electrical energy (see Chapter 4 of this book) that has been produced elsewhere – whether in a power station, or in the manufacturing of batteries. As we saw at the beginning of the chapter, many forms of transportation were developed to extract energy directly from fossil fuels such as coal, oil, or petroleum (gasoline) extracted from oil through distillation (see *MYP Sciences by Concept 1* Chapter 2). A fuel is any substance containing potential energy that can be extracted to provide energy for a machine.

In the case of fossil fuels, energy is released by the process of combustion, or burning. Fossil fuel combustion is a relatively rapid chemical reaction in which **hydrocarbons** are oxidized. Hydrocarbons are molecules formed from carbon and hydrogen. When combustion occurs, the bonds between the carbon and hydrogen break and oxygen is added to the reactants. Since the products of this reaction require less potential energy than the reactants, the 'extra' energy is released in the form of light and heat. This is an example of an **exothermic** process. For the reaction to take place, the **activation energy** must first be overcome (Figure 1.29).

In an **endothermic** process, the opposite occurs. The initial activation energy is used to break the bonds of the reactants, and afterwards some of this energy remains stored in the bonds of the products. The additional energy is taken from the surroundings as heat (Figure 1.30).

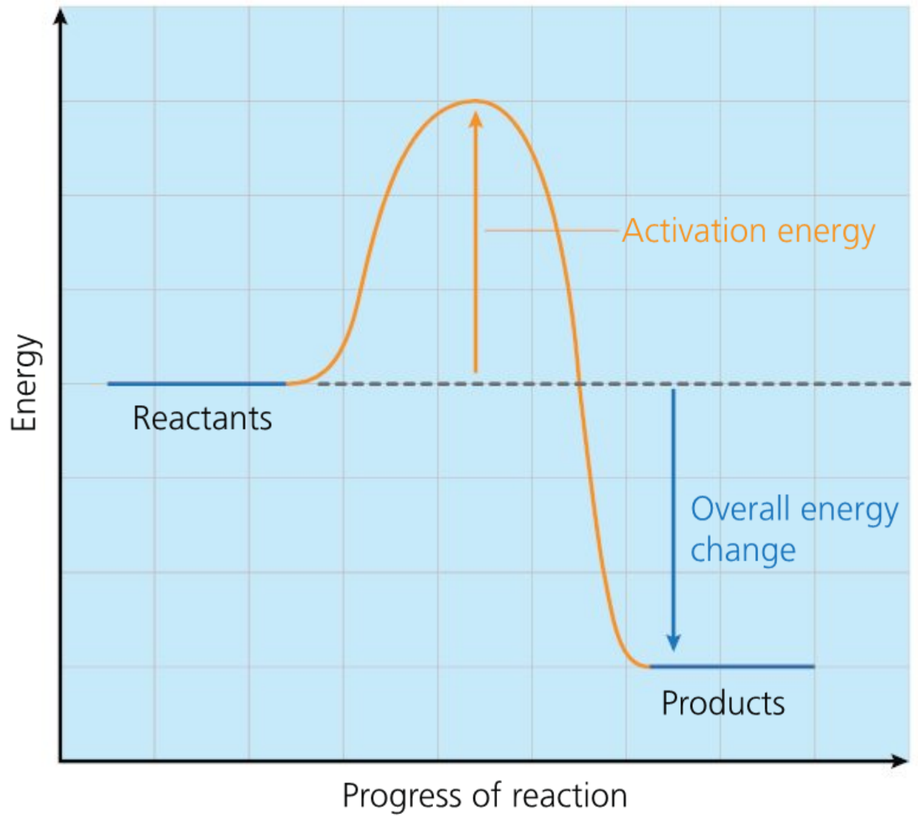


Figure 1.29 Energy changes in an exothermic reaction – the potential energy in the bonds of the products is lower than the energy stored in the bonds of the reactants

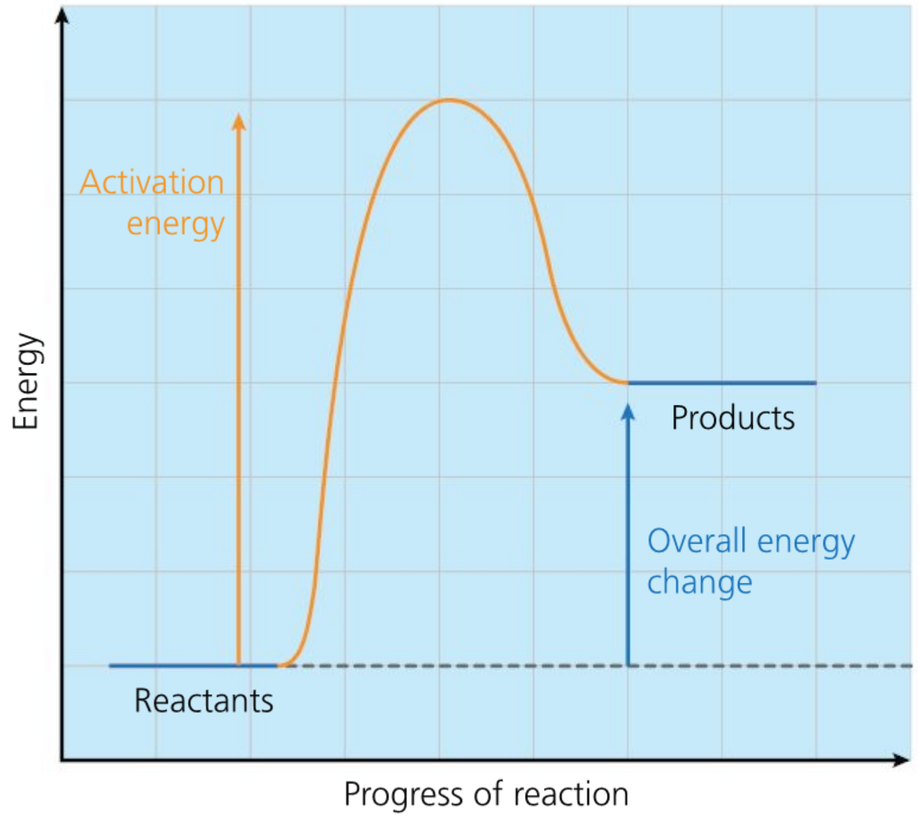


Figure 1.30 Energy changes in an endothermic reaction – the potential energy in the bonds of the products is higher than the energy stored in the bonds of the reactants

Methane is the simplest example of a hydrocarbon, found in the Earth as natural gas. A methane molecule consists of one carbon atom with four hydrogen atoms attached. When methane undergoes combustion, the products are carbon dioxide and water (Figure 1.31).

methane + oxygen → carbon dioxide + water

$CH_4(g) + 2O\ (g) \rightarrow CO_2(g) + 2H_2O(l)$

Provided there is plenty of oxygen available, all pure hydrocarbons burn to produce carbon dioxide and water. Both water (as steam) and carbon dioxide are **greenhouse gases** (see *MYP Physics by Concept 4&5*, Chapter 8, for more detail on this). If the hydrocarbon undergoes combustion when the amount of oxygen is limited, this can also produce the gas carbon monoxide (CO), which is toxic.

If you have Bunsen burners in your laboratory, they may use methane or its bigger cousin propane (C_3H_8).

Figure 1.31 A landfill gas flare. Organic matter in landfill sites decays and produces methane gas, which can build up and cause explosions if it's not removed. Methane is 20 times more effective than carbon dioxide as a greenhouse gas, so burning it reduces the impact on the environment. If there is enough methane produced, it can be used to generate electricity in a power station

Most fuels are not pure hydrocarbons. Coal and gasoline contain a mixture of hydrocarbon molecules with chains of carbon atoms of different lengths, and often many other impurities as well, such as sulphur compounds. When these fuels undergo combustion, the impurities are released into the atmosphere as pollutants such as sulphur dioxide (SO_2

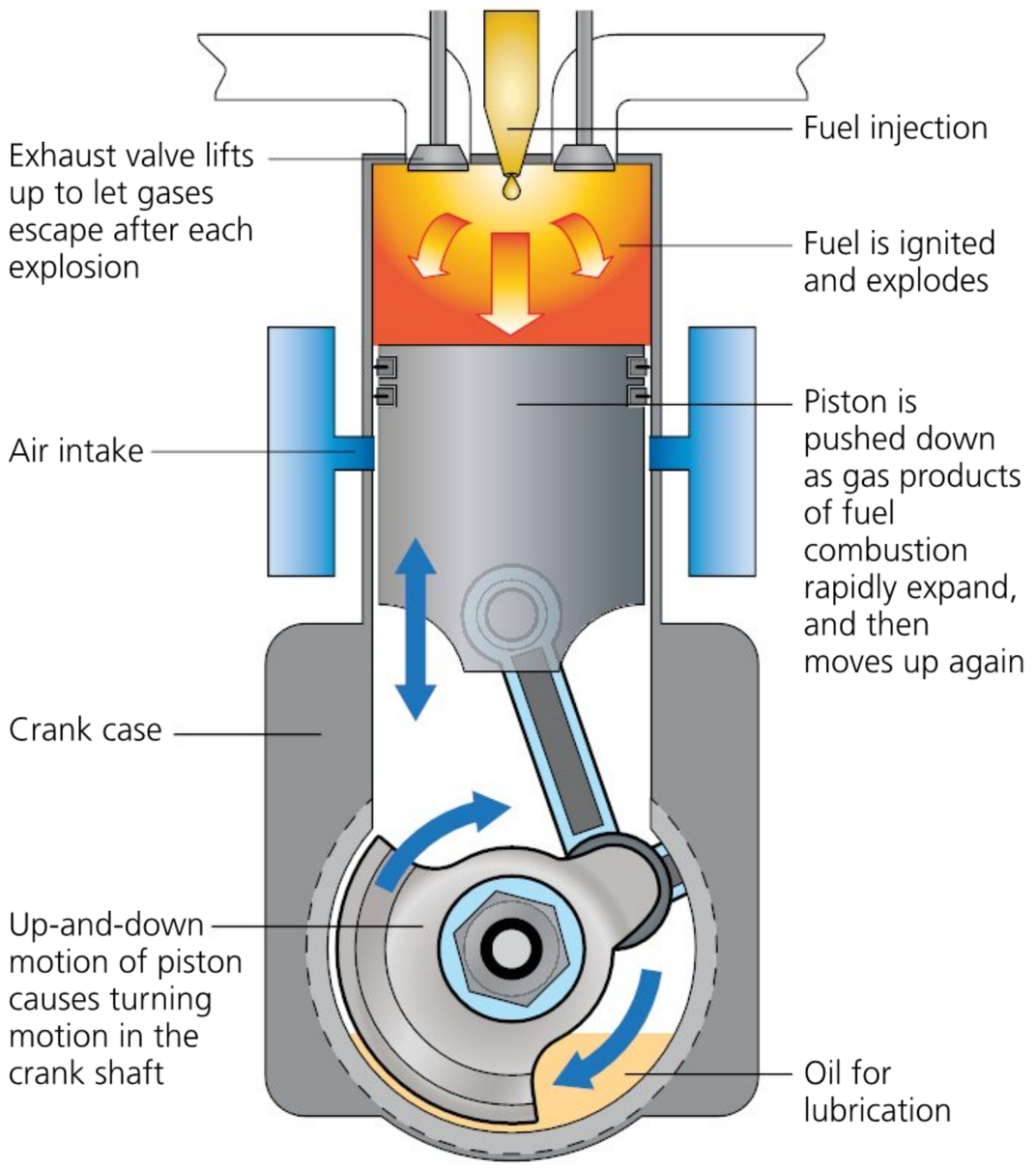


Figure 1.32 In an internal combustion engine, fuel is ignited so that it explodes inside a piston. The rapid combustion releases heat, which causes the gas reaction products to expand rapidly, and so do work on the piston

ACTIVITY: Heating up, cooling down

ATL

- Information literacy skills: Collect, record and verify data

Individually or in pairs: In this activity you will observe and measure energy changes in exothermic and endothermic reactions.

Equipment

- **3 × 100 ml beakers**
- **Spatulas**
- **Thermometer and stopwatch, or temperature sensor and datalogging device**
- **Aqueous (dissolved) citric acid ($C_6H_8O_7$)**
- **Crushed limestone (calcium carbonate, $CaCO_3$)**
- **Sodium bicarbonate (sodium hydrogen carbonate, $NaHCO_3$)**
- **Dilute sulphuric acid (H_2SO_4)**
- **Dilute sodium hydroxide (NaOH)**

Experiment 1

1. **Pour 50 cm^3 of aqueous citric acid into a beaker. Measure the temperature of the acid.**
2. **Add 1 spatula of calcium carbonate and stir. Measure the temperature of the solution until it has returned to the starting temperature.**
3. **Now add 4 more spatulas of calcium carbonate and stir. Measure the temperature as before.**

Experiment 2

Again, pour 50 cm^3 of citric acid into a beaker. Measure the temperature of the acid. Repeat the procedure for experiment 1, but this time adding sodium bicarbonate (sodium hydrogen carbonate) instead of calcium carbonate. Measure the temperatures as before.

Experiment 3

1. **Measure 25 cm^3 of dilute sulphuric acid into a beaker. Measure the temperature of the acid.**
2. **Now add 5 cm^3 of sodium hydroxide solution. Stir and measure the temperature.**
3. **Repeat until you have added 30 cm^3 of sodium hydroxide, measuring the temperature change for each additional 5 cm^3.**

Organize your results in a suitable table, showing units of measurement. **Present** your data using a graph.

In a conclusion, **summarize** your findings in each experiment. **State** whether the reactions were endothermic or exothermic. **Compare** the energy changes in each reaction.

Evaluate your experiment. Could you have improved its accuracy or validity? **State** improvements you could have made.

Assessment opportunities

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

DISCUSS

Figure 1.33

Many other reactions are endothermic or exothermic. What kind of energy change is occurring in these heat pads, and in the cold pack?

Will energy ever run out?

We saw earlier in the *Energy matrices* and *Humans versus automobiles* activities that all energy changes produce wasted energy, most often in the form of heat. This is due to the effect of friction. Consequently, the efficiency of a machine is always less than 100% (more on this in *MYP Physics by Concept 4&5* Chapter 6). So will energy ever run out?

Energy is a property of the universe – it could be thought of as an expression of the way the universe is 'uneven' or inhomogeneous. If everything was the same everywhere, there would be no energy difference and so there would be no change at all. This is the logical outcome of the idea that *some* energy in a change is always turned into heat – hypothetically, in the end *all* energy will have turned into heat. This idea is known as 'heat death' in Physics. Fortunately, we expect that this process would take a very long time – in fact, longer than estimates of the likely remaining lifetime of the universe itself (for scientists who believe that the universe *will* eventually end), and certainly longer than the lifetime of our star, the Sun.

Notice, though, that heat death does not mean that energy will have *run out*, rather that energy *differences* will have disappeared. The 'total' amount of energy in the universe is thought by most **cosmologists** to be the same as it was when the universe began in the Big Bang, it is just that the energy changes form over time. This is known as the **principle of conservation of energy**

For human purposes, it makes more sense to ask when *our energy resources* will run out. This is a far more practical problem, but not one with a clear answer.

We saw in *MYP Sciences by Concept 1*, Chapter 4, that humanity takes energy from a variety of energy resources; Table 1.4 provides a quick summary of these.

You may know that **renewable energy** resources are those that will never run out – at least for as long as we can imagine. **Non-renewable energy** resources, however, are finite – they will eventually run out. This

Non-renewable energy resources	Renewable energy resources
Fossil fuels	Solar
Coal	Wind
Oil	Tidal
Natural gas	Wave
Nuclear	Hydroelectric
Uranium	Geothermal
	Biomass or waste

Table 1.4 Summary of global energy resource types

is because they are mineral resources found in the Earth. Fossil fuels were all created in the Earth many millions of years ago. During the **Carboniferous period** around 300 million years ago the Earth's tropical regions were covered with forest. When the vegetation died and decayed in the ground, geological processes converted the carbon in the plant matter into hydrocarbons containing carbon and hydrogen. This formed coal. Similarly, oil was formed from the remains of tiny animals in the ocean beds. Nuclear power, on the other hand, uses a less-common **isotope** of the element uranium, which is found in small quantities in ore minerals such as pitchblende (UO_2). None of these substances are being renewed in the Earth, and so we are dependent on what we find.

Tables 1.5 and 1.6 and Figures 1.35 to 1.37 give some information on energy resource use in different places. Complete the activities on pages 26–27 to understand better the problem of non-renewable energy resource depletion.

How long will non-renewable resources last? In the case of uranium, it is thought that reserves are plentiful and will last many hundreds of years – at current rates of consumption. However, energy consumption is generally increasing, and is likely to continue to do so unless some global disaster reduces the human population.

ACTIVITY: Case study – comparing energy consumption

ATL

- Communication skills: Read critically and for comprehension; Make inferences and draw conclusions
- Critical-thinking skills: Interpret data; Draw reasonable conclusions and generalizations; Identify trends and forecast possibilities

Individually: In this activity you will use data on energy resource consumption in the United States to understand the factors affecting energy use.

Summarize what the data show for each column of Table 1.5. Consider the units.

Present the data in a visual form, such as a chart or graph, that helps you to compare the different energy resources.

Hint

You may wish to use a spreadsheet to produce your graph. To do this, you will need to program the spreadsheet to show the data on the same axes, for easy comparison. If you are not sure how to do this, refer to *MYP Sciences by Concept 2*, Chapter 1.

Interpret the data in Table 1.5 and in your chart or graph. **Summarize** your conclusions in the form of a paragraph. In your writing, consider the following questions:

- **What factors might cause the increase in total energy consumption during the period 1950–2013?**
- **Why is there no contribution from nuclear energy until 1970?**
- **Using calculations, outline the relative importance of renewable and non-renewable energy resources to the United States.**

Now **compare** the data for the United States to that for other countries shown in Figures 1.35 and 1.36, and in Table 1.6. **Describe** how the energy resource use differs for different countries.

Research online to find out a little more about all these countries. Find out about their economy and their history during the years shown in the graphs and tables. **Suggest** or **identify** the factors that might contribute to these differences in energy resource use.

With reference to the trends you identify in the data for the last 40 years, **suggest** what changes may occur in patterns of energy resource use during your lifetime.

Year	Energy consumption by source (%)					
	Coal	Gas (including propane)	Oil (petroleum)	Nuclear	Renewable	Total
1950	12.3	6.3	13.0	0.0	3.0	34.6
1960	9.8	13.1	19.3	0.0	2.9	45.1
1970	12.3	22.9	28.3	0.2	4.1	67.8
1980	15.4	21.7	33.0	2.7	5.5	78.3
1990	19.2	20.8	32.4	6.1	6.1	84.6
2000	22.6	25.8	36.4	7.9	6.2	98.9
2013	18.5	28.3	35.2	8.5	9.5	100.0

Table 1.5 United States energy consumption by source (%). Consumption includes power generation, domestic and industrial use, and transportation (source: US Energy Information Administration, **www.eia.doe.gov**)

It is less clear how long fossil fuels will last. In the 1950s, it was proposed that oil reserves would last about another 40 years, a prediction that turned out to be highly inaccurate, since estimates of global oil reserves are now far greater than before. In 1996 about 90% of global energy consumption was still provided for by fossil fuels. Geologists point out that as technology develops, we are likely to be able to find new reserves of fossil fuels. Economists argue that as oil becomes more scarce, some 'conditional' reserves that we already know about become economical to exploit. The only thing that all parties agree on is that fossil fuels *will* run out at some point.

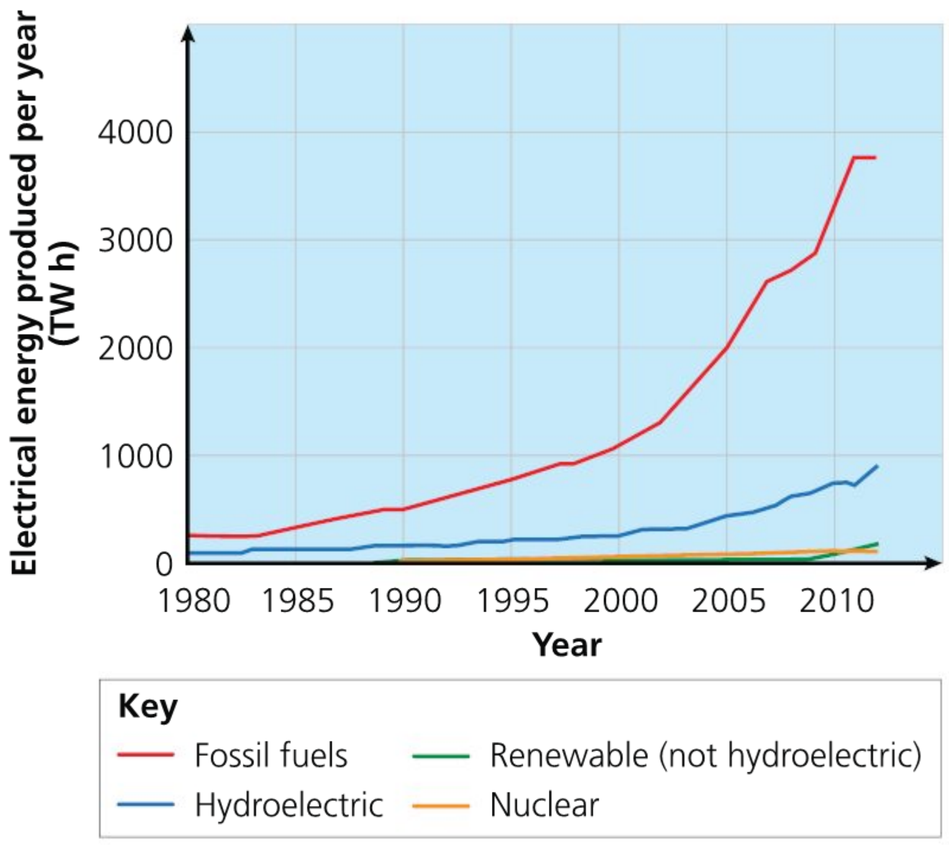


Figure 1.35 Energy production in China (source: US Energy Information Administration (EIA))

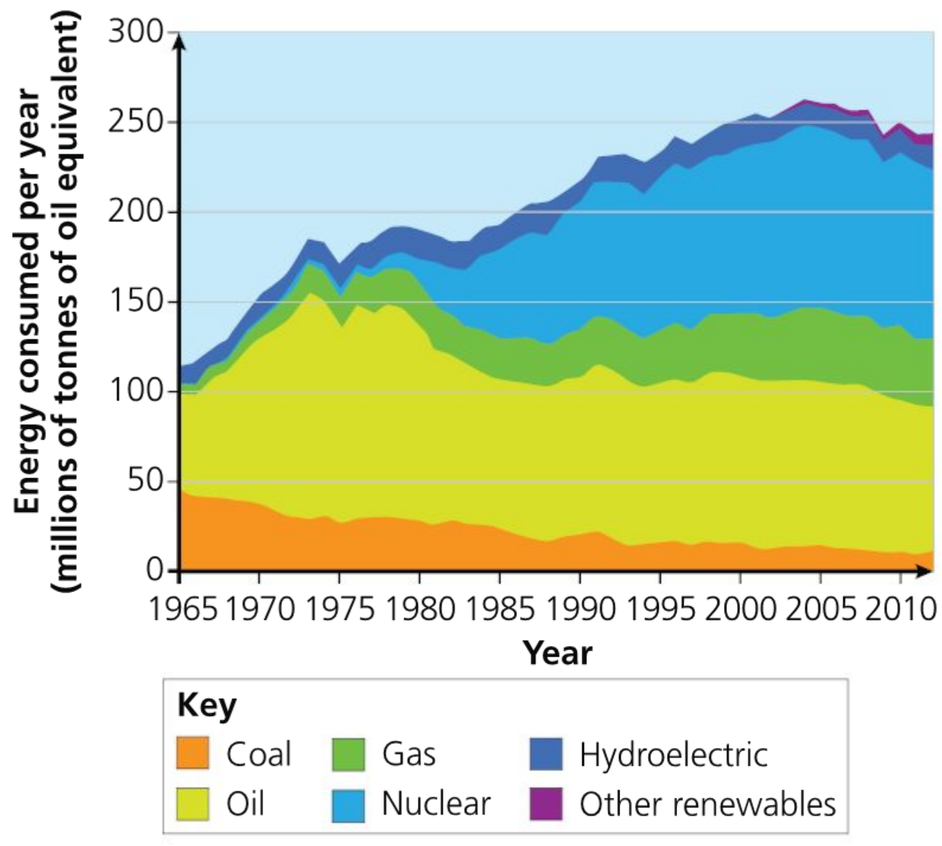


Figure 1.36 Energy consumption in France (source: BP)

Country	Population (millions)	Gross energy consumption ($\times 10^{15}$ J)	Energy consumption per person ($\times 10^{9}$ J)
Australia	23.13	5 372.80	232.18
Brazil	198.66	11 801.16	59.38
China	1 350.70	121 231.07	89.71
France	65.43	10 566.16	161.41
Haiti	10.17	168.89	16.60
India	1 237.69	33 017.92	26.66
Japan	127.55	18 947.30	148.48
Kuwait	3.25	1 446.12	444.75
Russia	143.53	31 687.91	220.67
Saudi Arabia	28.29	8 391.70	296.49
UK	63.71	8 053.92	126.36
USA	314.28	89 669.82	285.18

Table 1.6 Population and energy use for selected countries, 2012 (source: US Energy Information Administration, **www.eia.doe.gov**)

Assessment opportunities

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

Of course, there is another argument for reducing our reliance on fossil fuels. As we saw in *MYP Sciences by Concept 1*, Chapters 4 and 6, fossil fuel combustion is agreed by scientists worldwide to be the main contributor to carbon and other pollutants in the atmosphere that are leading to global climate change. What do you think we should do? And just as importantly, how are we going to do it?

SEE–THINK–WONDER

Look at the fossil fuel consumption calculator at **http://cf-trust.org/how-much-fossil-fuel-has-been-used-in-your-lifetime**.

What information do you **see**? What does it make you **think**? What does it make you **wonder**?

ACTIVITY: You don't know what you've got until it's gone

ATL

- Information literacy skills: Access information to be informed and inform others; Evaluate and select information sources based on their appropriateness
- Media literacy skills: Seek a range of perspectives from multiple and varied sources
- Critical-thinking skills: Recognize unstated assumptions and bias; Consider ideas from multiple perspectives

In pairs: In this activity you will be a science journalist. Your task is to produce a balanced article for the science section of your school magazine or online newsletter. You will research some ideas about how long fossil fuels will last, and about new sources of oil. You will also compare sources and make judgments about their reliability.

Before you begin, search the terms below to find definitions. Write the definitions down.

production cost reserves conditional resource inferred resource

Read the article reproduced here:

http://peakoil.com/consumption/how-long-will-fossil-fuels-last

Summarize what you consider to be the most important information in the article in five bullet points.

Discuss: What organization is using this article? Why do you think this organization might be interested in sharing this information? Does this affect your view of the information in the article?

The same article was originally hosted by this online news source:

www.business-standard.com/article/punditry/how-long-will-fossil-fuels-last-115092201397_1.html

Discuss: Does this change your view of the information in the article? If so, why?

Now read another discussion of the question of fossil fuel use here:

www.ecotricity.co.uk/our-green-energy/energy-independence/the-end-of-fossil-fuels

Summarize what you consider to be new information in the article in bullet points as before.

Discuss: What organization produced this article? Why do you think this organization might be interested in sharing this information? Does this affect your view of the information in the article?

Finally, read this article:

www.livescience.com/37469-fuel-endures.html

Discuss: What organization is using this article? Why do you think this organization might be interested in sharing this information? Does this affect your view of the information in the article?

Finally, research online to find out about **shale oil** and **fracking**

Find out what shale oil is, and how it is extracted. Find out how fracking is used to extract new reserves of oil. Find out also what are some of the benefits and disadvantages of these new ways to extract oil from the Earth. As above, try to use a variety of sources, with different viewpoints on the issue. **Summarize** your findings in bullet points.

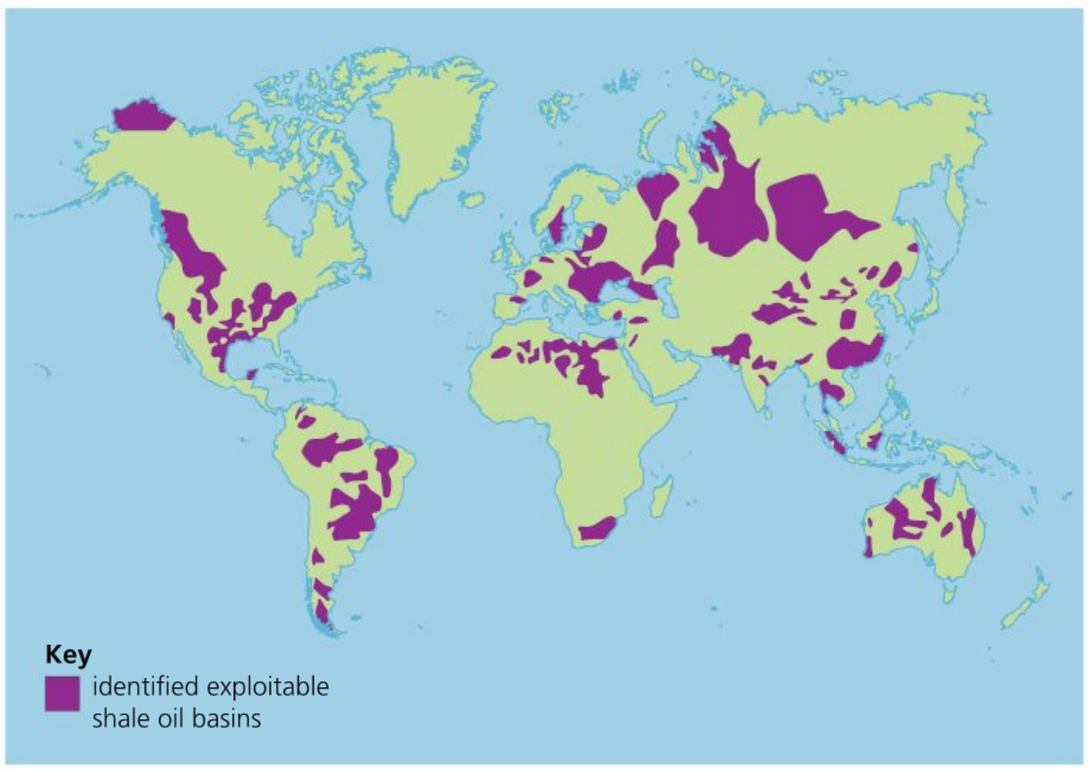
Now write your magazine article, **outlining** the information you have researched in an interesting way that can easily be understood by other students in your school. Include any data you found, and if possible **present** the data in new ways using charts, diagrams or graphs. **Describe** how new sources of oil are affecting predictions about fossil fuel use. **Discuss** and **evaluate** the advantages of these new sources, and evaluate their disadvantages. Use the new scientific vocabulary you have researched. Be sure to source and reference all your research using the referencing standards your school recommends. Display your articles in school on a noticeboard, or post them online in your class blog.

Assessment opportunities

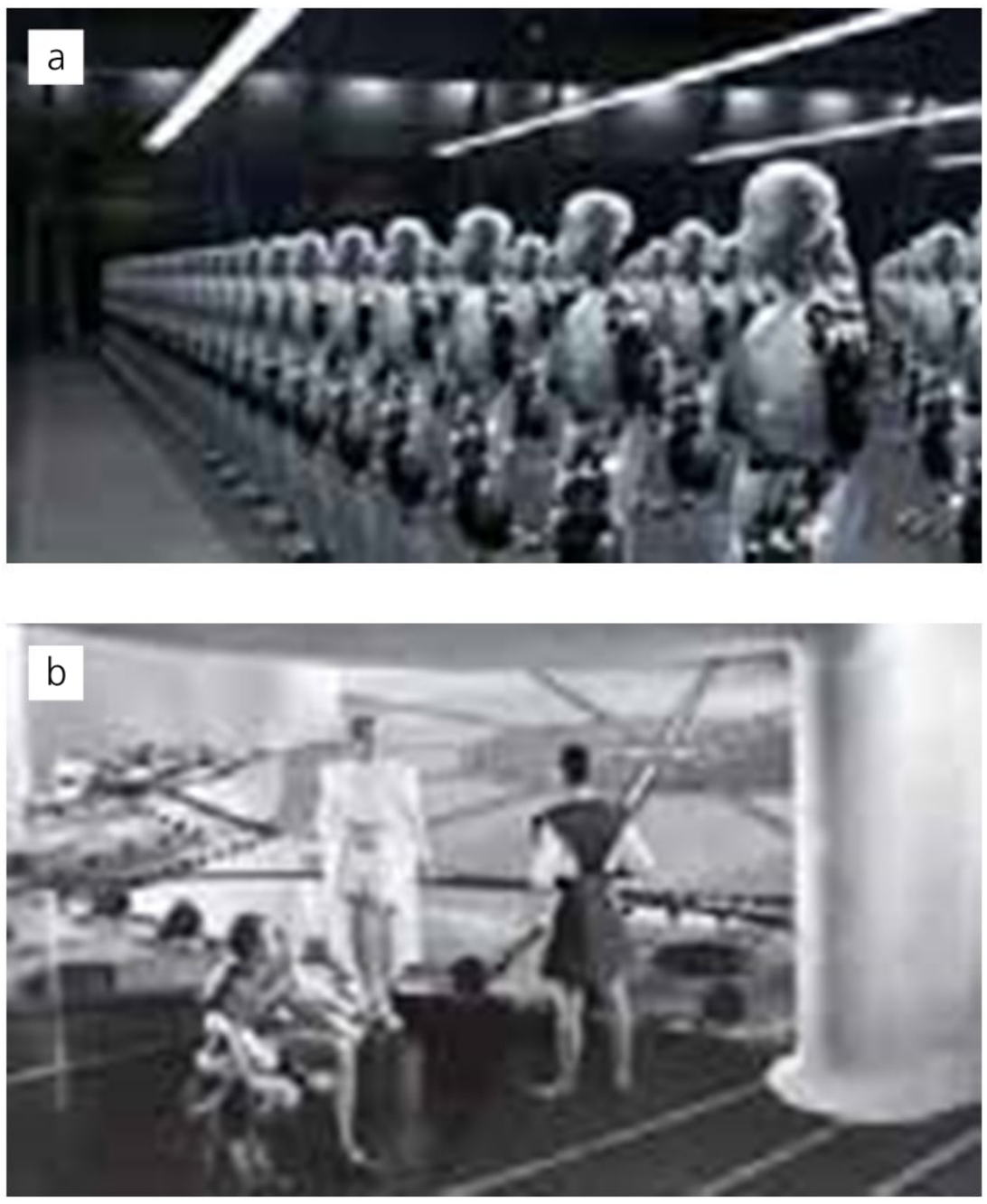
- This activity can be assessed using Criterion D: Reflecting on the impacts of science.

What have been the good and the bad consequences of using machines to do work?

There seems little doubt that we need machines – but do machines need us? As our machines have become more and more complex, many have asked whether one day machines might become *like* us – intelligent, thinking beings. There are different visions of this future. Some have argued that as machines become better at thinking, they will do more of the work that humans have to do. Humanity will then live in a 'leisure society', where we are freed from work to enjoy the richer things in life, to create, imagine, and play. Others have suggested that maybe intelligent machines will come to the conclusion that we need them more than they need us – and then humanity will become no more than an inconvenience. And what if they decide to do away with that inconvenience?



■ **Figure 1.37** World reserves of shale oil (source: US Energy Information Administration, **www.eia.doe.gov**)



■ **Figure 1.38** Different visions of the technological future: (a) the movie *I, robot* (b) *The Shape of Things to Come* by HG Wells

▼ Links to: Language and literature

Predicting the future has been of interest for a long time for creative writers. English philosopher Sir Thomas More (1478–1535) wrote an imaginary description of an island where 'philosophers' – whom we might now call scientists – used technology to improve life. More called his imaginary island 'Utopia', which is a version of a Greek word meaning 'no-place' – and this gave the genre of optimistic, futuristic writing its name. On the other hand, many writers have found drama and thought-provoking material in the idea of a nightmarish future, where technology has taken over – a 'dystopia'. Can you think of any dystopian novels, TV series or movies you have read or seen lately? What do you think the future will hold?

In reality, we have already seen some of these predictions come true. In the developed world, fewer people now work in manual labour (with their hands) than ever before, and technology plays an increasing role in both our leisure and working lives. On the other hand, in many parts of the world people still have to make their living through the physical work they do with their own bodies.

! Take action! Machines for all

ATL

- Collaboration skills: Practise empathy; Help others to succeed
- Organization skills: Plan long-term assignments; Set goals that are challenging and realistic

! Many people in the western world take complex technology for granted.

! However, there are still many parts of the world where even the basic necessities of life are hard to obtain – such as water. One of the United Nations sustainable development goals for 2030 is clean water and sanitation for all (see **www.undp.org/content/undp/en/home/sdgoverview.html**).

! The simplest machines can make a difference. Installing a water pump in rural villages in places prone to drought can have a huge positive impact on people's lives.

! Research online to find out about a **water pump charity**. You might wish to start with this non-governmental organization, but there are many others: **www.pumpaid.org/about-us/our-story**

! **Find out**:

- What problem do water pumps aim to solve?
- How do they do this? How do they work?
- What are the impacts on local people when a water pump is installed? Are there any disadvantages or problems with non-governmental organizations installing pumps themselves?

! Make contact with one of the organizations you have selected, and ask how you can help.

! Organize an awareness-raising campaign in your school and local community, and advertise the importance of clean water and water pumps. You can use assemblies, poster campaigns, connecting with local radio or TV, or just talking to people you know. Find data to support the claims that you make. **Summarize** your research in the form of a campaign leaflet or online appeal. In your leaflet or appeal, include charts, diagrams or graphs to **present** the data behind your message in different ways. Use diagrams and scientific terminology to explain how a pump works, and the difference water pumps can make.

! Use your campaigning to help fund-raise for a chosen organization over the school term or even the whole school year. Work with others to plan your campaign events and schedule them at the most impactful times.

◆ Assessment opportunities

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

Reflection

In this chapter, we have **described** how energy changes form but is never created or destroyed. We have **described** how work is done when energy changes, and **calculated** work done in some different situations. We have **analysed** simple machines for doing work, and we have **explained** how they make work more efficient. We have **summarized** the use of energy resources globally, and **outlined** some of the problems with global dependency on fossil fuels. We have **taken action** to increase access to a simple machine that can make a real difference to people's lives – a water pump.

Use this table to reflect on your own learning in this chapter.						
Questions we asked	**Answers we found**	**Any further questions now?**				
Factual: What is a machine? What do we mean by 'energy'? How do we measure energetic change? What is efficiency? What kinds of machines are there? What are fuels?						
Conceptual: How do energy changes determine chemical change? Will energy ever run out?						
Debatable: What have been the good and the bad consequences of using machines to do work?						
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**	
Communication skills						
Collaboration skills						
Organization skills						
Information literacy skills						
Media literacy skills						
Critical-thinking skills						
Creative-thinking skills						
Learner profile attribute(s)	Reflect on the importance of thinking for your learning in this chapter.					
Thinkers						

2 How do humans impact the natural world?

The **environment** **changes** as a **consequence** of how we **develop and manage** **natural resources** around the world.

Figure 2.1 Humans have harvested the environment's natural resources for thousands of years

CONSIDER THESE QUESTIONS:

Factual: What different values and viewpoints on the environment do people have? What are the characteristics of a healthy environment? How does the environment change? How do humans develop and manage natural resources?

Conceptual: What determines how humans develop and manage natural resources? How can managing and developing natural resources change the environment? How can different values and viewpoints on the environment influence how it changes?

Debatable: To what extent do people have the 'right' to use natural resources? To what extent should all people have the same responsibility to care for the environment?

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

IN THIS CHAPTER, WE WILL …

- **Find out** what makes a healthy environment and how environments change.
- **Explore** how human actions can have consequences for the environment.
- **Take action** by suggesting options to bring about positive change in the environment.

These Approaches to Learning skills will be useful…

- Communication skills
- Reflection skills
- Critical-thinking skills
- Creative-thinking skills

We will reflect on this learner profile attribute…

- Principled – we will practise being principled as we consider the ways in which people use, manage, and develop natural resources.

Assessment opportunities in this chapter…

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

KEY WORDS

environment
nature
resource

Throughout this chapter your job is to think like a mobile application designer. You will need to design an application for a mobile device that will be used to help people make decisions that contribute to the healthy management and development of natural resources around the world. There is no requirement for exactly what your app must do, but it will help users understand the relationship between us and the condition of the environment and offer suggestions or guidance for how we can take actions that contribute to positive change in the environment.

DISCUSS

Do your actions have an impact on the natural world? Do you think that impact is positive or negative?

What different values and viewpoints on the environment do people have?

WHAT IS THE VALUE OF NATURE?

What do you personally appreciate about nature?

Aldo Leopold, who lived from 1887 to 1948 in the United States, is considered by many people to be the 'father' of the modern environmental **conservation** movement. He was a strong supporter of the idea that all people share the responsibility of **environmental stewardship**. In other words, we all share the duty of protecting and caring for the environment by conserving, or preventing the waste of, the land and **natural resources**. He worried how people used the land and the resources it holds, and believed that, *'We abuse land because we regard it as a commodity belonging to us. When we see land as a community to which we belong, we may begin to use it with love and respect.'* He spent his life learning, writing, talking and teaching about **ecology** and conservation of nature.

Many of the ideas and principles Leopold developed and shared are still valid messages – some are even more valid today in the face of the rapid social, political, economic and environmental changes that are occurring now across the planet. In this chapter, we consider more deeply what it means to be members of the 'Earth community', and what we might do, and help others to do, so that we can all be good stewards of the land that supports us.

DISCUSS

In *MYP Science by Concept 1*, you learned the terms biotic and abiotic. What is the difference between biotic and abiotic? What are some examples of biotic components of an ecosystem? What are some abiotic components?

Figure 2.2 Natural landscapes may be fertile and productive or harsh and unforgiving

ENVIRONMENTAL PERSPECTIVES

People have different relationships with or feelings about the environment and nature. As with many things – like food, sports, movies, or books – what some people really embrace or care for, others may reject or dislike. There are people who are in the middle, who are more neutral – they feel neither love nor hate, or they both agree and disagree with some aspects of something. And then there are those who don't *totally* love or *totally* hate, or *totally* agree or *totally* disagree with something, but they are not neutral either.

It is the same when we consider the environment, in particular when we think about our relationship with nature and natural resources. The beliefs and values that we have about nature and the use of natural resources are our environmental ethics, or our environmental values system.

Where do you stand on the environment?

ATL

- Reflection skills: Consider ethical, cultural and environmental implications

What are your beliefs about our relationship with nature?

For this activity, your class will need three pieces of paper to create a 'spectrum' of responses to some environmental statements, which say 'Completely disagree', 'Completely agree' and 'Agree in some ways, disagree in some ways'.

Next, create the 'spectrum' of responses by putting the paper with 'Completely disagree' on the wall or floor at one end of the room, the paper with 'Completely agree' at the other end, and the paper with 'Agree in some ways, disagree in some ways' somewhere in the middle (Figure 2.3).

Now, holding your own piece of paper horizontally, draw three boxes containing the same response categories. Connect the boxes with arrows.

Next, listen to your teacher read a statement about the environment, nature, and natural resources, and our relationships with them, from the list below. Think about the statement and decide how you feel about it: do you completely agree, completely disagree, or agree in some ways and disagree in some ways? Or are you somewhere in between these categories of response? Whatever you believe is fine – just be ready to explain what makes you feel that way.

When your teacher says so, move to the area of the spectrum that best represents how you feel in response to the statement. Share what you believe and why according to your teacher's instructions. As you listen to your classmates, you may reconsider or think about the statement from a different perspective – that is okay! Feel free to move around the spectrum as your views change and become more clear.

Once everyone has had a chance to share and explain their views about the statement and you have settled on where you are on the spectrum, write the statement number on your personal spectrum in the position where you stand on this issue. So, after the first four statements, your personal spectrum might look something like Figure 2.3.

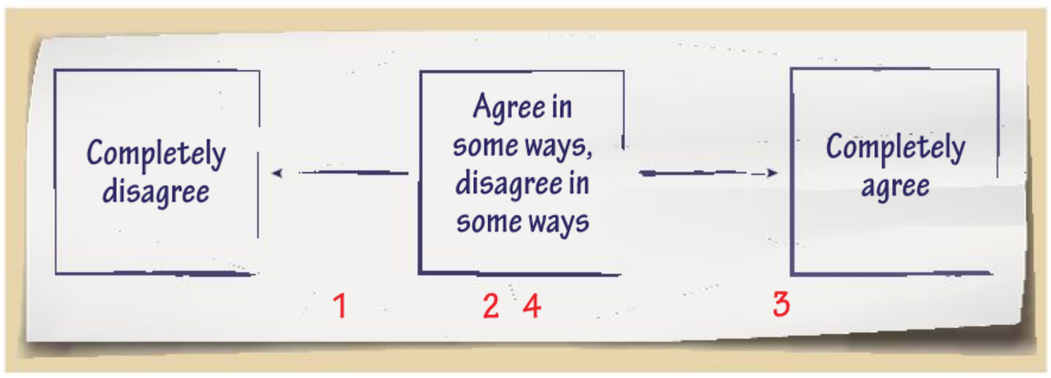


Figure 2.3 Write the number of each statement to show where you stand on it, on the spectrum of responses

Assessment opportunities

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

Statements about the environment, nature and natural resources

1 Humans have the right to use natural resources as much as we want, and in any way we want.

2 Scientific and technological developments will be the solution to any problems that come from or are related to the environment.

3 We can use natural resources to help make our lives better, but we should create laws or other systems to be sure we use them responsibly.

4 Everything that makes up the environment, including all living things and non-living natural resources and people, has equal value and importance – we should respect everything that makes up nature.

5 Countries can develop economically by using natural resources in a responsible way.

6 There are plenty of natural resources to maintain, and continue to improve, human lifestyles – and, if not, we will be able to think of some way to get around it.

7 People have the responsibility to care for, protect, and save nature and natural resources.

ACTIVITY: It's only natural

ATL

- Communication skills: Paraphrase accurately and concisely; Preview and skim texts to build understanding

We have been talking a lot about natural resources, and how people use them. But what do we actually mean by 'natural resources', other than resources that come from nature?

Describe the term 'natural resources' and source photos or drawings of both biotic and abiotic natural resources and where they are found. If possible, use your phone or camera to take your own photos. Otherwise, you can search for images online or draw your own pictures.

Describe the cultural, economic, environmental, ethical, political, or social factors that affect the use of natural resources.

Present your information to the rest of the class. You might choose to use a graphic organizer, such as a table, or a slideshow, to **organize** and share what you learn about the types of natural resources and factors that might affect how they are used.

Figure 2.4 The planet contains a variety of natural resources

Assessment opportunities

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

As we saw in the *Where do you stand on the environment?* activity, we can think about our relationship with and beliefs about nature on a spectrum. At one end are those who feel that we do not have to manage or care for natural resources, because we will be able to develop technology in time to overcome any environmental problems. From this viewpoint, shortages in natural resources or changes in the environment are not a concern because, through scientific development, we will find solutions to make life on Earth possible and comfortable for humans. These beliefs are **technocentric**, because they put technology (represented by the root *techno*) at the focus or centre (represented by the root *centric*) of our interactions with nature.

At the other end of the spectrum are people who feel that we have a duty and responsibility to treat everything in nature with respect and care, as all of the biotic and abiotic things in nature play important roles in maintaining a healthy global community. People who feel this way can be described as **ecocentric**, because they believe that the needs of all things coming from nature (represented by the root *eco*) should be the focus or centre of life on Earth. Aldo Leopold, who you read about in the introduction, would be considered an ecocentrist.

Somewhere in the middle of the spectrum are those who feel that humans are the most important species on the planet, and, therefore, can use and develop natural resources for economic growth – as long as we regulate what we use through political or social solutions, such as laws and taxes. Those who feel this way can be described as anthropocentric, because they consider humans (from the root *anthropo*) to be at the focus or centre of environmental systems.

Of course, most people do not agree 100% with any of the response categories. Some tend to share more beliefs with the technocentrists and feel that our technological developments give us access and rights to use natural resources in any way that we want in order to develop our societies, while others tend to share more beliefs with the ecocentrists, believing that we need to care for nature as well as we care for ourselves.

What are the characteristics of a healthy environment?

HEALTHY ENVIRONMENTS

A sports team is successful when it is made up of different players, each playing their own position but cooperating and working together. If a soccer team of 11 goalkeepers were on the pitch, they would not have a very successful match. They would not know whose responsibility it was to guard the net, and they would not have all the skills associated with the other positions. An orchestra produces beautiful music because so many different people are playing different instruments and notes, which they rehearse and synchronize together.

Similarly, the environment is successful when there are a variety of different species, each with its own role, but dependent on the others. As you know from what you have studied about food webs and species interactions, each species is important in the flow of energy from sunlight throughout the ecosystem. The interactions between different species – like predation, herbivory and competition, as well as symbiotic relationships like mutualism, parasitism and commensalism – result in balanced population sizes. When population sizes are balanced, the resources in the environment are not overused, and there are enough resources to support all the species.

This variety of different species is called **biodiversity**, and it is one of the key features of a healthy environment, or, more specifically, a healthy ecosystem.

BIODIVERSITY

Figure 2.5 A healthy coral reef with a high biodiversity, and one that has been 'bleached' and has low biodiversity

DISCUSS

With your partner, consider the analogy of the players of a sport team or the members of an orchestra, and discuss why biodiversity is so important to the health of an ecosystem.

Then, think of some of the different roles that different species play in an ecosystem. What would happen if some of the species no longer lived in the ecosystem?

EXTENSION

What is the current state of biodiversity in the world? How is biodiversity being protected? Search for **Global Biodiversity Outlook 3** on **youtube.com** for a video summary of recent studies.

Biodiversity is key to the health of an ecosystem so that all the processes that living things depend on can occur. If you think back to what you have learned about ecosystems, you will remember that plants are vital, as they convert the energy of sunlight into usable forms of energy for other organisms, and produce oxygen needed for respiration through the process of photosynthesis (more on that in Chapter 3). Decomposers like worms, insects and bacteria are crucial for breaking down dead matter and replenishing the nutrients in the soil, allowing plants to grow. Animals in the ecosystem feed on plants and on other animals, keeping populations in balance, and all organisms release carbon dioxide into the environment during respiration, which is required for photosynthesis in plants.

Another reason why a wide variety of species is important for ecosystem stability is that if the population of one species is significantly reduced, there are other species with a similar role in the ecosystem that remain and keep the system in balance. For example, if large numbers of rabbits in an ecosystem were wiped out by a virus, but there was still a healthy deer population, the deer would help keep the population of grasses and other plants under control. Furthermore, because the abiotic conditions in an ecosystem do not stay the same throughout the year, a high biodiversity means that there are more likely to be species adapted to the various conditions at different times. This makes it possible for the necessary species interactions to occur all year long.

DISCUSS

As you will have learned if you carried out research for the *Extension* activity on this page, in 2010, a report called *Global Biodiversity Outlook 3* was published to summarize the state of biodiversity and progress towards conserving biodiversity at that time. But what were some of the important messages in the report? Read the following two excerpts and discuss the questions that follow.

> The overall message of this Global Biodiversity Outlook is clear. We can no longer see the continued loss of biodiversity as an issue separate from the core concerns of society: to tackle (fight) poverty, to improve the health, prosperity and security of present and future generations, and to deal with climate change. Each of those objectives is undermined (influenced) by current trends in the state of our ecosystems, and each will be greatly strengthened if we finally give biodiversity the priority it deserves.

1 **What is the relationship between biodiversity and other concerns like fighting poverty, improving conditions for current and future generations, and managing climate change?**
2 **Why is there a relationship between biodiversity and those other concerns?**

> Well-targeted policies focusing on critical areas, species and ecosystem services can help to avoid the most dangerous impacts on people and societies from biodiversity loss in the near-term future, which it will be extremely challenging to avoid. In the longer term, biodiversity loss may be halted (stopped) and then reversed, if urgent, concerted and effective action is applied in support of an agreed long-term vision.

3 **Does this excerpt from the report indicate that it is possible to make positive changes towards biodiversity, or that it is not possible? What makes you say that?**
4 **What is needed in order to prevent serious negative consequences resulting from the loss of biodiversity?**

How does the environment change?

Although we often refer to healthy ecosystems as 'balanced' or 'stable', it does not mean that they will never change. If we look at the trees of the temperate forest pictured in Figure 2.6, we can see an example of natural changes that an ecosystem experiences.

When changes occur naturally in an ecosystem, there are systems and cycles in place that allow the organisms that live there to survive or recover from the changes. For example, some animals – like bears, bats and chipmunks – survive the winter months when little food is available by hibernating, so they can still be strong enough to reproduce in the spring. Many plants are adapted to survive the destruction of forest fires. Indeed, the seeds of some species, such as giant sequoias, actually need fire to initiate the process of germination so that new trees can grow. Even after a devastating natural event causing massive destruction, such as the eruption of the Mount St Helen's volcano in Washington State, in the United States of America, in 1980, ecosystems are able to recover.

DISCUSS

What are some natural changes that occur in different ecosystems? Consider different ecosystems around the world, and try to come up with examples of natural changes for each one.

EXTENSION

Explore the natural changes in an ecosystem further. There are many photos and videos of the changes that occurred in the ecosystem surrounding Mount St Helen's. Try image or video searches for **Mount St Helen's before and after** and **Mount St Helen's present day**.

■ **Figure 2.6** The changing of leaves through the seasons is an example of a natural change that can occur in an ecosystem

■ **Figure 2.7** Different species are able to cope with the natural changes that occur in an ecosystem, such as this dormouse hibernating in the winter and giant sequoia seeds germinating only after a fire

ACTIVITY: Everything changes

ATL

- Critical-thinking skills: Interpret data; Draw reasonable conclusions and generalizations

In order to inform the public about the changes that are occurring throughout the global environment, ecologists and other scientists often create graphics to represent and illustrate the findings from their research in a concise way. However, in order for the findings to be meaningful, it is important that the people who are looking at the graphics are able to analyse and understand what the data says.

In this activity, using Figures 2.8a to 2.8d, you will practise the skill of reading and analysing data when it is presented in different types of graphics. To get a realistic understanding of what each graphic illustrates, you should:

1. **read the titles of the graphic, and, if present, the labels on the x and y axes**
2. **look for a legend or key and read what it represents**
3. **identify the units**
4. **read the caption**
5. **identify trends:**
   - **What increases and when?**
   - **What decreases and when?**
   - **What stays steady?**
   - **Are the increases and decreases slight, gradual, sudden, or sharp?**

Once you have considered those points, and perhaps some others that you think of, summarize what you understand from Figures 2.8a to 2.8d in a copy of Table 2.2. An example has been done for you for Arctic sea ice in Figure 2.8a.

Graphic topic	When I look at this graphic, I see...	This means that...
Arctic sea ice	The y axis shows the area (in km) of Arctic sea ice there is. The x axis shows time, from 1980 to 2009. The area of Arctic sea ice goes up and down every year. The largest area was about 7.8 km in 1980 and 1996. The smallest area was about 4.4 km^2 in 2007. The red line shows an overall negative trend.	Even though the area of Arctic sea ice goes up and down over the years, the overall trend is that the area is decreasing. The habitat and living space of animals that depend on Arctic sea ice is decreasing. There are fewer resources for the animals that live and depend on Arctic sea ice.

Table 2.2

Assessment opportunities

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

Many changes in ecosystems are not natural, and are therefore difficult for organisms to survive and recover from. These changes mainly result from human actions. Some human actions directly change an ecosystem, such as deforestation to clear land for building or ranching. Other human actions indirectly change an ecosystem, such as the melting of polar ice caps as a result of climate change due to greenhouse gas emissions.

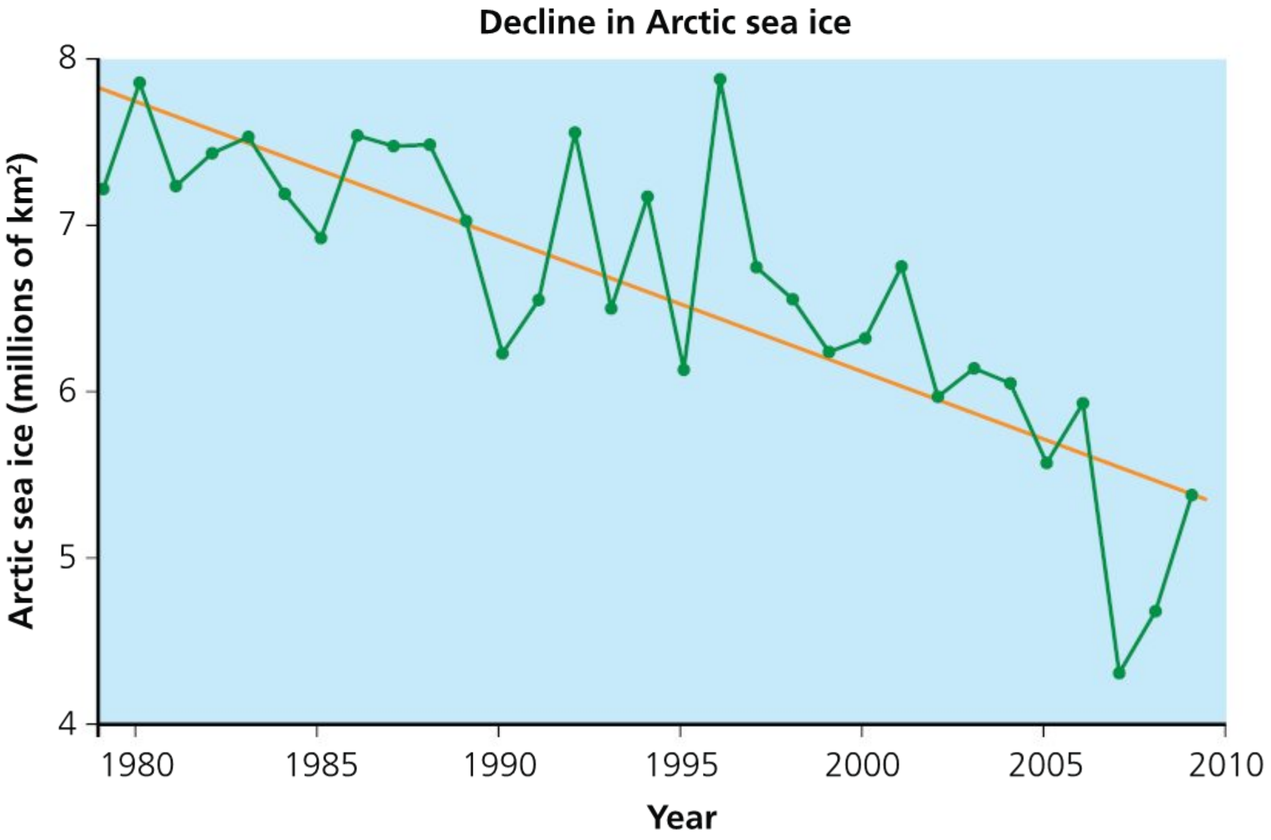


Figure 2.8 (a) The amount of Arctic sea ice that is floating in September of each year (September is when sea ice is at its minimum) (source: Convention on Biological Diversity)

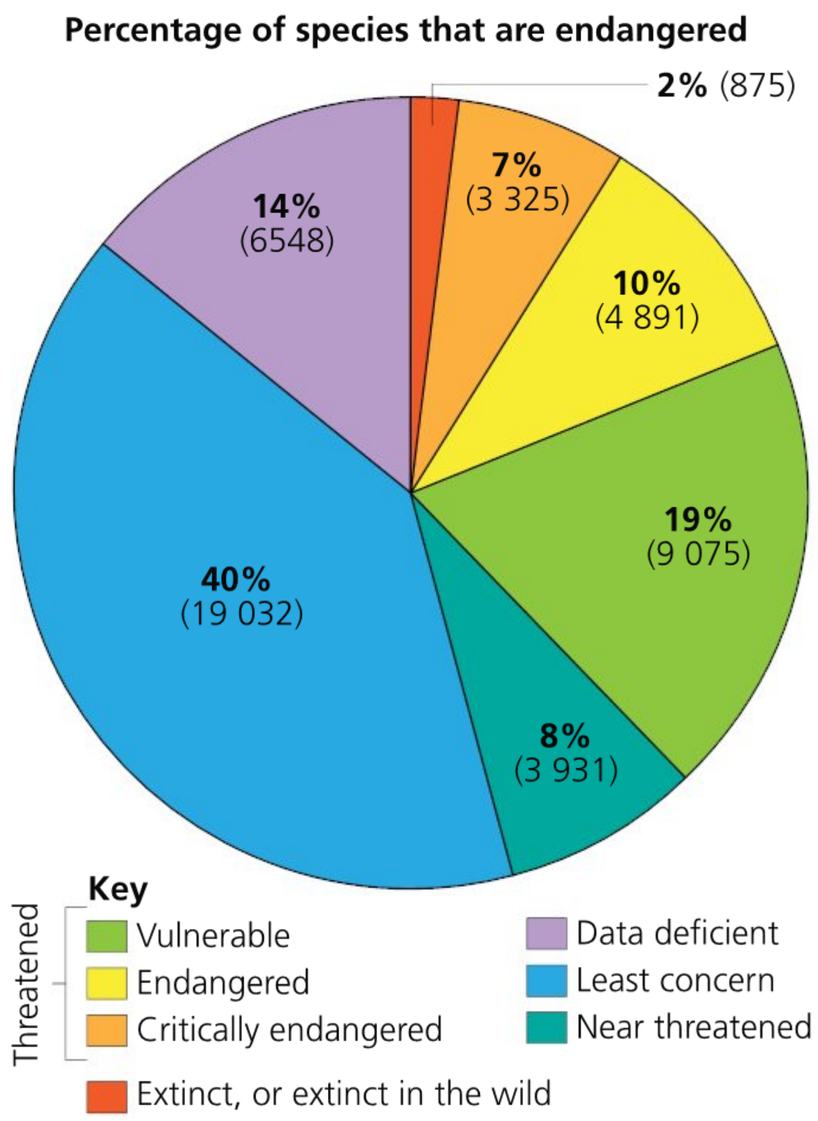


Figure 2.8 (b) The proportion of species under threat of becoming endangered or extinct, based on data from 47 677 species (source: IUCN)

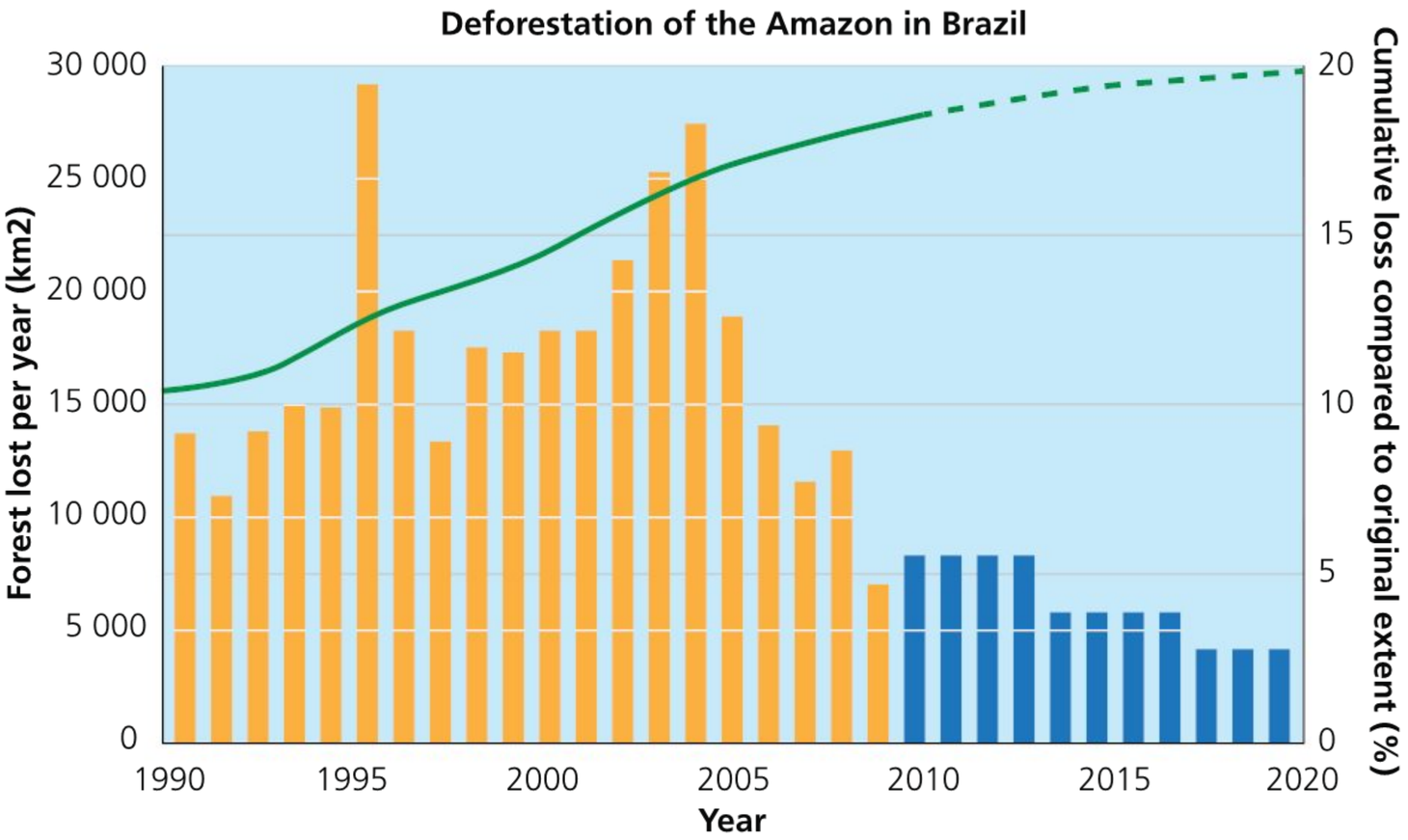


Figure 2.8 (c) Annual and cumulative deforestation of the Brazilian Amazon. The blue bars are the projected, or predicted, area of deforestation, while the orange bars represent the actual area. The solid line shows the actual total loss due to deforestation, while the dotted line shows the projected total loss (source: Brazilian National Space Research Agency)

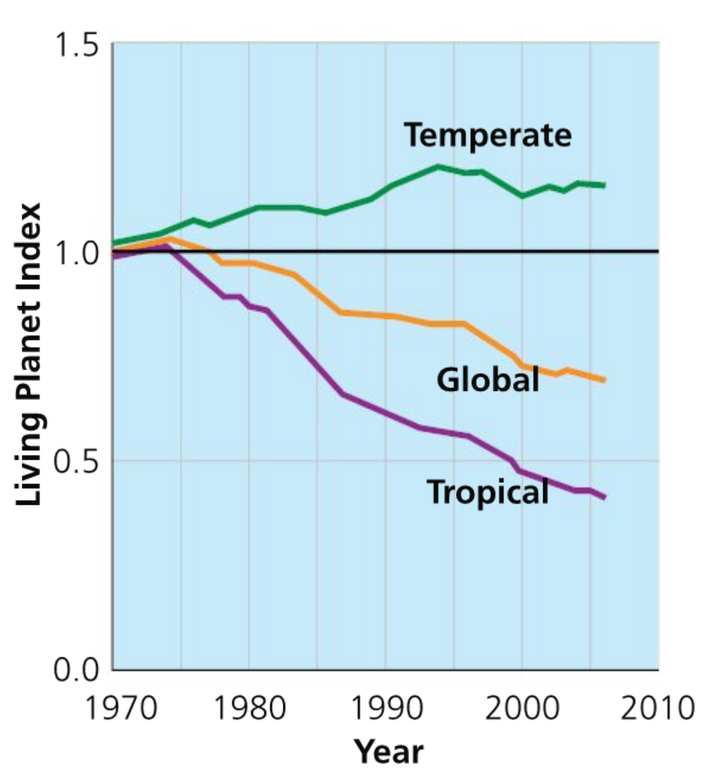


Figure 2.8 (d) Ecological sensitivity refers to the percentage of ecosystems that are projected to undergo changes in plant life by 2100 as a result of the current trends in climate change (source: NASA/JPL-Caltech)

DISCUSS

A riddle

'Suppose you own a pond on which some water lilies are growing. The lily plants double in area each day. If the lilies were allowed to grow unchecked, they would completely cover the pond in 30 days, choking off the other forms of life in the water. For a long time the area covered by the lilies seems small, and so you decide not to worry about cutting them back until they cover half the pond. On what day will that be?'

adapted from The Limits to Growth, *by Donella H. Meadows*

In other words, if you wait until the water lilies cover half of your pond, how many days (before the 30th day) will you have to clear them out before they completely cover the pond and kill the other things living here? Why is this a problem?

Figure 2.9 How long will it take before the water lilies completely cover your pond?

Although positive changes can and do occur in the environment, many changes are associated with serious negative consequences. However, because the negative consequences are usually not immediately obvious – some may take years and years to occur – it is possible for people to ignore or not consider the results of their actions. For example, if you eat a lot of candy and drink a lot of sugary drinks and don't brush your teeth as regularly you should, you will not immediately get a cavity – as a result, because there is no clear negative consequence (your teeth still feel okay), you might think it is fine to consume lots of sugar and not brush your teeth afterwards. In other words, you will probably continue with your habits.

Some may argue that this is not necessarily a bad thing – since we cannot observe any negative consequences, they do not yet exist, and we can just fix the problem once it appears. If you followed this thinking, you would continue your poor dental hygiene until you got a cavity, and then just get your tooth drilled and filled. However, it is not as easy as that to fix a problem in nature. Read and discuss the riddle above to understand why unseen consequences are not always easy to fix.

As you discussed when considering the riddle, sometimes by the time we notice the negative consequences, it is just too late to take enough actions for positive change. Going back to the dental hygiene example, if you wait too long before taking care of your teeth, they might get so damaged that they could not be fixed by drilling and filling the cavities, and the only solution would be getting your teeth pulled out. This is because, as small changes build up little by little over time, one day, a **tipping point** is reached, and a large, irreversible change occurs without our being able to control it.

But, again, why is this huge, uncontrollable change such a bad thing? Let's go back to our riddle. If we know that on the 30th day the uncontrolled lily plants will cover the pond completely, that means that the day before – on the 29th day – the lily plants will cover only half of the pond (because they double in size each day). This leaves you only *one day* to clear out all the lily plants so that the rest of the living things in your pond can survive.

VISIBLE THINKING – Headlines

What is the important message about tipping points? Write a newspaper headline to show what you understand about tipping points, and why it is important to consider tipping points when thinking about human impacts on the environment. Before you write, discuss with your class what makes a good headline, so you can make yours as clear and effective as possible.

Share your headline with the class. Are there any big ideas that you understand from hearing your classmates' headlines?

As you may have already discussed, this is a bad thing because you would have very little time to clear out all the lily plants. Maybe you would have to hire some people to help, or maybe you would have to buy some equipment to clear them out. This means that clearing out your pond would be expensive at best and impossible at worst – maybe the number of lily plants is so big that you would not be able to clear them out fast enough in order to avoid permanent damage to and loss of life in your pond. Biologically, this is a problem because since the lily plants were able to take over the pond and make it impossible for other living things to survive, the biodiversity of your pond was drastically reduced and the pond was no longer a healthy ecosystem.

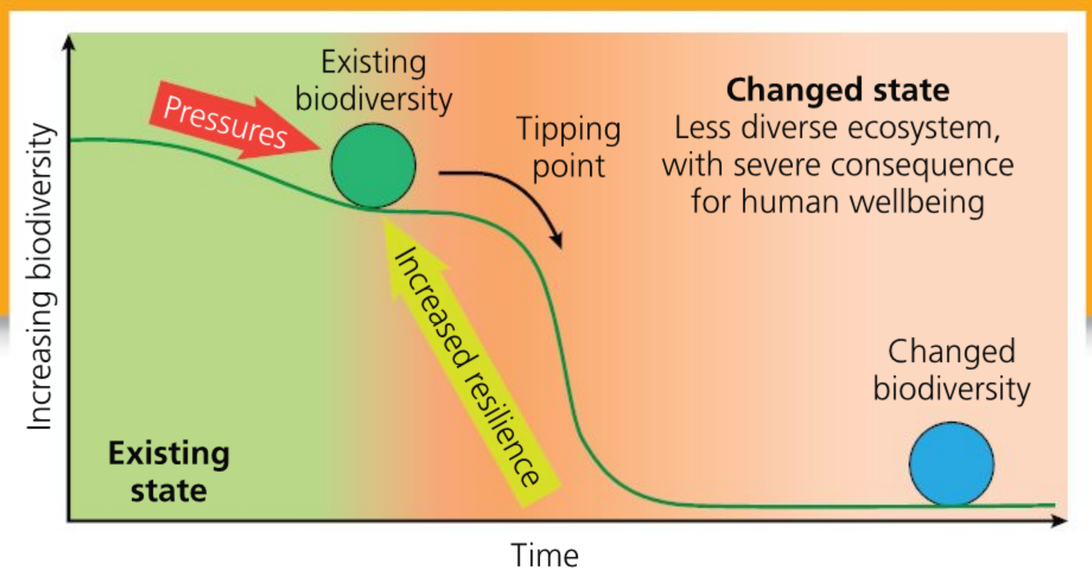


Figure 2.10 An illustration of how reaching the tipping point of biodiversity loss can impact human life as well as that of other organisms. How does this compare to your non-verbal representation? How can you summarize the effect of tipping points when looking at this graphic?

Reaching the tipping point of environmental change is serious because once the tipping point is reached, the changes that occur cannot be reversed – a new reality now exists. In an ecosystem, depending on the nature of the changes, this often means that the conditions necessary for the native organisms to live no longer exist, and the native organisms cannot survive. In other words, the biodiversity is reduced and the ecosystem is no longer healthy and in balance.

ACTIVITY: You've reached the tipping point

ATL

- Creative-thinking skills: Generate metaphors and analogies

How can you represent the principle of tipping points in a non-verbal way? You may use an environmental example of a tipping point, such as what happened with the lily plants and biodiversity, or you may think of another example.

What 'non-verbal' way do you prefer to represent tipping points? Will you draw a series of pictures? Make a graph? Maybe act something out? Whatever you choose to do, you must make it clear that you understand the seriousness of reaching a tipping point.

Key subject skills

In this activity we have practised using non-scientific metaphors and analogies to explain scientific ideas. This is an important skill that scientists frequently use to help people understand complex scientific processes or concepts. Creating models is another way that scientists help people understand scientific processes that cannot otherwise be visualized.

Assessment opportunities

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

How do humans develop and manage natural resources?

Figure 2.11 What natural resources are being used here?

Human survival depends on materials, or resources, that come from nature. From people who live in the most remote and traditional villages to those who live in the middle of the largest and most modern cities, all that we do requires the use and processing of **natural resources**. Because we depend so much on natural resources, they have become very valuable.

Even in our modern lives, natural resources surround us. It is not only the water that we drink or the fossil fuels that we use in our cars and for electricity. If we look at Figure 2.11, we can see many more examples of natural resources. The cotton fibres that are used to make this woman's T-shirt, the wood that is used for the chair, table and cooking utensils, and the grains that have been made into her breakfast cereal all come from the natural resource of plants that grow in the natural resource of soil, and require the natural resource of water. The milk in her cereal comes from the natural resource of animals (which also require the natural resources of plants, soil and water). The cement that was used to build parts of her house comes from the natural resource of rocks. The plastic covering of her cell phone and the paint on the woodwork and walls all contain petroleum, a natural resource from fossil fuels. And the list could go on and on.

All of these products from natural resources that we use in our daily lives are important to us. Some are necessary for our survival – like water and the resources that provide us with food and shelter. Others make our lives easier, more convenient or more entertaining. Therefore, natural resources hold great value for us – economically as well as personally. Some people who live in regions containing large amounts of important natural resources may make money – sometimes large amounts of money – by extracting them from the Earth and selling them to companies that process them into different products.

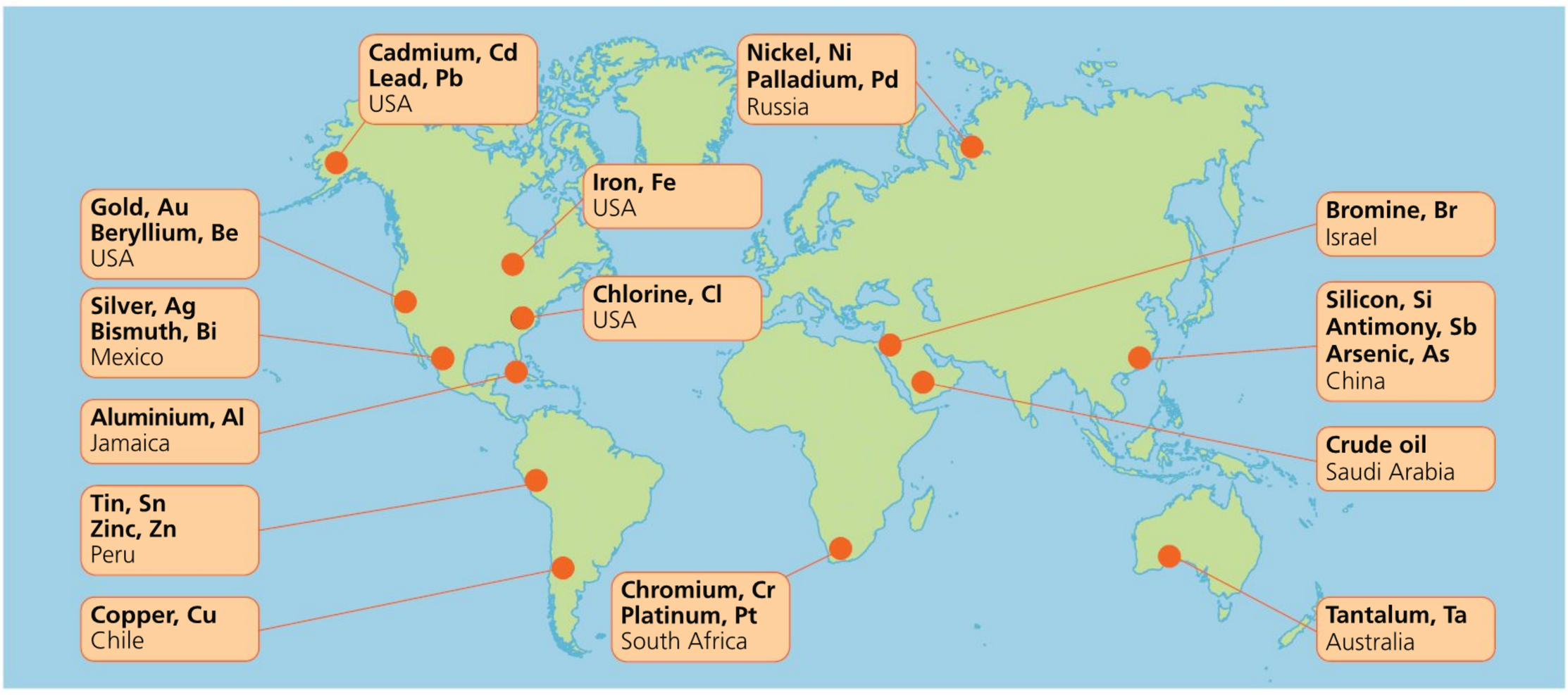


Figure 2.12 A map showing where some of the natural resources that are used for cell phones may come from

ACTIVITY: Natural resources in our lives

ATL

- Critical-thinking skills: Gather and organize relevant information to formulate an argument; Consider ideas from multiple perspectives

Most of what we use in our daily lives comes directly or indirectly from natural resources. Beyond those we have already mentioned, what are some other products that come from or contain natural resources?

Make a copy of Table 2.3. Research in order to find out how people get access to the following natural resources: fossil fuels, plants, animals, rocks, soil and minerals, and find products or uses of them. Indicate whether the natural resource is renewable or non-renewable. Be sure to cite the sources of your information.

Hint

Try starting your search with products made from a resource, or uses of it. For example, you could search for products made from minerals, or uses of water

Once you have completed your research, complete the last column about the consequences of using each natural resource. What happens to the environment as a result of people getting access to the natural resource? What are the possible political, economic, or cultural effects?

Assessment opportunities

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

Natural resource	How people get access to it	How it is used (specific examples)	Renewable or non-renewable?	Consequences of using the natural resource
Water	Using pumps to get it from underground wells; collecting it from lakes or rivers; collecting it from rain; collecting it from the ocean and removing it from the salt	Drinking, cooking, hygiene (showering, brushing teeth), washing and cleaning, irrigating crops, hydroelectric power (from **http://water.usgs.gov/edu/wudo.html**)	Surface water (like lakes and rivers) is renewable; groundwater under the surface of the Earth is non-renewable (from **www.fao.org/docrep/005/y4473e/y4473e06.htm**)	

Table 2.3 Uses of natural resources

Some natural resources take so long to form inside the Earth that once we use them up, they will be gone. These are **non-renewable resources**. For example, the petrol and gas we use to run our vehicles and heat our homes formed over millions of years as tiny, dead sea plants and animals got buried and compressed under layers of rock by huge amounts of pressure and heat, until they were transformed into petroleum and natural gas. Because that process of turning the remains of dead organisms into fossil fuels takes so long, once we use up the fossil fuel reserves we have in our Earth, we will not have access to any more.

Other natural resources are 'refreshed' by natural cycles and processes. For example, the water that forms lakes, rivers and oceans is replenished through the water cycle, a process that occurs constantly all over the world. These types of natural resources are called **renewable**.

How can managing and developing natural resources change the environment?

Because natural resources are a source of income, countries manage how they exploit, or develop, them in different ways. Most countries have a governmental agency or ministry that is in charge of monitoring, researching and protecting natural resources, so that they are hopefully exploited in a sustainable way. However, because many natural resources, such as fossil fuels, timber (trees), and the land itself, have such high monetary value, countries depend on the extraction and sale of their natural resources as a large source of income for the country. Some of the currently more economically developed countries (MEDCs), such as those in North America and in Western Europe, have been developing and exploiting their natural resources, such as coal, land and timber, since the nineteenth and early twentieth centuries, while some of the currently less economically developed countries (LEDCs), such as Brazil, India and China, have recently begun exploiting their natural resources, including oil, natural gas, timber and land. Intergovernmental agencies, such as the United Nations Environment Programme (UNEP), are working with governments around the world to establish a way for countries to find environmentally sustainable solutions to development and avoid the overexploitation of natural resources.

The consequences of exploiting natural resources are not limited to a reduction in the quantity of the resource itself. In fact, the entire process of extracting the resource from the land, getting it to and from processing plants, and processing it into forms that we use, has many consequences. For example, in order to get access to timber, oil and land for development in the Brazilian rainforest, it is necessary to build roads that can support large vehicles in previously untouched natural areas. Building the roads means the habitats of different plants, insects, amphibians, reptiles, birds, fish and mammals are disrupted or even destroyed. This causes a reduction in biodiversity. Furthermore, some indigenous tribes who live in these remote areas are forced to leave their homes, where they have lived sustainably from the land for generations.

The vehicles that take the workers to and from the natural area and that are used to carry out the extracted resources, as well as the extraction machinery, all pollute the environment with exhaust fumes and fuel spills. The factories that are used to process the resource require fossil fuels for power, large amounts of water, and, often, dangerous chemicals that are a risk to the environment as well as to the health of people who work there. Moreover, the people who are hired to extract the resource, such as miners, and to process the resource in factories, may be exposed to dangerous working conditions, work long hours, and receive low wages.

DISCUSS

Besides the fact that the resources themselves, many of which are non-renewable, are being used up, what are some other consequences of the exploitation of natural resources? Think about what has to be done to the natural resource – such as oil, land, or diamonds – before it is in a usable form. You might want to do some research to learn about the industries associated with different types of natural resources. In your discussions, consider the cultural, economic, environmental, ethical, political and moral factors.

Figure 2.13 There are many impacts of developing natural resources: (a) petroleum and gas refineries use huge amounts of water and energy, (b) slash-and-burn of a rainforest to get land for ranching results in the loss of habitat and biodiversity, (c) sulphur miners go into the mouths of volcanoes to remove huge chunks of sulphur, (d) diamond miners face difficult working conditions to extract diamonds from the Earth

ACTIVITY: Case study – processing petrochemical products

ATL

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

For this activity, you will read information about petrochemicals over the next few pages. While reading, write down the points that you find most interesting and questions that you have. Read the information silently, or out loud with your partner or class. Then, write or discuss your response respond to the questions below.

Questions

1. **What effect does the variety and popularity of petrochemical products (Figure 2.14) have on the demand for petroleum?**
2. **What might be some economic, environmental, or political factors associated with the production and use of petrochemical products?**
3. **Using the facts you have learned about how fossil fuels are formed and processed, make a judgment on the extent to which the use of and demand for petrochemical products contributes to the enhanced greenhouse effect and climate change.**
4. **What are the implications of using petrochemical products when searching for ways to reduce the amount of CO_2 that is released into the environment from processing fossil fuels?**
5. **What are the environmental impacts of the disposal of unused or unwanted petrochemical products?**
6. **What are some actions that people can take to reduce the environmental impacts of using petrochemical products?**

Assessment opportunities

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

PETROCHEMICALS

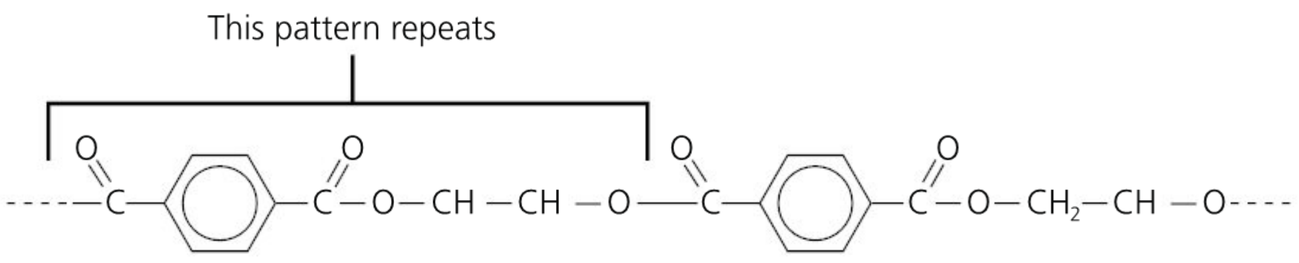
Figure 2.14 What do these products have in common?

■ **Figure 2.15** Crude petroleum is a thick, sticky black liquid

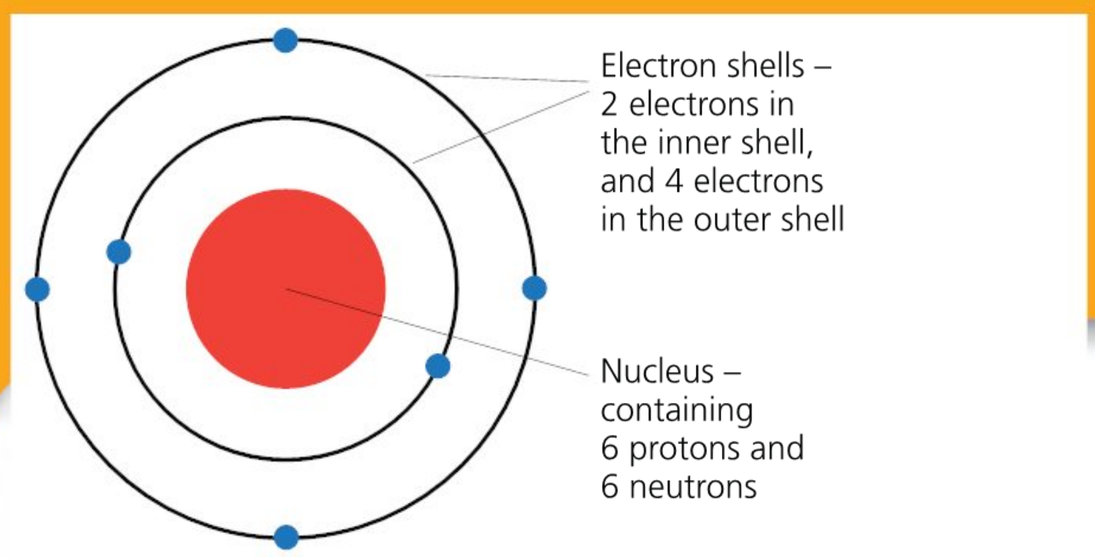
Take a look at the products in Figure 2.14. What do they all have in common?

Believe it or not, these products are related because they all contain petroleum – the same substance that is used as fuel for our vehicles is also used for many of the things we use in our daily lives. But how can that be? How can petroleum – a thick, black liquid – also be a piece of red plastic, or a soft fleece jacket, or pink lipstick?

The answer lies in the basic chemical components of petroleum. As you know, petroleum and other fossil fuels have formed over millions of years as the remains of dead plants and animals have been compressed and heated deep under the surface of the Earth. Because fossil fuels have formed from the remains of living things, they are made up of some of the same compounds that living things are made of, in particular those that contain carbon and hydrogen, or **hydrocarbons**.



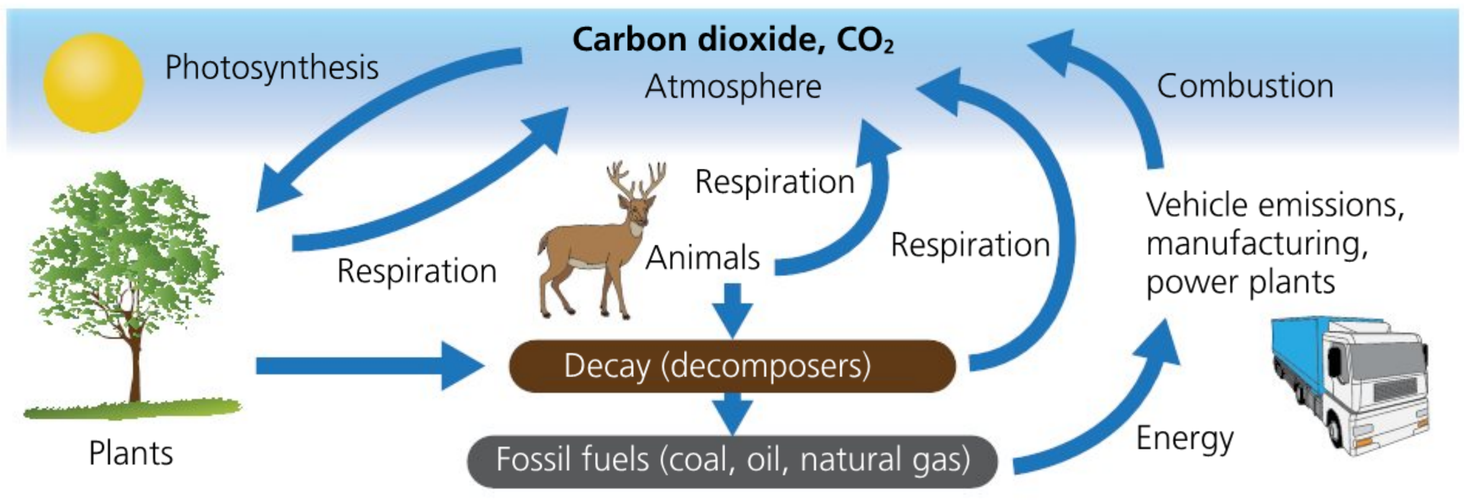
■ **Figure 2.17** Polyester is a carbon polymer that is used for different types of clothes



■ **Figure 2.16** A carbon atom has four outer electrons

Carbon is a unique atom. Because of its atomic structure with four valence electrons, it is able to bond with a variety of other atoms and molecules and form different types of bonds, including single bonds, double bonds, or a combination of both.

Carbon is often part of large molecules called **polymers**. A polymer is formed when many molecules of the same chemical structure bind together to form one large molecule. For example, carbon is part of polyester, a polymer that is used to make some clothes, like fleece jackets and sports jerseys (Figure 2.17). Polyester is a long chain of molecules bound together.



■ **Figure 2.18** The carbon cycle shows that processing fossil fuels in the petrochemical industry contributes a large amount of the CO_2, a major greenhouse gas, that is released into the atmosphere

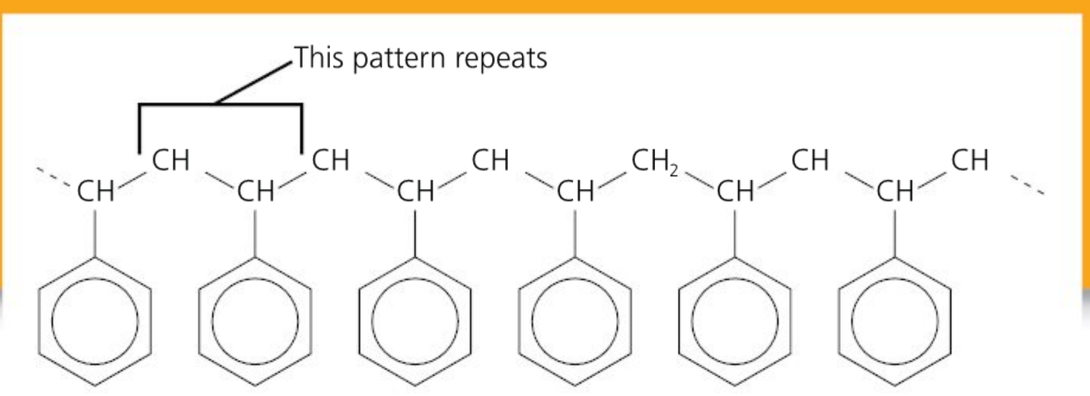
■ **Figure 2.20** Polypropylene is one of the carbon compounds used to make plastic containers

Carbon is also part of polypropylene (Figure 2.20), one of the polymers that makes up plastic containers, and polystyrene, the polymer that makes up insulated packaging (Figure 2.21).

Currently, the largest source of the hydrocarbons that are used to make all of these different products is petroleum – which is why these products are known as **petrochemicals**. This is because petroleum is, at this time, the largest, most convenient, and least expensive source of molecular raw materials (hydrocarbons) that can be processed in a variety of ways to make a variety of products.

So petroleum is used not only to make fuel for different vehicles, but also to make the different plastics, fabrics, paints and other products shown in Figure 2.16 that we use in our daily lives. In the process of making these products, petroleum extracted from oil wells is transported to processing plants, where large amounts of electricity, water and chemicals are used to transform the crude petroleum into the designated product. Throughout this process, significant amounts of toxic waste substances are produced. In addition, as the petroleum is processed, much of the carbon that was stored in it is released in the form of carbon dioxide (CO_2), which is one of the main molecules in the atmosphere contributing to the enhanced greenhouse effect and climate change.

As well as being very versatile, petrochemicals are also very durable. This means that polyester fabric used to



■ **Figure 2.21** Polystyrene is a carbon polymer that is used in insulated packaging

make your clothes will not easily tear, and petroleum-based paint will not fade on your house. However, it also means that petrochemical products do not biodegrade, or break down, due to natural decomposition processes. As a result, any petrochemical products released into the environment, either accidentally through a leak or spill, or on purpose when we throw them into landfills, will stay there unless we do something to remove them from the environment. Some petrochemical products, like some plastics, can be recycled, but most must be either stored or left to build up in the environment when they are no longer wanted.

The petrochemical industry began with some accidental discoveries in the mid 1800s, though purposeful production of most products did not begin until early in the 1900s. (Go to **www.petrochemistry.eu** to learn more about this industry and find a timeline of discoveries.) Since that time, due to the demand for and popularity of petrochemical products, the petrochemical industry has grown to be one of the most profitable in the world. In fact, it is expected to grow to be worth $758.3 billion (US dollars) by 2022, compared to $514.5 billion in 2014.

I used to think, now I think...

How has your understanding of the ways in which humans impact the natural world changed as a result of what you have learned in this chapter?

Make a two-column chart, with the left column labelled 'I used to think…' and the right column labelled 'but now I think…' Fill in some of the things you used to think about the consequences of our actions on the environment, and what you now think based on what you have read, discussed and done in this chapter. Share your list with your class. How has your classmates' thinking changed?

! Take action! An app for the environment

■ ATL

■ Creative-thinking skills: Create novel solutions to authentic problems; Make unexpected or unusual connections between objects and/or ideas; Design new machines, media and technologies; Apply existing knowledge to generate new ideas, products or processes

! You will use what you have learned about the changes that occur in the environment as a consequence of our development and management of natural resources to identify an aspect of conservation that you would like to support with the creation of an app that people can use to help themselves make decisions that contribute positive environmental change.

! Remember, there is no requirement for exactly what your app must do, but it must help the user understand the relationship between humans and the condition of the environment, and offer suggestions or guidance for how we can take actions that contribute to positive change in the environment.

! Before you begin, search online for **environmental apps** or **eco-friendly apps** in order to see some that already exist. Use your findings as inspiration for your own app. Perhaps you want to take an app that already exists and make it specific to your area. Maybe you want to refine one of the apps so it is better suited for teenagers. Or maybe you want to come up with a completely new idea based on your interests and environmental values.

! You can choose how you would like to share your app design. For example, maybe you would like to do a slideshow or video, or maybe you would like to create a paper-based design. Whatever you choose to do, your design must include the following:

1 Name of the app

2 Description of the app
   - What are the environmental issues that the app will address?
   - How will the app contribute to environmental conservation?
   - What environmental values does the app support?
   - What positive environmental changes can come as a result of using the app?

3 How and when people will use the app

4 Possible challenges or shortcomings of the app
   - How might cultural, economic, environmental, ethical, political, or social factors impact the use and success of your app?

5 Diagrams or drawings of what the app would look like when it is being used

6 Appropriate citation of resources you used to develop your app

! Note: If you would like to try and actually build your app, you could search online or on **youtube.com** for **how to build an app for free**.

! Share your app with your class – what are some other ideas for apps that your classmates have come up with?

! Then, discuss with your class how the members of your school community may be able to benefit from the idea of your app, even if you cannot actually build it. For example, are there any 'shopping guidelines' that you may have included in your app that you can share with people to help raise awareness of the products they might avoid or opt for in order to support positive environmental change?

◆ Assessment opportunities

◆ This activity can be assessed using Criterion A: Knowing and understanding, and Criterion D: Reflecting on the impacts of science.

Links to: Design

In design, you also look at how technology can be used to address problems and needs.

Reflection

In this chapter, we have **described** what makes a healthy environment and how human actions can impact the balance and health of different ecosystems. We have **analysed** data to get a better understanding of the changes that are occurring. In addition, we have **reflected** on and **discussed** how different factors and values can impact our approach to conservation. Finally, we used our understanding of the consequences of human actions on the environment to **create solutions** for some current environmental problems.

Use this table to reflect on your own learning in this chapter.

Questions we asked	**Answers we found**	**Any further questions now?**
Factual: What different values and viewpoints on the environment do people have? What are the characteristics of a healthy environment? How does the environment change? How do humans develop and manage natural resources?		
Conceptual: What determines how humans develop and manage natural resources? How can managing and developing natural resources change the environment? How can different values and viewpoints on the environment influence how it changes?		
Debatable: To what extent do people have the 'right' to use natural resources? To what extent should all people have the same responsibility to care for the environment?		

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**
Communication skills					
Reflection skills					
Critical-thinking skills					
Creative-thinking skills					

Learner profile attribute(s)	Reflect on the importance of being principled for your learning in this chapter.
Principled	

3 What should I eat?

Because what we consume is **related** to, and has **consequences** on how our bodies **function** and feel, we can choose what we eat and drink based on **scientific principles and developments**.

Figure 3.1 What does it mean if 'you are what you eat'?

CONSIDER THESE QUESTIONS:

Factual: What molecules do organism need to function? How much or how little do we need of each nutrient? What processes are necessary for organisms to function? How do organisms have energy for life functions?

Conceptual: If you are what you eat, what are you? How has scientific understanding been applied to improve the performance of the human body?

Debatable: To what extent should people rely on industrially processed foods or supplements to establish or maintain good health?

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

IN THIS CHAPTER, WE WILL …

- **Find out** the basic components of a balanced and healthy diet.
- **Explore** the ways in which the science of nutrition is used to influence what people eat.
- **Take action** to design a healthy meal plan to meet specific food preferences and lifestyles.

These Approaches to Learning skills will be useful…

- Organization skills
- Information literacy skills
- Critical-thinking skills

We will reflect on this learner profile attribute…

- Balanced – we will learn how to be balanced with our choices of what we eat and drink in our daily lives.

Assessment opportunities in this chapter…

- **Criterion A**: Knowing and understanding
- **Criterion B**: Inquiring and designing
- **Criterion C**: Processing and evaluating

■ **Figure 3.2** People eat different foods for different reasons. Is there any way to decide what foods are 'best'?

ACTIVITY: Healthy restaurant

Imagine you are going to open a healthy restaurant filled with all of your favourite healthy foods. What would you include in your menu? Some traditional meals from a country you have lived in or visited? Or maybe some unique dishes you have had only in your home? Create a colourful menu of a few beverage and food options, with a brief description of each item. Find and include pictures from an online image search. Try to make your menu look as appealing as possible. Show your menu to the class. Who would like to eat at your restaurant? In what ways are your classmates' menus similar? In what ways are they different?

DISCUSS

What do you think about the expression 'You are what you eat'? In what ways do you think the expression is true? In what ways do you think it is not true?

'You are what you eat' is a popular expression in English. But what exactly does this expression mean? Of course, it does not literally mean that if you *eat* a hamburger you *are* a hamburger! But is there any truth behind this saying? In this chapter we will take a closer look at what happens to the food and drinks we consume, and at the relationship between what we eat and drink and how we feel and how our bodies work.

KEY WORDS

calories	diet	fats	nutrients
consume	energy	molecules	

If you are what you eat, what are you? What molecules do organisms need to function?

Food is an important part of life. Not only is it biologically necessary for survival, but it also has strong cultural, social and personal connections. When we are children, we eat what we are given or what we are told to eat but as we get older, and become more independent from our parents, choosing what to eat or drink on our own becomes an important decision. This is because everything that we consume has an impact on our health and how we feel not only today, but far into the future. We want to eat what tastes good to us, things that smell good and look good, things that we like – but, in order to be as healthy as possible, in order to have the highest levels of performance that we can, we need to put in the best possible 'fuel' for our bodies.

But, how do we know what is the best 'fuel'? We hear a lot about eating **protein**, **carbohydrates** and fats, but how much of each should we eat? Where can we look if we want to know what to eat and drink in order to have healthy skin, or build muscle, or conserve the environment, or become vegetarian or vegan? It turns out, there is not just one place to go for the answer, there are more than 37 trillion places to go – our body cells!

Figure 3.3 Food is more than just a biological need – it is related to our family, culture and lifestyle

VISIBLE THINKING – Zoom in

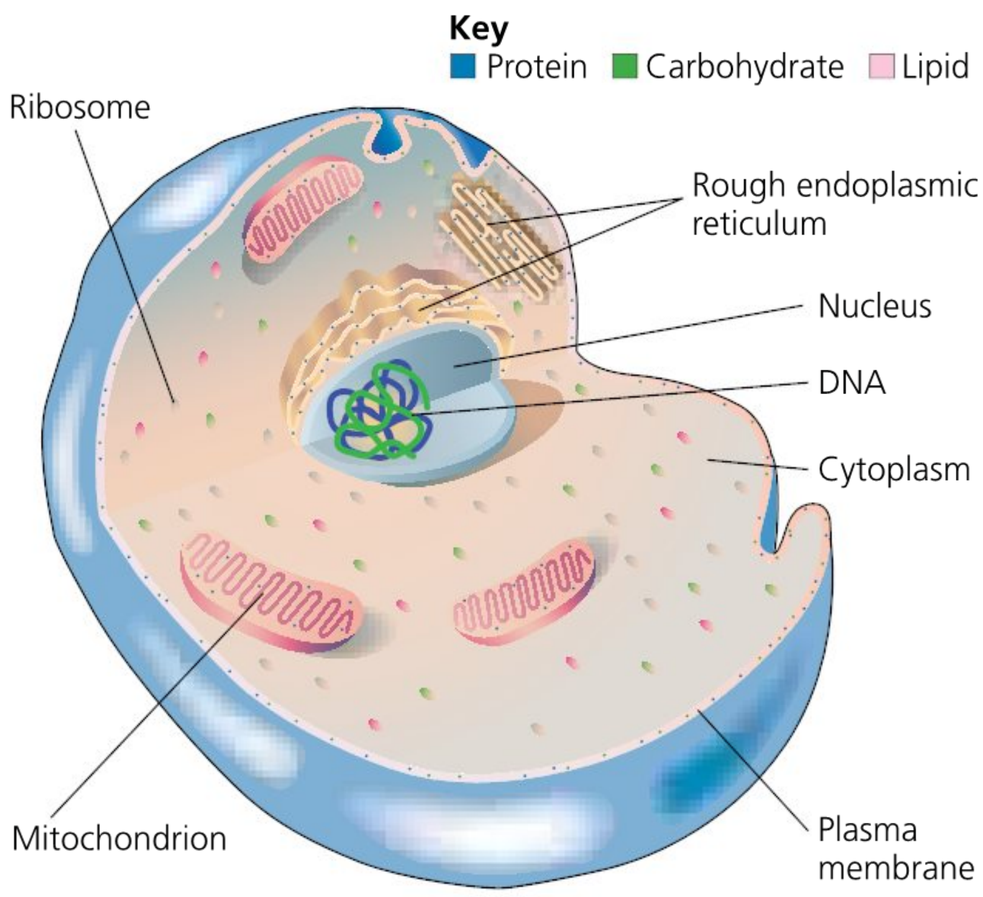


Figure 3.4 This 'zoomed in' look at a cell can help to determine what cells need to function

Look carefully at the illustration of a generalized human body cell. What cell structures are labelled?

Then, look at the 'zoomed in' illustrations. What molecules make up or are used by the different cell structures?

Cells work independently and in coordination with each other, forming functioning tissues, organs, systems and organisms. Therefore, if we want to know what we humans – as organisms – need to consume to function, be healthy and do all the things we like to do in our daily lives, all we have to do is 'zoom in' to our cells and see what *they* need in order to function and be healthy.

In the *Zoom in* visible thinking activity, you and your classmates probably noted that different cell structures, or organelles, are made up of or require substances in order to function. For example, ribosomes use substances called **amino acids** to make proteins. The plasma membrane and nuclear membrane are made up mostly of fats, but also include some proteins and carbohydrates. DNA is made up of sugars and proteins. Sugars that have been processed by the cell go into mitochondria and they produce energy. When we zoom in on the cytoplasm, we see the substances used

■ **Figure 3.5** Proteins, carbohydrates, fats and fibre are examples of macronutrients

and produced by the cell structures 'floating around'. So, we can understand that everything that cells need to live and function comes from inside the cells themselves, in the cytoplasm. But where do the cells get these substances in the first place?

The answer to this is, of course, from our food and drink. Everything that we eat and drink gets broken down into smaller molecules during the process of digestion (more on that later). These molecules then get distributed around our body to all of our cells, by blood and **lymph**. The molecules pass through the cell membranes and enter our cells by the process of **diffusion**. Once the molecules are inside each cell, cell structures utilize the molecules to carry out different cell functions and form different substances that keep the cell – and the whole body – alive.

The molecules that cells use to perform different functions and form different substances are called nutrients. There are many different types of nutrients that function in different ways. Some nutrients, like iron, iodine and vitamin A, are needed in relatively small quantities, and are called **micronutrients** (*micro* means small). Other nutrients are called **macronutrients** (*macro* means large) because they are needed in relatively large quantities for cells to carry out their functions. Some macronutrients are proteins, carbohydrates, fats and **fibre**.

Macronutrients are essential for our survival, because they are required for the most basic, life-sustaining functions or to produce the most basic, life-sustaining substances in the body. In order for our cells to be able to use macronutrients, the macronutrients must first be broken down into their smaller building blocks during digestion. For example, the carbohydrates we eat are broken down during digestion into **simple sugars** – in particular, **glucose** – which cells use to produce the form of chemical energy, **ATP**, that is required for every single **biochemical** process occurring in the body. The proteins that we eat are also broken down into smaller molecules, called amino acids, which cells recombine to make different types of proteins, such as **enzymes**, and use to build up muscles and other structures in the body. Fats from our diet are broken down into **fatty acids**, which are used for forming and repairing cell walls. Fats are also used for energy when glucose is not available or during endurance (long-lasting) activities.

How much or how little do we need of each nutrient?

Carbohydrates	Fats	Proteins	Fibre
Brown and white rice	Olive oil	Chicken	Broccoli
Wholegrain and white bread	Butter	Fish	Cabbage
Wholegrain and white pasta	Margarine	Red meat	Apples
Candy, cookies, cakes and other sweets	Avocado	Sandwich meats	Wholegrain bread and pasta
Fruits	Nuts	Tofu	Nuts
Root vegetables	Cheese	Lentils	
	Cream	Nuts	
	Fried foods		

Table 3.1 Examples of sources of macronutrients

The 'right' amounts of carbohydrates, proteins and fats to consume every day are related to the number of calories that our bodies need to have enough energy to perform life functions while maintaining a healthy body weight. You might be familiar with the word 'calories' or **kilocalories** (kcal) from reading nutritional labels on food packages. It is important to understand that calories are just a unit of energy, just as centimetres are a unit of length. Therefore, when we talk about calories in the food we eat, we are talking about the amount of energy the food supplies us with in order to do the 'work' necessary for survival.

Research shows that carbohydrates should make up 45–65% of the calories that we consume in a day. This is because carbohydrates can be easily broken down into glucose, the simple sugar that cells use to produce ATP. ATP is the form of energy required by every cell in the body to perform the metabolic reactions that keep us alive (more on how that happens in the next section). For example, energy from ATP is used to:

- transport certain molecules into and out of cells
- assemble proteins, DNA and other cellular products
- send impulses along nerve cells (see Chapter 6)
- move the cilia of cells lining the intestine so they can function in digestion, and the flagella of sperm cells so that fertilization can occur (Chapter 6).

Fats, also known as lipids, should make up 20–35% of our daily calories. This is so we have enough fatty acids to repair the membranes of damaged cells or construct membranes of new cells that are formed to replace dead cells. For example, our skin cells, which can get damaged and need to be replaced relatively often, need to have access to plenty of fatty acids for repair and construction. Furthermore, fats that make up neurons play an important role in how quickly messages can be sent throughout our nervous system. In addition, the fat that is stored in our cells is vital for protecting our internal organs, keeping us warm and providing us with a source of energy when the food we eat is not sufficient to meet our energy needs.

Proteins should make up 10–35% of our daily calories. Proteins, as you may recall, perform a wide variety of functions in our body, including structure and support for our cells and as carriers or channels to pass important molecules into and out of cells. Proteins are also necessary in the production, growth and repair of body cells and tissues. Enzymes, a specific type of protein, are needed to speed up chemical reactions in our cells, so that they can happen quickly enough to keep us alive. Proteins are made up of different amino acids. There are 21 amino acids. Nine of these, called the **essential amino acids**, are available to our cells only through the foods we eat. The other 12 amino acids can be produced by our body cells. Ribosomes put together different combinations of these 21 amino acids to form all the different proteins that our body needs.

Another important macronutrient is **fibre**. Fibre is a type of carbohydrate, and it should make up 20–25% of the carbohydrates that we eat. Because we cannot digest fibre completely, it acts as a 'scrub brush' in our intestines to help move along the feces formed during digestion so they can be eliminated from the body. In addition, fibre helps us feel more full when we eat, which can help avoid overeating.

ACTIVITY: Breaking it down

ATL

- Organization skills: Use appropriate strategies for organizing complex information

Copy this table into your notebook or computer. Use it to help you organize what you have learned so far about these macronutrients. If you are doing this on a computer, you could add some photos or pictures that you find online.

Macronutrient	Building blocks	Function(s) in the body	Food sources
Carbohydrates	Simple sugars		
Proteins			
Fats			
Fibre			

Assessment opportunities

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

DISCUSS

For each of the nutrients below, what would the consequences be if we did not consume enough of each one? How would we feel? How would a lack of these nutrients affect our daily activities?

- **Carbohydrates**
- **Fats**
- **Proteins (and amino acids)**
- **Fibre**

CARBOHYDRATES

When planning what to eat, in order to have the suggested balance of macronutrients, it is important to know that not all kinds of carbohydrates, fats, proteins and fibre are the same. Our cells are able to process some sources of macronutrients better than others. In other words, some sources of macronutrients are of a higher quality than other sources. For example, brown rice, an example of a **complex carbohydrate**, is a higher quality source of carbohydrates than candy, a simple sugar. This is because it takes the body longer to break down the complex carbohydrates into glucose, which means the cells will be able to produce ATP at a slower but more steady rate. Contrast this to the energy that comes from eating candy or other sugary foods: simple sugars are quickly broken down into glucose, so the cells produce a large amount of energy quickly, leaving us feeling tired and un-energized afterwards.

■ **Figure 3.6** Some examples of foods containing unsaturated fats, saturated fats and trans fats

■ **Figure 3.7** High levels of LDL cholesterol can cause fatty plaques to build up in arteries, leading to narrowing and blockages in blood vessels

FATS

There is also a difference in the quality of fats that we eat. Some fats – like the oils from olives, avocados, nuts and salmon – are examples of **unsaturated fats**. These are often referred to as 'good fats' and are usually a liquid at room temperature. Doctors recommend that 90% or more of your daily intake of fats should come from unsaturated fats.

Saturated fats, on the other hand, are found in foods like butter, beef, the dark meat of chicken, bacon, and processed meats like salami. These fats are solid at room temperature. Saturated fats are often described as 'bad fats', and doctors recommend that they make up 10% or less of what you eat.

Another type of fat, called **trans fat**, is often used to fry fast foods like chips, and to make commercially processed foods like cookies, cakes, or microwaved popcorn. Trans fats are found only in tiny amounts naturally in some meat and dairy products – most are formed artificially through a chemical process that converts unsaturated liquid fats to saturated solid fats. When added to foods, trans fats give baked goods a soft and appealing texture and provide a cheap alternative to frying oil that has a longer shelf life than natural frying oils. However, despite these appealing characteristics of trans fats, they are potentially harmful to your health, and doctors recommend that you avoid them completely.

But why are unsaturated fats 'good', while saturated fats and trans fats are 'bad'? First, it would be better to think of unsaturated fats as 'potentially beneficial' to your health, while saturated and trans fats are 'potentially harmful'. Also, unlike trans fats, both unsaturated and saturated fats can contribute to a healthy diet when we consume them in proportions that are appropriate to our activity levels and energy requirements.

Saturated and trans fats raise the level of another type of fat, called low-density lipoprotein cholesterol (or LDL cholesterol), in our blood. LDL cholesterol, which comes from our cells as well as from the foods we eat, is necessary in the body because it is part of cell membranes. However, this type of cholesterol can also bind to fats and build up in the blood, causing narrowing and blockages in **blood vessels** (Figure 3.7). If this occurs in the **artery** that carries blood from the heart to the rest of your body, it reduces the blood flow throughout the body, and it can lead to heart attacks or strokes.

Unsaturated fats, however, can raise the level of **high-density lipoprotein cholesterol** (or HDL cholesterol) in our blood. HDL cholesterol, which is also produced naturally by our cells, functions by picking up and transporting 'previously used' LDL cholesterol molecules so they don't build up in the blood vessels. HDL cholesterol delivers the LDL cholesterol molecules to the liver, where they can be 'recycled' and sent back into the bloodstream to do their job of repairing and forming cell membranes. When HDL cholesterol is plentiful, it is able to prevent the build-up of LDL cholesterol in the blood vessels, maintain a strong blood flow, and reduce the chances of heart attacks and strokes.

ACTIVITY: That's fat!

ATL

- Critical-thinking skills: Use models and simulations to explore complex systems and issues

The different characteristics of saturated, unsaturated and trans fats are due to the molecular structure of each. In this activity, we will observe, compare and contrast their molecular characteristics.

For this activity, you will need several pieces of paper to help visualize the effects of the different molecular structures. Use waste paper – it doesn't have to be blank, but it must be flat.

Before you begin, make a chart with three columns, labelled 'Saturated fats', 'Unsaturated fats' and 'Trans fats'. You will fill the columns with information about each type of fat, in order to compare the characteristics of each. You could also include photos or sketches of the different stages of the models.

First, carefully observe the diagrams showing the molecular structures of the three types of fatty acids in Figure 3.8. (Remember, what is the relationship between fatty acids and fats?) What are some things that you notice about the atoms, bonds and physical structure of each molecule? In what ways are the molecules similar? In what ways are they different? Organize your observations in your chart.

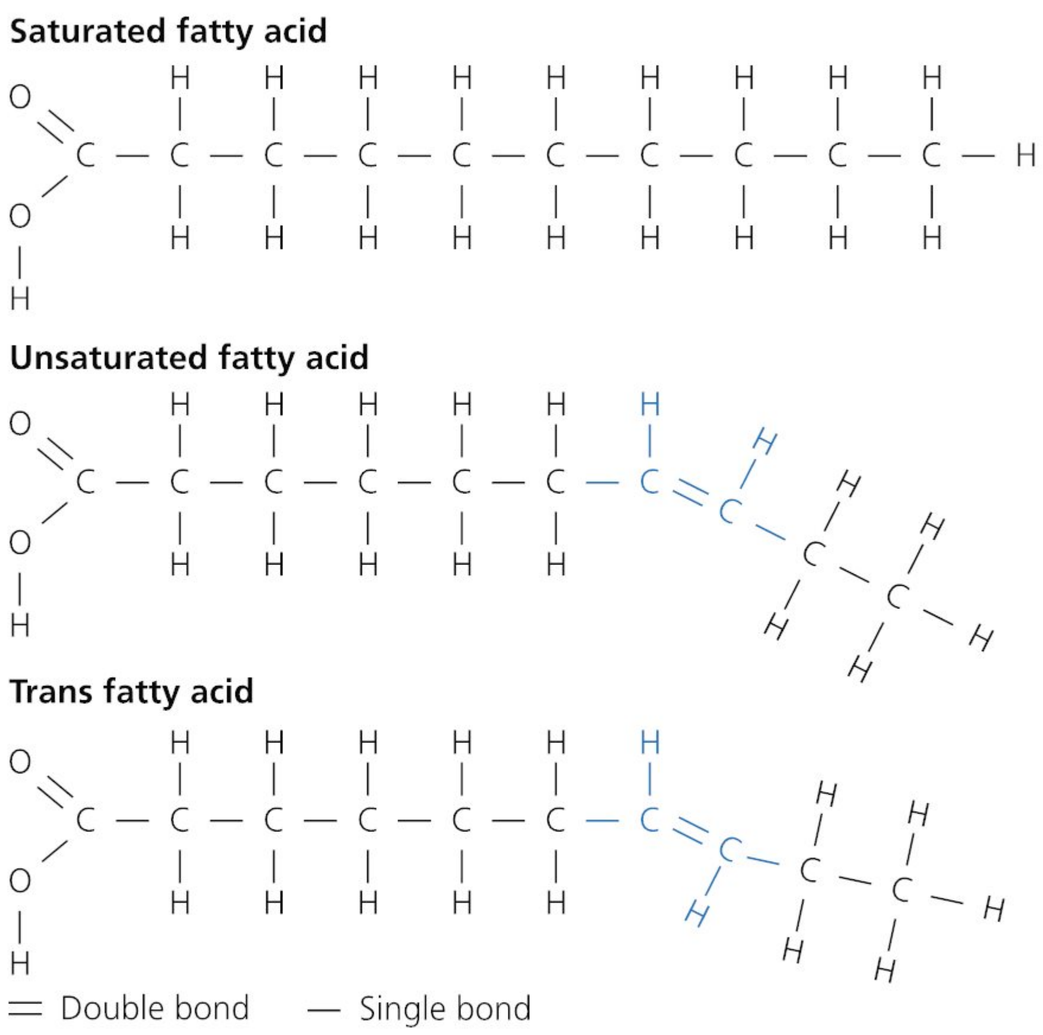


Figure 3.8 Diagrams to show the difference in molecular structure between types of fats

You could use a periodic table to identify the atoms that make up each type of fat. You could then tally the number of each atom per fatty acid.

Now look at your pieces of paper – these represent the fatty acids that make up the fats in food. Hold up one piece of flat paper and compare it to the diagrams of the fatty acid molecules. Does this flat piece of paper represent a saturated, unsaturated, or trans fatty acid? Add a note about this in the appropriate column of your comparison chart. Now, take all of the flat pieces of paper and stack them on top of each other. This represents the way that molecules of this type of fatty acid bind together when they are in food. How does this model of fatty acids explain the state (solid or liquid) of this type of fat at room temperature?

Next, take one of the pieces of paper and crumple it up a bit. Does this crumpled piece of paper represent a saturated, unsaturated, or trans fatty acid? Add a note to your comparison chart. Now, crumple up the rest of the pieces of paper and stack them on top of each other. How does this model of fatty acids explain the state (solid or liquid) of this type of fat at room temperature?

Finally, take one of the crumpled pieces of paper and flatten it out. Does this flattened piece of paper represent a saturated, unsaturated, or trans fatty acid? Add a note to your comparison chart. How does it compare to the original flat paper? Now, flatten out the rest of the crumpled pieces of paper and stack them on top of each other. This represents the way that molecules of this type of fatty acid bind together when they are in food. How does this model of fatty acids explain the state (solid or liquid) of this type of fat at room temperature?

Compare your comparison chart with those of your classmates – did anyone make any observations that you could add to your chart?

Assessment opportunities

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

Food sample	Protein (% by mass)	Essential amino acid content (mg per g of protein)									
		Tryptophan	Threonine	Valine	Methionine	Isoleucine	Leucine	Phenylalanine	Histidine	Lysine	Total
Rice	6.51	8	34	57	32	35	77	53	23	36	354
Wheat flour	10.6	12	28	42	21	29	65	45	22	26	290
Lentils	27.7	9	37	49	5	38	73	52	23	76	362
Pangasius	15.9	15	43	48	35	39	72	39	20	79	390
Rohu	20.6	15	42	48	31	37	70	40	26	77	386
Tilapia	20.8	14	43	45	32	37	72	39	23	77	383
Chicken breast	22.3	13	44	52	36	44	75	38	36	72	411
Chicken legs	19.2	12	43	51	34	42	77	39	27	73	399
Eggs	14.5	15	31	63	31	63	72	85	14	43	417
Milk	3.08	11	40	61	22	42	87	44	25	73	406

■ **Table 3.2** Essential amino acid content of some foods (pangasius, rohu and tilapia are types of fish)

PROTEINS

Just as there are different types of carbohydrates and different kinds of fats, there are also different kinds of proteins. In fact, there are many different proteins, each one defined by the combination of amino acids of which it is made.

It is important to know that not all foods we eat contain the same essential amino acids. (Take a moment to review what essential amino acids are compared to non-essential amino acids.) Take a look at Table 3.2 to see some of the differences between different foods.

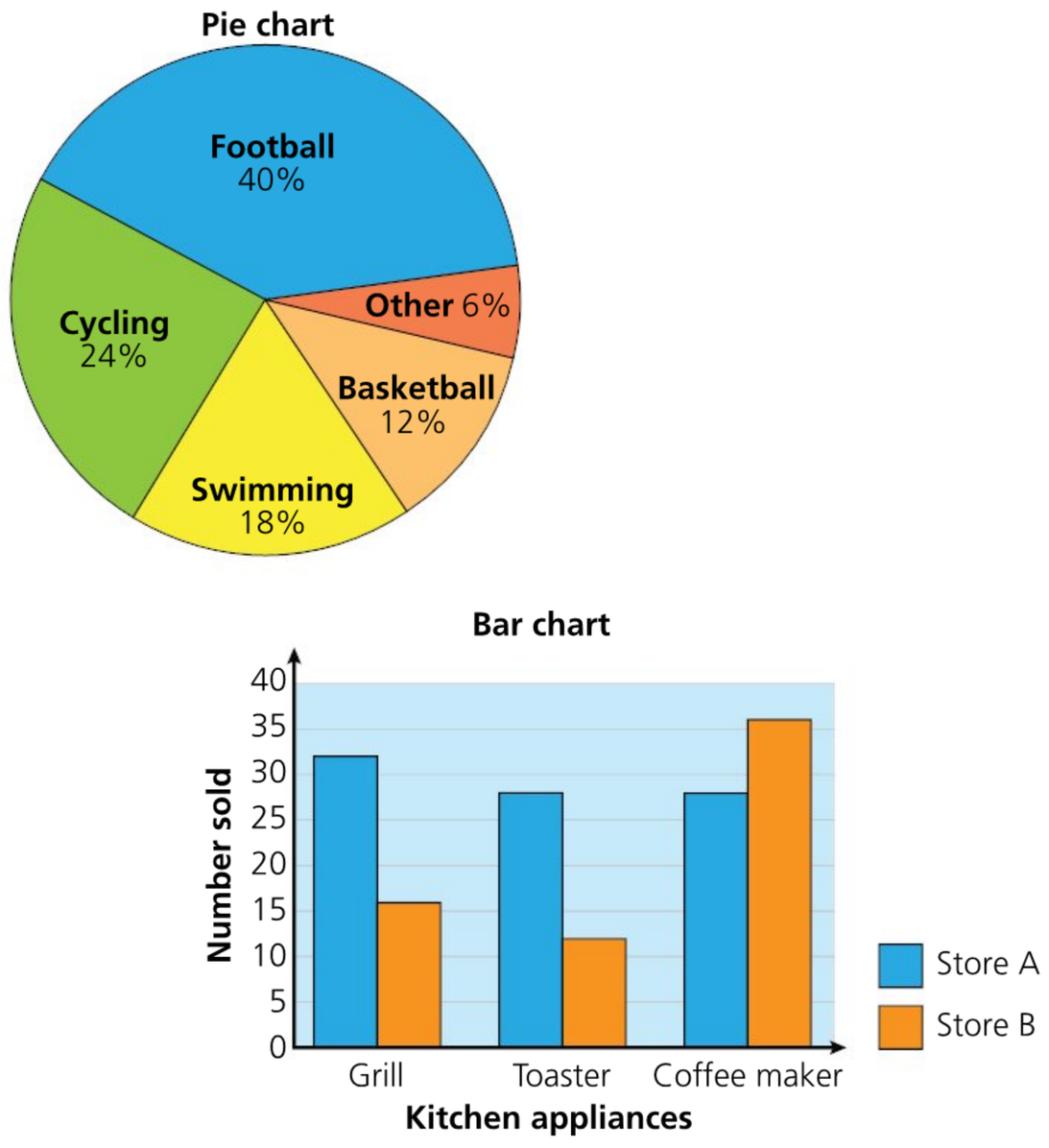
VISIBLE THINKING: What makes you say that?

In addition to considering the types of proteins, carbohydrates and fats we eat, we must also think about the number of calories – the amount of energy – that the food contains. Some foods, in particular vegetables like broccoli, lettuce and cauliflower, contain a lot of fibre, but are very low in calories. In other words, vegetables like these are a low energy 'fuel' for our body.

What are the benefits and limitations of eating high fibre, low calorie foods? When might be a good time to eat foods like these? When would it be better to choose another type of food? What makes you say that?

EXTENSION

Which foods are healthy sources of carbohydrates, fats, proteins and fibre? In your search bar, type **healthy sources of** and then the kind of macronutrient you are searching for. What are some good options for a healthy and balanced diet?



■ **Figure 3.9** Types of graphs and charts

ACTIVITY: Making numbers into a visual

ATL

- Information literacy skills: Process data and report results

Tables, like Table 3.2 above, are useful to organize information, which can then be analysed to identify patterns and form conclusions. When a table contains quantitative (numerical) data, it can be transformed to create a visual representation. A visual representation, such as a graph or chart, is helpful to get a quick understanding of the patterns and possible conclusions.

For this activity, you will create a visual representation of the essential amino acids contained in three to five foods of your choice. It is important that you graph single foods, not combined foods. For example, if you wanted to find out the essential amino acids in pizza, you could research the essential amino acids found in cheese, dough (or maybe just white flour or bread), tomatoes and one other ingredient that you like on your pizza, such as chicken or mushrooms. You would then graph and compare the amino acids in each of these foods.

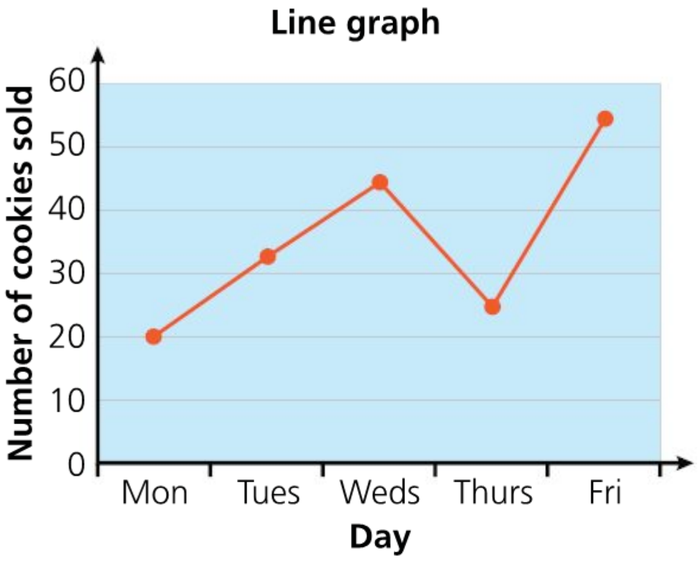
Research online to find the essential amino acid content of each of the foods you have chosen. Graph your results using a spreadsheet program such as Excel or Google Sheets. Using Figure 3.9 to help you, choose two or three different types of visual representations that are appropriate for the data that you have. Paste your visual representations into a slideshow.

Make a brief conclusion about the amino acids in the foods you have graphed. What does this tell you about which food(s) you should eat to ensure you have all nine of the essential amino acids? Present your conclusions along with your slideshow to the class.

Assessment opportunities

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

Line graph

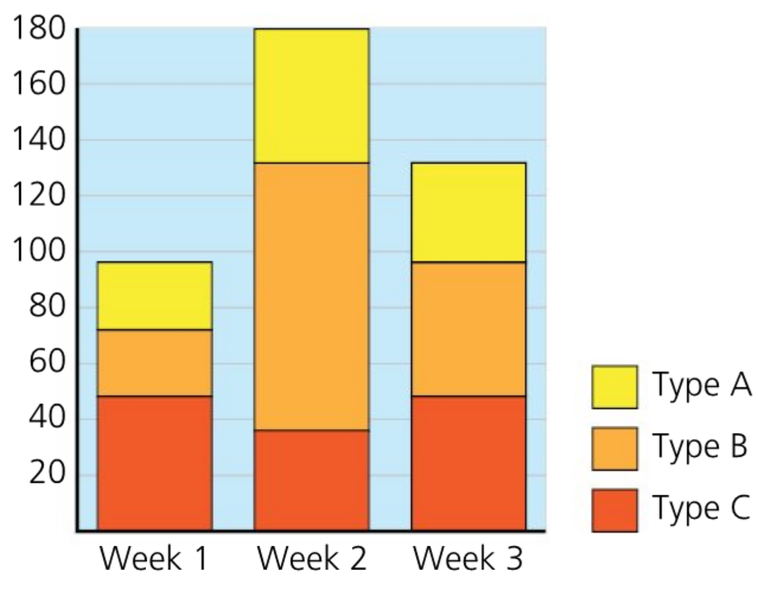


Pictograph

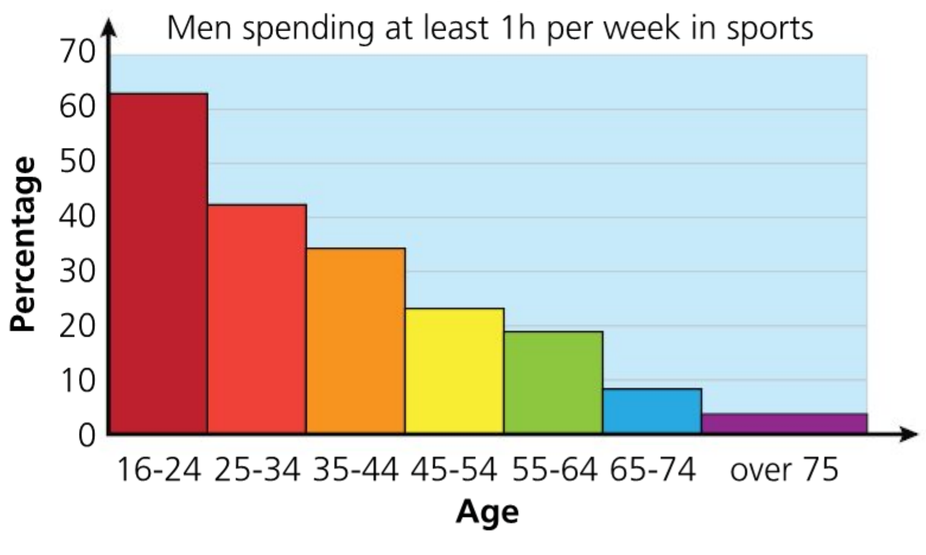
Blood type	Number of people
Type A	6
Type B	5
Type AB	2
Type O	7

= 5 people

Stacked bar chart



Histogram



Percentage bar chart

ACTIVITY: Protein combining: myth or fact?

ATL

- Critical-thinking skills: Consider ideas from multiple perspectives

In this activity, you will learn more about the idea of protein combining and decide, based on what you have read and your understanding of amino acids, to what extent protein combining is a practice that people who have a plant-based diet, like vegetarians or vegans, should follow in order to ensure they consume sufficient essential amino acids.

To do this, search for **protein combining** and **protein combining myth**. Choose two or three reliable sources of information that support the practice of food combining, and two or three reliable sources that claim protein combining is a myth. You will then support your position for or against food combining, citing scientific evidence from your research and from what you have learned in this chapter. You can decide with your teacher in which way you will present and support your position – perhaps through a class conversation or debate, or perhaps in a written form.

Assessment opportunities

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

It is important to note that there are many unreliable sources of information on the internet relating to food, diet, health and eating. Many people use blogs to post their personal experiences or opinions about nutrition without referencing or applying documented scientific evidence to support their views. It is important that you avoid getting information or making decisions based on what may be just one person's beliefs. Therefore, you should be cautious of websites that have the .com or .net suffix, and you should completely avoid online question-and-answer forums, like ask.com

Instead, look for information that comes from:

- **governmental institutions**, like the Food and Drug Administration in the United States or the Medicines and Healthcare Products Regulatory Agency in the UK. These governmental agencies have web addresses that end in .gov or the country suffix (like .ca for Canada or .jp for Japan)
- **educational institutions**, like universities, whose websites often have the .edu or .ac suffix
- **intergovernmental institutions**, like the World Health Organization, whose websites often have the .int suffix.

Be sure to document your sources of information – this is not only an important aspect of maintaining academic honesty, it will also help support your claim.

As scientists and dieticians have learned more about food at a molecular level, more and more people have tried to apply this scientific knowledge and understanding to design diets specialized for their lifestyles, in order to be as healthy as possible.

One of these approaches to food choice stems from an understanding of amino acids in our food and how they are used by our cells. Because scientists have identified the essential amino acids, and the foods in which they are contained, people can ensure that they consume all of the essential amino acids in appropriate amounts. This has been particularly relevant for vegetarians and vegans because, unlike animal sources of protein, plant sources of protein may not contain all of the essential amino acids.

Figure 3.10 Do we have to combine foods in a certain way to be healthy?

What processes are necessary for organisms to function?

BREAK IT DOWN

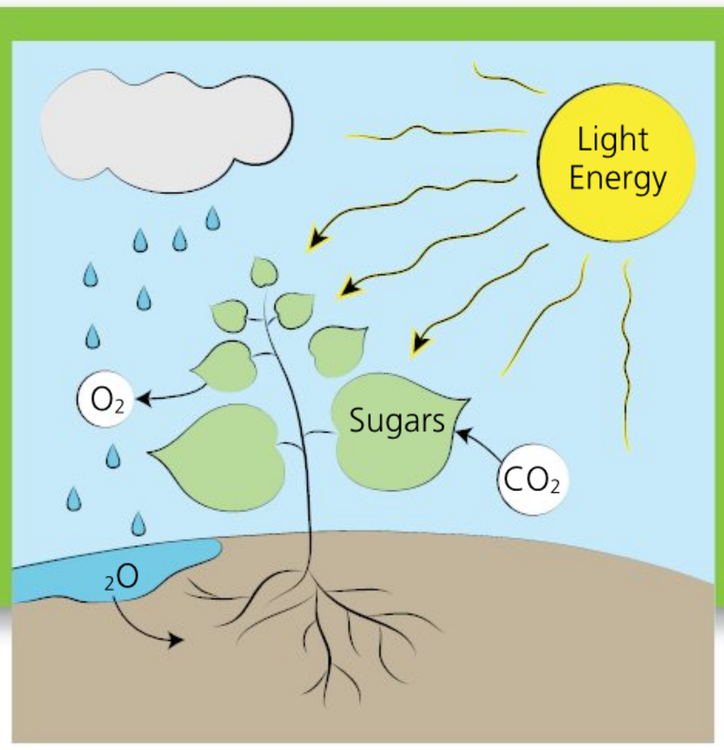
Energy is the most important requirement for life. Without energy, nothing could function in our bodies. All of the other things we need to survive, like oxygen, water and food, are necessary *because* we use them to produce energy. But how does that work? How do we turn oxygen, water and food into energy?

To understand, we have to start at the original source of energy for almost everything on Earth: the Sun. The Sun produces huge amounts of energy through nuclear fusion reactions of hydrogen atoms. A majority of this energy dissipates in space. Nonetheless, at any moment, approximately 1.74×10^{17} watts of energy from the Sun reaches the Earth. That is the equivalent of the energy that comes from turning on approximately 2.9×10^{15} light bulbs at the same time. (If you have a hard time picturing that, write out 29 and then follow it with 14 zeros – that's how many light bulbs you would need!)

This is a huge amount of energy, but of course we cannot use it directly in our own bodies – our cells have not evolved to be able to use solar energy. Instead, our cells require chemical energy, in the form of glucose, to produce another type of chemical energy, called ATP, that we *can* use to perform all of our basic cellular and bodily functions. For that reason, we depend on plants, which are **autotrophs**, to take the solar energy from the sunlight and transform it into glucose. (*Auto* means the organism 'does it on its own', while *troph* refers to feeding.) Not all of the energy of sunlight gets transformed into the glucose that plants produce, but there is enough to be the source of chemical energy that humans – and other **heterotrophs** – need to survive. (*Hetero* means 'different' – the organism gets food from a different source to itself.)

You can think of these different forms of energy like different currencies of money. For animals, the energy coming to the Earth from the Sun is like being given 40 000 Brazilian reais in cash to try and buy things in a small German village. Forty thousand Brazilian reais is a large amount of money, but you can't use it because in Germany they can't accept reais – they use Euros. So, in order to be able to buy anything, you have to go to a bank to exchange your reais into the form of money that you *can* use – Euros. Some money is lost in the exchange, because the bank keeps some as part of a fee, but you are left with enough money to buy the things you need to live for a while.

Figure 3.11 (a) Autotrophs make the glucose they need for energy themselves, using sunlight; (b) heterotrophs need to consume glucose from other sources



■ **Figure 3.13** In photosynthesis, solar energy is converted into chemical energy

The process of transforming solar energy into chemical energy in the cells of autotrophs (most commonly, plants) is called photosynthesis. As you may recall, photosynthesis is a series of chemical reactions that occur in the chloroplasts of plant cells. During this process, carbon dioxide (CO) and water (H O) chemically interact to produce glucose (C_{6} $_{12}O_{6}$) and oxygen (O_2).

Plants, and other autotrophs, are able to perform photosynthesis because they have specialized organelles called **chloroplasts** (*chloro*, from the Greek root, means 'green', and *plast* refers to organelles). The chloroplasts contain a green pigment called **chlorophyll**. This specialized, coloured protein is able to set off a cascade, or chain, of reactions that transfers energy through the membrane of the chloroplast. This transfer of energy allows for a variety of chemical reactions that ultimately result in the formation of glucose.

As with all chemical reactions, in the formation of glucose, bonds between atoms are broken and re-formed. Energy is required both to break and make the bonds. In photosynthesis, the energy needed to break the bonds holding together the carbon and oxygen of the carbon dioxide (CO_2) and the hydrogen and oxygen of water (H_2O), and the energy needed to form the bonds between the carbon, hydrogen and oxygen of the glucose ($C_6H_{12}O_6$) and oxygen molecules (O), originated in the Sun. One way to think of it is that part of the solar energy that came from the Sun becomes 'stored' in the bonds of the molecules of glucose.

SEE–THINK–WONDER

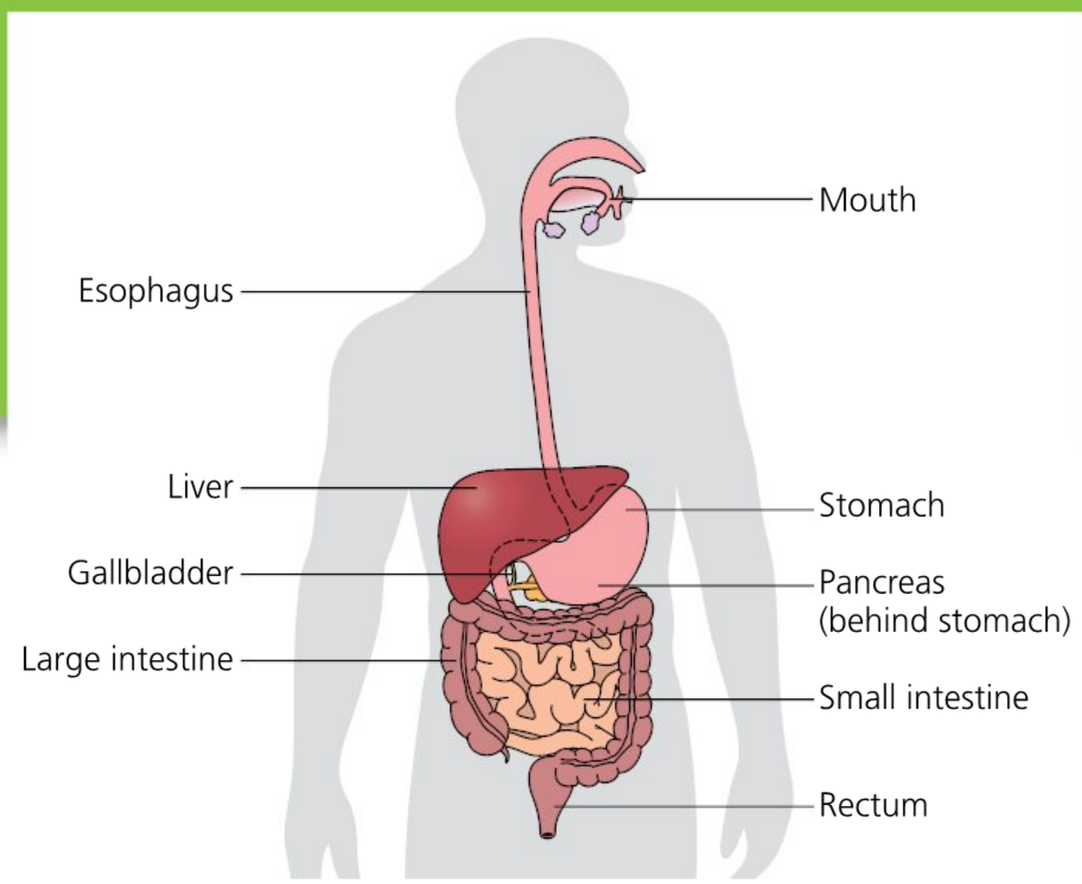
Look carefully at Figure 3.13. What do you **see**, **think** and **wonder** about the process of photosynthesis? Write down or discuss your observations, thoughts and questions. Can you use your observations or thoughts to help answer others' questions? Can their observations and thoughts help with yours?

So, when the bonds within the glucose molecules are broken, the energy that originated in the Sun is released.

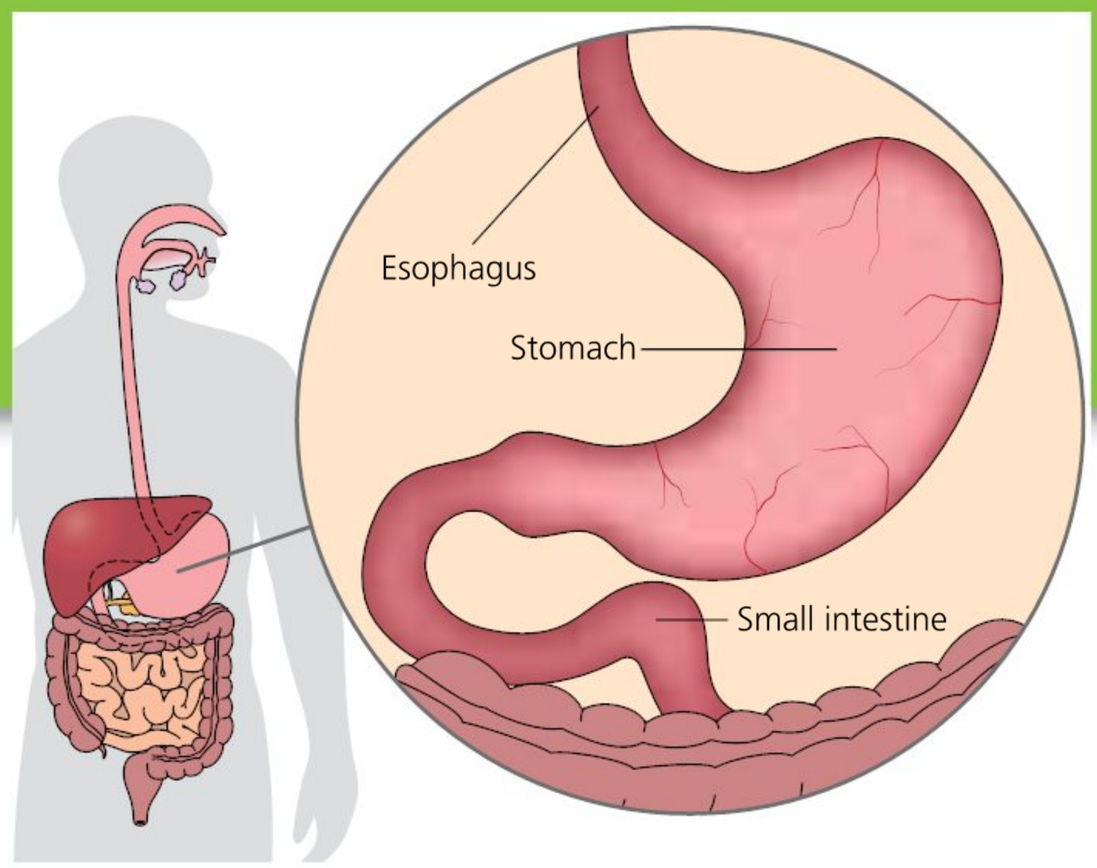
We know that our cells need glucose in order to produce the form of energy, ATP, that is used to power the various metabolic reactions and interactions occurring throughout the body. And we know we need other nutrients to perform the different actions that keep us alive. But how do our cells get glucose and other nutrients from the food we eat? It happens through the process of **digestion**

The process of transforming all that we eat into nutrients begins even before we eat. What happens when you see or smell or even think about food that you like to eat? In English, we say that your 'mouth begins to water'. In fact, the liquid that gets produced in your mouth in response to the presence or thought of food is actually **saliva**, which contains **enzymes** Remember that enzymes are specialized proteins produced within cells, which function to 'jump start' or speed up biochemical reactions. The enzymes that are found in saliva are known as **amylases**, and they are specialized to break down **starches**, a type of carbohydrate, in our food.

The action of the amylase enzymes in your mouth begins the process of **chemical digestion** of carbohydrate-containing foods you eat. The chewing action breaks up the food into smaller pieces, which is the start of the **physical digestion** process. These two actions of chemical digestion (when enzymes chemically break down the food into its constituent molecules) and physical digestion (when the food gets mashed up, mixed around and squeezed) will continue through the entire process of digestion and throughout the gastrointestinal (GI) tract.



■ **Figure 3.14** The gastrointestinal (GI) tract contains the organs involved in the process of digestion



■ **Figure 3.15** The stomach is a muscular bag that produces and contains a variety of acids and enzymes to continue the physical and chemical digestion processes

As you chew food, your tongue muscle helps to mash it up and mix it with your saliva. This helps to really mix the enzymes into the food, but it also helps get the food into a texture that is easy to swallow. Once you have chewed the food enough, the tongue muscle pushes the food – called a bolus – to the back of your mouth and into your **esophagus**. Muscles in your esophagus squeeze the food down into your stomach, where the next major step of digestion begins.

The stomach is like a muscle-covered bag filled with acid and enzymes. When the bolus enters the stomach, the stomach stretches, which stimulates some of the stomach cells to produce more acid, a combination of hydrochloric and other acids collectively referred to as **gastric acid**. The stomach muscles churn the bolus with the gastric acid, producing a watery substance called chyme.

In addition to producing and containing gastric acid, the stomach produces and contains enzymes. For example, pepsin, an enzyme that breaks down proteins, is activated by the increased production of gastric acids that occurs when the stomach stretches. Therefore, while the digestion of carbohydrates began in the mouth, the digestion of proteins begins in the stomach.

Once the chyme has been sufficiently processed in the stomach, which takes between 2.5 and 4 hours, it moves into the **small intestine**. The small intestine, while small in diameter, is actually very long – about 7 m long in adults! It is like a thin, muscular tube that bends itself back and forth in the lower portion of your abdominal cavity. As the muscles of the small intestine squeeze the digesting food along, it is mixed with water, mucus and enzymes. This process breaks down the former food into the macronutrients and micronutrients that it was made of.

EXTENSION

When people have problems with their digestive system, it can impact every aspect of life. Whether they frequently feel nauseous, have diarrhea after eating dairy foods, or experience constipation, digestive problems can cause people to feel tired and weak, develop skin conditions, lose weight, or worse.

What are some of the common digestive disorders that exist today, and how can people manage them? Do an internet search for **common digestive disorders**. What did you learn about causes, symptoms and treatment? Share your findings with the class.

Secondary digestive organs play an important role in the digestive process that occurs in the small intestine. The pancreas produces some enzymes that continue to break down carbohydrates, some that continue to break down proteins, and some that begin the process of breaking down fats. Two other secondary digestive organs, the liver and gallbladder, produce a substance that works in the small intestine to break down fats.

In the last section of the small intestine, the nutrients and other substances from the digested food diffuse through the cells of the intestine wall and enter the

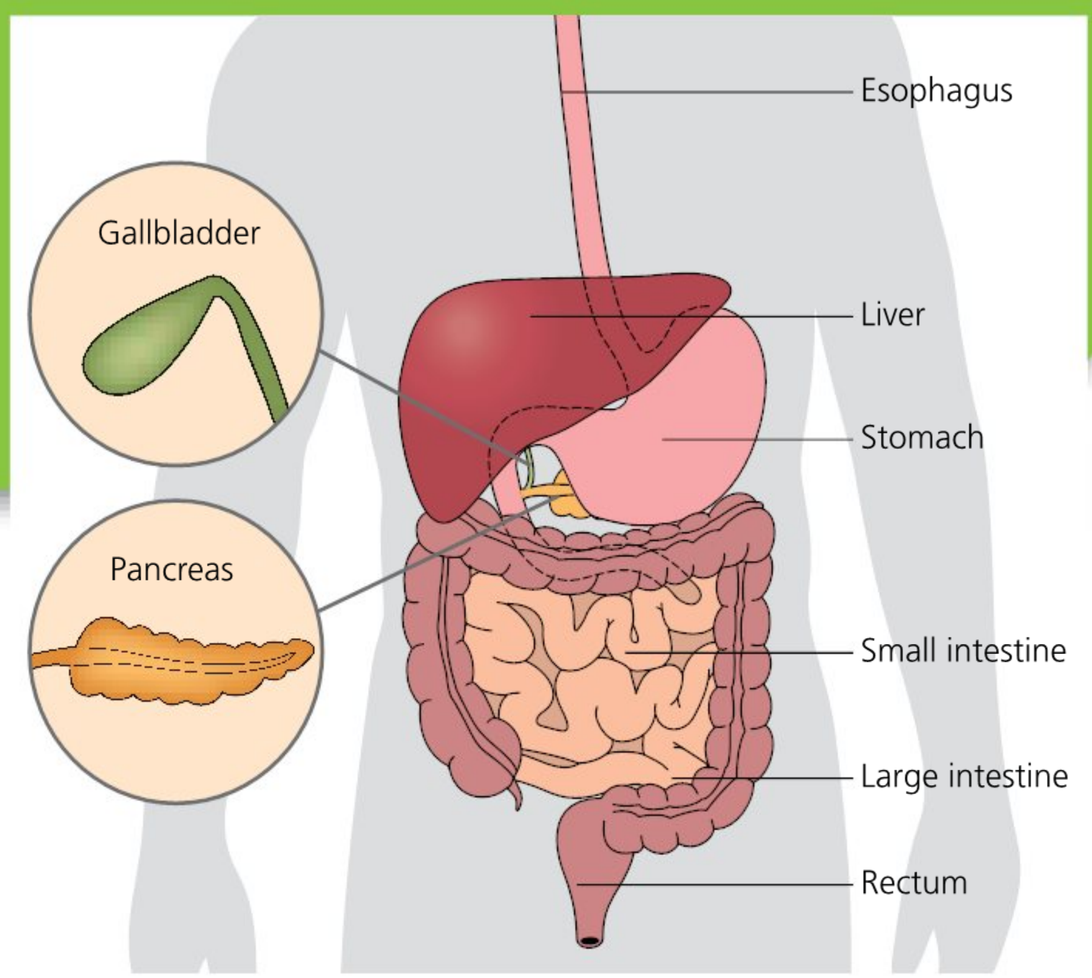


Figure 3.16 The liver, pancreas and gallbladder are secondary digestive organs because the digesting food does not pass through them – instead they produce enzymes and other substances that are used in the small intestine in chemical digestion

bloodstream in a process called absorption. Once in the bloodstream, enzymes produced by the liver break down toxic substances, such as the components of alcohol, cigarettes and drugs, to prevent those substances from entering the body cells.

From the bloodstream, the nutrients, including glucose, are distributed throughout the body so that they can diffuse into cells. When the nutrients enter the cells, the cells **assimilate** them. In other words, the cells incorporate and utilize the nutrients in their various biochemical reactions, such as cellular respiration (more on that below) and the formation of proteins.

But what happens to the parts of this mixture in the small intestine that are not absorbed? The unabsorbed portion, which contains water and indigestible components of food, passes into the large intestine. The job of the large intestine, which is much shorter but much wider than the small intestine, is to reabsorb the water so that it is not lost from the body when elimination of solid waste, or feces, occurs. If the food waste moves through the large intestine too quickly, or if the cells of the large intestine are not able to absorb sufficient water, diarrhea occurs, which may lead to dehydration if it is severe or frequent.

VISIBLE THINKING – What makes you say that?

Review what you have already learned about the enzymes that are used in digestion. Are digestive enzymes specific for certain macromolecules, or can they break down all of them? In other words, are certain enzymes only used to break down proteins, others used to break down carbohydrates, and others used to break down fats? What makes you say that?

DISCUSS

Considering the process of digestion, why does it make sense that carbohydrates are the first source of glucose for our cells?

The last section of the large intestine holds onto the feces, which mostly contain the indigestible components of food (like parts of some leafy green vegetables, or seeds) and bacteria, until they are ready to be eliminated from the body through the rectum and anus. This whole process usually takes between 30 and 40 hours after eating.

In addition to the enzymes that our body produces in order to chemically digest our food, there is another component present in huge quantities in our intestines, which is absolutely crucial for healthy digestion to occur – bacteria. Yes, our intestines contain a wide variety of beneficial bacteria with which we have a mutualistic relationship – they help us break down food that we could not otherwise digest, and they get an ideal habitat with plenty of food for them to live and reproduce. In addition, these beneficial bacteria, known as **probiotics**, also play an important role in supporting our immune system, because they tend to outnumber and outcompete any harmful bacteria that may have made it past the stomach. Fermented foods like sauerkraut, kimchi and yoghurt all contain probiotics, so including these types of foods in our diet can help us maintain a balance of beneficial bacteria. People may also take probiotic capsules if the balance of harmful to helpful bacteria has been disrupted due to illness, stress, or other factors.

ACTIVITY: Applying science to improve performance

ATL

- Organization skills: Use appropriate strategies for organizing complex information

We have learned about and inquired into different ways that people try to improve their health or performance by applying – or attempting to apply – scientific principles related to digestion and the biochemical reactions that occur in the body.

This information is important for your final assessment, in which you will suggest a meal plan based on the needs of your 'client'. In order to prepare, go back through your notes, activities and the chapter to respond to our conceptual question, 'How have scientific understanding and developments been applied to impact the function and performance of the human body?'

You may respond individually or with a partner, in a written or oral format.

Assessment opportunities

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

ACTIVITY: Raw food diet debate

ATL

- Critical-thinking skills: Test generalizations and conclusions

It has become increasingly popular to follow what is known as a 'raw food diet'. It is claimed that the enzymes found in raw foods, such as fruits, vegetables and sprouted grains, improve the process of digestion in our body, allowing us to better absorb and assimilate nutrients and eliminate wastes. Some people suggest that even if you are eating cooked foods, you should start each meal with raw vegetables in order to prepare the stomach and digestive processes with the enzymes from the raw foods. But do raw fruits, vegetables and sprouted grains really contain active enzymes?

For this experiment, you will need fresh pineapple and the seeds of a papaya (if available). Then choose some other fruits, vegetables or sprouts you are interested in testing. You should mash each one with a pestle and mortar to extract the juices, which you can then add to the food samples you will try to digest.

To identify whether the raw foods can digest proteins, carbohydrates or fats, you need a sample of food for each macromolecule. For example, to test for enzymes that digest protein, you could use prepared gelatin or cooked egg whites. To test for enzymes that digest carbohydrates, you could use cooked potatoes or pasta or a crumbled cracker softened with a little water. To test for enzymes that digest fats, you could use margarine or butter.

When designing your investigation, it is important that you think of what you will look for in order to determine whether there are enzymes in the raw fruits, vegetables or sprouts. Discuss this with your classmates and come to an agreement of what you will look for, so that you can all compare your results. In addition, it is very important that you include a control group for each food you test. **Discuss** with your class what the control groups will be and why they are so important in this experiment.

Some other things to consider are the extent to which you would like to model the conditions in the human digestive system, and how long you would like to keep the experiment running.

Because your experiment will probably only result in qualitative data, you won't be able to graph your results. However, you can still organize and **analyse** your qualitative observations and come to a conclusion. You will be able to evaluate your hypothesis and method, and suggest some appropriate extensions or variations to the method.

Assessment opportunities

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

How do organisms have energy for life functions?

LET'S MAKE SOME ENERGY

Now that we have learned about two processes that are necessary for our survival – photosynthesis and digestion – we will now learn about one more essential process. This process, called **cellular respiration**, is the last step in converting solar energy into a form of chemical energy that we can use for all of our cellular and bodily functions.

Cellular respiration begins where digestion leaves off. After glucose is absorbed into the bloodstream from the small intestine and assimilated into the body cells, the process of chemically transforming glucose into energy begins. The first set of chemical reactions, called **glycolysis**, occurs in the cytoplasm. During glycolysis, each molecule of glucose gets broken down into two smaller molecules, called pyruvate. Two molecules of **ATP** – the form of energy that our cells are able to use to perform all of their functions – are also produced during glycolysis. This is a very small amount of ATP, but is enough to perform some cellular functions for a limited amount of time. Because oxygen is not used during glycolysis, this step in cellular respiration is also called **anaerobic respiration** (*an* means 'without', and *aero* refers to oxygen).

In order to produce enough ATP to carry out all cellular functions, the pyruvate has to be broken down even further, which occurs in the mitochondria. The portion of cellular respiration that occurs in the mitochondria requires oxygen, and so is called **aerobic respiration** After the pyruvate diffuses through the mitochondria, several more chemical reactions and transformations occur. At several stages during these chemical reactions, small amounts of ATP are released, but the largest amount is not produced until the final step. It is the final step that requires oxygen, and it is the final step that has the largest 'pay off' of ATP, when 34–36 molecules are produced. Without oxygen, the final step of cellular respiration could not occur, and without the final step of cellular respiration, the cell would not have enough usable energy (ATP) to perform the other biochemical reactions that keep the cell alive. If this lack of oxygen occurs through all of the cells throughout the body, it means that none of the body systems will be able to carry out their functions, and the organism could not survive.

DISCUSS

Muscles require ATP for all of their movement. Therefore, your muscle cells must constantly produce large amounts of ATP in order for you to be able to move. Considering what you have just learned about how cells produce ATP, why does it make sense that we have to breathe more heavily when we are running or doing other physical activities?

In addition to producing ATP, cellular respiration also produces carbon dioxide and water. This is why when we exhale, we release CO . Below are the chemical equations for cellular respiration and photosynthesis. What do you notice about these two reactions? How do the chemical equations compare?

Photosynthesis:

$$\underset{\text{carbon dioxide}}{6CO_2} + \underset{\text{water}}{6H_2O} \xrightarrow{\text{chlorophyll, sunlight}} \underset{\text{glucose}}{C_{6\ 12}O_6} + \underset{\text{oxygen}}{6O_2}$$

Respiration:

$$\underset{\text{glucose}}{C_6H_{12}O_6} + \underset{\text{oxygen}}{6O_2} \longrightarrow \underset{\text{carbon dioxide}}{6CO_2} + \underset{\text{water}}{6H_2O}$$

The process of converting glucose into ATP, carbon dioxide and water occurs continuously and simultaneously throughout all cells in your body. Countless molecules of glucose are undergoing cellular respiration at every moment of every day in every cell of your body. That is because our bodies require a huge amount of energy to perform the basic processes we need to stay alive. When you add in the sports and other activities you do, your energy needs increase even more, and you have to be sure to consume enough food to keep your cells supplied with sufficient sources of glucose. If you don't have enough glucose from the carbohydrates you consume, your body starts to break down the stored energy sources in your body fat or muscle tissue in order to produce ATP.

However, it is important to realize that some people have a slower metabolic rate than others. People who have a slower **metabolism** require less energy in the form of food calories than people who have a faster metabolic rate. In addition, people who are less active have a lower metabolic rate, and require fewer food calories.

DISCUSS

Marathon runners need to plan their meals very carefully. They need to ensure that they have a good immediate source of energy when they start their race, and also enough 'fuel' to keep them going hours later.

Which of the following meals do you think would be the best choice for a marathon runner to eat before a run that lasts 3.5 hours or more?

- **a green salad with plenty of vegetables**
- **a peanut butter and honey sandwich on wholegrain bread**
- **a steak**

Use what you have learned from this chapter to support your answer.

EXTENSION

Athletes tend to have greater energy needs than non-athletes. In addition, many athletes want to increase their muscle size and strength to improve performance. As a result, some athletes, or people who are not athletes but are interested in gaining muscle mass, choose to use what are known as sports supplements.

Search for **sports supplements** in your search engine or on **youtube.com**. What do you find? When you have reviewed the information you find, **discuss** these questions with your partner:

- What macronutrients do these supplements emphasize?
- What do they claim that they will help achieve?
- What might be some potential benefits or concerns for people who take these supplements?
- To what extent are these supplements based on and supported by accepted scientific principles of nutrition?

DISCUSS

Now that we have explored a variety of aspects of what it means to have a healthy diet, let's take some time to discuss the debatable question for this unit: 'To what extent should people rely on industrially processed foods or supplements to establish or maintain good health?'

Use what you have learned from this chapter, as well as your personal research, in order to support your opinion.

Links to: Design

In Design, it is also important to understand the needs of the stakeholders. You need to understand the *perspective* and needs of your clients. In addition, you have to ensure that your design is able to perform the desired *function*. As a dietician you must consider both the perspective of your clients and the purpose or function of the meal plan you create.

Throughout this chapter we have learned about the different substances our bodies need and produce in order to survive. We have explored the processes that occur around and within us that support our survival. We have also researched different ways people have tried to apply scientific principles related to nutrition in order to meet their personal health and lifestyle needs. Now it is time for you to apply what you have learned in order to take the role of a dietician and design a food plan for one of your clients.

! Take action! Diet design

ATL

- Critical-thinking skills: Analyse complex concepts and projects into their constituent parts and synthesize them to create new understanding

! You are a dietician. Your job is to develop meal plans based on the food preferences and nutritional needs of your clients according to their activity levels, lifestyles and goals for health and fitness.

! To begin, you must choose a client. For example, you might find a classmate, teacher in your school, or family member who would like to start a vegetarian or vegan diet, train for a marathon, increase muscle mass and strength, or simply make their traditional diet more healthy and balanced.

! Using what you already know about the different types of nutrients we need and the different processes that occur in our body to keep us alive, in addition to some additional research about the specific dietary needs of your client, design a meal plan that your client can follow to meet his or her needs. Your plan should include all the meals, drinks and snacks for at least one day. In order for your client to understand why he or she should follow your food plan and hire you as their dietician, you must include scientific reasoning to support your recommendations.

! Decide on the best way to present your plan. Perhaps you would like to write out the plan, including diagrams and other visual aids to illustrate the most important points. Maybe it would be more effective for you to make a presentation. Or maybe you would like to make a video in which you could show your client how to cook the different meals you recommend. No matter what you choose, be sure that the scientific basis for your meal plan is clear, and you document your sources of information.

Key subject skills

In this activity, you have used scientific reasoning to help others make decisions. Scientists often have to communicate complex principles to people who are not familiar with them. Therefore, they need to choose clear and simple – yet factual – means of communication so that everyone can understand.

◆ Assessment opportunities

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

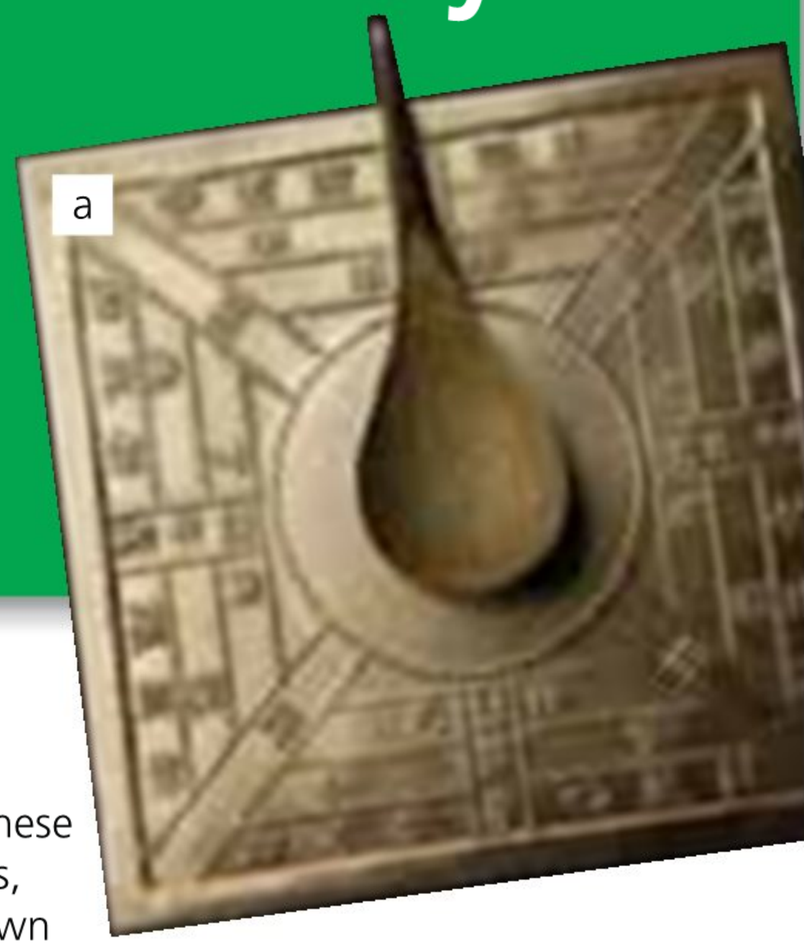
Reflection

In this chapter we have **applied** scientific reasoning to **support** our judgments about what to consume in order to be healthy. We have **designed** and carried out a complete investigation and **applied** our results to **form** a conclusion about the presence of enzymes in raw foods. We have **investigated** and **inquired** into different trends and products that claim to have health benefits for different lifestyles and food preferences. Finally, we have **applied** our knowledge and understanding about the nutrients the body needs and the processes the body goes through in order to **formulate** a meal plan for a balanced lifestyle.

Use this table to reflect on your own learning in this chapter.						
Questions we asked	**Answers we found**	**Any further questions now?**				
Factual: What molecules do organisms need to function? How much or how little do we need of each nutrient? What processes are necessary for organisms to function? How do organisms have energy for life functions?						
Conceptual: If you are what you eat, what are you? How has scientific understanding been applied to improve the performance of the human body?						
Debatable: To what extent should people rely on industrially processed foods or supplements to establish or maintain 'good health'?						
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**	
Organizational skills						
Information literacy skills						
Critical-thinking skills						
Learner profile attribute(s)	Reflect on the importance of a balanced approach for your learning in this chapter.					
Balanced						

4 How do we put electricity and magnetism to work?

Electrical and magnetic forces **fill space** as fields; understanding their **form** and **relationships** allows us to **transform** energy in useful ways.



■ **Figure 4.1** (a) An early Chinese compass, (b) amber attracts, (c) a spiral galaxy like our own

CONSIDER THESE QUESTIONS:

Factual: How do force fields affect matter? What causes magnetic force? What causes electric force? How do electrical circuits work?

Conceptual: How are electrical and magnetic fields related? How can electrical energy be harnessed?

Debatable: How does it help to be organized?

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

IN THIS CHAPTER, WE WILL …

- **Find out** how electrical and magnetic fields affect the space around them.
- **Explore** how to control electric current by configuring electric circuits and components.
- **Take action** to use knowledge and understanding of electrical circuits to help others have fun while learning.

These Approaches to Learning skills will be useful…

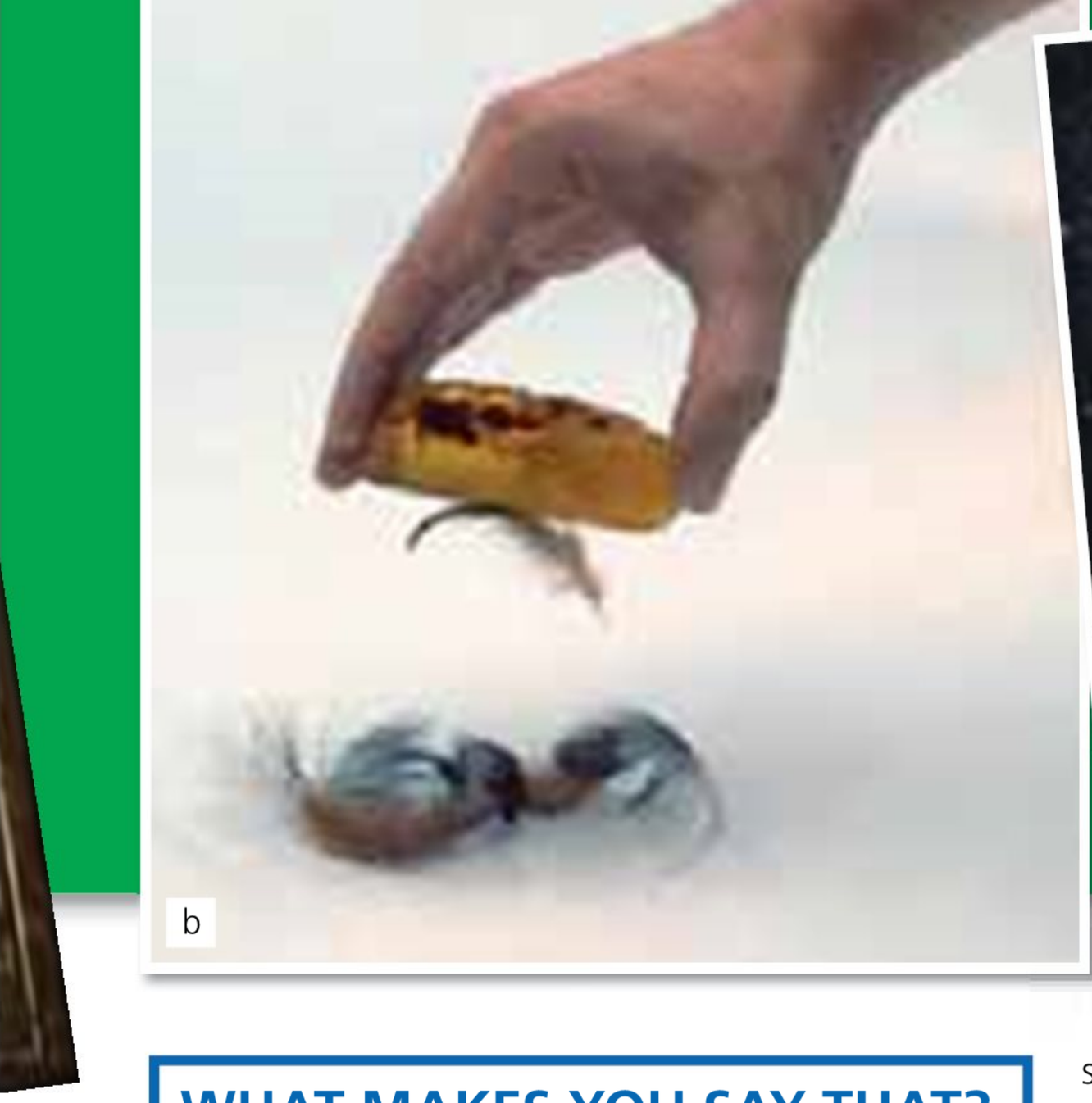
- Information literacy skills
- Creative-thinking skills
- Critical-thinking skills
- Transfer skills

We will reflect on this learner profile attribute…

- Thinkers – in this chapter we will use creative-thinking and critical-thinking skills to understand complicated systems, and transfer understanding by analogy.

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



WHAT MAKES YOU SAY THAT?

Look at the images in Figure 4.1. Think individually, then share with a partner.

What's going on in each image? What makes you say that?

The force of gravity is all around us all the time. We take it for granted, as part of the way things just are – objects fall. As we saw in *MYP Sciences by Concept 2*, Chapter 1, it was only in the sixteenth and seventeenth centuries CE that humanity began to develop an understanding that gravity is a force that acts on mass, rather than a feature of matter itself. Similarly, humans have for millennia observed other forces in action: lightning, or the strange attraction of particles to naturally occurring substances such as amber or the way that certain kinds of rock or bits of iron can be made to move all on their own. Humans attributed these phenomena to magical forces at work, something from 'outside' nature. The invention of science gave us the conceptual tools to **analyse** and understand that these strange observations were in fact the effects of other natural forces: electricity and magnetism. In this chapter we will explore the way that electrical and magnetic forces affect objects in the space they occupy, and how we can harness those forces to do work for us.

KEY WORDS

attract
component
harness
phenomenon (plural: phenomena)
repel

THINK–PUZZLE–EXPLORE

You have grown up in a technological society where electricity and magnetism are used everywhere. Perhaps you have wondered about how this is done, and about how this technology works? Before we begin, take a few moments to reflect individually.

What do you **think** you know about this topic? What questions or **puzzles** do you have? What does the topic make you want to **explore**?

Make a note of your ideas. Write any important questions you have on a note and stick them up in your classroom, or post them online in your class blend-space.

When you have finished your inquiry into this topic, use your questions to help you reflect on your learning.

How do force fields affect matter?

To sim or for real?

There are many very powerful online simulations (sims) available that allow us to try out experiments without actually using apparatus. This is a great way to learn, since you can try out experiments in a sim without needing a lot of unusual laboratory apparatus. On the other hand, there is nothing like the real thing – seeing it happen for real, with your own eyes, is what scientific experimentation is all about. (After all, the word 'experiment' derives from the Latin word for experience.)

Why not download some sim apps on your own cell phone, tablet or computer? Some suggestions are given in each section of this chapter.

How do pigeons find their way home? Migratory birds can travel for many thousands of kilometres and find the exact same roosting place that they use each year. How this can happen has been a mystery, but it is thought that migratory birds are able to sense the Earth's magnetic field. This gives them a sense of direction which, when combined with other information (such as air temperature or visible landforms such as rivers), allows them to find their way every year.

Figure 4.2 How do pigeons find their way home?

Magnetic fields are everywhere around us. The Earth's magnetic field is thought to be caused by the metals present in the Earth's core: as the Earth rotates, their motion generates a field which envelops the planet from the magnetic north pole to the magnetic south pole (Figure 4.3). Notice that the magnetic poles are not in the same place as the geographic North and South Poles – that is, the points where the Earth's axis passes through its surface, which are given the coordinates 90° north and 90° south respectively. If you happen to be standing on certain kinds of rock, the magnetic field will also be affected.

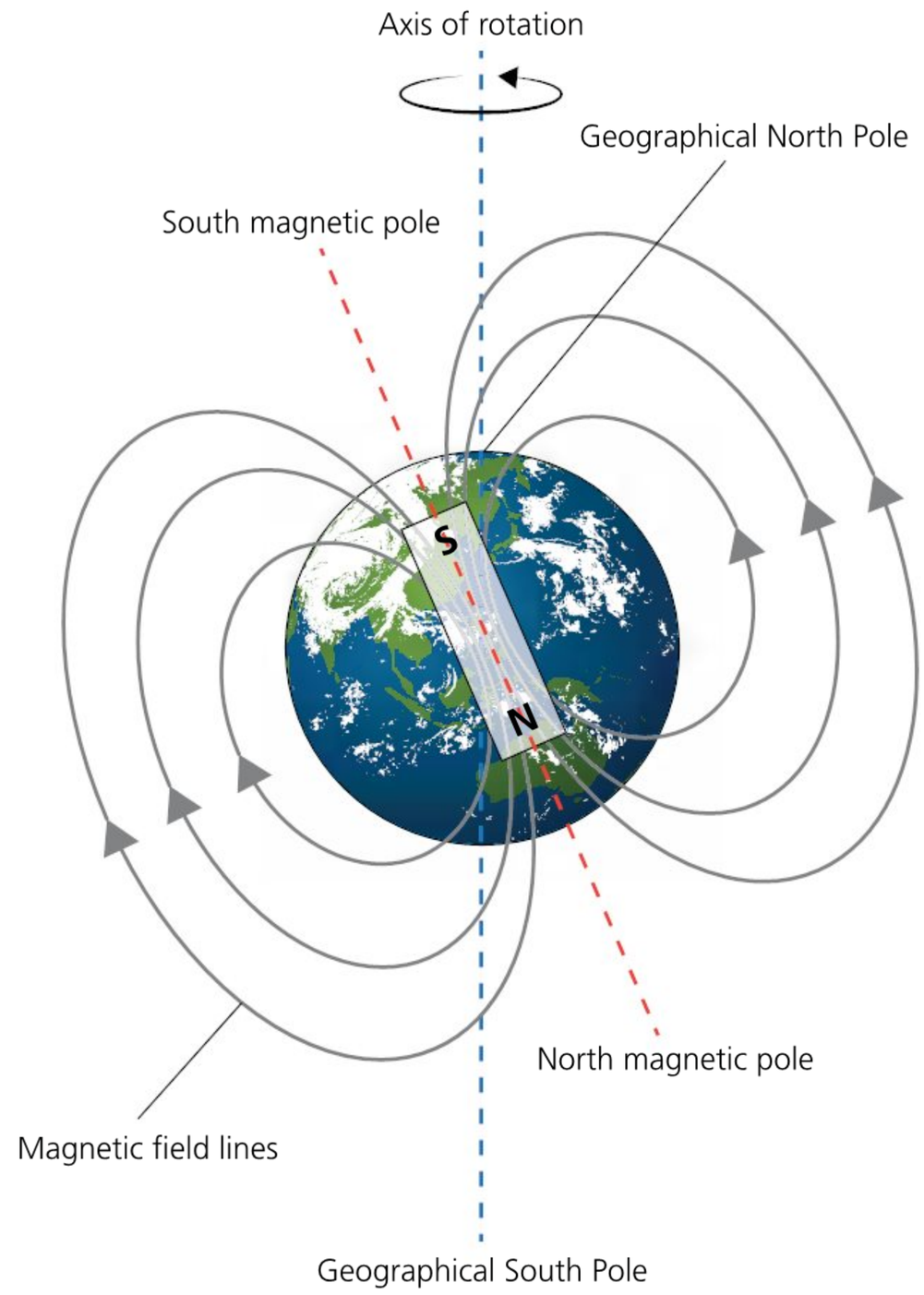


Figure 4.3 Earth's magnetic field. If you follow a compass needle north, will you get to the North Pole?

ACTIVITY: Magnetism all around us

ATL

- Information literacy skills: Collect, record and verify data

In this activity you will use sensitive devices to explore your magnetic environment.

How strong are the magnetic fields around us?

Hint

Magnetic field strength is measured in tesla (T).

For this activity, you will need:

- **A directional compass, or a compass app on your device**
- **A magnetometer, sensitive to microtesla (μT)**

Method

1. **Either draw by hand or download a map of your school and its area.**
2. **In your classroom, using the directional compass, find the direction of the north pole. Mark this on the map. Label this point 'reference point'.**
3. **Use this to draw a grid on your map, aligned with the compass points: north, south, east, west.**
4. **On the map, select points where you will measure the magnetic field strength. Discuss and select a suitable distance between points and make sure the points are spaced out at regular intervals in each direction.**
5. **You can use GPS and a location-finding app to make sure you are standing at each of the points you have identified on your grid. If the app shows them, make a note of your longitude and latitude (see *MYP Sciences by Concept 2*, Chapter 1).**
6. **At each grid point, measure:**
   - **the overall direction of the magnetic field (the direction shown by the compass needle or app)**
   - **the magnetic field strength – if your app displays readings for the x, y and z axes, make a note of each of these (Figure 4.4).**

Figure 4.4 Output from a magnetometer app (courtesy Vieyra Software Physics Toolbox Suite)

Present your readings as a magnetic field map of your locality.

Interpret your results. Were there any anomalies or surprising readings? Try to **identify** what might have caused these. **Evaluate** your measurements – do you think they were reliable? How would you check this?

Assessment opportunities

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

What causes magnetic force?

A magnet is any piece of material that produces a measurable magnetic field in the space around it. Magnets occur naturally, by chance, in rock that is rich in magnetic metals – most especially iron (Fe) (Figure 4.5).

The discovery of natural magnets led to the invention of the compass. The needle of a compass always points to the Earth's magnetic north pole (which actually corresponds to the south pole of the imaginary 'magnet' inside the Earth – see Figure 4.3). This must have seemed magical to ancient peoples. Legends occur in some cultures of islands of magnetic rock at the ends of the Earth, to which all other magnetic rock wishes to return. Magnetic Island, off the coast of Queensland, Australia, is reputed to be so named because it was reported to have confused the ship's compass on Captain James Cook's voyage of 1770.

In fact, the real magnetic north pole is currently over the north polar ice cap, and slowly moving towards Russia (Figure 4.6).

Magnets occur where tiny groups of atoms in certain metals align in a particular way. The arrangement of electrons in the atoms causes a magnetic force, which is amplified when all the atoms are aligned. Each group of atoms then exerts a force to align nearby atoms in the same direction, and this is what gives a magnetic field its direction from a north end, or **pole**, to a south pole. Another word for a magnet is a dipole.

Figure 4.5 Magnetite is a naturally occurring magnetic ore of iron

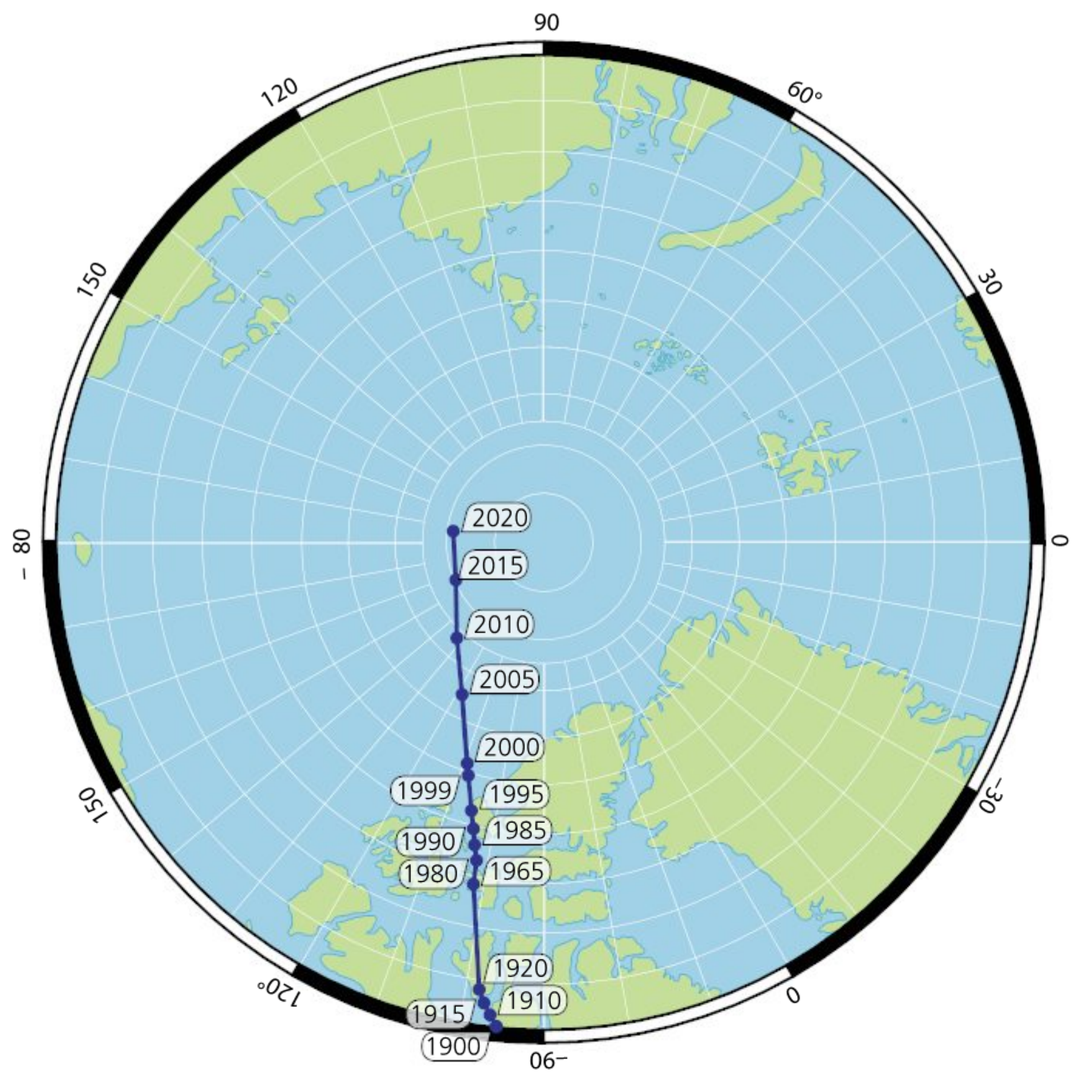


Figure 4.6 Tracking the magnetic north pole (source: Woods Hole Oceanography Institute)

DISCUSS

Magnets are dipoles, where the ends are called north and south. What happens if you cut a magnet in two, separating the poles?

ACTIVITY: Seeing the field

ATL

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

When a magnetic material is placed in a magnetic field, the dipoles in the material align with the field. If the pieces of material are small enough, they will move to position themselves along the direction of the field, forming lines.

Write a hypothesis to **explain** and **predict** what will happen when different or the same poles of magnets are brought close to each other.

Equipment

- **2 small magnets**
- **Small plotting compass**
- **Iron filings in a sprinkler (e.g. salt or pepper pot)**
- **A piece of thin card**

Method

1. **Place a magnet under a piece of thin card.**
2. **Use the plotting compass to identify the north and south poles of the magnet.**
3. **Move the plotting compass around the magnet and observe what happens to the needle.**
4. **Sprinkle magnetic filings over the region where the magnet is concealed.**
5. **Observe the patterns produced in the filings in these different cases:**
   - **a single bar magnet or dipole**
   - **two same poles close together**
   - **two different poles close together.**

Sketch and **summarize** your observations for both the shape and the direction of the magnetic field. How does the field differ for different kinds of interaction? Use *all* the words below in your summary.

attractive	repulsive	approach	avoid	cancel

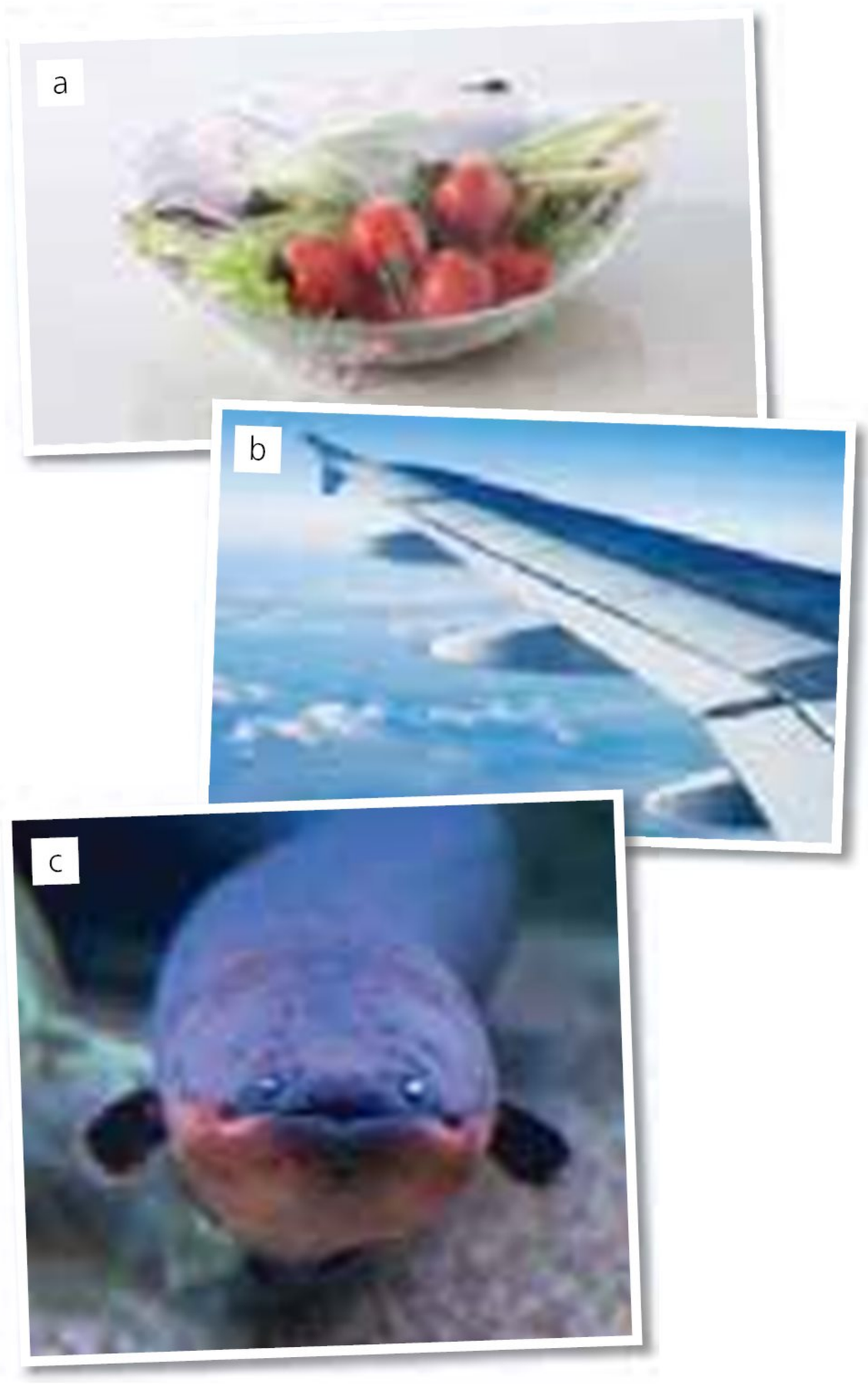
Assessment opportunities

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

What causes electric force?

DISCUSS

A dielectric is charged when it gains extra electrons or loses some of its electrons to another object. What sign will the charge on the dielectric have in each case?



■ **Figure 4.7** (a) What makes clingfilm clingy? (b) Aircraft often have static discharge wicks on the tailing edges of the wings. (c) A shocking fish!

Like magnetic fields, electrical fields originate within atoms. As you may recall from *MYP Sciences by Concept 2*, Chapter 2, atoms contain particles that carry a property called electric charge (Table 4.1)

Electric fields are caused by differences in electric charge. Electric charges tend to want to cancel each other out or balance. Wherever there is a charge, another charge nearby will experience a force that interacts with it. If the two charges are opposite, then they will be attracted together. If the two charges are alike, they will tend to be repelled and pushed apart. Only matter that carries electric charge is affected by electric fields – which is why we do not find ourselves sticking to the positive or negative poles of a battery! All the same, some materials are better at 'holding onto' electric charge than others – these materials are called dielectrics. Since they do not allow charge to move easily, they are also insulators. This happens because the molecules in dielectric materials allow electrons to move around between their constituent atoms, and they can temporarily attract or repel electrons from other objects.

Other materials, such as metals, tend to allow charge to move through them very easily. These materials are called conductors.

Electric fields can be elusive, because quite large amounts of charge are required to produce effects observable by us. Still, there are examples in nature. The amber in Figure 4.1 is produced when the resin of trees is hardened, and amber is a natural charge carrier. Electric eels are capable of generating and storing electric charges in special cells, and can produce enough electric charge to stun their prey in the water!

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}	1/1800	– (negative)

■ **Table 4.1** Properties of subatomic particles

ACTIVITY: Bright sparks

ATL

- Critical-thinking skills: Draw reasonable conclusions and generalizations; Evaluate and manage risk
- Creative-thinking skills: Practise visible thinking strategies and techniques

In this activity, you will experiment as a class to explore the properties of electric fields.

For this activity, you will need a Van de Graaff generator kit.

A Van de Graaff generator is a machine designed to collect quite large electrical charges. The dome part stores the negative charge, which is collected from the earth connection of the mains electrical plug (Figure 4.8).

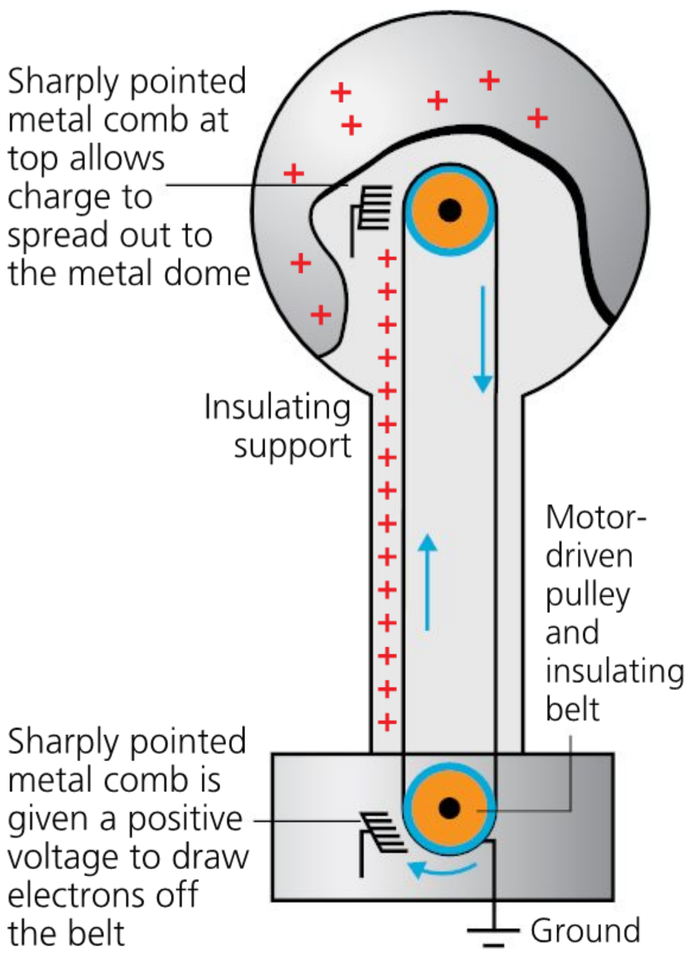


Figure 4.8 A Van de Graaff generator

SAFETY: Your teacher should supervise these experiments. The charge stored on the dome of the generator can produce voltages of thousands of volts. The current produced in the sparks is quite small, and so the electric discharge is not usually dangerous. However, a spark in the eye would be very painful and damaging. Do not place your face near to the generator. Wear safety glasses whenever close to the generator dome. Similarly, if you have a heart condition or an implant that is electronic you should not approach the Van de Graaff generator.

As a class, try the following activities. (The activities you try will depend on the contents of your generator kit.) **Record** your observations, **sketching** diagrams as appropriate.

1 **Sparking spheres. Position a metal sphere close to the generator dome using a lab stand. Connect the sphere to the earth using a wire. Now move the sphere close to the dome. Observe what happens. Move the sphere away. When does the effect stop? Why?**
2 **Hair-raising charge. Turn off the generator and use the metal sphere to discharge it safely. Kneel on a laboratory stool or stand on a plastic sheet. Place your hand lightly on the dome. Start the generator. What happens to you? What do you feel? Why?**
3 **Sharing the charge. Now get a couple of friends to kneel on stools or stand on the same plastic sheet beside you. Hold each other's hands or wrists gently. When the generator dome has been safely discharged, place your hand lightly on top again. Start the generator. What do you all feel? What happens? Why?**
4 **Popcorn If your kit contains a 'popcorn can' (a small plastic container with polystyrene balls inside), connect this to the contact in the top of the dome. Start the generator. What happens to the balls in the can? Why?**

When you have finished, **apply** your knowledge of electric charge and electric fields to **explain** what you observed in each case.

Observe, connect, explain, elaborate

To help you organize and develop your ideas about these experiments, you may like to use the visual organizer below. The explanations in the right-hand column may apply to one or more of the experiments above. **Connect** your **observations** to the **explanations** (the first example is done for you). Along the connectors, **elaborate** on your observations.

Experiment	Connection – observation	Explanation
1 Sparking spheres	Electric charge from the dome is attracted to the metal sphere and makes a spark.	Electric charge is conducted into a body and then stored. The extra stored charge exerts a repulsive force on same charges in the body.
2 Hair-raising charge		Electric charge is drawn to the earth and conducts through the air.
3 Sharing the charge		Bodies gain extra charge. Same charges repel, and the body moves away from the source of charge. When the body touches a conductor, it loses the extra charge and is attracted back to the charge source.
4 Popcorn		Electric charge is conducted between bodies, and each body stores extra charge. The extra stored charge exerts a repulsive force on same charges in each body.

Assessment opportunities

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

Reinforce and enrich your learning in this section using these or other online simulations. (These simulations require Java to be installed on your computer with a compatible browser.)

Easy to use:

https://phet.colourado.edu/en/simulation/legacy/magnet-and-compass

https://phet.colourado.edu/en/simulation/magnets-and-electromagnets

https://phet.colourado.edu/en/simulation/charges-and-fields

Slightly more complex:

www.cco.caltech.edu/~phys1/java/phys1/EField/EField.html

physics.weber.edu/schroeder/software/EField

Requires Shockwave Flash to have been installed on your computer and in your browser:

www.flashphysics.org/electricField.html

ACTIVITY: Spinning fields

ATL

- Creative-thinking skills: Make guesses, ask 'what if' questions and generate testable hypotheses

A dielectric bar can be charged by rubbing it against a suitable cloth. Friction between the cloth and the bar will transfer charges between them, such that a positive or a negative charge remains on the bar.

Equipment

For this investigation you may select apparatus from the following list. You may also **suggest** your own apparatus.

- **Various kinds of dielectric bar**
- **A watch glass**
- **Wooden blocks**
- **Large dish to contain water**
- **Cloth**

Method

Brainstorm all the variables that might affect the amount of charge held on a dielectric bar, and how the size of the force produced by that charge could be measured.

Select your independent (changed, controlled) and dependent (measured) variables.

Write an inquiry question for your investigation, clearly stating the independent and dependent variables that you have selected.

Design and then carry out an investigation that will allow you to measure the relationship between the variables.

Hint

The watch glass or the wooden blocks floating in water could reduce friction in the experiment.

SAFETY: Before you begin, always check your design with your teacher.

Assessment opportunities

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

How are electrical and magnetic fields related?

So far we have seen that electrical and magnetic fields have some similarities. They also have some differences. We will see later this chapter that wherever one exists, the other is available – and that we have been able to use the relationship between electrical and magnetic fields to our benefit. The relationship between the two fields was first discovered by accident in 1820 by the Danish experimenter Hans Christian Ørsted (1777–1851), and later explained by British physicist James Clerk Maxwell (1831–1879). . We will also explore the close connection between electrical and magnetic fields in the context of electromagnetic waves in Chapter 5.

Figure 4.9 James Clerk Maxwell (1831–1879) developed the first full mathematical description of electromagnetism

ACTIVITY: Fields – compare and contrast

ATL

- Creative-thinking skills: Practise visible thinking strategies and techniques

Figure 4.10 shows some observations made by students while inquiring into electrical and magnetic fields in this chapter.

Can you add any additional observations to these?

Organize the observations using a visual Venn organizer (see Chapter 1). To do this, make two interlocking circles. **Label** one circle 'Electric fields' and the other 'Magnetic fields'.

Consider:

- **What should you write in the two circles?**
- **What should you write in the region where they intersect?**

Now **identify** and **state** the evidence that you have seen for each of these statements. **Present** the evidence on your visual organizer so that it is clear and easy to understand.

Assessment opportunities

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

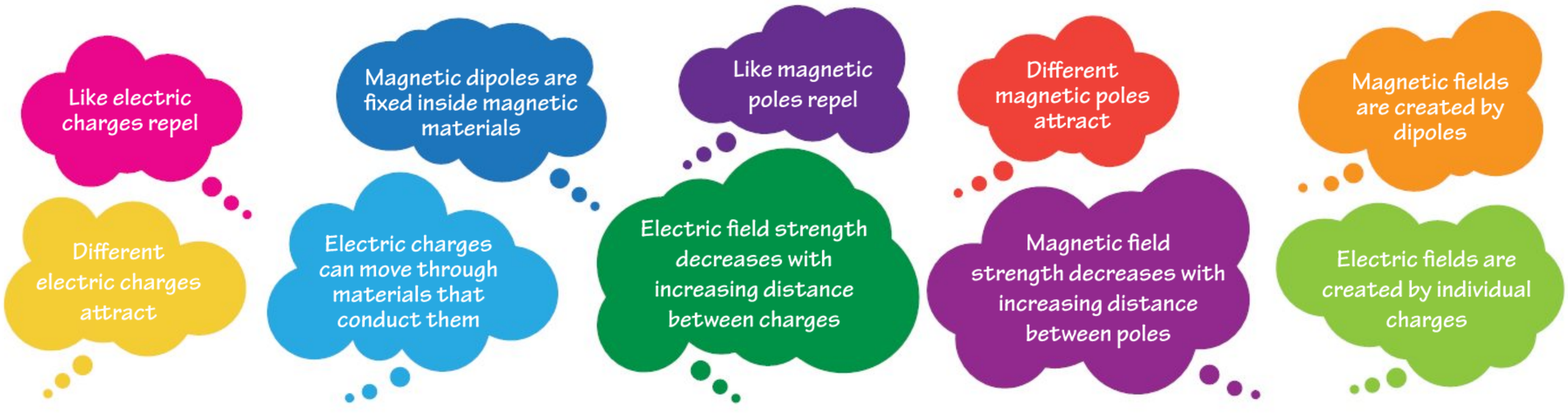


Figure 4.10 Electrical and magnetic observations

How can electrical energy be harnessed?

Figure 4.11 Fulgurite

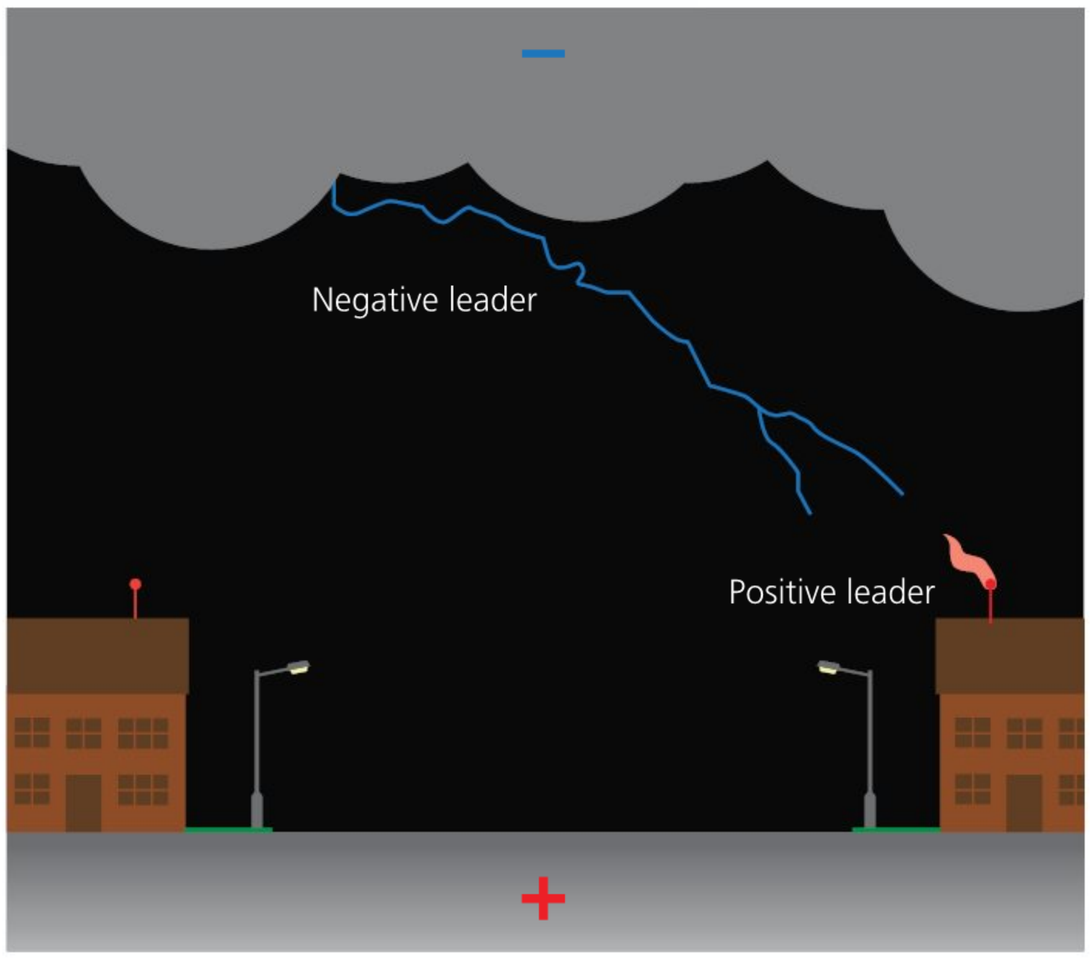


Figure 4.12 How cloud–ground lightning occurs

The strange object in Figure 4.11 is called fulgurite. It is the result of lightning striking the ground in a desert location. The lightning produces such high temperatures that the silica in sand is melted and fused – giving us a petrified 'snapshot' of the pathway of the lightning into the ground. The melting point of silicates in sand is 1800°C, but the energy in the lightning can produce far higher temperatures. Lightning is perhaps the most striking visual evidence that electric fields are in action around us, and have been associated over millennia with the mysterious powers of gods and other supernatural forces.

We now know of course that lightning is caused when electric charge is built up within storm clouds. Most lightning occurs between different regions of a cloud, and this is what we often see as sheet lightning, lighting up the sky. Sometimes lightning occurs between the base of the cloud and the ground.

Figure 4.12 shows how lightning occurs. Storm clouds build up huge negative electrical charge, which **induces** a relatively positive charge on the ground below the cloud. The negative charge from the cloud is attracted to this positive region, and so a negative 'leader' begins to fork its way towards the ground. At the same time, the positive charge in the ground is drawn up towards the negative 'leader'. When the two connect, a pathway is formed along which electric charge can travel through the air. In fact, the brightest part of the lightning – the part we usually see as the initial flash – is caused by positive charge moving *upwards* from ground to cloud. Afterwards, if excess charge remains on the cloud, there may be secondary discharges down into the ground – which we see as the flickering of a lightning strike.

■ **Figure 4.13** Lightning conductors are used to attract lightning leaders to a conductor that allows the lightning to discharge safely into the ground

EXTENSION

Find out more about **lightning conductors** and see how we can control the effects of lightning strikes on buildings. Find out about **static discharge wicks** to see how aircraft reduce the effects of electrical discharge (Figure 4.7b).

You may explore electric charge induction and conduction further in *MYP Physics by Concept 4&5*, Chapter 9.

Lightning bolts can carry many hundreds of megajoules of energy, but it is not practical to harness this natural electrical energy, since the longest discharges occur in a fraction of a second – and it is not possible to predict where they will occur. Instead, we must use processes that transform other kinds of energy into electrical energy in a more reliable way. In *MYP Sciences by Concept 1* and we have already seen how electrical energy can be produced from natural energy resources such as wind, solar energy, wave or tidal energy, or from fossil fuel combustion. Another way to harness electrical energy is to transform it from stored chemical energy. This method is usually called a cell or **battery**. Note that a battery does *not* actually contain stored electrical energy – rather, when the battery is connected, chemical processes begin that generate electrical charge. The chemical processes within the battery produce an excess of electrons at one of the battery **terminals**, and a deficit of electrons at the other, producing a difference in electrical charge. When these terminals are connected together, the charge moves. When the connection is made with a metal wire, the charge is carried by electrons that **conduct** through the wire. This movement of charge is then called an **electric current**. Electric current is measured in **amperes** (A), or amps for short, using a device called an **ammeter**.

DISCUSS

Which way does it go? Electric current is the flow of electrical charge through a conductor. When the conductor is a metal, the charge is carried by electrons moving through the metal. This will only happen when there is a difference in charge between one end of the conductor and the other – so one end is relatively positive, and the other end is relatively negative. In which direction do you think the electrons will move?

How do electrical circuits work?

ACTIVITY: Comparing batteries

ATL

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

Background information

Batteries produce electric current by using the different chemical properties of metals. Some metal reactions result in the metal losing electrons. This is another way to understand the chemical process known as **oxidation**. Other metal reactions result in the metal gaining electrons – known as reduction. (See *MYP Science by Concept 2*, Chapter 2, for more on oxidation and reduction.) The combination of the two processes is then known as a **redox reaction**.

Equipment

- **A lemon or lime**
- **1 strip of zinc (Zn) metal**
- **1 strip of copper (Cu) metal**
- **A 1.5 V alkaline battery (with battery holder and connectors)**
- **Connecting wires with connecting clips**
- **A sensitive ammeter with a 100 milliamp scale (mA)**
- **A sensitive voltmeter with a 1 volt scale (V)**
- **A light-emitting diode (LED)**

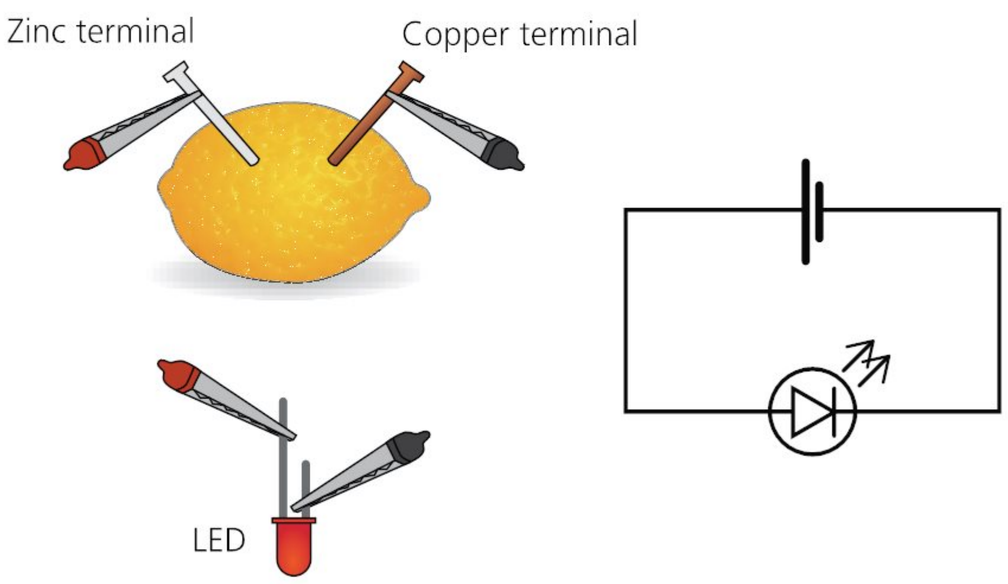


Figure 4.14 How to set up your circuit

Method

Figure 4.14 shows the circuit you will need to build for this experiment.

Notice that it is important that you connect the positive (+) and negative (–) terminals of the battery to the correct connections for the LED.

1. **Build the circuit, and test using the alkaline battery. If the LED does not light at first, try changing the connectors around.**
2. **Observe the brightness of the light produced by the LED and record the current flowing in the circuit using the ammeter. Record the voltage (V) across the LED using the voltmeter.**
3. **Now remove the alkaline battery and prepare your fruity battery. Do this by pushing the strips of zinc and copper through the skin of the fruit, about 2 or 3 cm apart. These are the terminals of your battery.**
4. **Observe the brightness of the light produced by the LED, then measure and record the current and the voltage as before.**

Concluding and interpreting

Interpret your results and so **compare** and **describe** the operation of the two kinds of battery.

Evaluate your experiment. **Compare** your results to those of other groups in your class. Were your results valid for comparing the batteries? Were your results reliable? **Describe** any improvements or extensions you could make to this experiment.

Assessment opportunities

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

In the *Comparing batteries* activity you will have noticed that the arrangement and orientation of the parts, or components, in the circuit was very important. The LED only allows current to flow through it in one direction. Other components – such as switches and conventional light bulbs – allow current to flow through them in both directions.

Notice also how we drew the circuit diagram for the simple battery circuit (Figure 4.14). While a picture of a circuit might be helpful, it can be confusing to follow, especially when the circuit becomes very complicated. For this reason, scientists and engineers represent electrical circuits using a **circuit diagram**. A circuit diagram is a simplified schematic 'map' showing how the components in the circuit are arranged and orientated. The real circuit may look different – it will probably be much less tidy!

Drawing circuit diagrams

When drawing circuit diagrams, follow these simple rules.

- Use circuit symbols for the components in the circuit, not drawings (Figure 4.15).
- Draw connecting wires as straight lines.
- Show electrical connections with dots.
- Always draw circuit connections at right angles.

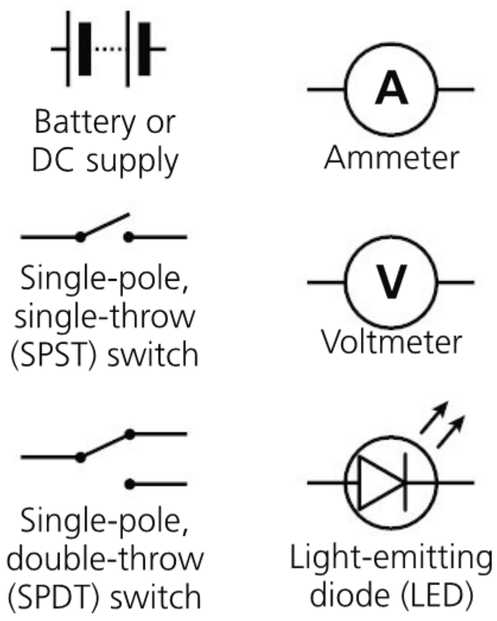


Figure 4.15 Circuit symbols for components used in this chapter

ACTIVITY: Going with the flow

ATL

- Critical-thinking skills: Use models and simulations to explore complex systems and issues

This activity uses the analogy of river water to model how electric current flows in circuits.

Inquiry question: How well can we model electric current flow by thinking about river water?

River water flows downwards, because work is being done to move the water by the Earth's gravitational field. This is similar to the way that electric current flows, because work is being done to move the charge by the electric field in the conductor.

Look at the pictures of different river formations in Figure 4.16. For each of the river formations, **compare** and **describe**:

- **how quickly the water is flowing**
- **how much water is flowing**
- **the factors affecting how much water is flowing.**

In what ways is the river water similar to electric current flow? **Suggest** how an electric circuit could be similar to each of the river formations in Figure 4.16. **Suggest** what factors would change the way the electric current flows in the circuit in each of the different examples.

Models and analogies can be a powerful way to deepen and even extend our understanding. By transferring understanding from a situation we know well to a new context, we can also make new hypotheses. However, we must be careful that the model or analogy does not mislead us, so think carefully about how the model might be different to the reality!

Assessment opportunities

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

Figure 4.16 River formations

Figure 4.17 Early incandescent bulbs, like this one similar to a design by US inventor Thomas Edison, used current flowing in thin wires in a vacuum to produce light

We can control electric current to make it do useful work for us by carefully designing electric circuits. In the following activities, we will investigate the ways in which switches and light bulbs can be used to control and influence the flow of electric current.

In the *Illuminating circuits* activity we change the function of the circuit by changing the orientation and configuration of the components. We have seen how circuit configuration affects the current flow around the circuit. In the *Comparing batteries* activity we also saw how different power sources can change the voltage available to make the current flow. Voltage is a measure of the difference in energy across a circuit or a component within a circuit, and is properly called **potential difference**, or p.d. for short. Components such as light bulbs affect the p.d. because they use some of the energy available from the flow of current to do work – so there will be less energy available after the current has flowed through the component. In the case of a light bulb, for example, the energy is taken from the electric current to produce heat and light. Just as we measured the current flowing from the different batteries using an ammeter, the p.d. produced in the circuit is measured using a device called a **voltmeter**.

ACTIVITY: Illuminating circuits

ATL

- Critical-thinking skills: Evaluate evidence and arguments; Propose and evaluate a variety of solutions

In pairs: You will investigate the way that different kinds of switches can be used to control electric currents in a household stair light system.

Inquiry question: How does electric current flow around circuits?

Background information

Switches can be used to make or break circuits and so stop electric current from flowing. Light bulbs transform the energy carried by electric current into heat and light.

In a house lighting system, it is useful sometimes to be able to control the light using different switches – for example, at the top and bottom of some stairs (Figure 4.18).

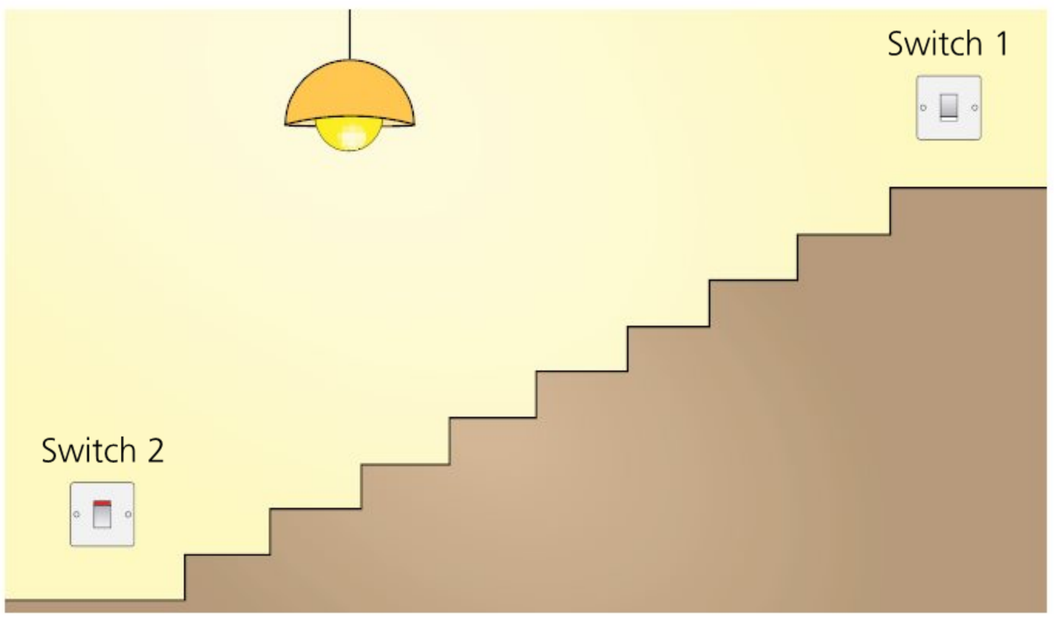


Figure 4.18 Household stair light system

Discuss Why are there two switches in the stair light system? How does each switch control the light?

We will experiment with two kinds of switch – a single-pole, single-throw (SPST) switch and a single-pole, double-throw switch (SPDT) (refer to Figure 4.15 for circuit symbols).

Interpret the circuit diagrams for the two kinds of switch (Figure 4.19 and Figure 4.20) and so **describe** how you think the switches work. **Predict** how each of the switches could be used in the household stair light system.

Equipment

- **A power supply or battery pack, 1.5–6.0 V (depending on the requirements of your light bulb)**
- **A light bulb (1.5–6.0 V)**
- **2 SPST switches**
- **2 SPDT switches**
- **Wire connectors**

Method

1. **First build the circuits shown in Figure 4.19, using the SPST switches.**
2. **Experiment with the switches and observe the effect on the bulb. Record your observations for each of the switch settings in a clear manner.**

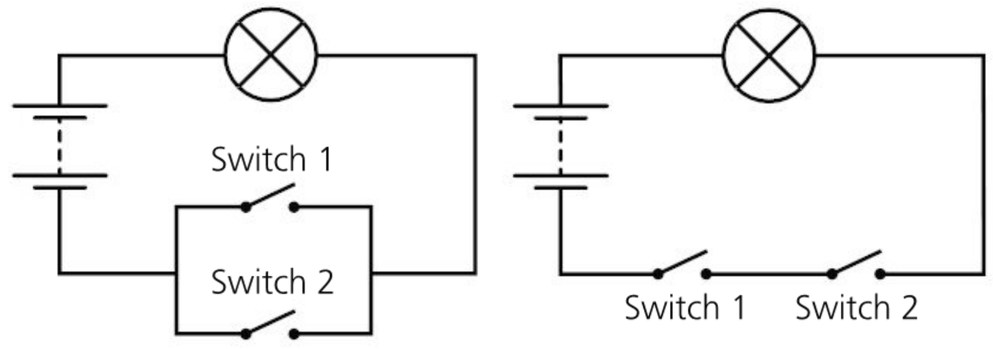


Figure 4.19 SPST circuits

3. **Now reconfigure your circuit by replacing the SPST with SPDT switches as shown in Figure 4.20.**

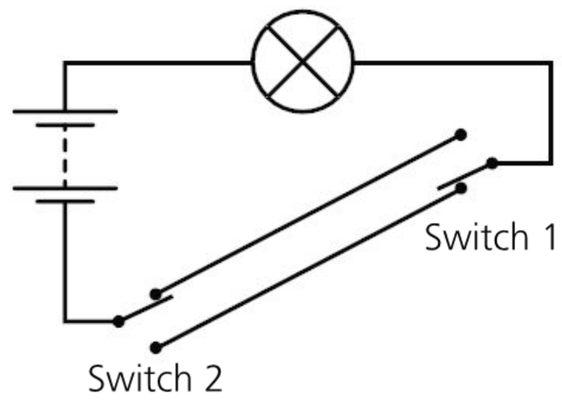


Figure 4.20 SPDT circuit

4. **Experiment with the switches and observe the effect on the bulb. Record your observations.**
5. **Interpret your observations. Describe what was happening to the current flowing in the circuit in each case, and so explain how the circuit affected the light bulb.**
6. **State which of the circuits would be the best to use for the stair light system? Explain your answer.**

Assessment opportunities

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

ACTIVITY: What's the difference?

ATL

- Critical-thinking skills: Evaluate evidence and arguments; Propose and evaluate a variety of solutions

Individually or in pairs: You will investigate the best circuits to model a street lighting system.

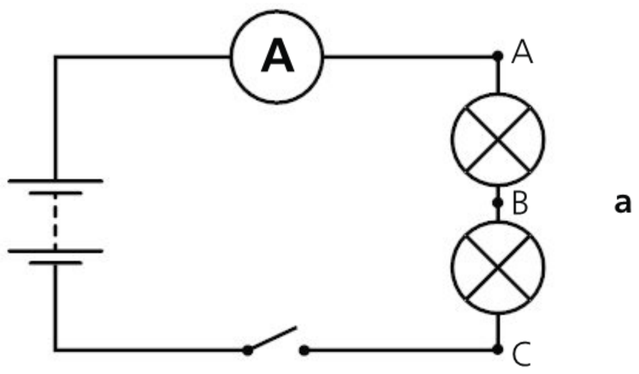
Inquiry question: How do circuit branches affect the current and the voltage (p.d.) in a circuit?

Look at the circuit configurations in Figure 4.21.

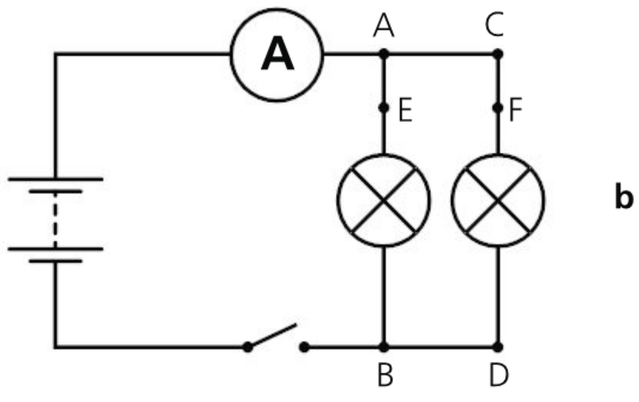
- **Circuit (a) is called a series circuit, because the components in the circuit (the bulbs) follow on one from another.**
- **Circuit (b) is called a parallel circuit, because the components (the bulbs) are side by side.**

Discuss: What is the same and what is different about the configurations?

Predict how you think the configuration of each circuit will affect the brightness of the bulbs. **Explain** your predictions, with reference to what you know about current and voltage. **State** which of the circuits you think would be best to use for a street lighting system in a town. **Explain** your answer.



a



b

Figure 4.21 Circuit configurations

Equipment

- **A power source (1.5–12.0 V depending on your light bulb requirements)**
- **2 light bulbs (1.5–6.0 V)**
- **1 SPST switch**
- **1 ammeter (0.5 A maximum scale)**
- **1 voltmeter (5.0–15.0 V maximum scale depending on your light bulb requirements)**
- **Connecting wires**

Method

1. **Build the series circuit shown in Figure 4.21. Measure and record:**
   - **the current in the circuit, using the ammeter as shown**
   - **the voltage between points A and C – do this by connecting one terminal of the voltmeter to the circuit at A and the other at point C**
   - **the voltage between points A and B, and between points B and C.**
2. **Now build the parallel circuit shown in Figure 4.21. Discuss and decide how to measure and record:**
   - **the current flowing through *each* of the two bulbs**
   - **the voltage across *each* of the two bulbs.**
3. **Organize your data in a clear table that allows you to compare the measurements made in each circuit.**
4. **Interpret your data to write a conclusion about the way that current and voltage are affected in each of the circuits. Explain what is happening to the current, and how the p.d. (energy) in the circuit is shared.**
5. **State whether your prediction about the brightness of the bulbs was correct, and explain the brightness you observed with reference to current and voltage (p.d.). State which of the circuits would be the best to use for a street lighting system, and explain your reasons.**
6. **Evaluate your experiment. Were your results reliable and valid? Suggest how you could have extended the experiment – perhaps by redesigning or adding to the circuits.**

Assessment opportunities

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

Figure 4.22 High voltage insulators

SEE–THINK–WONDER

Look at Figure 4.22. What do you **see**? What do you **think** it is for? What does this make you **wonder**?

We have seen how components such as light bulbs transform electrical energy and so create a potential difference in a circuit. Conventional light bulbs (often called incandescent bulbs) transform energy because the bulb holds a very thin wire which becomes very hot when electric current flows through it. The wire doesn't burn, however, because the atmosphere inside the bulb contains no oxygen. Instead, electrical energy is released continuously as heat and light. The amount of energy transformed from electric current by a component is measured by its **resistance**, in ohms. The Greek letter omega, Ω, is the symbol used for ohms. Materials with a very high electrical resistance – like those shown in Figure 4.22 – are called **insulators**.

ACTIVITY: Light traffic

ATL

- Critical-thinking skills: Use models and simulations to explore complex systems and issues
- Transfer skills: Apply skills and knowledge in unfamiliar situations

Individually: In this activity you will think about conductors and resistance by analogy to traffic.

Figure 4.23 Highway traffic

Look at Figure 4.23. What is happening to the traffic?

Describe what you would expect to happen if:

- **the road were made wider by adding more lanes**
- **the road were made narrower due to roadworks in one lane**
- **a second road were built alongside this road**
- **the picture were taken at 2.00 am at night, when fewer people want to travel.**

Now look at the images of some different conductors in Figure 4.24.

Figure 4.24 Electrical conductors

Outline how each of the traffic situations above might help explain the way that electric current passes through the conductors. **Suggest** what you would expect to happen in the conductors in each case. Would electrical energy be transformed? Into what?

Assessment opportunities

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

ACTIVITY: Does it conduct?

ATL

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

Individually or in pairs: In this activity you will measure the resistance of some different materials and determine whether they should be **classified** as conductors or insulators.

For this activity you will need some different materials and a sensitive resistance meter.

The materials you will need are:

- **Copper**
- **Steel**
- **Wood**
- **Paper**
- **Pencil lead**
- **Tap water (in a beaker)**
- **Distilled water (in a beaker)**
- **Salty water (in a beaker)**
- **Plastic bag**

Material	Resistance (Ω)	Conductor or insulator?
Copper		
Steel		
Wood		
Paper		
Pencil lead		
Tap water (in a beaker)		
Distilled water (in a beaker)		
Salty water (in a beaker)		
Plastic bag		

A resistance meter (measuring resistance is usually one function of a multipurpose electrical meter called a **multimeter**) measures the resistance of any material placed between its terminals (Figure 4.25).

Use the resistance meter to **measure** the resistance of each of the materials.

Figure 4.25 A multimeter

Hint

Take care – will the resistance of a long piece of material be the same as that of a shorter piece? Make sure that you always position the probes of the resistance meter the same distance apart. Press down firmly on the material to ensure good contact.

Record your measurements in a copy of the table above. **Discuss** your results, and so **classify** each material as a conductor or an insulator.

Were there any materials for which it was hard to decide whether it was a conductor or insulator? How could you improve the measurement method to make it easier to decide?

Assessment opportunities

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

ACTIVITY: Investigating conductors

ATL

- Critical-thinking skills: Gather and organize relevant information to formulate an argument
- Creative-thinking skills: Make guesses, ask 'what if?' questions and generate testable hypotheses

In pairs or in groups: You will design and carry out an investigation to determine the factors affecting the resistance of a metal conductor.

Inquiry question: What factors affect the resistance of a metal conductor?

Electrical systems need high-quality conductors with low resistance to work efficiently – otherwise electrical energy is wasted when it is transformed, due to resistance in the conductors. Computer network cabling systems are an example of an electrical system where this is very important.

Research what conductors are used in computer network cabling systems. Using what you have learned, **design** an investigation to find out what factors affect the resistance of this kind of metal conductor.

Using the findings of your investigation, write a report for your school on the best kinds of network cabling to use. **Outline** the problem that the cabling must overcome, and **describe** the characteristics that the cables should have. Research some of the materials used in real computer network cabling, and so **suggest** some of the limitations of the cabling you have chosen and how these might affect the choice of conducting material to use.

In your report, be sure to use the scientific terminology you have learned in this chapter accurately. **Document** any sources of information you used for research in line with your school's research guidelines.

Assessment opportunities

- This activity can be assessed using Criterion B: Inquiring and designing, Criterion C: Processing and evaluating, and Criterion D: Reflecting on the impacts of science.

Figure 4.26 Lie detectors or polygraphs use changes in the resistance of human skin to detect increased sweating – which is supposed to indicate when someone is lying!

Links to: Design

Solving a technological problem such as network cabling requires some creative thinking. Many different factors need to be taken into account by designers, such as costs and environmental impact. Sometimes the best overall solution may not be the scientifically perfect solution.

How does it help to be organized?

! Take action! Electric games

■ ATL

- Information literacy skills: Present information in a variety of formats and platforms
- Creative-thinking skills: Apply existing knowledge to generate new ideas, products or processes

■ **Figure 4.27** A printed circuit board (PCB) from a laptop computer

! Printed circuit boards (PCBs) are used in electronic devices to make sure that circuits are configured in the most space-efficient way possible. Instead of using individual wire connectors, copper sheet is etched (dissolved using acids) to make the circuit configuration. The electronic components are then connected by melting an alloy called solder.

- You can make a printed circuit board by using aluminium cooking foil – simply draw your circuit onto the foil, cut it out and then carefully paste it onto a cardboard base.
- Use what you have learned about electrical circuits in this chapter to design and build an electric circuit that can be used to help other students test their knowledge in a science quiz. Your game should use a light or a buzzer to tell them when they connect a question to a correct answer.
- Connect the questions and answers by carefully designing your 'PCB'. Of course, the connections should be invisible to the person playing the game, so you will need to design a cover to conceal the connections.
- Test your games!
- **Evaluate** the design of your game. What circuit types did you use? How did the 'PCB' help to keep the circuit organized? What problems might you have encountered if you had not used the 'PCB' design?

Reflection

In this chapter, we have **outlined** the properties of electrical and magnetic fields, and **described** how they interact. We have **explained** electrical and magnetic fields in terms of atomic structure. We have **described** how the movement of electrons as electric current can be controlled in different ways, and how the energy carried by electric current can be used to do work for us. We have **described** the way circuit configuration affects electric current and **measured** the effects on current and voltage of different circuit components and configurations. We have **described** how resistance affects the energy transformed in a conductor, and **classified** materials as conductors or insulators of electricity.

Use this table to reflect on your own learning in this chapter.					
Questions we asked	**Answers we found**	**Any further questions now?**			
Factual: How do force fields affect matter? What causes magnetic force? What causes electric force? How do electrical circuits work?					
Conceptual: How are electrical and magnetic fields related? How can electrical energy be harnessed?					
Debatable: How does it help to be organized?					
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(s)	Reflect on the importance of being a good thinker for your learning in this chapter.				
Thinkers					

5 How can we connect?

We **interact** and **express ourselves** through **systems** that manipulate information as different forms of **energy**.

Figure 5.1 How do you use technology to express yourself?

CONSIDER THESE QUESTIONS:

Factual: How do you communicate? What instruments have we made to manipulate waves? How can information be carried by a wave? What are the advantages and disadvantages of analogue and digital systems?

Conceptual: How can we share information effectively?

Debatable: What rights and responsibilities do we have when communicating using digital media?

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

IN THIS CHAPTER, WE WILL …

- **Find out** how information and voices can be communicated using different kinds of communications technology.
- **Explore** the science that makes it possible to encode and transmit information.
- **Take action** to use digital media safely, responsibly and constructively, and help others to do so.

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

These Approaches to Learning skills will be useful…

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

We will reflect on this learner profile attribute…

- Communicators – in this chapter we will explore how technology helps us to be better communicators.

KEY WORDS

encode	online
medium (plural: media)	telecommunications
network	transmit

Figure 5.1 suggests some ways that you might already be using technology to express yourself. From the earliest times, human beings have used machines to entertain and to communicate – whether playing drums around a fire, or watching a video show as part of a music concert. It can be argued, however, that the last 40 years have seen an explosion of technologies that allow all of us to communicate our thoughts, feelings and experiences using digital media. Now more than at any time in history, *anyone* can become a communicator or an entertainer. As with any technology, this can bring real opportunities and also new challenges and even dangers. In this chapter we will inquire into the science that makes these communications technologies possible. We will also consider their impacts.

THINK–PAIR–SHARE

Perhaps you use online digital media every day, or perhaps your parents or carers ask you to limit your time online?

Individually, look at the different kinds of online media below.

Think: What applications do you use? How often do you use them?

Organize the findings from your self-survey.

- **Personal online sharing**
- **Chat, personal messaging, microblogging**
- **Online gaming**
- **Cell phone**
- **Face-to-face communications**
- **Fixed digital media**
- **Free online media**
- **Commercial streaming service**

Now **compare** your findings with those of a partner. **Discuss** the reasons for any differences you have identified.

Find out: Do any of these online sites or applications have age restrictions? Are you complying with those age restrictions?

Now share your findings as a class and **discuss**.

Write down the questions your class has about online media and post them somewhere in your science classroom so that you can refer to them throughout this chapter.

How do you communicate?

From a scientist's perspective, all communications media work in the same way. Information is encoded in energy, the energy is transformed so that it can be transmitted or shared, and then the energy is transformed again in order to receive the information. In many cases, the energy is transmitted in the form of a wave of some kind. You may have inquired into the properties of waves such as seismic waves, light and sound in *MYP Sciences by Concept 2*, Chapter 4, or in your learning previously. You may wish to refresh your understanding with the next activity.

ACTIVITY: Testing, testing, 1, 2, 3

ATL

- Communication skills: Negotiate ideas and share knowledge with peers
- Collaboration skills: Help others to succeed; Encourage others to contribute; Exercise leadership and take on a variety of roles within groups

In this activity, you will review your knowledge and understanding of waves and their properties with a partner by participating in a short quiz with the rest of your class.

1 **Firstly, in groups of two to four, choose a team name and a team captain for the quiz.**
2 **In your team, discuss what you already know about waves. Brainstorm or use a mindmap to share and structure your ideas (see Chapter 1).**
3 **From your brainstorm or mindmap, choose five wave facts that you know.**
4 **Discuss and then write down the wave facts in the form of five questions. Careful – make sure that the question can be answered orally by another team (so no long calculations) and be sure of the answer yourself!**
5 **When all teams have questions, start the quiz. Here are some ideas for making it work.**
   - **Each team asks another team in turn, going around all the teams in the class for a maximum of five rounds.**
   - **You are not allowed to look at resources or look up information online!**
   - **Your teacher should keep score and act as a referee in case any of your questions are challenged.**
   - **If another team asks a question you have on your list, too bad – you lose the question! It might be a good idea to have a couple of extra backup questions.**
6 **As well as rounds where anybody in the opposite team can answer, have some fun rounds such as:**
   - ***Nominate* – you get to choose who in the other team has to answer!**
   - ***Captains only* – team captains have to go to the front of the class. If they answer the question (correctly!) alone, they win 2 points. If they have to confer with a member of their team, they win only 1 point.**
   - ***Time challenge* – the opposite team must answer in a short time, say 5 seconds.**
7 **When you have finished the quiz, discuss how useful it was as a review activity. Did it help everyone review their knowledge of waves? Did it help review understanding of waves? How could you improve the activity?**

Assessment opportunities

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

What instruments have we made to manipulate waves?

■ **Figure 5.2** Cameras – CCTV, phone camera, DSLR, TV camera

As Figure 5.2 shows, it seems like cameras are everywhere. Our images are constantly being taken, stored and perhaps shared – sometimes because we want to, but sometimes also without us being aware of it.

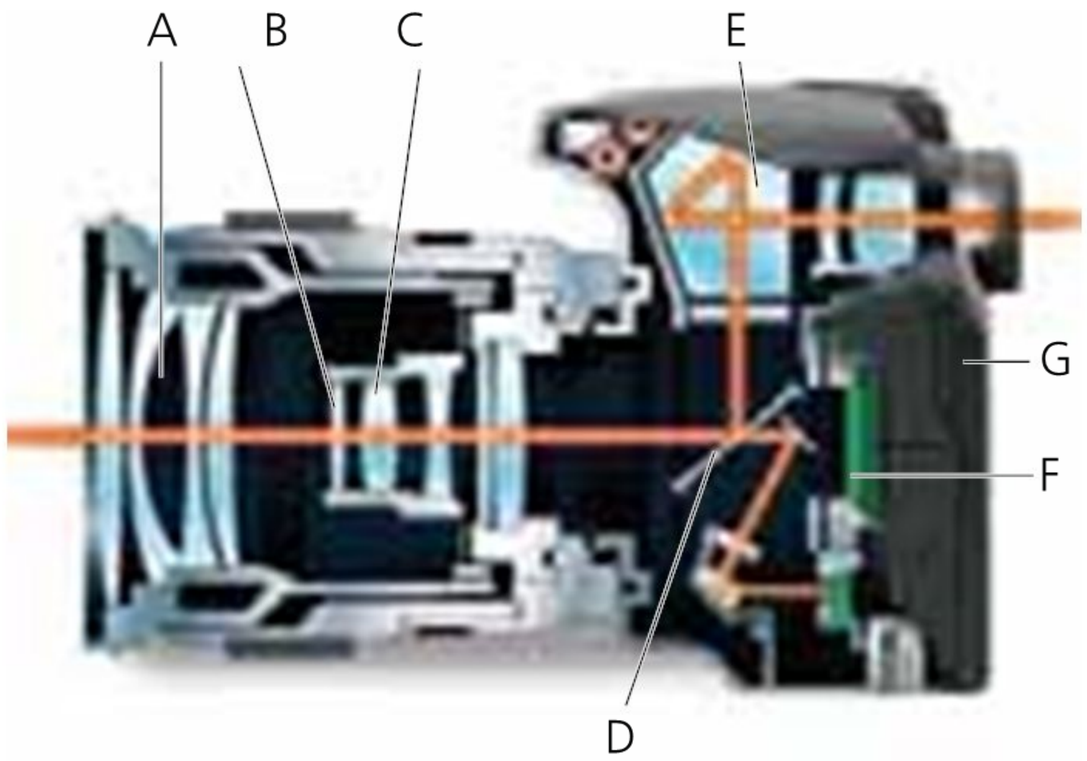
Sight and hearing are our two most important communicative senses, and for this reason we have developed increasingly sophisticated machines (or scientific instruments) to manipulate and communicate light and sound. In this section we will begin by looking at the science of making and communicating images.

In *MYP Sciences by Concept 2,* Chapter 4, you may have learned how the path of light waves can be represented using a **ray diagram**, where lines are used to show the direction of propagation of light waves. The cutaway image in Figure 5.3 shows the path of light through a DSLR (digital single-lens reflex) camera, which is the most commonly available high-performance camera.

The science of manipulating light is known as optics. A DSLR camera is an example of an optical instrument that utilizes all the most important optical effects. In the next pages, we will inquire about and explore those effects.

▼ Links to: Arts

Before it was possible to capture an image instantly using a photograph, the only images available were made by artists – painters and sculptors. Images were then perhaps more valued by those who possessed them. Equally, perhaps, photography made it possible for everyone to 'see' differently. In what other ways might the instant image have changed the way we see ourselves?



■ **Figure 5.3** The inside of a DSLR camera

ACTIVITY: Smile!

ATL

- Information literacy skills: Access information to stay informed and to inform others; Understand and use technology systems
- Critical-thinking skills: Revise understanding based on new information and evidence

In this activity you will use scientific vocabulary to **describe** the operation of parts in a DSLR camera, **outline** how the camera works, and **make judgments** about different camera designs.

Look at Figure 5.3 on the previous page. The key parts of the camera are labelled with letters.

Using a science dictionary or by searching online, **describe** the function of the different parts given below:

lens prism mirror CCD (charge-coupled device) shutter diaphragm screen

The statements below **describe** how the parts labelled A–G function in the camera. **Apply** your research on the function of the parts given in the box to match the statements with the labels A–G.

Function in the camera	Label A–G
Detects the light from the image, transforms it into electrical energy and captures it	
Reflects the light from the image up to the viewfinder, but moves out of the way when the image is to be captured	
Reflects the light from the image back into the photographer's eye	
Position of part that opens and closes in front of the mirror to control the amount of light entering the camera	
Gathers light from the object and brings it to focus on the CCD	
Caps: Opens and closes rapidly to expose the CCD to light from the object	
Displays the image to be captured	

Some other types of digital camera no longer have a viewfinder, only the screen. This means they don't need a mirror (Figure 5.4).

Figure 5.4 A mirrorless digital camera

With reference to what you know about light, and perhaps your own background knowledge of using digital cameras, **outline** what might be the advantages and disadvantages of this mirrorless design over the DSLR.

Assessment opportunities

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

To Sim or for Real?

As we saw in Chapter 4, there are many very powerful online simulations available that allow us to try out experiments without actually using apparatus.

An online, web-based optics sim from the Institute of Physics:

www.physicsclassroom.com/Physics-Interactives/Refraction-and-Lenses/Optics-Bench/Optics-Bench-Refraction-Interactive

A very effective sim from the pHET project at the University of Colorado:

https://phet.colourado.edu/en/simulation/legacy/geometric-optics

(This can be run from the web if your device can use Macromedia Flash, but you can also download it to run offline if your device has Java installed.)

You can also download apps for Android, iOS or Windows that will work on your portable devices. Just search **optics simulation** in your favourite app store.

Go and experiment and have fun!

Reflecting on it

Figure 5.5 Mystical and magical mirrors?

Everyone has seen their reflection in a mirror or in a reflective surface. We can see that mirrors have fascinated human beings for millennia – when made from polished obsidian or silver, they were thought by many cultures to capture the soul. In Lewis Carroll's novel *Through the Looking-Glass* (1871), Alice steps through a mirror to enter a wonderland.

The most familiar kind of mirror is one with a flat reflective surface, known as a **plane mirror**. Perhaps now we take mirrors for granted – but are you sure you understand all you need to know about a mirror? For instance, why is the image in a mirror switched around (Figure 5.6) from left to right? And why is it *not* switched around from top to bottom? This property of a mirror image is known as **lateral inversion** and if we analyse the way a mirror works using a ray diagram we can see why it happens.

Figure 5.6 Mirror images are laterally inverted

ACTIVITY: What's my image?

ATL

- Information literacy skills: Collect, record and verify data; Process data and report results

In pairs: In this activity you will carry out two experiments. In the first experiment, you will investigate how a mirror reflects a light ray. In the second experiment, you will investigate the properties of the mirror image. You will also learn some new scientific vocabulary.

For both experiments, you will need:

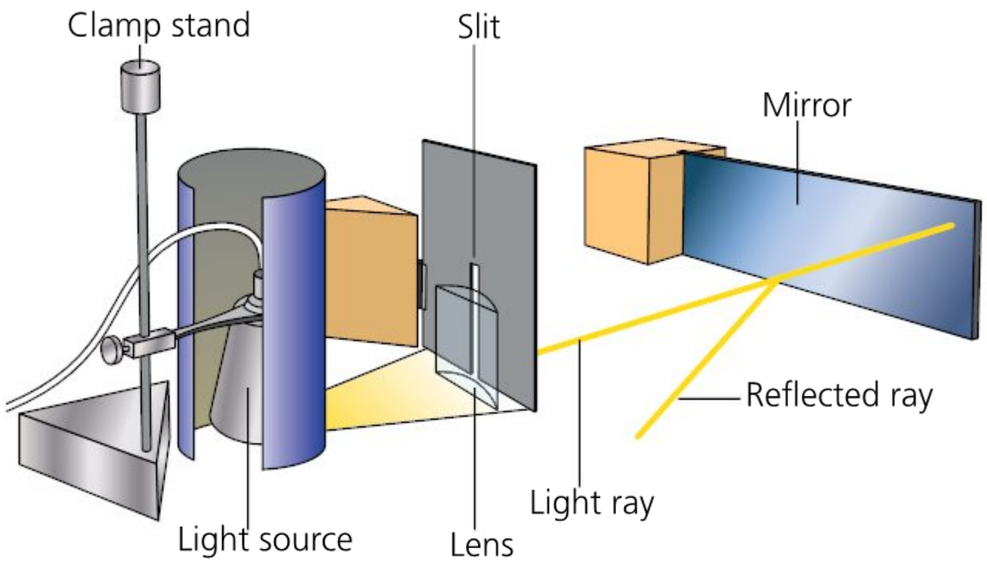
- **Ray box with a collimating lens**
- **Power supply or similar for the ray box**
- **Ray box card with a single slit**
- **Ray box card with three slits**
- **Millimetre graph paper**
- **A plane mirror**
- **Ruler**
- **Protractor (angle measurer)**

SAFETY: Some ray boxes use light bulbs that can become very hot to touch after long periods of time. Do not touch the light bulb in the ray box.

Experiment 1

Inquiry question: How does a plane mirror reflect light rays?

1. **Set up the apparatus as shown in Figure 5.7. You may be able to position the collimating lens on your light source so that the light rays emerging from the end of the light source are parallel.**
2. **Drop the single-slit card in front of the ray box so that a single narrow ray emerges. This will be your incident ray.**
3. **Now position the mirror on the millimetre graph paper so that the ray strikes the mirror somewhere near the middle. Change the angle of the mirror until the ray is reflected exactly back on itself (so you don't see a reflected ray at all).**
4. **With a sharp pencil, draw along the edge of the mirror on the paper. Draw dotted lines to also show the position of the ray.** ➤



■ **Figure 5.7** Plane mirror experiment

5 **Now change the angle of the plane mirror by a few degrees. Be careful to ensure that the incident ray still strikes the mirror at the same point as before. Draw along the edge of the mirror. Draw dotted lines to show the position of the reflected ray.**

Hint

It may be helpful to colour code or number the line along the edge of the mirror and the reflected ray each time so that you can tell which measurements belong to each other.

6 **Repeat the procedure for at least five angles.**

Interpret your data.

- **For each angle of the mirror, draw a line at 90° to the surface of the mirror, starting from the point where the incident ray struck the mirror. This line is called a normal.**
- **Measure the angle of incidence between the incident ray and the normal. Measure the angle of reflection between the reflected ray and the normal.**

Organize and present your data in a way that makes it easy to interpret.

Summarize your findings.

Evaluate your experiment. How could you have improved the reliability of your experiment? How could you have improved the validity of your experiment?

Experiment 2

Inquiry question: How do the light rays form a mirror image?

1 **Use the same setup as for Experiment 1, but with a new sheet of paper.**
2 **Replace the single-slit with a three-slit card.**
3 **Now adjust the collimating lens so that this time the three rays from the ray box spread out or diverge.**
4 **Direct the three rays onto the plane mirror. Draw along the edge of the mirror as before.**
5 **Trace the paths of the three incident and reflected rays onto the paper as before.**
6 **Look into the mirror. What do you see? Describe your observation.**

Interpret your data.

- **Remove the mirror from the paper. Using the ruler, trace the paths of the reflected rays back behind where the mirror was, until they meet. Mark this point and label it 'image'.**
- **Similarly, trace the paths of the incident rays back to a point where they meet. Mark this point and label it 'object'.**
- **Measure the following distances and record them.**
  - **(a) Distance along the central ray from the object point to the mirror surface – this is called the object distance**
  - **(b) Distance along the central ray from the mirror surface to the image point – this is called the image distance.**

Organize your measurements so that you can **deduce** a relationship between the object distance and the image distance.

Evaluate your experiment as before. How could you have improved the reliability of your experiment? How could you have improved the validity of your experiment?

◆ Assessment opportunities

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

You may have realized from the first experiment in the *What's my image* activity that rays striking a plane mirror are reflected away from the mirror at the same angle. This is known as the **law of reflection**

angle of incidence = angle of reflection

Try waving at yourself in a plane mirror. Since the rays on your left-hand side are reflected back on the left-hand side at the same angle as they are incident, your left hand still appears on the left of the image. However, your image is looking back at you, as though you had turned around to face yourself. So your image in the mirror is actually using its right hand! This is how lateral inversion occurs.

Similarly, you probably noticed that the image in a mirror appears to be 'behind' the mirror the same distance as the object is placed in front of it. But the image isn't really there – it may sound silly, but if you place your hand behind the mirror, you don't see the image appearing on your hand! An image that cannot be 'caught' like this or projected in reality is called a **virtual image**. This may make more sense when we compare to the opposite case. The images that you see projected onto a classroom interactive whiteboard or onto a cinema screen can be touched if you reach out your hand to touch the screen. You would even see the image appear on the back of your hand. Since this kind of image exists in 'real space' it is called a **real image**

There is another property of the mirror image that we should note, even though it seems obvious. The image in a plane silver mirror is in colour, and the colours are the same as those of the object. This may not be the case, however, if our mirror is tinted or coloured in some way, so that it reflects certain colours but not others – such as the image we see reflected in the surface of a piece of coloured plastic.

Figure 5.8 Funhouse mirrors

Finally, the image you see in a plane mirror is the same size as the object producing it. But what about the images in the mirrors in Figure 5.8? We can see that a curved mirror may produce images that are a different size to the object, and indeed are not even the same way up! The funhouse mirrors in Figure 5.8 produce their weird effects by combining concave and convex surfaces to make us look more interesting!

ACTIVITY: Spoon mirrors

ATL

- Communication skills: Make inferences and draw conclusions; Organize and depict information logically

Individually: In this experiment you will use spoons to model the effects of curved mirrors. (If your school laboratory has larger curved mirrors, you can use those too.) You will also learn some new scientific vocabulary.

Inquiry question: What are the properties of images produced by mirrors with different curved surfaces?

For this experiment you will need one large, very polished spoon, such as a soup spoon or ladle.

To make observations, you will need to use scientific vocabulary precisely. Use a scientific dictionary or search online to find the meanings of the words below. **Define** the terms in writing.

magnified diminished upright inverted
virtual image real image

- **Turn the spoon so that you are looking into the bowl part, curving inwards. This is known as a concave surface.**
- **Hold the spoon as close as you can to your face while still being able to see an image. Describe the image you see using the words you defined above.**
- **Now slowly move the spoon away from yourself. Stop every few centimetres and observe the image produced. Make a note of any changes.**
- **Now turn the spoon around so that you are looking into the back, curving outwards towards you. This is known as a convex surface.**
- **Repeat the procedure to observe the image formed, as above.**

Organize your observations and **present** them such that the image properties can be compared. **Summarize** your observations of the two kinds of mirror image produced, using the vocabulary above.

Assessment opportunities

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

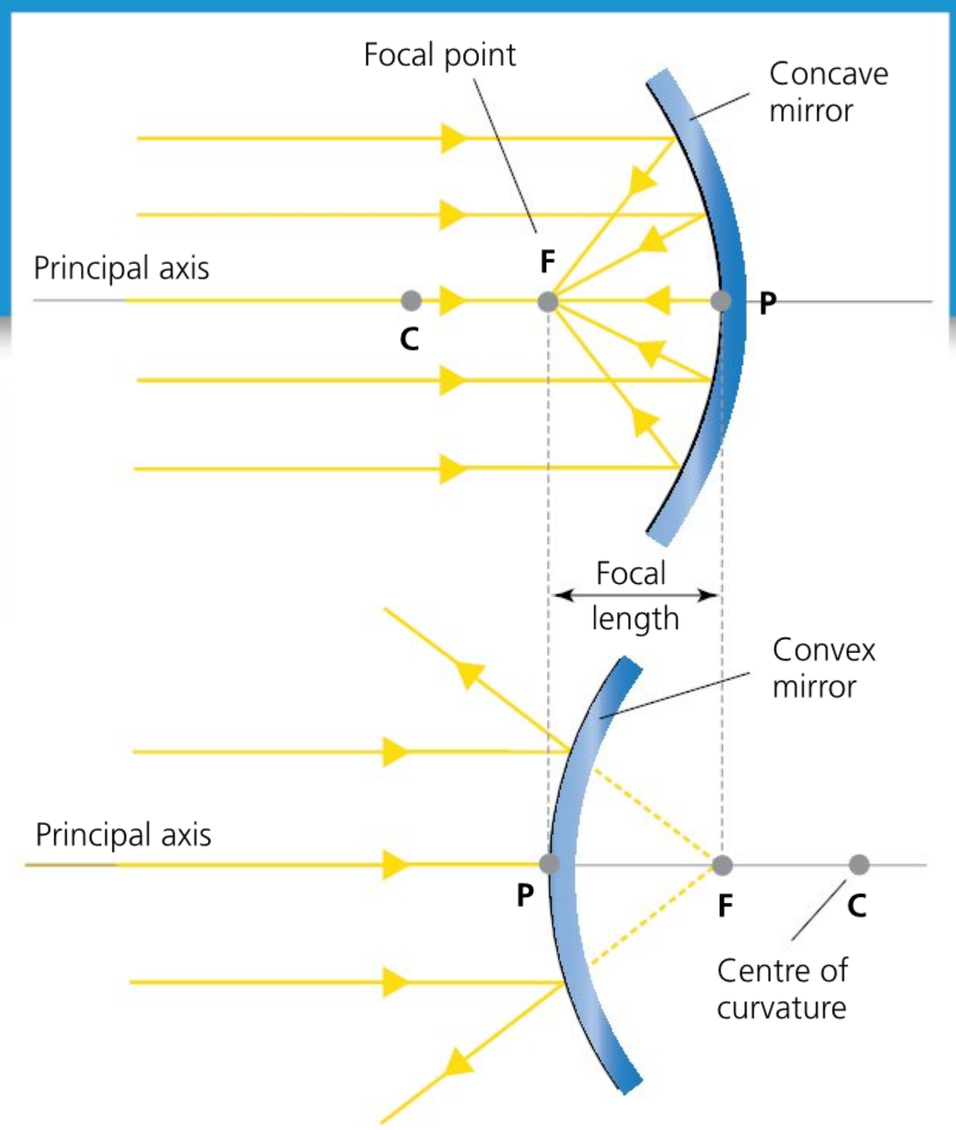
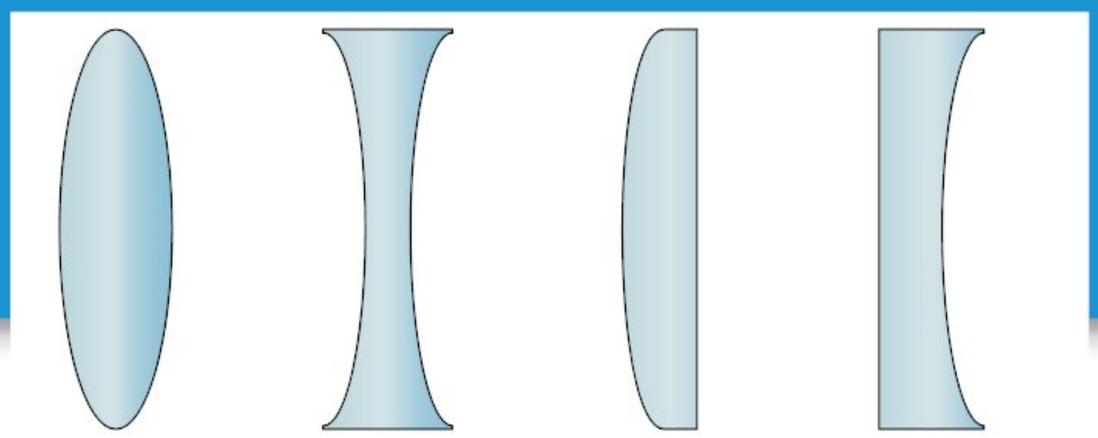


Figure 5.9 Concave and convex mirrors

Figure 5.9 shows how concave and convex mirrors reflect incident rays that strike parallel to the **principal axis** of the mirror – that is, the line that is at 90° to the curve at the centre point of the mirror (marked P in Figure 5.9).

When rays spread out they are said to **diverge** For this reason, a convex mirror might be called a diverging mirror. Conversely, when rays are collected together to a point they are said to **converge** and the mirror is a converging mirror. Parallel rays reflecting from a converging mirror all cross the principal axis at the **focal point**, F. Since a convex mirror does not converge the rays but diverges them, the rays look as though they came from a focal point that is *behind* the mirror – so the focal point is virtual.

Figure 5.10 A reflecting astronomical telescope



■ **Figure 5.11** Convex and concave lenses

A BIGGER PICTURE

What is the first part of the camera in Figure 5.3 encountered by light rays? If you look closely, you will see a sequence of glass shapes in the front of the camera. These are the lenses. You may recall from your light review quiz, or from *MYP Science by Concept 2*, Chapter 4, that our eyes also contain a lens. A lens is really a special kind of prism that uses refraction to change the path of incident light rays. Refraction occurs whenever light waves (or other kinds of wave) pass from one kind of material or medium to another.

Just as with mirrors, lenses are named according to the curvature of their surfaces. If both surfaces of a lens are curved, they are called biconvex or biconcave (Figure 5.11).

$$\text{power of lens, } P = \frac{1}{f}$$

where power P is measured in dioptres (D), and f is the **focal length** of the lens in metres (m). So what properties of the lens affect its power?

ACTIVITY: Making images

■ ATL

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

In pairs: In this activity, you will use lenses of different shapes to produce images.

Inquiry question: What are the images produced by biconvex and biconcave lenses?

With reference to Figure 5.11, and using what you have already learned about the effects of mirrors on incident rays, **predict** what you think will be the effect of the two lens types on incident light. What kinds of images do you think they will produce?

For these experiments you will need:

- **A biconvex lens**
- **A biconcave lens**
- **A bright source of light**
- **A piece of squared paper**

Experiment 1

1 **Hold the biconvex lens up to a bright source of light that is a fairly long distance away – for example, on the other side of the room (a window or a light bulb).**
2 **Hold a piece of squared white paper behind the lens and move it steadily backwards and forwards until you see an image produced on it.**
3 **Describe the image you see, with the scientific vocabulary you have learned.**
4 **Now try the same with the biconcave lens. Describe what you see on the paper.**

Experiment 2

1 **Take the biconvex lens and hold it close over this page. Look through the lens. Move the lens backwards and forwards until you see a clear image.**
2 **Describe what you see in the lens, using the correct scientific vocabulary.**
3 **Now try the same with the biconcave lens. Describe what you see this time.**

Were your predictions correct? **Explain** why you saw the images you observed with the different lenses.

◆ Assessment opportunities

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

EXTENSION

Investigating lenses

Here are two ideas that you could develop as scientific investigations.

1. Spectacles are used to help the lenses in the eye to form an image. To see a clear image, we need our eyes to focus the image on the retina at the back of the eye. The lens in some people's eyes focuses distant objects too close to the lens, while for other people the focal length is too long and the image is formed beyond the retina. The kind of lens required for the spectacles will depend on the way the eye lens works.

   Design an investigation to investigate the way different spectacle lenses affect incident light.

2. It is possible to make lenses using frozen distilled water, or even transparent jelly. The lenses can be formed using moulds made from putty. This allows you to control the shape and curvature of the lens.

   Design an experiment to investigate the effect of lens curvature on strength using your own homemade lenses.

SENSE IT

In the *Investigating spectacle lenses* activity you may have noted that the purpose of spectacles is to bring an image into focus onto each eye's retina. In *MYP Sciences by Concept 2*, Chapter 4, we saw that the retina consists of tissue covered with special light-sensitive cells that transform the incident light energy into electrical nerve impulses for the brain. The retina is a kind of **sensor**, since it transforms the information in a light wave into signals that can then be interpreted.

Naturally, all digital cameras also require a sensor to fulfil the same function as the retina. The charge-coupled device (CCD) at the back of the camera does this. A CCD is made from a grid of **semiconductor** 'switches' that release electrons whenever they interact with light. (It may be interesting to note that before CCDs were invented, all cameras used a chemical-coated film to produce images in hard copy. Some photographers still prefer this method.) A CCD thus has a similar function to a retina, but in fact the CCD responds quite differently to a human eye.

Of course, CCDs are not the only kind of sensor. Just as living things gather information about their world in multiple ways (smell, taste, touch, hearing and so on) so we have developed artificial sensors to measure all kinds of properties.

ACTIVITY: Seeing the light

ATL

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

Individually: In this activity you will explore how a CCD works and evaluate its function.

Figure 5.12 The LED on a TV remote control transmits the information

- **Take a TV or music system remote control. Identify the emitter – the light-emitting diode (LED) – at the end of the remote.**
- **Press any button on the remote and observe. See anything?**
- **Using any digital camera device (such as your cell phone, tablet or a camera), record the remote LED while buttons are being pressed. What do you see? Is this surprising?**

Now answer these questions:

1 **Describe the observations you made of the TV remote with your eyes, and then with the CCD device.**

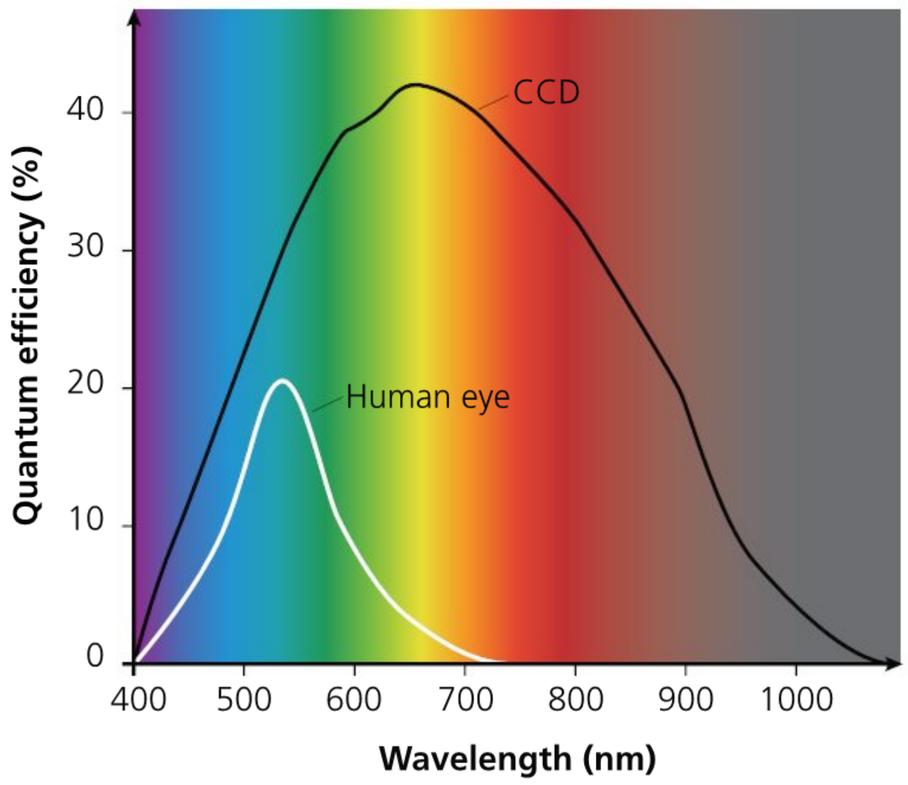


Figure 5.13 Response of a standard CCD and human eye to incident light

2 **Outline what is shown in Figure 5.13. Research to find out what 'quantum efficiency' describes. Apply this information in order to interpret and explain what the x axis of Figure 5.13 represents.**

3 **Compare the information for the human eye and the CCD in Figure 5.13. Outline the information in the graph by identifying at least three differences between the response to incident light of the human eye and that of the CCD.**

4 **Explain why you can see the TV remote LED flashing with the CCD, but not with your own eyes.**

Assessment opportunities

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

How can information be carried by a wave?

■ **Figure 5.14** (a) Morse code keys, (b) Beacon fire, (c) a semaphore, (d) maritime signal flags

Long-distance communication holds societies together. We noted in Chapter 1 that early civilizations devised complex networks of communication, such as roads, for carrying messages. In England during the sixteenth century, a network of beacon fires across the country was used to send news of invading ships. Unfortunately, the possibility of rainy or foggy days meant that the main method of communication remained postal delivery or a spoken message delivered by a person. This didn't change until the science of electricity was understood in the nineteenth century. The first long-distance messaging system was the telegraph. A telegraph is an electric circuit containing a power source, a switch and a signaling device such as a buzzer or light. The switch and the signal device, however, may be far apart, connected by wires. But *how* to communicate the message?

Samuel Morse (1791–1872) was a US inventor who, in 1837, invented a code consisting of dots and dashes that represented the letters of the alphabet and a few punctuation symbols. The dots could be represented by short buzzes or flashes of light, and dashes by longer signals. With practice, a Morse operator could transmit perhaps 50 words per minute this way. Morse code still exists and is used in certain emergency situations. Although crude, the breakthrough was conceptual, because Morse had invented a method of **encoding** information using a wave.

Morse code

A	•–	J	•–––	S	•••	1	•————
B	–•••	K	–•–	T	–	2	••–––
C	–•–•	L	•–••	U	••–	3	•••––
D	–••	M	––	V	•••–	4	••••–
E	•	N	–•	W	•––	5	•••••
F	••–•	O	–––	X	–••–	6	–••••
G	––•	P	•––•	Y	–•––	7	––•••
H	••••	Q	––•–	Z	––••	8	–––••
I	••	R	•–•			9	––––•
						0	–––––

ASCII codes

A	41	J	4A	S	53	1	31
B	42	K	4B	T	54	2	32
C	43	L	4C	U	55	3	33
D	44	M	4D	V	56	4	34
E	45	N	4E	W	57	5	35
F	46	O	4F	X	58	6	36
G	47	P	50	Y	59	7	37
H	48	Q	51	Z	5A	8	38
I	49	R	52			9	39
						0	30

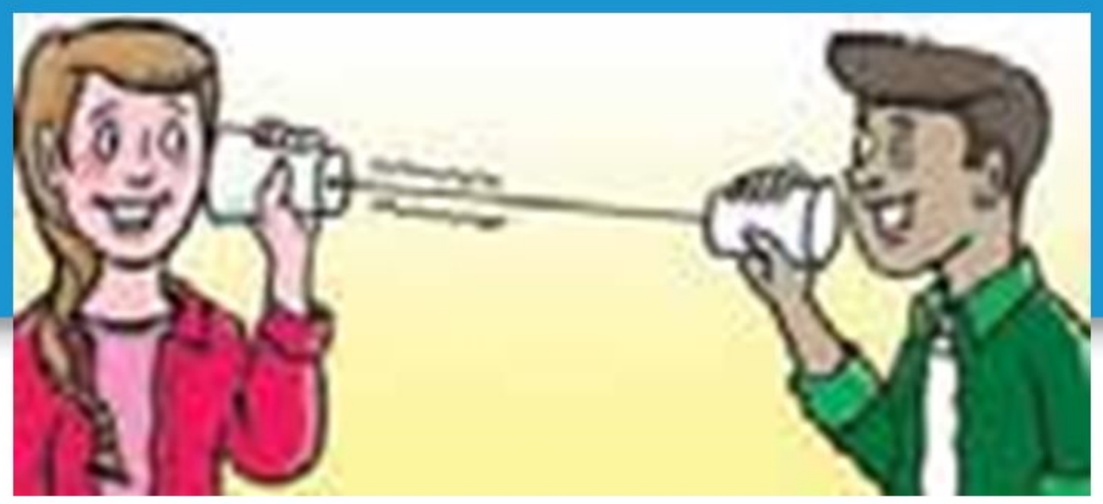
■ **Figure 5.15** Morse code and computer ASCII codes

■ **Figure 5.16** Telephones through the ages

HANGING ON THE TELEPHONE

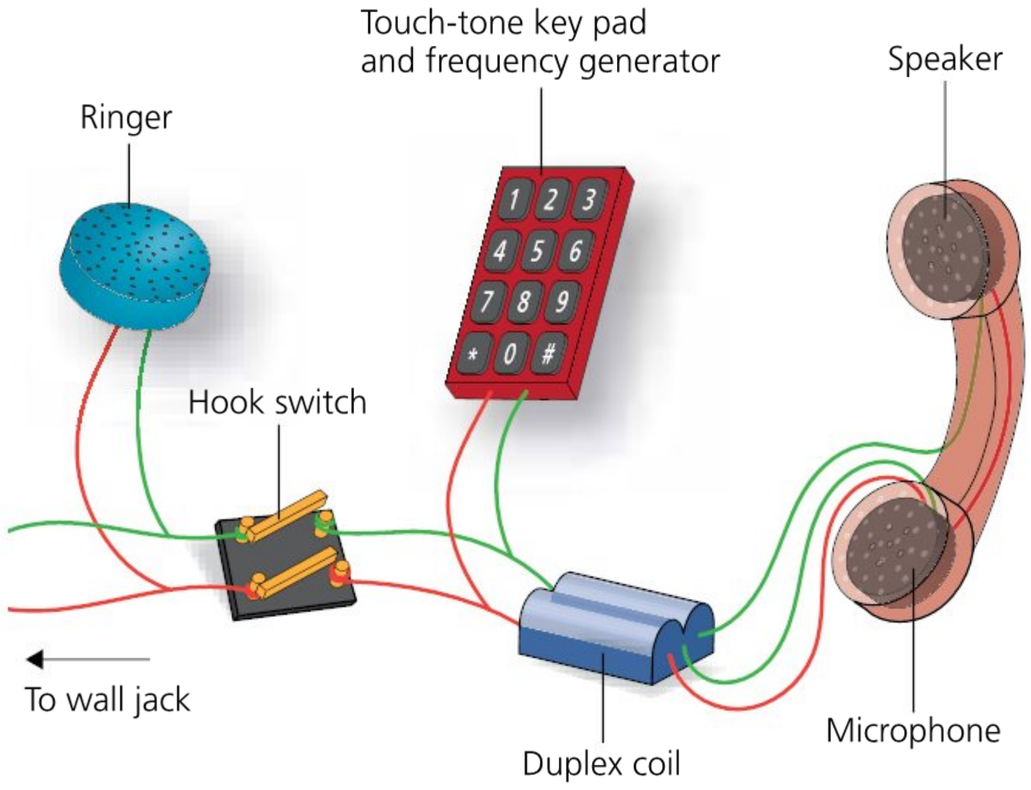
No matter how revolutionary, telegraphy is not much of a way to communicate personal information. Since human beings communicate with continuous sound waves, engineers now focused on finding a way to transmit the human voice. Perhaps you have made a simple cup-and-string telephone like the one shown in Figure 5.18? The string telephone works because the paper cups transform sound waves in the air into physical vibrations that travel along the string, and then transform the vibrations back into sound waves. However, you will have noticed that this is not very efficient, since the signal sent along the string is very weak and quite often works no better than simply shouting to each other across the room!

In the early nineteenth century, a number of inventors filed patents claiming to have achieved transmission of the human voice using electrical signals – such as Italian inventor Antonio Meucci (1808–1889). Their inventions were not very practical and so were never developed as commercial devices. Scottish-American inventor Alexander Graham Bell (1847–1922) is credited with achieving the first practical transmission of a human voice. Bell's device transformed sound waves into electrical energy and back again – using a microphone

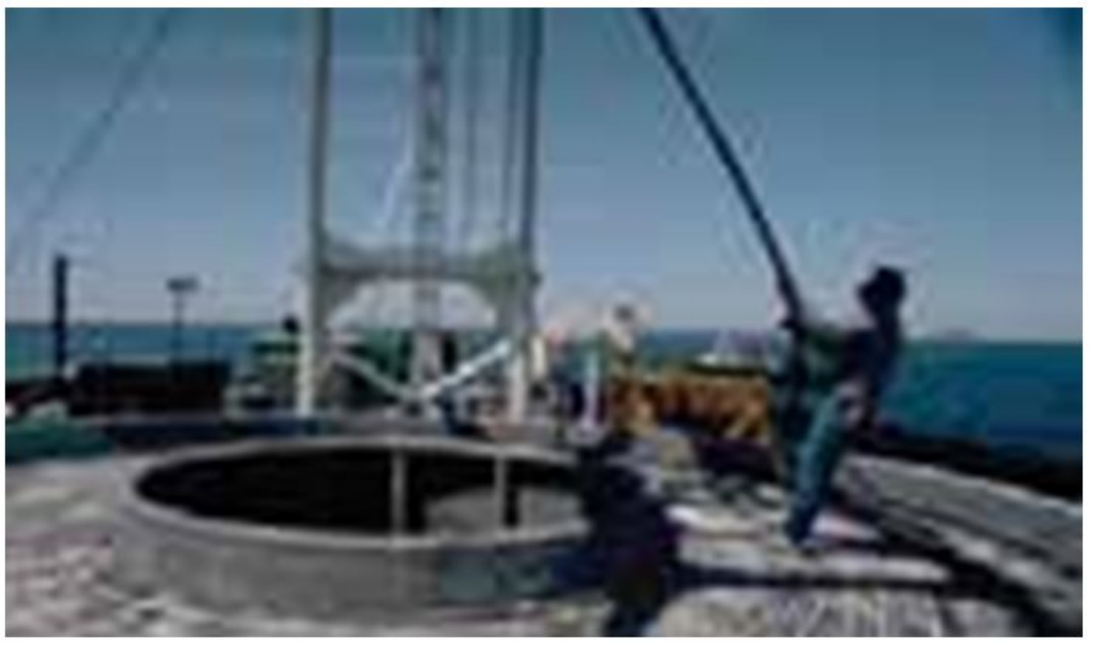


■ **Figure 5.17** Cup-and-string telephone

and a loudspeaker. Bell adopted the name telephone for his invention, from ancient Greek meaning 'to hear at a distance'. The first telephone conversation occurred between Bell, in his laboratory at home, and his assistant Thomas Watson, who was in the cellar. Bell is reputed to have said, '*Mr Watson, come here, I want to see you* and Watson replied that he would be right there!



■ **Figure 5.18** Components and energy transfer in a telephone. The microphone and the loudspeaker are essentially the same device, working to transform sound energy to electrical energy and back again



■ **Figure 5.19** Real telephone cables – such as this transatlantic cable – carry signals over very large distances

ACTIVITY: Telephone signals

ATL

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

Equipment

- **A microphone**
- **A loudspeaker**
- **A cathode ray oscilloscope (CRO) *or* an oscilloscope app on a mobile device or computer, capable of measuring external signals in millivolts (mV)**
- **An amplifying signal generator or tone generator app on your mobile device or computer**
- **5 × 1 Ω resistors (low power)**
- **Wires and connectors**

Background information: An electrical signal is an electric current that travels through a conductor as a wave. The amplitude of the signal is related to the power carried by the signal. In this experiment, we will use resistors to model the way a very long wire affects a signal.

Suggest a hypothesis to **explain** how an electrical signal might change as it travels through a telephone wire. **Predict** how this will affect any measurements you might make of the signal.

Method

1. **First connect the microphone directly to your CRO. Speak into the microphone with a normal voice. Some oscilloscope software will automatically adjust its sensitivity to show the signal produced by the microphone, but with a CRO you will need to manually adjust the sensitivity until you see the signal. The output potential difference from a small laboratory microphone is usually around 1 V.**
2. **Estimate the average amplitude of the signal produced.**
3. **Now disconnect the microphone and connect the tone generator to the CRO. Select a sine wave. Set the frequency on the generator to around 500 Hz. Set the amplitude on the generator to give a signal approximately equal in amplitude to the signal observed for your voice.**
4. **Now connect the signal generator to the resistors as shown in Figure 5.20.**

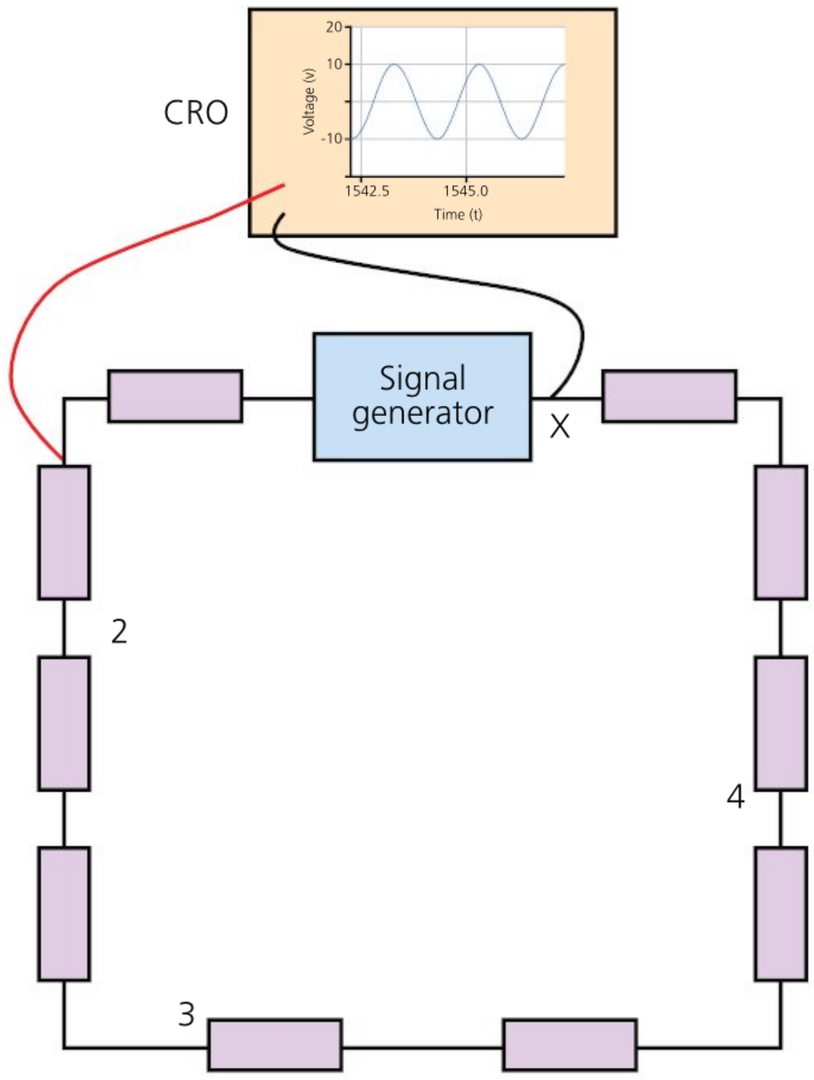


Figure 5.20 Signals circuit setup

5. **Turn on the signal generator. Connect one terminal of the CRO or app connectors to point X.**
6. **Now connect the other connector of the CRO or app to points 1, 2, 3, 4. Measure the amplitude of the signal at each point.**

Record all of your results appropriately, with units.

Describe your results in a conclusion. **State** whether your prediction was correct. **Explain** what you observed in terms of what you know about electric circuits and resistance (see Chapter 4).

The loss of amplitude – and power – in a signal when transmitted is called signal attenuation.

Outline what your observations suggest about the attenuation of a signal produced by a telephone over much longer distances.

Evaluate your experiment. How could you have improved the experiment's design to make it more reliable? How valid was your experiment as a way to find out how a signal is affected by long-distance transmission? **Suggest** ways in which a telephone system could be modified to reduce attenuation.

Assessment opportunities

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

Even while work was taking place to develop communications through a wire, another discovery had been made that would make it possible to send signals across the planet, but with no physical connection at all. In 1887, German physicist Heinrich Hertz (1857–1894) had demonstrated an earlier prediction by James Clerk Maxwell (1831–1879) that invisible waves of **electromagnetic energy** could carry energy through space. Hertz's demonstration used a spark to create an **electromagnetic pulse** or EMP of radio waves, which was then detected by a loop of wire nearby. When asked what use might be found for his apparatus, Hertz replied, *'It's of no use whatsoever'* – yet he had invented a simple radio!

The challenge was to turn this interesting phenomenon into a useful communications system. The Italian entrepreneur and inventor Guglielmo Marconi (1874–1937) was one of the most prominent figures in developing and commercializing the effect. In 1897, he sent a Morse code signal produced by a spark **transmitter** across Salisbury Plain in England, and by 1903 had succeeded in transmitting a Morse code message from President Roosevelt in the United States to King Edward VII in England.

But telephones could already do more than this: most importantly, they could transmit the human voice. It was a Brazilian amateur scientist and priest, Landell de Moura (1861–1928), who first managed to build a device to transmit his voice over 8 km in São Paolo, and in 1906 the Canadian Reginald Fessenden (1866–1932) was able to transmit himself playing the violin across a distance of hundreds of kilometres to ships in the Atlantic Ocean. The radio age had arrived!

It is much more complex to transmit a **continuous wave signal**, such as a human voice, than to send a single pulse of energy. The part of the **EM spectrum** that is classified as radio waves extends from **frequencies** around 1 megahertz (MHz) to a few gigahertz (GHz) – a factor of thousands of cycles of difference. However, the human voice is mostly comprised of sound waves with frequencies that are around a few hundred kilohertz (kHz). Transforming sound waves directly into electromagnetic energy would not therefore produce radio waves.

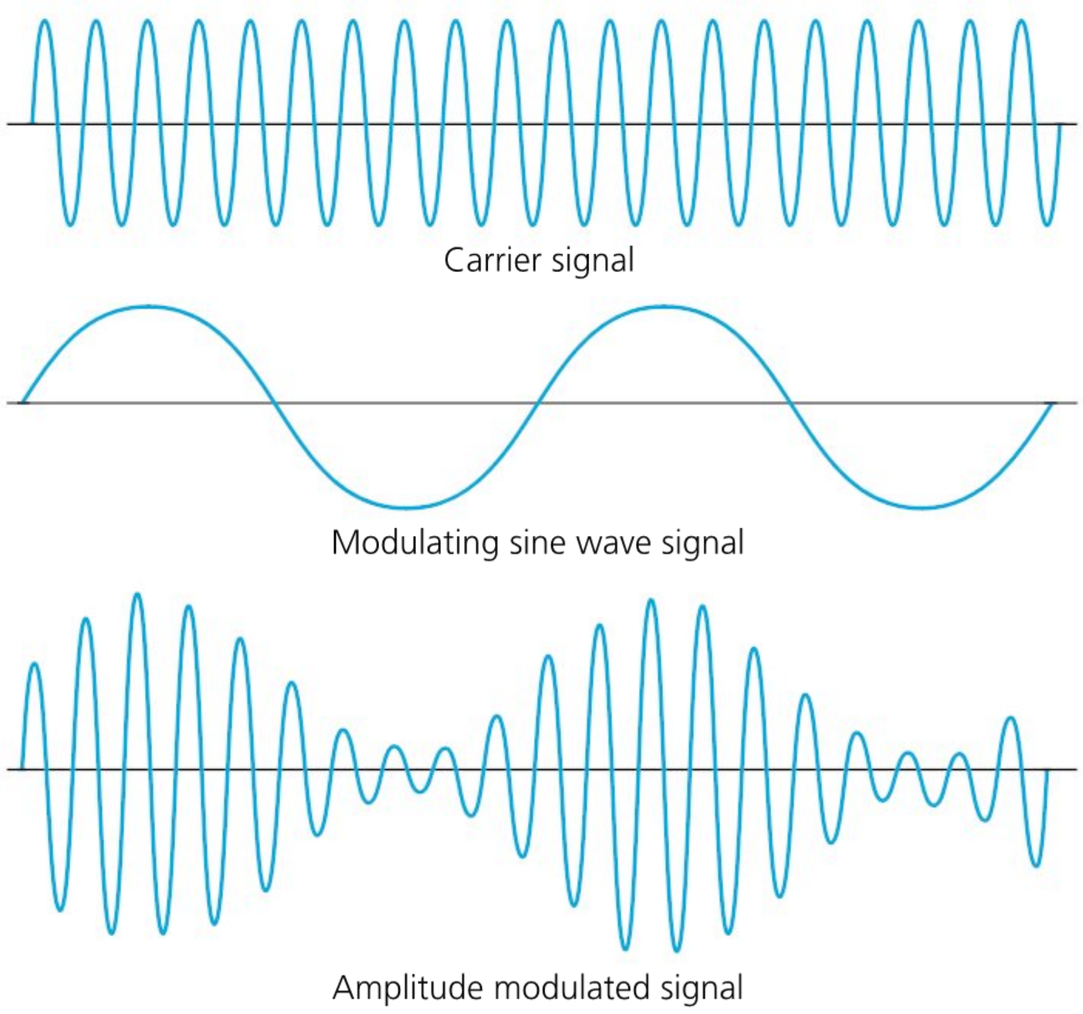


Figure 5.21 Amplitude modulation of a radio wave

The solution to this problem was to use a radio wave whose amplitude varied in the same waveform as the information that was to be transmitted – such as the sound of Reginald Fessenden's violin. The radio signal then carries the information signal encoded in its amplitude. This technique is known as amplitude modulation.

The radio receiver then has to demodulate the information signal, separating it out from the carrier wave so that it can be transformed back into sound. This is achieved using special kinds of electric circuits called **resonators**. You can find out more about this in *MYP Physics by Concept 4&5*, Chapter 7.

Radio transmission and telephony have brought the world together and created the conditions for a global society of instant communication. The quest for faster, better communications continues. Radio signals are

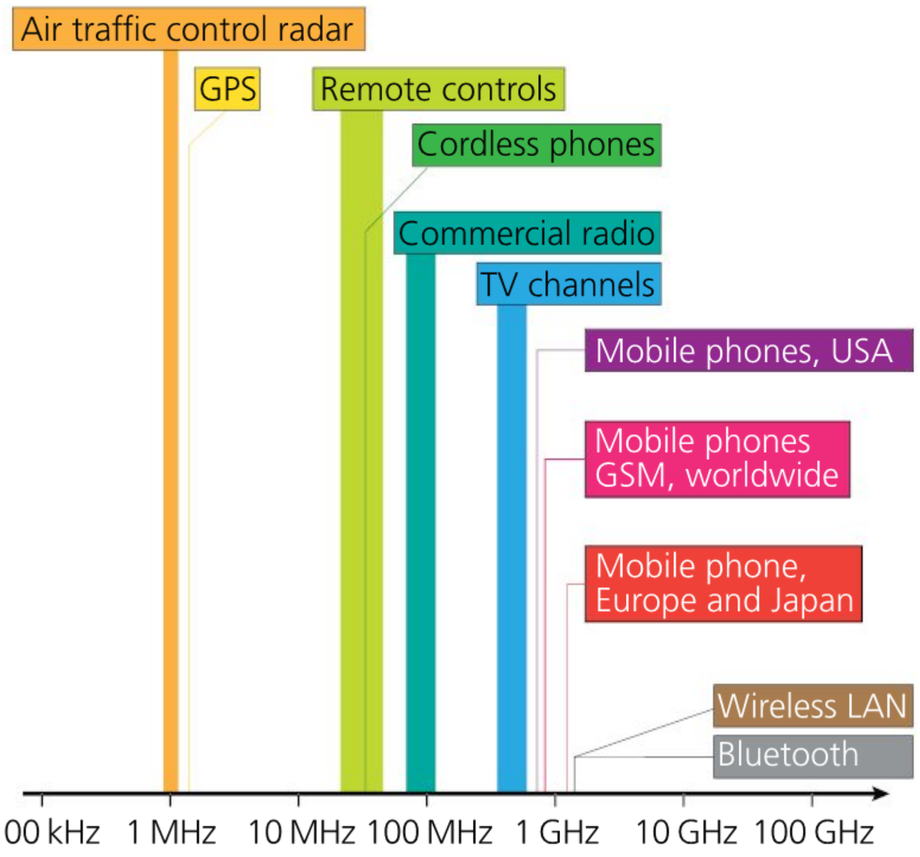


Figure 5.22 Typical frequency ranges for different kinds of radio transmission

Figure 5.23 Optical fibre versus copper cable

vulnerable to interference from other radio sources, and like all kinds of electromagnetic radiation, their strength decreases rapidly as they spread out from the transmitter. Similarly, we have seen how signal attenuation occurs in copper wires due to electrical resistance.

Figure 5.23 shows a modern **optical fibre** next to a copper telephone cable. What differences do you notice? While the copper cable can carry tens of

ACTIVITY: Voices across the globe

ATL

- Communication skills: Make inferences and draw conclusions; Paraphrase accurately and concisely
- Information literacy skills: Access information to stay informed and to inform others

In this activity you will write a letter to a scientific journal of the early twentieth century about the possibility of long-distance radio transmission.

In the early days of radio, many scientists dismissed the new discovery, believing that it could only ever be used over short distances – at most, as far as the horizon. Marconi demonstrated that this was not correct with his early long-distance transmissions. In fact, it was amateur radio enthusiasts who reputedly first achieved really long-distance two-way continuous wave transmission from Europe to North America.

Research the terms below, and write notes about them. Make note of the sources you use.

skywave ionosphere relay satellites

Imagine you are an amateur radio enthusiast in the early twentieth century. You want to argue that radio transmission could be used to communicate across the whole world.

Write a letter to a scientific journal, in which you:

- **outline** the arguments of those who think that radio can only be used to communicate over short distances
- **describe** the science showing that this is not the case – **explain** how skywaves occur in the ionosphere, and **outline** the conditions under which long-distance communication might best be achieved
- **suggest** how (in the future!) satellite telecommunications could work
- **summarize** how you think the new technology of long-distance radio might change the world socially, economically and politically.

In your letter, use the scientific terminology you have learned. Be sure to include citations and references to your sources, using the referencing standards recommended by your school.

Assessment opportunities

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

signals at the same time, the optical fibre can carry many thousands of signals simultaneously, with very low interference and signal attenuation. Optical fibres use light to transmit the information, rather than electrical signals. For this reason, they are made from high-quality glass rather than expensive copper metal – and are cheaper as a result. Many countries are now replacing their copper cable telephone systems with optical fibre networks.

Optical fibres transmit light rays using a phenomenon called **total internal reflection**. The prism in the DSLR camera also uses this effect. Can you deduce from Figure 5.3 how the light ray is affected by the prism?

ACTIVITY: Total reflection

ATL

- Communication skills: Take effective notes in class
- Critical-thinking skills: Practise observing carefully

Inquiry question: Can light be trapped?

In pairs: In this activity you will observe total internal reflection occurring in a water spout.

SAFETY: In this demonstration you will be using a laser pointer. Laser pointers can damage your eyes if the beam enters them directly – take care never to point at anyone. While carrying out the experiment, make sure that the eye level of all observers is above the bottle, to avoid accidental reflections of the laser.

Equipment

- **An empty plastic bottle**
- **A bradawl or other implement for making a small hole**
- **A laser pointer**
- **A bowl**
- **A small rubber bung**
- **Water**

Method

1. **Make a small hole at the bottom of your plastic bottle. Enlarge the hole until it is about 1 cm in diameter. Try to remove any jagged edges.**
2. **Push the bung into the hole so that it seals.**
3. **Support the bottle about 30 cm above the bowl.**
4. **Pour water into the bottle.**
5. **Point the laser pointer through the side of the bottle and aim the beam at the hole (note safety caution above – take care to avoid accidental reflections of the beam).**
5. **Remove the bung so that water pours out of the hole and into the bowl.**

What do you observe at the point where the water spout meets the water in the bowl? Do you notice anything else along the edges of the water spout?

Summarize your observations in a paragraph.

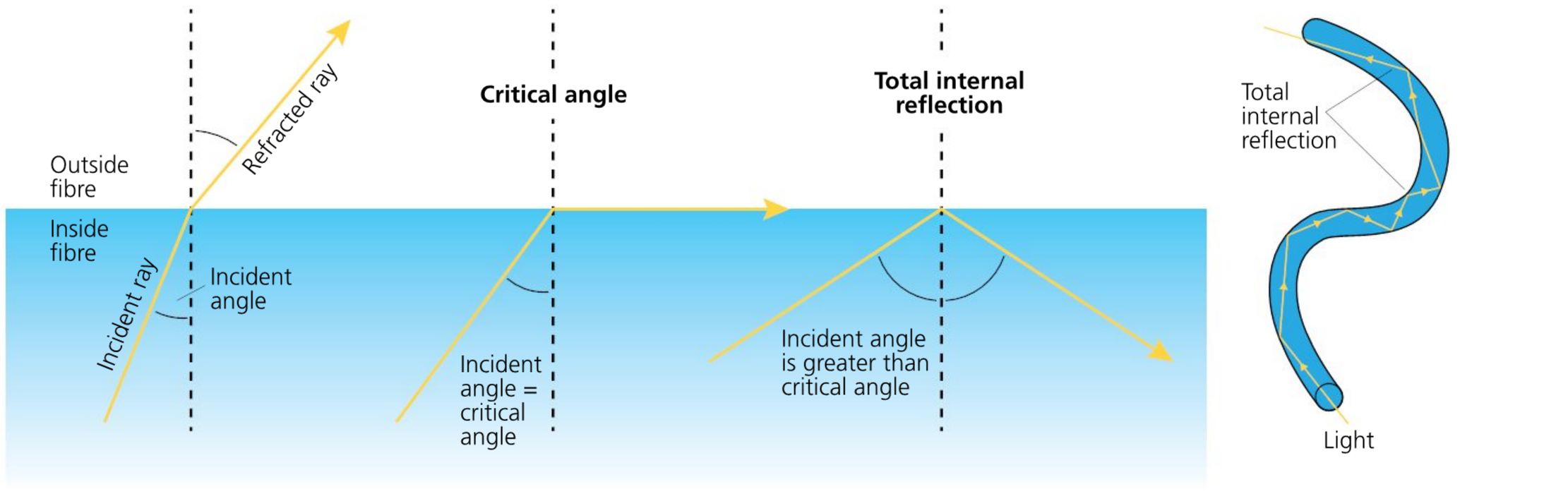


Figure 5.24 Total internal reflection occurs where incident light is reflected back at the boundary between two media

Total internal reflection only occurs where the angle of incidence of the light is above a certain **critical angle** (Figure 5.24) – at other angles, the light rays will refract and 'leak' out of the medium. Fibre optic communication systems use tiny lasers to transmit information through optical fibres that utilize this effect. The lasers encode the information into the light ray by flashing on and off, so this is a form of amplitude modulation. In the next section we will explore how such a simple on/off modulation can be used to encode very complex information, provided you can do it quickly enough!

What are the advantages and disadvantages of analogue and digital systems?

THAT'S ENTERTAINMENT!

■ **Figure 5.25** (a) Edison phonograph, (b) a vinyl LP record, (c) a magnetic audio tape cassette, (d) a BluRay disc

We have seen that there are really two fundamental ways to communicate information: either through a continuous wave that captures the information from the original source, or by sending wave pulses that encode the information using a code of some kind.

Most early entertainment systems used direct recording and reproduction of a sound. The Edison phonograph (Figure 5.25) was invented in 1877 by the famous American inventor Thomas Edison (1847–1931). It worked by capturing sound in a trumpet that ended in a **diaphragm**. In the centre of the diaphragm a needle then vibrated and scratched a rotating drum covered with tin foil. Search **Edison phonograph Mary had a little lamb** or go to this location on SoundCloud to hear online reproductions of his very first recording – a children's nursery rhyme!

https://soundcloud.com/kpcc/mary-filter?in=kpcc/sets/edison-1878-tin-foil

You will notice that by today's standards the sound quality is relatively poor, but technological improvements led to the development of the gramophone and long player (LP) record.

An LP is an example of an **analogue** system, because it captures and reproduces the original waveform. Analogue recordings dominated sales of music from the 1920s to the 1980s. With the introduction of **transistor** electronics in the 1950s, new machines had been made that carried out calculations using electronic switching systems. In a digital computer, information is encoded by a series of switches that can be either on or off. Each switch can then store either a zero (off) or a one (on) (usually the voltage representing a one is between 3.5 V and 5 V).

■ **Figure 5.26** (a) Close-up of an LP track with the stylus in the groove

Links to: Mathematics and computing

Counting to one: Binary notation is a number system containing just two digits: 0 and 1. Like other number systems, or bases, the actual value represented by a digit depends on its position within a number (Table 5.2). Starting from the right and working left, each column represents a power of 2.

Power of 2	$2 = 2 \times 2 \times 2$	$2^2 = 2 \times 2$	$2^1 = 2$	2
Decimal place value	8	4	2	1
Decimal value of number = 1 × 1 = 1	0	0	0	1
Decimal value of number = (1 × 1) + (1 × 2) = 3	0	0	1	1
Decimal value of number = 8 + 4 + 2 + 1 = 15	1	1	1	1

■ **Table 5.2** Place value in binary

In computing, each of the digits in a binary number is called a binary digit, or bit for short. Table 5.2 shows four bits – the maximum value this can represent is the binary number 1111, which is equal to 15 in our usual decimal number system. Computer memory is measured in bytes, where 1 byte = 8 bits.

Numbers can then be represented using a number system called binary notation. Since there are only two possible numbers in binary notation (0 or 1), even quite small numbers tend to be very long. On the other hand, electronic systems can work very quickly and so can process a lot of information very rapidly: a modern microprocessor used in an average laptop computer can carry out billions of instructions per second (and this is often multiplied when the microprocessor in fact contains multiple cores).

In fact the computing power of microprocessors has more or less doubled every two years: a prediction made by computer scientist Gordon Moore in 1965!

A barcode – like those found on all goods sold in shops or elsewhere – is an example of a binary coding system. The dark bars encode the catalogue number of the product, where thinner bars represent zeros and thicker bars represent ones (the white spaces are just to distinguish one bit of information from the next).

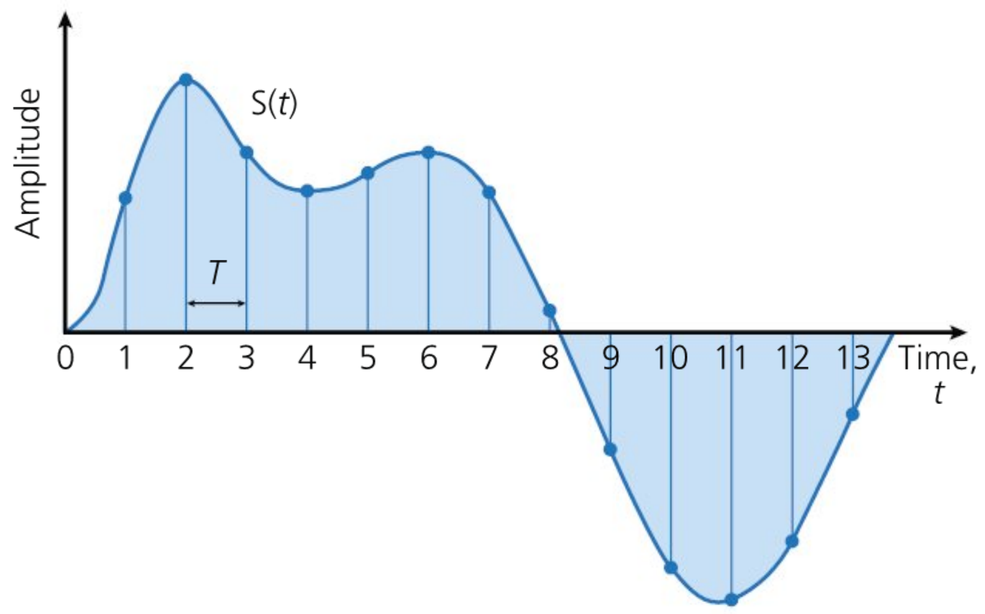
■ **Figure 5.27** Early transistors were about 5 mm in size, and made it possible to reduce the size of a radio to a handheld device

■ **Figure 5.28** A modern microprocessor contains billions of individual transistors in a chip about the same size as the transistor in Figure 5.28

■ **Figure 5.29** Barcodes encode information as binary

How then can a digital system reproduce something as complicated as the waveform of a human voice? The process of **sampling** is used to convert a continuous wave into a series of binary numbers. The waveform is sampled' by a circuit that measures its amplitude very quickly – the faster the measurements are made, the better is the reproduction of the waveform. The rate at which samples are measured is then called the **sample rate**

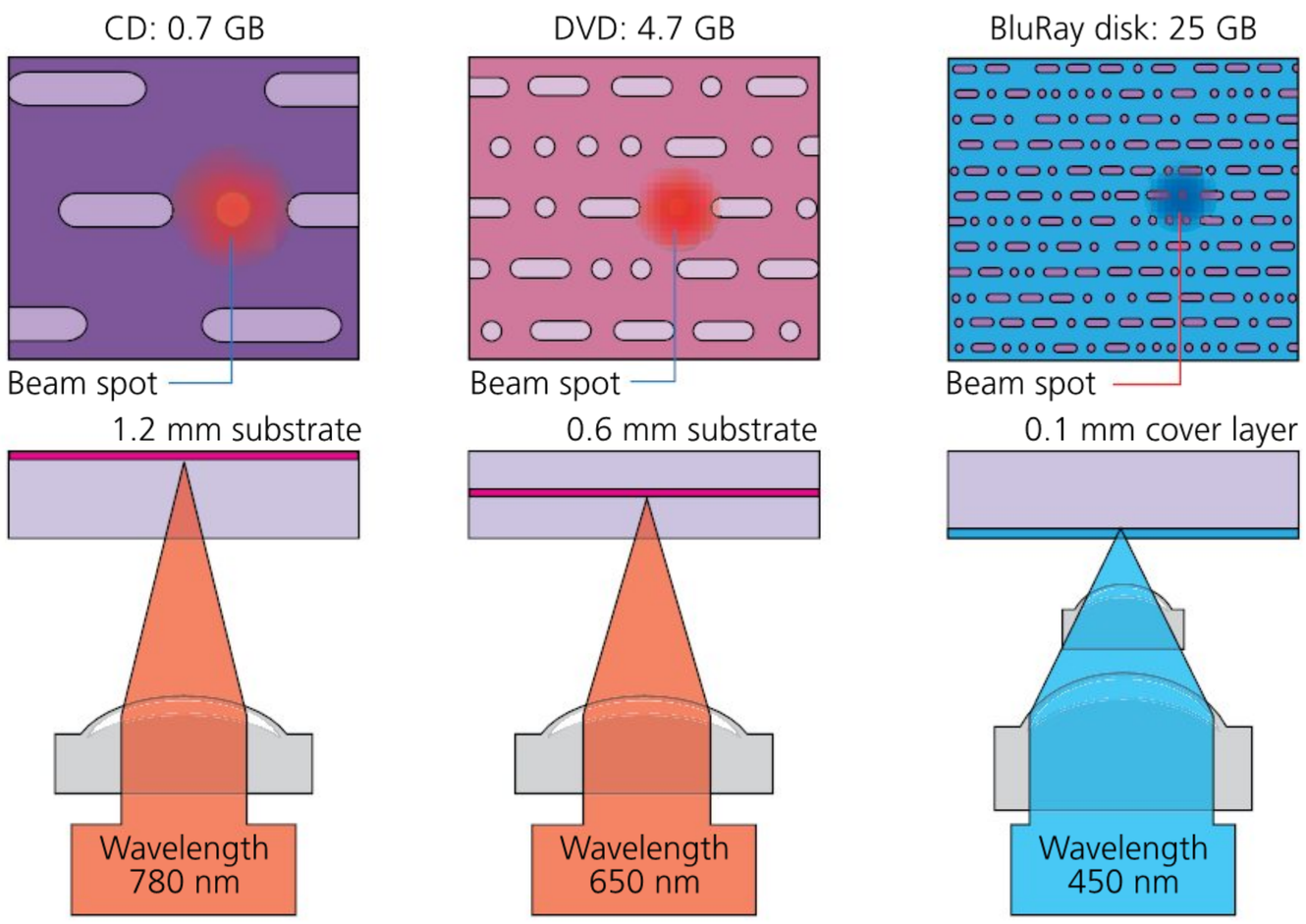
Compact discs (CDs) were developed in the 1980s. CDs and DVDs use a laser to read a spiral track – just like on an LP. However, in the CD the information is encoded digitally as microscopic bumps and pits, which cause



■ **Figure 5.30** Sampling of a waveform

the laser beam to reflect at different angles. When this happens, the reflected beam is detected by sensors, and the different reflections are interpreted as ones and zeros (Figure 5.32).

CDs can hold much more information than any analogue recording system – up to 700 MB (1 megabyte = a million bytes). As technology has advanced, the size of the pits and bumps on discs has become smaller, such that more and more information can be stored.



■ **Figure 5.31** CD, DVD and BluRay data recording

How can we share information effectively?

Figure 5.33 An early cell phone

THE POWER OF SHARING

Figure 5.32 Global internet traffic, captured

SEE–THINK–WONDER

Look at the graphic representation in Figure 5.32.

What do you **see**? What does it make you **think**? What does it make you **wonder**?

Whether transmitting voices or signals by radio waves or by cable, the power of telecommunications lies in connectivity: the bigger the network, the more we can share, and so the more we can collaborate and discover. In this section we will explore the way in which two very important communications networks function as systems: the cellular phone network and the internet.

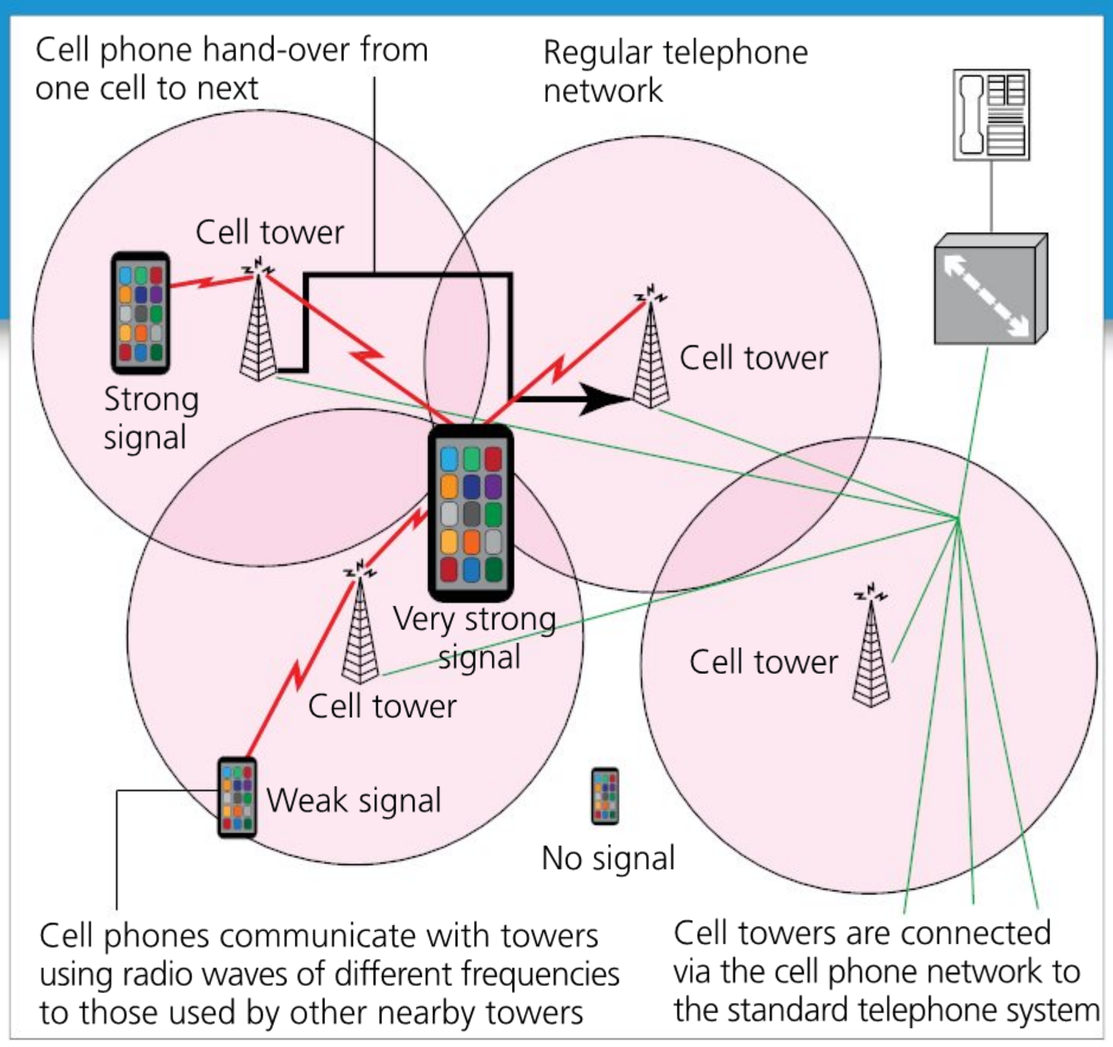
MOBILE VOICES

In the early days of mobile telephony, mobile phones looked like Figure 5.33. This mobile phone could carry voices and nothing else – so no smart apps, no computing power at all! We have seen how radio transmission can be limited in distance. This technological problem has two possible solutions. Either:

- every mobile phone transmits by radio to all other mobile phones in the world, or
- mobile phones transmit to local connections and then use the global telephone cable network.

In fact, both systems exist. A global network of telecommunications satellites makes it possible for satellite telephones with relatively high-power transmitters to connect. These are particularly useful for those who wish to travel in regions where there is no cell phone coverage, or for military applications. However, the radio frequencies available for communication in this way are limited. Each call must use a particular frequency, allocated within a certain region of the radio spectrum (Figure 5.21), called a **channel**. If this frequency is simultaneously used by another telephone, then the signals will become mixed up or interfere.

The problem of frequency interference was solved by the cellular network, used by **cell phones** (often called simply mobile phones). In a cell phone network, phones with relatively low-power radio transmitters can be used to communicate with a network of **base stations**. Each base station has its own limited range of channels available – if you have ever tried to use your mobile phone at a big event, such as a concert, then you may even have experienced what happens when everyone tries to call at the same time and all the channels are used up! The base stations have a range of around 0.8 km in cities and around 8.0 km in rural



■ **Figure 5.34** A cell phone network

areas – these areas are called **cells**. They are arranged in a patchwork network, where transmitters that are next to each other in the network do not use the same frequencies, to avoid interference across channels. When a cell phone user moves from one cell to the next, his or her phone communicates with computer systems at the base station, which then hand over the cell phone to the next base station, so switching to a new frequency. This happens so quickly that we don't notice it when making calls.

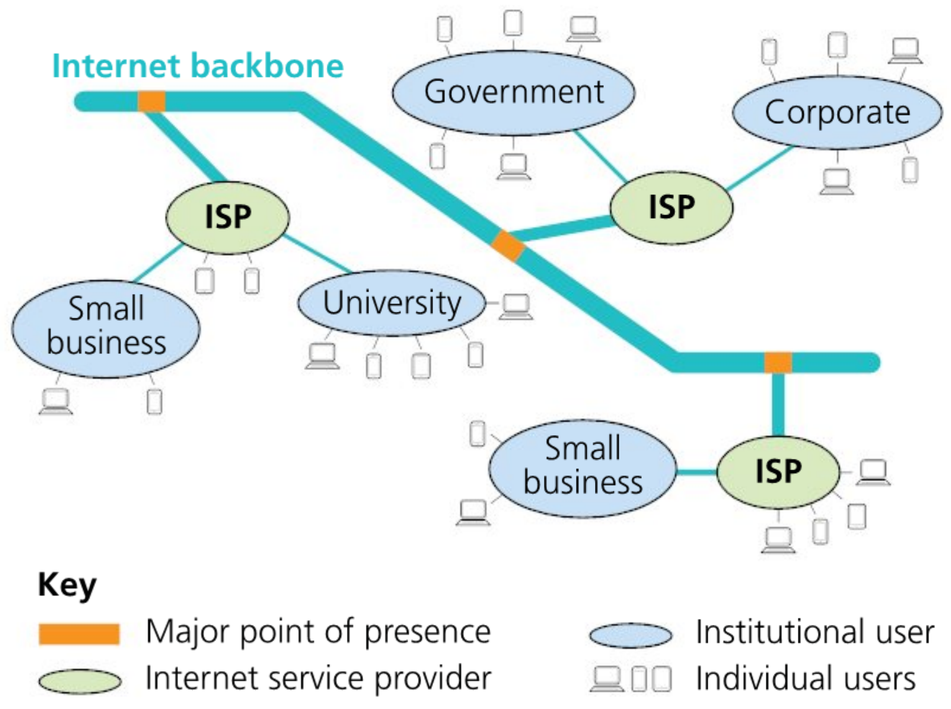
When the signal from a mobile phone is received by the base station, it is then relayed to an exchange that connects the signal to the regular telephone network. In this way a mobile phone can be used to connect to a wired telephone, or to the servers that connect to the internet. Early electronic computer systems in fact began as large **mainframe** computers whose resources were shared by a number of users – perhaps in a company or in a university – using **terminals** connected to a network. When microprocessor electronics progressed very quickly in the 1970s, it became possible to make smaller and smaller computers that could be used individually. One of these was called a personal computer, or a PC for short. While this had the advantage that individual users could utilize all the computing power in the PC for themselves, it also meant that computing became more individualized and less connected. Computer networking is the technology

■ **Figure 5.35** A base station transmitter. Have you seen these where you live?

of connecting computers together so that they can send information to each other, and also potentially combine their individual computing power.

In a **local area network**, or LAN, a number of computers are connected using cables or WiFi transmission. A device called a **router** is used to switch between the connections, and often one computer in the network will be a **server** that holds shared resources such as files. You may have a LAN at your school, or in your home if you share a printer, music library or video streaming service with the rest of your family. Each computer or device on the network is identified by a name called an **internet protocol**, or IP, address, which is four numbers from 0 to 255 separated by dots – for example, 192.168.1.1.

The internet is, in fact, a collection of many, many networks, all interconnected at different levels. Each layer of the network consists of a set of **nodes**, or points at which information may be exchanged from one branch to another.



■ **Figure 5.37** Internet layers and nodes allow all parts of the network to communicate

What rights and responsibilities do we have when communicating using digital media?

STAY SMART, STAY SAFE

ACTIVITY: Trace and ping

ATL

- Information literacy skills: Understand and use technology systems
- Critical-thinking skills: Draw reasonable conclusions and make generalizations

Some antivirus software and some apps allow you to trace the route across the internet of the information that you download or browse on your computer or device. There are also commands built into the **operating system** of your computer that allow you to do this.

Individually in this activity you will use two computer commands to observe the route to a website on your computer.

To carry out the activity, you will need to use a terminal or command prompt programme. Your teacher will help you with this.

- **On a Microsoft Windows computer, use the start menu search tool to search for 'command prompt'. Run the program when it appears.**
- **On an Apple iOS computer, use Spotlight to search for the Terminal program.**
- **On a Linux computer, use the search function to find the Linux Terminal program.**

The trace function gives the IP addresses of all the computers or devices along the route from your computer to the web location you choose.

The ping function gives the time taken to receive a response (a ping) from a chosen computer on the internet or local network.

Now use the commands in Table 5.3 to trace and ping the route to your chosen website. (Figure 5.38 shows this being done on a Windows computer.)

Figure 5.38 Screenshots of a trace command on a Windows computer

Interpret the results of your commands. Can you **identify** some of the levels in the internet diagram (Figure 5.37)? What is the first node in the trace? Which parts of the route seem to take the longest? What are the units of time used for the ping command?

Operation	Windows command	iOS command	Linux command
Trace path to a certain site or server on the internet	tracert [web URL]	traceroute [web URL]	trace [web URL]
Measure response time of a site or server on the internet	ping [web URL]	ping [web URL]	ping [web URL]

Table 5.3 Operating system commands

! Take action! Stay smart, stay safe, spread the word

ATL

- Information literacy skills: Access information to informed and to inform others
- Communication skills: Make inferences and draw conclusions; Paraphrase accurately and concisely

! Digital communications and the internet have revolutionized the way we share, collaborate, communicate and understand – and the revolution is continuing. All change brings with it uncertainty and risk, and while it is important that we continue to use and develop digital media as a way to share, collaborate, communicate and understand, so we need to remain vigilant to make sure that we are not exposing ourselves to harm. We also need to make sure that we take responsibility and protect others from harm.

! Perhaps in your school you already have a code or charter for safe and ethical use of digital media. Perhaps you are even an online ambassador with the responsibility to help others use digital media safely and constructively. If so, Task 2 below may be most interesting for you.

Task 1: Stay SMART – Taking action on digital media safety

! **Individually or in pairs:** In this activity, you will reflect on the risks inherent in using online resources. You will **identify** the online activities that carry risk, and **suggest** ways to minimize the risk.

- Using the acronym SMART, research and **design** a poster and web page to inform everyone in your school how to use the internet and other digital media safely.
  - S **Stay Safe**. Take care not to give out any personal information when online.
  - M **Don't Meet** someone you connect with online in real life (IRL) unless your parents or carers know the person and are happy with the meeting.
  - A **Don't Accept** files, emails, messages, pictures or SMS texts from anyone you don't know or trust. Make sure you have an antivirus program installed or that your computers are virus-checked.
  - R Make sure that information you obtain from the internet is always **Reliable** Check sources. Make sure you check information before you believe it.
  - T **Tell** a parent, carer or other trusted adult (such as a teacher) if anything you see or receive online makes you upset, worried or uncomfortable.
- For each of the letters S-M-A-R-T, find out what actual kinds of activity might be most important to consider, and how your fellow students might be put at risk when doing those activities.
- Make a 'digital firstaid kit', such as a network folder, booklet or website containing advice and guidance on what to do if any of these issues arise.
- Find out about online ambassadors. Search **cyber bullying** and see if you can engage and help other young people use the internet safely and constructively.

! Take action! Stay smart, stay safe, spread the word

Task 2: Spreading the word – cell phone technology

■ **Figure 5.39** Global communication for everyone?

! Nearly every part of the globe now has connectivity to the digital network. But not *every* part of the world does – why might this be? The headline above is taken from an advertisement for a cell phone company in the United States.

! **Individually or in pairs:** In this activity you will **analyse** the technological challenges of a cell phone network, and **identify** what has been required to solve them.

- **Analyse** the stages that a signal from your cell phone must pass through in order to reach another cell phone.
- **Identify** how the signal is transformed or relayed. Find out and **describe** the technology that must be used to achieve this.
- **Organize** and **present** your ideas in the form of a chart or diagram showing each stage, the technological challenge it presents, and the solution that has been found.
- **Summarize** the technological challenges of installing cell phones in every part of the globe.
- In some parts of the world, the introduction of cell phone technology has allowed people to work and trade with each other in completely new ways. For example, in West African countries, smartphone apps for transferring money are now used regularly even in places where conventional banks do not operate. **Find out** about these new uses of technology. **Evaluate** their use and **describe** the advantages and disadvantages.

! Be sure to cite any sources you used for your research.

◆ Assessment opportunities

- This activity can be assessed using Criterion A: Knowing and understanding, and Criterion D: Reflecting on the impacts of science.

Reflection

In this chapter we have **identified** the key media in the development of mass telecommunications and information transfer. We have **analysed** and **described** systems that allow us to capture images and share them, and **explained** how they work using the science of optics. We have **described** some systems of information transfer and **outlined** how information can be transmitted using analogue and digital methods. We have **explained** how the information can be encoded using waves and digital methods. We have **outlined** how communications systems such as cell phone systems and the internet are structured, and we have **discussed** how to use digital communications technologies safely. We have **evaluated** the impacts of digital communications globally, and their use in less economically developed countries.

Use this table to reflect on your own learning in this chapter.						
Questions we asked	**Answers we found**	**Any further questions now?**				
Factual: How do you communicate? What instruments have we made to manipulate waves? How can information be carried by a wave? What are the advantages and disadvantages of analogue and digital systems?						
Conceptual: How can we share information effectively?						
Debatable: What rights and responsibilities do we have when communicating using digital media?						
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**	
Communication skills						
Collaboration skills						
Information literacy skills						
Critical-thinking skills						
Learner profile attribute(s)	Reflect on the importance of being a good communicator for your learning in this chapter.					
Communicators						

6 How do our bodies work?

By understanding how our body **systems** **function**, people can learn to **make** **decisions** for **balanced** and healthy lifestyles.

CONSIDER THESE QUESTIONS:

Factual: What are the structures and functions of different body systems? How do our body systems work together? How and why do our bodies change as we get older? What are the characteristics and benefits of social interactions and group behaviour?

Conceptual: How can understanding body systems help us to make decisions for balanced and healthy lives? How can people effectively share information about human body processes?

Debatable: To what extent should people follow traditions, culture, science or personal preferences when making lifestyle choices?

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

IN THIS CHAPTER, WE WILL …

- **Find out** about some of the functions of different body systems.
- **Explore** the changes that occur in the body as people get older.
- **Take action** by sharing information about how the body systems work and some things we can do to lead more balanced and healthy lives.

These Approaches to Learning skills will be useful…

- Communication skills
- Organization skills
- Media literacy skills
- Critical-thinking skills
- Creative-thinking skills

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 6.1 Team sports can be a great way to improve health and to have fun

For this chapter, you will create a platform for communication to share scientifically based information about how the human body works, to help teens in a chosen part of the world make decisions for more balanced and healthy lifestyles. You may choose how you would like to communicate this scientific information. For example, you might choose to create a series of videos, podcasts or blog posts, a social media campaign, or print resources like brochures or infographics.

You will design and develop the communication platform based on your target audience. You will share information in a way that is appropriate and ethical for the cultural, economic, political and social situation in the part of the world you have chosen. You will consider the morals within the community where you will be sharing the information, and how these personal principles of right and wrong might influence teens' decision making for balanced and healthy lifestyles.

We will reflect on this learner profile attribute…

- Communicators – we will practise being effective communicators as we share information about how the human body works with other teenagers.

KEY WORDS

cell	organ	skeleton	tissue
muscle	signal	system	

What are the structures and functions of different body systems?

THE HUMAN MACHINE

For hundreds of years, philosophers, scientists and physicians have been studying, wondering about and marvelling at how the human body works. The philosopher René Descartes (1596–1650) compared the human body to a machine when he stated, 'The body is nothing else but a statue or earthen machine.' Similarly, the physician and philosopher Julien Offray de La Mettrie wrote in 1748 in his book *Man a Machine*, 'The human body is a machine that winds its own springs. 'When we think about the human body, we can find examples of how, indeed, it does function like a machine. But there are also many differences between the human body and a machine.

Our bodies work all day, every day, without our asking or often even realizing. Throughout each day of our lives, the cells, tissues, **organs** and **systems** (Figure 6.2) of our body take in, process, utilize and release different substances so that we are able to grow, move, communicate, learn and so much more.

The famous mathematician, artist and inventor Leonardo da Vinci (1452–1519) was fascinated by the human body. He spent years of his life studying, analysing and drawing all aspects of human **anatomy** He spoke with doctors and their patients, dissected cadavers to find the hidden internal structures of the human body, observed and measured the external structures of living men and women in a variety of situations, and identified patterns and relationships in human anatomy by calculating ratios between different body parts. As a result of his focus, keen observational skills, dedication and curiosity, he was able to draw precise sketches with painstaking detail of external and internal human anatomy.

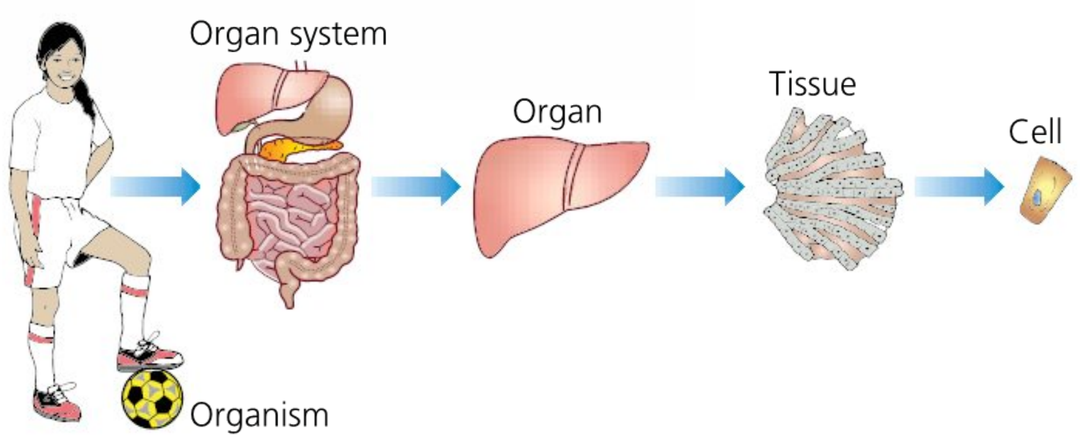


Figure 6.2 Multicellular organisms function through the interaction of organ systems, which are made up of specialized organs, which are made up of specialized tissues, which are made up of specialized cells

Because Da Vinci's work generally focused on the anatomy of the human body, as opposed to its **physiology** (all the physical and chemical processes that allow the body to function), his insights and achievements were mostly associated with the physical structures. This means that, while he was able to dispel some long-standing misconceptions of human anatomy, he developed some incorrect ideas about human physiology. For example, because he studied by dissecting dead bodies, he was not able to observe and understand the way that people actually swallow their food, how a fetus develops inside a woman's uterus, or how the lungs receive and process air.

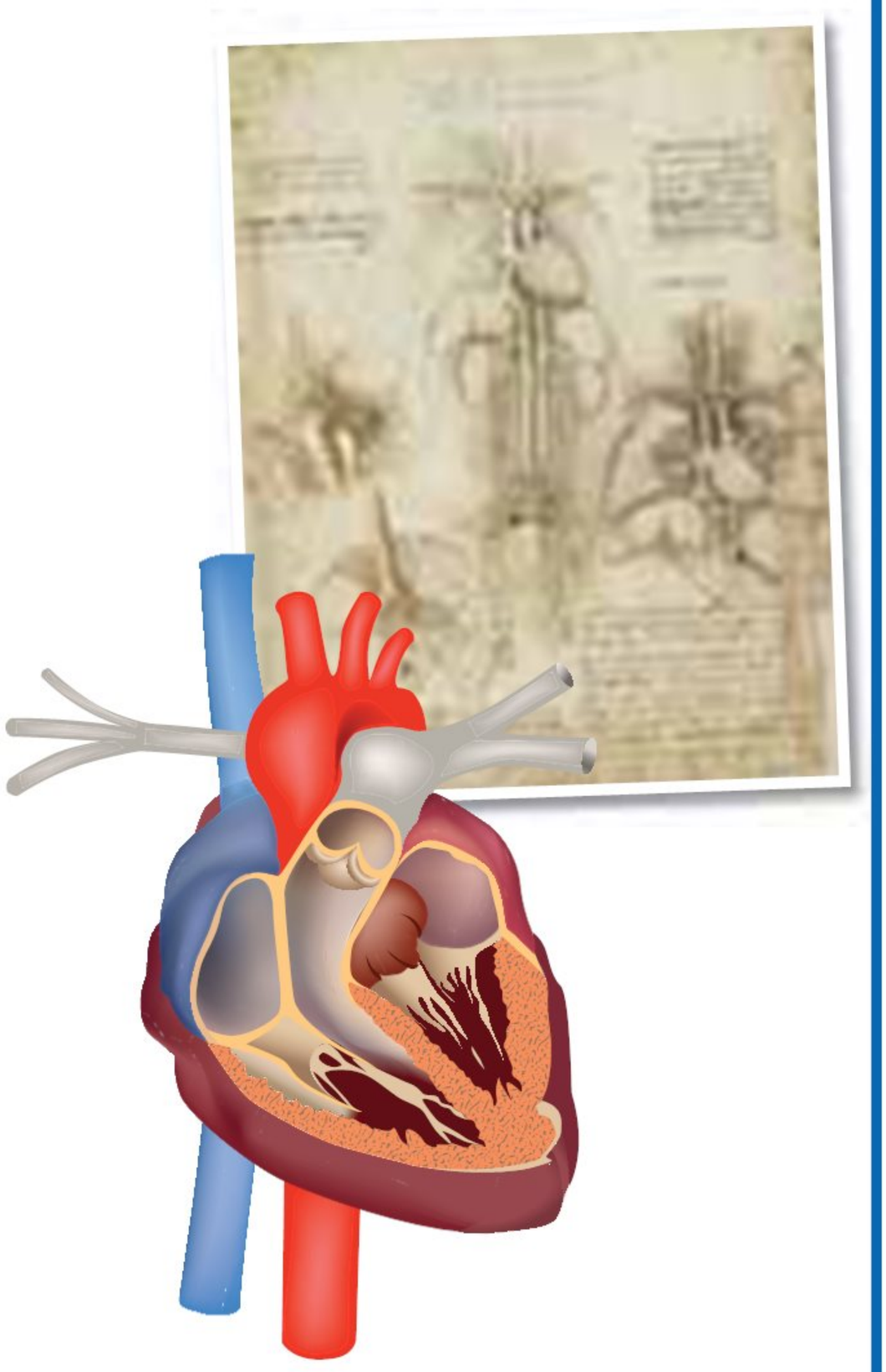
In this chapter, we will look not only at the anatomy of some of the major organs and systems of the body, but also at their physiology. This will help us to identify and understand the choices we can make to lead more balanced and healthy lifestyles.

EXTENSION

Does the work of Leonardo Da Vinci in the field of anatomy sound interesting to you? Try searching for Leonardo Da Vinci anatomist in order to learn more about what he did and see more of his detailed sketches.

VISIBLE THINKING – See–Think–Wonder

Look carefully at this sketch that Leonardo Da Vinci made more than 500 years ago of the heart, and at the computer-generated image of the same organ.



What do you **see** when you look at the sketch and computer-generated image? What do you **think** is similar or different between them? What things do you **wonder** about how Da Vinci was able to make his drawings? Write your ideas down and share them with the class.

DISCUSS

With your partner or the class, discuss what you know about how we perceive and respond to our surroundings. Here are some questions to consider.

- **What are the sense organs?**
- **What are some examples of stimuli?**
- **What happens in our body once we perceive a stimulus?**
- **What are some ways our body responds to the stimuli?**

If you have difficulty remembering, you might search for some notes you have saved on your computer or do some quick research to refresh your memory.

In *MYP Sciences by Concept 2*, you learned that we are able to respond to different situations in our surroundings by perceiving stimuli with our sense organs, transmitting and processing those stimuli through the **nervous system**, and then responding with some sort of movement or production of chemicals in the body.

An important part of the process of perceiving and responding to stimuli depends on signaling, which is done by **signaling molecules**. Signaling by signaling molecules is, as you will learn throughout this chapter, an important part of how all systems function in the body, not just the nervous system. However, when exploring the nervous system, there is one main type of signaling molecule that is relevant, which is the **neurotransmitter**. In addition to sending signals with neurotransmitters, nerve cells are also specialized to produce and transmit **electrical signals**, in what is known as an **action potential**. This action potential is what conducts the message from the sensory cells along the neurons in the nerves to the central nervous system, and then from the central nervous system to the **effector cells**, such as muscle cells, so the body can respond.

These two specialized means of signaling in the nervous system – neurotransmitters and electrical signals – work together to create the different types of responses we experience in our bodies.

ACTIVITY: Chain reaction

ATL

- Critical-thinking skills: Use models and simulations to explore complex systems and issues

Figure 6.3

Equipment

- 6 student volunteers
- A name tag for each student stating his or her role: 'Lion', 'Neuron 1', 'Neuron 2', 'Neuron 3', 'Neuron 4' and 'Leg muscle cell'
- 4 desks, positioned in front of the left arm of each Neuron
- 4 pieces of paper, crumpled into balls and each placed on a desk (Figure 6.3)

Rules

- Neurons can only pick up a ball of paper with their left hand.
- Neurons can only pass paper that they have picked up from their own desk.
- Neurons and Leg muscle cell can only receive paper with their right hand.
- Neurons and Leg muscle cell can only move when they receive paper.

Instructions

1. Line up as shown in Figure 6.3. Neurons should face their desk and have their arms out as in the drawing with fingers spread – but should not be touching each other.
2. Lion: Turn to Neuron 1 and say '*roar!*'.
3. Neuron 1: Move your right arm in a 'wave', pick up the paper ball with your left hand, and pass it to the right hand of Neuron 2.
4. Neuron 2: As soon as you get the paper, move your right arm in a 'wave', pick up the ball of paper on your desk with your left hand, pass it to the right hand of Neuron 3, and return Neuron 1's paper ball to its original desk. Take your original position.
5. Neuron 3: Repeat the same actions as Neuron 2.
6. Neuron 4: Repeat the same actions as Neurons 2 and 3, but you will pass your paper to the right hand of the Leg muscle cell.
7. Leg muscle cell: As soon as you receive the paper from Neuron 4, return it to its desk and run a few steps in the opposite direction of the Lion. Return to your original position.

Variation 1

Repeat the basic instructions, but this time:

1. Lion: *As soon as* the piece of paper gets returned to Neuron 1's desk, roar again immediately – do this for five rounds.
2. Neurons and Leg muscle cell: Repeat the basic instructions for each round that the Lion roars.
3. Lion: After the fifth round, stop roaring and walk away from the Neurons and Leg muscle cell.

As you were able to see in the *Chain reaction* activity, both neurotransmitters and the action potential have vital roles in responding to stimuli. Without the action potential, the neuron does not release the neurotransmitters into the **synapse**. Without the neurotransmitters, the message from the stimuli is not passed along and there will not be an appropriate response. In addition, we can understand that the **receptors** play an important role in 'catching' the neurotransmitters so that the **postsynaptic neuron** can respond according to the message of the neurotransmitter and according to the type of cell the receptor is located on.

Variation 2

1. **Lion: Roar at Neuron 1, as in the basic instructions.**
2. **Neurons and Leg muscle cell: Repeat the basic instructions, only this time drop the piece of paper on the floor instead of putting it back on the desk of the previous Neuron.**
3. **Lion: After the leg muscle cell returns to the original position, roar two more times at Neuron 1.**
   - **Neuron 1: What do you do when the lion roars but there is no paper on your desk?**
   - **Neurons 2–4 and Leg muscle cell: What do you do?**
4. **Lion: Continue roaring for a few more times.**
5. **Neurons and Leg muscle cell: Lie or sit down on the floor.**

Discuss

Once you have finished the basic instructions and variations, discuss the following.

Imagine that the Neurons and Leg muscle cell are in the body of a person who is on an African safari.

- **What do you think happens to the person under the conditions of variation 1? What makes you say that?**
- **What do you think happens to the person under the conditions of variation 2? What makes you say that?**

What is the role of the paper ball? Why is it important that each paper ball is returned? What happens to the chain if a paper ball is not returned? What would happen to the chain if each time one of the neurons tried to return the paper ball to the desk, another student blocked it or took it away before the paper got to the desk?

Now, look at Figure 6.4.

Using the labelled diagram in Figure 6.4, how do you think each of the following Is represented in the *Chain reaction* activity?

- **stimulus**
- **synapse**
- **action potential**
- **neurotransmitters**
- **receptors**
- **response**

Now, use what you have observed and discussed from the activity, as well as the information in Figure 6.4, to describe how signals are sent and received between neurons and other cells. Be sure to use all of the scientific terms that are in Figure 6.4.

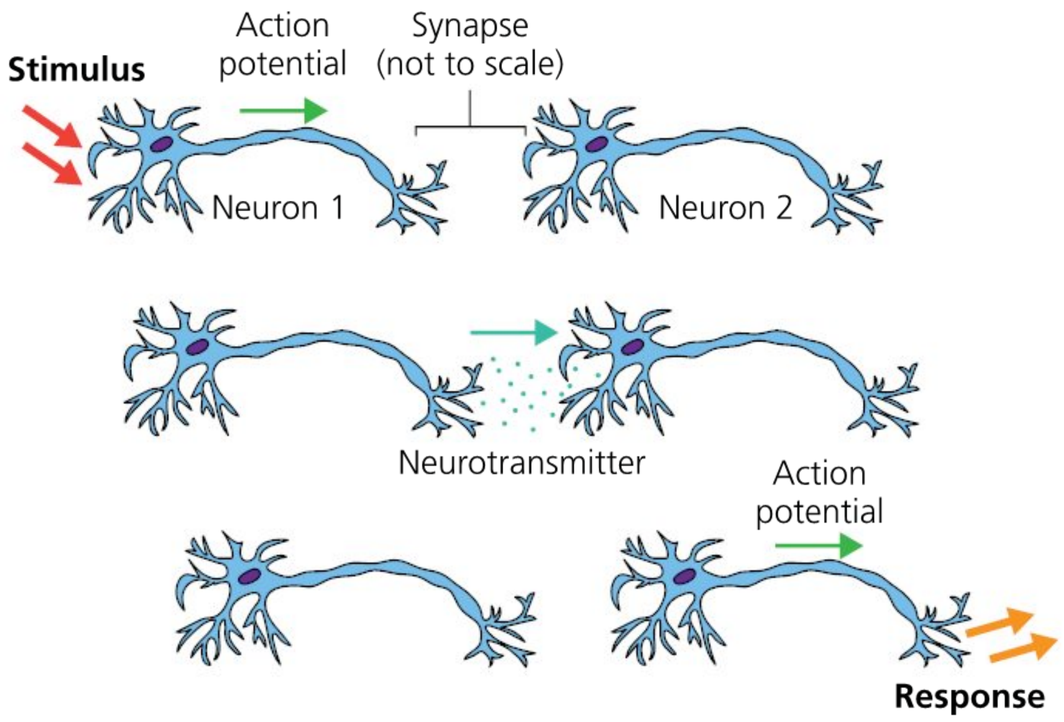


Figure 6.4 Signaling in the nervous system

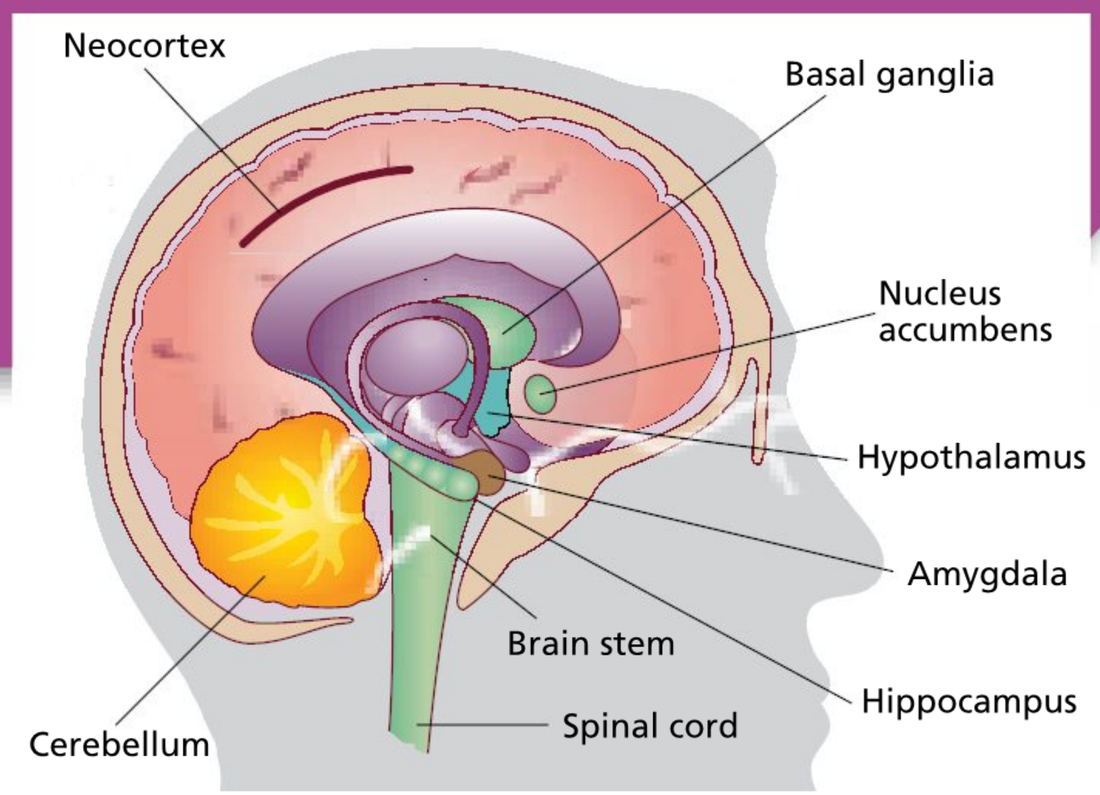
Assessment opportunities

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

In the *Chain reaction* activity, the paper balls represented a particular neurotransmitter called **acetylcholine**. Acetylcholine is a neurotransmitter that is not only transferred between neurons, but also between neurons and muscle cells. The transfer of the neurotransmitter acetylcholine then stimulates the muscles to move. This movement can occur in **skeletal muscles**, like those that make up our leg and arm muscles (more on that later), or **cardiac muscle**, which makes up our heart.

DISCUSS

In consideration of the *Chain reaction* activity, in what ways can we observe the fight or flight response? In what ways is acetylcholine used in this response?



■ **Figure 6.5** Some of the areas of the brain involved with neurotransmitters

Acetylcholine is the neurotransmitter that is associated with the fight or flight response that causes us to react to a stressful situation by either aggressively confronting the cause of the stress or escaping it.

There are many different kinds of neurotransmitters, each resulting in a different type of response in our body. Some neurotransmitters result in an increased rate of action potentials along the neurons – these are known as **excitatory neurotransmitters**. Others result in a decreased rate of action potentials, and are known as **inhibitory neurotransmitters**.

Neurotransmitter	Excitatory or inhibitory?	Location(s) of receptors	Functions and effects When present in appropriate quantities, it contributes to regulating ...
Dopamine	Excitatory	Deep inside the midbrain in the basal ganglia	Coordinated, fluid movement
		Frontal cortex of the brain	Attention, focus, memory and problem solving
		Reward and memory centres of the brain	Anticipation of, desire for, and feelings of enjoyment or pleasure; Remembering and learning what things cause feelings of enjoyment or pleasure
Serotonin	Inhibitory	Throughout the brain	Feeling calm, peaceful, balanced, and stable, including desires and choices for food; Regular sleep cycle
		Intestines	Appropriate functioning of the digestive system
Epinephrine	Excitatory	Throughout the nervous system	Considered to be both a neurotransmitter and hormone; Increasing energy production in the body by stimulating the body to break down stored carbohydrates
Norepinephrine	Excitatory	Throughout the nervous system	Considered to be both a neurotransmitter and hormone; Increasing energy production in the body by stimulating the breaking down of stored carbohydrates; Increasing heart contractions and blood flow and oxygen to muscles and brain; Attention and learning
Endocannabinoids	Inhibitory	Deep within the midbrain, including the amygdala, basal ganglia, hippocampus, hypothalamus and nucleus accumbens	Emotions, feelings of fear and anxiety; Feelings of motivation and reward; Learning and memory; Appetite; Sexual behaviour
		Outer layer of the brain – neocortex	Complex thinking
		Base of the brain – cerebellum and brainstem	Coordination, balance; Communicating information between brain and spinal cord
		Spinal cord	Communicating information between brain and body

■ **Table 6.1** Some neurotransmitters and their functions

VISIBLE THINKING – Creative questions

Later in the chapter, you will explore and inquire into how our understanding of the functions of body systems can help us make decisions for a more balanced and healthy lifestyle.

To help you be more focused in the topics that follow, let's develop some questions about the different systems of the body and how they function. Since you will use these questions and others you come up with throughout this section, set aside some pages in your notebook or journal, or create and save a document on your computer. Another option is to create a shared list of questions with your class. Whatever the case, organize, title and save the list of questions in a format that you can locate and refer to easily later.

For the first set of questions, you may decide to work together as a class. Here is what you will do.

1 **Read Table 6.1 and look at Figures 6.4 and 6.5 very carefully.**

2 **Brainstorm a list of as many questions as possible about the information in the table and diagrams.**

3 **From your list, pick some questions that you can enhance into questions that challenge your imagination or invite you to inquire or research more deeply.**

For example, you could take a question from your brainstorm list, and write a follow-up question about it, using one of these starters:

- **What would it be like if…?**
- **How would it be different if…?**
- **Suppose that…**
- **What would change if…?**
- **How would it look different if...?**

Here is an example.

- **Brainstorming question: What kind of effect does serotonin have on emotions?**
- **Enhanced question: What would it be like if a person had a lot of serotonin? How would that change if a person had too little serotonin?**

As we saw in the *Chain reaction* activity, the production of neurotransmitters – and the following bodily response – happens in response to the conditions that surround us. More specifically, the production of neurotransmitters is regulated by the conditions that surround our cells. The 'surroundings' of our cells can be outside of the body – including the lion that we hear roaring and see close to us – or inside the body.

One of the ways we change the conditions inside our body is by what we consume. In other words, what we eat, drink and breathe in gets processed by the body (for example, during digestion – Chapter 3) and results in the production of compounds that change the chemistry of our cells. Through this process, some molecules become more available to our cells and can act as a chemical stimulus to our nervous system. Conversely, if we don't eat, drink or breathe in certain things, some molecules become less available to our cells, and there is a different response in the nervous system.

It is not only what we consume that affects the chemical surroundings of our cells – it is also what we do and how we feel on a day-to-day basis. For example, our activity or exercise level not only has an impact on our physical body, but also on the chemistry within our cells. In addition, we saw in the *Chain reaction* activity that a sudden, stressful situation (like being confronted by something dangerous) causes a reaction in the nervous system, which impacts the production of neurotransmitters and the body's response. Day-to-day stress can also affect the nervous system and the body's response.

Knowing which substances that we consume have which effects on our body's responses – and why – can help us make healthy decisions about what we put into our bodies. We will explore this in much more depth in the next section.

DISCUSS

How do the conditions of our cells' 'surroundings' within our body change? What are some things that we do that can change the conditions inside our bodies? What are some things that happen naturally that change the conditions inside our bodies?

How do our body systems work together?

Now, we will explore the systems of the body that allow us to move – both the big, powerful movements like running and jumping, and the small, delicate movements like writing or typing. The systems are the skeletal and muscular systems, and are made up of the bones, joints and muscles.

The **skeletal system** is extremely important in the body. The bones and joints that make up the skeletal system provide structure to our body and allow us to move. Furthermore, the bones of the skeletal system form a 'cage' to house and protect our delicate and vital internal organs. Bones also act as storage houses for fat cells and minerals, which cells throughout the body use for various processes.

DISCUSS

When you think of the bones that make up your body, what are some words that come to mind? What are some words or phrases that you associate with 'bones'? Are bones living or non-living structures of the body? What makes you say that?

Why are bones important in the body? In other words, what is the function of the skeletal system?

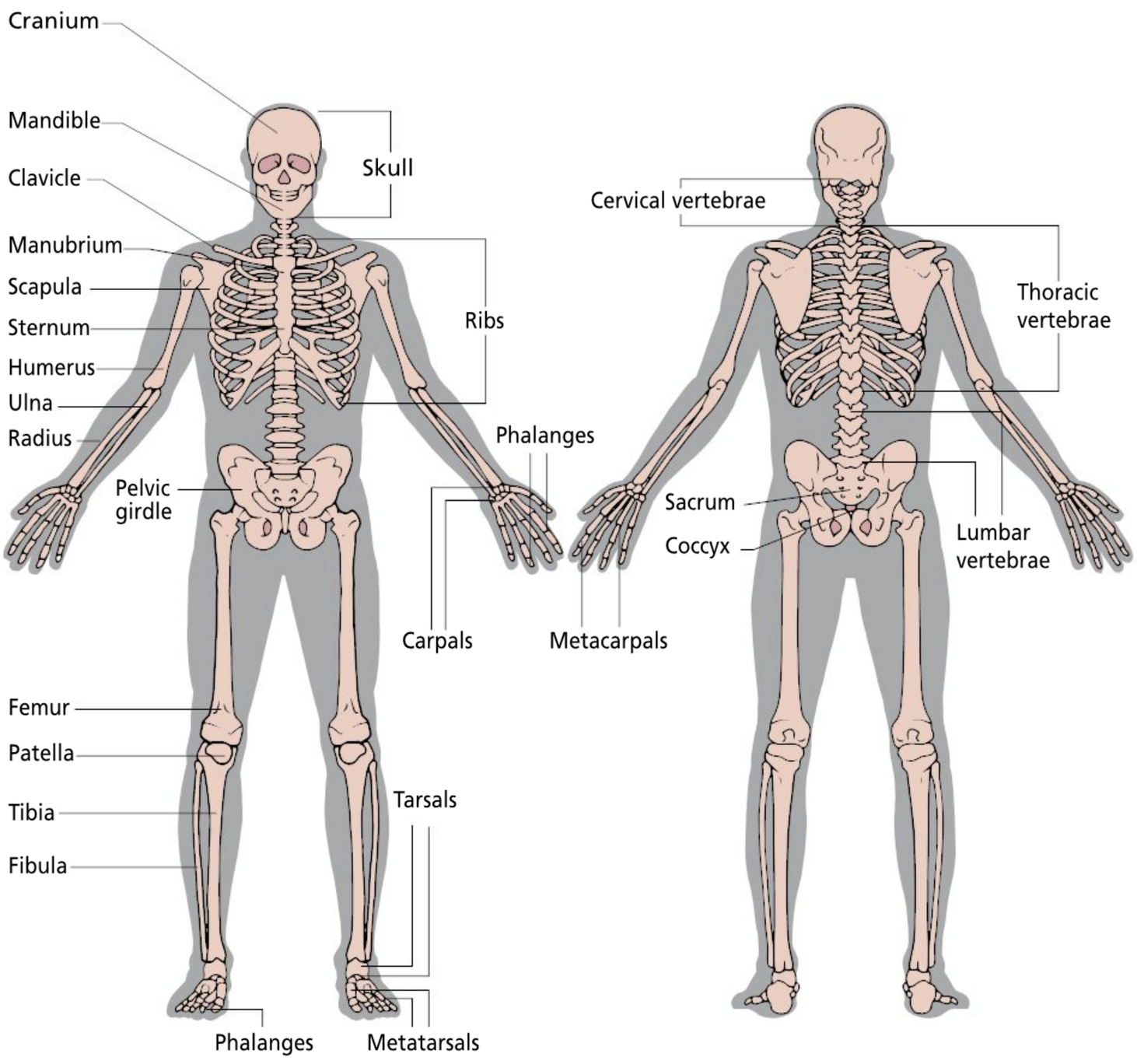


Figure 6.6 The skeleton of the human body is made up of approximately 206 bones

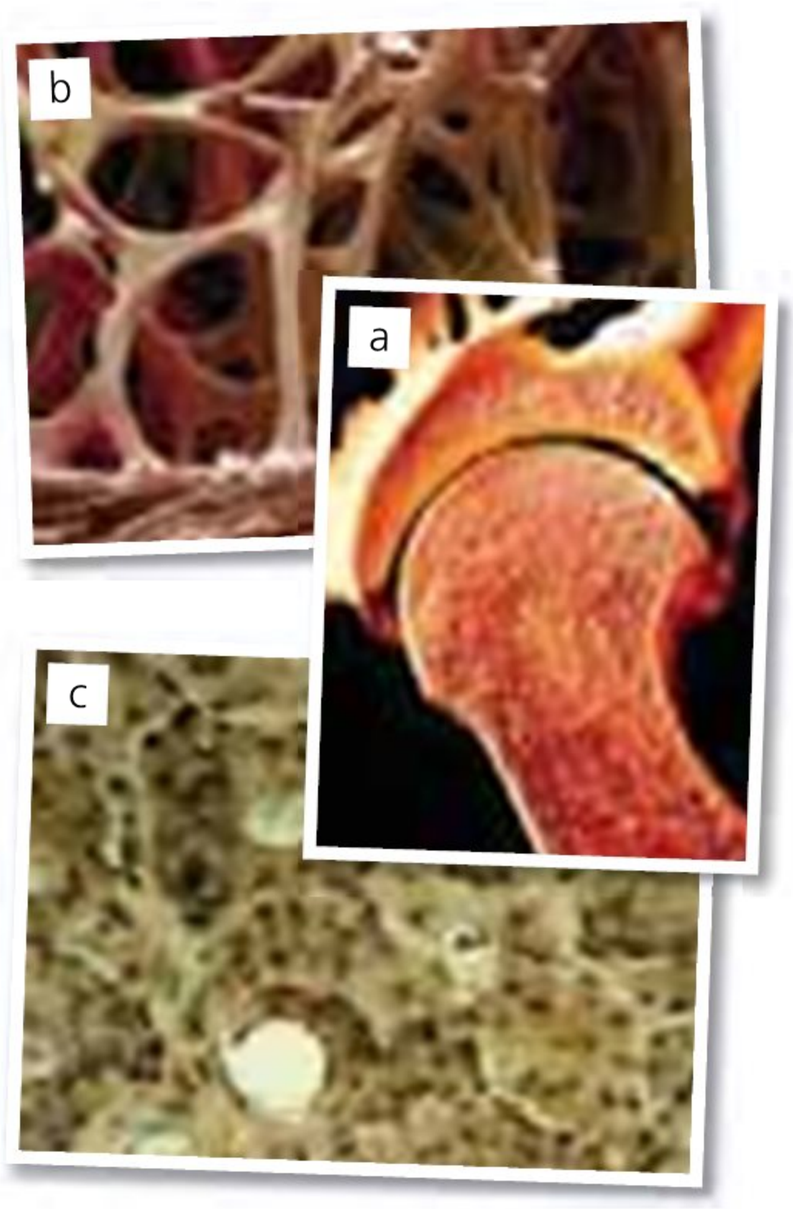


Figure 6.7 Internal view of bones: (a) a longitudinal section of the humerus (upper arm bone) at the shoulder joint, (b) a close-up of the bone toward the joint, (c) a close-up of the outer layer of the bone

ACTIVITY: Break a (chicken) leg!

ATL

- Critical-thinking skills: Draw reasonable conclusions and make generalizations

Bones are unique structures that have several seemingly contrasting characteristics. In this activity, we will do two mini experiments to be able to observe some of these characteristics, which will help us understand what we can do to have healthy bones.

Aim: To observe and identify some of the special characteristics of bone.

Part 1

You will put a chicken bone into vinegar for several days and observe the effects on the characteristics of the bone.

Notes

Once you set up this mini experiment, it needs 3 days to sit until it is time for the final observations. For that reason, it might be helpful to set it up on a Thursday or Friday so that you can make the observations on the following Monday.

Materials

Each group will need:

- **2 raw chicken leg bones – be sure that all of the meat has been cleaned off, and that the bones are about the same size and shape**
- **1 glass jar with a lid, or 1 beaker – big enough for one of the chicken bones to fit easily inside**
- **Clear cellophane wrap – enough to wrap up one of the bones, and also to cover the beaker if you are using it**
- **White vinegar – enough to completely submerge the chicken bone in the jar or beaker**
- **pH test strips**
- **Rubber gloves**
- **Paper towels**
- **Access to a refrigerator**

Method

1. **With your rubber gloves on, carefully observe the two bones. Take note of the texture of the bones – how do they feel? Gently try to bend the bones – what happens?**
2. **After you make your observations, take one of the bones and wrap it in clear cellophane wrap. Put this bone in the refrigerator to use it as a control.**
3. **Use one of the pH test strips to test the pH of the vinegar. What do you notice? What does this tell you about vinegar?**
   - **Make your hypothesis – what do you predict will happen to the chicken bone after 3 days in the vinegar? What makes you say that? Give a scientific reason to support your prediction. Share your hypothesis with your class.**
   - **What else would you like to measure or document about the bone (or vinegar) before you put it in the vinegar? These additional observations may help you get a better understanding of the special characteristics of bone. Discuss this with your partner and teacher, and take any agreed measurements before continuing.**
4. **Take the other chicken bone and put it in the jar or beaker.**
5. **Pour in enough vinegar to completely cover the chicken bone. Cover with the lid or clear cellophane wrap.**
6. **Label your jar, and put it somewhere in the classroom where it will not be disturbed for 3 days.**
7. **Be sure you clean your working surface with soap and warm water or a special spray and wash your hands.**
8. **After 3 days, take the control chicken bone out of the refrigerator. Using gloves, take the chicken bone out of the vinegar, rinse it off and dispose of the vinegar according to your teacher's instructions. Carefully observe the control bone and the vinegar bone – how do they feel? Gently try to bend the bones – what happens?**

Questions

1. **Soaking the bone in vinegar removes one of the substances that makes up bone. After removing this substance using vinegar, what happened to the bone?**
2. **What characteristic does this suggest that this substance gives to bones?**
3. **How or why did the vinegar remove the substance from the bone?**

Part 2

You will put a chicken bone in the oven for a few hours and observe the effects on the characteristics of the bone.

Notes

1. **You will need access to an oven of some kind for this part of the experiment. If you do not have one at school, you might try it at home and video the process to share with the class.**
2. **This part of the experiment requires 3 hours in the oven. Coordinate with your teacher a schedule for removing the bones from the oven after that time – you can make the observations on the next day.**

Materials

Each group will need:

- **2 raw chicken leg bones – be sure that all of the meat has been cleaned off, and that the bones are about the same size and shape**
- **Heat-proof pan and gloves**
- **Clear cellophane wrap – enough to wrap up one of the bones**
- **Rubber gloves**
- **Paper towels**
- **Access to a refrigerator**

Method

1. **As in part 1, with your rubber gloves on, carefully observe the two bones. Take note of the texture of the bones – how do they feel? Gently try to bend the bones – what happens?**
2. **Take one of the bones and wrap it in clear cellophane wrap. Put this bone in the refrigerator to use it as a control.**
3. **Before you put the chicken bone in the oven:**
   - **Make your hypothesis – what do you predict will happen to the chicken bone after 3 hours in the oven? What makes you say that? Give a scientific reason to support your prediction. Share your hypothesis with your class.**
   - **What else would you like to measure or document about the bone before you put it in the oven? These additional observations may help you get a better understanding of the special characteristics of bone. Discuss this with your partner and teacher, and take any agreed measurements before continuing.**
4. **Place the chicken bone on the oven-proof tray.**
5. **Put it into the oven at 180° C for 3 hours. (It is okay to make your observations of the baked bone in the next class, as long as it has been carefully wrapped and stored.)**
6. **After the bone has been removed and has cooled, take the control bone out of the refrigerator. Using gloves, take the baked chicken bone off the tray. Carefully observe the control bone and the baked bone – how do they feel? Gently try to bend the bones – what happens?**

Questions

1. **Exposing the bone to heat removes a different substance that makes up bones. What happens to the bones when this substance is removed?**
2. **What characteristic does this suggest that this other substance gives to bones?**
3. **How or why did the heat remove this substance from the bone?**
4. **Finally, complete the following prompts.**
   Some characteristics of bones are…
   These are important characteristics for bones to have because…

In this activity, the vinegar and exposure to heat each removed a different substance that makes up bones, which you will learn about soon.

Additional optional steps: After you have finished with the control bone, take a closer look at different characteristics of the bone. You might try breaking it in half and looking at what is inside – what do you see? Try using a hand lens to see more details. Maybe you would like to take some cells and look at them under a microscope.

Take a close look at the ends of the bone – try poking or squeezing them with tweezers.

What else are you interested in looking at? Talk with your teacher and try different things out. Just be sure you clean up properly and wash your hands well.

Assessment opportunities

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

SEE–THINK–WONDER

Look carefully at the images in Figures 6.7 and 6.8. For each image, ask yourself:

- **What do I see when I look carefully at this image? What are some interesting details, pattern, or unique characteristics that I notice? Write these thoughts down for the 'See' column.**
- **What do I think that this image might be? What are some hypotheses I have for what I notice? Write these thoughts down for the 'Think' column.**
- **What do I wonder about when I look at this image? What are some questions I have, and what are some things I would like to get more information about? Write these thoughts down in the 'Wonder' column.**

Try to come back to your answers as you learn more in this section to see which of your 'wonderings' you can answer.

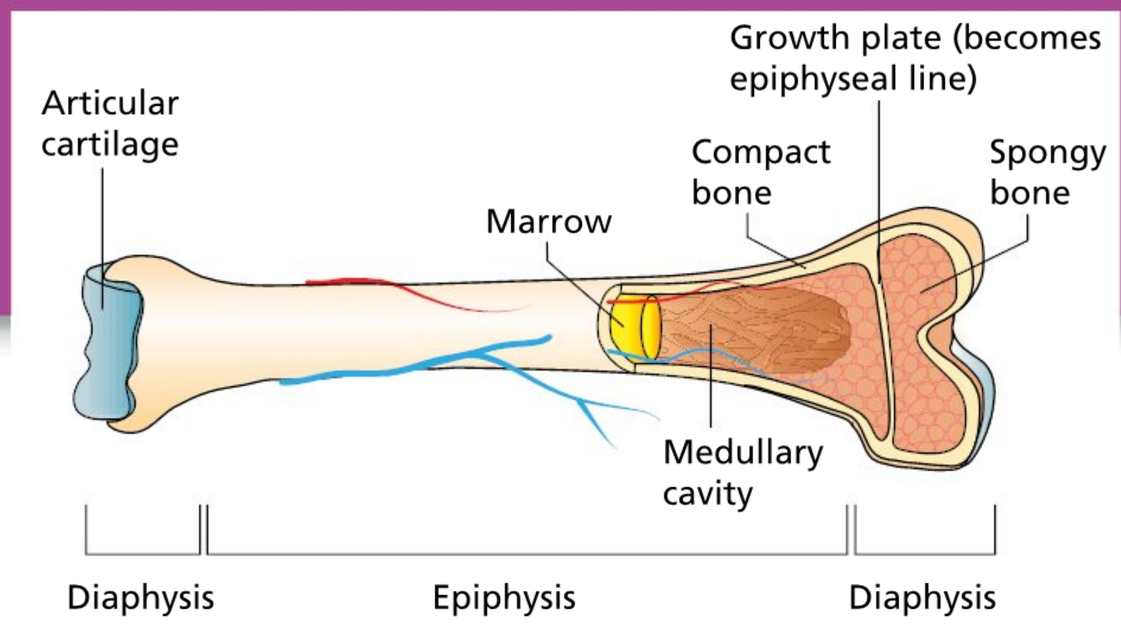


Figure 6.8 A longitudinal section of the humerus (upper arm bone), showing the different tissue types

Figure 6.9 A sea sponge and kitchen sponge look similar to spongy bone, but actually have very different physical characteristics

DISCUSS

Why do you think that bone is not completely compact? What are the benefits and weaknesses of the structure of spongy bone? Consider the images in Figures 6.9 and 6.10 in your discussion.

The structure and characteristics of bones are quite different to how they appear to be on the surface. In fact, many of the physical characteristics of bone seem to contrast with each other, as bones are simultaneously extremely strong while being relatively light with delicate and fragile features.

For example, we can see in Figure 6.7a that bones have a dense outer layer, called **compact bone**. The compact bone seems to be one solid section of bone, but when we look up close using a microscope, as in Figure 6.7c, we can see that the compact bone also has open spaces, called canals, seen as the larger black circles in the image. The canals are surrounded by the densely packed bone cells, called osteocytes (*osteo* is a root meaning 'bone' and *cyte* means 'cell'), which are seen in the image as little black dots.

The compact bone, which makes up the great majority of our bones – about 80% – surrounds the more delicate-looking and porous (holey) inner section. The inner section is called **spongy bone** (Figure 6.7b) because of its similarity to how a sea sponge or kitchen sponge looks.

Although spongy bone has a delicate structure and looks soft in Figure 6.7a, the material that makes up the spongy bone is actually quite rigid. So why might this be? Why isn't bone completely made up of the more solid compact bone?

As you may have discussed with your partner, the spongy or mesh-like structure of bones, eggshells and honeycombs allows these structures to be strong as well as lightweight. This makes it possible for birds to fly, easier for us to carry around our own skeleton, and less likely that the weight of a beehive will cause it to fall. It also means that the organisms producing these structures have to produce fewer of the compounds used to build them (such as different kinds of proteins or carbohydrates) – and when an organism is producing less, it means it is using less energy, which means it will have more energy for other important life functions.

The way the fibres, or internal components, are spread out has an effect on what happens to the structure when it is under physical pressure. What do you think happens when one of the structures in Figure 6.9 or Figure 6.10 is put under pressure?

Because of the network of fibres that spreads out through the structure, the pressure also spreads out and is distributed across the structure. This means the point of pressure on the structure does not have to withstand the force all by itself. This allows the structure to be stronger than it would be if it were a compact construction of the same material and mass.

There is another, biological, reason why it is important that these structures have spaces in them – the open spaces allow other things to move or flow through. For example, bees can move through the honeycomb, and air can move through the membrane of the egg shell.

But what moves through bone? Think back to the *Break a (chicken) leg!* activity and take another look at Figure 6.8. What did you notice on the inside of the bones?

You likely noticed a soft, dark material if you broke the chicken leg, and we can see that same substance in the drawing in Figure 6.8. This substance, which fills the cavity (open space) we see in Figure 6.8, is called **bone marrow** (or just marrow), and it is has many blood vessels going through it. This is important because bones are living tissues, so they require a source of blood and other fluids to deliver necessary substances to bone cells and take away their cellular products and waste.

There are two types of marrow: yellow and red. In teenagers and adults, red marrow is found in only some of the bones, such as the skull, shoulder blades,

■ **Figure 6.10** The internal structure of a bird bone is similar to that of human bone, but has some differences. What might be the reason for those differences?

breast bone (sternum), vertebrae and hip bone, as well as in the spongy bone at the ends of the upper arm bone (humerus) and upper leg bone (femur). In babies and children, though, red marrow is found in most of the bones. Red marrow produces **red blood cells** which help to carry oxygen through your body, **white blood cells**, which work with your immune system to protect you from disease, and **platelets**, which help you to stop bleeding through the process of clotting. The yellow marrow, which is in the other bones, functions as a storage unit for fat.

Therefore, because blood vessels as well as nerves have to run through the bones, it is important that there are plenty of open space and canals for them to run through. This is another important reason why bones are not completely solid structures.

We have learned about the physical structure of bones, but what are they actually made of and how do they work? Knowing this will help us make good decisions about what we consume and the type of activity that we do.

Bone is mostly made of protein and minerals. The protein **collagen** and the mineral calcium are particularly important and make up most of our bones. The collagen protein creates a network of criss-crossed fibres, which helps give bones their flexibility. Calcium, on the other hand, covers and fills in the network of collagen fibres, and gives bones their strength.

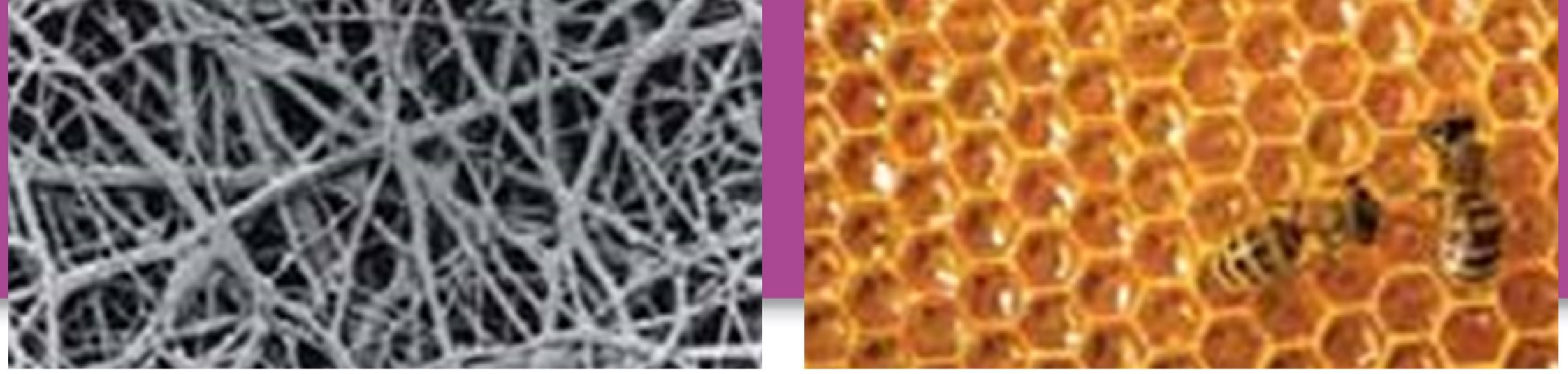


Figure 6.11 Many structures in nature are strong but lightweight, such as the mesh-like network of an egg shell membrane and the honeycomb of a beehive

As we have learned, bone is a living substance in our body. Bones do not stay the same throughout our lives. Instead they go through periods of growing in length and width, increasing in density and strength, and decreasing in density and strength. As bones get longer, we get taller, and as bones get wider and more dense, they get stronger. It is important that compact bone is as dense as possible, because denser bones are stronger bones – and stronger bones are less likely to break or deteriorate.

As you might predict, bones do their most of their lengthening through the teenage years, as the living bone cells (osteocytes) divide and multiply. This occurs in sections of the bone known as the **growth plates** – it is here that the osteocytes are rapidly dividing, by the process of **mitosis**. (Take a moment to chat with your partners and remind yourselves about what occurs in mitosis.) As teenagers get older and reach the end of **puberty**, the growth plates begin to thin, and the number of reproducing osteocytes decreases, therefore reducing the rate of bone lengthening. Eventually, each growth plate thins so much it is only a line, called the epiphyseal line (Figure 6.8). At this point, the bones will not get any longer – and you will not get any taller!

While bones are getting longer, they are also increasing in their density by laying down calcium on top of and within the lengthening collagen network. Vitamin D is an important nutrient in this process, as it is required for bones to be able to extract calcium from the blood.

The calcium needed to support and strengthen the bones is delivered through the bloodstream. It, along with vitamin D, enters the body from what we eat. Foods like dairy products and dark green vegetables are rich in calcium, while salmon and other fatty fish are good sources of vitamin D. Cells can also make vitamin D when they are exposed to sunlight.

Therefore, an adequate diet and sufficient, safe exposure to sunlight supply our bodies with the calcium and vitamin D we need to build up our bones as well as perform other body functions – for example, calcium plays an important role in muscle contraction and relaxation.

With the help of vitamin D, bones can also pick up and store any excess calcium that might be dissolved in and carried by the bloodstream, making our bones even stronger. However, this process of increasing bone density does not occur at the same rate for our whole lives: when we reach the age of 30–35, bones naturally stop increasing in density and begin to actually *lose* density. At this point, the process of reabsorption occurs, which is when calcium stored in the bones is broken down and carried away by the bloodstream. This process of reabsorption makes our bones less dense and therefore less strong.

Getting older is not the only time when reabsorption can occur. It also occurs during times of malnutrition, when a person does not have enough calcium in the diet to carry out the other body functions it's needed for. For women, reabsorption also occurs when **menstruation** no longer occurs. Menstruation can stop because the woman has reached the age of **menopause**, or because she is experiencing a time of amenorrhea, which means 'absence of menstruation'. Amenorrhea can occur when a woman's physical or athletic activities greatly exceed her calorific intake and requirements.

In contrast to the circumstances that contribute to the loss of bone density due to calcium reabsorption, bone density can increase as a result of physical activities, called weight-bearing activities, which put additional pressure on the bones. The additional pressure from the force of gravity and from additional pulling on the

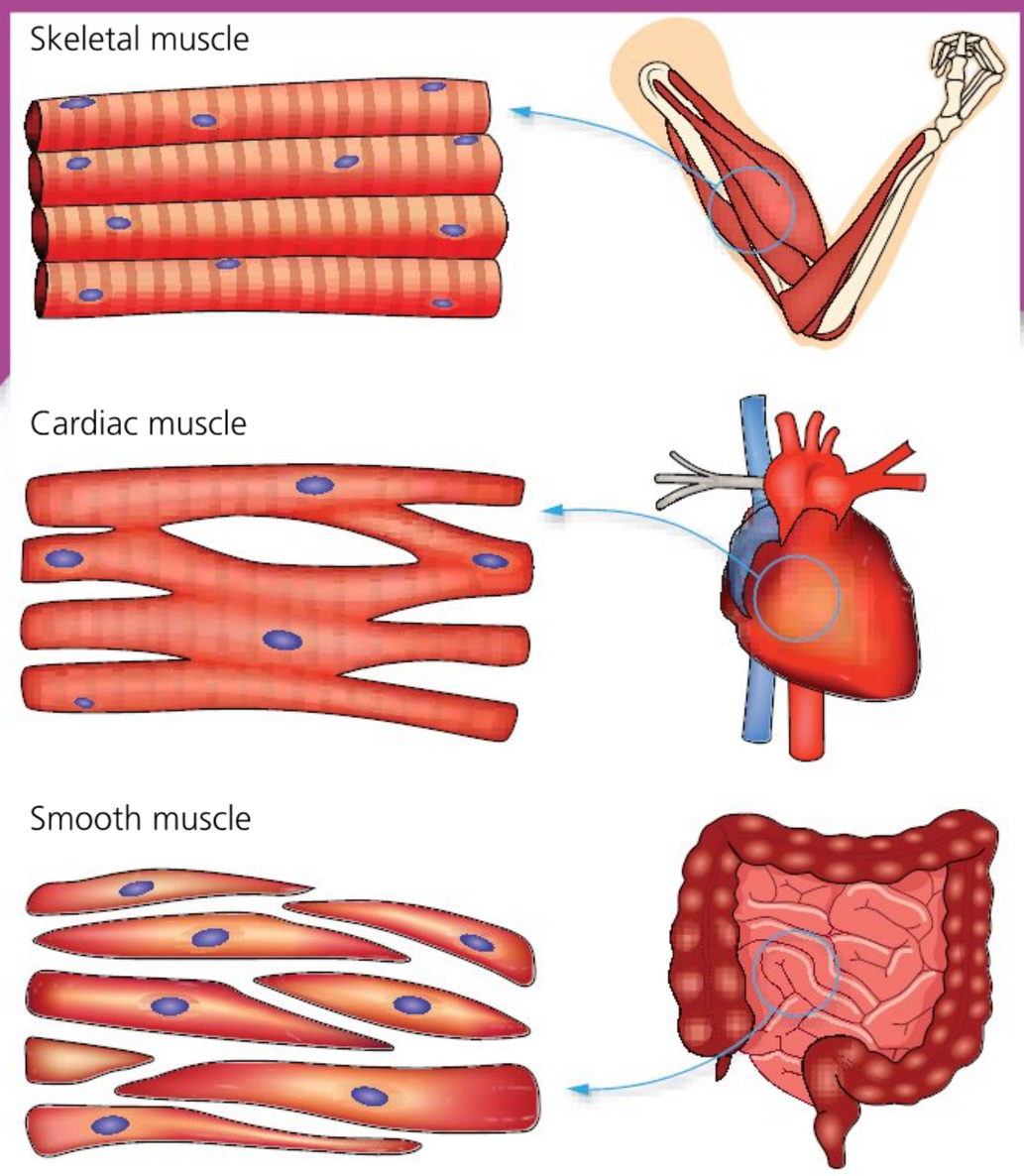
■ **Figure 6.13** Weight-bearing activities, such as jogging or lifting weights, can help to increase bone density

bones from the muscles, stimulates bones to extract and incorporate more calcium from the bloodstream.

As we consider the positive effect that weight-bearing activities have on bone density, it is time for us to explore the muscular system and the role of muscles in body movement, the beating of the heart, and the functioning of internal organs.

As you saw in Figure 6.13, there are three different types of muscle tissue.

- **Skeletal muscle** is the kind we usually think about when we think about muscles. The biceps are an example of skeletal muscle.
- **Cardiac muscle** is the specialized type of muscle that makes up the heart – cardiac muscle is only found in the heart.



■ **Figure 6.13** The three different types of muscle cells, also known as a muscle fibres. Muscle fibres are multinucleate (cells with many nuclei)

- **Smooth muscle** is the type of muscle that makes up blood vessels and internal organs, such as the stomach or intestines.

Each type of muscle is specialized to perform its unique functions. However, they all share a common trait: muscle cells are all able to **contract** and **relax**, bringing about movement in the body.

What does it mean when we refer to muscles contracting and relaxing? To understand, go over to a

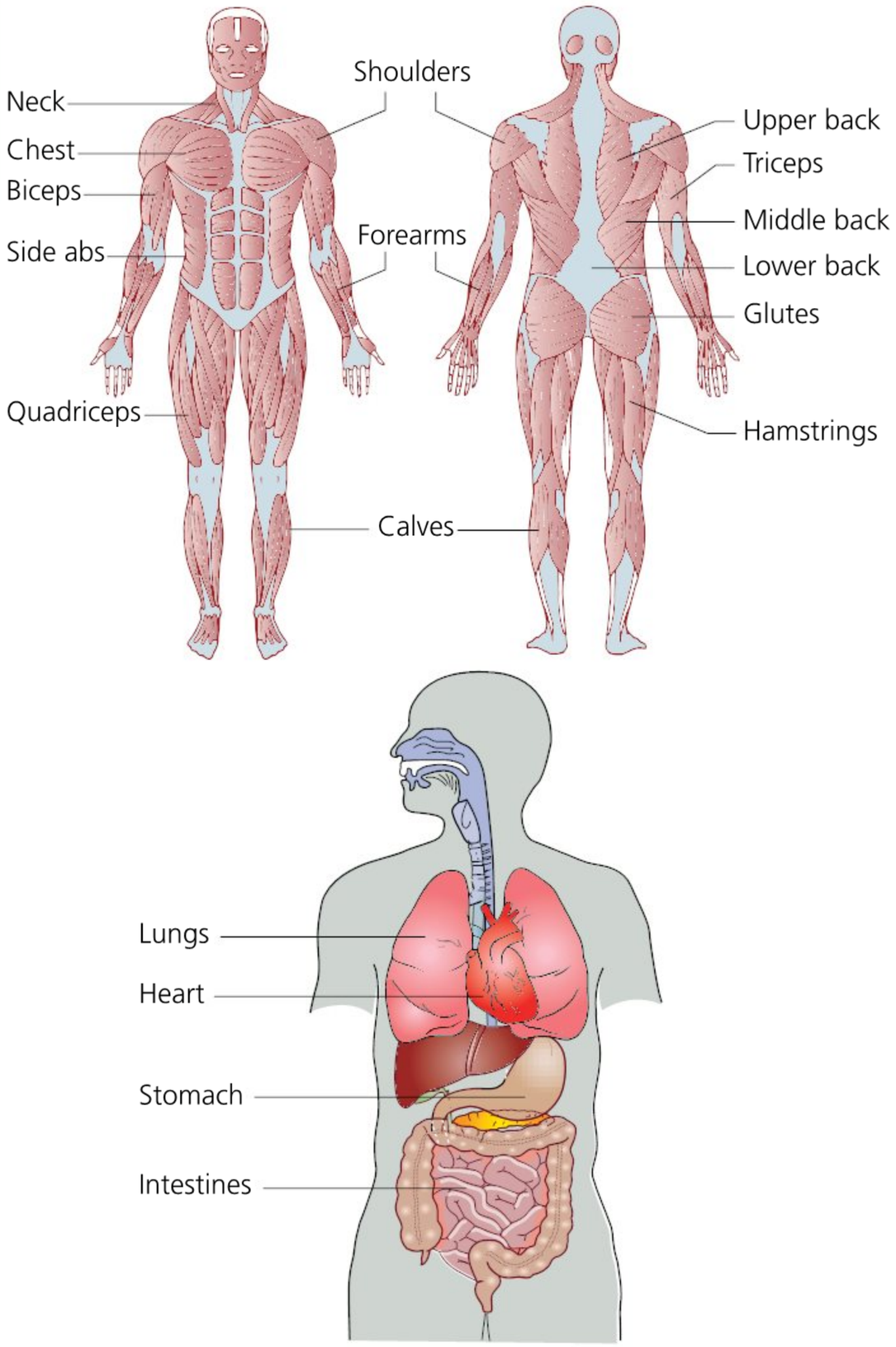
SEE–THINK–WONDER

Draw a three-column See–Think–Wonder chart.

Look carefully at the images in Figure 6.13. For each image, ask yourself:

- **What do I see when I look carefully at this image? What are some interesting details, patterns or unique characteristics that I notice? Write these thoughts down for the 'See' column.**
- **What do I think that this image might be? What are some hypotheses I have for what I notice? Write these thoughts down for the 'Think' column.**
- **What do I wonder about when I look at this image? What are some questions I have, and what are some things I would like to get more information about? Write these thoughts down in the 'Wonder' column.**

Share your thoughts with your class. Can you add anything to any of the categories? Try to come back to your chart as you learn more in this section to see which of your 'wonderings' you can answer.



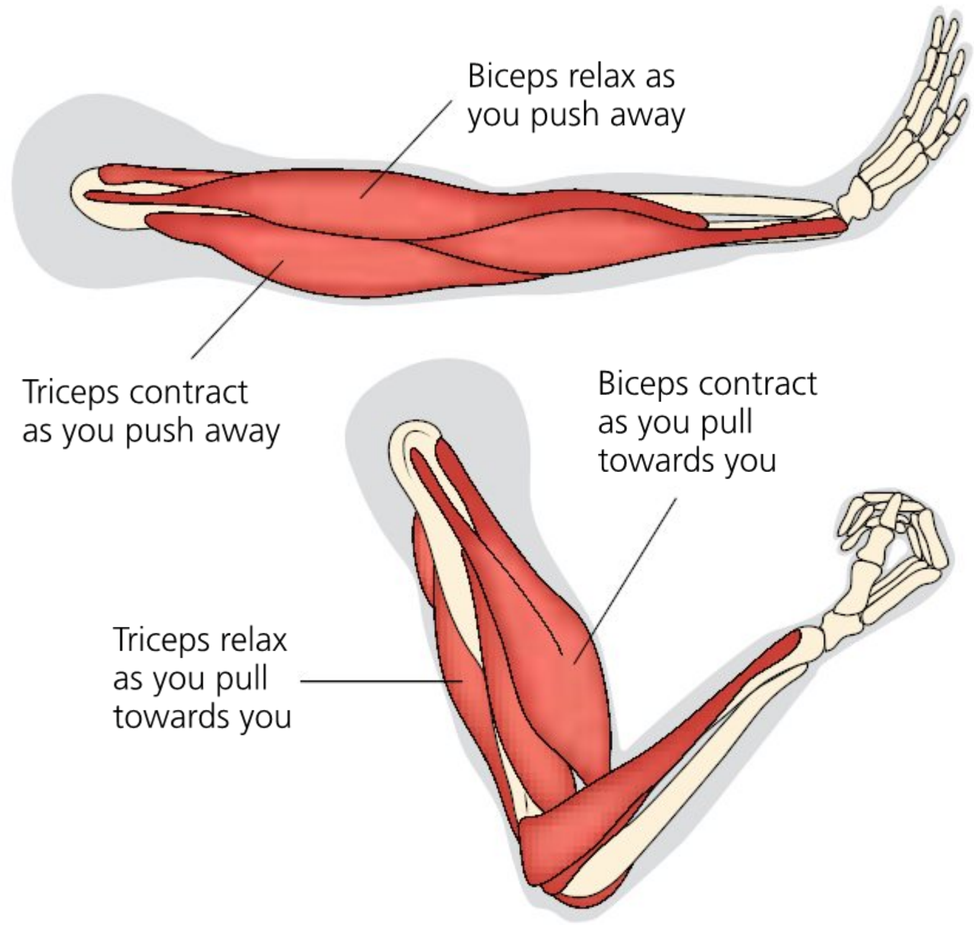
■ **Figure 6.14** Whether it is our heart, intestines, biceps or quadriceps, all muscles are made up of either cardiac, smooth or skeletal muscle cells

DISCUSS

If the function of muscle cells is to contract and relax, bringing about movement in the body, what are the things that each muscle type can move? What does skeletal muscle move? What does cardiac muscle move? What does smooth muscle move?

What is different in the way that the types of muscle move?

wall or door. Raise and straighten one of your arms in front of you and push it against the wall – be sure to push into the wall strongly. This movement of pushing your arm away from you requires your triceps muscles to contract. You can most easily observe the effects



■ **Figure 6.15** Pushing things away from you requires that your triceps contract, while pulling things towards you requires that your biceps contract

DISCUSS

When your skeletal muscles contract a part of your body moves. But what happens when your heart contracts and relaxes? What about smooth muscle, in your intestines or bladder, for example – what happens when it contracts and relaxes?

of your triceps muscle contracting if you look towards (and feel) the back of your outer arm (Figure 6.15). What do you notice about the size and shape of the triceps muscle when it is contracting?

While keeping your arm pushing away, what do you notice about your biceps muscle (on the top and towards the front of your arm)? In this position of pushing your arm away, your biceps muscle is relaxed. How does it look and feel?

Now, take your arm from the wall and bend it at the elbow, as if you were pulling something towards your face. When your elbow is at about a 90° angle, pause and take a look at your biceps and triceps. When you pull something towards your body, the biceps muscle contracts and the triceps muscle relaxes – how do they look and feel now?

You might have noticed that in their contracted positions, your biceps and triceps muscles are shorter (take up less length) than when they are in the relaxed state. This is because during muscle contractions, the muscle fibres slide over each other to come closer together, whereas during muscle relaxation, the fibres slide over each other so they are further apart. This sliding action is the result of the interaction of specialized strands of **proteins** in the muscles, called **myosin** and **actin filaments**, with other molecules, including calcium, enzymes, magnesium and ATP.

To understand how the actin and myosin filaments work together, we will compare muscle action to climbing a knotted rope. Maybe you can try it in your next PHE class!

Picture this. To move up the rope, your right hand grips a knot, and you move your body upwards as you bend your right arm. Then you reach your left hand up and grab onto the knot above you and try to pull yourself up a bit more. Now you can't move up the rope any further unless you release your right hand and reach it up to grip the knot above you, and then do the same with the left hand. Your PHE teacher is there each time you want to move, to help you release your hands one at a time and get you ready to reach up and grab the knot above.

In this scenario, the rope is the actin filament, your body is the myosin filament, and your hands are a specialized portion of the myosin, called the myosin heads. The knots in the rope represent the binding sites of myosin heads (where the myosin can bind to the actin filament). Your PHE teacher helping you to release your hands and set you up to grab the next knot is like the ATP that binds to the myosin head to release it from the actin filament and prepare it to bind to another binding site. Each time you pull yourself up is a bit of muscle contraction, and each time you release your hand is a small relaxation. The full muscle contraction is when you reach the top of the rope, and the full muscle relaxation is when you let go of the rope completely and drop back to the floor.

Figure 6.16 Climbing up a rope is like the action of myosin heads pulling along an actin filament

ACTIVITY: Making connections

ATL

Creative-thinking skills: Generate metaphors and analogies

When understanding a complex process, it is helpful to make an analogy with something that is more familiar. The analogy about climbing the rope aims to help you understand the complex process of muscle contraction by showing how it is related to a process that is easy to visualize.

In order for the analogy to be effective, it is important that you are able to make a connection between the analogous aspects of the process.

Use each of the components of the rope-climbing analogy to identify its analogous part in the mechanics of muscle contraction (Figure 6.17). You will organize the relationship in a table, with columns for the rope-climbing analogy, the muscle contraction, and an explanation of the analogy. The

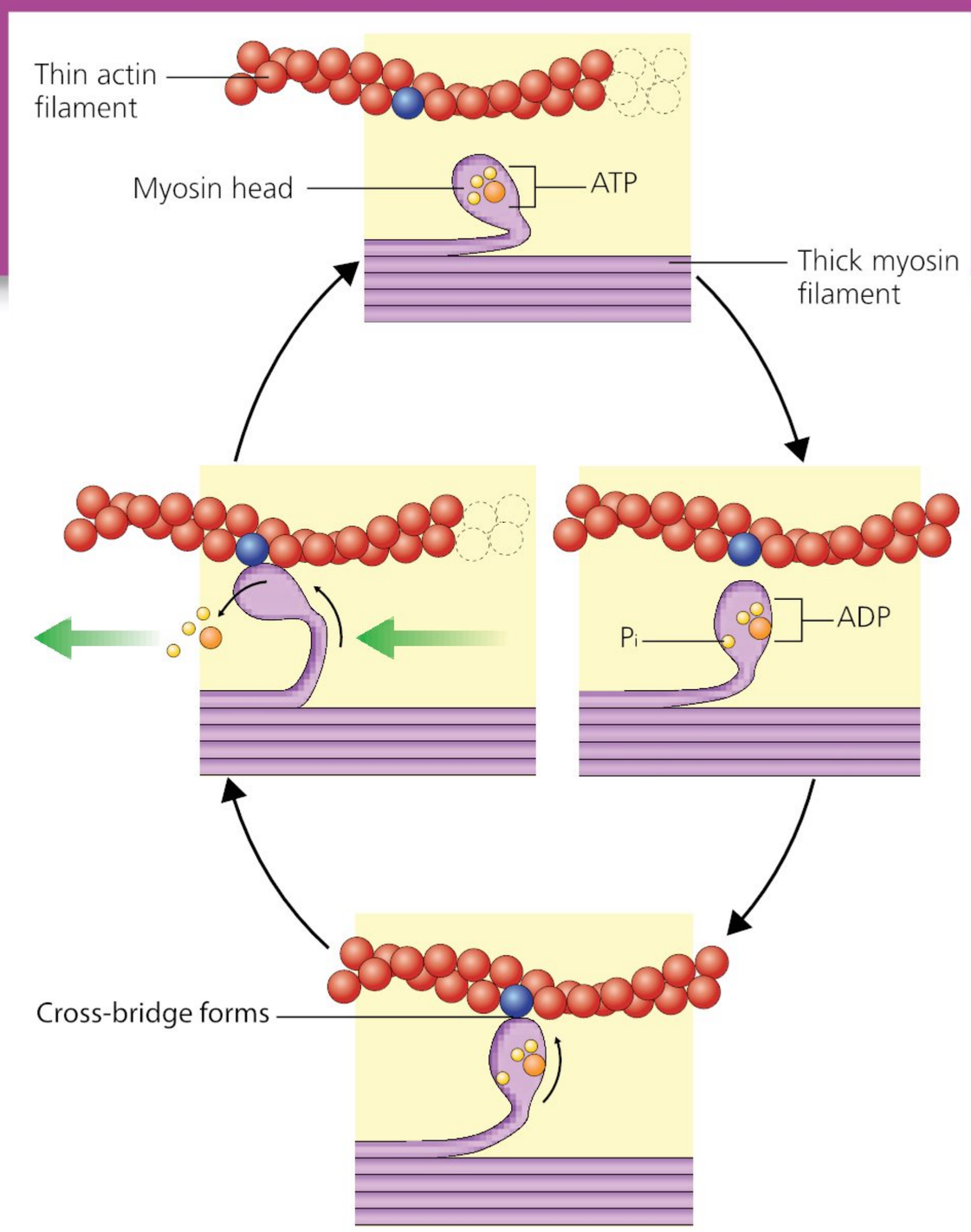


Figure 6.17 The mechanics of muscle contraction

aspects of the rope-climbing analogy are:

- **You**
- **Your hands**
- **The rope**
- **The knots in the rope**
- **Your PHE teacher**
- **Moving up the rope**
- **Temporarily releasing your hand from the rope**
- **Reaching the top of the rope**
- **Going back down to the ground**

A table like this is useful for organizing complex information, making comparisons and finding patterns. In an upcoming activity, you will create your own table to organize information about muscle types, so you can refer to this table as an example.

Assessment opportunities

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

VISIBLE THINKING – Zoom in

Figure 6.17 shows the roles of actin, myosin and ATP in muscle action. But these molecules do not work on their own. Use Figure 6.18 to zoom in on muscle action to see some of the other molecular players that are involved.

What can you add to the rope-climbing analogy to make it more complete? Discuss it with a friend and share your zoomed in analogy with your teacher. Be sure to include a justification for your additions to the analogy.

Once you have zoomed in using Figure 6.19, it is time to zoom in with your mind. Because muscle cells demand a lot of ATP in order to function, what other molecules need to be plentiful in muscle cells? Also, what type of molecules need to be present in order for muscles to produce all of the proteins they need to function? How do those molecules become available in the muscle cells?

Hint

Think back to what you learned in Chapter 3.

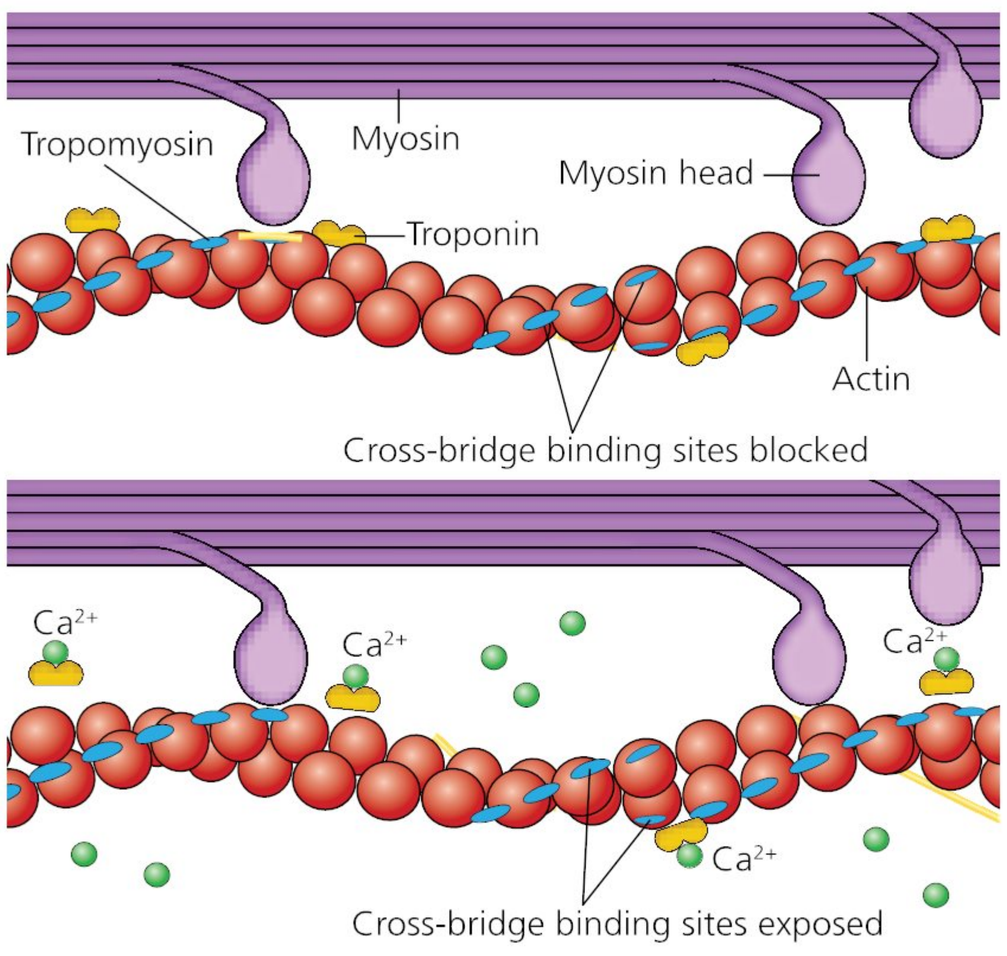


Figure 6.18 A deeper look at the mechanics of muscle contraction, showing the role of calcium ions

ACTIVITY: Skeletal muscle: Fast or slow?

ATL

- Organization skills: Use appropriate strategies for organizing complex information

In this activity, you will learn about different types of skeletal muscle. You will then choose a graphic organizer – such as a table, chart or Venn diagram – to help you sort and understand the information.

When reading complex information that can be grouped together in different ways, the first thing to do is to identify the different categories. One way to do this is by using the headings or titles in the text. For example, from its title we can understand right away that this activity is about skeletal muscle and whether it is 'fast or slow'. Even if you don't know what it means for skeletal muscle to be 'fast or slow' at this point, it is a good starting point to help you identify the different categories of information you're likely to encounter. Then, once you begin reading, you can look for the characteristics of the categories, and possibly identify additional categories, to include in your graphic organizer.

After reading the text once, decide what will be the best way to organize the information. Re-read the text to decide on the categories and characteristics that you need to organize.

Next, set up the graphic organizer. If you decide to make a table, how many columns will there be? How many rows? For example, you might make a column for each type of skeletal muscle and rows for the characteristics of different skeletal muscle cells.

Once you set up the graphic organizer, re-read the text again (at least one more time) in order to fill in the organizer. Share your graphic organizer with your partner or the class. What did others do? Can you add anything to your graphic organizer?

Assessment opportunities

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

We have learned how muscles contract, and we know that the contraction of skeletal muscles results in movements of our body. But how does this happen? As we can see in Figure 6.15, muscles are attached to bones by **tendons**, which are made up of collagen – just like bones! As a skeletal muscle contracts, it pulls on the bone to which it is attached, which makes the bone move in the direction of the contracting, pulling muscle. So, because the biceps muscle is attached by a ligament to the bones of the forearm, when the biceps muscle contracts, it pulls the forearm towards the body. Similarly, because the muscles of the forearm are attached with ligaments to the bones of the fingers, to move your fingers, your forearm muscles must contract.

Muscles do not only work with bones during movement, they also work with other sets of muscles. For all large movements, like squatting down or throwing a ball, there are many different muscles involved. Muscles work together in **antagonistic pairs**. The muscle that contracts and creates the main force responsible for the movement is called the **agonist** muscle, while the muscle that is relaxed is the **antagonist** muscle. The antagonist muscle plays an important role in helping to slow down or control the movement that results from the action of the agonist muscle.

Figure 6.19 In lead climbing, the two partners take it in turns to lead the movement and to control and support the other. In the same way, antagonist muscles help to control and reinforce the contraction and movement of agonist muscles in the body

Fast-twitch and slow-twitch muscles – endurance versus power

When you are doing sports or working out in a PHE class, do you prefer to do things like jogging, swimming or riding your bike for a long distance at a slower rate, or do you prefer to race over a short distance? When you have to jump high – over a hurdle for example, or jumping to catch a ball – does it feel good to your body, or does it feel like a big effort to get off the ground?

Have you ever wondered why this is? What makes some athletes skilled in running marathons, while others excel at short-distance sprints? There may be several reasons, but one of the most important reasons comes from the type of skeletal muscle fibres that make up the muscles in their body.

Skeletal muscles, like your quadriceps, hamstrings and biceps, are composed of **slow-twitch fibres** and **fast-twitch fibres** the names refer to how quickly the muscle fibre is capable of contracting. The proportion of slow-twitch to fast-twitch fibres that a person has contributes to whether that person does better at activities requiring endurance or activities that require shorter bursts of power. Whether muscle fibres are slow twitch or fast twitch depends on several components of the muscle cells themselves.

Slow-twitch muscle fibres contract more slowly, but they do not get fatigued, or tired, very easily. They are responsible for muscle contractions that need to occur over long periods of time, like those that allow us to sit up, stand or jog long distances. Slow-twitch muscles have a lot of small blood vessels, called **capillaries**, that carry dissolved oxygen, glucose and other nutrients to the muscle, and carbon dioxide and cellular waste away from the muscle.

Slow-twitch muscle fibres, also known as **Type I muscle**, contain a large amount of a protein called **myoglobin** Myoglobin, in turn, contains a type of iron which is capable of holding onto the oxygen delivered from the blood, and also has a red-brown colour. In addition, slow-twitch fibres have a lot of mitochondria and an enzyme called ATPase. In other words, slow-twitch muscle fibres are capable of generating a lot of energy over a long period of time because of the abundance of oxygen-storing myoglobin and mitochondria and consistent supply of glucose and other nutrients that are delivered from the capillaries.

Another characteristic of slow-twitch muscle fibres is that they are small in diameter, so muscles that contain a lot of slow twitch muscle fibres tend to be small as well.

Fast-twitch muscle fibres, known as **Type II muscle**, on the other hand, fatigue quickly. They contribute to quick, powerful movements, like sprinting quickly after a ball or high jumping. Fast-twitch muscle fibres are large in diameter, so muscles that have a lot of fast-twitch muscle fibres tend to be large.

There are actually two types of fast-twitch muscle fibres: **Type IIa** and **Type IIb**. Type IIa fibres have medium amounts of mitochondria, capillaries and myoglobin, whereas Type IIb fibres have few mitochondria and capillaries and a small amount of myoglobin. This means that Type IIa muscle is more resistant to fatigue than Type IIb muscle, which tires very quickly. For this reason Type IIa is used when sprinting longer distances like 400 m, while Type IIb is used for activities that need a lot of force over a short period of time, like sprinting 100 m. While both types of fast-twitch muscle fibres are larger in diameter than slow twitch, Type IIb is larger than Type IIa.

People have different proportions of fast-twitch and slow-twitch fibres in their muscles, according to their genetic characteristics. This means that, although people can train to develop their fast-twitch or slow-twitch muscles in order to enhance their athletic performance, we each have a genetically determined proportion of Type I, IIa and IIb muscle cells, which contributes to people being better suited for sports that require endurance, like long-distance cycling, or short bursts of power, like hurdling.

Figure 6.20 Why do some people tend to do better at long-distance activities, while others prefer short bursts of quick movement? A person's genetic proportion of slow-twitch to fast-twitch muscle fibres affects their tendencies for muscle mass and athletic performance

Links to: Physical and health education (PHE)

In PHE, you also explore the concepts of balance and systems. In addition, you inquire into energy, movement and function. Each of these concepts is closely related to what we have been studying in this chapter. How might you transfer your understanding of the skeletal and muscular systems (as well as the digestive system from Chapter 3) to what you are learning and doing in your PHE class?

How and why do our bodies change as we get older?

Although changes occur throughout life, one of the most important and noticeable periods of change occurs when we enter into **puberty**. During puberty, our bodies begin to produce **hormones** that act on various parts of the body, resulting in the development of adult characteristics. The production of hormones depends on a person's specific genetic information, which provides information to the body cells that says which and how much of the different hormones to produce. In other words, everyone's DNA 'programs' them to produce more or less of different hormones, resulting in individualized tendencies and appearance.

Hormones are another type of signaling molecule. They are produced by organs called glands that make up the **endocrine system**. There are a wide variety of hormones that influence many body processes, from helping us digest our food, to responding to stress, to the development of adult sexual characteristics.

The processes and changes associated with puberty are closely linked to the ability to reproduce. However, reproduction, of course, is not limited to humans. All organisms – from the smallest, simplest single-celled bacteria to the largest, most complex plants and animals – are genetically programmed with a means of passing on genetic information. It is through reproduction that a species evolves, and – whether an organism is one cell that divides through binary fission, or made of billions of cells and reproduces through sexual reproduction – all organisms come with an innate genetic message allowing for reproduction.

It is true that living things do not think of reproduction in this way – a bacterial cell or a plant or a bird or even a human doesn't think, '*Okay, it is time to reproduce so that my species can continue*', but because passing along genetic information to offspring is the way that a species will survive, through the process of evolution, organisms have been genetically programmed either to pass on genetically identical copies of themselves through asexual reproduction, or to have the ability to combine and pass on genetic information from a male and a female through the process of sexual reproduction.

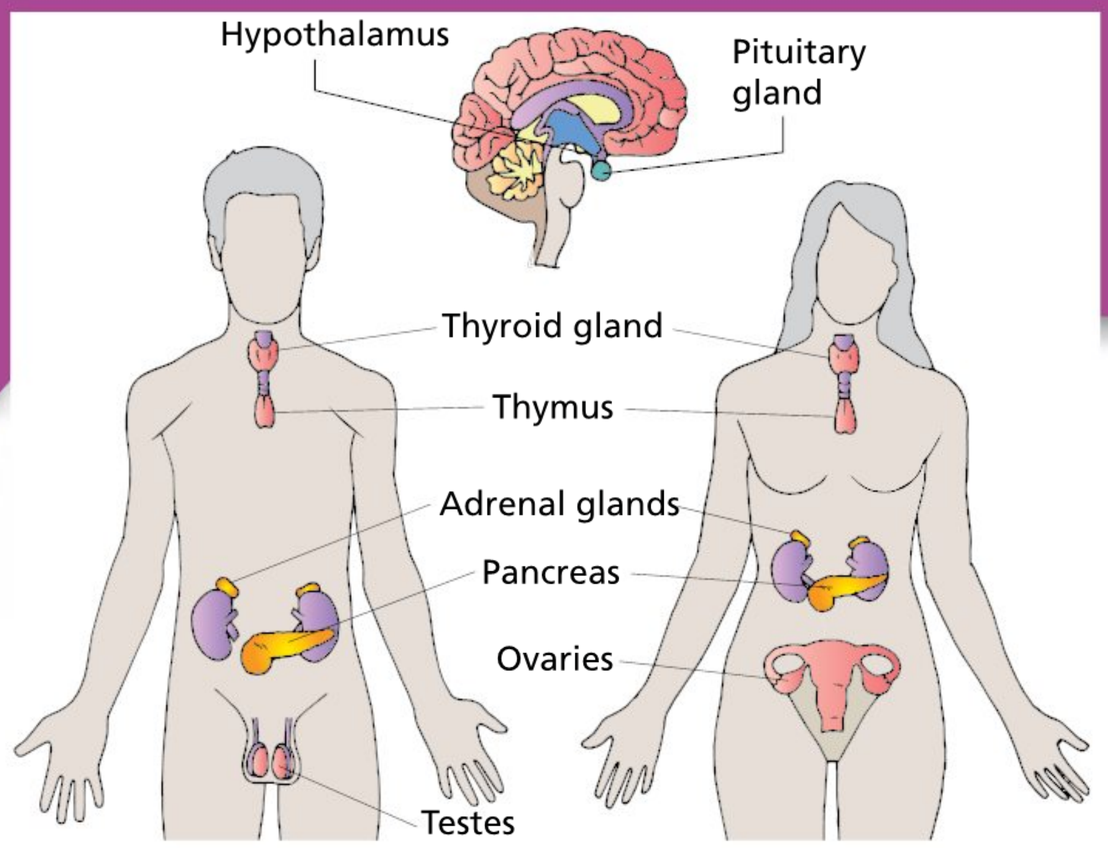
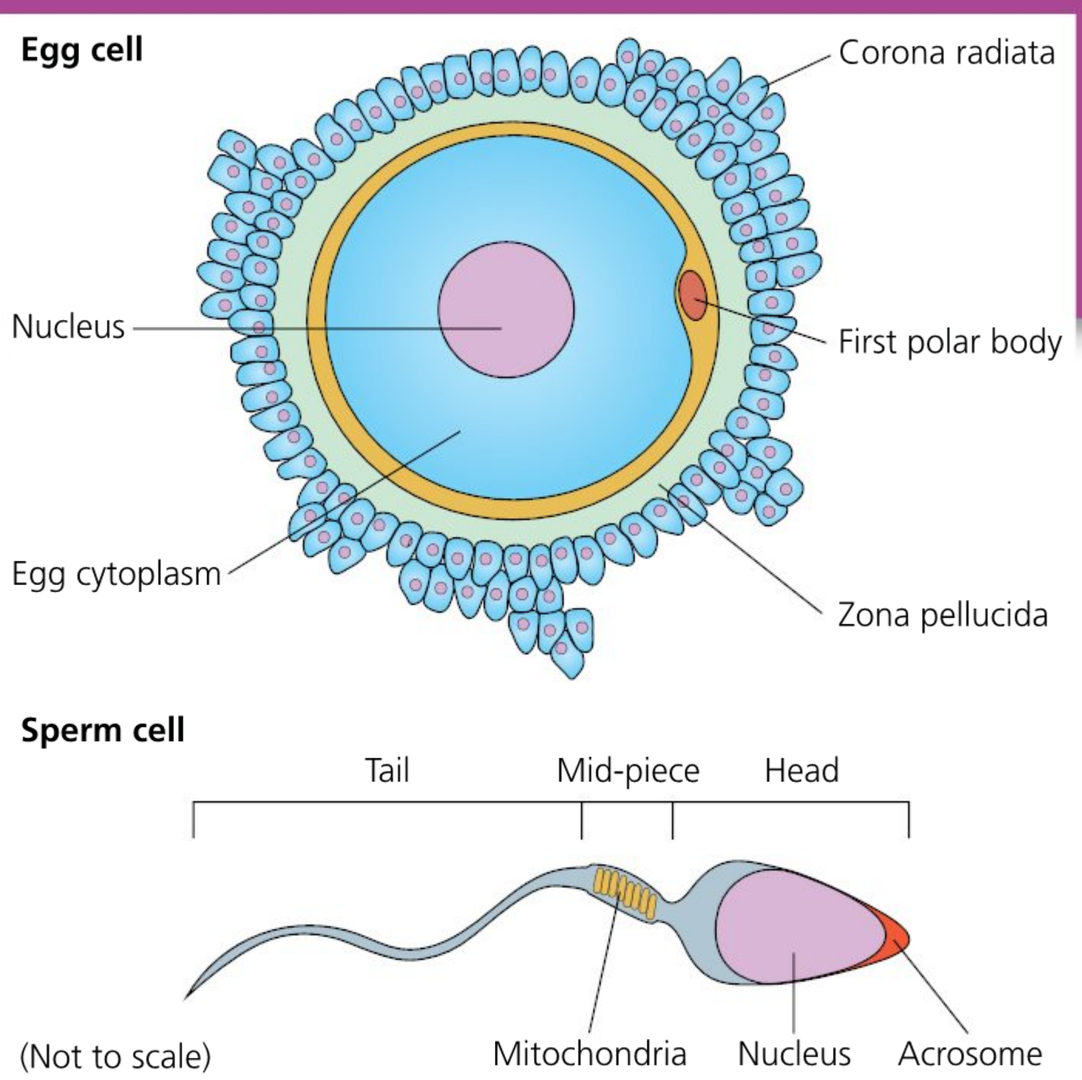


Figure 6.22 The glands of the endocrine system produce different hormones that contribute to various functions throughout the body

So, if we are thinking of sexual reproduction as a biological process that occurs in many types of organisms, not just humans, what is actually happening? In all types of sexual reproduction, the nucleus of a single **sperm** (male gamete) combines with the nucleus of a single **egg** (female gamete), in the process of **fertilization**

Figure 6.25 All organisms have systems to pass along genetic information through the process of reproduction

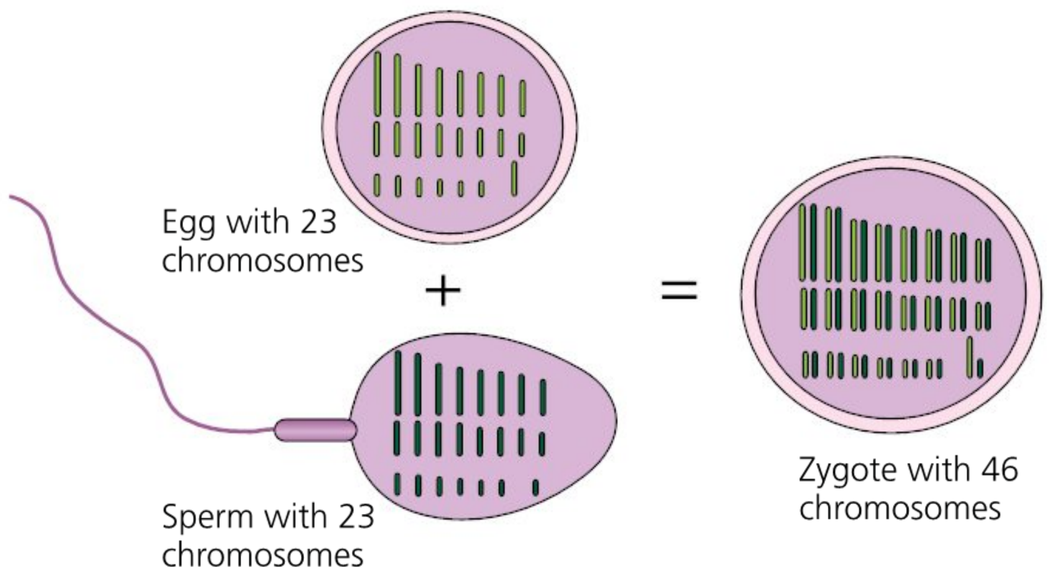


■ **Figure 6.24** A sperm cell has three basic sections: the tail, the body (or midpiece) and the head. An egg cell looks more like a typical animal cell, but with a very large nucleus. Where are the chromosomes located within the sperm and egg cells?

When the nuclei of the sperm and egg unite, the cell is no longer referred to as an egg or a sperm cell – it is called a **zygote**. It is in the formation of the zygote when the single set of **chromosomes** that come from the sperm combine with the chromosomes of the females so that there is a double set of chromosomes in the zygote. These chromosomes from the sperm and egg, with their unique combination of genes, are now the full set of DNA of the future offspring.

As you may recall, humans have two sets of 23 chromosomes, for a total of 46 chromosomes, in all of cells except in the egg or sperm cells, which have only one set of 23 chromosomes.

■ **Figure 6.25** Fertilization occurs and a zygote is formed when a sperm cell nucleus enters into an egg cell and the chromosomes from each combine. What do you notice about the egg (coloured in yellow in the image) compared with the sperm (blue)?



■ **Figure 6.26** A zygote with 46 chromosomes is formed when the 23 chromosomes from an egg cell and the 23 chromosomes from the sperm cell combine. What do you notice about the 23rd chromosome of egg cells and sperm cells?

EXTENSION

Sometimes during meiosis and the formation of egg and sperm cells, one of the sister chromatids does not separate properly, in a process known as **non-disjunction**, and there is an extra chromosome in the gamete. If this gamete then goes on to successfully form a zygote and develop into an embryo and fetus, the resulting offspring will have an extra chromosome in his or her cells. This will have different effects on offspring depending on which chromosome there is an extra copy of. For example, Down syndrome results from having an extra chromosome 21, known as trisomy 21.

Do an image search for **non-disjunction** to learn about some other syndromes or effects of having an extra chromosome.

EXTENSION

Are you interested in how twins (or triplets) form? Search online for **formation of twins** or **how twins form** to learn more.

DISCUSS

What are some reasons, such as cultural, economic or social factors, contributing to why humans may choose or choose not to reproduce? How does this compare to the process of reproduction in other mammals?

Chromosomes 1 to 22 are named according to their number, and the 23rd chromosome, called the sex chromosome, is either an X or a Y. So, just as a person has two sets of each of the numbered chromosomes (two of chromosome 1, two of chromosome 2, and so on), each person has two sex chromosomes. Therefore, just as the genes present on chromosomes 1 to 22 determine and code for characteristics like hair colour, height or skin colour, some of the genes of chromosomes X and Y determine and code for the characteristics associated with females and males. So, two X chromosomes ('XX') is the genetic signal for the development of female characteristics, while the combination of an X and a Y ('XY') is the genetic signal for the development of male characteristics.

Once fertilization occurs, there are a series of biochemical reactions that occur, resulting in several rapid rounds of cell division and duplication, forming the embryo, and, in later stages of pregnancy, the fetus (Figure 6.27).

For humans, these biological processes that you just learned about are more complex than with other organisms, because of our highly developed nervous system and our ability to reason and make decisions based on factors other than a basic reproductive imperative. The instinct to reproduce for humans is not as direct as it is for other organisms, even other mammals. While other animals are simply driven by genetics and the hormones that they are genetically programmed to produce to seek out a reproductive mate, humans can and do go through a decision-making process about when or whether it is time to seek out a partner for reproduction. Similar to how eating and drinking for humans is often based on factors other than basic survival, reproduction for humans is not based just on passing on genetic information.

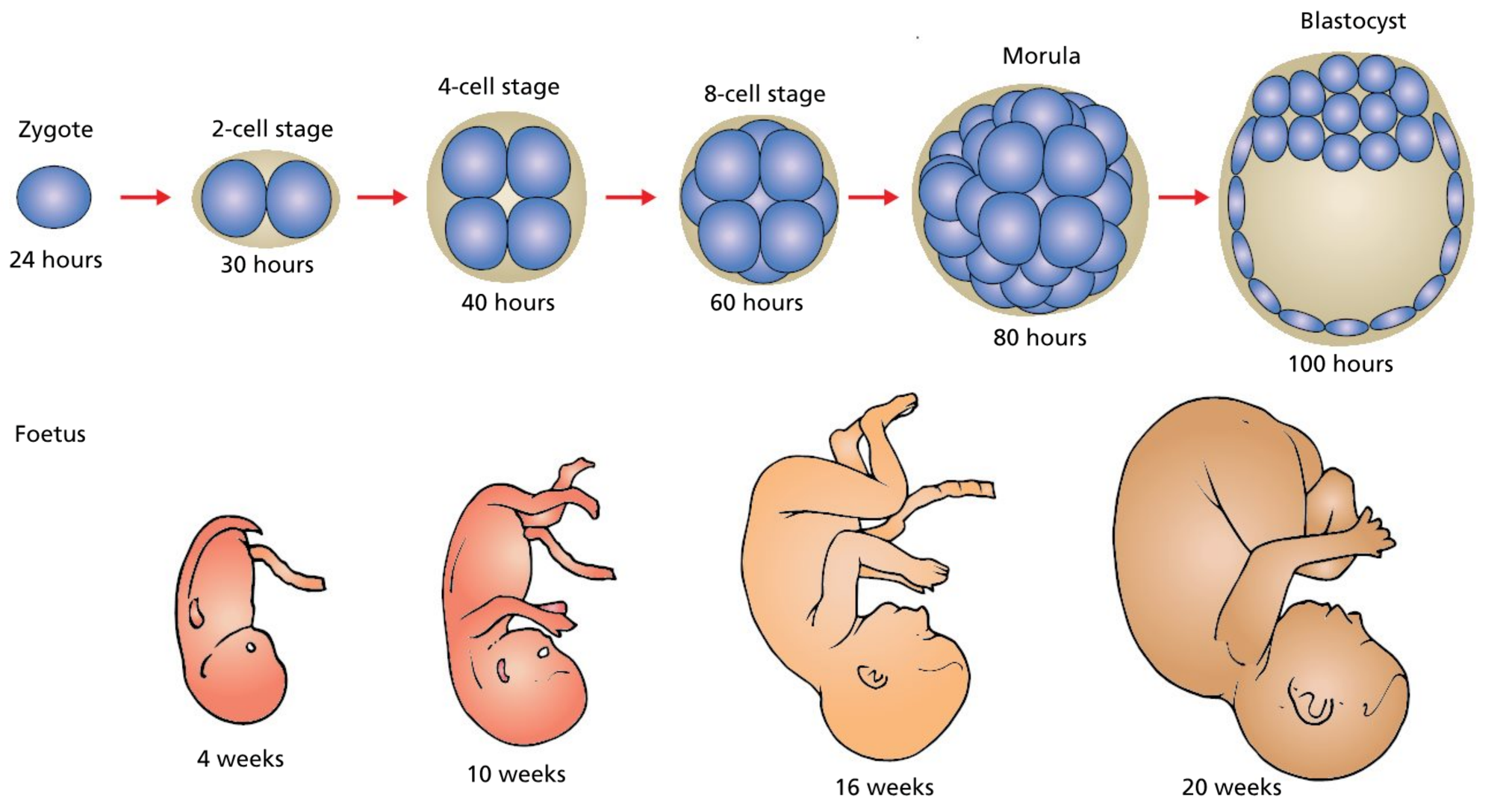


Figure 6.27 Human development from zygote to 20-week fetus

Regardless of whether people decide to have children or not, because the message 'Pass along your genes!' is still carried by our DNA, humans produce hormones that develop our bodies so that the process of sexual reproduction can occur. By understanding this biological process, people can be better prepared to make healthy and balanced decisions related to the changes that occur during puberty.

One of the most important things to understand about the process of puberty is that each person experiences it in a different way and at different times. That means that while there are some general patterns or processes that occur, because the development of adult characteristics is dependent on instructions from each person's DNA, each person will go through their own, unique process.

Puberty begins when the **hypothalamus** in your brain (Figure 6.22) begins to produce a hormone called **gonadotropin releasing factor (GnRH)**. The word gonad refers to organs in males and females that produce the sex cells, or gametes, as well as other hormones. (In males, the gonads are the **testicles** or testes, while in females they are the **ovaries**.) Therefore, we can understand that GnRH contributes to gonads producing and releasing other hormones, those that are responsible for the reproductive characteristics of adult males and females, which, in turn, results in the growth and development of the gametes.

The process begins in the same way in both males in females. At some point in late childhood, the DNA in a girl's or boy's cells sends the signal that it is time for the hypothalamus in the brain to start producing larger amounts of GnRH. The GnRH travels to the nearby **pituitary gland**, which is stimulated to release hormones that function in the reproductive system – **follicle stimulating hormone (FSH)** and **luteinizing hormone (LH)**. It is at this point that things differ for males and females.

When GnRH is first released in a girl, it travels through the bloodstream to the ovaries (the female gonads) and stimulates them to produce and release more hormones, including **estrogen**. These hormones are responsible for the development of the characteristics that are associated with adult females, including enlarged breasts, wider hips, a narrower waist, increased production of fatty tissue, and a menstrual cycle. These hormones, and their resulting characteristics and processes – in particular, the menstrual cycle – prepare the body and make it possible for a female to become pregnant and give birth.

In males, when FSH and LH reach the testes (the male gonads), they stimulate the production of the hormone **testosterone**. Testosterone is the hormone that is responsible for the characteristics that are associated with adult males, such as a deeper voice, increased facial and body hair, increased production of muscle tissue, and the production of sperm, the male sex cells that fuse with a female's egg at fertilization and result in pregnancy.

Estrogen and testosterone are not only produced by the ovaries and testes. Estrogen is produced by fat cells and also by the adrenal glands, which are located on the top of the kidneys.

Testosterone is also produced by the adrenal glands and, in women, in the ovaries. When considering the production of the hormones estrogen and testosterone, it is important to know and understand that, even though females produce more estrogen and males produce more testosterone, both genders produce both hormones. That means that females produce testosterone and males produce estrogen. Moreover, even among females and males, there is a range, due to genetic or other external factors, in the production and levels of estrogen and testosterone.

Estrogen functions or contributes to...	Testosterone functions or contributes to...
Slow down the process of growing taller	Speed up the process of getting taller
Reduce the development of muscle tissue	Increase the production of protein in cells and the development of muscle tissue
Increase breast size	Increase the size of the testes and penis
Increase fatty tissue around hips and reduce fatty tissue around waist	Reduce body fat more effectively
Increase the growth of pubic and underarm hair	Increase the growth of pubic, underarm, facial and body hair
Regulate the menstrual cycle	Produce sperm
Maintain bone density	Maintain bone density
Maintain healthy and smooth skin	Some skin problems, like acne
Maintain a balanced mood	Increase some feelings of aggression, competition, dominance or self-confidence
Control cholesterol levels	Increase red blood cell production in bone marrow
Retain (hold onto) sodium (salts) and water in body cells	

Table 6.2 Summary of some functions of estrogen and testosterone

Estrogen and testosterone have many functions in the body, beyond those directly related to reproduction. Take a look at Table 6.2 for a summary of some of the functions of estrogen and testosterone. What do you notice about their functions?

For humans and other organisms that reproduce with sexual reproduction, offspring are possible when a female egg cell and a male sperm cell fuse at fertilization. This process of fertilization allows the chromosomes from the male to combine with the chromosomes of the female, so that the offspring have a unique combination of genes and a unique combination of characteristics.

An egg becomes available for fertilization as a result of the events that occur during the menstrual cycle in response to the levels of the hormones FSH, LH and estrogen, and other hormones. It is during the menstrual cycle that these hormones help to prepare the female's body for a possible pregnancy. For example, as a result of the changing levels of FSH, LH and estrogen, one ovary releases one egg in the process of **ovulation**, while the walls of the uterus get thicker and better supplied with blood in preparation for an embryo potentially implanting if fertilization occurs. After implantation, the embryo receives all that it needs while it goes through the different stages of fetal development during pregnancy. However, if fertilization does not occur or an embryo does not implant into the wall of the uterus, the female releases excess tissue and blood cells from the uterus, and she experiences menstruation or a menstrual period.

Sperm have the opportunity to reach the egg cell when the male ejaculates, or releases sperm from the **penis** into the **vagina**, during sexual intercourse. The sperm cells must travel through the female's reproductive system up to the **Fallopian tube** (or **oviduct**) into which the egg was released and meet up with the egg. In order for fertilization to occur, one sperm cell must reach and break through the membrane of the egg cell at just the right moment – if the sperm arrives at the egg cell too soon or too late after the egg enters the Fallopian tube, fertilization will not occur. Of the hundreds of millions of sperm cells that are released during ejaculation, only a few hundred make it even close to the egg cell.

From the information in Table 6.3, we can see that human females from the start of puberty and beyond are generally able to get pregnant once a month, though this can and does vary greatly with each female's menstrual cycle. This is because the egg that is released from the ovary lives for between 12 and 24 hours after it has been released. If, after the egg has been released, there are no sperm present and fertilization does not occur, the female menstruates. However, it is possible for

	Female gametes	Male gametes
Name	Egg	Sperm
Size	0.1 mm	0.05 mm
Chromosomes present	One set of chromosomes 1–22 plus one X chromosome	One set of chromosomes 1–22 plus one X chromosome *or* 1 Y chromosome
Where it is produced	In the ovaries	In the testes
When it is produced	Before birth	From puberty throughout life
How many are produced during a lifetime	A few hundred thousand	Hundreds of billions
How many are released during a lifetime	300–400	Hundreds of billions
During what process they are released	During ovulation	During ejaculation
How often they are released	Approximately once every 28 days, depending on the female's cycle	As a result of sexual arousal or excitement
How many are released each time	One	Hundreds of millions
Until what age they can be released	Until menopause, usually around the age of 45 to 50 years old	Throughout life

■ **Table 6.3** Comparison of the female and male gametes

SEE–THINK–WONDER

Draw a three-column See–Think–Wonder chart.

Look carefully at the information in Table 6.3. Ask yourself:

- **What do I see when I look carefully at this table? What are some interesting details, patterns or unique characteristics that I notice from this information? Write these thoughts down for the 'See' column.**
- **What do I think about this information? What are some patterns I notice? What are some hypotheses I have for what I notice? Write these thoughts down for the 'Think' column.**
- **What do I wonder about this information? What are some questions I have, and what are some things I would like to get more information about? Write these thoughts down in the 'Wonder' column.**

Share your thoughts with your class. Can you add anything to any of the categories?

a female to get pregnant even *before* her first menstrual period. This could happen if a male and female have sexual intercourse at the time when the female has released an egg for the first time and has therefore not menstruated yet. Moreover, because the release of an egg does not always occur at the same point of the menstrual cycle, it is possible that an egg can be released at any time – even during menstruation. So, while it is true that ovulation must occur in order for a female to get pregnant, because the cycle of ovulation can be irregular for reasons such as stress or changes in diet or activity level, it cannot be said with 100% certainty whether or not it is the time of the female's cycle when ovulation has occurred.

Fertilization and pregnancy can occur in ways other than through sexual intercourse. For example, a doctor can perform a medical procedure, called artificial insemination, to insert sperm into the vagina and the female reproductive system, so that fertilization and implantation may occur as it does following the process of intercourse. Another alternative for pregnancy is a laboratory procedure called *in vitro* fertilization, during which eggs and sperm are put together for fertilization to occur under special laboratory conditions, and then inserted by a doctor into the female so that the embryo may implant into the uterus and continue to develop into a full pregnancy.

DISCUSS

When is it possible for a female to become pregnant?

What are the characteristics of social interactions and group behaviour?

If we think of the different types of interactions between people, the only interaction that definitely requires two people is reproduction – as we learned, the sperm from a male and the egg from a female are needed for reproduction to occur. However, if we think about the other things that we do in our lives, interacting or working with others has many benefits. From learning, to preparing food, to just having fun, working with others often has a better outcome than if people tried to do the same activities on their own.

Humans, like other animals, instinctively seek out and interact with others of the same species. Just like schools of fish swim together as protection from predators, birds travel together in flocks to make flying easier for the group, and wolves hunt together to have better chances of killing their prey, people work together to make life's tasks easier. Unlike other animals, and as we considered in the previous section about the reproductive system, humans also have the ability to seek out others in order to fulfil our needs for friendship, camaraderie or love.

However, not all interactions or group behaviours have positive outcomes. For example, if we think that sometimes, in order to fit into and be accepted by others, people choose unhealthy or risky behaviours like smoking, taking drugs, or having unprotected sex, we can see how the instinct to seek out and interact with others can at times actually be more harmful to us than helpful.

DISCUSS

What are some of the group behaviours or interactions that occur regularly in your life? What are some benefits of those interactions? What might be some negative outcomes?

ACTIVITY: 'When in Rome…'

ATL

- Critical-thinking skills: Consider ideas from multiple perspectives

There is an expression in English, 'When in Rome, do as the Romans do' – which suggests that people should base their lifestyle decisions on those of the people around them.

Designate and label areas of the room that represent the following belief statements:

- **I strongly agree with the statement.**
- **I kind of agree with the statement.**
- **I am neutral about the statement.**
- **I kind of disagree with the statement.**
- **I strongly disagree with the statement.**

When the statements (below) are read aloud, each person moves to the area of the room that best represents his or her feelings or response to the statement.

Once everyone has moved, you and your classmates will provide some evidence or reasoning for what makes you feel the way that you do. Remember to include as much fact-based evidence or reasoning as possible to support your opinions.

Statements

- **Individuals should always follow the traditions of their family when making lifestyle choices.**
- **Individuals should always follow the traditions of their culture when making lifestyle choices.**
- **Individuals should only rely on scientific information when making lifestyle choices.**
- **Individuals should make lifestyle choices based solely on their personal interests or needs.**

Now complete a reflection to summarize your feelings about the debatable question for this chapter after listening to others' perspectives. You might choose to do individual written reflections or a group discussion.

Assessment opportunities

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

How can understanding body systems help us to make decisions for balanced and healthy lives?

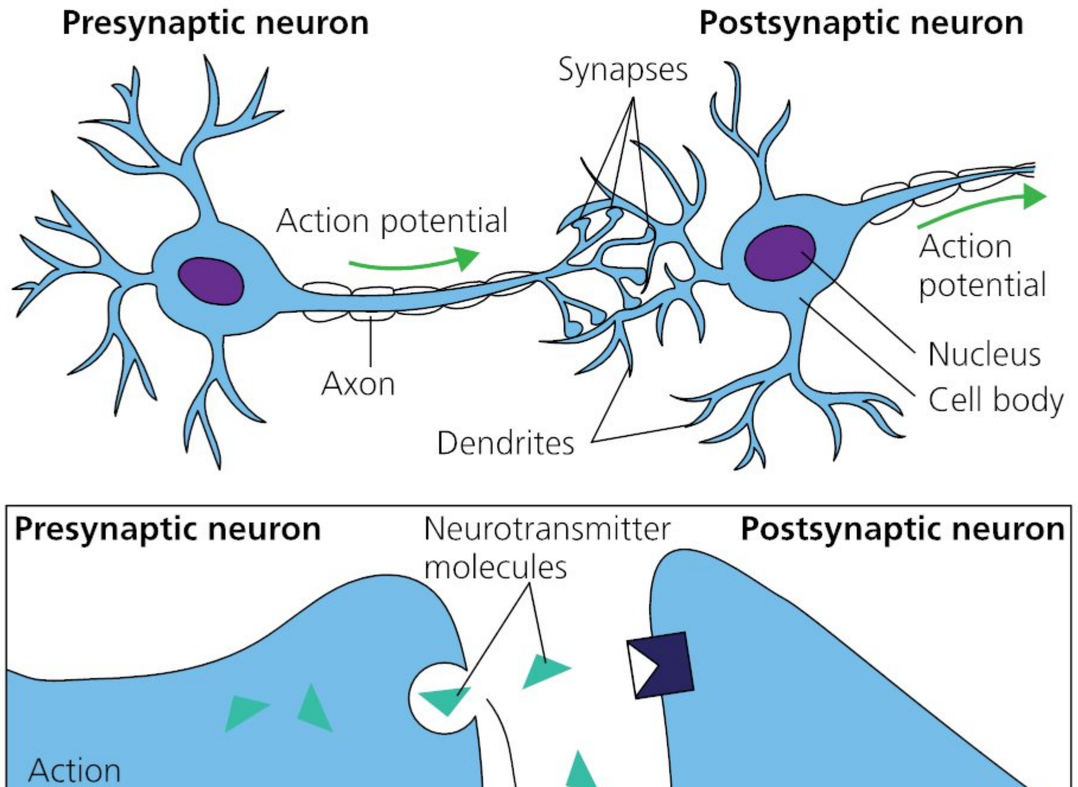
Throughout this chapter, we have learned about different systems in the body. However, we do not live in an isolated vacuum – every day we consume and are exposed to substances and have to make decisions that influence our body systems. For example, drugs such as cocaine change the way we think, feel and perceive our surroundings, because they interrupt the system of signaling between neurons and neurotransmitters. Take a look at Figure 6.31. What is the effect that cocaine has on the signaling system between the neurons? What short- and long-term effects does it have on a person? Then go back to Table 6.1 and look at the functions of dopamine. How do the effects of cocaine relate to those of dopamine? What connection can you make between cocaine, dopamine and addiction?

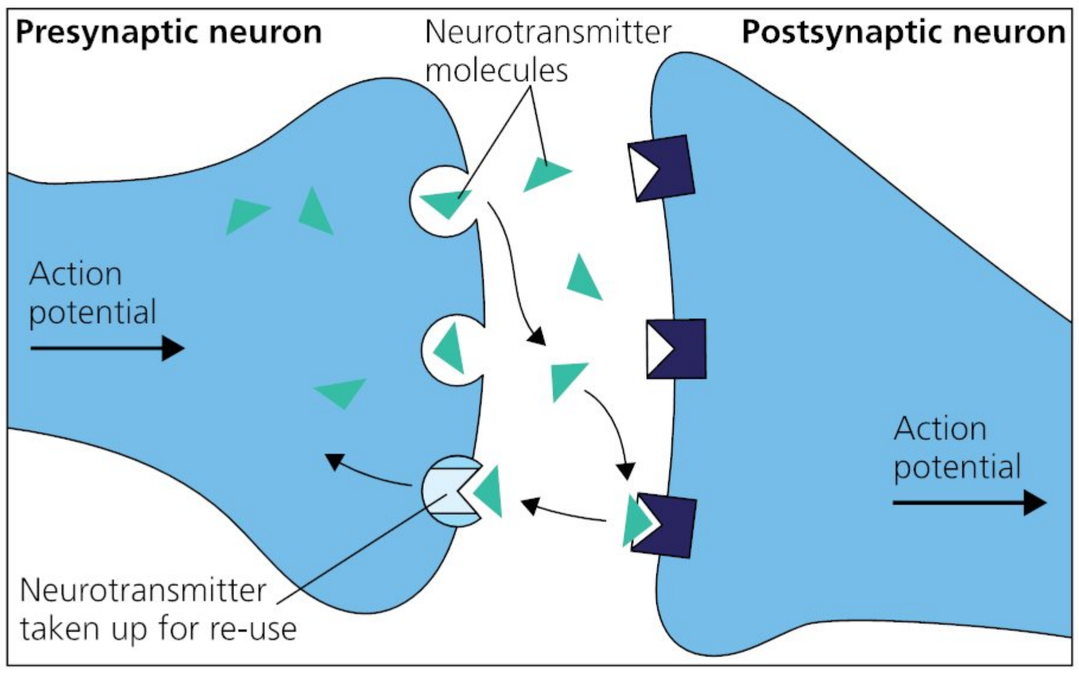
Possible short-term effects	Possible long-term effects
Increased energy	Addiction
Increased attention and 'alertness'	Feeling irritable
Reduced appetite	Frequent changes in mood
Increased blood pressure	Feeling restless or unsettled
Increased heart rate	Feeling paranoid
	Hallucinations

Table 6.4 Effects of cocaine

Making decisions to have balanced and healthy lifestyles is not a one-size-fits-all formula. The different circumstances that people live with has an important impact on our options and approaches to a balanced life. However, even though the external conditions vary from culture to culture or even home to home, the basics of our bodies – the anatomy and physiology of the body – follow the same systems and patterns. Furthermore, having a better understanding of how the body works can help us to understand the changes or responses we experience in our body as a result of different circumstances.

Therefore, we can all benefit and make better choices by being better informed about what is going on beneath the surface.





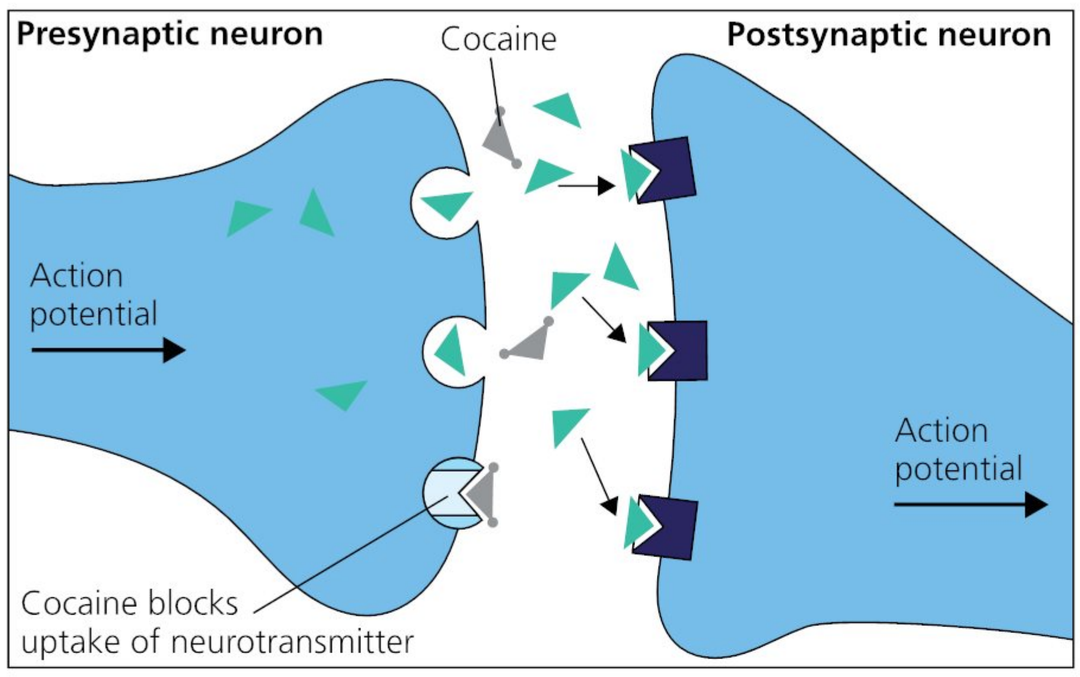


Figure 6.31 The effect of cocaine at synapses

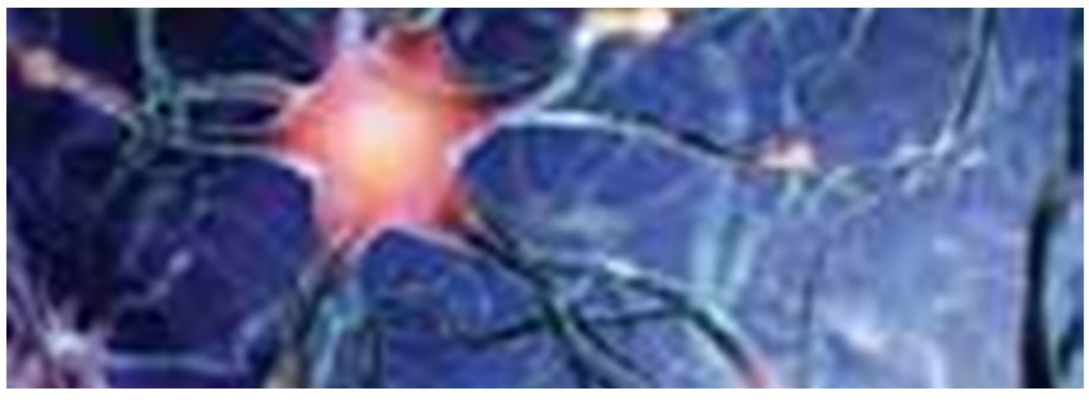


Figure 6.32 How do different chemical substances affect our nervous system and body functions?

ACTIVITY: Under the influence

ATL

- Communication skills: Use appropriate forms of writing for different purposes and audiences; Use a variety of media to communicate with a range of audiences

As we learned in earlier in this chapter as well as in Chapter 3, everything that we consume is able to make its way – as some chemical substance or another – into our cells. Our cells are then able to utilize those chemical substances. Substances that enter our body, either through eating, drinking, inhaling or even injection, are used by our cells to perform, enhance or interrupt the basic biochemical reactions that occur to keep us alive.

Often, we are not sure why the body responds in the way that it does to things that are consumed. For example, we might know that some people feel happy (and often want more) when they eat sugar, we might know that drinking alcohol makes a person feel and act drunk, and we might know that smokers crave and can get moody without the nicotine in cigarettes. Because you have learned more about your body systems, in particular the nervous system, you are now able to take a closer look at the responses that people have to different substances. You will be able to describe the effect on a biological level and provide information that will help you make decisions for a healthier or more balanced life.

Your goal for this activity is to describe what you know about the signaling system of neurons and neurotransmitters in the nervous system and how this system affects our actions. However, you will describe this system according to the effects of substances such as sugar, nicotine or alcohol that people may consume. In other words, you will describe how the system functions under usual circumstances and how it functions when it is under the influence of these substances.

How can people effectively share information about human body processes?

You will analyse the information that you find in your research in order to be able to make scientifically supported judgments about the effects of the substances. Then use what you understand about the nervous system signaling system to describe and come up with what you think is a helpful, scientifically supported approach to inform others of the impacts of these substances.

For this activity, you must be sure that you consider your audience and what will be the best way to share this information with them. What media, such as print, audio, video or digital, will be the most effective? Would it be appropriate to use social media? How about creating a forum? Discuss with your classmates and your teacher in order to determine what means of communication you will use.

Before you get started, you should also brainstorm how you want the information to look or sound. What features will you include to make the information as understandable as possible? Will you include diagrams, tables or graphs? For example, in Figure 6.31 and Table 6.4, a labelled diagram as well as a table help people to visualize as well as read about the effects of cocaine on neurotransmitters and the body.

Some possible substances you may choose to research are:

- **nicotine**
- **sugar**
- **alcohol**
- **marijuana**
- **heroin.**

Hint

When beginning your research, do a web or image search for *effects of 'substance' on neurotransmitters*, or *effects of 'substance' on brain*. For example, you could search for *effects of nicotine on neurotransmitters*.

When you have completed your work, decide with your class what will be the best way to share the information with the school. How can you share what you have learned to help others?

Assessment opportunities

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

! Take action! How to make healthy choices

ATL

- Communication skills: Use appropriate forms of writing for different purposes and audiences; Use a variety of media to communicate with a range of audiences; Negotiate ideas and share knowledge with peers and teachers; Participate in, and contribute to, digital social media networks

! Create a communication platform to help teens understand the anatomy and physiology of their bodies and then use this understanding to make decisions for more balanced and healthy lifestyles. Pick one of the topics that you think is most important for teens to know more about.

! For communication to be effective, it must take into consideration the needs, interests and resources of the target audience. You must first decide who will be your target audience and what will be the best way to reach them. Here are some questions you might ask yourself in order to decide who will be your target audience.

- Is there a city or area of the world that you have learned about or visited where teens and young adults have difficulty attaining a healthy lifestyle?
- Where is home for you? Could teens and young adults benefit from this information to use scientific reasoning to make decisions for a healthy and balanced lifestyle?
- What about your current or previous school? Would the teens and young adults there be well served by your message?

! Once you decide who will be the target of your messages, you should choose how you would like to communicate this scientific information about body systems. For example, you might choose to create a series of videos, podcasts or blog posts, a social media campaign, or print resources, like brochures or infographics. before you begin, you should discuss the following with your classmates.

- What is the culture of your target audience? Are there certain social or cultural expectations for how people exchange information?
- Are there any regulations for communication that might influence how your target audience could receive the information you will share?
- What are some environmental or economic factors that might prevent your target audience from getting access to your message?
- How might personal principles of right and wrong (a person's morals) influence decision making for balanced and healthy lifestyles?

! Would you like to create a real podcast? Are you unsure how to get started? Try searching online for **how to make a podcast**. Be sure you talk with your teacher about the options that you are given to ensure that you are not signing up for a service that you have to pay for.

! Before you begin your work, it is important to know how much scientific information you should include. Take some time to brainstorm with your class the information about the body systems and the scientific terminology you should include, so that it is clear that your message is based on scientific reasoning and not just opinions or personal beliefs. Then you should come up with a system for yourself, such as making a checklist or referencing the assessment criteria, so that you are sure to include all the components necessary for demonstrating the highest levels of achievement.

Key subject skills

In this activity we have communicated scientific understanding with a larger community. Scientists must often share information from their research with non-scientists in a way that is easy to understand. By effectively communicating what they learn through their experiments and investigations, scientists can help people make well-informed decisions about health, the economy, laws and more.

◆ Assessment opportunities

- This activity can be assessed using Criterion A: Knowing and understanding, and Criterion D: Reflecting on the impacts of science.

Links to: Design

In design, you have inquired into the concepts of resources and perspective when creating your designs or products. These concepts are equally as important now when deciding on and creating your communication platform. What skills or important principles from your design class can you transfer to create an effective platform for communication now?

Reflection

In this chapter, we have **analysed** diagrams, images and text to understand how the several different body systems function. We have demonstrated our knowledge and understanding by **describing** in different platforms of communication how these body systems work. We have also **applied** our scientific understanding to help others make decisions for balanced and healthy lifestyles, after **discussing** and **analysing** different factors that may impact the way we choose to communicate our message. We have practised different approaches to research and different ways to share information, while **documenting** the work of others that we used to develop our final work.

Use this table to reflect on your own learning in this chapter.		
Questions we asked	**Answers we found**	**Any further questions now?**
Factual: What are the structures and functions of different body systems? How do our body systems work together? How and why do our bodies change as we get older? What are the characteristics and benefits of social interactions and group behaviour?		
Conceptual: How can understanding body systems help us to make decisions for balanced and healthy lives? How can people effectively share information about human body processes?		
Debatable: To what extent should people follow traditions, culture, science or personal preferences when making lifestyle choices?		

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**
Communication skills					
Organization skills					
Media literacy skills					
Critical-thinking skills					
Creative-thinking skills					
Learner profile attribute(s)	Reflect on the importance of being a good communicator for your learning in this chapter.				
Communicators					

Glossary

action potential The change in the electrical current in muscle or nerve cells to send nerve impulses
activation energy The minimum energy required for reactants to undergo a particular reaction
aerobic respiration Cellular respiration that occurs with oxygen
agonist The set of muscles that contracts during movement
amino acids The chemical building blocks of proteins
ammeter Device used for measuring quantity of electric current
amperes S.I. unit for electric current
anaerobic respiration Cellular respiration that occurs without oxygen
analogue Transmission of information as continuously varying signal
angle of incidence Angle formed between an incoming ray and a line normal (at right angles to) the boundary between two media
angle of reflection Angle formed between a reflected ray and a line normal (at right angles to) a reflective surface
angular speed Angle turned through by a rotating object each second
antagonist The set of muscles that relaxes during movement
artery Blood vessels contract to conduct blood away from the heart
assimilate When cells take in, process, and utilize the products of digestion
ATP Adenosine triphosphate; used by cells as energy
autotrophs Organisms (i.e., plants) that produce their own food
base stations A unit which relays signals across a network
battery A collection of electrical cells; a source of current
biochemical Chemical processes that occur in cells of living organisms
biodiversity The variety of plants and animals living in a habitat
blood vessels The tube-like structures that carry blood to and from the heart throughout the body
bone marrow Inner part of bones that produces blood
capillaries Smallest blood vessels that carry blood at the cellular level
carbohydrates Macronutrients, such as starches and sugars
cardiac muscle Muscle cells that make up the heart
cell phones A mobile telephone of relatively short range whose signals are relayed across a network of communications cells
cellular respiration Creation of ATP by breaking down glucose in cells
channel A range of frequencies designated for telecommunications
chemical digestion Chemical breakdown of foods through the action of enzymes and other substances produced by the body
chlorophyll Protein pigment in plant cells that contribute to the green colour of plants and allows photosynthesis to occur
chloroplasts Cell structures where photosynthesis occurs
circuit diagram A diagram showing the arrangement of an electric circuit
compact bone The dense portion of bone, mostly on ends and edges
complex carbohydrate Carbohydrates that are made up of many different monosaccharides or simple sugars
concave surface A surface with an inward curvature
conservation The act of protecting or caring for the environment
continuous wave signal Continuously varying wave carrying information
converge When the distance between two things decreases with distance travelled, such as light rays
convex surface A surface with outward curvature
critical angle The angle of incidence after which rays passing across the boundary from a denser to a less dense medium are no longer refracted but reflected instead
diffusion The process of one substance spreading through another
digestion Breaking down food into its smaller chemical components
distance magnifier Increases the distance over which a force acts
diverge When the distance between two things increases with distance travelled, such as light rays
ecology The study of the interactions that occur in the natural world
effector cells Cells that respond to signals from the nervous system
efficient The maximum output for the minimum possible input and waste
effort A force applied to produce a mechanical effect
electric current The flow of electric charge
electrical signals Electrical impulses that are generated by and travel through cells
electromagnetic energy Energy carried by electrical and magnetic fields that travel in the form of a wave
endocrine system Body system responsible for producing and releasing hormones
esophagus Tubular structure connecting the mouth to the stomach
estrogen Hormone associated with sexual development, and menstruation
exothermic Chemical change resulting in the release of heat
Fallopian tube Tube structure extending from the ovaries through which egg cells travel to the uterus
fast-twitch fibres Muscle cells responsible for fast bursts of activity
fatty acids One of the chemical building blocks of fats or lipids
fertilization When the genetic material of a sperm cell enters into an egg cell and combines with its genetic material
focal length Distance between optical axis and focal point of a lens
focal point A point at which waves or rays meet or originate
follicle stimulating hormone Contributes to the regulation of the reproductive processes in both males and females
force magnifier A machine that reduces the force required to move a load by increasing the distance over which the effort is applied
frequencies The number of wave cycles per second
gastric acid Acidic liquid produced by stomach cells
gears A wheel that is used with others to alter the relationship between the speed of a driving mechanism and other parts
glucose Simple sugar used by cells during respiration
glycolysis The stage of cellular respiration that occurs without oxygen when glucose is initially broken down
greenhouse gas An atmospheric gas that contributes to the greenhouse effect by absorbing infrared radiation
growth plates The portion of bones where elongation occurs
heterotrophs Organisms that must consume food
hydrocarbons Compound containing hydrogen and carbon
hypothalamus Portion of the brain that signals the release of certain hormones and coordinates aspects of the nervous system
incident ray A light ray incoming to any optical component
induces When an electrical or magnetic object produces an electrical or magnetic effect in another without touching
internet protocol Rules for transmission of data over the internet
isotope Different forms of elements that have the same number of protons but different numbers of neutrons in their nuclei

joule The SI unit of work and energy
kilocalories Unit of energy; used to indicate energy stored in foods
lateral inversion The reversal of left and right in an image
lever A machine by which effort is applied to an object via a fulcrum
light-emitting diode An electronic device that allows electric current to flow in one direction only and produces light
load The force exerted by an object to which an effort is applied
local area network A telecommunications or computer network which links devices within a building or locally
lymph Clear liquid portion of blood
macronutrients Nutrients that are needed in large amounts to fulfil humans' nutritional needs
mainframe A central computer used to deal with large quantities of data
menopause The time of life when menstruation no longer occurs
menstruation In females, the process during which blood and some tissue from the uterus exits the body through the vagina
metabolism Processes that occur within cells of living things to keep them alive
micronutrients Nutrients needed in small amounts to fulfil nutritional needs
moment In mechanics, the turning effect of a force around a pivot
multimeter A device for measuring various electrical properties
nervous system Network of nerves to send signals throughout the body
network In telecommunications, a system of interlinked devices
neurotransmitter Chemicals released at the end of a nerve cell and that has an effect on the neighboring nerve or muscle cells
nodes A point through which numerous devices in a network are linked
non-renewable sources Natural resources that can be used up; there is no way to regenerate them
normal A line at right angles to an optical surface or boundary
operating system Software supporting a computer's key functions
optical fibre A flexible glass fibre used to transmit signals using light
organs A group of tissues that perform a bodily function
ovaries Organs in a female body where egg cells are produced, stored, and released
oviduct Small tubes that lead from the ovaries to the Fallopian tubes
ovulation The process of an egg releasing from the ovary
parallel circuit An electrical circuit in which electric current divides into multiple circuit branches and then recombines
penis Male genital organ through which semen passes
petrochemicals Substances made from petroleum or its by-products
physical digestion Mechanically breaking down food into smaller pieces
pituitary gland An important gland in the brain that helps to control growth, development, and other bodily functions
plane mirror A mirror with a flat surface
platelets Parts of blood that contribute to clotting
pole End of a magnet or an electrically charged point
potential difference Difference in electric potential energy between two points in space or in a circuit; measured in Volts
potential energy Energy held inside a body due to bonds or other forces, or due to the position of a body within a force field
power The work done in a certain time, measured in Watts
principal axis A line through the centre of an optical system
probiotics Bacteria that are beneficial for human health
proteins Chemical substances made up of large chains of amino acids
puberty The time of life when adolescents reach sexual maturity
ray diagram A schematic diagram showing the path of light rays
real image An image that exists in space
receptors Cells that receive an impulse or signal
red blood cells Cells that transport oxygen throughout the body
redox reaction A reaction where electrons are gained and lost by reactants
renewable Resources that can be regenerated
resistance Effect on electrical current passing through a material by which energy is lost in the form of heat
resonators Objects that increase volume of sound through resonance
router A device that relays data from one point in a network to another
saliva Liquid formed in the mouth, containing digestive enzymes
sample rate the number of times that an analogue signal is 'sampled' or measured per second
saturated fats Fats that are formed by a high number of single bonds; usually considered to be less healthy in the diet
secondary digestive organs Organs that produce enzymes and other chemicals for digestion, but food does not pass through
semiconductor Materials which act like a conductor at high temperatures and an insulator at low temperatures
sensor A device for measuring a physical property electrically
series circuit A circuit in which there is only one current pathway
server A computer in a network that acts as a central resource
signaling molecules Chemical substances, such as hormones, that send signals throughout the body
simple sugars Monosaccharides
skeletal muscles Muscles that allow the skeleton to move
skeletal system System in the body that is composed of bones, joints, ligaments, and tendons
slow-twitch fibres Muscle cells responsible for slow, sustained activity
small intestine Part of the digestive system after the stomach, where the majority of nutrients are absorbed into the blood stream
spongy bone Part of the bone made up of lattice bone tissue
starches A type of complex carbohydrate
synapse The space between nerve cells through which neurotransmitters and signals pass
tendons Strong fibres in the body that attach muscles to bones
terminals Points by which an electric circuit is connected externally
testicles Organs in a male's body where sperm is produced
testosterone Hormone associated with sexual development in males, but also produce in females
tipping point The moment when a number of small changes leads to a larger change that cannot be reversed
total internal reflection When light rays are reflected from a boundary between a more and a less dense medium
trans fat Produced when an unsaturated fat is converted to a saturated fat
transistor A component used as an electronic switch or as an amplifier
transmitter An antenna used to transmit signals as EM waves
unsaturated fats Fats formed by a high number of double bonds
vagina Female genital organ through which menstruation and child birth occur
virtual image An image formed by the eye from the light rays appearing to diverge from an optical component
voltmeter A device for measuring the potential difference in a circuit
watt The SI unit of mechanical and electrical power
weight-bearing activities Activities that require a person to work against gravity
white blood cells Cells that work to protect the body from diseases or infection
work The transfer or transformation of energy by a system
zygote Cell that forms after an egg cell has been fertilized by a sperm cell

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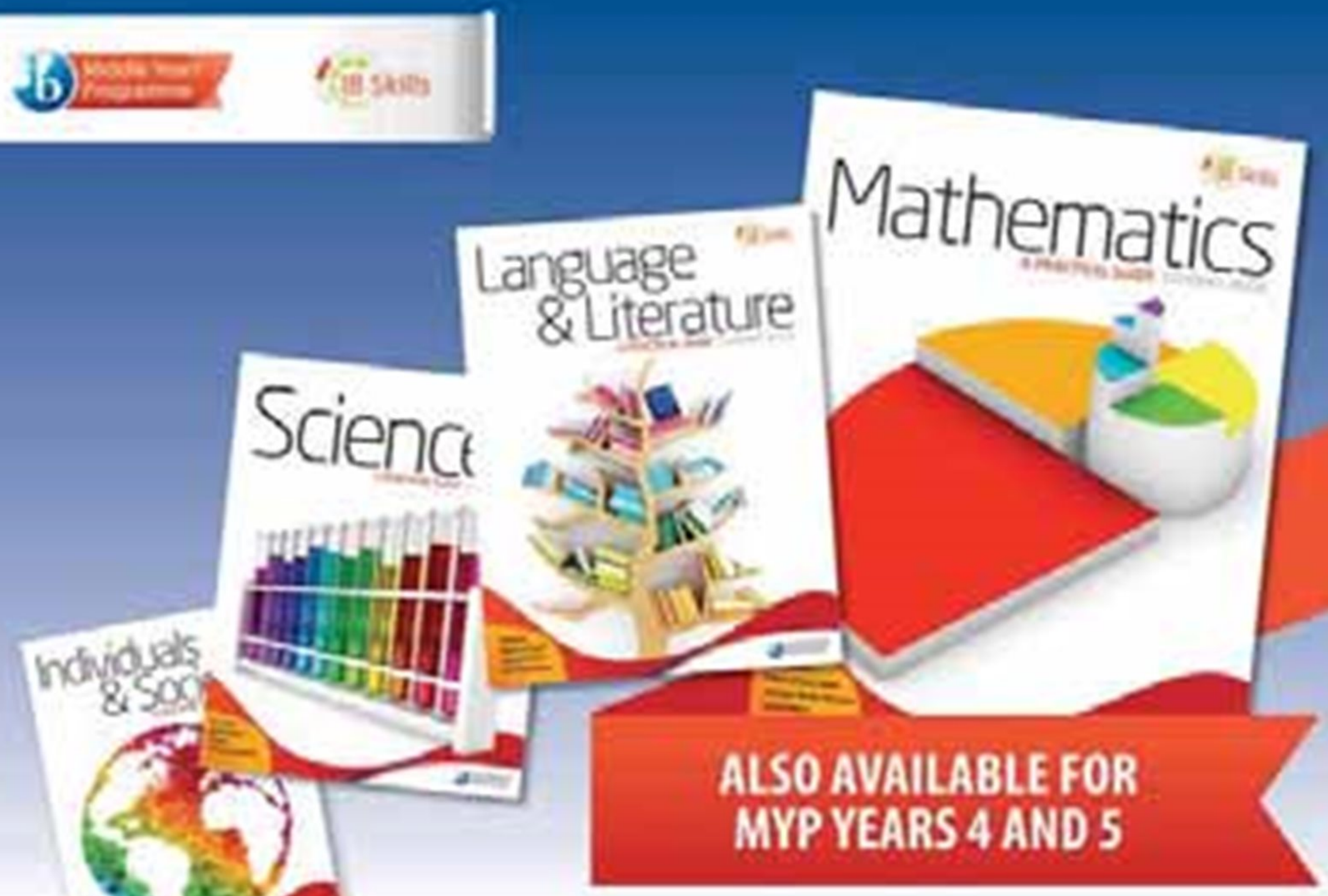

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