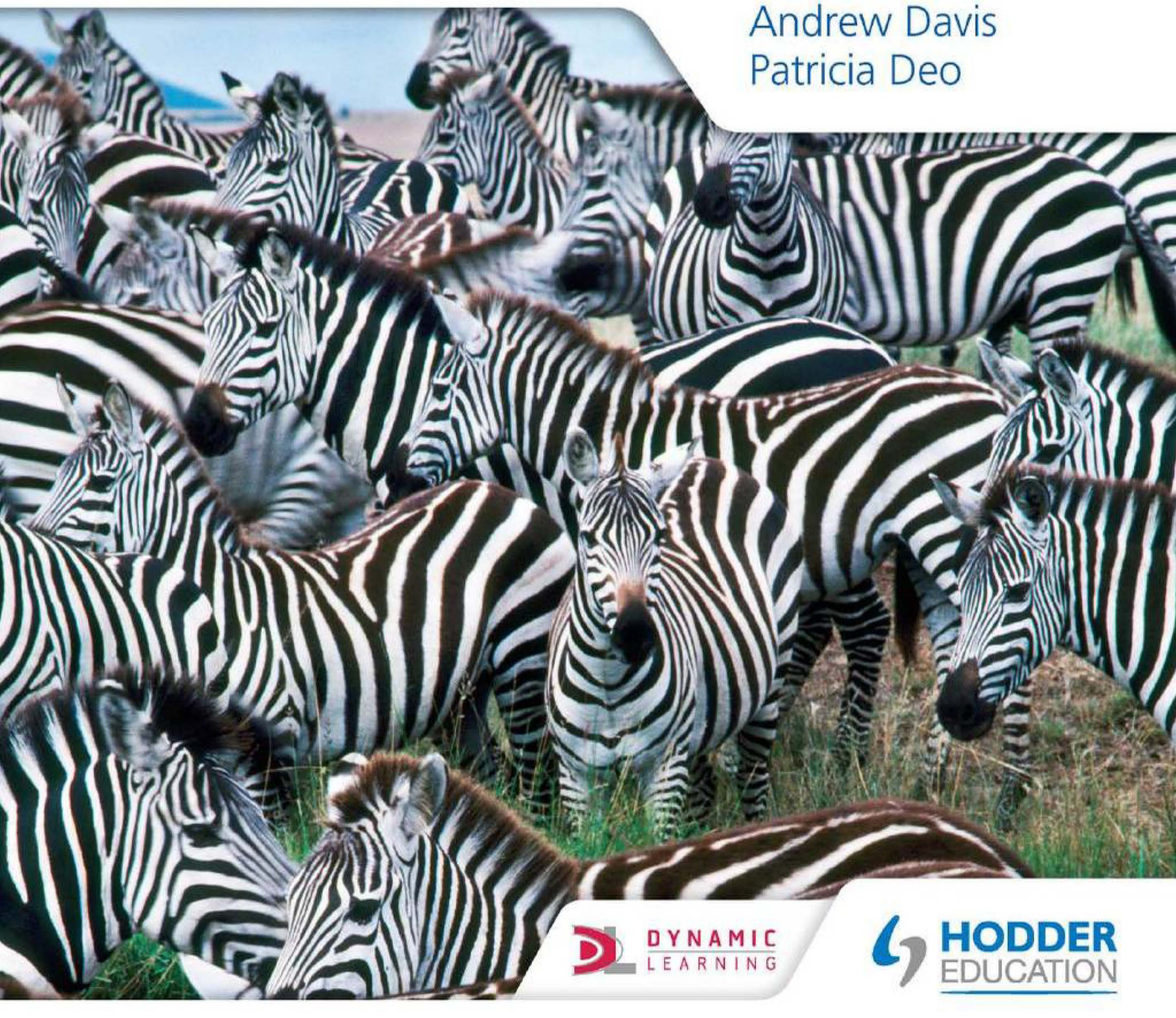
MYP *by Concept*
4 & 5

Biology

Andrew Davis
Patricia Deo



DYNAMIC LEARNING

HODDER EDUCATION

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Dedication

Andrew Davis – For Alice, Alexander and Freya

Patricia Deo – For Cesar, for his constant understanding, patience and support, and to Liz, to whom I owe so much

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Published by Hodder Education
An Hachette UK Company
Carmelite House, 50 Victoria Embankment, London EC4Y 0DZ

Impression number 5 4 3 2 1
Year 2018 2017 2016 2015

Cover photo © Mint Images – Frans Lanting
Illustrations by DC Graphic Design Limited and Oxford Designers & Illustrators
Typeset in Frutiger LT Std 45 Light 10/14pt by DC Graphic Design Limited, Hextable, Kent
Printed in Slovenia

A catalogue record for this title is available from the British Library

ISBN: 9781471841705

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 biology, and how they interact in real-life global contexts.

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


Relationships

Patterns; Function

Identities and relationships

1 How is life organized?

Your identity is determined by the relationship between different levels of organization in your body which, although differing in complexity, share patterns and functions with all life on Earth.

CONSIDER AND ANSWER THESE QUESTIONS:

Factual: What are the characteristics of living things? What are cells and how are they structured? What roles do cells carry out? What are the characteristics and functions of different cells, tissues and organs? How are organisms grouped and classified?

Conceptual: What determines whether something is alive or not? Are viruses alive? How does cell structure relate to function? What does it mean for organisms to be 'related'? What characteristics make some organisms more closely related than others?

Debatable: Should scientists use new research to reclassify organisms? Are humans a special form of life? Will it be possible to create artificial life?

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

Figure 1.1 Cells are the basic building blocks of living things (the cells have been coloured in this image to make them more clearly visible)

IN THIS CHAPTER, WE WILL ...

- Find out:
  - how the identify of an organism is determined by the parts it is made up from;
  - what determines whether something is alive or not.
- Explore how living things are classified into groups with similar identities.
- Take action by finding out whether it is possible to create artificial life.

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

- Critical-thinking skills
- Creative-thinking skills
- Organization skills

KEY WORDS

embryonic
hierarchy
multicellular
organization
physical
unicellular

2 Biology for the IB MYP 4&5: by concept

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.

ATL

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

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

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.

KEY WORDS

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

Definitions are included for important terms and information boxes are included to give background information, more detail and explanation.

EXTENSION

Extension activities allow you to explore a topic further.

● We will reflect on this learner profile attribute …

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


We will reflect on this learner profile attribute ...

- Thinkers – using critical- and creative-thinking skills to analyse problems.

Assessment opportunities in this chapter:

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

WHAT DOES IT MEAN 'TO BE ALIVE'?

Suppose, for a moment, that an alien from another planet landed on Earth – how would it be able to tell whether something is living or not?

Figure 1.2 Three objects – are they alive or not?

ACTIVITY: Alive or not?

Look at Figure 1.2. It will be clear which ones show something that is living and which show something that is non-living. What characteristics define whether something is 'alive' or not? Make a checklist that you could give to our friendly alien so they could use it to establish whether something is living or not.

Now you have reminded yourself of the characteristics of living things, how could you use these to explain to an extra-terrestrial that stalactites and stalagmites growing in a cave are not living, yet corals are?

Figure 1.3 Flooded limestone cave where stalactites, made from calcium carbonate, have formed in the roof and stalagmites on the floor beneath

Figure 1.4 Corals are formed by animals called polyps that secrete a protective skeleton of calcium carbonate around themselves

1 How is life organized? 3

You are prompted to consider your conceptual understanding in a variety of activities throughout each 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 learnt in practical ways, you must be an active part in this process. Activities help you explain the ways in which biology can be applied and used, and also to discuss and evaluate the implications of using biological principles to address specific issues. This should give you a better understanding of the issues facing biologists 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.

◆ Assessment opportunities in this chapter:

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

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

Use this table to 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 our learning in this chapter.*				

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.

▼ Links to:

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

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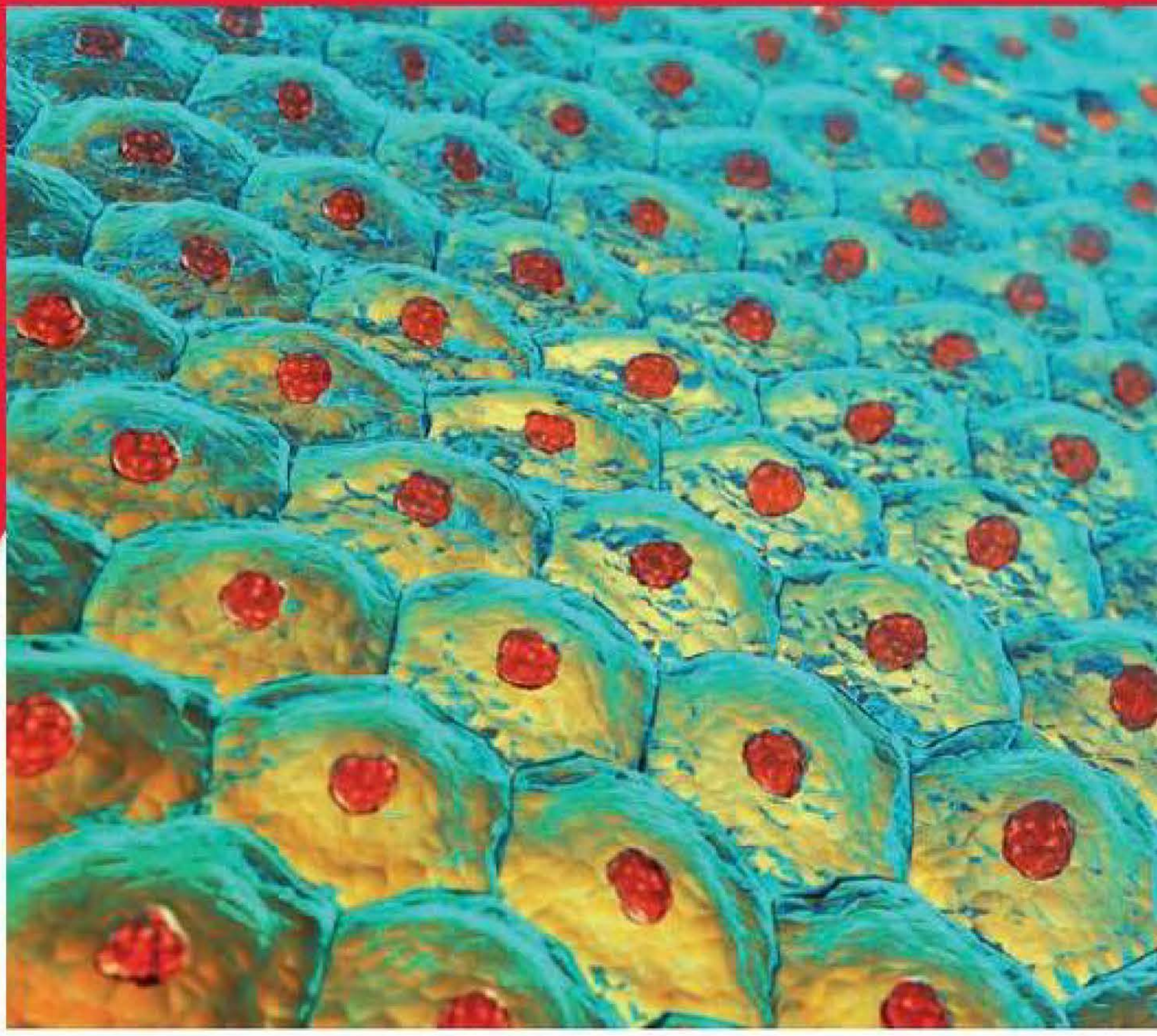

■ **Figure 1.1** Cells are the basic building blocks of living things (the cells have been coloured in this image to make them more clearly visible)

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Figure 1.4 Corals are formed by animals called polyps that secrete a protective skeleton of calcium carbonate around themselves

What are the characteristics of living things?

Robert Hooke was a pioneer of cell biology. He was fascinated by **microscopy**, and developed a microscope to observe the structure of cork. He drew and described cork cells, and measured their size. He was the first person to use the term 'cells' to describe the basic building blocks of life.

In 1665 he published a book of all his drawings made using his microscopes: it became the first scientific best-seller, and inspired a wide public interest in the new science of microscopy. Hooke was also famous for discovering the law of elasticity, which describes the linear variation of tension with extension in an elastic spring: the law still bears his name.

In this chapter, we will compare our **physical** (biological) identity with that of other organisms to understand what it means to be human. In order to begin this process, we must understand how organisms are structured, from the simplest to the most complex level. Although they vary in form and function, **cells** are the basic building blocks of life. The idea that cells are the unit of structure and function from which organisms are made is known as 'the cell theory'. Cell theory states that:

- cells are the building blocks of structure in living things
- cells are the smallest unit of life
- cells are made from other cells by division.

Key scientists in the development of cell theory were Robert Hooke (born 1635), Antonie van Leeuwenhoek (born 1632) and Louis Pasteur (born 1822).

Figure 1.5 A sample of cork wood drawn by Robert Hooke

Although I say so myself, I was a brilliant microbiologist who changed the way that scientists view life. People used to believe that life could spontaneously generate itself: that maggots on dead flesh, for example, and bacteria and other growths on food matter could appear from nowhere.

I established that life does not spontaneously generate, and that the bacteria that 'appear' in broth are microbes freely circulating in the air, which contaminate exposed matter.

I was born in Delft in the Netherlands. Although I had no formal training in science, I developed a hobby of making lenses, which I mounted in metal plates to form simple microscopes. I was able to magnify my specimens up to ×240 – quite a feat at the time!

I was able to observe blood cells, sperm and single-celled organisms in pond water. I wrote to Robert Hooke with my findings but he did not believe me – until he had developed a microscope as powerful as mine.

Figure 1.6 Antonie van Leeuwenhoek

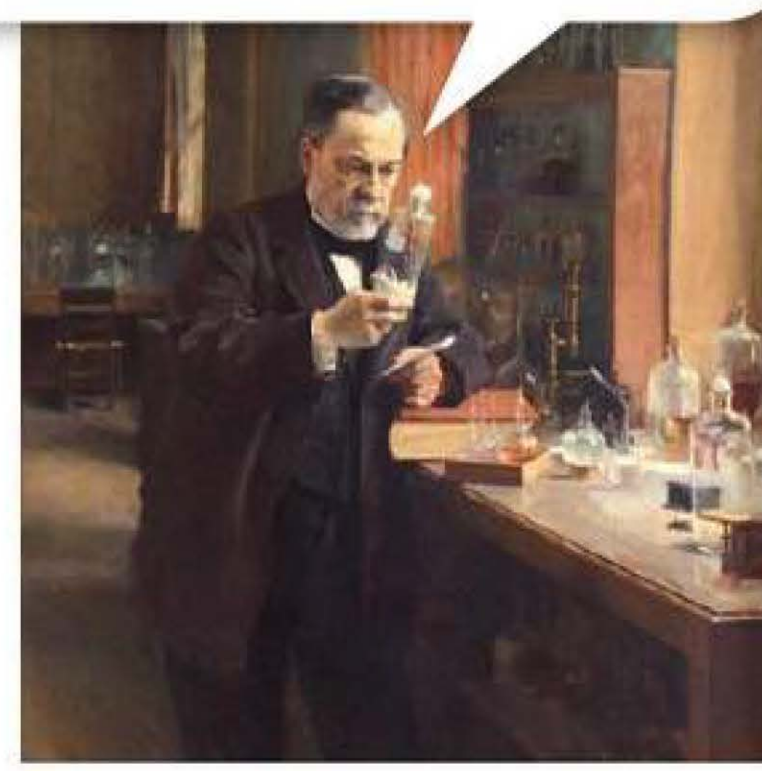


Figure 1.7 Louis Pasteur

ACTIVITY: Are viruses alive?

ATL

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

In this activity you will **apply** your knowledge of living things to answer the problem: are viruses alive or not? **Viruses** are minute particles that can infect animal and plants cells. One group, the bacteriophages, attack bacteria cells. Viruses are a variety of different shapes and sizes.

The word comes from the Latin *virus*, meaning 'to poison'. Typically, viruses carry a small amount of nucleic acid (either **DNA** or **RNA**) surrounded by a protective coat of protein. Some viruses use the cell membrane of the host cell they infect to form their own membrane.

Use the Internet to research viruses. Do viruses carry out life processes? How do they live? Can they exist on their own?

Use the information you have found to write about whether you think viruses can be described as 'alive' or not. **Summarize** your views in one paragraph. To do this you can apply the following thought process:

- **Describe the characteristics that determine whether something is alive or not.**
- **Interpret the information that you have found about viruses to make scientifically supported judgements about whether you think viruses are alive or not.**

Note: there is no 'right' answer! Now share your ideas with your neighbour, and then feedback your thoughts to the whole class.

- **Explain the life cycle of a specific virus and how it uses its host cell to fulfill life functions.**
- **Analyse and evaluate information to make scientifically supported judgements.**

Assessment opportunities

- This activity can be assessed using Criterion A: Apply scientific knowledge to solve problems.

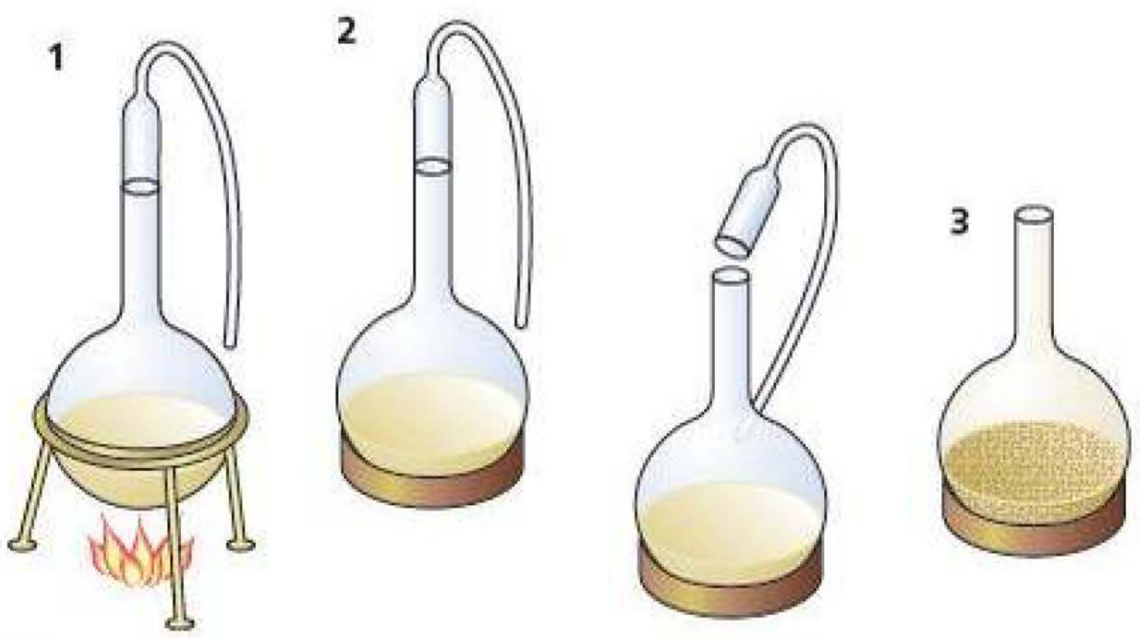


Figure 1.8 Pasteur's experiment, in which broth was sterilized (1), and then either exposed to air (3) or protected from air-borne spores in a swan-necked flask (2). Only the broth in (3) became contaminated with bacteria

EXTENSION

- Research one virus, for example virology, HIV, polio, Ebola, influenza, and produce a fact sheet about it. Does it cause a disease? If it does cause illness, what are the causes of the symptoms?
- Write an essay comparing computer viruses with natural viruses.
- Read about how viruses may have affected **evolution** by researching virolution.

WHAT DETERMINES WHETHER SOMETHING IS ALIVE OR NOT?

Living things are characterised by several properties. These functions of life are:

- **nutrition** (obtain nutrients by feeding or making food)
- **respiration** (break down glucose to release energy)
- **growth** (achieve a permanent change in size)
- respond to changes in the environment (**sensitivity**) which enables the survival of the organism
- **excretion** (get rid of waste products produced by chemical reactions in cells)
- **homeostasis** (maintain a constant internal environment)
- **reproduction** (produce offspring)
- **movement** (relocate from one place to another).

Something can be identified as living or not by asking whether it can carry out all these life processes.

DISCUSS

- **Discuss with a partner how you would describe to an alien visiting this planet for the first time whether something was alive or not.**
- **Do you and your partner agree whether viruses are alive or not? What evidence do you have to support your argument?**

What are cells?

HOW ARE CELLS STRUCTURED?

As we have discussed in the introduction to this chapter, all living things are made of cells. Non-living biological matter, namely viruses, are particles and require other cells for their survival. But how are cells structured, and what functions do they carry out?

ACTIVITY: DIY cell

ATL

- Creative-thinking skills: Use visual diagrams to generate new ideas; Make unexpected connections between ideas; Apply existing knowledge to generate new ideas

Design a structure that does the following things:

- **is the basic building block for all living things**
- **is the site of metabolic reactions, such as respiration**
- **contains the genetic information of the organism**
- **may have to be used to help physically support the organism.**

You will have worked out from this list that your task is to design a cell! You will **apply** your scientific knowledge to **solve** the problem of the best design for a cell. The design you come up with may be similar to or the same as how actual cells are structured, or be very different. You will **explain** how your cell works, and link the design with its function.

You need to **draw** a diagram of your design, and add labels to show how it works. Be inventive! Things to think about …

Type of organism

How large is your organism? Does it have a backbone? How will this affect the design of your cell?

Entry and exit

How do substances enter and exit the cell? How does the cell control this?

Hint
Think about how your organism will be supported.

Where is the genetic blueprint for the organism kept?

How might this be kept in one place and protected? How and where is this information read and used to make the structural molecules of life (proteins)?

What chemical reactions will be needed for the cell and where will they take place?

Would all the chemicals for different metabolic reactions be mixed up together or separated?

Hint
*This may depend of the **size** of the cell.*

Different types of cell may have to have different metabolic reactions (e.g. can your cell make its own food/sugar?)

Is the cell on its own or part of a bigger organism?

If it is on its own, how does it move?

If it is part of a bigger organism, how does it get food, water and oxygen?

Be as creative as you can. The cell you design may or may not look like cells you are familiar with, but *must* follow the rules outlined above. Do not forget to **explain** the relationship between the design of the cell and its function.

Assessment opportunities

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

ACTIVITY: Looking at cells

ATL

- Organization skills: Use technology effectively and productively
- Critical-thinking skills: Draw reasonable conclusions and generalizations

In this activity you will examine animal and plant cells under the microscope. You will **draw** and **annotate** diagrams of the cells you see.

Materials you will need for this activity:

- Microscope
- Slides and cover-slips
- Methylene blue solution (0.5% to 1%)
- Plastic pipette or dropper
- Sterile, individually packed cotton swabs
- Detergent
- Pondweed (*Elodea*)

Safety: Make sure you dispose of the cotton swab in a beaker of detergent to avoid germs being spread. Avoid contact with methylene blue as it is a stain.

Cheek cells

1. Take a clean cotton swab and gently scrape the inside of your mouth.
2. Smear the cotton swab on the centre of the microscope slide. Put the cotton wool bud into detergent as soon as you have finished with it.
3. Add a drop of methylene blue solution and place a cover-slip on top. Do not add too much solution! The methylene blue stains the nucleus blue.
4. Remove any excess solution by allowing a paper towel to touch one side of the cover-slip.
5. Place the slide on the microscope, with 4× (low) or 10× (medium power) objective lens in position, and find a cell. Then view at higher magnification.
6. Draw the cell. What structures can you see?

Pondweed (*Elodea*)

1. Pick an entire healthy looking *Elodea* leaf, using your fingers or cutting the leaf off with small scissors.
2. Place the leaf on the microscope slide.
3. Add a drop of water and a cover-slip.
4. If you do not have access to *Elodea*, look at the plant on the following website: www.exploratorium.edu/imaging-station/students/elodea.html#elodea or use the following search terms: *Elodea*, cells, microscope.
5. Draw and label *Elodea* cells.
6. Look carefully at the chloroplasts (the green structures in plants that carry out photosynthesis). Can you see them moving? How do you think they move, and why?

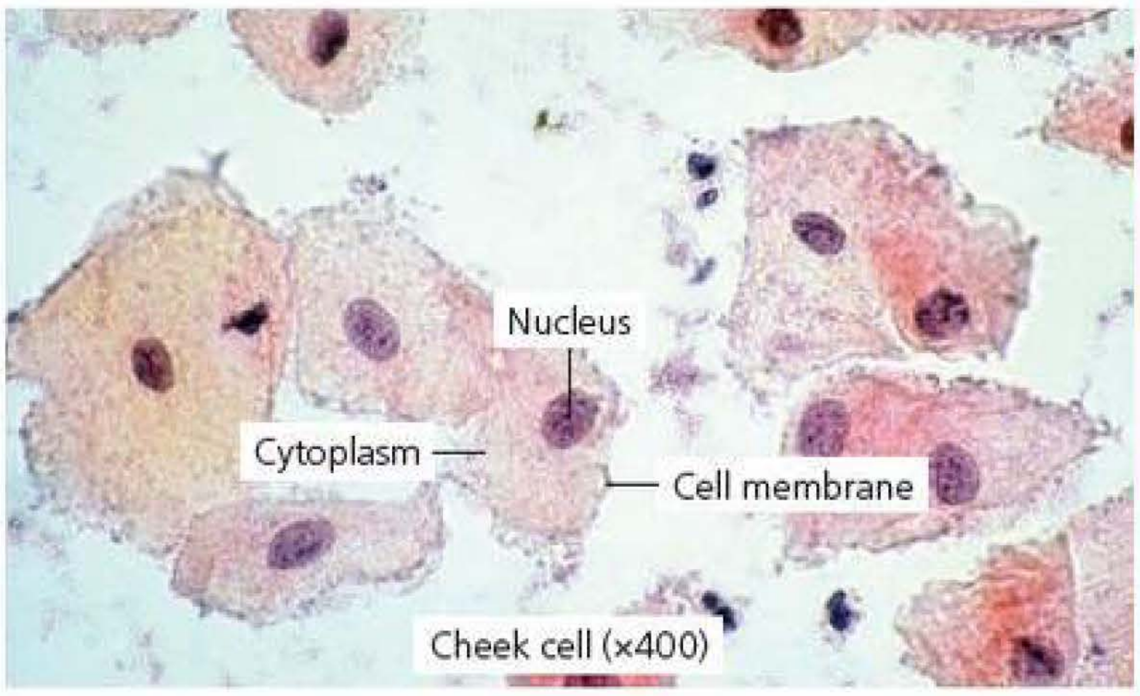


Figure 1.9 Cheek cells seen under a microscope at ×400 magnification. Parts of the cell that are visible are labelled

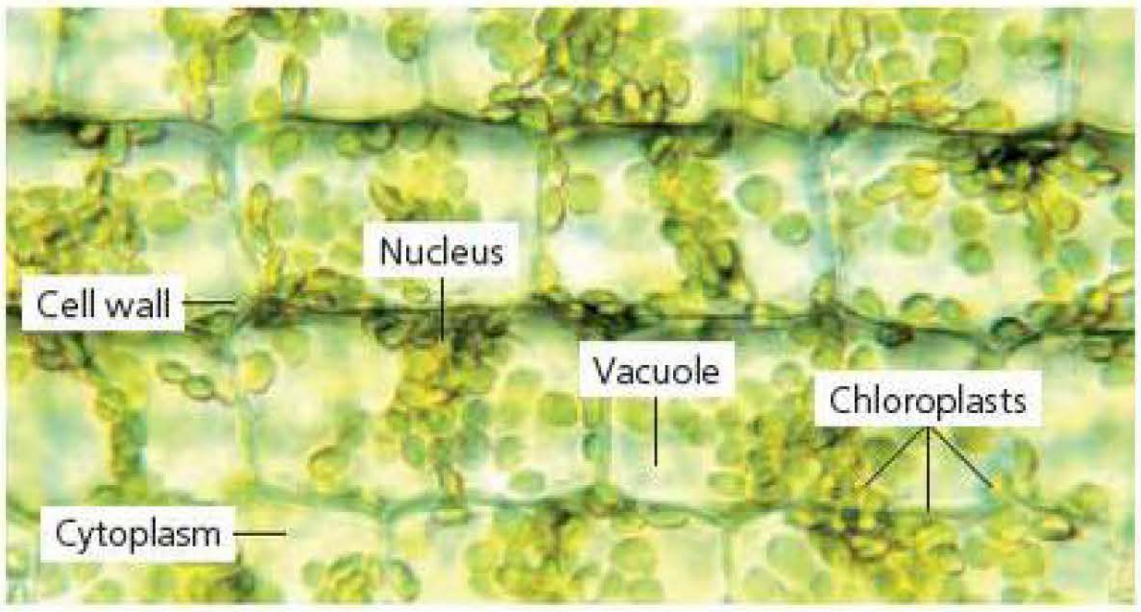


Figure 1.10 *Elodea* cells at ×400 magnification, seen under a light microscope

In this activity we have observed and interpreted microscopic information by using staining techniques and the correct use of the objective (magnification) lenses.

Assessment opportunities

- In this activity you have practised skills that are assessed using Criterion C: Present data in visual forms; Interpret data and explain results using scientific reasoning.

What roles do cells carry out?

EXTENSION

There are organelles other than the ones we will discuss in this section. Explore these using this website: http://learn.genetics.utah.edu/content/cells/insideacell/ or search: **inside cell**.

How did cells **evolve**? Where did they come from? Explore cell evolution using this website: http://learn.genetics.utah.edu/content/cells/organelles/ or search: **cell evolution**.

ORGANELLES AND CELL FUNCTION

The structures found within cells are called **organelles**. Which organelles could you see in the animal and plant cells? Did they have the same organelles, or were there differences?

Table 1.1 shows the range of organelles found in cells, and the function of each.

Different cells have different functions. In your body you have more than 250 different types of cells, each with a specific role. Depending on their job, cells have organelles that enable them to carry out their role – for example muscle cells have many **mitochondria** to provide the energy for them to contract. Can you think of any other cell that has a **specialized** function, and which organelles it needs in abundance if it is to carry out its role effectively?

Table 1.1 The function of animal and plant organelles

Part of cell	Function/job/notes	Found in plants, animals or both?
Nucleus	Contains genetic material (DNA organized into chromosomes for inheritance)	Plants and animals
Cytoplasm	Jelly-like material Site of many chemical reactions controlled by enzymes Contains organelles such as mitochondria and chloroplasts	Plants and animals
Cell membrane	Partially permeable membrane Forms cell boundary Controls passage of substances in and out of cell	Plants and animals
Cell wall	Semi-rigid Made of **cellulose** Supports cell Prevents turgid (swollen) cells from bursting	Plants
Chloroplast	Organelle found in **cytoplasm** Contains **chlorophyll** (green pigment which traps light energy to drive **photosynthesis**)	Plants
Vacuole	Large fluid-filled sac that swells, pushing the cytoplasm against the cell wall, making the cells turgid Cell shrinks when vacuole gets smaller (plasmolysed/flaccid)	Plants
Mitochondrion (plural – mitochondria)	Small organelle found in cytoplasm Site of respiration	Plants and animals

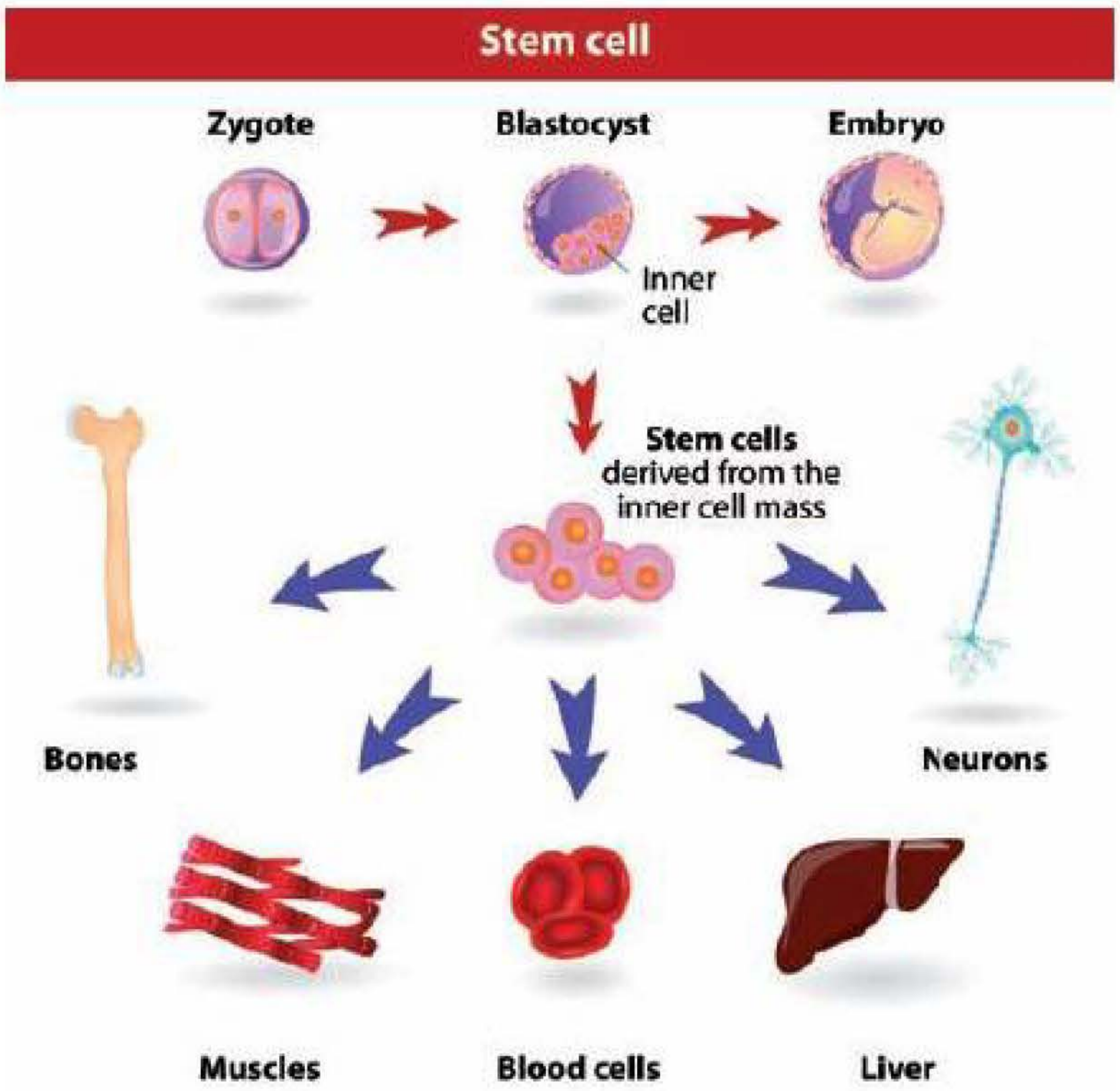
What are tissues, organs and organ systems?

HOW DOES CELL STRUCTURE RELATE TO FUNCTION?

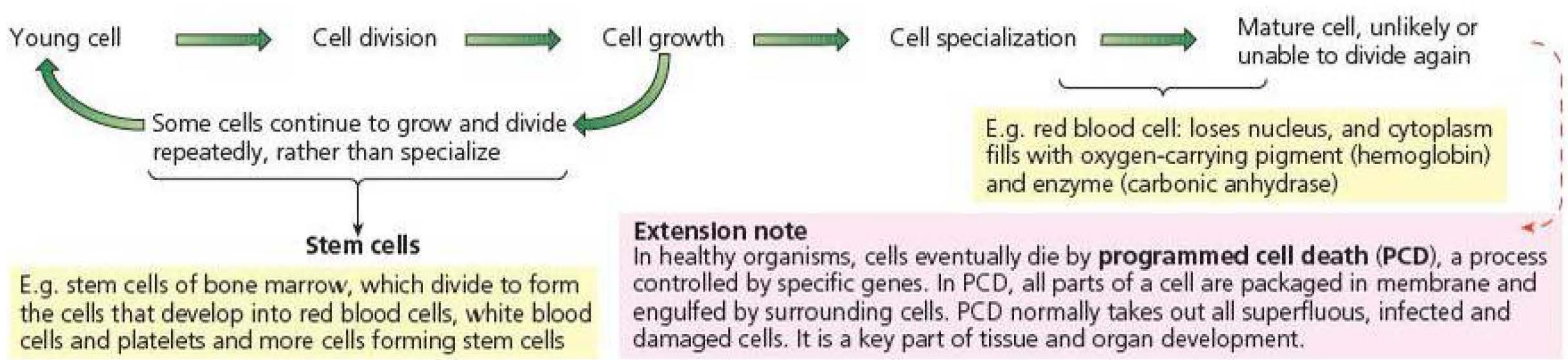
Organisms made from many cells, known as **multicellular** organisms, begin life as a single cell, which grows and divides, forming very many cells, and these eventually form the adult organism (Figure 1.11). So, cells arise by division of existing cells.

Our personal identity is founded on the relationship between the different cells, **tissues** and **organs** in our body, which work together to make us function as a whole organism.

The first step in developing a new organism is the continual division of cells to produce a blastocyst and then an **embryo** (see Figure 1.12). All these cells are capable of further divisions, and they are known as **embryonic stem cells**. A stem cell can repeatedly divide into more stem cells, which are unspecialized (i.e. have yet to become specific types of cell), and later can **differentiate** into mature cell types, such as muscle, blood and nerve cells. At the next stage of embryo development most cells develop into the tissues and organs that make up the organism. However, a very few cells within these tissues do retain many of the properties of embryonic stem cells, and these are called adult stem cells (Figure 1.12). Ethical issues regarding the use of stem cells in research are explored on pages 291–293 and page 297.

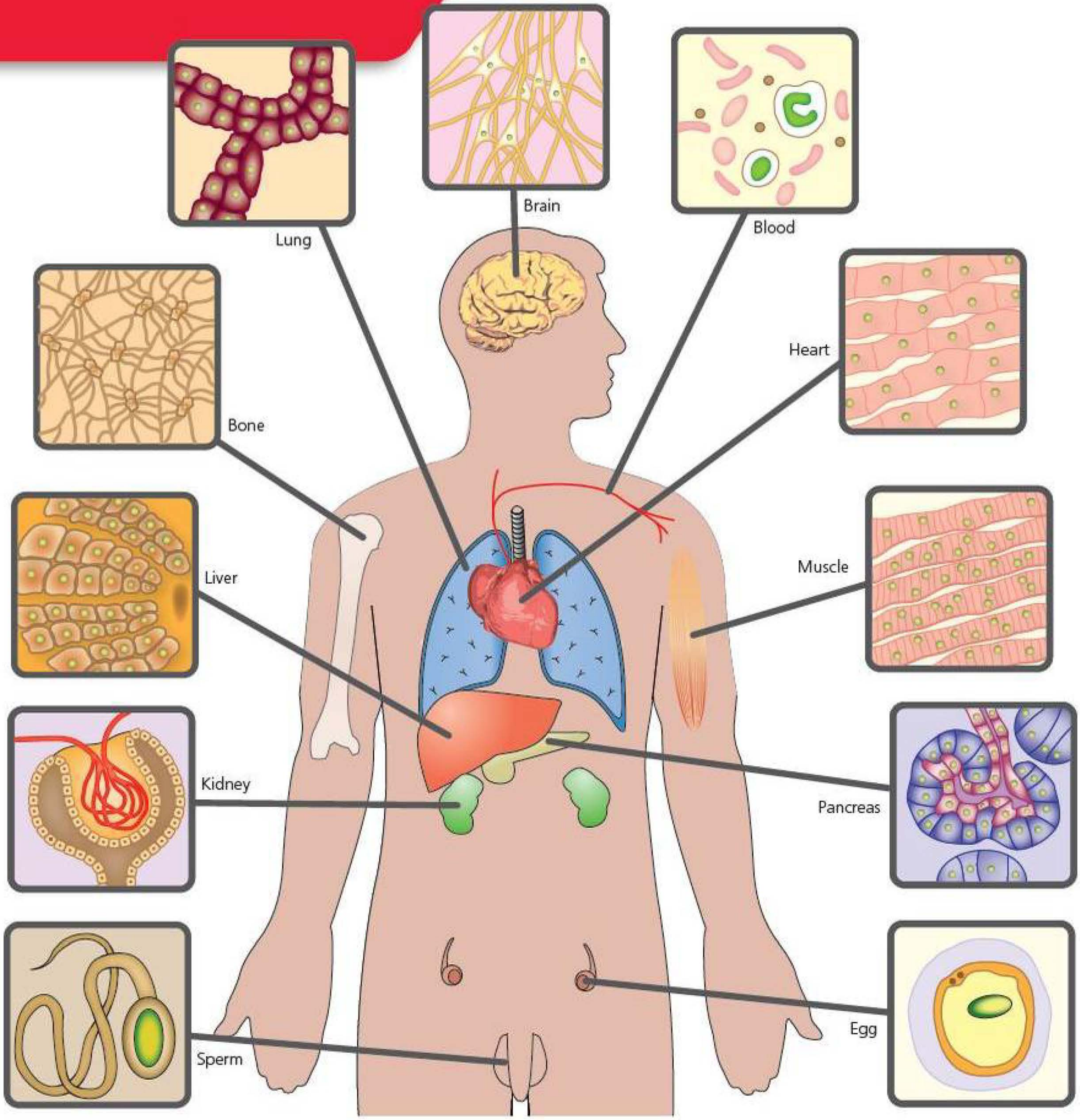


■ **Figure 1.12** A range of different specialized cells develop from undifferentiated stem cells. These cells form the tissues and organs of the body



■ **Figure 1.11** The life history of a cell

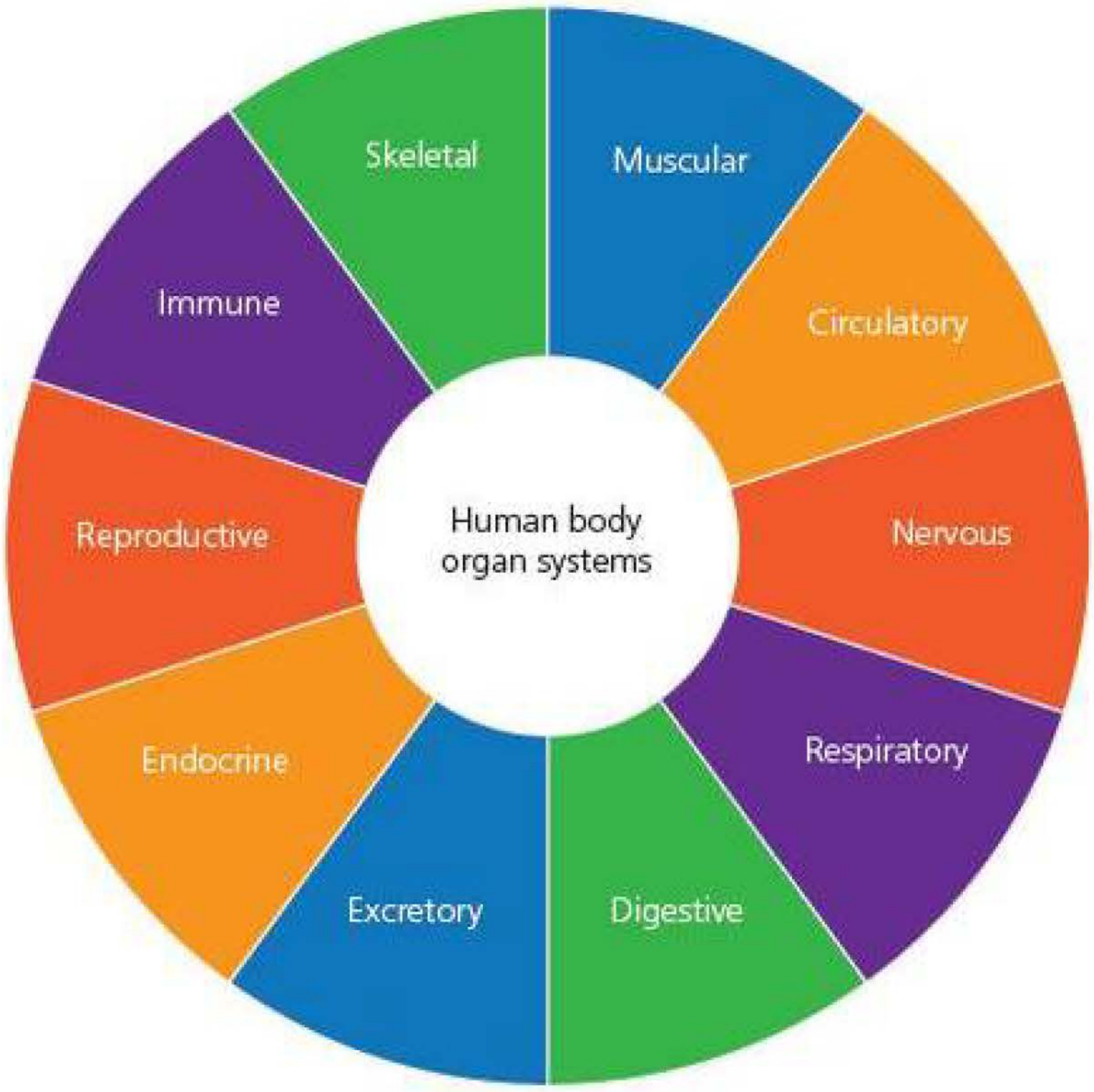
There are many different types of specialized cell. Look at the cells in Figure 1.13 – how are they adapted to the job they do?



■ **Figure 1.13** Specialized cells in the human body

What are the patterns and functions of cells, tissues and organs?

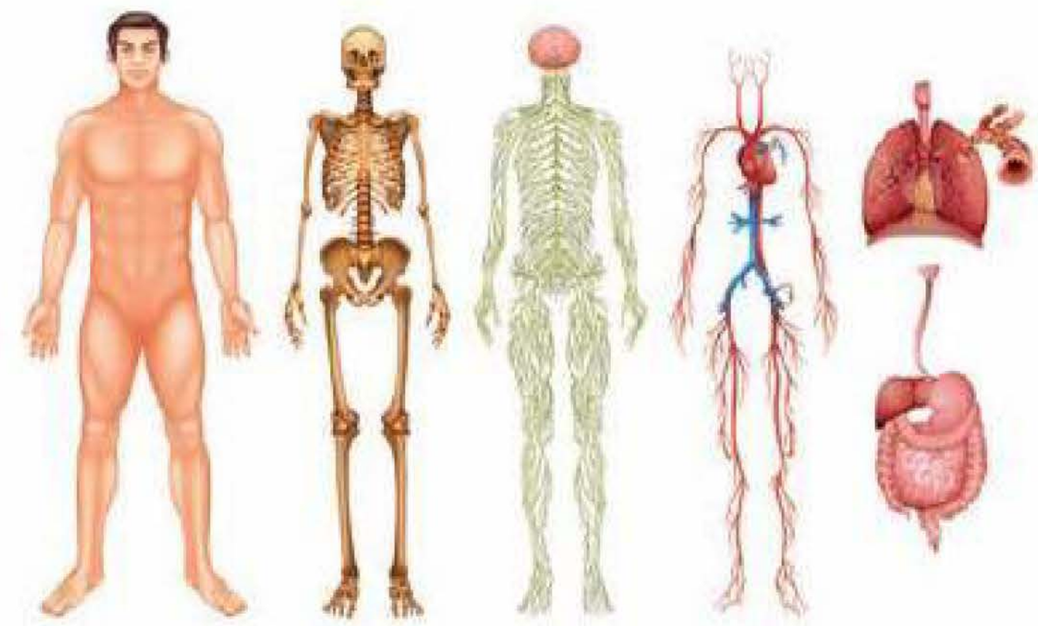
Tissues are groups of cells of similar type that work together to perform a particular function in the body, such as muscle and bone tissue. Organs are groups of tissues that work together to carry out a specific function, such as the skin, heart or **lungs**. **Organ systems** are groups of organs that work collectively to perform a function for the body, such as the digestive, reproductive or circulatory systems.



■ **Figure 1.14** The human body organ systems

THINK–PAIR–SHARE

What organ systems are shown in Figure 1.15?



■ **Figure 1.15** Four different organ systems

What specialized cells would each organ system contain?

Could you build an organ by selecting the correct tissues? Use the following website to find out: www.centreofthecell.org/learn-play/games/build-an-organ/

Discuss in pairs, and then share your ideas with another group, or the class:

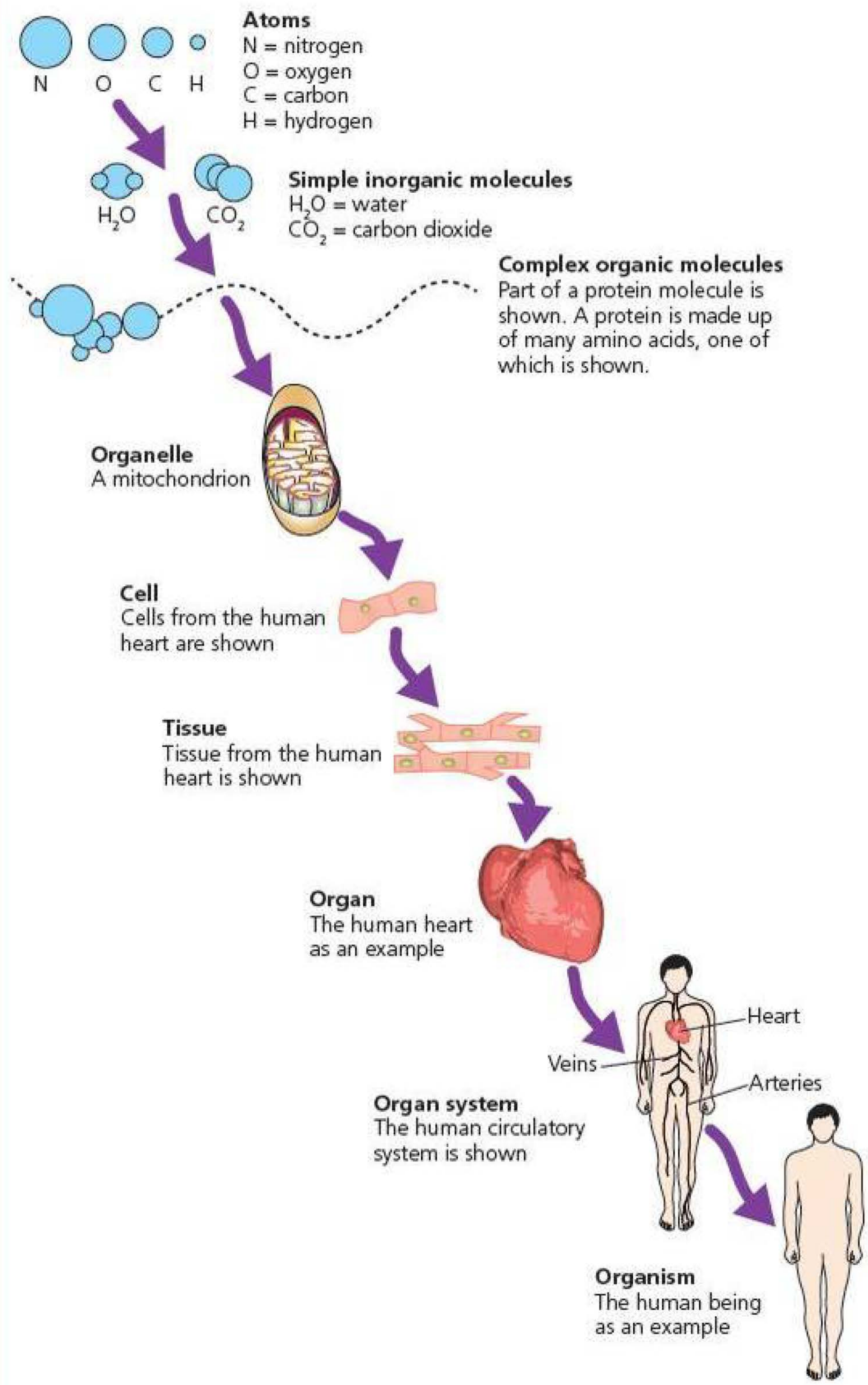
- What are specialized cells and how are they made?
- What are the differences between cells, tissues, organs and organ systems?
- To what extent does the **hierarchy of organization** in our bodies determine our identity?

ACTIVITY: The hierarchy of life

In this activity you will **summarize** information presented in one form in a new way. You will need to **interpret** the information provided to make judgements about how to arrange the information in the table.

ATL

- Critical-thinking skills: Gather and organize relevant information



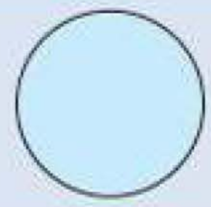
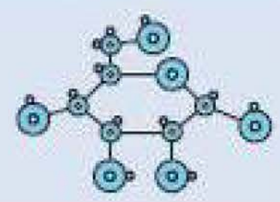
■ **Figure 1.16** The levels of organization

Using the chart below:

1 **In the first column match each illustration with its correct level of organization using items from the list below (the first entry has been done for you as an example):**
Atom Cell Molecule Organ Organelle Organ system Tissue Organism

2 **In the second column match each label and illustration with the correct description using items from the following list (the first entry has been done for you as an example):**

Use the information in Figure 1.16 to complete the following table:

Level of organisation	Description	Example
Atom	**H** Fundamental unit of matter	Carbon 
		Glucose 
		Mitochondrion 
		Fat cell 
		Muscle 
		Heart 
		Digestive system 
		Human 

A Group of tissues that carries out a particular function
B Membrane-bound cell structure that carries out particular functions
C Group of organs working together
D Individual living thing
E The building blocks from which living things are made
F Group of similar cells with similar functions
G Formed from atoms chemically bound together. Cell structures are made from millions of them
H Fundamental unit of matter

◆ Assessment opportunities

- Inhis activity you have practised skills that are assessed using Criterion A: Apply scientific knowledge and understanding to solve problems.

What does it mean for organisms to be 'related'?

HOW ARE ORGANISMS GROUPED AND CLASSIFIED?

We have seen how different organelles help cells perform their various functions. Differences exist between different types of cells and different types of organism. These differences can be used to place organisms into different groups. The division of life into different groups is called **classification**. This system of classification allows us, as humans, to see ourselves not separate from the rest of life on Earth, but very much as part of a complex tree of life (see Chapters 6 and 7). Our personal identities are therefore linked not only to other humans, but also to the rest of biological life that inhabits this planet.

Cell structure can be used to divide life into five main groups, or **kingdoms**. Each kingdom can be subdivided into smaller and smaller groups, with the smallest division being the **species** itself.

■ **Figure 1.17** *Euglena* in pond water

ACTIVITY: Classifying *Euglena*

■ ATL

- Organization skills: Use technology effectively and productively
- Critical-thinking skills: Analyse complex concepts and synthesize them to create new understanding

1. Put a drop of pond water onto a slide. Look at micro-organisms (microscopic living **unicellular** organisms) under a microscope.
2. Find *Euglena*. If it is moving too fast, use a slide with a dimple in it (a dip in the middle) – this will restrict its movement to one part of the slide.
3. If you don't have access to pond water containing *Euglena*, access the following website: www.microscopyu.com/moviegallery/pondscum/euglena/ or use the search terms: pond life, microscope.
4. What organelles (structures in the cell) can you see? Do the features belong to the animal kingdom? To the plant kingdom? How would you classify this organism? Use scientific reasoning to **explain** what you have observed.
5. **Draw** and **label** a diagram of *Euglena*, using your interpretation of the organism you have seen under the microscope, using scientific reasoning regarding the structures you have observed.

◆ Assessment opportunities

- ◆ In this activity you have practised skills that are assessed using Criterion C: Present data in visual forms; Interpret data and explain results using scientific reasoning.

Table 1.2 Plant cells vs animal cells

Plant cells	Animal cells
Multicellular organisms	Multicellular organisms
They contain chloroplasts and are able to carry out photosynthesis	They do not contain chloroplasts and are not able to carry out photosynthesis
They have cellulose cell walls	They have no cell walls They usually have nervous coordination and are able to move from one place to another
They store carbohydrates as starch or sucrose	They often store carbohydrate as glycogen
Examples include flowering plants	Examples include mammals and insects

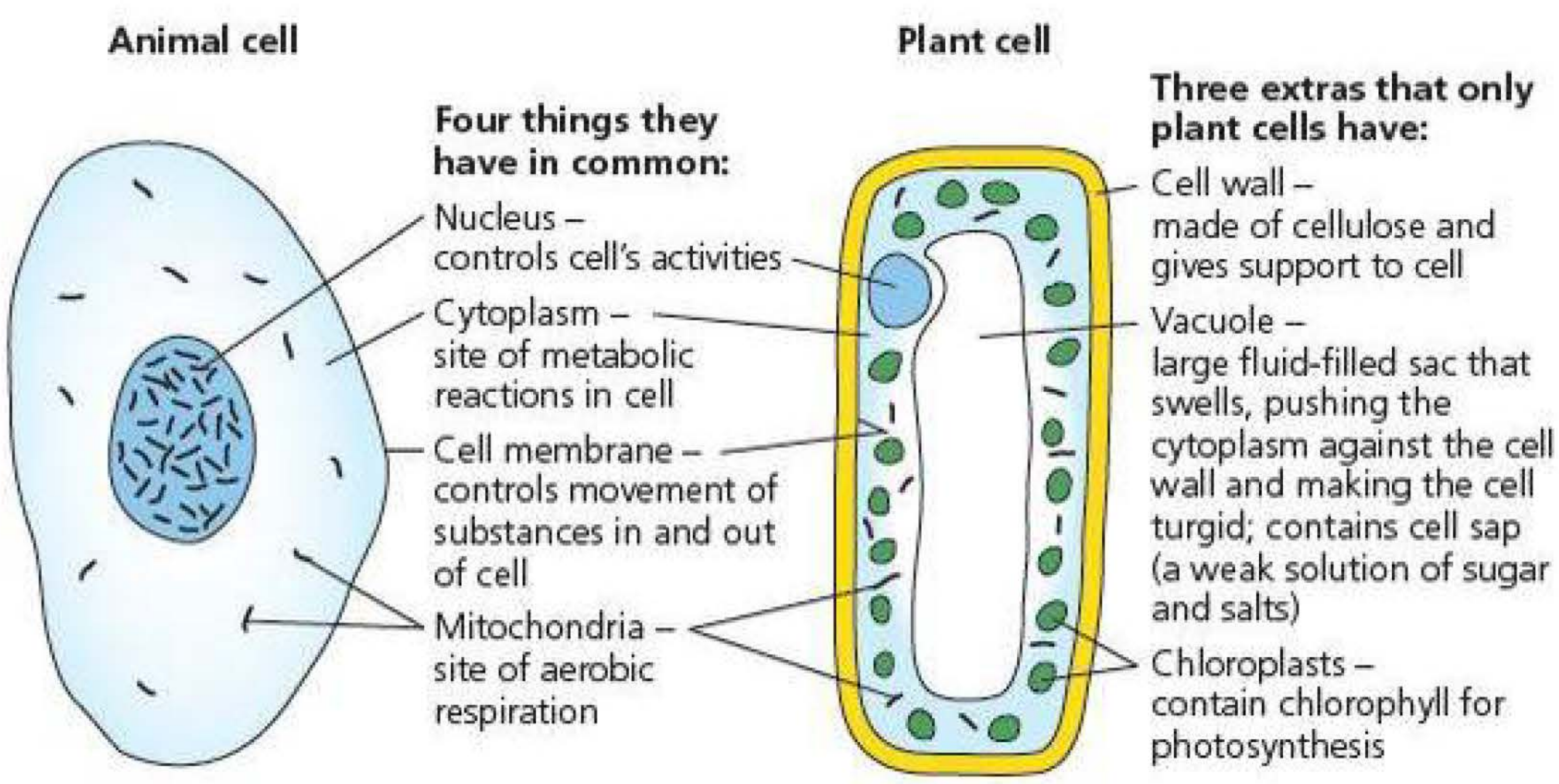


Figure 1.18 Comparing animal and plant cells

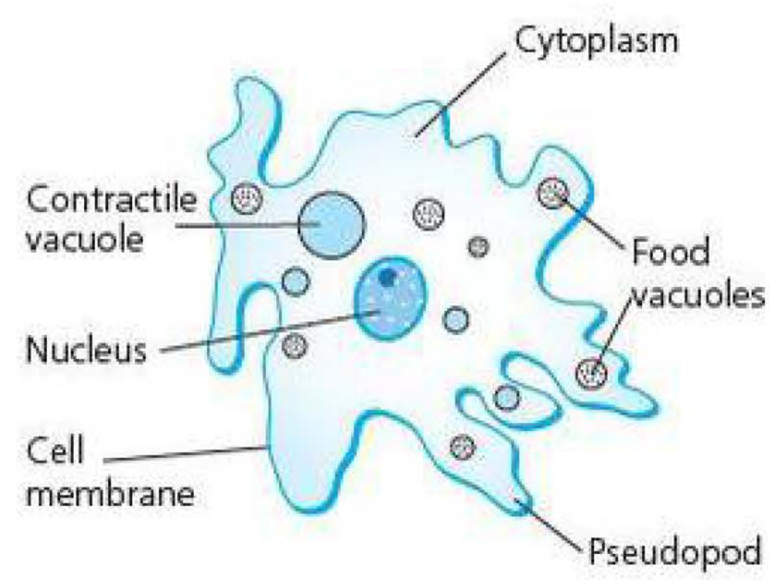


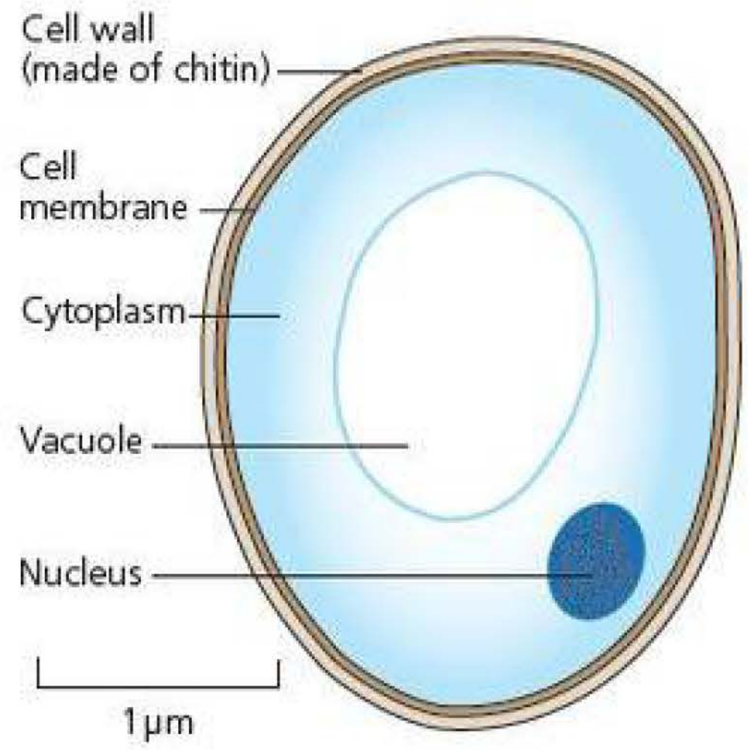
Figure 1.19 An amoeba (animal-like protoctist). The contractile vacuole is different from the permanent vacuole found in plants, and helps the amoeba control water content. Food vacuoles are temporary structures that digest food. Pseudopods are foot-like extensions that form as the amoeba moves

Euglena is not classified as an animal or a plant, as both these kingdoms contain multicellular organisms. *Euglena* is unicellular and contains features of both animals and plants. *Euglena* belongs to the kingdom **Protoctista**, which contains all unicellular, microscopic organisms. Some protoctists have the characteristics of animal cells whereas others are like plant cells in that they contain a cell wall and chloroplasts.

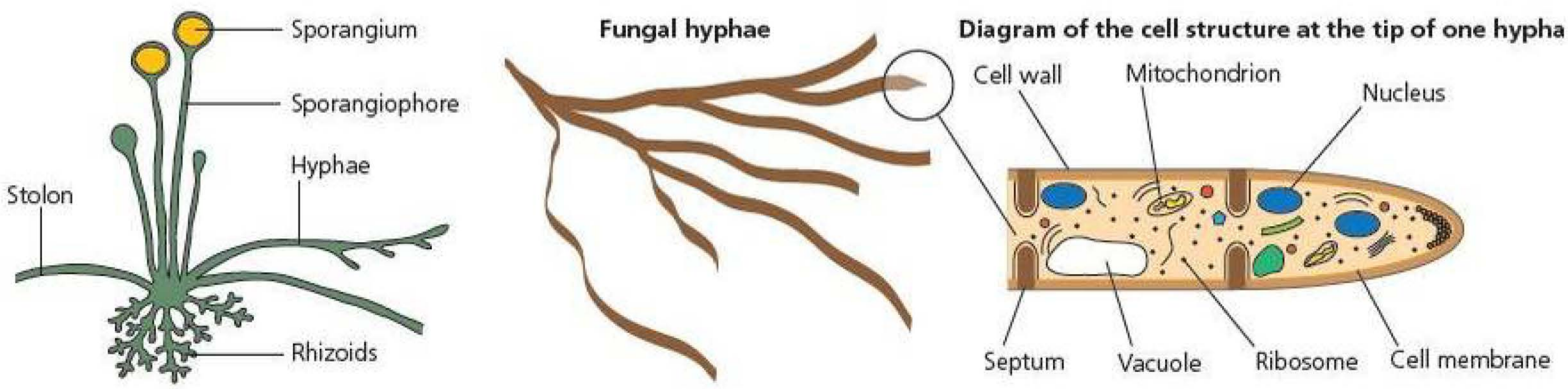
Protoctista

- Are microscopic
- Most are unicellular (seaweeds are multicellular)
- Some have features like animals (e.g. *Amoeba*)
- Some have features like plants (e.g. *Chlorella*)
- Some have features of both animals and plants (e.g. *Euglena*)
- Some cause disease (e.g. *Plasmodium* parasite that causes malaria).

■ **Figure 1.20** Fungi (*Mucor*) growing on bread. The spherical objects are reproductive organs (sporangia) which send spores into the air so that the fungi can colonize new areas in search of food. An interpretive diagram of *Mucor* is shown in Figure 1.21



■ **Figure 1.22** Diagram of a yeast cell. Yeast is a single-celled fungus



■ **Figure 1.21** Interpretive diagram of *Mucor*, showing cell structure

There are two other kingdoms: **fungi** and **prokaryotes** (**bacteria**).

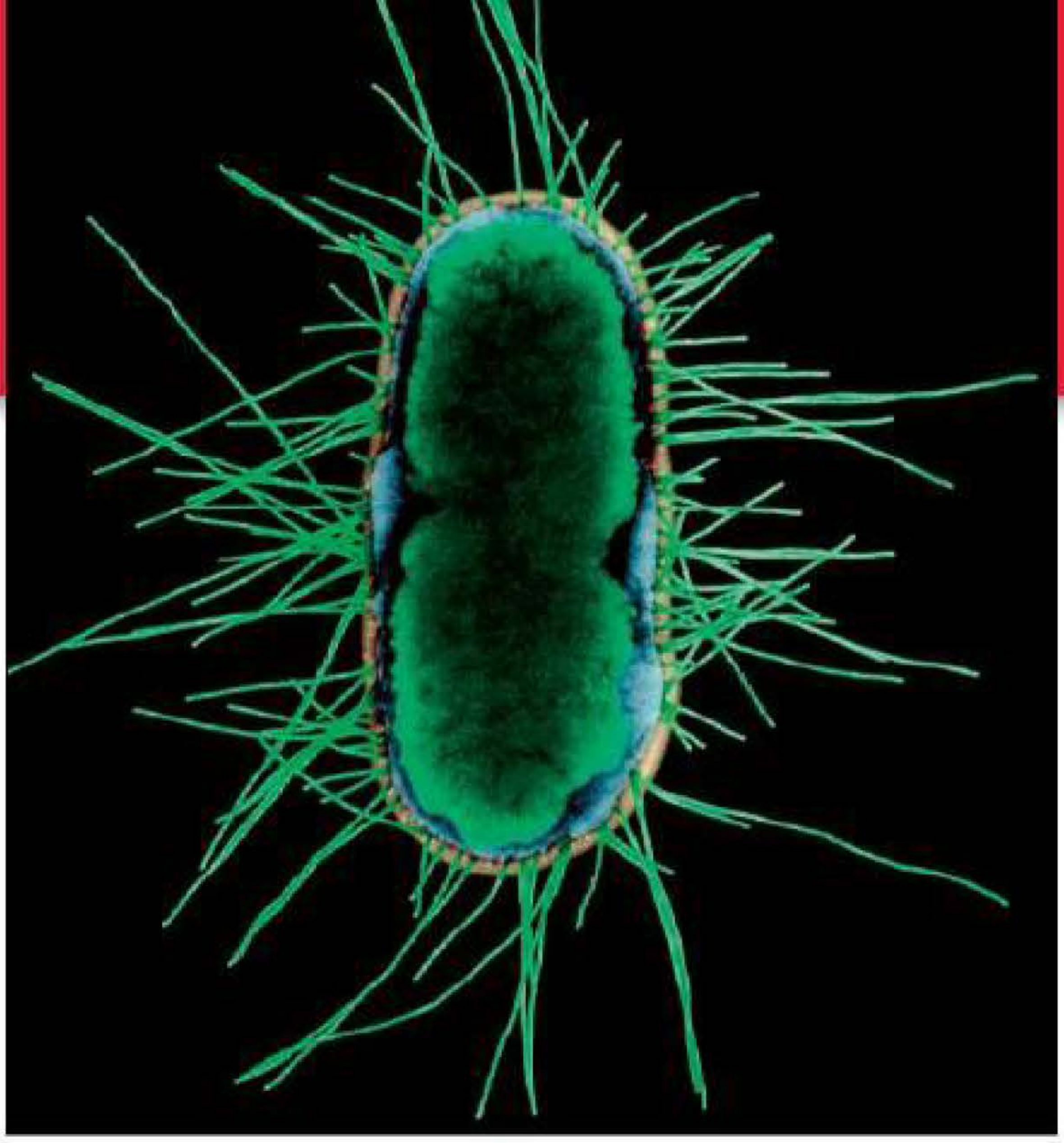
Fungi

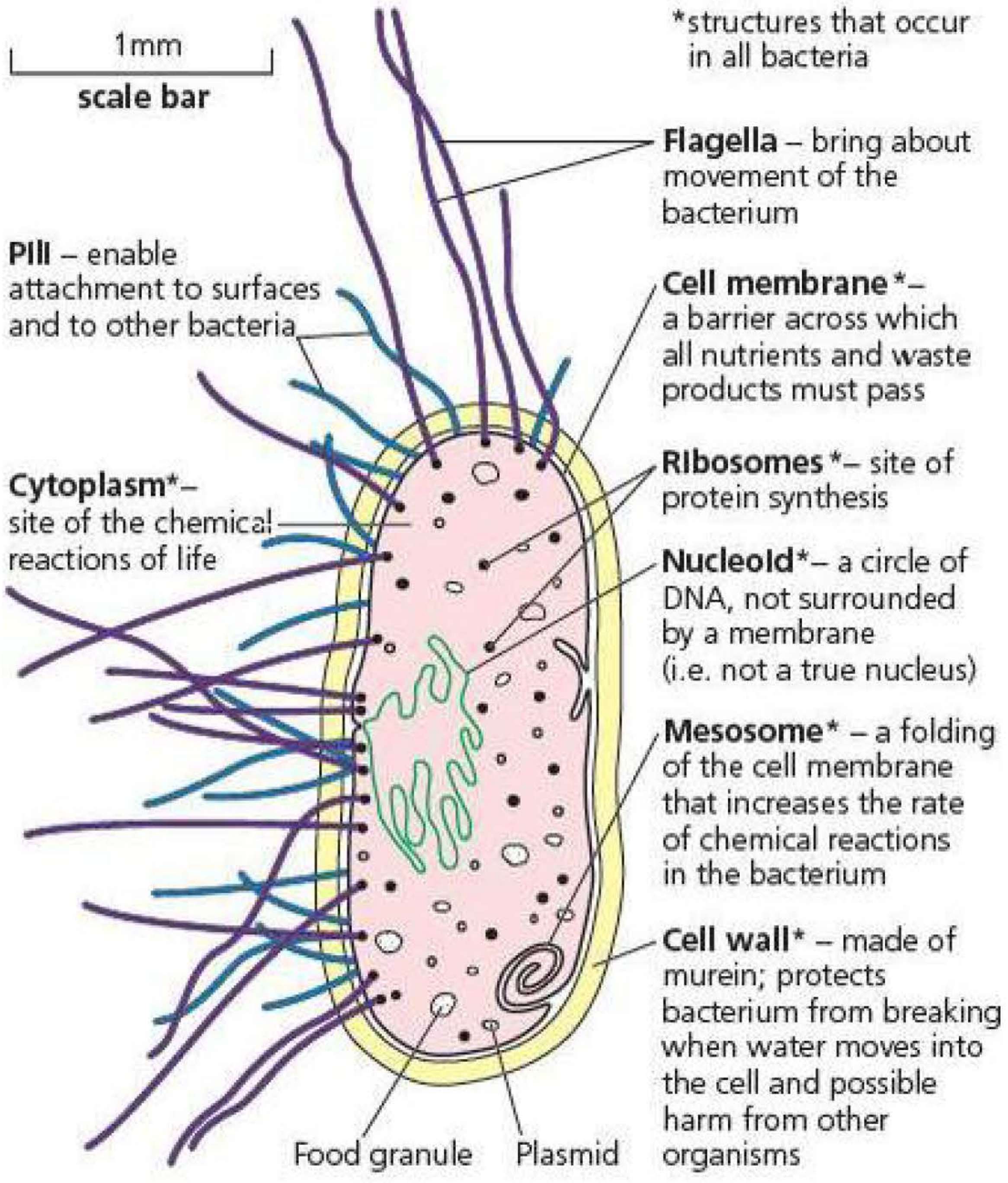
- Have no chloroplasts (cannot photosynthesize)
- Some are single-celled (e.g. yeast), some multicellular (e.g. *Mucor*)
- Have a cell wall made of chitin
- Store sugar as **glycogen**.

Multicellular fungi such as *Mucor* have root-like structures called **hyphae**, grouped into **mycelium**, which they use for feeding. Hyphae secrete enzymes that externally digest food into soluble products which are then absorbed by the fungus (this known as saprotrophic nutrition). Hyphae are nothing like roots as they have a completely different structure, including a cell wall made of **chitin** rather than cellulose. Fungi cells are fused together to form long multinucleated (i.e. containing many nuclei) cells: septa show where the end cell walls of the original cells were found.

Prokaryotes (bacteria)

- Have no true nucleus (DNA is not contained within a membrane-bound nucleus)
- Are much smaller than the cells of other kingdoms
- Are unicellular, although can clump together in colonies
- Do not have internal organelles (other than **ribosomes**, which manufacture proteins)
- Have a cell wall made of murein.





■ **Figure 1.23** The structure of a bacterial cell (*Escherichia coli*), together with an interpretative drawing. *E. coli* are found in our digestive systems and help us to break down the food we eat

All kingdoms, except animals, have a cell wall (although animal-like protoctista do not have one). The sugar that cell walls are made from varies from one kingdom to another, and can be used to classify different organisms (plants and plant-like protoctists – cellulose; fungi – chitin; bacteria – murein).

EXTENSION: Classification

You have now examined the five major kingdoms into which all life is divided. But what about the smaller groups that were mentioned at the start of this section? Within each of the five kingdoms there are smaller sub-divisions – phylum, class, order, family, genus and species. There are also three domains which are one level up from the kingdoms – these groups are the highest level of classification.

Find out about the other classification groups at these websites or use the following search terms: **levels of classification**, **kingdom**, **species**.

www.boundless.com/biology/textbooks/boundless-biology-textbook/phylogenies-and-the-history-of-life-20/organizing-life-on-earth-133/the-levels-of-classification-541-11750/

www.exploringnature.org/db/detail.php?dbID=87&detID=1192

Choose one animal and plant and find out its full classification (what is its phylum, class, order, family, genus and species?). Produce a poster to summarize your findings.

ACTIVITY: Five kingdoms

Create a table summarizing the differences between the different kingdoms. Put the five kingdoms along the top of the table and different characteristics down the side. You can then put ticks, crosses or comments against each characteristic for each kingdom.

REVIEW

- **What is classification?**
- **What are the five kingdoms?**
- **What features can be used to decide which kingdom an organism should be placed in?**
- **Can you draw the cell structure for each of the five kingdoms? Start with animal and plant cells, and then draw cells for the other three kingdoms.**

What characteristics make some organisms more closely related than others?

As well as classification being based on cell type, other features of organisms are used to divide species into different groups. Ultimately, classification needs to reflect real relationships between organisms, based on how closely related they are.

ACTIVITY: Dolphins and dogfish

ATL

- Critical-thinking skills: Draw reasonable conclusions and generalizations

Look at the pictures of a dolphin and a dogfish (Figures 1.24 and 1.25). Are these animals closely related? What features may make you think that they are closely related? But then think about what you know about the groups of animals they are in – are they *in fact* closely related? Which of the two would be more closely related to a human?

Use these sites to help you find out the features of both animals:

Dolphins

http://oceanservice.noaa.gov/facts/dolphins.html

www.imms.org/dolphinfaq.php

Dogfish

http://britishseafishing.co.uk/dogfish/

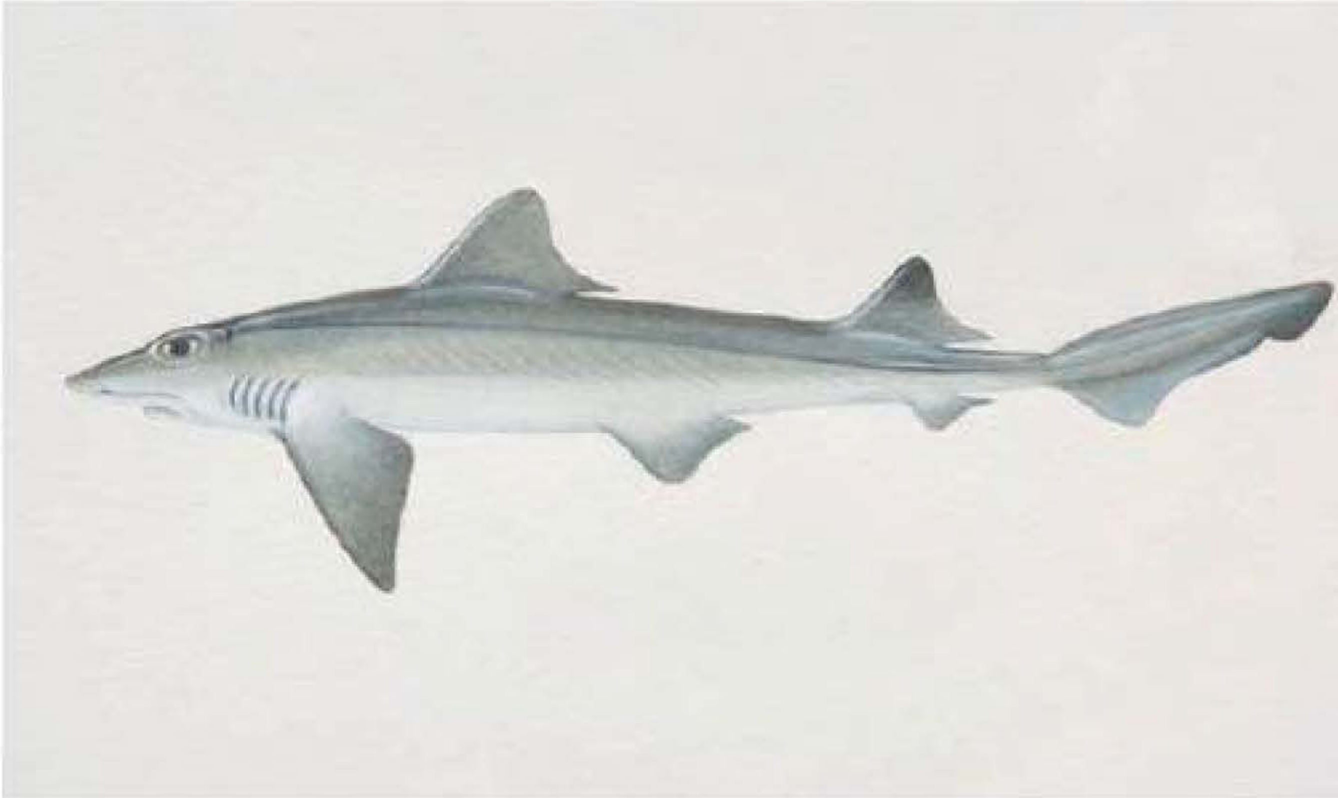
http://eol.org/pages/1857/overview

- **Analyse** and **evaluate** the information you have found out about each animal to **explain** the implications of using only physical characteristics to classify organisms.
- Why should features that indicate common evolutionary origin be used (such as characteristics that group all mammals together compared with characteristics that group all fish) rather than superficial physical characteristics (e.g. the similarity in appearance between dogfish and dolphins)? **Justify** your answer using scientifically supported judgements.
- **Explain** the way in which science is applied and used to address the problem of classifying organisms. Why is it important to use the correct method of classification?
- **Explain** why it is important to use the same method of classification throughout the scientific community.

Assessment opportunities

- In this activity you have practised skills that are assessed using Criterion A: Explain scientific knowledge; Analyse and evaluate information to make scientifically supported judgements.

■ **Figure 1.24** A dolphin

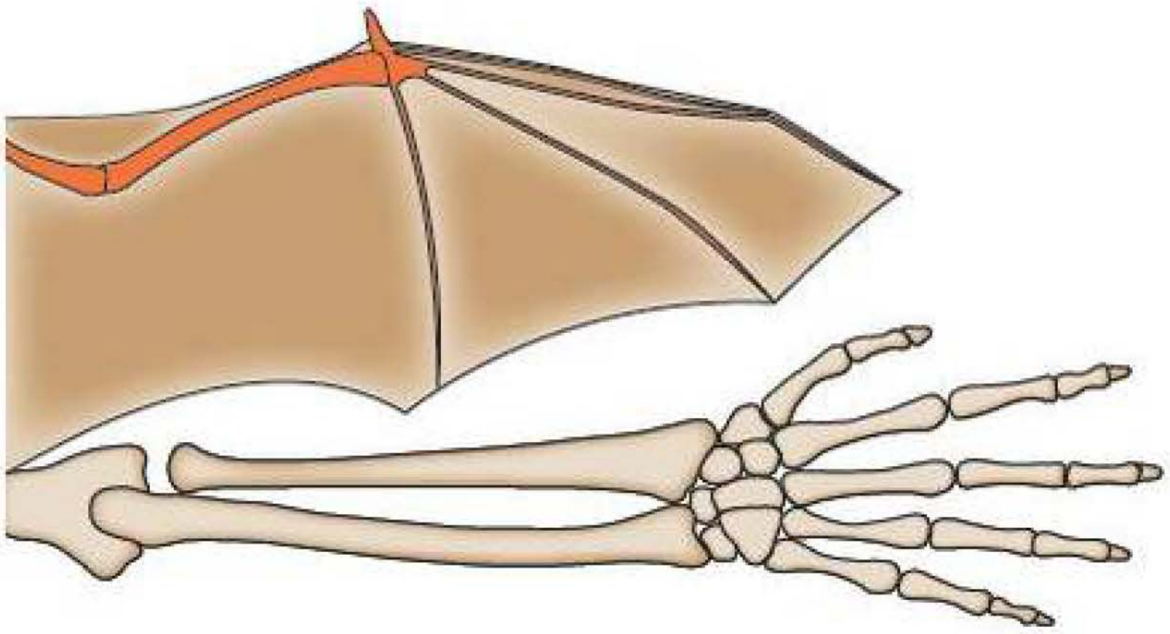


■ **Figure 1.25** A dogfish

Dolphins are mammals and dogfish are fish. Although they look superficially very similar, they are in fact not at all closely related. The dolphin is most closely related to a human – both are mammals, which feed milk to their **offspring**. Fish are very different anatomically and in terms of origin – they have gills rather than lungs, and have a heart with two chambers rather than four, for example. The similarities between dolphins and dogfish are due to the **environment** in which they live. Both are **aquatic** (i.e. both live in water) and their similar shapes make them move through water easily (i.e. they are hydrodynamic).

This shows the importance of looking beneath the skin when classifying organisms. Classification should reflect evolutionary origins (see Chapter 7 for more on evolution) rather than superficial similarities. **Analogous features** are features that have similar functions in different organisms. The similarity of function makes them look similar, such as the fins in dogfish and sharks, or bird and insect wings – they are not similar either in terms of anatomy or origin.

Homologous features are ones that have a common evolutionary origin and reflect real similarities between organisms, and should therefore be used when classifying them. Homologous features may serve different functions in modern animals, such as the arm of a human and the wing of a bat (see Figure 1.26), but the underlying structure is very similar (see also Figure 7.5, page 175).



■ **Figure 1.26** The human arm and bat wing look very different but have the same basic bone structure

EXTENSION

Access the following website to explore more about the relationships between organisms:
www.pbs.org/wgbh/evolution/change/family/

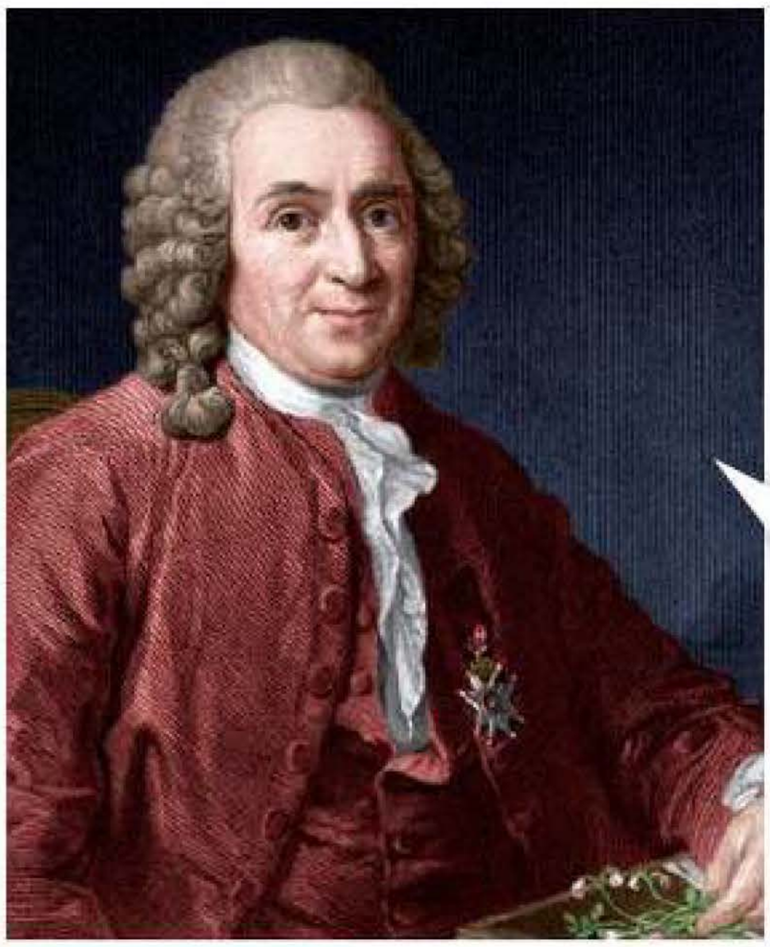
DISCUSS

- **Why do some organisms look superficially the same?**
- **What are analogous structures? Should they be used to classify organisms?**
- **What are homologous structures? Should they be used to classify organisms?**

Should scientists use new research to reorganize organisms into different classification groups?

THINK–PAIR–SHARE

The close relationship between the different species of *'Homo'* poses questions about our identity as humans – are we separate from the other species of ape, or actually just one branch of a closely related group of similar organisms? Can humans be seen as a special form of life? See Figure 1.29 below.

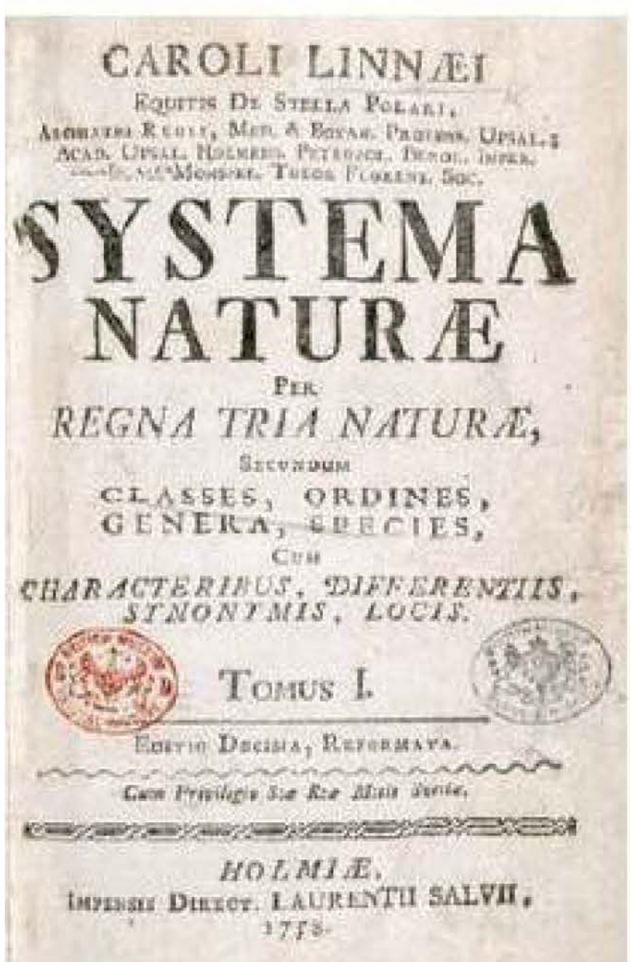


■ **Figure 1.27** Carl Linnaeus

My name is Carl Linnaeus. I was a Swedish botanist, physician and zoologist, and a great classifier of living things. In the 1730s I developed the method of classifying organisms that is still used today, called binomial nomenclature.

In 1735 I published *Systema Naturae* (The Natural World), in which I divided flowering plants into classes determined by the structure of their sexual organs. In 1749 I introduced the binomial nomenclature for which I am now famous – each plant was given a Latin noun (the genus) followed by an adjective (the species).

I am known as the father of modern taxonomy, and am also considered one of the fathers of modern ecology.



CAROLI LINNÆI

EQUITIS DE STELLA POLARI,

SYSTEMA NATURÆ

PER

REGNA TRIA NATURÆ,

SECUNDUM

CLASSES, ORDINES, GENERA, SPECIES,

CUM

CHARACTERIBUS, DIFFERENTIIS, SYNONYMIS, LOCIS.

TOMUS I.

EDITIO DECIMA, REFORMATA.

HOLMIÆ,

IMPENSIS DIRECT. LAURENTII SALVII,

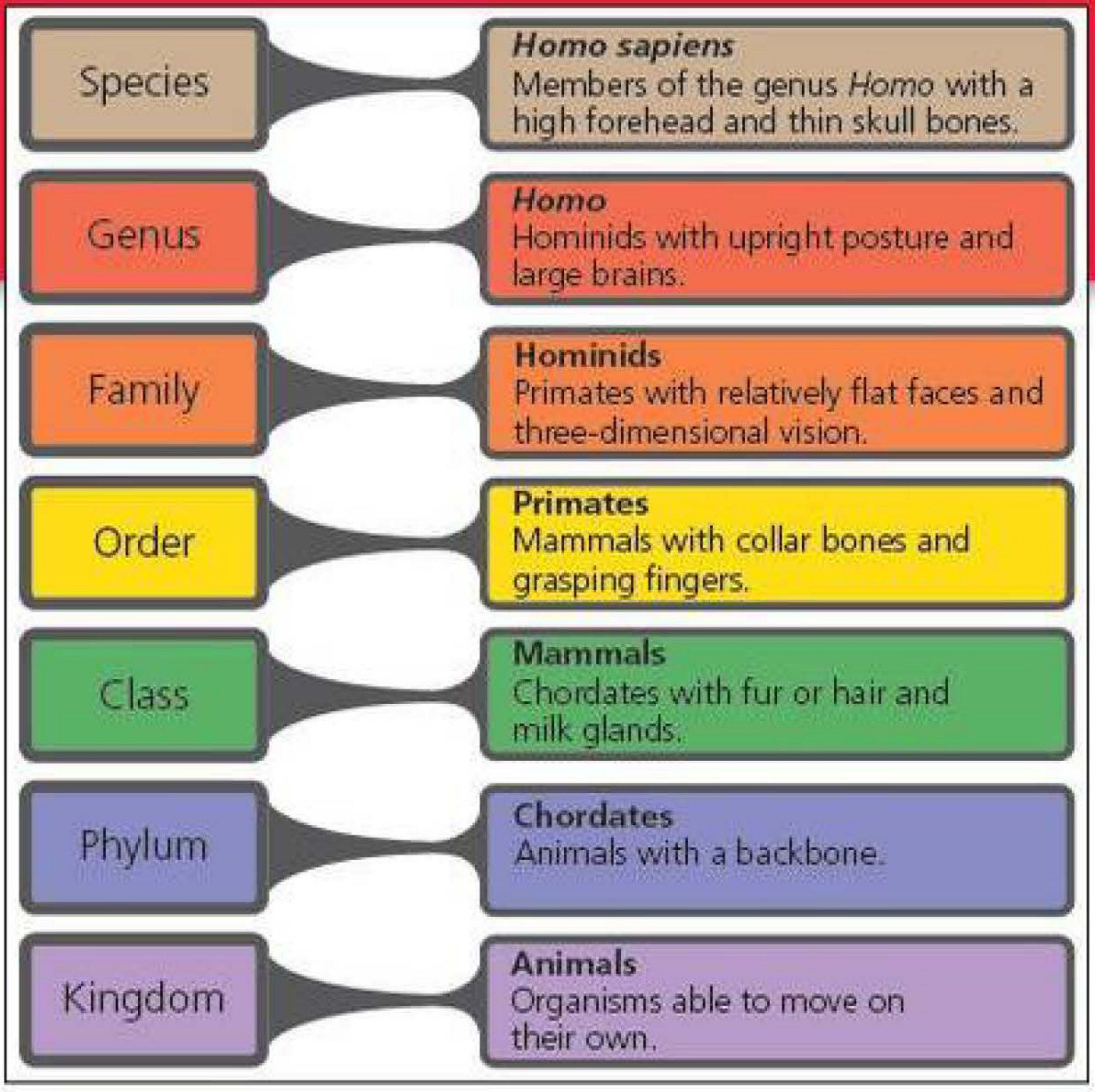
■ **Figure 1.28** Carl Linnaeus' most famous work. *Systema Naturae* showed for the first time how life could be classified

Carl Linnaeus was a remarkable scientist. He worked out a way of classifying organisms that we still use today. Every species has a name made from two parts – the genus and the species. Humans, for example, have the species name *'Homo sapiens'* (*'Homo'* is the genus and *'sapiens'* is the species). There can be several different species in a genus – we share the *'Homo'* genus with several other (now extinct) species such as the Neanderthals (*Homo neanderthalis*).

■ **Figure 1.29** Skulls of species in the genus *'Homo'*

DISCUSS

Discuss in a small group the work of Linnaeus.
Why was his work so revolutionary? Why is his work so important to science? How do you think the science of taxonomy will develop in the future?



■ **Figure 1.30** The classification of humans from species to kingdom

ACTIVITY: A modern classification?

■ ATL

■ Critical-thinking skills: Draw reasonable conclusions and generalizations

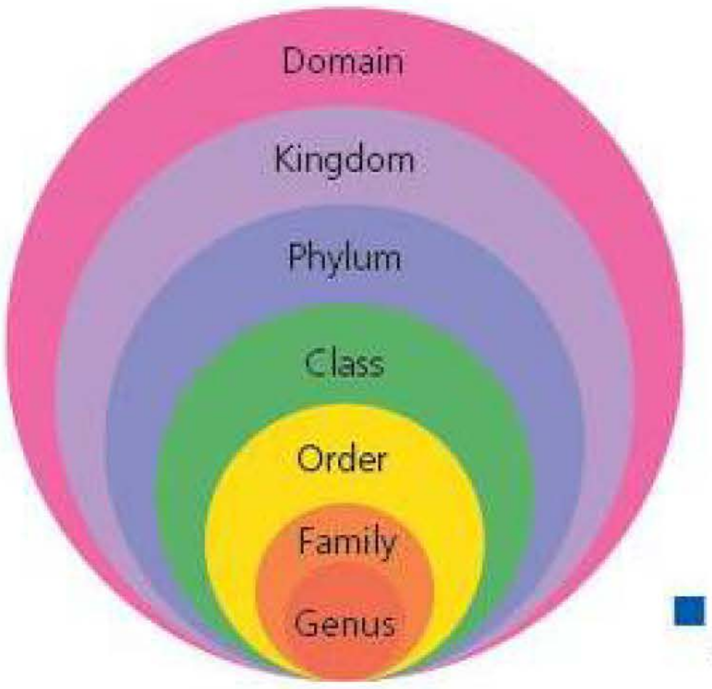
Traditional methods of classification involve looking at physical characteristics of different organisms. Can you think of any problems involved with this?

Modern science has techniques that were not available until relatively recently, and were certainly not around at the time of Linnaeus.

Find out about these modern techniques here: **www.nhm.ac.uk/discover/naming-nature-putting-life-in-order.html** or use the following search terms: **history**, **taxonomy**.

We will investigate the basis for these methods further in Chapters 6 and 7.

Should scientists use new research in order to reorganize organisms into different classification groups? Should things be left as they are (so continue using methods that have served science for the past 350 years)?
What do you think?



■ **Figure 1.31** The hierarchy of life

Thousands of years ago, people classified plants, animals and fungi according to their taste. Greek philosopher Aristotle (384–322BCE) organized 500 types of animals according to habitat and body form.

Read more here: **www.biologyreference.com/Ta-Va/Taxonomy-History-of.html**

Create your own classification system

If you were to create your own method for classifying living things, what system would you use?

◆ Assessment opportunities

◆ This activity can be assessed using Criterion D: Explain the ways in which science is applied and used to address a specific problem.

Will it be possible to create artificial life?

Take action

- Find out about the Harvard University group who are creating artificial cells. Use the following search terms: **scientist**, **artificial life**, **Mycoplasma mycoides JCVI-syn 1.0**.
- Here are some websites to start off your reading:

  https://iamisatthedoors.wordpress.com/2012/06/05/scientist-accused-of-playing-god-after-creating-artificial-life-by-making-designer-microbe-from-scratch-but-could-it-wipe-out-humanity/

  http://news.harvard.edu/gazette/story/2009/03/taking-a-stride-toward-synthetic-life/

  www.newscientist.com/article/dn18942-immaculate-creation-birth-of-the-first-synthetic-cell.html#.VNdqYOasVvA

  www.bbc.co.uk/news/science-environment-18953034

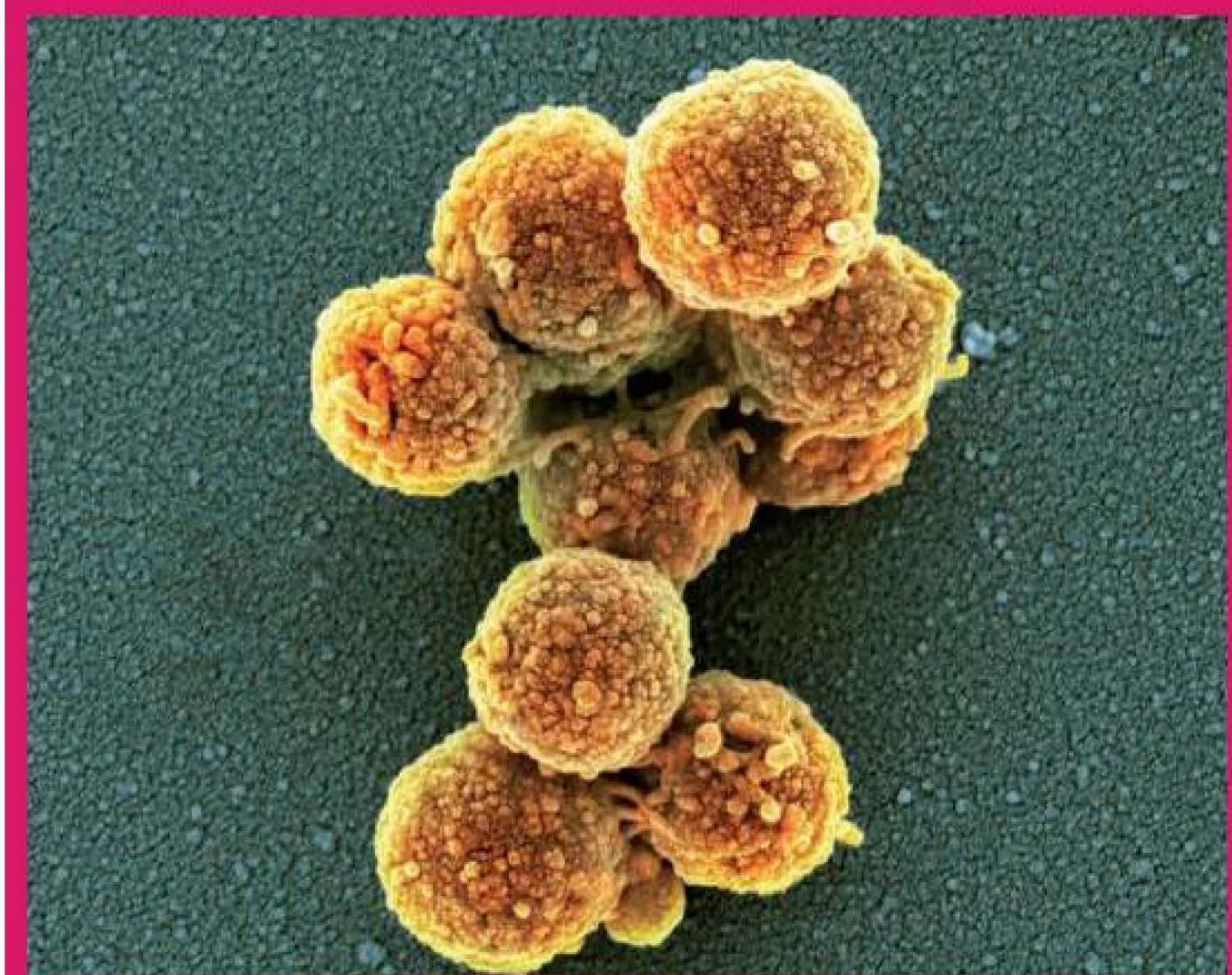


Figure 1.32 Artificial life – *Mycoplasma mycoides* JCVI-syn 1.0

- What ethical issues does their work raise?
- Do you think that it will be possible to create new species artificially? Would this be desirable?

Assessment opportunities

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

SOME SUMMATIVE PROBLEMS TO TRY

Use these problems to apply and extend your learning in this chapter. These problems are designed so that you can evaluate your learning at different levels of achievement in Criterion A: Knowledge and understanding.

THESE PROBLEMS CAN BE USED TO EVALUATE YOUR LEARNING IN CRITERION A TO LEVEL 1–2

1 **State** the seven characteristics of life.

2 **Suggest** why the alien thinks that the car is a living organism.

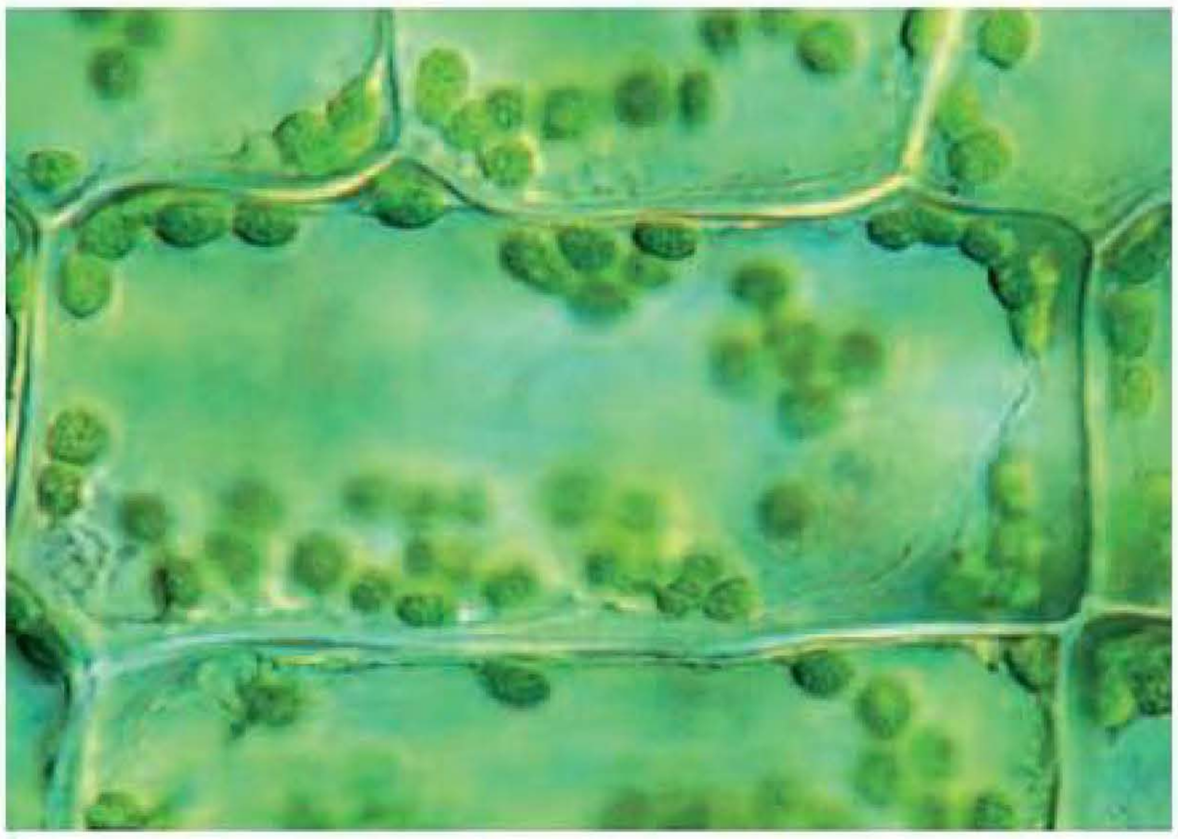
■ **Figure 1.33** An alien's view of a car

3 **Suggest** the appropriate kingdom for the following organism. **State** why you have put it in this group.

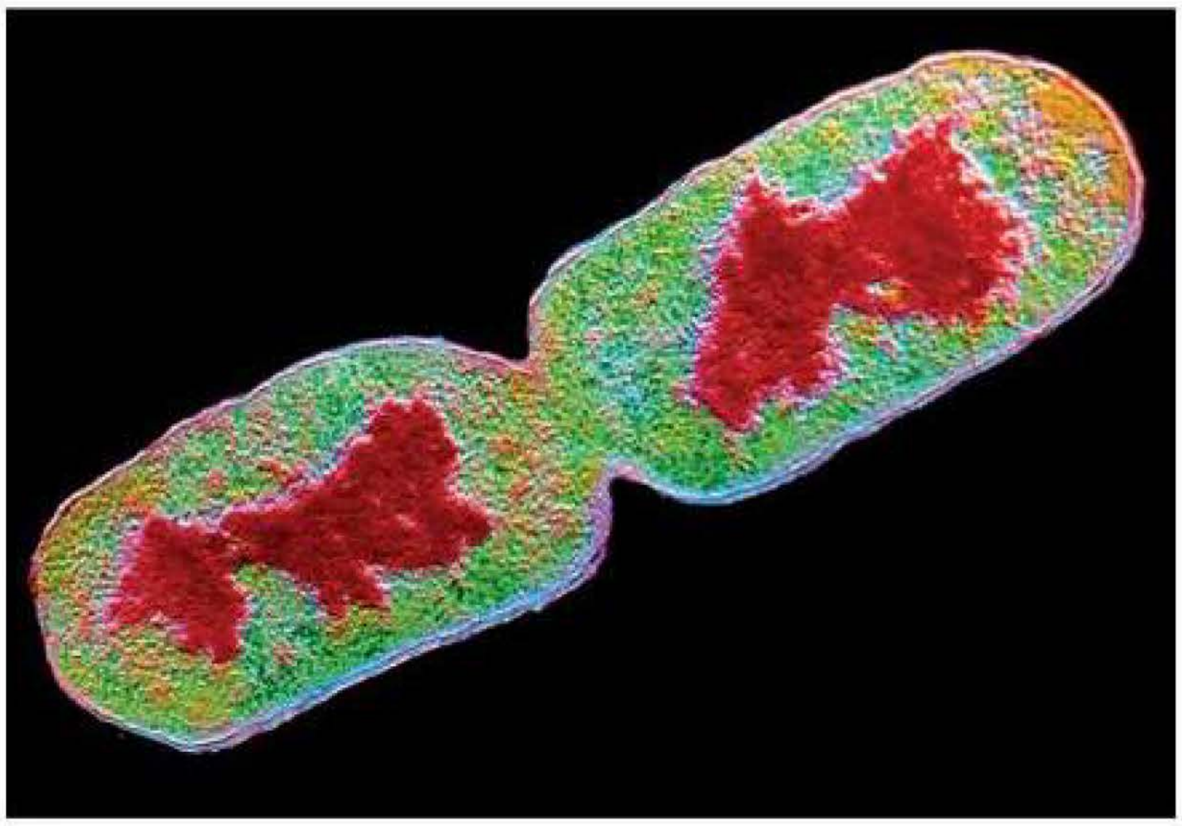
■ **Figure 1.34** *Euglena*

THIS PROBLEM CAN BE USED TO EVALUATE YOUR LEARNING IN CRITERION A TO LEVEL 3–4

4 **Outline** two similarities and two differences between the following two types of cell.



■ **Figure 1.35** A pondweed cell



■ **Figure 1.36** An *Escherichia coli* bacterium dividing in two. *E. coli* is found within the human intestine and helps to digest food

THESE PROBLEMS CAN BE USED TO EVALUATE YOUR LEARNING IN CRITERION A TO LEVEL 5–6

5 **Describe** the function of the following organelles:

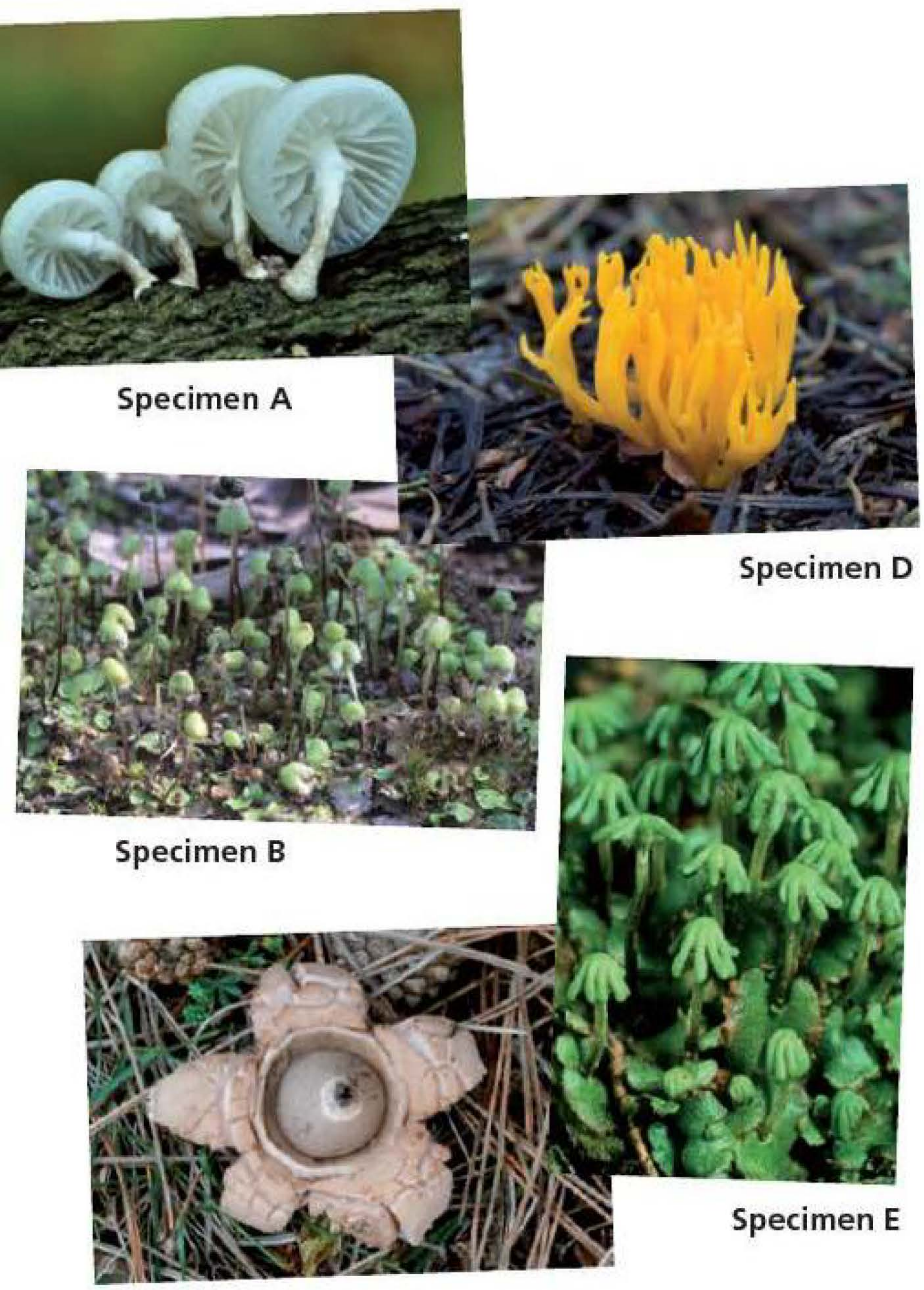
a Mitochondria

b Nucleus

c Chloroplast

d Permanent vacuole

6 You have collected a number of specimens during a field trip and have been asked to put them into groups of related organisms. **Suggest** which organisms you would group together.



■ **Figure 1.37** A collection of specimens for classification

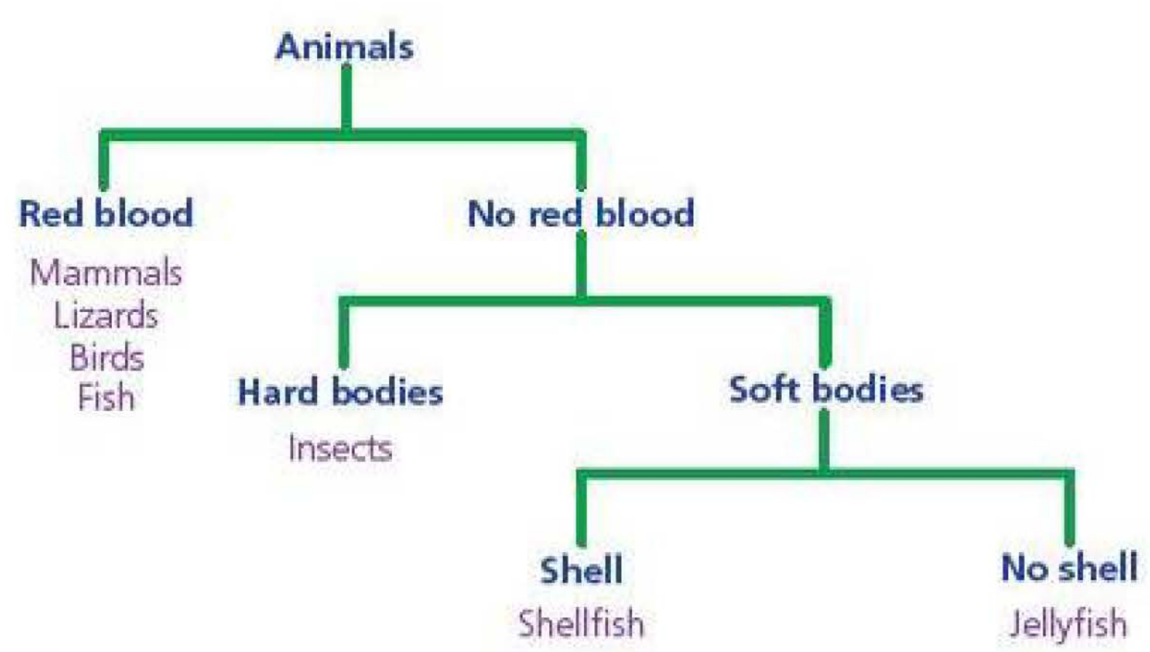
THIS PROBLEM CAN BE USED TO EVALUATE YOUR LEARNING IN CRITERION A TO LEVEL 7–8

7 Lichens consist of a fungus and algae living together.

■ **Figure 1.38** A lichen growing on a branch

- a The fungus grows hyphae that help it feed by saprotrophic nutrition. **Explain** what is meant by the term 'saprotrophic nutrition'.
- b i **Suggest** one reason why we know that the photo shows a lichen and not just a fungus.
  - ii Use information from the photo to **suggest** a process that a lichen can carry out but a fungus cannot.
  - iii **Suggest** an advantage to the fungus of being able to carry out the process you have named in part **ii**).

8 Aristotle was a Greek philosopher (384–322BCE). The diagram below shows how Aristotle grouped mammals, lizards, birds, fish, insects, shellfish and jellyfish.



■ **Figure 1.39** Aristotle's classification of animal groups

- a Aristotle also divided animals into three groups according to how they moved. **Evaluate** this method of classification.
- b **Explain** Linnaeus' binomial classification system.

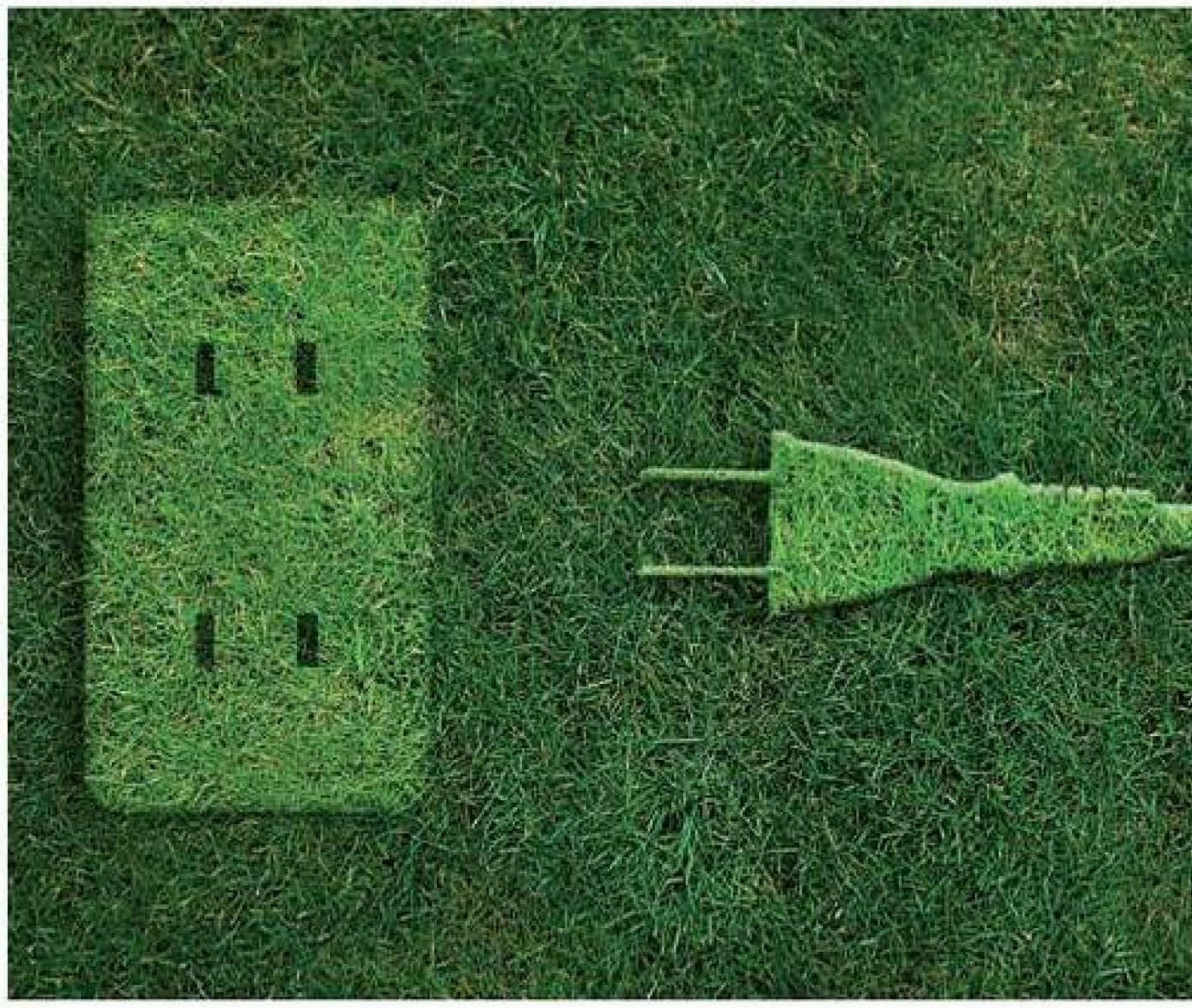
Reflection

In this chapter we have seen how life exists at a range of scales and discovered how the identity of an organism is determined by the parts it is made up from and the relationship between them. We have found out about how organisms differ in form and complexity, and explained ways in which they are grouped and classified. We have explored the patterns in structures, functions and biological processes that are necessary to sustain life, and discussed whether it is possible to create artificial life. We have learnt about our role as a thinker, and how we can use critical- and creative-thinking skills to analyse complex 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 are the characteristics of living things? What are cells and how are they structured? What roles do cells carry out? What are the characteristics and functions of different cells, tissues and organs? How are organisms grouped and classified?					
Conceptual: What determines whether something is alive or not? Are viruses alive? How does cell structure relate to function? What does it mean for organisms to be 'related'? What characteristics make some organisms more closely related than others?					
Debatable: Should scientists use new research to reclassify organisms? Are humans a special form of life? Will it be possible to create artificial life?					
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
Critical-thinking skills					
Creative-thinking skills					
Organization skills					
Learner profile attribute(s)	How did you demonstrate your skills as a thinker in this chapter?				
Thinker					

2 What chemical processes support life?

The **systems** of life are supported by biochemical reactions and the **transformations** of **energy** that occur within cells. **Innovations** in science could lead to these reactions being utilized to meet growing energy and food needs.



■ **Figure 2.1** Plants trap sunlight energy which enables organisms to carry out life processes

CONSIDER AND ANSWER THESE QUESTIONS:

Factual: What are some chemical reactions which occur inside cells? What occurs in the process of cellular respiration? What occurs in the process of photosynthesis? What factors are needed for photosynthesis? How can the rate of photosynthesis be measured? What are enzymes and how do they work? How do chemical and physical reactions in cells determine the survival of organisms?

Conceptual: Why are enzymes needed? Why do some organisms need to feed themselves whereas others do not? Can the chemical reactions of life occur outside cells? Can biochemical reactions be replicated in the lab?

Debatable: Should chemical reactions be manipulated in order to meet our food and fuel needs?

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

IN THIS CHAPTER, WE WILL …

- **Find out**:
  - how chemical reactions are controlled in cells;
  - what increases and decreases these reactions.
- **Explore** how innovations in science could lead to these reactions being utilized to meet growing energy and food needs.
- **Take action** by campaigning to reduce food waste in our home and community.

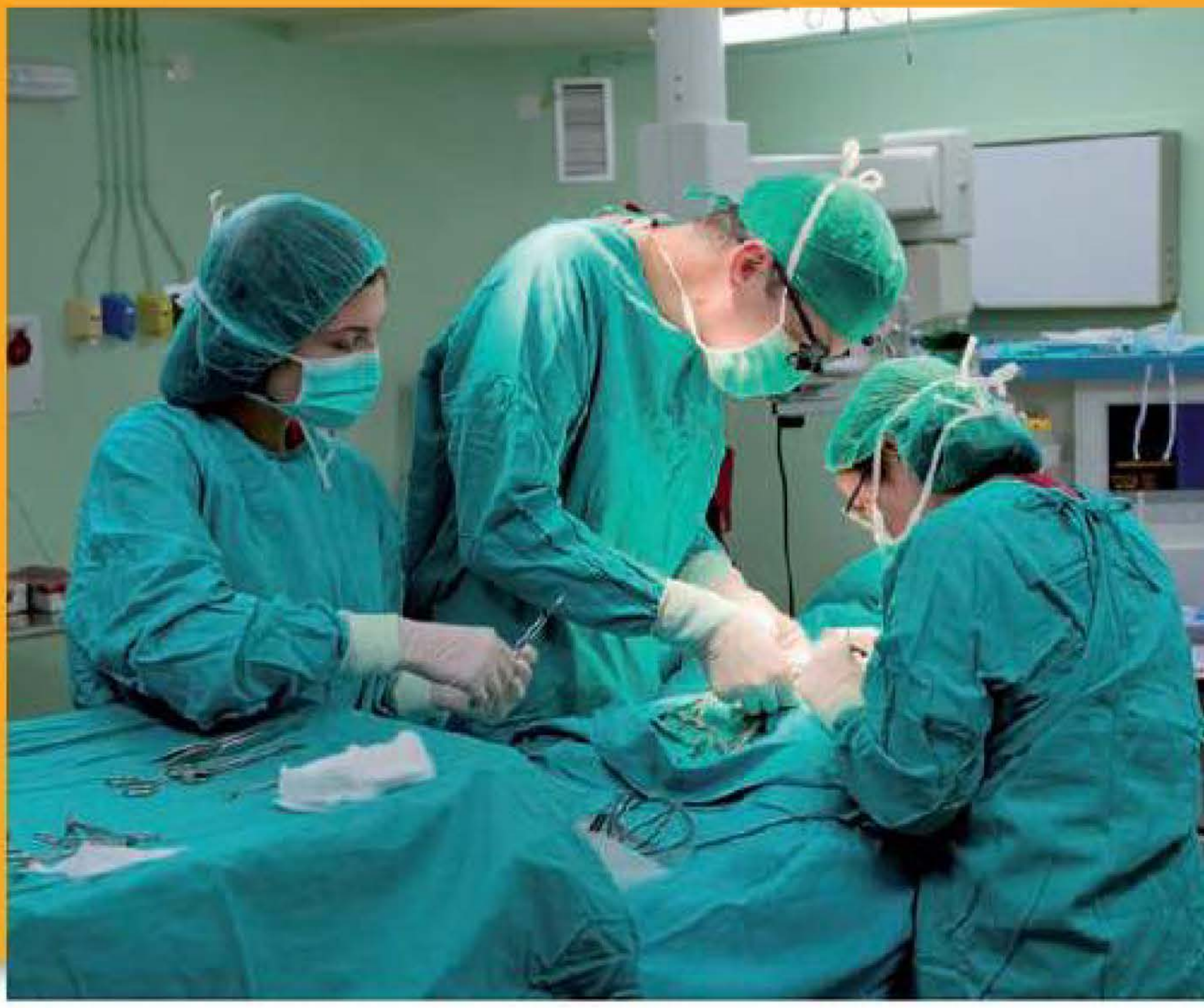


Figure 2.2 Operations could use extreme cooling during life-saving surgery

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

- Critical-thinking skills
- Organization skills
- Information literacy skills
- Communication skills
- Self-management skills

We will reflect on this learner profile attribute …

- Inquirers – nurturing curiosity, developing skills for inquiry and research.

Assessment opportunities in this chapter:

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

KEY WORDS

catalyst	metabolic
kinetic	transfer
limiting	yield

SUSPENDING LIFE

When a casualty arrives at the emergency department of a hospital with a traumatic injury, such as a gun-shot wound, doctors have little time to save the patient's life. Fewer than 1 in 10 patients with severe injuries that lead to extensive blood loss survive. Blood loss leads to cardiac arrest (the heart stops functioning) and death. Doctors are working on ways to give them more time to operate – techniques that only a few years ago would have seemed more appropriate in the realm of science fiction.

Watch this video: **http://edition.cnn.com/2014/06/23/tech/innovation/suspended-animation-trials/**

Now, read this article: **www.bbc.co.uk/news/health-11389464**

THINK–PAIR–SHARE

In pairs or groups, **discuss** what you have just watched and read. Consider these questions:

Why does extreme cooling allow surgeons to operate by stopping the patient's heart? What does this technique tell you about the processes that are going on in cells? How can a person still be alive if there is no pulse, blood pressure or signs of brain activity? What does cooling do to cells that enables life to continue? How are patients 'brought back to life'?

What are some chemical reactions which occur inside cells?

In Chapter 1, we saw how cells contain **organelles** that sustain life. Each organelle has a different function, carrying out a specific biological process. At the most basic level, chemical reactions within the organelles are what sustain life. The organelles separate the various chemical reactions that are needed to support the cell's function – each organelle with a different set of chemical reactions (see Figure 2.3).

Separating the reactions of life in this way means that they can be controlled and don't interfere with each other (in the same way that different operations in a factory are divided into different areas; for example in a car factory one area will be used to assemble the engine, another to put together the chassis, and so on).

These chemical reactions can be slowed down and speeded up, in the same way that all chemical reactions can. In a chemical reaction, the **reactants** (i.e. the chemicals that will be reacting together) need to meet up – increasing temperature means that their **kinetic** energy (i.e. energy of movement) increases and they are more likely to collide and react (Figure 2.4).

Cooling down the cell will have the opposite effect. By cooling the body to such an extent that the chemical reactions in cells are slowed so that life is 'suspended', surgeons can operate without cells needing a constant supply of food and oxygen, which means the heart can be stopped.

The chemical reactions in cells are known as **metabolism**, and **metabolic reactions** need a supply of reactants to sustain them – if metabolic reactions are slowed then the supply of reactants can also be reduced.

But what metabolic reactions are going on in cells? The cytoplasm, as we have seen in Chapter 1, is the site of many metabolic reactions. We also know that the mitochondria are the site of **aerobic respiration** – releasing energy from food in the presence of oxygen. **Respiration** actually starts in the cytoplasm, where it can begin without a need for oxygen (this is called **anaerobic respiration**). Respiration is the essential metabolic reaction in cells – it supplies the cell, and ultimately the organism, with energy that supports all life processes. We will explore this reaction further in the next section.

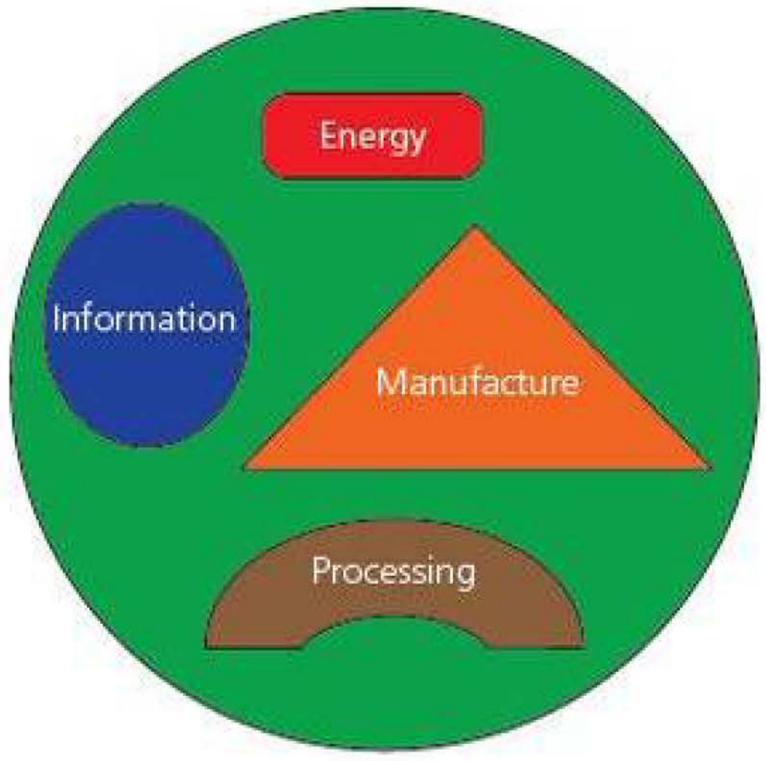


Figure 2.3 Compartments in cells – each fulfils a different role and contains different chemical reactions

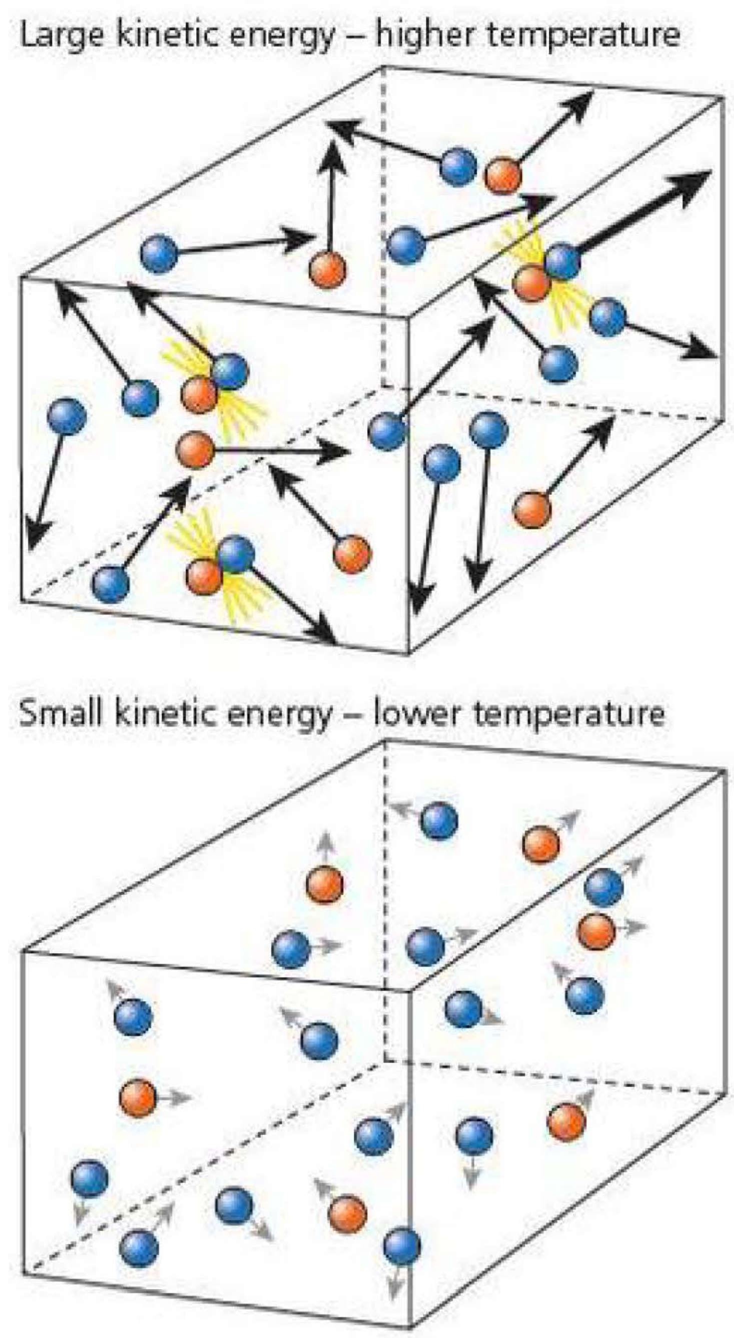


Figure 2.4 Molecules in cells are more likely to collide and react at warmer temperatures, as they have more kinetic energy

EXTENSION: Mitochondrial disease

Figure 2.9 (page 31) shows that mitochondria have their own DNA. Scientists believe that they were once free-living bacteria that were taken inside an early animal-like cell (mitochondria are the same size as bacteria and have many similar features). As with DNA in the nucleus, mutations in the DNA (see Chapter 6) can lead to mitochondria not working properly. Find out more about mitochondrial disease here: www.thelilyfoundation.org.uk/animation/

Chemical reactions in cells are of two types – one builds up bigger **molecules** from smaller ones (these are called **anabolic reactions**). The other type breaks big molecules into smaller ones (these are called **catabolic reactions**). Respiration is a catabolic reaction. In Chapter 3 we will see how food is digested in the body, and how 'breaking' (catabolic) and 'building' (anabolic) reactions are used to move nutrients into cells and then use them to build new structures.

Plants also have many metabolic reactions in their cells. Photosynthesis takes place inside chloroplasts – light energy is stored as chemical energy in the form of glucose. This chemical reaction is essential to support life – not just that of the plant, but also of the organisms that feed on the plants and obtain their energy that way. We will explore this reaction on pages 33–34.

We have discussed how temperature can increase chemical reactions. Chemical reactions can also be increased by using **catalysts** (which you may have encountered in chemistry). Catalysts speed up reactions but are not broken down in the process – they can be reused. Cells have naturally occurring catalysts called **enzymes** (i.e. biological catalysts). We will look at these on pages 40–45.

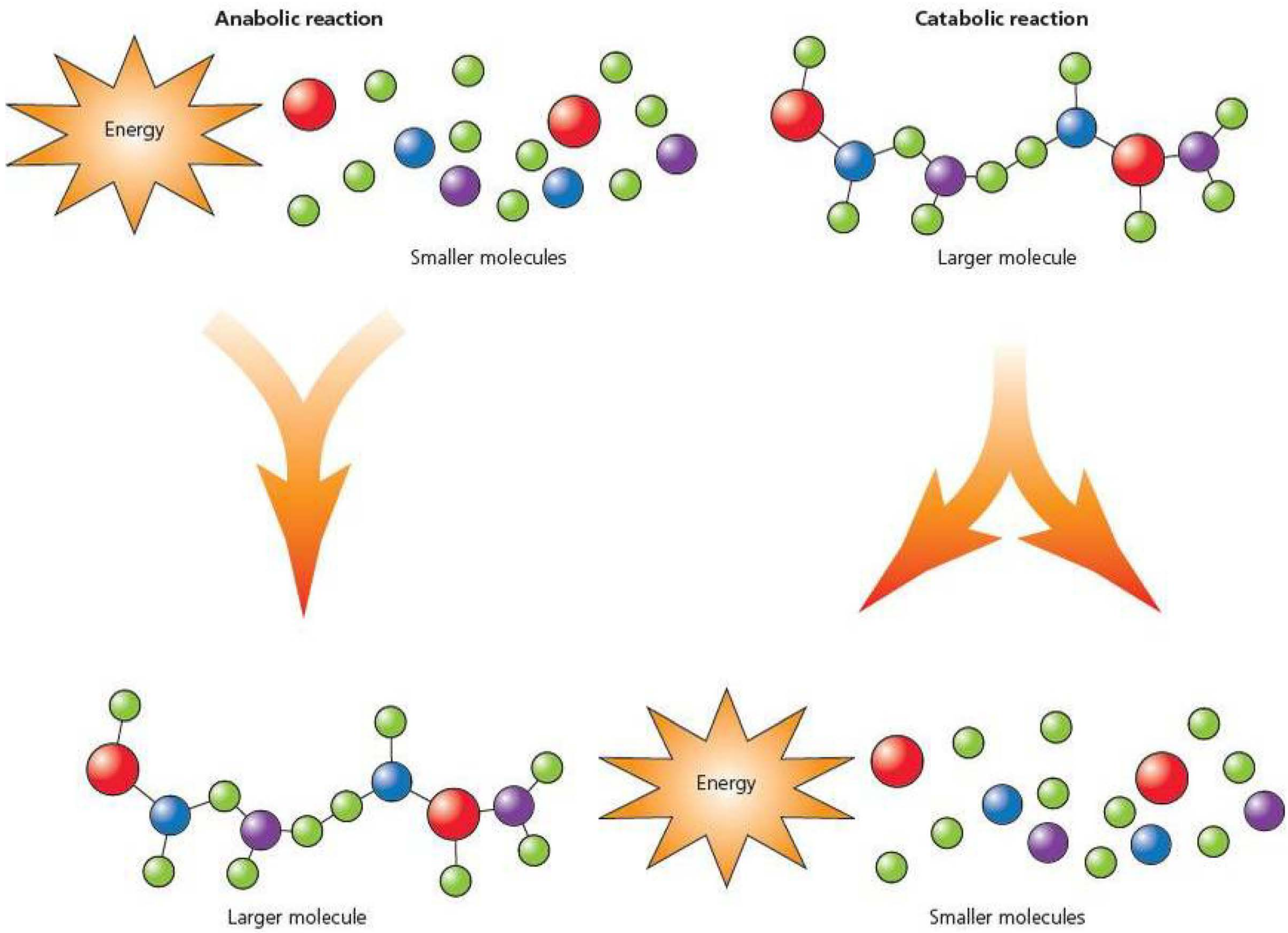


Figure 2.5 Metabolic reactions in living things

What occurs in the process of cellular respiration?

ACTIVITY: Burning glucose

ATL

- Critical-thinking skills: Draw reasonable conclusions

For this experiment you will need a clean and dry jam jar with a lid, a Bunsen burner, cobalt chloride paper, limewater, glucose powder (or another source of food), a combustion spoon (a wire spoon).

Safety: Ensure you wear safety goggles when using the Bunsen burner, and take care of naked flames.

1. Place a small amount of glucose powder in the combustion spoon, and hold it in a Bunsen flame until the glucose ignites.
2. Hold the jam jar upside down about 2 cm above the burning glucose so that the gases from the flames enter the jar (see Figure 2.6).
3. When the sides of the jar appear misty, place the wire spoon and burning glucose into a beaker of water to extinguish the flame and cool the spoon. Immediately put the lid on the jar.
4. Using tweezers, put a dehydrated piece of blue cobalt chloride paper into the jar and replace the lid.
5. Turn the jar so that the cobalt chloride paper comes in contact with the sides and leave it for one minute. Note any colour change in the cobalt chloride paper.
6. Pour a small amount of limewater into the jar. Shake the limewater in the jar. Note any change in the appearance of the limewater.

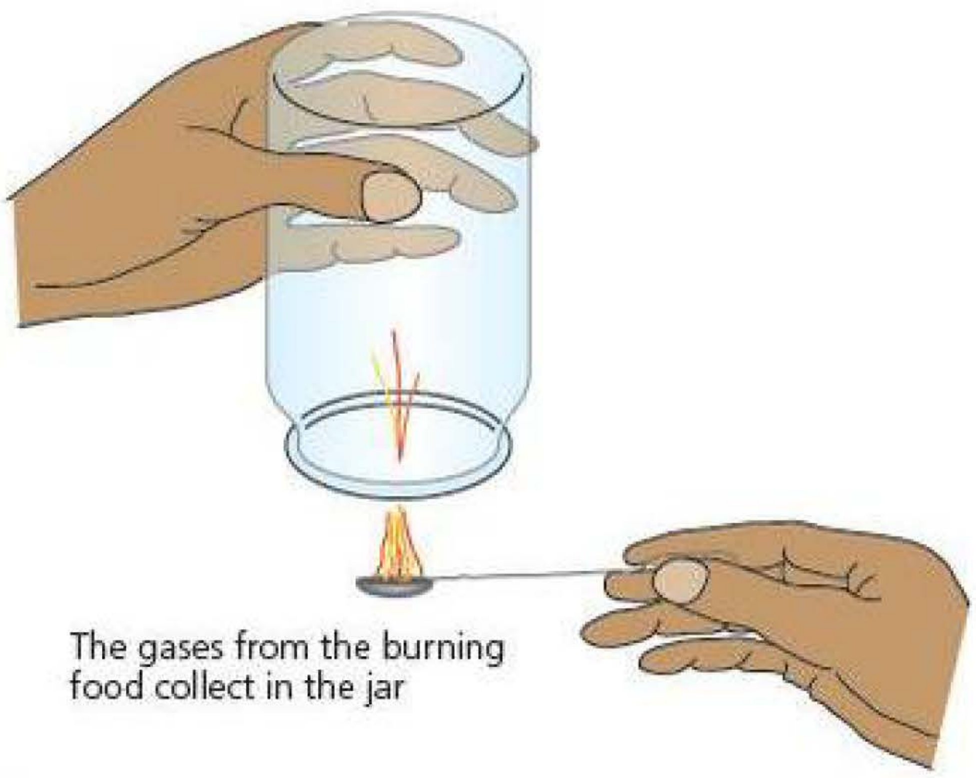


Figure 2.6 Collecting the products of combustion

7. Take a glass cylinder that has been filled with oxygen (your lab technician will do this using an oxygen tank).
8. Take a fresh combustion spoon and ignite the glucose as before. Put the combustion spoon inside the glass cylinder (see Figure 2.7).
9. Note any differences between this experiment and the previous one.

Safety: If you have long hair, tie it back before starting this experiment. Ensure that the glass cylinder is on a flame-proof mat away from any sources of combustion (paper, for example).

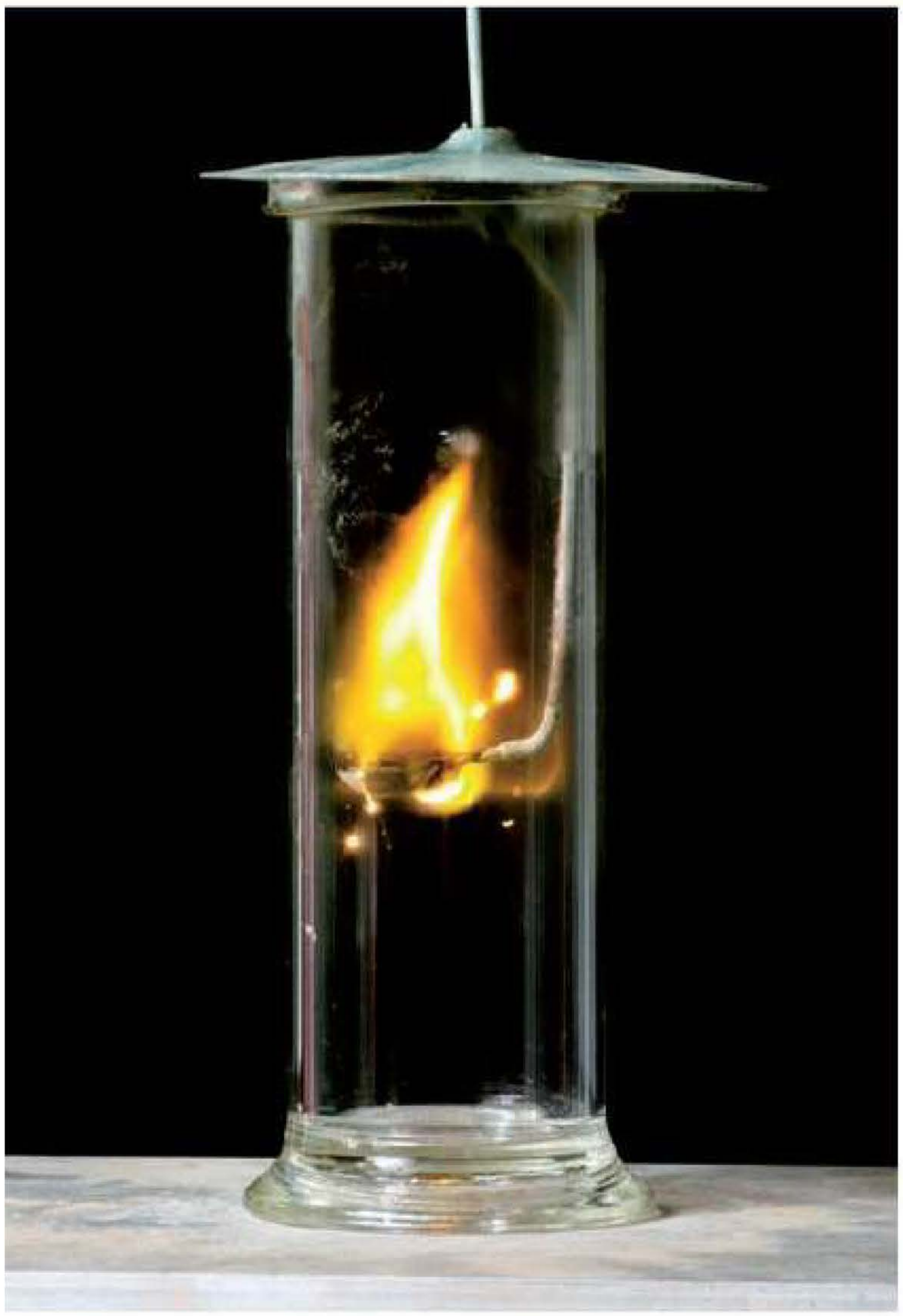


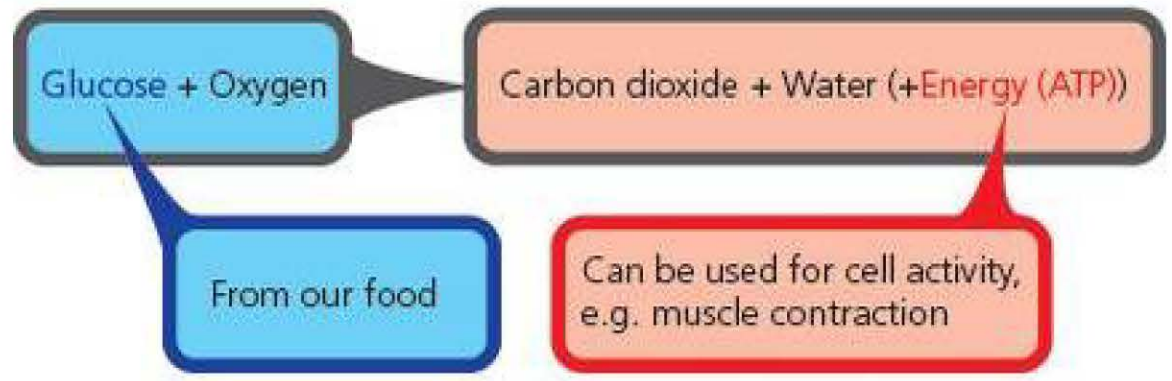
Figure 2.7 Burning glucose in oxygen

- **What have you observed? How do you interpret your results? What gases are produced by the burning glucose?**
- **What evidence do you have to prove that these gases are produced? Explain your reasoning.**
- **What evidence is there that energy is released from the food during the experiment?**
- **Glucose contains carbon, hydrogen and oxygen. Explain the production of the two gases from burning food in simple chemical terms.**
- **Living organisms obtain their energy from food. Compare the burning of glucose in these experiments to the use of food for providing energy in the body.**
- **What differences did you notice when you burnt the glucose in pure oxygen? Can you explain your observations?**

◆ Assessment opportunities

- ◆ In this activity you have practised skills that are assessed using Criterion C: Interpret observations and explain results using scientific reasoning.

The word and chemical equation for aerobic respiration is:



$C_6H_{12}O_6 + 6\ O_2 \longrightarrow 6\ CO_2 + 6\ H_2O$ (+ Energy)

Figure 2.8 The equation for aerobic respiration

Mitochondria are where the majority of energy is released.

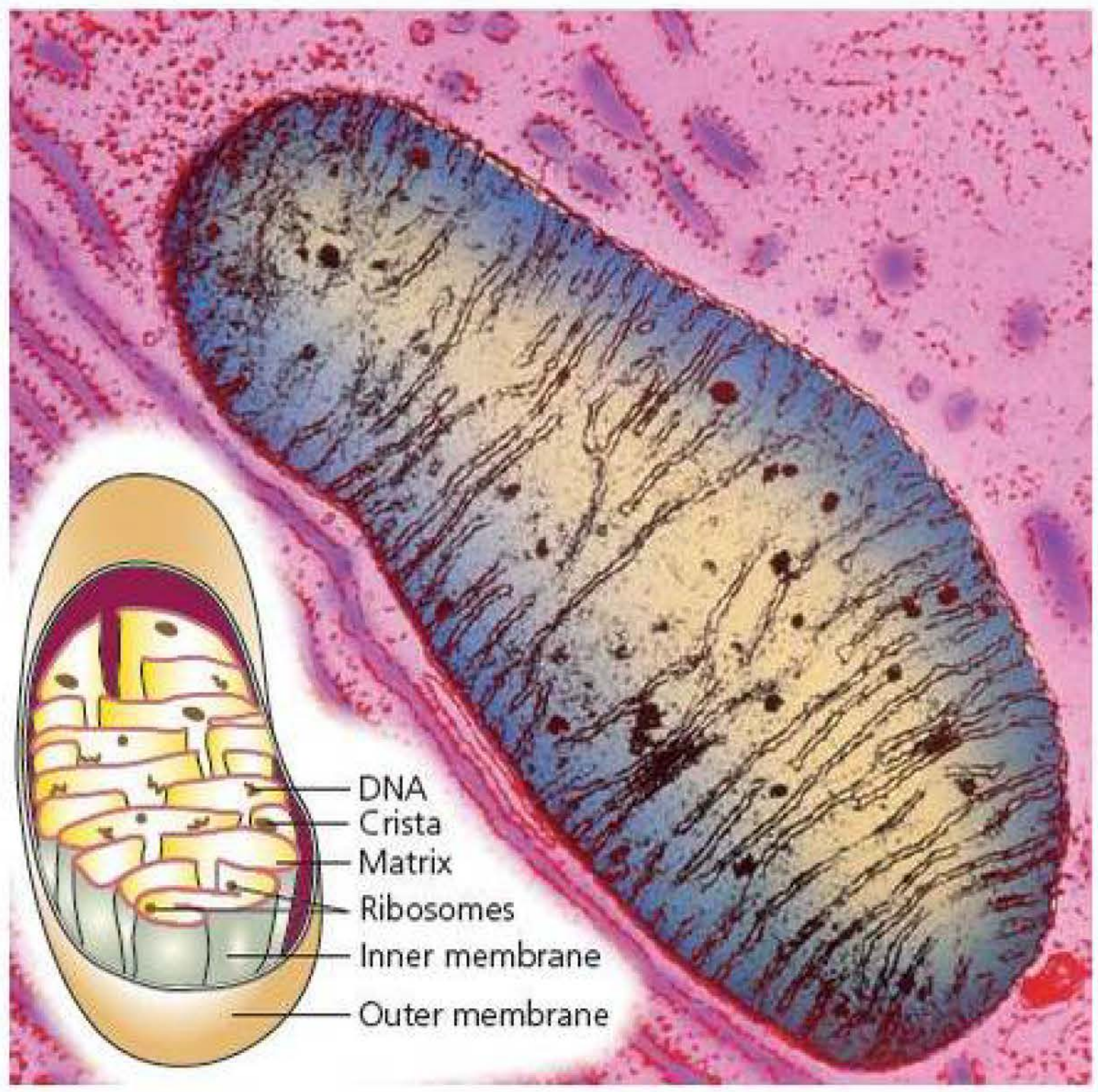


Figure 2.9 A mitochondrion (photo taken using an electron microscope) and an interpretive diagram. The folds inside the mitochondria increase surface area for the reactions of respiration. The matrix contains the enzymes for aerobic respiration. DNA and ribosomes inside each mitochondrion enable them to make their own proteins

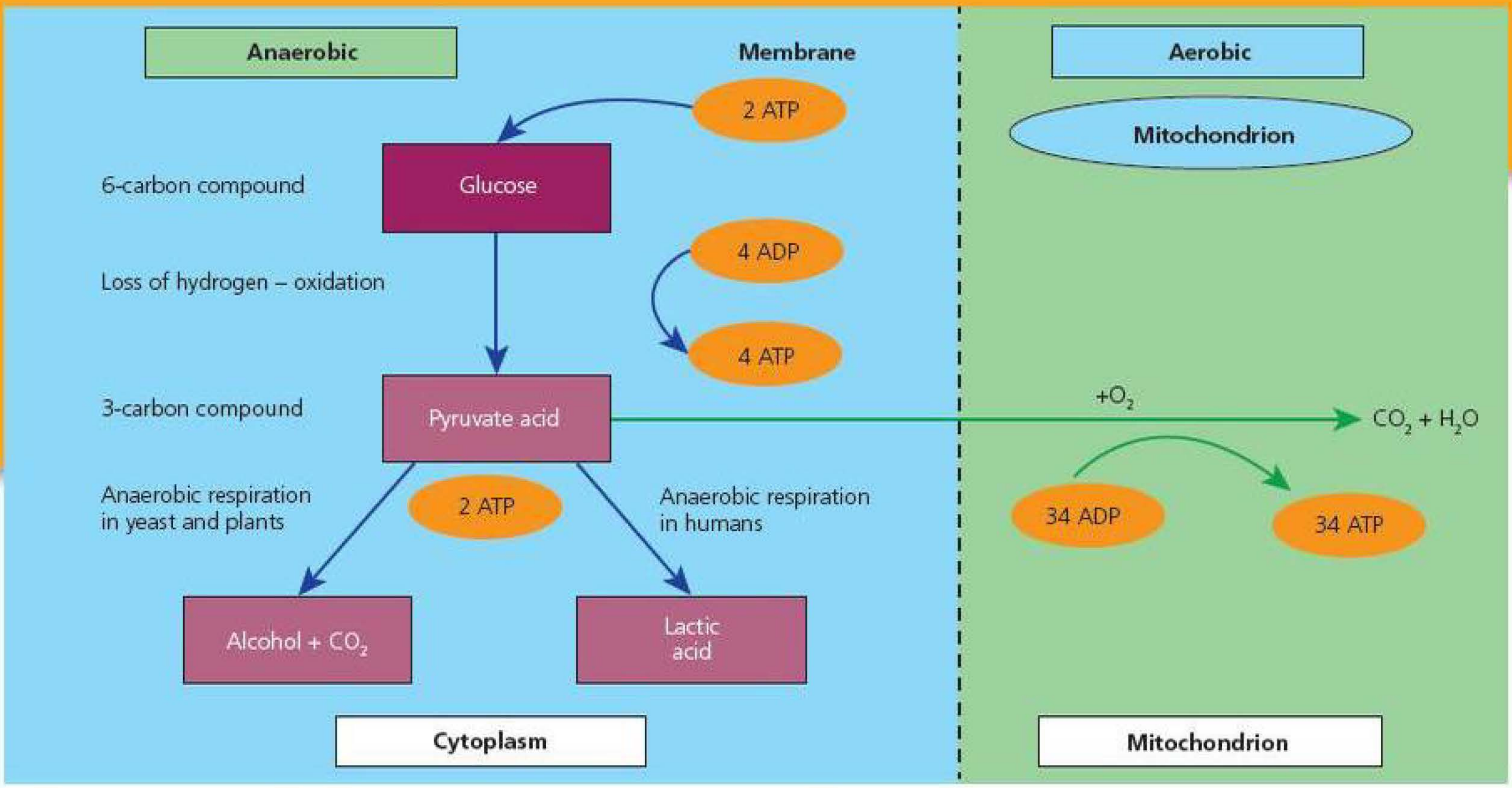


Figure 2.10 Respiration begins in the cytoplasm and ends in mitochondria

Respiration **transfers** chemical energy in glucose into another molecule, ATP. Glucose is a very stable molecule that does not readily break down to release energy – ATP easily breaks down and so is a more suitable source of direct energy in cells.

Respiration breaks down the glucose stage by stage, gradually releasing the energy. In combustion the energy is released all in one go – if this occurred in our bodies then the heat generated would mean we would self-combust! The gradual breakdown of glucose in cells is controlled by enzymes (pages 40–45).

Glucose contains six carbon atoms and so is called a 6-carbon compound. In the cytoplasm of the cell it is broken down into a 3-carbon compound called pyruvic acid by a process called glycolysis ('glucose-splitting'). No oxygen is needed for this process, but only a limited amount of energy is released. If no oxygen is present then either lactic acid is formed (in humans) or alcohol and carbon dioxide (in yeast and plants). If enough oxygen is present in the cell, the pyruvic acid is completely broken down in the mitochondria, resulting in carbon dioxide and water, and the production of much ATP (Figure 2.10).

Hold your hand in the air and repeatedly clench your hand into a fist. What starts to happen after a while? What is building up in your hand and why does that make continued clenching difficult and painful? Shake your arm to get blood moving into the hand once more – why does this return your hand to normal? How does this relate to what happens after strenuous exercise such as a sprint?

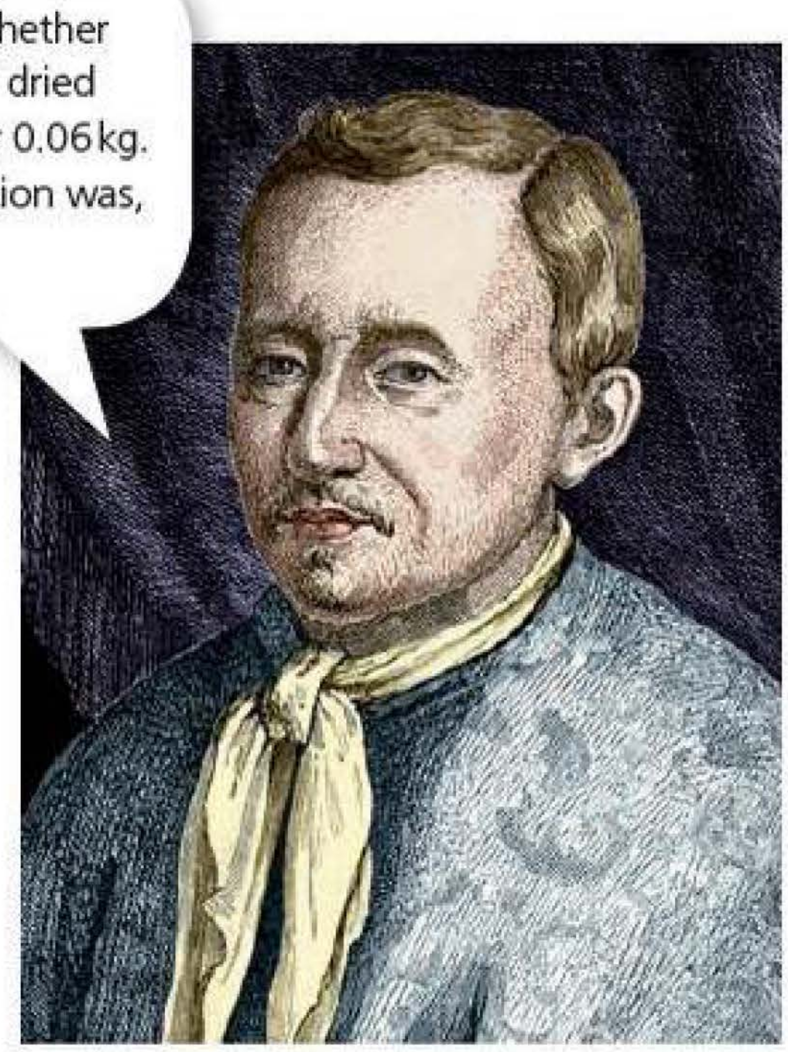
Why does glucose ultimately need to be broken down in the presence of oxygen (there are several reasons)?

SUMMARY REFLECTION

- **What have you learnt about the process of cellular respiration?**
- **What are the differences between anaerobic and aerobic respiration?**
- **What are the word and chemical equations for aerobic respiration?**
- **How does respiration differ from combustion?**
- **What is the difference between aerobic and anaerobic respiration?**
- **What is the word equation for anaerobic respiration in humans?**
- **What is the word equation for anaerobic respiration in plants and yeast?**
- **How do we make use of anaerobic respiration in yeast?**

Why do some organisms need to feed themselves whereas others do not?

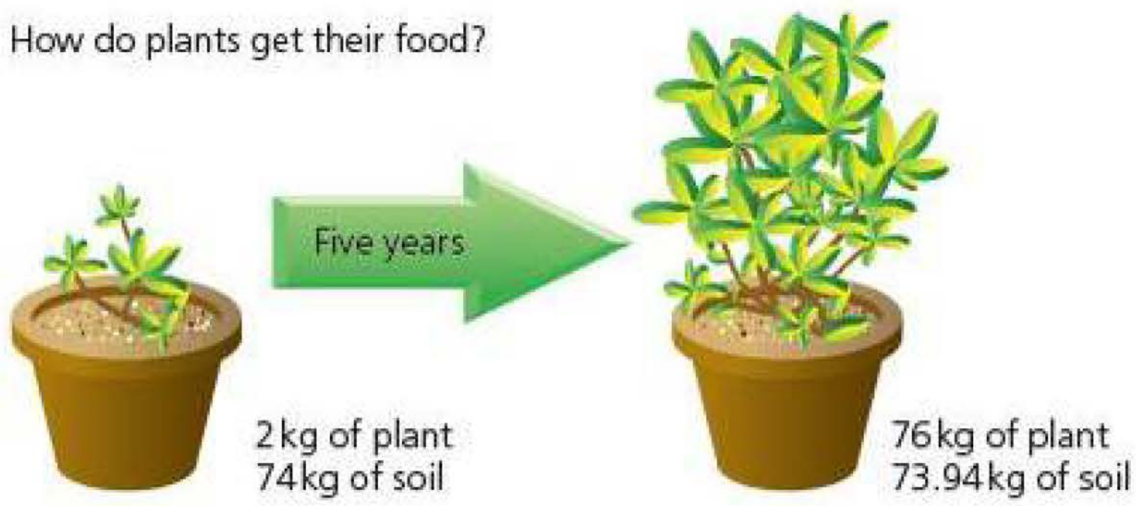
Before me, scientists thought that plants were fed by the soil. I was determined to prove whether this was true or not. I took a plant and watered it – nothing else was added. After 5 years I dried the soil and re-weighed both the plant and soil. The tree gained 74 kg and the soil lost only 0.06 kg. This proved that the soil had not been taken in by the tree to give its new mass – the question was, where *had* the new mass come from? I stated that I thought it was from the water alone.



■ **Figure 2.11** van Helmont

WHAT FACTORS ARE NEEDED FOR PHOTOSYNTHESIS?

In the seventeenth century, a Belgian physician, Jan Baptista van Helmont (1579–1644), set up an experiment in which he planted a willow sapling in a weighed amount of soil.



■ **Figure 2.12** van Helmont's experiment

Was van Helmont correct in saying that all of the new plant mass was gained by taking in water? Water contains hydrogen and oxygen – what other element is needed to make glucose? What molecule provides plants with this additional element?

Figure 2.13 shows the word and chemical equation for photosynthesis.

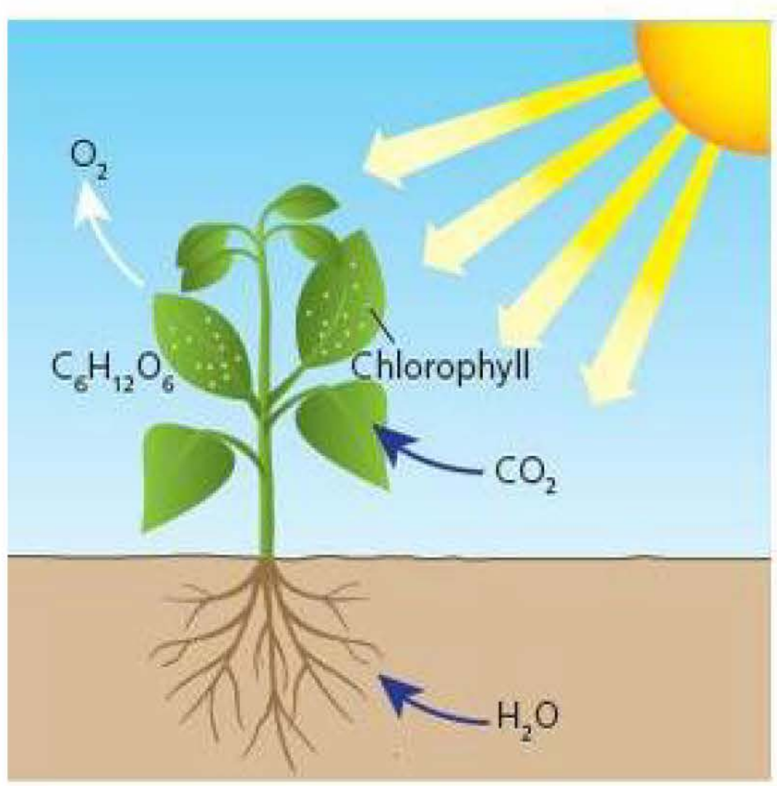
Word equation

$$\text{Carbon dioxide} + \text{Water} \xrightarrow[\text{Chlorophyll}]{\text{Sunlight}} \text{Glucose} + \text{Oxygen}$$

Chemical equation

$$6CO_2 + 6H_2O \xrightarrow[\text{Chlorophyll}]{\text{Light}} C_6H_{12}O_6 + 6O_2$$

■ **Figure 2.13** The equation for photosynthesis

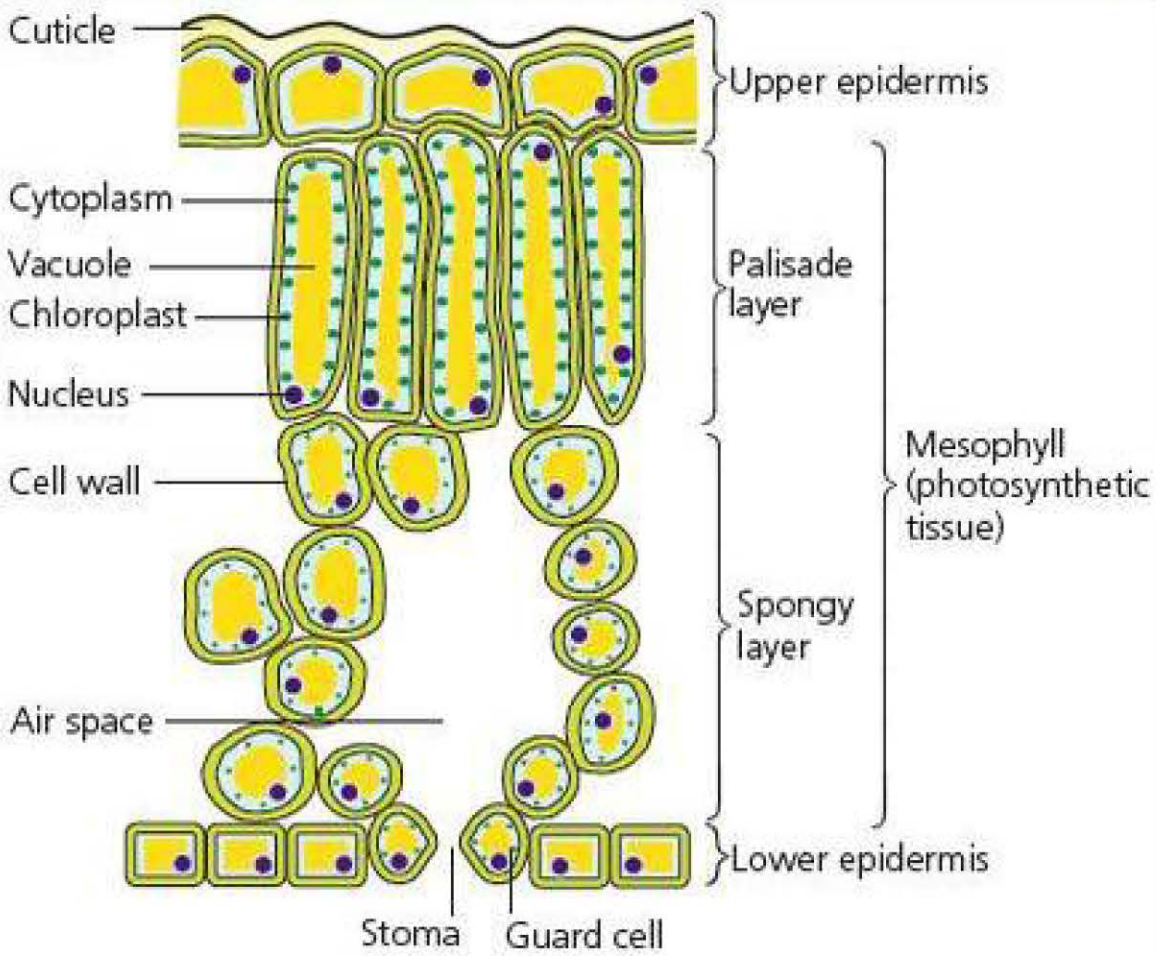


■ **Figure 2.14** Photosynthesis

So, van Helmont was partly correct – although he had not appreciated that carbon dioxide was also needed to make new plant mass (it supplies the carbon needed to make glucose – $C_6H_{12}O_6$).

What do you notice about the equations for photosynthesis and respiration?

Organisms with chlorophyll can capture sunlight energy and store it as chemical energy (glucose). Organisms that cannot do this need to feed themselves to obtain chemical energy. Organisms that can make their own sugars are called **autotrophs** (which means 'self-feeding') whereas those that cannot are called **heterotrophs** (which means getting food from several different sources). Animals, fungi, some bacteria and some protoctista (Chapter 1, pages 14–19) are heterotrophs.



■ **Figure 2.15** Section through a typical leaf showing the cell structure

Factors that plants need for photosynthesis are called **limiting factors**. If the plant does not have enough of them then the rate of photosynthesis is slower. Limiting factors include sunlight, carbon dioxide **concentration**, amount of chlorophyll and temperature.

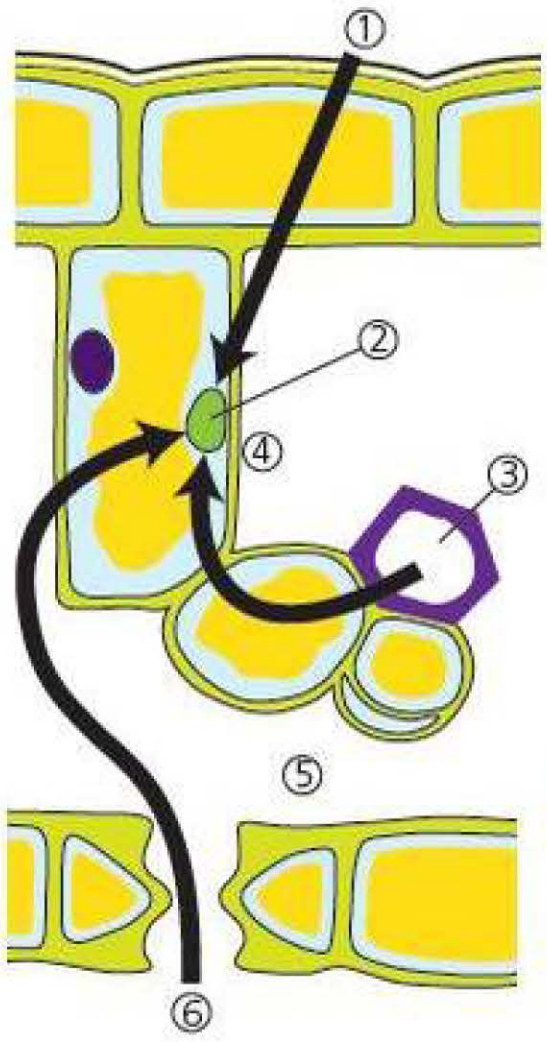
A leaf is adapted to absorb sunlight and carbon dioxide. The flat surfaces of leaves provide a large **surface area** for light absorption. The **palisade cells** that contain the most **chloroplasts** (see Figure 2.15) are near the top of the leaf where there is the most sunlight. Carbon dioxide enters the plant through pores (**stomata** singluar, **stoma**) in the lower surface of the leaf, and circulates in air spaces before being taken in by **spongy mesophyll** cells (which have a large exposed surface area). Water is absorbed by roots and taken into the leaves through veins.

ACTIVITY: How do substances needed for photosynthesis enter the leaf?

■ ATL

- Critical-thinking skills: Gather and organize relevant information

Look at the following figure:



■ **Figure 2.16** How raw materials needed for photosynthesis enter the leaf and reach the chloroplast

Match the following descriptions/words to the correct number:

- **Chloroplast**
- **Water enters leaf through vein (xylem vessel)**
- **Sunlight enters leaf through upper epidermis**
- **Carbon dioxide diffuses into leaf through stomata**
- **Water diffuses into chloroplast**
- **Air space.**

EXTENSION: Chemoautotrophs

Plants are known as photoautotrophs, which means that they use sunlight energy to make food in the form of glucose. Plants are not the only organisms that can make their own food. These organisms are thought to be the earliest forms of life on Earth.

Find out about chemoautotrophs and how they provide a source of energy for food chains. You could use the following search terms: **chemoautotroph**, **nitrifying bacteria**, **thermophiles**, **deep sea vents**.

Produce a poster summarizing your findings.

ACTIVITY: Testing a leaf for starch

ATL

- Critical-thinking skills: Interpret data

Glucose is stored as starch in plants, and so photosynthesis can be shown to be taking place in leaves by testing for starch.

For this activity you will need a plant with large leaves, such as a geranium, iodine solution, a white tile, a Bunsen burner or hot water bath, ethanol, boiling tubes and forceps.

- **Blue/black means starch present**
- **Brown/orange means no starch**

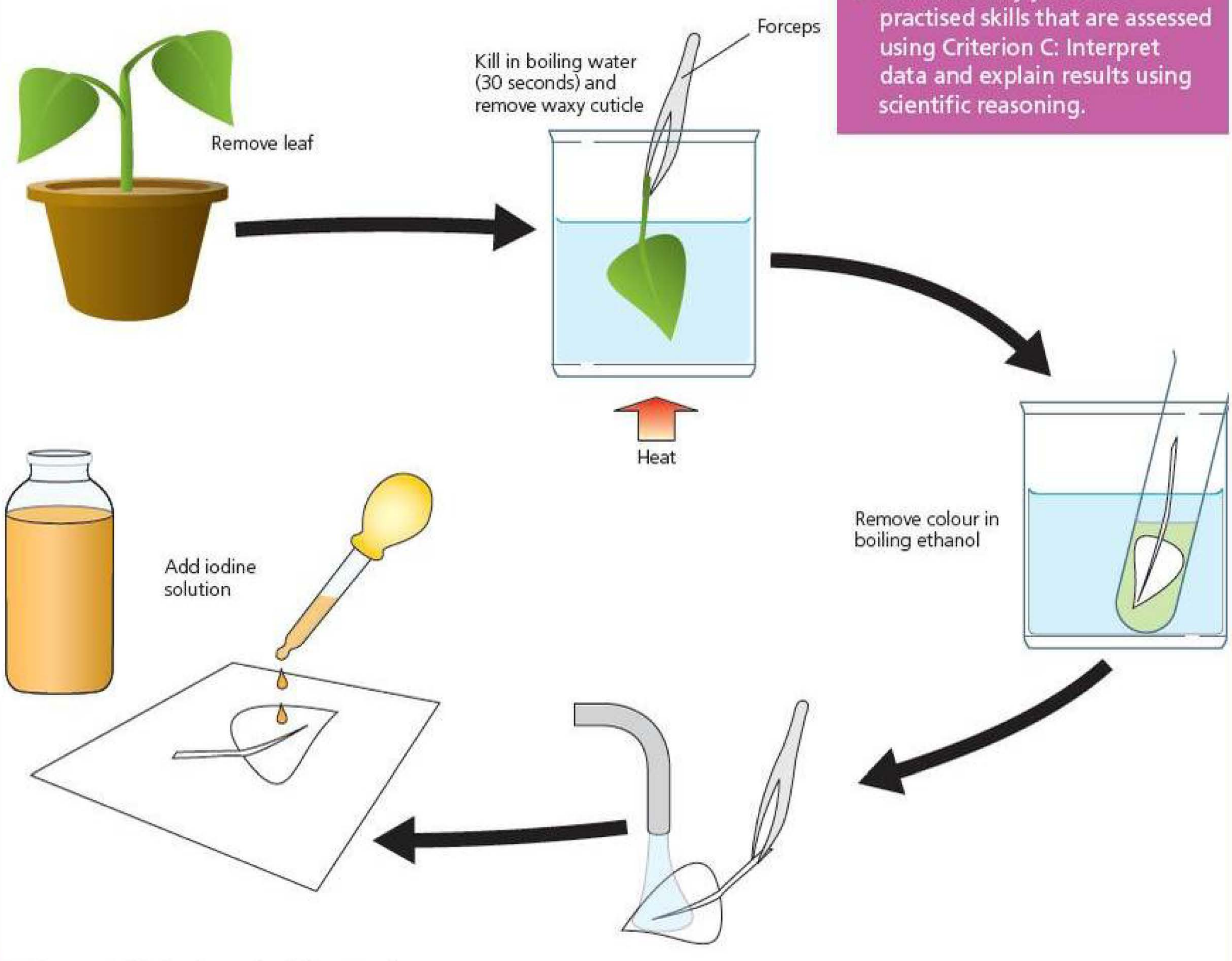


Figure 2.17 Testing a leaf for starch

Think carefully about why you have carried out each stage of the procedure. Use your knowledge of leaf structure to **interpret** your results and **explain** why you have carried out each part using scientific reasoning.

Make a bulleted list explaining why you carry out each stage.

Assessment opportunities

- In this activity you have practised skills that are assessed using Criterion C: Interpret data and explain results using scientific reasoning.

ACTIVITY: Proving that oxygen is produced by photosynthesis

ATL

- Self-management skills: Plan a short-term assignment

Set up the following apparatus:

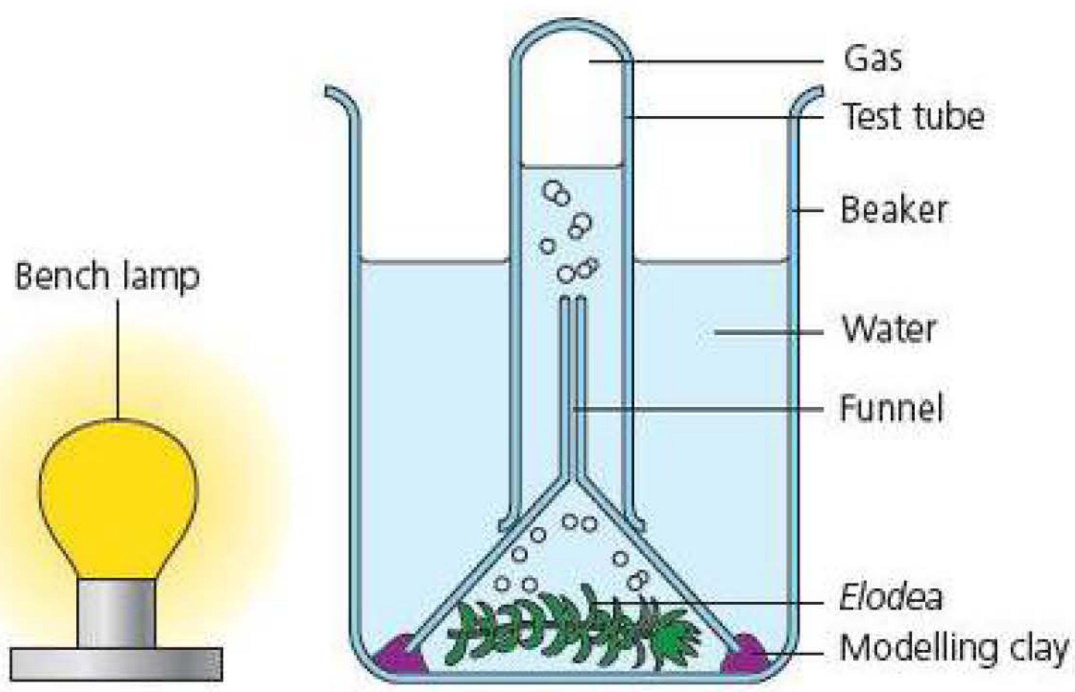


Figure 2.18 Proving that oxygen is produced by plants

Safety: You may need to support the test tube with a clamp stand. Keep test tubes in test tube racks when you are not using them and not loose on the bench as they may roll onto the floor and break.

- **Why is the funnel supported by modelling clay?**
- **How would you test for the presence of oxygen?**

Now use the information provided here to **design** an experiment to measure how light intensity affects the rate of photosynthesis.

- **Explain the question to be tested by the investigation.**
- **Formulate and explain a testable hypothesis using scientific knowledge.**
- **Explain how to manipulate the variables, and explain how sufficient relevant data will be collected.**
- **What will your independent, dependent and control variables be?**
- **How will you ensure reliability and accuracy?**
- **Design a logical, complete and safe method in which you select appropriate materials and equipment.**

In this activity we have applied the scientific method, including control variables and repeats, to ensure the validity of our investigation.

Assessment opportunities

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

THINK–PAIR–SHARE

Think about experiments you could set up in class to prove the equation for photosynthesis – that light, carbon dioxide and chlorophyll are necessary ingredients. **Discuss** your ideas and share them with your neighbour. Then report back to your whole class – have they come up with similar or different ideas? Now read about the experiments on the next page.

ACTIVITY: Proving that light, carbon dioxide and chlorophyll are needed for photosynthesis

ATL

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

Look at Figures 2.19 to 2.21. In what ways do they prove that light, carbon dioxide and chlorophyll are needed for photosynthesis? Before each experiment, the leaves were **destarched** (i.e. starch removed) by placing the plants in a dark room for one week.

Part 1 – Does photosynthesis need light and chlorophyll?

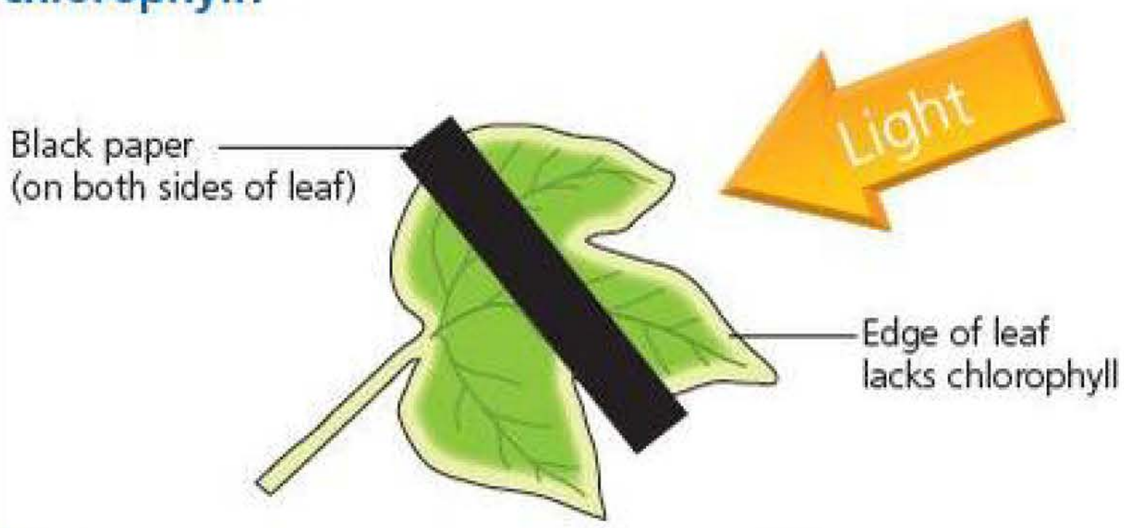


Figure 2.19 Proving that leaves need light and chlorophyll for photosynthesis. Note that a variegated leaf is used here – the outer edge of the leaf does not contain chlorophyll

- **The leaf is now tested for starch. On the leaf in Figure 2.20, show the colour you would expect the different parts of the leaf to be after iodine has been added.**
- **Draw the leaf below to show the colours after testing for starch.**

What two things does this show?

- **How would the experiment be controlled?**

Figure 2.20 The leaf from Figure 2.19 is tested for starch

Part 2 – Does photosynthesis need carbon dioxide?

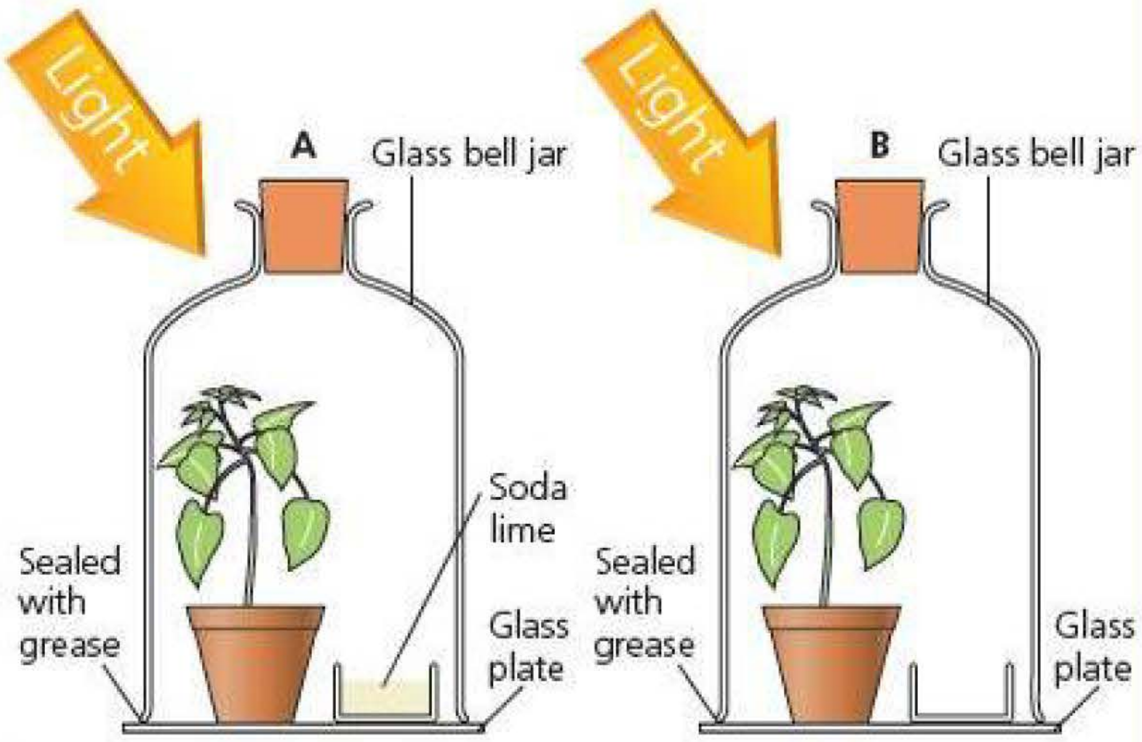


Figure 2.21 Proving that leaves need carbon dioxide for photosynthesis

- **What is the soda lime for?**
- **What is the purpose of bell jar B?**
- **What results would you expect? Use a drawing to show what you would expect if you tested a leaf from both bell jars for starch.**
- **What does this show?**

Assessment opportunities

- In this activity you have practised skills that are assessed using Criterion C: Interpret data and explain results using scientific reasoning.

In this activity we have used scientific equipment to test hypotheses.

ACTIVITY: An experiment to investigate the effect of light intensity on rate of photosynthesis

ATL

- Critical-thinking skills: Interpret data

In a previous activity you were asked to **design** an experiment to measure the effect of light intensity on the rate of photosynthesis. In this activity you will carry out this experiment and develop your own conclusions.

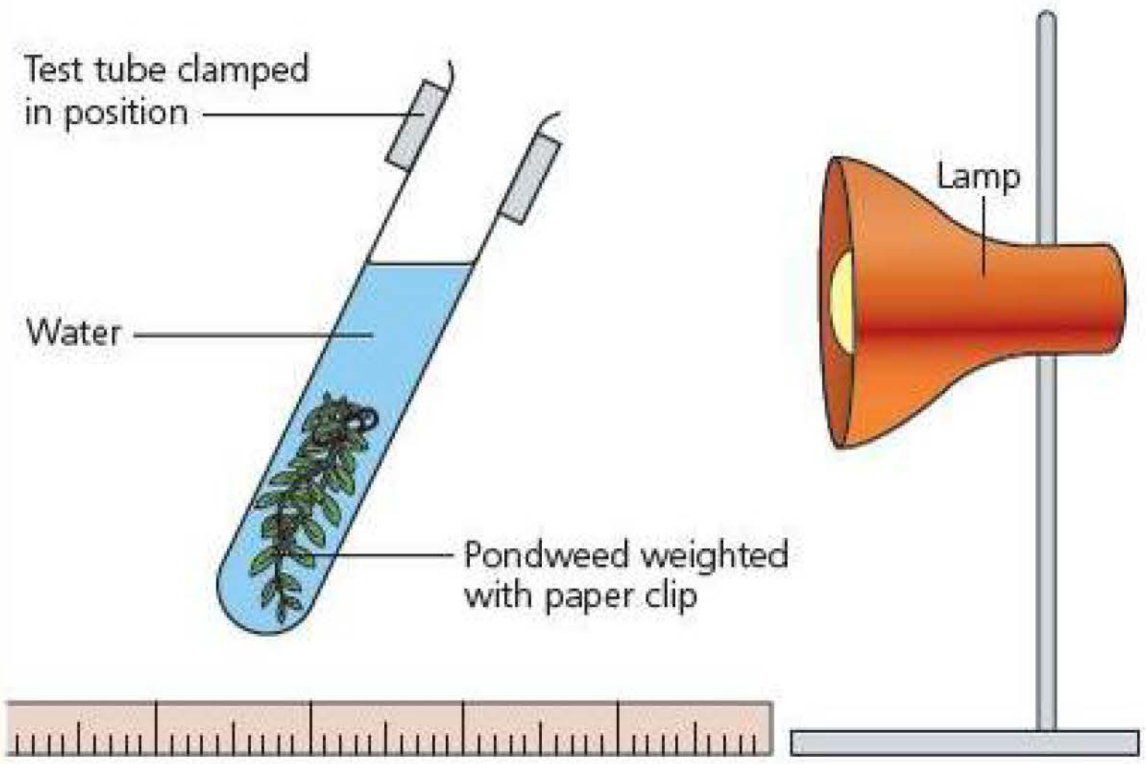


Figure 2.22 The pondweed experiment

1. Take a test tube and fill it two-thirds with water. Add a spatula measure of bicarbonate to add a controlled measure of carbon dioxide to the water.
2. Take a piece of pondweed (*Elodea*) and cut the bottom of the stem at a 45-degree angle (so that oxygen bubbles will be readily released from the stem in water).
3. Put the pondweed in the test tube so that the cut stem is uppermost. Make sure the cut end is not touching the side of the test tube. Add a paperclip to the bottom end of the pondweed to weigh it down so it does not float.
4. Take a desk lamp and put it a measured distance from the pondweed, e.g. 5 cm. Let the plant acclimatize for one minute, until a regular stream of bubbles is given off, and then record the number of bubbles emitted in one minute.
5. Move the plant a further fixed distance from the lamp, for example 10 cm, and repeat the procedure.
6. Continue the experiment until you have measured the number of bubbles given off per minute for at least 10 distances.
7. Repeat the experiment three times to ensure that you have reliable, valid, quantitative results.
8. Once you have correctly collected, **organized**, transformed and **presented** your data in a table, **plot** a graph of your mean results.
9. Apply a line of best fit to your mean data. The line of best fit in drawn so that the points are evenly distributed on either side of the line. If you are drawing the line with a ruler, you will only be expected to draw the line 'by eye'.
10. Accurately **interpret** your data and **explain** your results using correct scientific reasoning.
11. **Evaluate** the validity of the hypothesis based on the outcome of the investigation.
12. **Evaluate** the validity of the method based on the outcome of the investigation.
13. **Explain** improvements or extensions to the method that would benefit the investigation.

Safety: Keep test tubes in racks, not loose on the bench as they may fall on the floor and break. Take care when cutting the pondweed stem.

EXTENSION

Your independent variable is distance of pondweed from the lamp. How would you convert these data into light intensity?

Assessment opportunities

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

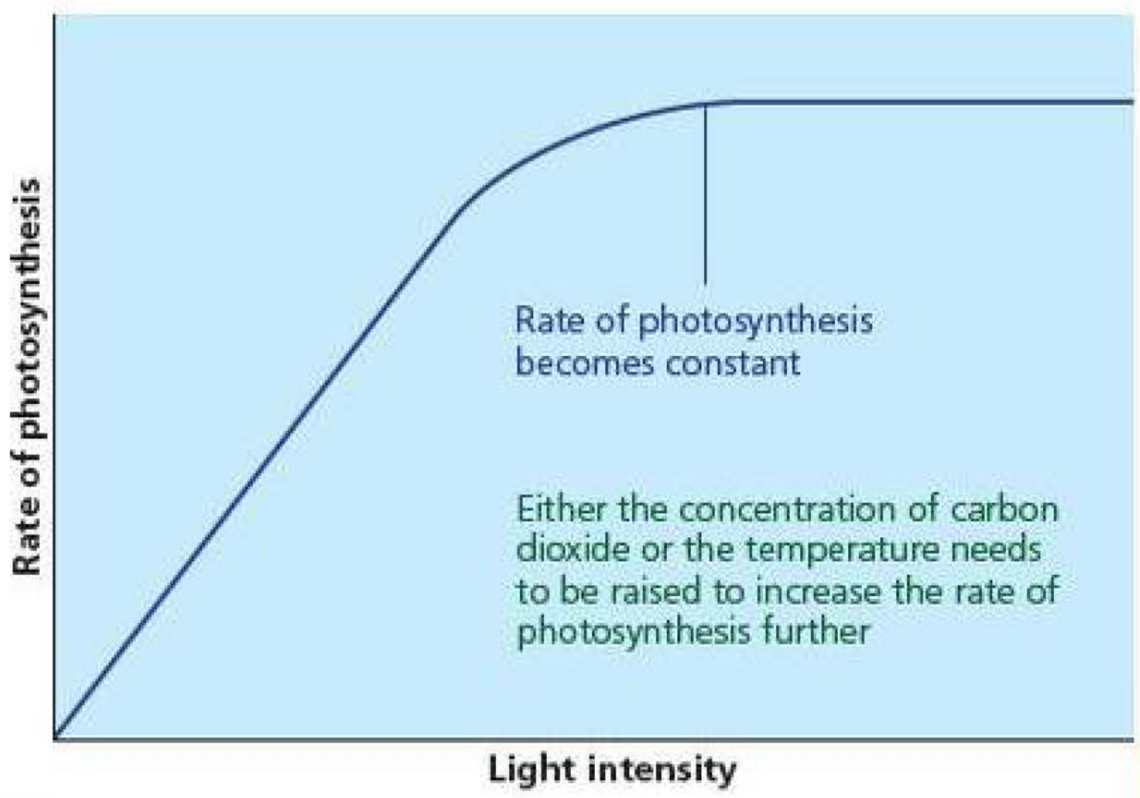
EXTENSION

Use the following website to investigate the effect of light intensity, carbon dioxide concentration, and temperature on the rate of photosynthesis: www.explorelearning.com/index.cfm?method=cResource.dspView&ResourceID=395

Plot your data and draw your conclusions.

Here is a simpler version of the same experiment: www.kscience.co.uk/animations/photolab.htm

When you investigate the effect of light intensity, carbon dioxide concentration and temperature on the rate of photosynthesis, you should get a graph like this:



■ **Figure 2.23** Effect of light on rate of photosynthesis

Initially light is limiting, because increasing the light intensity increases the rate of photosynthesis. At a certain level of light, the rate no longer continues to rise, and in fact levels off. At this point light is no longer limiting, but some other factor is, such as carbon dioxide concentration or temperature.

In this activity we have used a line of best fit to show the correlation between the independent and dependent variables.

ACTIVITY: Showing that plants carry out both respiration and photosynthesis

■ ATL

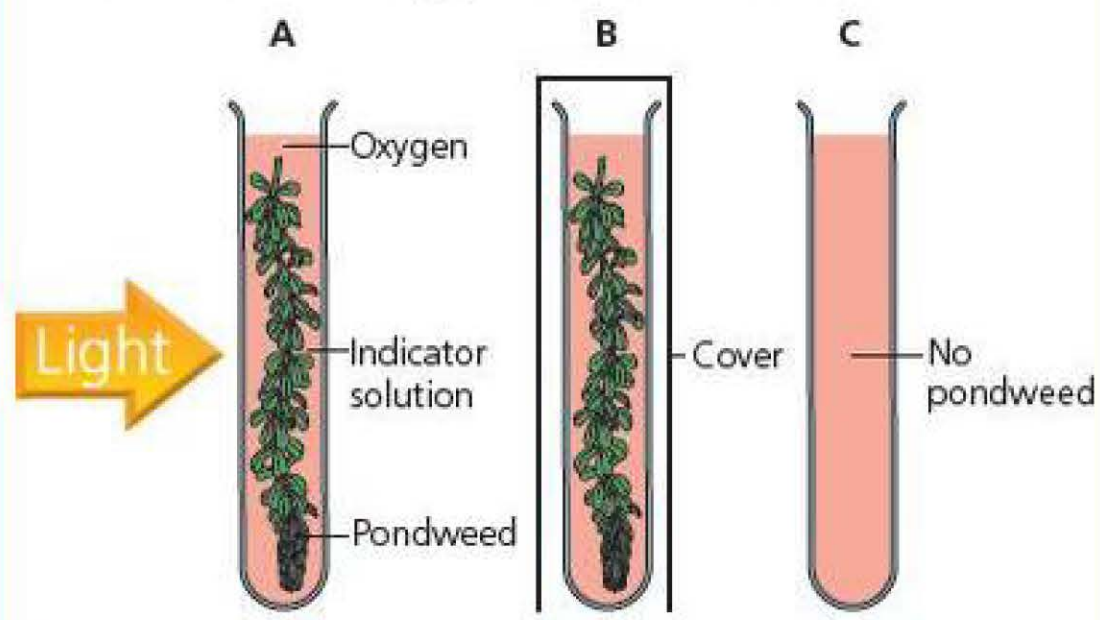
■ Critical-thinking skills: Interpret data

This experiment uses hydrogen carbonate indicator solution. The indicator changes colour with different concentrations of carbon dioxide:

Yellow	Purple
Acidic	Basic
CO_2 present	No CO_2 present

In low levels of CO_2 the indicator is red.

1 **Set up the equipment as follows. Tube B can be covered with tin foil to block out light.**
2 **Add a pinch of bicarbonate (releases CO_2) to each test tube if no oxygen evolves in tube A.**



■ **Figure 2.24** Showing that plants carry out both respiration and photosynthesis

Safety: Wear eye protection when handling the indicator solution, and wash hands after use.

1 **What is tube B for? What is tube C for?**
2 **What would you predict should happen to the colour in each tube, and why?**
3 **Leave the plants for 40 minutes in bright light. Record the colour of the indicator in each tube.**
4 **Write up your prediction, results, conclusion and evaluation.**

◆ Assessment opportunities

◆ In this activity you have practised skills that are assessed using Criterion B: Formulate a testable hypothesis and explain it using scientific reasoning.

Why are enzymes needed?

ENZYME THEORY

Enzymes are biological catalysts. This means that they speed up chemical reactions but are not broken down in the process. They are found inside cells and within the body systems, such as the digestive system. Some are involved with catabolic reactions, and other with anabolic reactions (page 29).

Here are some facts about enzymes:

- They are made of **protein**.
- Enzymes end in 'ase', e.g. **protease** breaks down protein, **carbohydrase** breaks down **carbohydrates** (sugars) and **lipase** breaks down **lipids** (fats).
- The part where reactions take place is called the **active site**. The active site has a specific shape (Figure 2.25).
- Enzymes react with substrates. For example, the enzyme amylase (found in saliva and secreted by the pancreas in the digestive system) reacts with the substrate starch.
- When an enzyme and substrate combine they form an **enzyme–substrate complex**.

Products are produced by enzyme reactions. For example, the products of starch digestion by amylase is the sugar maltose. Maltose is, in turn, broken down into glucose by the enzyme maltase (Figure 2.26).

- The way that enzymes react with the substrate is called the **lock-and-key mechanism**. The enzyme is the 'lock' which has a specific shape into which one substrate (the 'key') fits.
- Bonds are either broken or formed once the reactants are in the active site, forming new products.

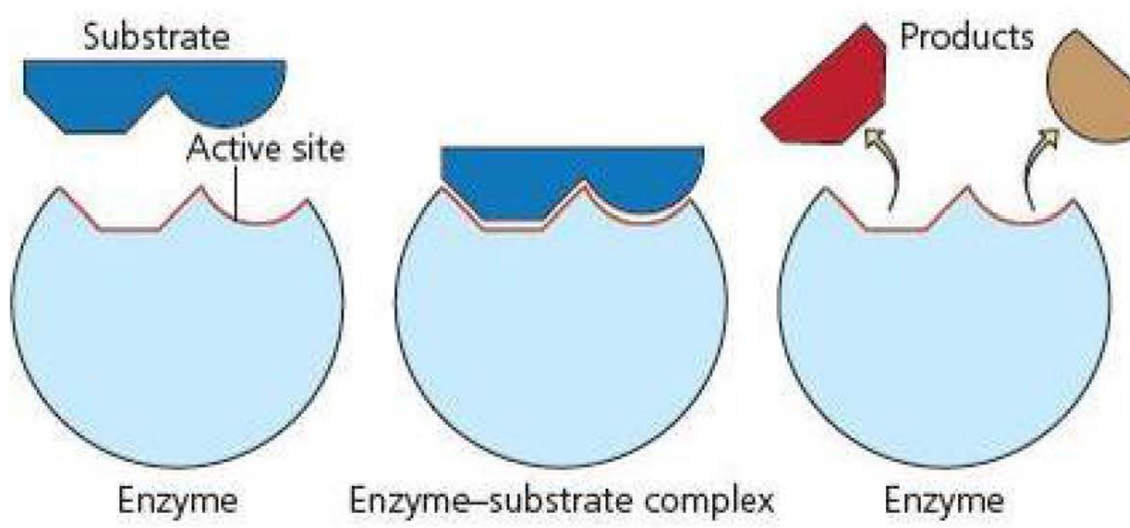


Figure 2.25 An enzyme-catalysed reaction

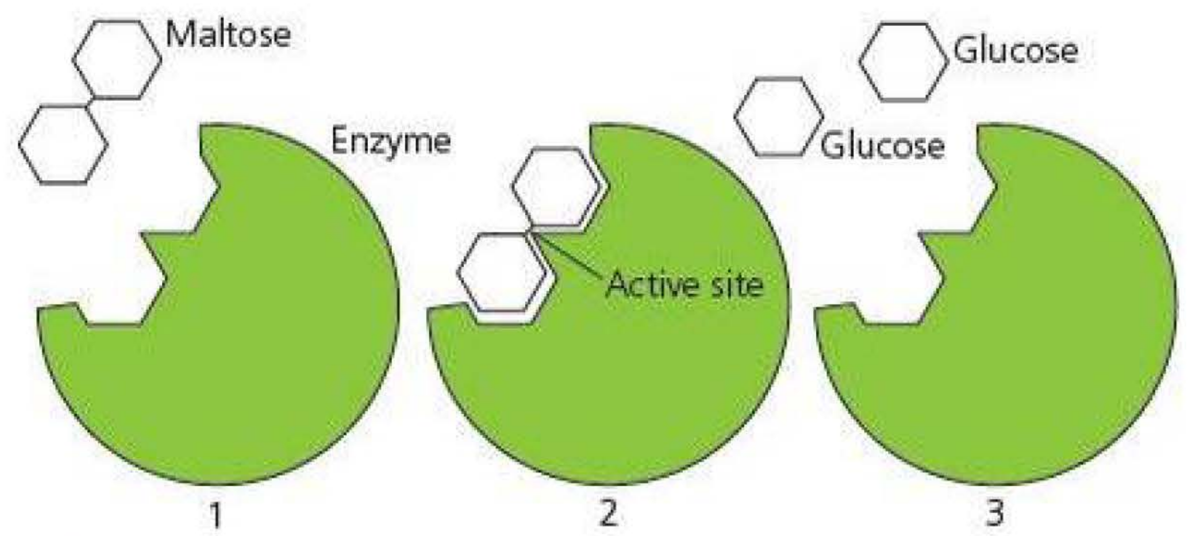


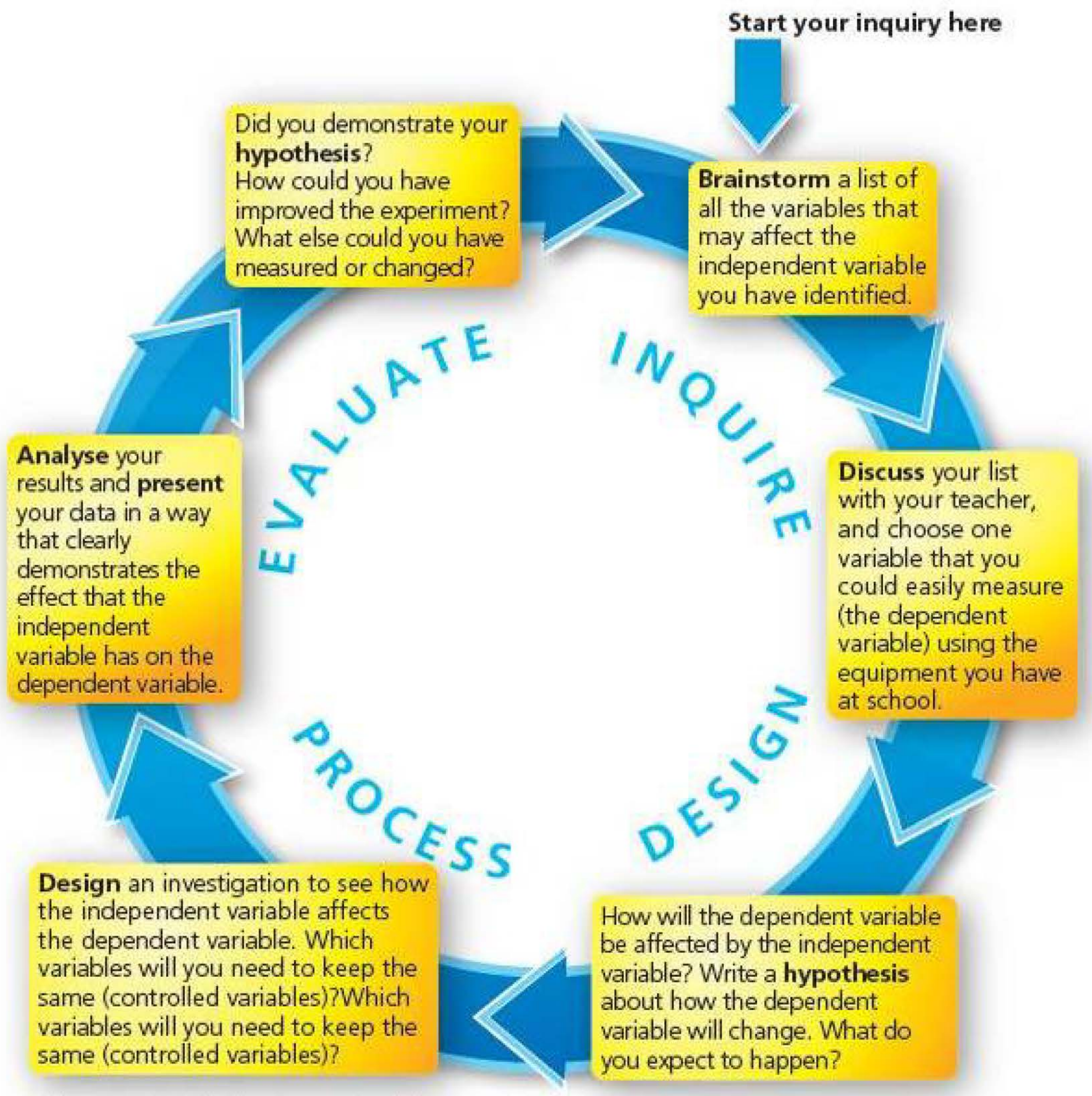
Figure 2.26 The sugar maltose is broken down into glucose by maltase

So far in this book, you have carried out experiments that investigate various biological principles. You will have noticed that each investigation follows a particular pattern. We will examine this '**scientific method**' in detail here.

The investigation cycle

All scientific inquiry starts with a question. This question is usually based on an observation – something that the observer has seen that they think needs explaining. This leads to an investigation that explores the question and ultimately results in an explanation. An evaluation of the method can lead to further investigations. The whole process can be thought of as a cycle (see Figure 2.27).

Over the next few pages the investigation cycle is used to investigate enzyme reactions. For each investigation, think carefully about how the cycle is being applied.



■ **Figure 2.27** The investigation cycle

scientific method The use of controlled observations and measurements to test a hypothesis.

variable A factor that is being changed, investigated, or kept the same in an investigation.

independent variable The variable that is being changed in an investigation.

dependent variable The variable that is being measured in an investigation.

hypothesis An untested proposal that can be investigated using the scientific method.

controlled variables These are variables are kept the same in an investigation. At least three should be listed, and information about how they will be kept the same included.

controlled Method that uses controlled variables.

accuracy How close to the true value a result is.

precision The number of significant digits to which a value can been reliably measured. For example, if a digital thermometer can measure to two decimal places, this is the precision of data that can be recorded.

ACTIVITY: Investigating the effect of enzyme concentration on rate of reaction

ATL

- Critical-thinking skills: Interpret data

This experiment investigates the effect of neutrase concentration on the breakdown of a protein in milk called casein.

Background

Powdered milk contains a protein called casein. When powdered milk is dissolved in water to make a solution, this protein in suspension makes the solution opaque (you can't see through it). In this investigation you will add different concentrations of a protease enzyme (breaks down protein) called neutrase to a powdered milk solution and time how long it takes for the milk solution to clear.

Materials

- 5% neutrase solution
- 2% powdered milk solution
- 5 ml syringes, 50 ml measuring cylinder
- 3 × 100 ml beakers
- stop-clock
- paper with pencil crosses marked on

Hypothesis

Formulate and **explain** a testable hypothesis using correct scientific reasoning.

Method

1. Work in pairs. Put on your safety glasses.
2. Place a piece of paper with a pencil cross drawn on it on the bench and put a 100 ml beaker on top.
3. Using a 5 ml syringe add 5 ml of 5% neutrase solution to the beaker.
4. Using a measuring cylinder add 25 ml of 2% powdered milk solution to the beaker. Pour the milk rapidly into the beaker to ensure the milk and neutrase mix well.
5. As soon as you have added the milk solution start the stop-clock.
6. Looking from above, stop the clock at the moment you can see the cross through the milk.
7. Record the time taken in your table.
8. Using the information in the table opposite make up the other concentrations of neutrase solution (4%, 3%, 2% and 1%) and repeat the experiment at each different enzyme concentration.
9. Repeat the entire experiment twice again (at all five enzyme concentrations).

10 Once you have correctly collected, **organized**, transformed and **presented** your data in a table, **plot** a graph of your mean results. Make sure you have:
- a suitable title
- a suitable scale on both axes
- both axes labelled (including units)
- points accurately plotted
- points joined together in the most suitable manner.

11 Apply a line of best fit to your mean data.

How to make the different neutrase concentrations:

Desired neutrase concentration/%	How much 5% neutrase solution do I need?/ml	How much water do I need to add?/ml
5	5	0
4	4	1
3	3	2
2	2	3
1	1	4

Safety: Wear eye protection at all times and wash your hands after handling the neutrase solution.

For the results of an investigation to be valid, variables other than the independent and dependent variables need to be controlled, the experiment should be repeated to improve reliability, and the experimental method should be appropriate for the research question.

Questions and assessment

- What were your independent, dependent and control variables?
- What were the values of your dependent variable?
- How did you ensure the reliability of the experiment?
- Accurately **interpret** your data and **explain** your results using correct scientific reasoning.
- **Evaluate** the validity of the hypothesis based on the outcome of the investigation.
- **Evaluate** the validity of the method based on the outcome of the investigation.
- What was the main hazard in the experiment and how did you eliminate this hazard?
- **Explain** improvements or extensions to the method that would benefit the investigation.

Assessment opportunities

- This activity can be assessed using Criterion B: Formulate a testable hypothesis and Criterion C: Processing and evaluating.

ACTIVITY: Investigating the effect of temperature on rate of reaction

ATL

- Critical-thinking skills: Interpret data

This experiment investigates the effect of temperature on the expansion of dough.

Information

- **Yeast is a single-celled fungus, a type of micro-organism.**
- **When it is short of oxygen yeast breaks down glucose in anaerobic respiration to release energy, carbon dioxide and ethanol. (Try to smell this.)**
- **Respiration is controlled by enzymes.**
- **The yeast suspension contains yeast and glucose.**
- **The carbon dioxide given off forms bubbles which make the dough rise.**
- **Your paste will be runny.**
- **You will carry out the experiment at 20, 30, 40, 50, 60 and 70 °C.**

Safety: Do not carry out the experiment if you are allergic to yeast. Take care when using the water baths at temperatures 50, 60 and 70 °C as hot water can scald.

Hypothesis

Formulate and **explain** a testable hypothesis using correct scientific reasoning.

Questions and assessment

- What made the dough rise?
- Describe the effect of temperature on the volume of dough produced.
- Accurately **interpret** your data and **explain** your results using correct scientific reasoning.
- **Evaluate** the validity of the hypothesis based on the outcome of the investigation.
- **Evaluate** the validity of the method based on the outcome of the investigation.
- **Explain** improvements or extensions to the method that would benefit the investigation.

Assessment opportunities

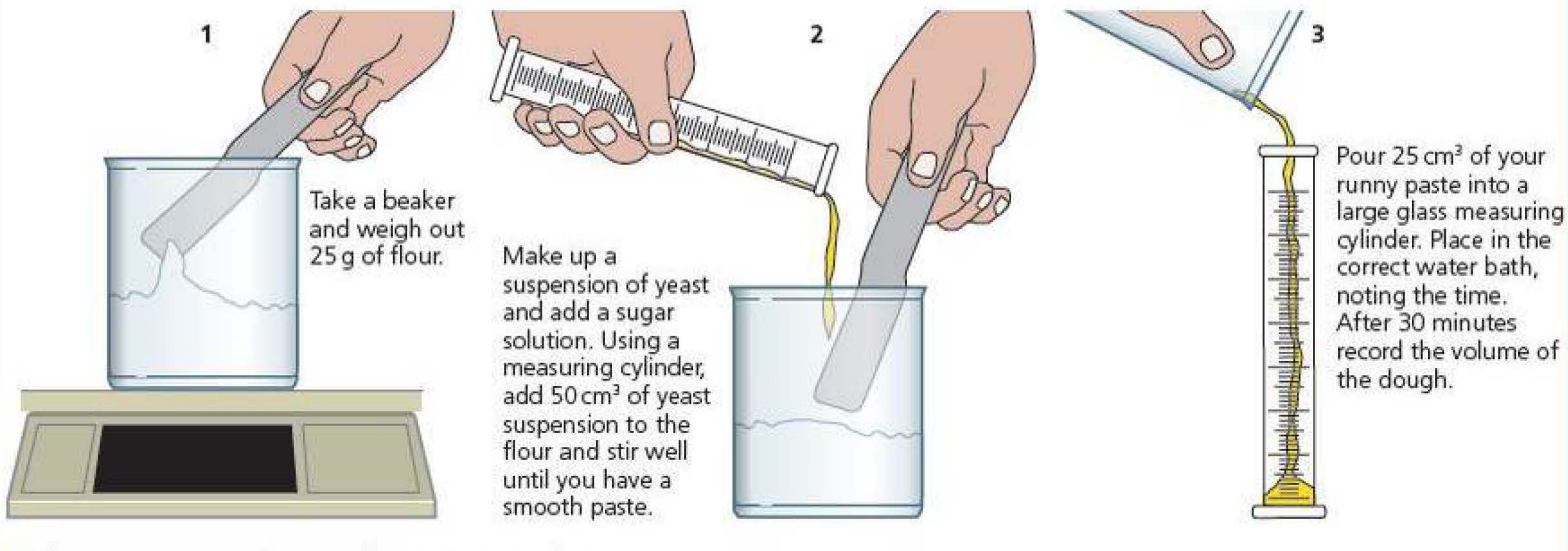
- In this activity you have practised skills that are assessed using Criterion B: Formulate a testable hypothesis; this activity can be assessed using Criterion C: Processing and evaluating.

EXTENSION

1 Why can the yeast cells use sugar but not flour as food?

2 What do yeast cells produce that enables them to use the sugar?

3 Why is yeast used in bread making?



■ **Figure 2.28** Setting up the yeast experiment

ACTIVITY: Enzyme poster

ATL

- Communication skills: Make effective summary notes; Organize and depict information logically

Your task is to produce a poster about enzymes.

Points to cover:

- **What type of biological molecule are enzymes made of?**
- **Are all enzymes the same shape? If not, why not? (Think about what you know about the type of biological molecule they are made from.)**
- **What is special about enzymes (e.g. what properties do they have)? (They are known as biological catalysts – what does this mean?)**
- **Why is the shape of an enzyme important?**
- **What is the 'lock-and-key' hypothesis? A diagram may help you to describe this …**

Words to use: enzyme, substrate, enzyme–substrate complex, products, active site.

- **What factors affect how well (or badly) enzymes work? There are two main factors for you to describe.**
- **How are enzymes used in respiration and photosynthesis?**
- **Can you find out anything else about enzymes? (For example, enzymes of digestion.)**
- **Make sure you explain how the structure of enzymes relates to their function.**

Enzyme picture bank

Use these diagrams to help you make your poster:

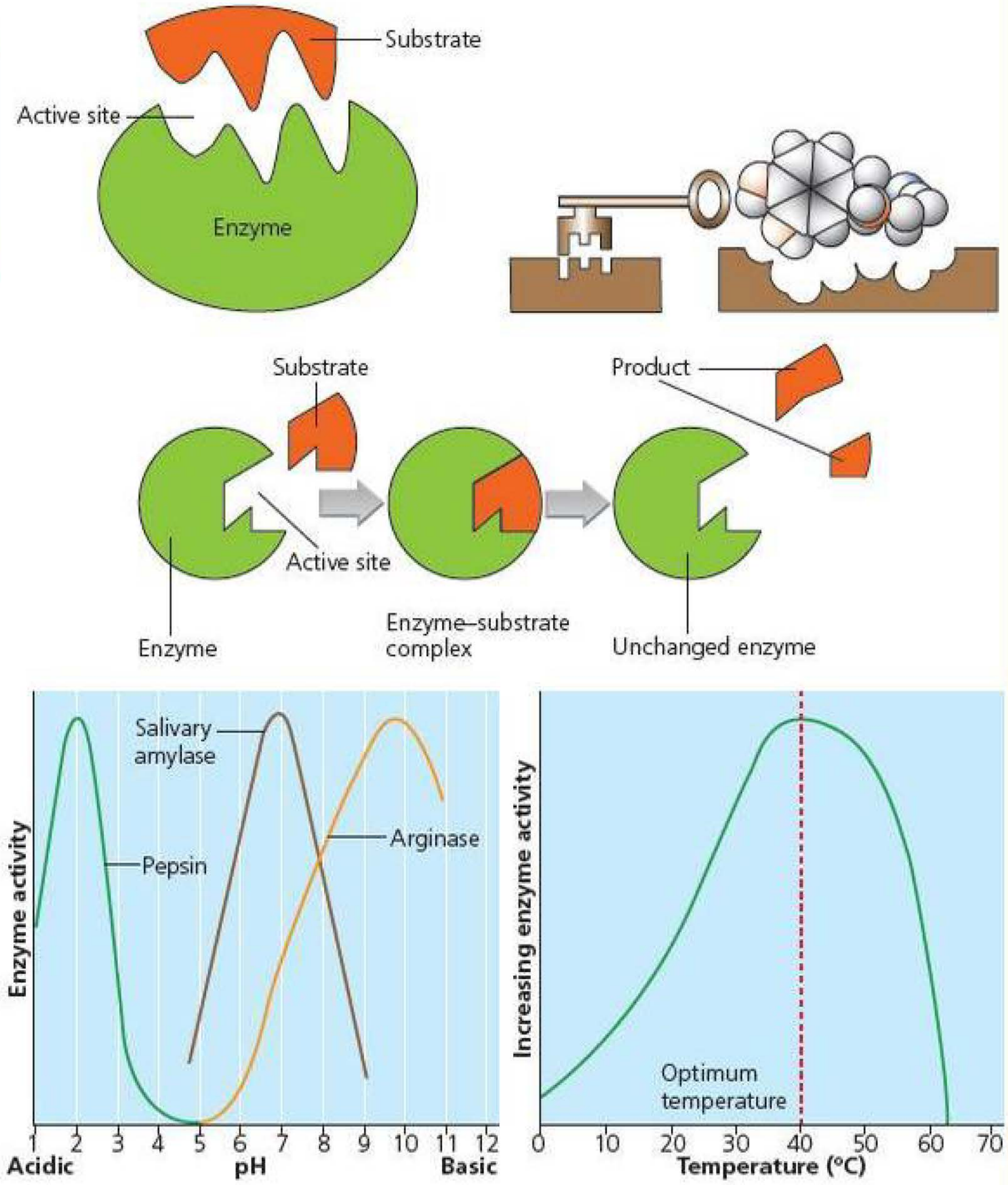


Figure 2.29 Enzyme picture bank

EXTENSION

Certain chemicals can inhibit the action of enzymes. There are two types – competitive inhibitors and non-competitive inhibitors. Find out about these different types of inhibitors: **describe** and **explain** how they work and then add notes about them to your enzyme poster.

Assessment opportunities

- In this activity you have practised skills that are assessed using Criterion A: Describe and explain scientific knowledge.

Should chemical reactions be manipulated in order to meet our food and fuel needs?

CAN THE CHEMICAL REACTIONS OF LIFE OCCUR OUTSIDE CELLS?

In Chapter 1 you explored whether artificial life is possible. Biochemical reactions that occur within cells are complex and driven by enzymes. Would it be possible to replicate these chemical reactions outside cells?

- What do you think? Exchange your ideas with your neighbour.

Reactions such as respiration can be represented in the lab by burning glucose in the presence of oxygen, but this releases all the energy in one go rather than replicating the gradual and carefully controlled release that occurs within cells.

Chemical reactions can certainly be manipulated, and are being used to meet our food and fuel needs. We will explore this further in the next activity.

ACTIVITY: Increase the growth of plants

ATL

- Organization skills: Plan a long-term assignment

Global food production will need to increase by more than 50 per cent before 2050 to meet the food and fuel demands of an increasing population. Are there ways of improving photosynthesis to increase crop **yields**? In Chapter 11 we will explore how DNA can be modified and exchanged between different species – it is possible that genetic modification can be used to improve crop yield. But would such changes be allowed – *what do you think?*

Currently, crop yield can be improved by using greenhouses. Using your knowledge of photosynthesis and enzymes, how can the rate of glucose production in plants be increased? What variables could be changed/ increased?

Figure 2.30 Tomatoes being grown in a greenhouse

In this activity you need to plan an experiment to investigate how to increase the growth of a plant, and then carry out an experiment to test your hypothesis.

Take action

- Read about how organisms can be modified to meet our fuel needs:

  http://phys.org/news/2013-03-fuel-bacteria-genetically-modified-cyanobacteria-efficient.html

  http://sciencenordic.com/biofuel-breakthrough-scientists-use-gmo-yeast-produce-fuel

  www.bbc.co.uk/news/science-environment-24489800

- Your experiment (see Activity on page 46 and below) should have shown how chemical reactions inside cells can be manipulated to increase growth. If done on a sufficiently large scale, do you think that such operations could help meet the world's food needs? Are there alternative approaches that you would prefer to see used, and if so what would these be?
- Produce a report on ways in which organisms can be modified to meet humanity's fuel needs. What issues do human populations face regarding fuel security? What alternatives to fossil fuel exist? Use your knowledge of energy systems in cells built up through this chapter.

Assessment opportunities

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

DISCUSS

Discuss within a small group this question:

- How can the (environmental/social) consequences of manipulating chemical reactions to solve our food and energy problems be justified?

SUMMARY REFLECTION

- What have you learnt in this chapter about how the systems of life are supported by biochemical reactions?
- What are the transformations of energy that occur within cells?
- What are enzymes and how do they work? What is meant by 'optimal conditions' for enzymes?
- How can innovations in science lead to biochemical reactions being utilized to meet growing energy and food needs?
- What have you learnt about yourself as an inquirer: how you nurture curiosity, and develop skills for inquiry and research?

1. Plan an experiment to change one variable to investigate its effect on plant growth.
2. **Explain** the question to be tested in the investigation.
3. Which species of plant will you use?
4. **Formulate** and **explain** a testable hypothesis using correct scientific reasoning.
5. Decide how you will change your independent variable.
6. How will you measure the plant growth?
7. **Explain** how to manipulate the variables, and **explain** how sufficient, relevant data will be collected.
8. **Design** a logical, complete and safe method in which you select appropriate materials and equipment.

Now carry out the experiment. Think about how you will record your results.

9. Correctly collect, **organize** and **present** your data.
10. Accurately **interpret** your data and **explain** the results using correct scientific reasoning.
11. **Evaluate** the validity of the hypothesis based on the outcome of the experiment.
12. **Evaluate** the validity of the method based on the outcome of the experiment.
13. **Explain** the improvements or extensions to the method that would benefit the investigation.

Assessment opportunities

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

! Take action: Food waste

■ **Figure 2.31** Food waste

! In this chapter we have investigated how energy is stored in food, and how we need this energy to carry out respiration in our bodies. We have also explored how these reactions can be manipulated to meet the world's food needs.

! A recent report by the UK's Institution of Mechanical Engineers claimed that as much as half of all the food produced in the world – equivalent to 2 billion tonnes – ends up as waste every year. Think of all that trapped solar energy simply being wasted!

! Think about ways in which you can reduce food waste. **Discuss** these ideas within your class. Ideas for cutting food waste could include:

- Make meals from leftover food.
- Think before you shop: have a look in the fridge for what you already have and have an idea of meals or recipe needs before you go shopping.
- Use leftovers to form compost for your garden, to recycle nutrients.
- If you know you are not going to use something, freeze it fresh for another day. A full refrigerator retains cold better than an empty one.
- Store food carefully.
- If you eat at a canteen, select what you want for a meal carefully so that you do not have leftover food.

! Organize a campaign within your school community, or at home, to cut down on food waste. How will you know whether you are being successful or not?

! Explore further by visiting this website: **www.lovefoodhatewaste.com/**

! Write up your findings as a fully referenced report, and use scientific ideas you have explored in the chapter.

Assessment opportunities

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

SOME SUMMATIVE PROBLEMS TO TRY

Use these problems to apply and extend your learning in this chapter. These problems are designed so that you can evaluate your learning at different levels of achievement in Criterion A: Knowledge and understanding.

THESE PROBLEMS CAN BE USED TO EVALUATE YOUR LEARNING IN CRITERION A TO LEVEL 1–2

1 a **State** the chemical equation for photosynthesis.
  b **State** the chemical equation for aerobic respiration.
  c What do you notice about the equations for photosynthesis and aerobic respiration?

2 An experiment investigated combustion by burning glucose inside a glass cylinder containing oxygen.

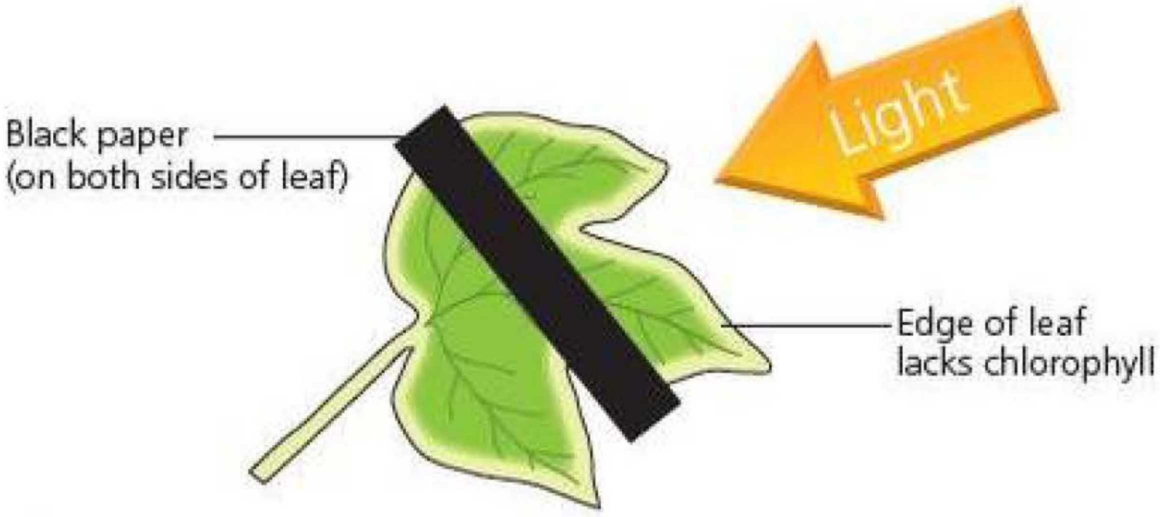
■ **Figure 2.32** Burning glucose

  a **Suggest** what products will be collected inside the glass cylinder.
  b **Suggest** what would happen if a higher concentration of oxygen was used inside the glass cylinder.
  c Give two similarities and one difference between combustion (shown in Figure 2.32) and respiration.

3 **Outline** reasons why animals need to eat food, whereas plants do not.

THESE PROBLEMS CAN BE USED TO EVALUATE YOUR LEARNING IN CRITERION A TO LEVEL 3–4

4 Figure 2.33 shows a variegated geranium leaf that has been destarched. A black strip of paper covers part of the leaf and the leaf is then exposed to light. The leaf is tested for starch.
  a Which parts of the plant result in a positive test for starch and which do not? **Justify** your answer using your knowledge of photosynthesis.
  b **Suggest** why the plant was destarched before the experiment.

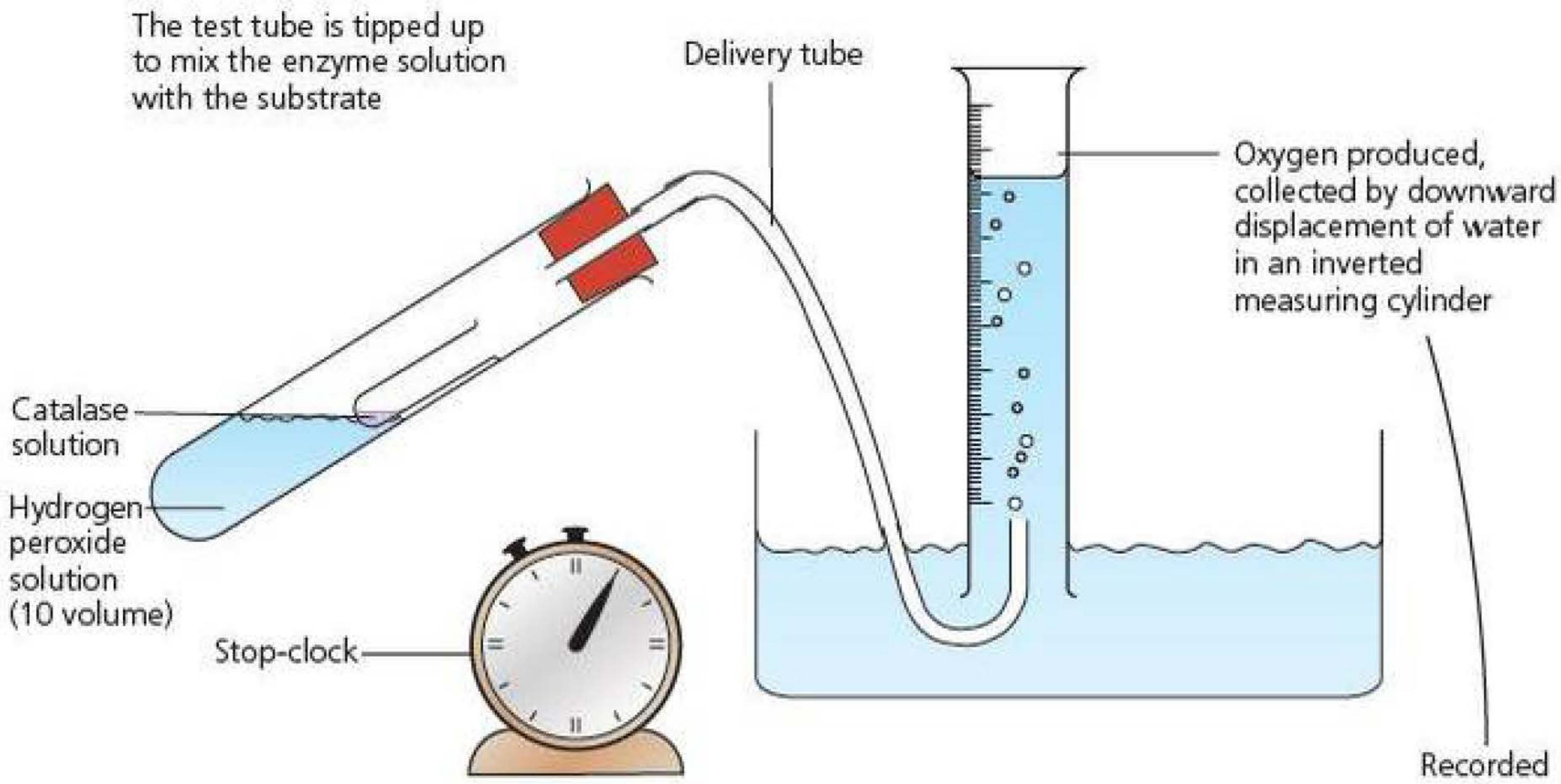


■ **Figure 2.33** Photosynthesis experiment. Before the experiment the plant had been put in a dark room for two weeks to destarch the plant (i.e. ensure that the leaves did not contain starch)

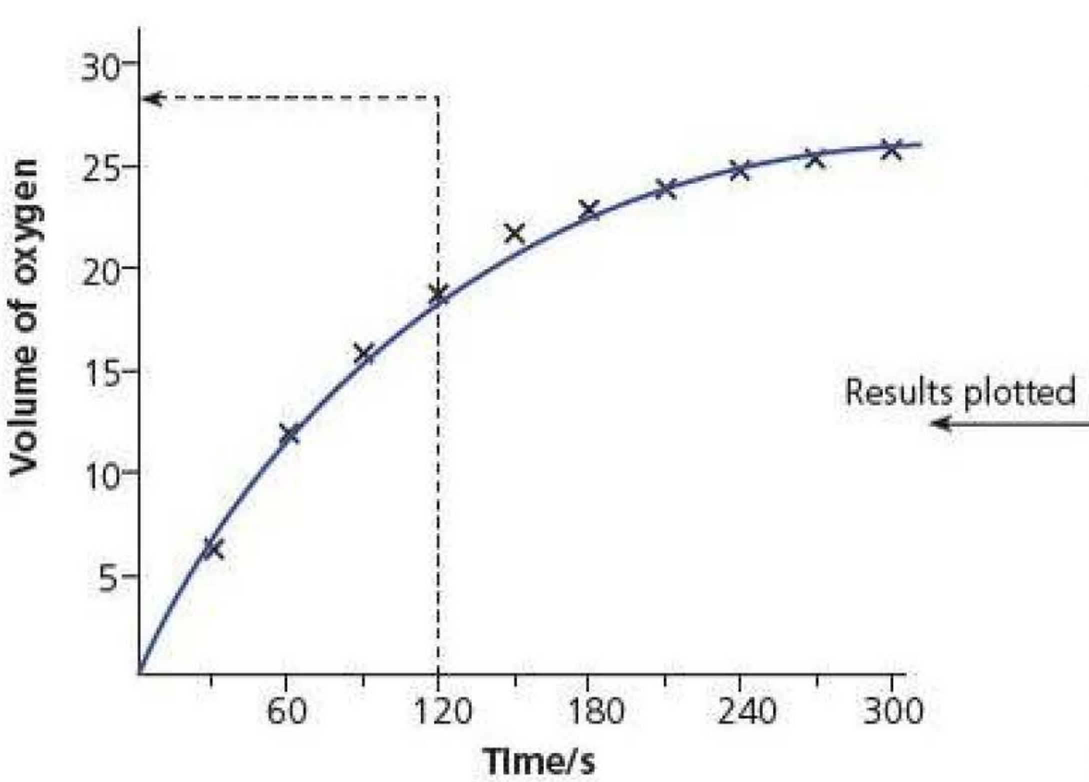
5 Catalase is an enzyme that occurs naturally in cells. It breaks down hydrogen peroxide into water and oxygen:

$$2H_2O_2 \rightarrow 2H_2O + O_2$$

The rate of reaction can be measured by measuring the volume of oxygen produced per minute. Figure 2.34 overleaf shows the experiment and data that were collected.
  a **Describe** the effect of time on the volume of oxygen produced.
  b The rate of reaction can be measured using the slope of the curve – the steeper the curve, the faster the rate of reaction. **Suggest** why the rate of reaction slows as time increases.



The rate of an enzyme reaction is greatest at the start, the initial rate.



Time/s	Gas volume collected/cm^3
30	6
60	12
90	16
120	19
150	22
180	23
210	24
240	25
270	25.5
300	26

■ **Figure 2.34** Measuring the rate of reaction using catalase

THESE PROBLEMS CAN BE USED TO EVALUATE YOUR LEARNING IN CRITERION A TO LEVEL 5–6

6 Coral reef is one of the most extensive ecosystems on Earth (Figure 2.35). It is made by small animals called polyps that secrete a hard skeleton of calcium carbonate for protection. Inside the animals many microscopic algae live – these protoctists contain colourful pigments that allow the algae to photosynthesize (Figure 2.36).

■ **Figure 2.35** Coral reef

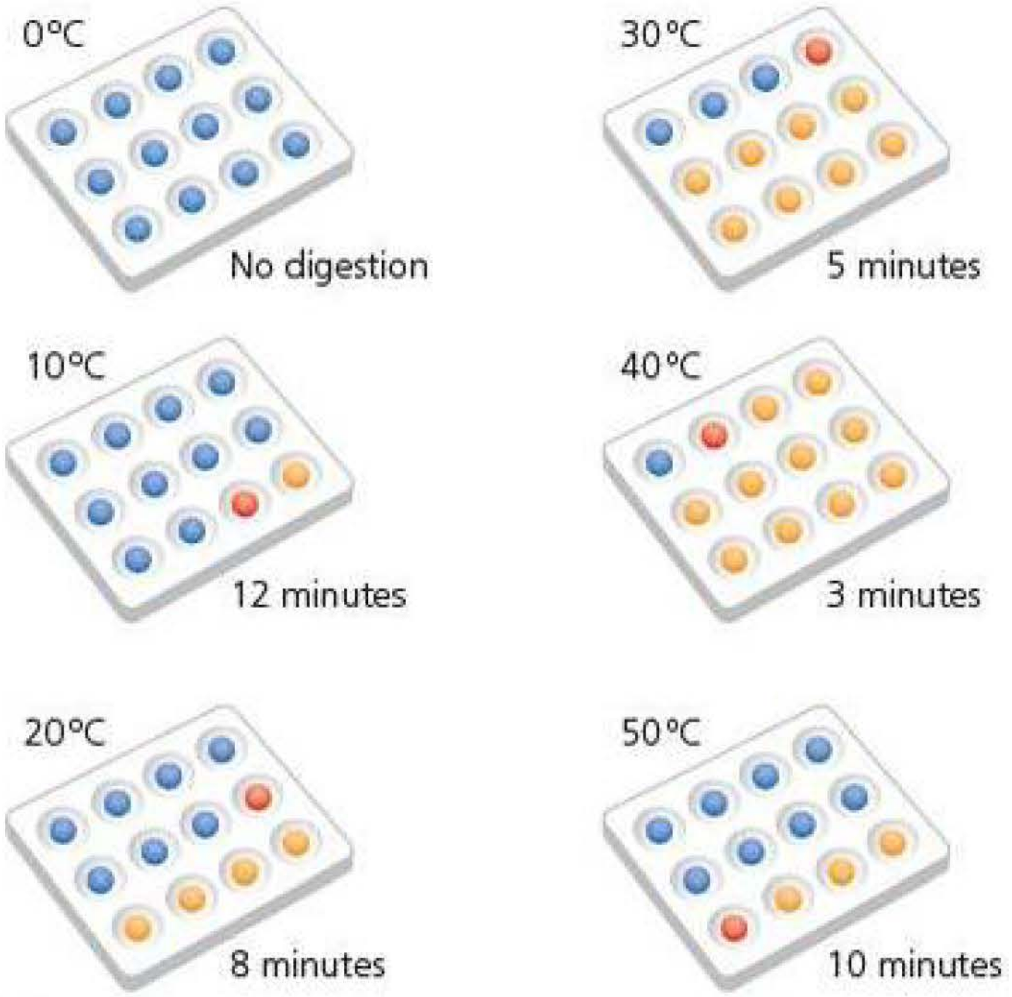
■ **Figure 2.36** Coral polyps containing orange algae

a **Suggest** how the polyp animal benefits from having algae living inside its body.

b Coral bleaching occurs when the algae leave the polyp animals, and the coral turns white. Global warming is increasing the temperature of the oceans where the coral is found, and increasing the depth of the water. **Suggest** why these factors lead to coral bleaching.

7 Amylase is an enzyme found in your saliva. It digests starch into maltose.

A series of water baths were set up in the lab at 10, 20, 30, 40 and 50 °C. Two test tubes, containing 5 cm^3 of starch and 1 cm^3 of amylase respectively, were heated in each water for 5 minutes. When the starch and amylase had reached the correct temperature, the starch and amylase were mixed together and a stopwatch started. After one minute, one drop of the reaction mixture was added to iodine on a spotting tile to test for the presence of starch. If starch were present, the reaction mixture turned blue/black. When the iodine no longer changed colour (i.e. no starch present) the time was recorded. The results of the experiment are shown below.



■ **Figure 2.37** Spotting tiles used to measure how quickly amylase digests starch to maltose at different temperatures

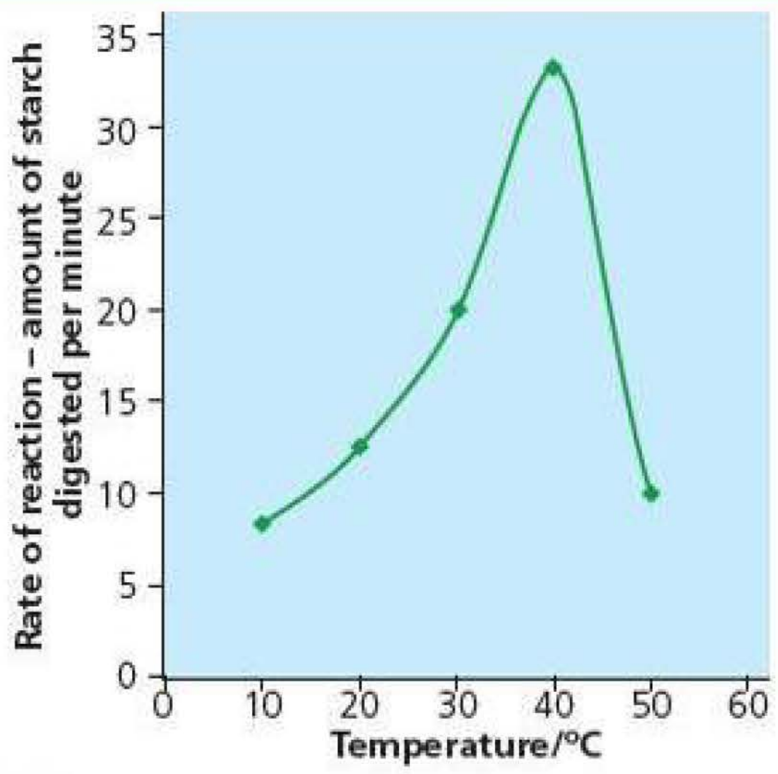


Figure 2.38 Results showing the effect of temperature on the rate of digestion of starch by amylase

- a **Explain** the effect of temperature on the rate of reaction shown in Figure 2.38.
- b **Explain** how the experiment could have been made more reliable.
- c i **State** three variables that should be kept constant in this experiment.
  - ii **Explain** why these variables should be kept constant.
- d **Evaluate** the experiment and **explain** how the results could have been made more accurate.

THIS PROBLEM CAN BE USED TO EVALUATE YOUR LEARNING IN CRITERION A TO LEVEL 7–8

8 An experiment was carried out to measure the effect of light intensity on rate of photosynthesis. The following equipment was used.

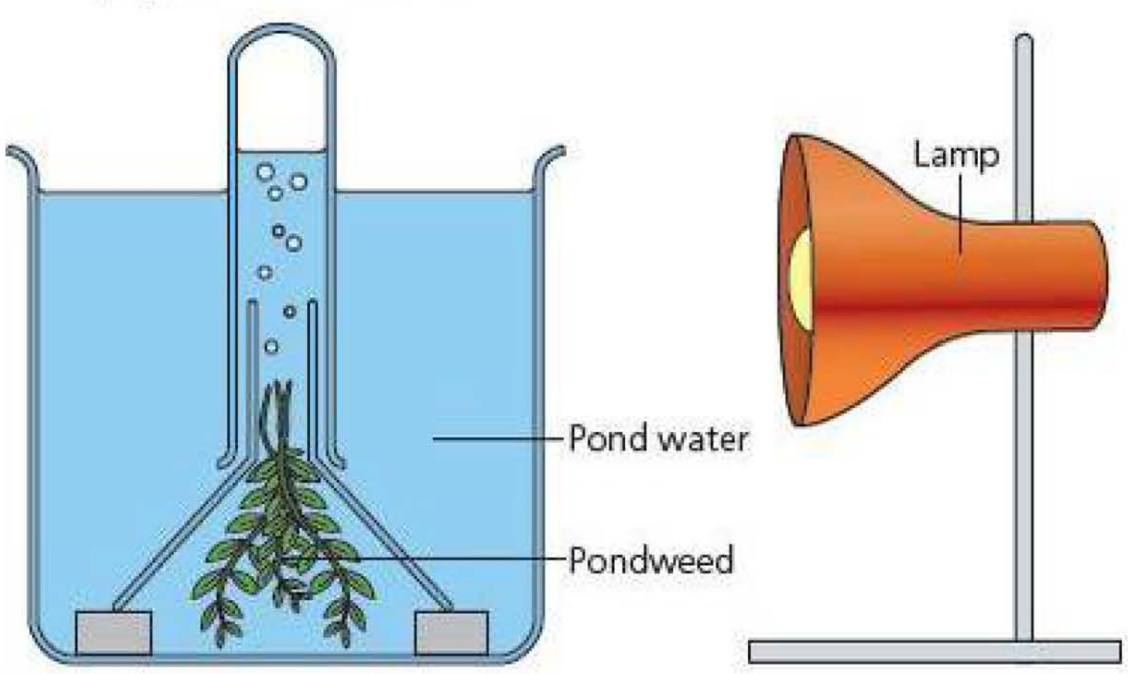


Figure 2.39 Experiment to measure the effect of light intensity on rate of photosynthesis

The rate of photosynthesis was measured by counting the number of bubbles of oxygen produced per minute, and light intensity was varied by putting the lamp at different distances from the pondweed.

- a **Evaluate** the method and **comment** on how the experiment could be improved to produce more accurate results.

Three separate experiments were carried out with three different concentrations of carbon dioxide in the water. Data are shown in Figure 2.40.

Analyse the graph and then answer the following questions.

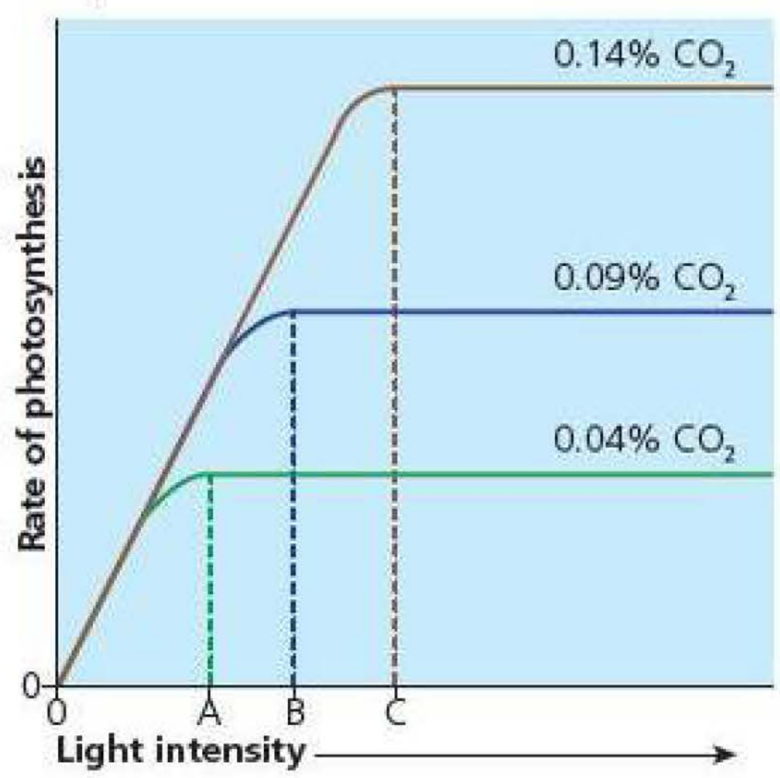


Figure 2.40 The effect of light intensity and carbon dioxide concentration on rate of photosynthesis

- b **State** the factor that limits the rate of photosynthesis between light intensity 0 and points A, B and C. **Explain** your answer.
- c **State** the factor that limits the rate of photosynthesis from points A, B and C onwards for each graph. **Explain** your answers.
- d **Explain** why the rate of photosynthesis increases from 0.04% through to 0.14% carbon dioxide.

Reflection

In this chapter we have learnt about how the systems of life are supported by biochemical reactions, and the transformations of energy that occur within cells. We have seen how enzymes work and explained what is meant by 'optimal conditions' for chemical reactions in cells. We have explored how innovations in science can lead to biochemical reactions being utilized to meet growing energy and food needs. We have learnt about our role as an inquirer, and how to nurture curiosity and develop skills for inquiry and research.

<table>
<tr><th colspan="6">Use this table to reflect on your own learning in this chapter</th></tr>
<tr><td>Questions we asked</td><td>Answers we found</td><td colspan="4">Any further questions now?</td></tr>
<tr><td>Factual: What are some chemical reactions which occur inside cells? What occurs in the process of cellular respiration? What occurs in the process of photosynthesis? What factors are needed for photosynthesis? How can the rate of photosynthesis be measured? What are enzymes and how do they work? How do chemical and physical reactions in cells determine the survival of organisms?</td><td></td><td colspan="4"></td></tr>
<tr><td>Conceptual: Why are enzymes needed? Why do some organisms need to feed themselves whereas others do not? Can the chemical reactions of life occur outside cells? Can biochemical reactions be replicated in the lab?</td><td></td><td colspan="4"></td></tr>
<tr><td>Debatable: Should chemical reactions be manipulated in order to meet our food and fuel needs?</td><td></td><td colspan="4"></td></tr>
<tr><td rowspan="2">Approaches to learning you used in this chapter</td><td rowspan="2">Description – what new skills did you learn?</td><td colspan="4">How well did you master the skills?</td></tr>
<tr><td>Novice</td><td>Learner</td><td>Practitioner</td><td>Expert</td></tr>
<tr><td>Critical-thinking skills</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Organization skills</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Information literacy skills</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Communication skills</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Self-management skills</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Learner profile attribute(s)</td><td colspan="5">How did you demonstrate your skills as an inquirer in this chapter?</td></tr>
<tr><td>Inquirer</td><td colspan="5"></td></tr>
</table>

3 How do organisms sustain themselves?

Systems in living organisms transfer energy and nutrients from the environment to cells, where they are used to maintain the balance of life. Diet can be affected by personal and cultural choices.

Figure 3.1 A balanced diet is needed to sustain a healthy body

CONSIDER AND ANSWER THESE QUESTIONS:

Factual: What nutrients do organisms need to survive? What occurs during the process of digestion? What occurs during the process of gas exchange? How are substances transported around an organism? How do substances move in and out of cells? What are diffusion, osmosis and active transport? What is homeostasis? How do elements essential for life cycle between the environment and organisms?

Conceptual: What processes are involved in movement and transport? Why do the conditions within organisms need to be kept in balance?

Debatable: Should people use drugs to try to control their weight?

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

IN THIS CHAPTER, WE WILL …

- **Find out:**
  - how the body can achieve a balanced diet;
  - whether people should use drugs to control their weight.
- **Explore** how food reaches the cells in our bodies after it has been eaten.
- **Take action** by campaigning to promote healthy eating in our local community.

KEY WORDS

balanced	diet	nutritional
concentration	gradient	oxygenated
cycle	homeostatic	vessel
deoxygenated	molecule	

THINK–PAIR–SHARE

Think about the types of food that you need to eat to maintain a healthy body. They can be divided into seven groups – think what they are. What are these different food groups needed for in the body? Now share and **discuss** your ideas with your neighbour.

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

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

We will reflect on this learner profile attribute …

- Knowledgeable – developing and using conceptual understanding, exploring knowledge across a range of disciplines.

Assessment opportunities in this chapter:

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

WHAT DO YOU EAT?

Consider the food you eat on a daily basis. Do you think about why you eat or what the meals you eat (your **diet**) contain? To maintain a healthy body there are certain types of food that you need to eat.

Figure 3.2 A balanced diet

ACTIVITY: Your daily intake

You can keep track of your daily intake of nutrients using these online resources:

Phone apps:
www.fooducate.com
www.shopwell.com/mobileapp
Online software:
www.supertracker.usda.gov/default.aspx
www.supertracker.usda.gov/foodtracker.aspx

These programs can be used to track all aspects of the food you eat. You can use them to keep a record of the food you eat and to analyse its **nutritional** content. Are you eating a **balanced** diet? You can use them to compare your daily intake to the recommended intake. Use one of these programs to explore the nutrients you eat over the current week.

- Keep a diary of the meals you eat each day. Do this for a week.
- Use the software to analyse the nutritional contents of each meal – the amount of carbohydrate, protein, lipid, vitamins and minerals.
- Use the software to calculate the quantity of energy you are consuming each day, and over the course of a week.

  The estimated *average daily* requirements for energy are:
  - Males, 15–18 years 11 510 kJ
  - Females, 15–18 years 8 830 kJ
- As a consequence of your calculation of intake of essential nutrients on a typical day, **analyse** and **comment** on how appropriate your think your diet is, and why.

How can diet be affected by personal and cultural choices? Choose a couple of countries/religions/cultures to explore the diet (restrictions and requirements) and to compare and contrast the effect of these on the nutritional content.

What is meant by a 'balanced diet'?

WHAT NUTRIENTS DO ORGANISMS NEED TO SURVIVE?

From the starter activity you will have found that the following are needed for a balanced diet:

- **Carbohydrates** (or sugars) – for energy.
- **Proteins** – help your body repair cells and make new ones.
- Fats (also known as **lipids**) – store of energy; insulation.
- **Minerals** (elements such as iron – to make hemoglobin in blood, and calcium – to make bone).
- **Vitamins** – chemicals that ensure cells function properly, for example vitamins C and D.
- **Fibre** – helps transit of food through the gut (soluble fibre lowers cholesterol).
- **Water** – about 80% of your body is water. You need to regularly drink water to ensure processes in the body are functioning properly and you remain hydrated.

Molecules contained in your food are either large (called **macromolecules**, made from combining smaller units together), or the individual units themselves. The bigger molecules are made from the smaller building blocks (the individual units).

Different food types contain different elements, although they all have carbon, hydrogen and oxygen in common. This section is a summary of each of the three main food groups and what each is made from.

Carbohydrates

- Elements: carbon, hydrogen and oxygen.
- Smallest unit: molecules such as glucose (a simple sugar, meaning it is made of one unit). Glucose contains six carbons and so can be drawn, for simplicity, as a hexagon.
- Macromolecule: starch, for example, is a macromolecule that is made from many units of glucose combined together. Other macromolecules include cellulose and glycogen.

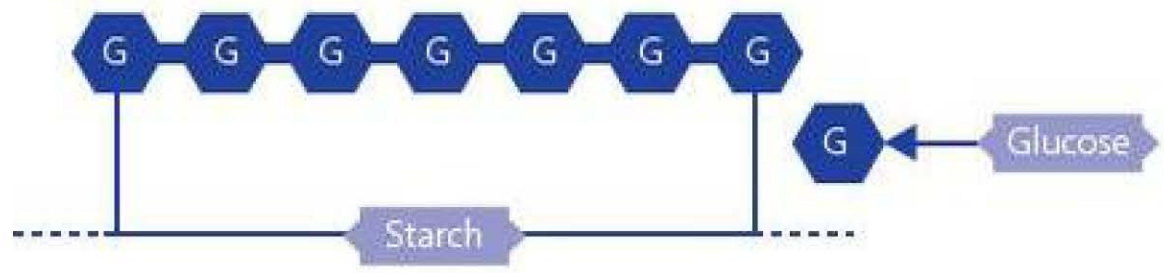
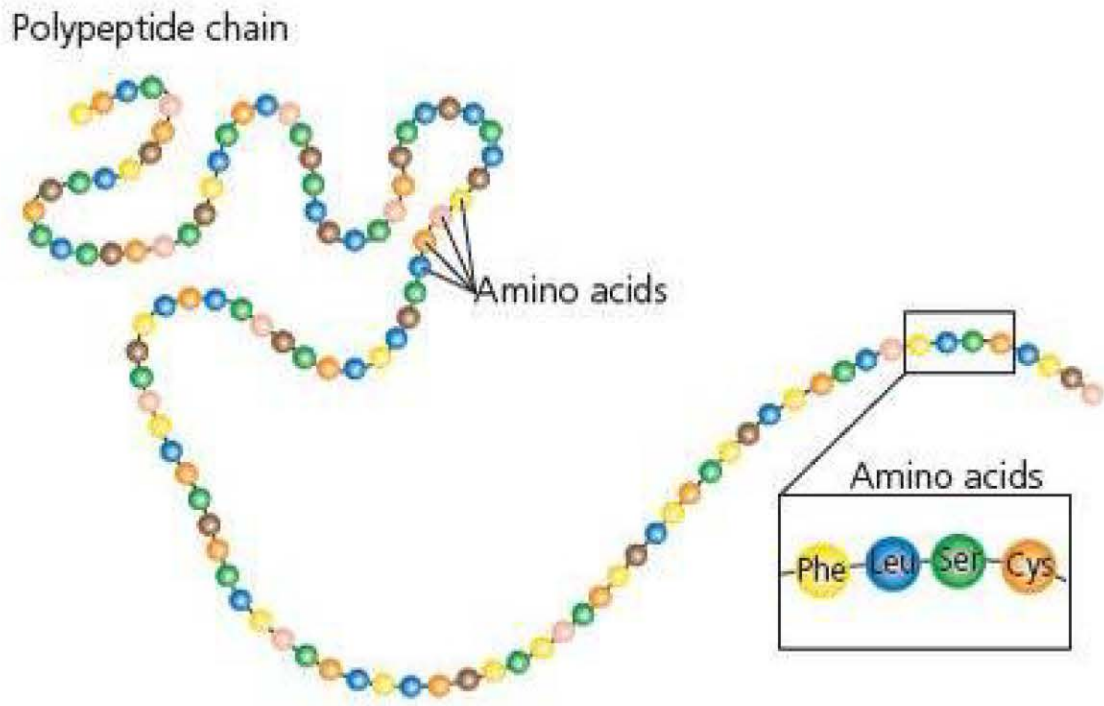


Figure 3.3 Starch is made from many glucose units

Proteins

- Elements: carbon, hydrogen, oxygen and nitrogen (some contain sulfur).
- Smallest unit: **amino acids**. There are 20 different amino acids in your diet – your body can make some of them but the majority must be contained in your diet.
- Macromolecule: protein molecules are made from many (up to thousands) of amino acids. The sequence of amino acids (i.e. the types of amino acid and the order in which they are joined together) determines the shape and properties of the protein.



Amino acids

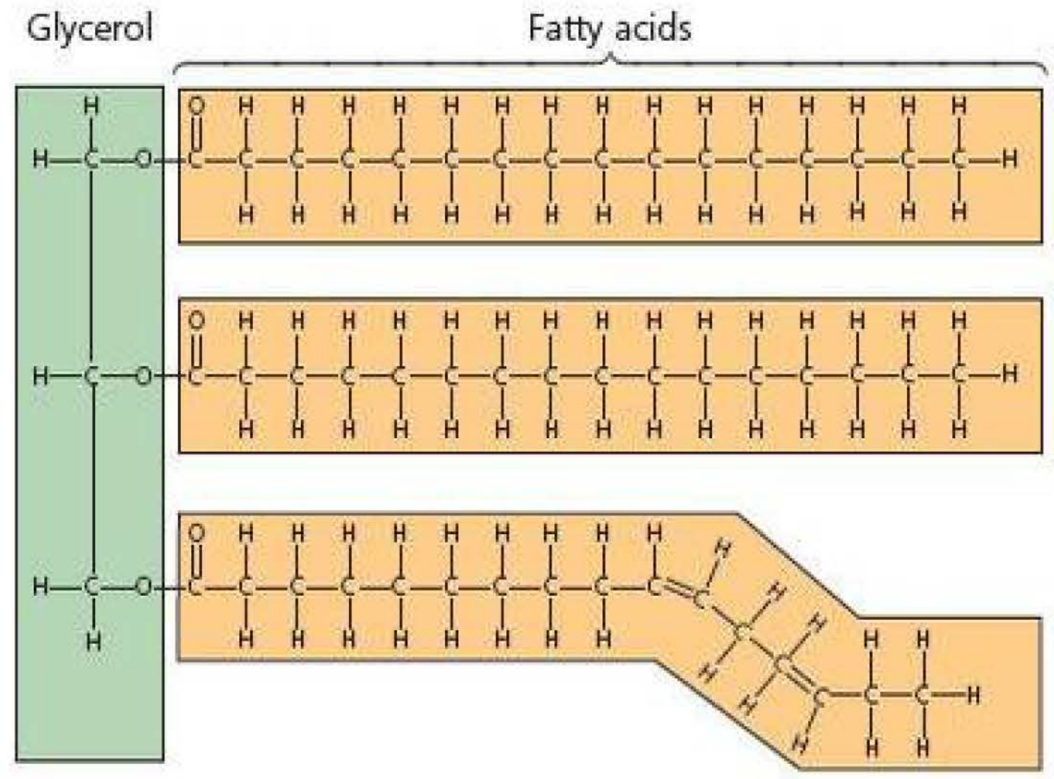
Ala: Alanine	His: Histidine	Ser: Serine
Arg: Arginine	Ile: Isoleucine	Thr: Threonine
Asn: Asparagine	Leu: Leucine	Trp: Tryptophane
Asp: Aspartic acid	Lys: Lysine	Tyr: Tyrosine
Cys: Cysteine	Met: Methionine	Val: Valine
Gln: Glutamine	Phe: Phenylalanine	
Glu: Glutamic acid	Pro: Proline	

■ **Figure 3.4** Proteins are made from long chains of amino acids. There are 20 different amino acids – the structure and function of the protein depends on the amino acids it is made from and the order in which they are put together

Lipids

- Elements: carbon, hydrogen and oxygen.
- Smallest units: **glycerol**, and three **fatty acids** (long chains of carbon and hydrogen).
- Macromolecule: the glycerol molecule is combined with three fatty acids to make the fat molecule. Fatty acids can be **saturated** or **unsaturated**. In unsaturated fatty acids some of the carbons are joined by double bonds, giving a bend in the chain, whereas in saturated fatty acids all the carbons are combined with hydrogen atoms. Saturated and unsaturated fatty acids have different properties.

In addition to these three main food groups, your diet should also contain minerals (elements such as iron for your blood) and vitamins. Vitamins are only needed in tiny amounts, but without them your body would not function properly.



■ **Figure 3.5** Lipids are made from glycerol and three fatty acids

ACTIVITY: Which vitamins and minerals do we need and why?

ATL

- Information literacy skills: Access information to be informed and inform others
- Collaboration skills: Work collaboratively in teams

In this activity you need to work in small groups to find out about vitamins and minerals.

- **Decide which vitamins or minerals you want to research. You must:**
  - **find out about the source of the vitamin or mineral**
  - **find out the function of the vitamin or mineral**
  - **explain the role of the vitamin or mineral in the body.**
- **Once the research has been carried out, summarize the results in a poster or other format so that the rest of the class can see what you have found.**

◆ Assessment opportunities

- ◆ In this activity you have practised skills that are assessed using Criterion A: Explain scientific knowledge.

The vitamins you need, and sources of each, and why you need them, are summarized in the following table.

■ **Table 3.1** Vitamins needed as part of a balanced diet

Vitamin	Source	Function
A	Fish liver oils, animal liver, made in body from carotene	Required for normal **immune system** function and for production of cells in the retina of the eye
D	Fish liver oils, butter, egg yolk, made in the body by action of sunlight	Needed for the absorption of calcium in the body
E	Plant oils	Antioxidant
K	Dark green leafy vegetables, made by bacteria of gut	Needed for blood clotting
B_1	Widely occurring	Needed for an enzyme used in respiration
B_2	Widely occurring	Needed for an enzyme used in respiration
B_3	Meat, yeast extract, potatoes, made from the amino acid tryptophan	Needed to make enzymes involved in respiration
B_5	Widely occurring	Needed to make an enzyme involved in respiration
B_6	Meat, fish, eggs, some vegetables	Needed to make an enzyme involved in the formation of amino acids
B_{12}	Liver, yeast, not found in plants	Needed to make an enzyme involved with cell division; for nerve function
folic acid	Liver, white fish, raw leaf vegetables	Needed to make an enzyme involved in DNA replication
H (biotin)	Liver, yeast, egg white, made by bacteria in the human gut	Used to make an enzyme involved with metabolic reactions
C (ascorbic acid)	Potatoes, green vegetables, fruits	Used to make an enzymes needed for protein metabolism; involved in iron absorption

About 15 minerals are known to be essential for a healthy body (Table 3.2). They are obtained from food sources where they are present in low concentrations.

■ **Table 3.2** Minerals needed as part of a balanced diet

Major minerals	Daily intake
Calcium	0.9 g
Phosphorus	1.5 g
Potassium	3.2 g
Sodium	3.4 g
Chloride	5.2 g
Magnesium	0.3 g
Iron	14.0 mg
Zinc	11.4 mg
Trace elements	**Daily intake**
Fluoride	1.82 mg
Copper	1.63 mg
Selenium	0.06 mg
Iodine	0.024 mg
Manganese	5.0 mg
Chromium	0.09 mg
Cobalt	0.3 mg

Examples of why minerals are needed by the body:

- Phosphorus is needed in the production of DNA and cell membranes.
- Calcium is needed for healthy teeth and bones.
- Sodium and chloride ions are used in the control of the composition of body fluids.
- Iron is needed to make hemoglobin – the oxygen-carrying molecule in red blood cells.

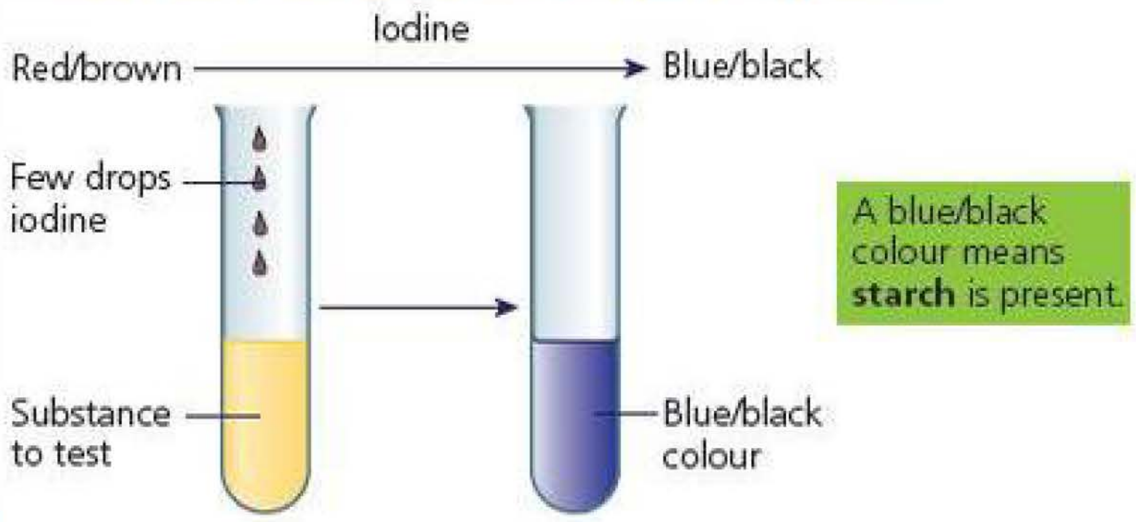
ACTIVITY: Food tests

ATL

- Critical-thinking skills: Interpret data

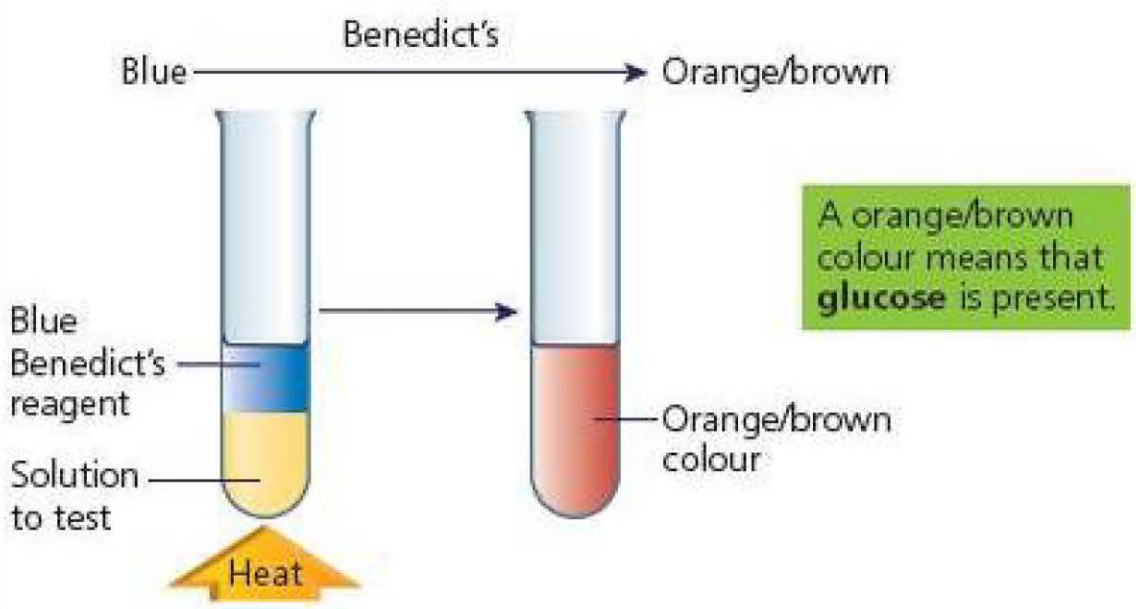
Food can be tested for carbohydrates, protein and lipids, using the following food tests.

Testing for starch (a complex carbohydrate)



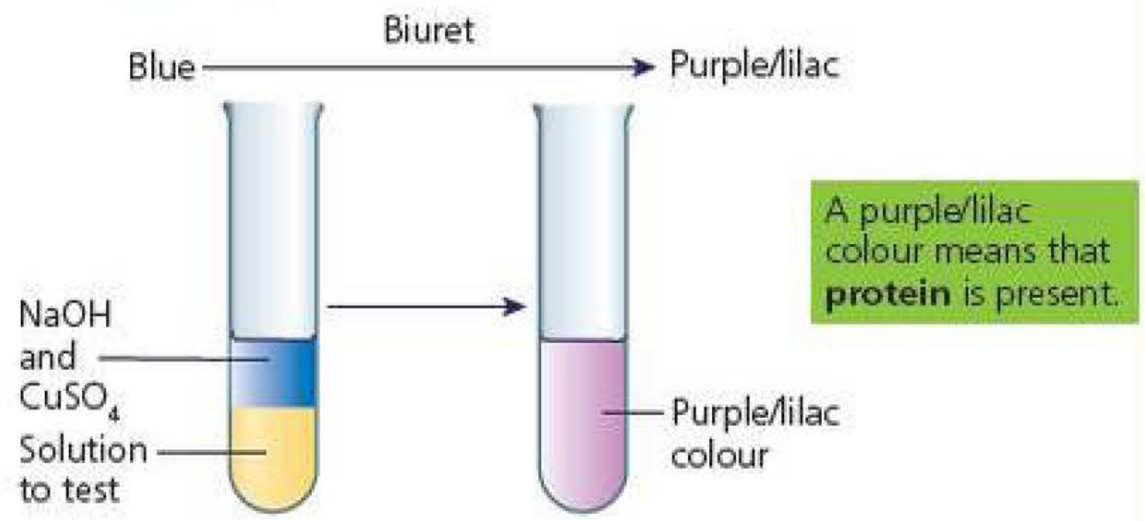
■ **Figure 3.6** Starch test

Testing for glucose (a simple carbohydrate)



■ **Figure 3.7** Test for glucose – a simple sugar. A water bath set at 70 °C can be used to heat the solution

Testing for protein



■ **Figure 3.8** Test for protein

Testing for lipids

A simple test for lipid is to put a little of your sample onto a piece of paper. If it leaves a greasy mark when it is dry, lipid is present.

Alternatively, an emulsion test can be carried out. A small quantity of alcohol is added to the test solution – the mixture is shaken vigorously. A milky-white emulsion is formed if fats are present.

Your teacher will provide you with a 'mystery solution' containing at least two different food groups. Can you work out which groups it contains?

Safety: Wear eye protection. Take care with the water bath when carrying out the Benedict's test. Wash your hands at the end of the practical.

- Carry out each of the food tests on the mystery solution and **observe** the results.
- Accurately **interpret** your data and **explain** results using correct scientific reasoning.

Assessment opportunities

- In this activity you have practised skills that are assessed using Criterion C: Collect data; Interpret data and explain results using scientific reasoning.

DISCUSS

Discuss in a small group what you have learnt about the nutrients organisms need to survive. What are macromolecules? What are the building blocks of macromolecules?

REVIEW

- What are the seven food groups that make up a balanced diet?
- What are the constituent parts of carbohydrates, lipids and proteins?
- How do you test food for:
  - starch
  - glucose
  - protein
  - lipid?

How can the process of digestion be modelled?

WHAT OCCURS DURING THE PROCESS OF DIGESTION?

Large **insoluble** molecules in our food must be broken down into small **soluble** ones, so that they can be absorbed from our guts into the blood and ultimately into cells. The process of **digestion** involves the physical (for example, teeth) and chemical (**enzymes**) breakdown of food.

ACTIVITY: Modelling digestion in the gut

ATL

- Critical-thinking skills: Use models to explore complex systems

Dialysis tubing (also known as visking tubing) can be used to model the digestion and absorption of foods in the intestine. Dialysis tube is an artificial partially permeable membrane made from cellulose or cellophane.

You will need for this model:

- **10 cm^3 of a 1% starch solution**
- **10 cm^3 of a 1% amylase solution**
- **Distilled water**
- **Beakers**
- **Test tubes**
- **A 10 cm^3 pipette**
- **Dialysis tubing**
- **Iodine solution**
- **Benedict's reagent**
- **Water bath**

Use the dialysis tubing to model absorption of digested food in the intestine. You could tackle this task and group discussion with others in your class.

Design an experiment to:

- **demonstrate whether a carbohydrate food item, such as starch, is able to pass across a selectively permeable membrane**
- **find out what happens when the starch is digested. Can the products of digestion cross the membrane and if so why?**

Evaluate how accurate your model is in demonstrating how digestion and absorption happens in the gut.

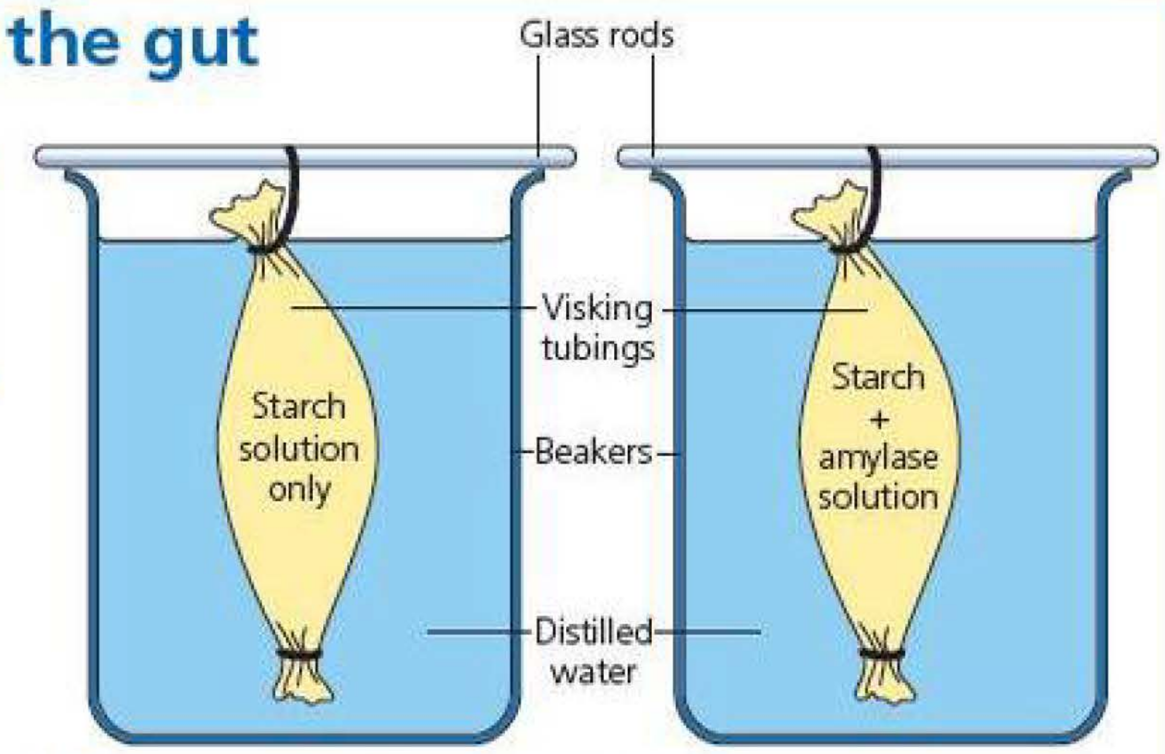


Figure 3.9 Making a model gut

Safety: Wear eye protection when handling iodine solution and Benedict's reagent. When carrying out the Benedict's test, take care when using a water bath to heat the solution.

- **How did you test for starch in the water surrounding the visking tubing?**
- **How did you test for maltose in the beaker water?**

Assessment opportunities

- This activity can be assessed using Criterion C: Interpret data and explain results using scientific reasoning.

In this activity we have used a biological model to demonstrate a complex system (see page 64 for an evaluation of models).

THINK–PUZZLE–EXPLORE

ATL

- Creative-thinking skills: Apply existing knowledge to generate new ideas
- Information literacy skills: Access information to be informed

Look at the diagram of the digestive system below.

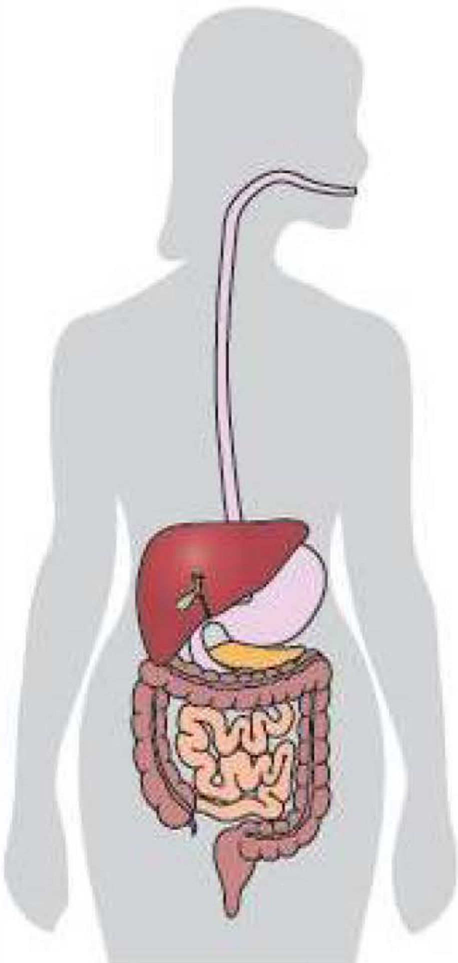


Figure 3.10 The human digestive system

What do you think you know about the digestive system already?

What is the role of the digestive system? What do the various parts do and why?

- **What questions or puzzles do you have?**
- **Are there parts that you do not know about? What questions can you think of to help you explore these parts further?**
- **How can you explore this topic?**
- **Where could you find out further information to answer the questions you have?**

Make summary notes (for example, diagrams, lists, mind maps) on what you already know about the digestive system.

Assessment opportunities

- In this activity you have practised skills that are assessed using Criterion A: Describe and explain scientific knowledge.

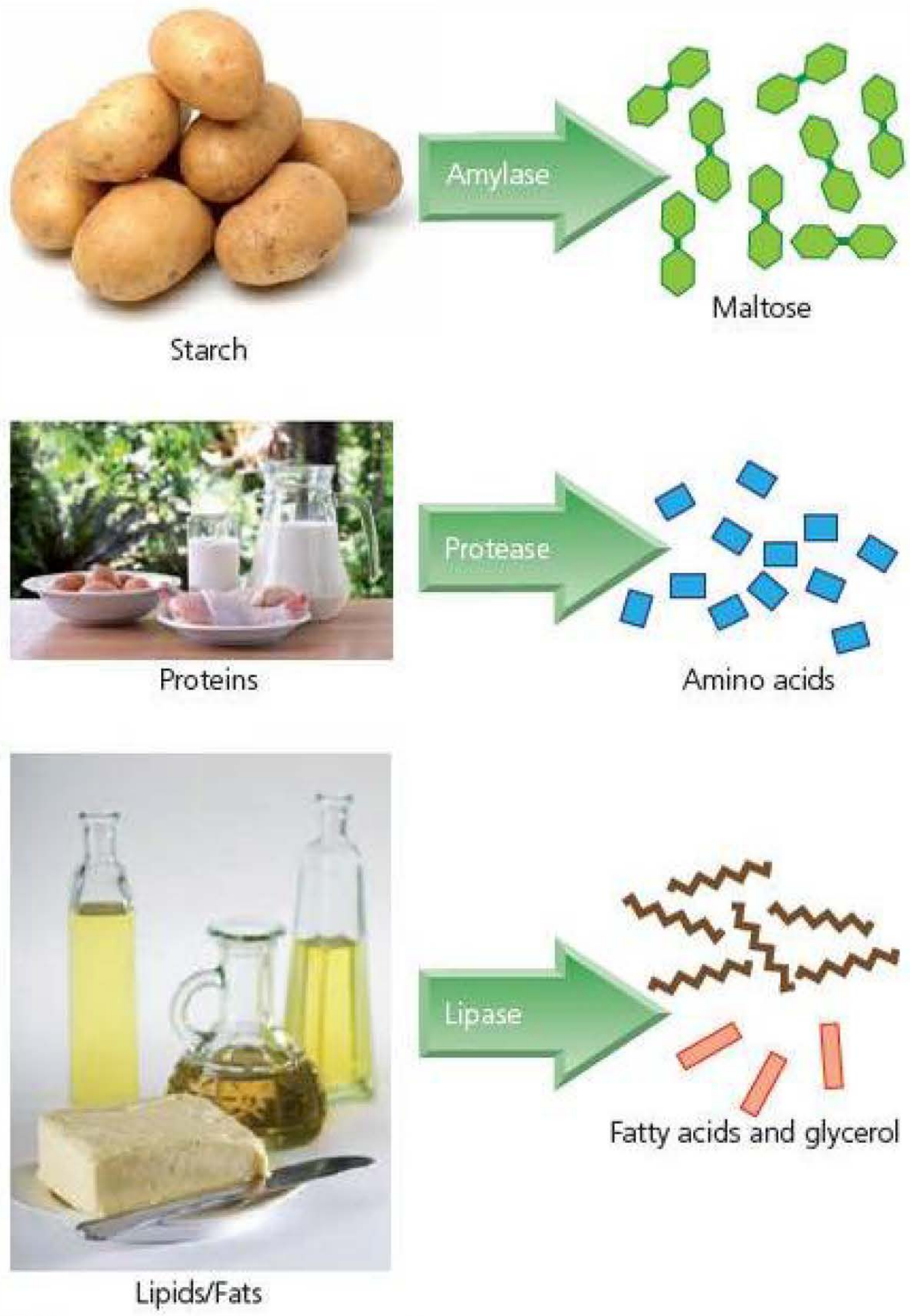


Figure 3.11 The breakdown of food into smaller molecules

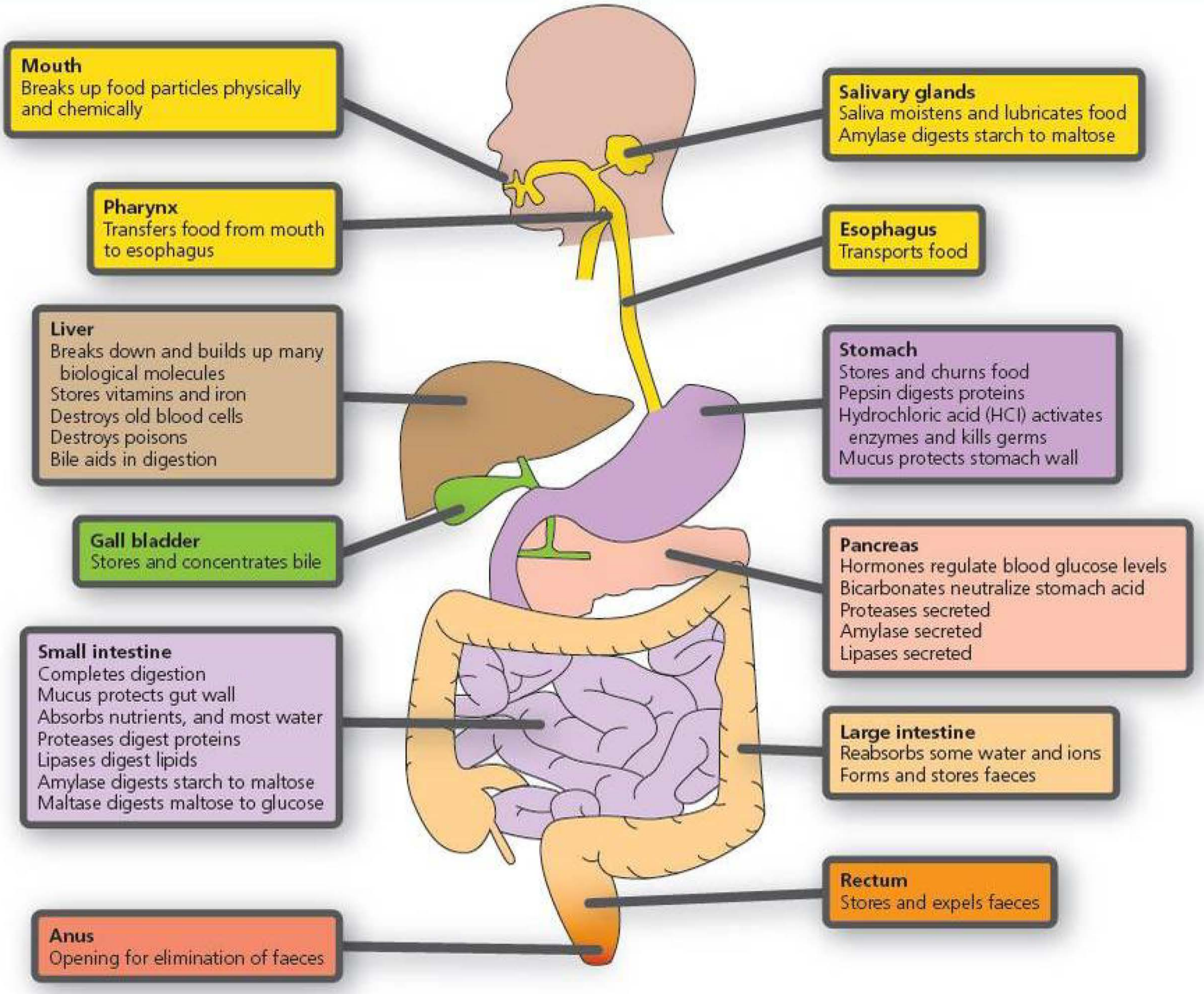
The digestive system takes large molecules and breaks them down into smaller units. Figure 3.11 shows how this is done. Earlier in this chapter we saw what the major food groups are made from – digestion breaks these molecules down into their smallest component parts.

But how is this done? Figure 3.12 shows how and where different molecules are broken down.

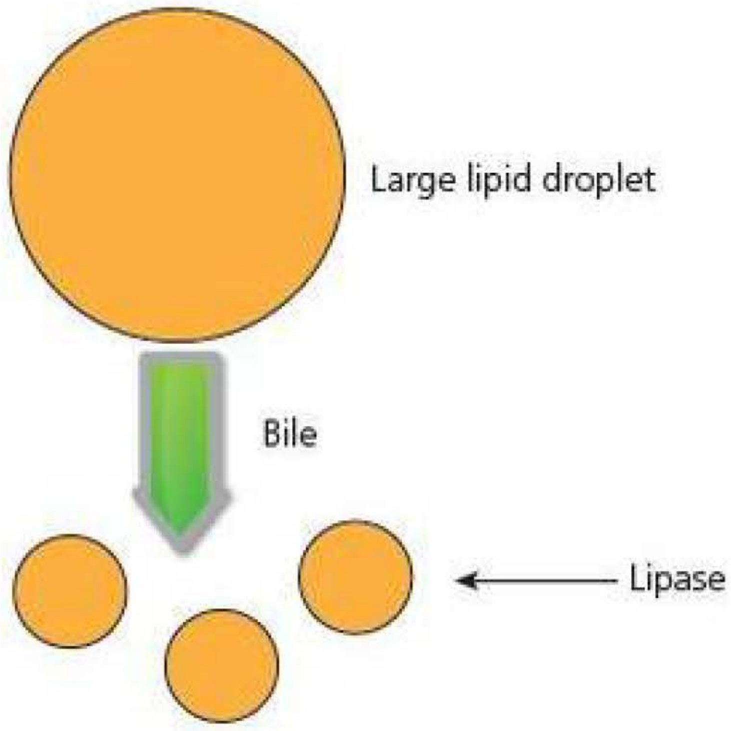
Bile, produced in the liver and stored in the gall bladder, helps to break down lipids through a process called **emulsification**.

The bile breaks down the lipids into smaller droplets so that lipase has a larger surface area to act on – this speeds up the digestion process (Figure 3.13). The issue of surface area : volume is addressed in more detail in Chapter 4 (pages 94–95).

The bile is also alkaline, which neutralizes the stomach acids, ensuring the enzymes in the **small intestine** have the correct pH (pH 7–8) to work in.



■ **Figure 3.12** What happens where in the digestive system



■ **Figure 3.13** Bile emulsifies fats, creating a larger surface area for lipase to act on

SUMMARY REFLECTION

- **What have you learnt about what occurs during the process of digestion?**
- **What new ideas or concepts have you learnt in this section?**

REVIEW

- **What three types of enzyme digest carbohydrates, lipids and proteins?**
- **What does amylase do?**
- **What is the role of bile?**
- **Why does food have to be digested?**

How does gas exchange support the body?

WHAT OCCURS DURING THE PROCESS OF GAS EXCHANGE?

In Chapter 2 we saw how oxygen is needed to fully release energy from glucose. How does oxygen reach the cells?

WHAT MAKES YOU SAY THAT?

ATL

- Creative-thinking skills: Apply existing knowledge to generate new ideas
- Information literacy skills: Access information to be informed

What's going on?

Look at the diagram of the human breathing system. Its role is to get oxygen into the blood and remove carbon dioxide. The oxygen needs to be continually supplied for respiration in cells – without this constant input we would quickly die. **Describe** the way that the breathing system is adapted to its function.

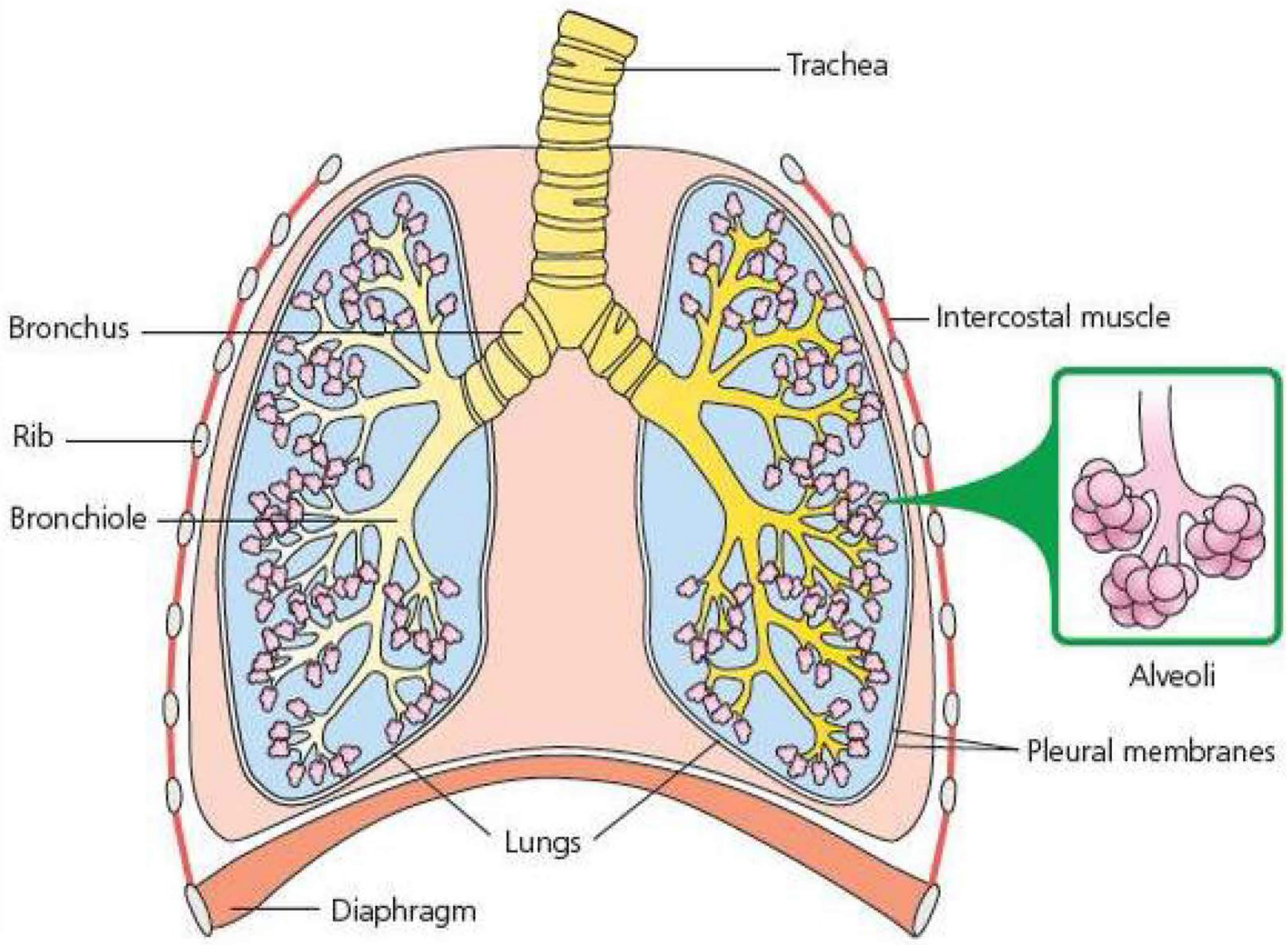


Figure 3.14 The human breathing system

What do you see that makes you say that?

Now **explain** the features you have noted. Aim for at least five different adaptations. What features can you explain that enable the breathing system to move oxygen into the blood at a fast enough rate to maintain life processes?

Assessment opportunities

- In this activity you have practised skills that are assessed using Criterion A: Describe and explain scientific knowledge.

ACTIVITY: How does air enter and leave the lungs?

ATL

- Critical-thinking skills: Use models to explore complex systems
- Transfer skills: Make connections between subjects and disciplines

Create a model of the breathing system, as follows:

- **Take a bell jar and attach a thin rubber sheet to the open end.**
- **Fix a 'Y' shaped glass tube to the top of the jar and attach two balloons to the end of the two branches.**

What is represented by:

- **the cavity of the bell jar**
- **the Y-shaped tube**
- **the balloons**
- **the rubber sheet?**

Models are used to show the structure or workings of a system.

The strength of models is that they are easy to understand and can simplify complex process. Their limitations are that they may be over simplified and miss out essential details, and be less accurate than the actual system.

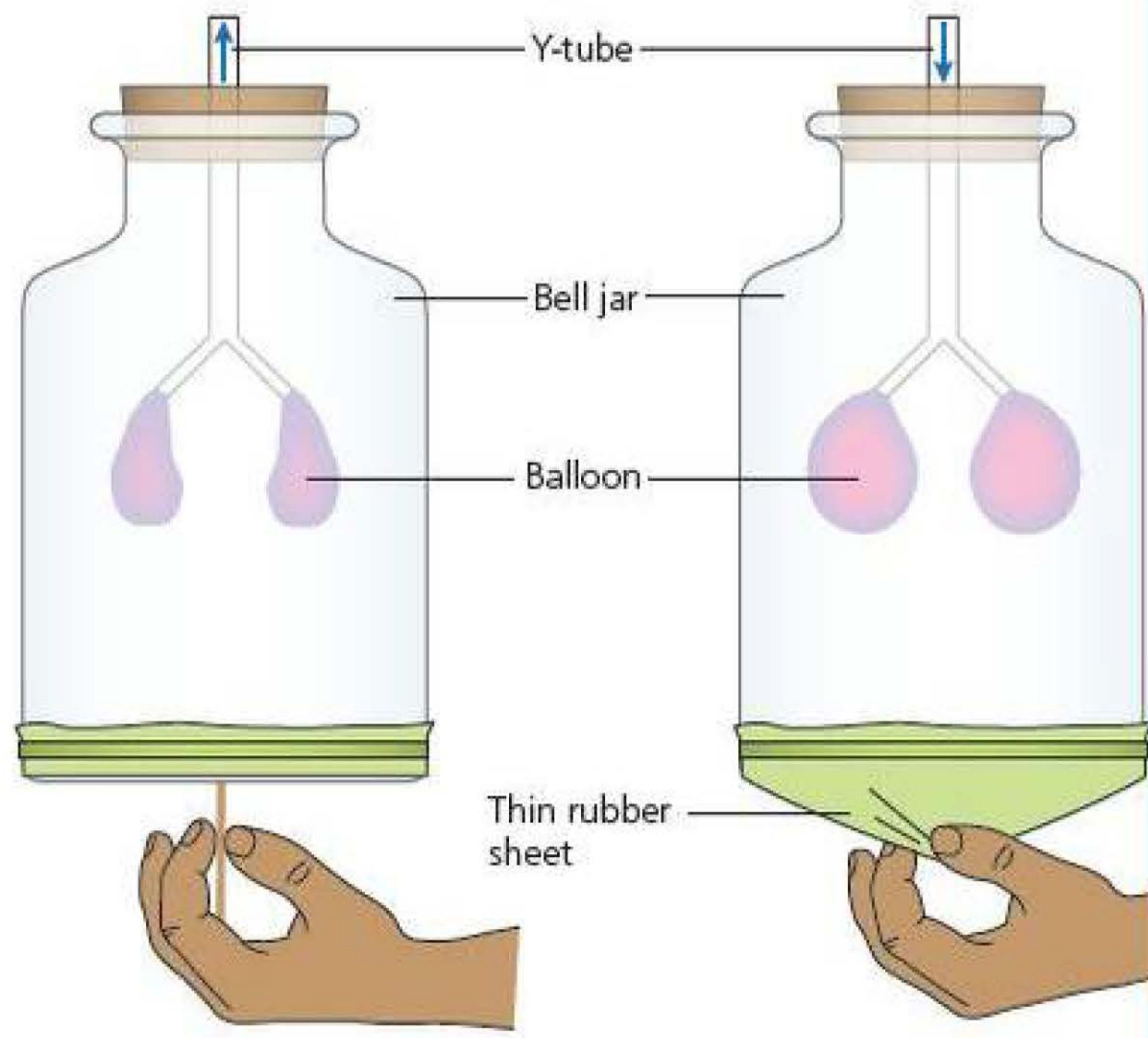


Figure 3.15 A model of the human breathing system

Pull down on the rubber sheet – what happens and why?

- **What is missing from this model of the human breathing system?**

Air is drawn into the lungs by pressure changes in the thorax.

Assessment opportunities

- In this activity you have practised skills that can be assessed using Criterion A: Describe and explain scientific knowledge.

Inhalation (breathing in)

- **Intercostal muscles** contract, pulling the ribs up and out.
- The **diaphragm** contracts and moves down (flattens).
- The volume of the **thorax** increases, and so the pressure decreases (see Figure 3.16), drawing air into the lungs.
- The **pleural membranes** surrounding the lungs and thoracic cavity ensures that the thorax is air-tight, enabling the pressure changes to occur.

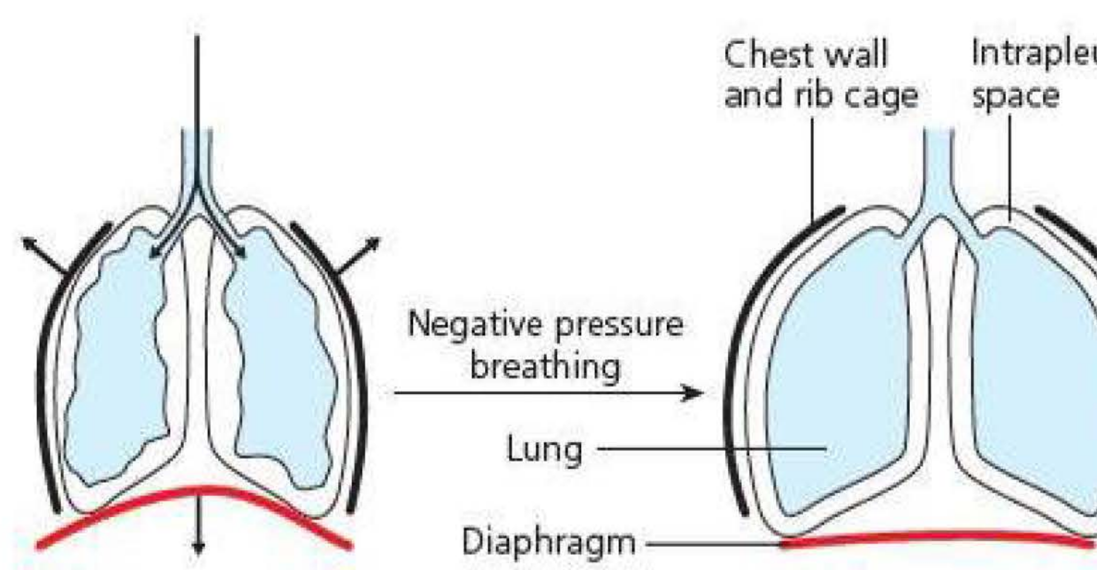


Figure 3.16 Inhalation

Expiration (breathing out)

- Intercostal muscles relax, moving the ribs down and in.
- The diaphragm relaxes and moves up (into a dome shape).
- The volume of the thorax decreases, and so the pressure increases.
- Air is forced out of the lungs.

Ventilation of the lungs (breathing) ensures there is always fresh air entering the **alveoli**, which means there is always a difference in oxygen concentration (i.e. a **concentration gradient**) between the alveolar air and the blood. Carbon dioxide moves in the opposite direction, from a higher concentration in the blood to a lower concentration in the alveolar air (see Figure 3.17).

- Why is there more carbon dioxide in the blood entering the lungs than in the alveolar air? What has produced the carbon dioxide?
- Why do large organisms need a specially adapted **gas exchange** system?
- How is the breathing system adapted to the job it does?

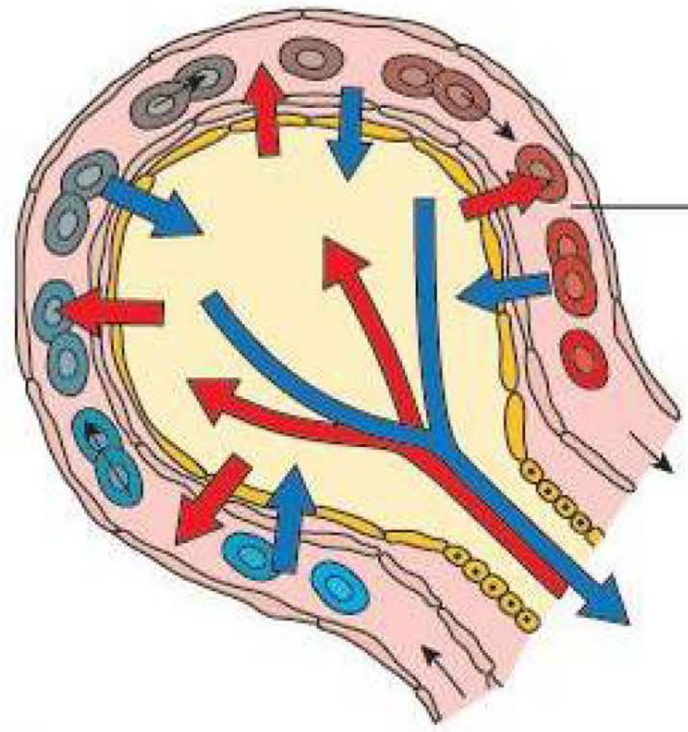


Figure 3.17 Oxygen (red arrows) diffuses into the blood at the alveolus, and carbon dioxide diffuses from blood (blue arrows)

How does the breathing system achieve the following things?

- A large surface area
- Concentration gradient (between alveolar air and blood capillaries)
- A small distance for diffusion

These three factors ensure that oxygen diffuses fast enough into the blood, and carbon dioxide out from it.

EXTENSION: Fick's law

What can you find out about Fick's law, and how it relates to the rate of **diffusion** of molecules?

DISCUSS

Discuss with your neighbour how the human breathing system maximizes gas exchange.

- **Why does oxygen need to move into the blood?**
- **By what process does oxygen move into the blood, and carbon dioxide out from it?**
- **Why does carbon dioxide need to be removed from the blood.**
- **Excretion is the process by which the waste products of metabolic reactions in cells are removed from the body. Why is the removal of CO_2 an excretion process?**
- **Why do we need a breathing system, whereas smaller organisms do not? (This will be addressed in the next chapter.)**

How are substances transported around an organism?

WHAT IS THE CIRCULATORY SYSTEM?

Blood, containing vital nutrients and oxygen, must be carried to each cell in the body. Large multicellular organisms are too large for this to happen without assistance. How then does food travel from the gut, where it is digested, to the cells where it is needed for metabolic reactions?

The **organs** of the body are composed of **tissues** whose **cells** are alive. That means they need glucose, oxygen and other nutrients to perform their various jobs and produce waste in the process (see Chapter 2).

The cells of the body occupy fixed positions, far from the source of food, oxygen and water. Also, the waste products will poison them if they are not removed quickly. An efficient system is, therefore, needed to service all cells.

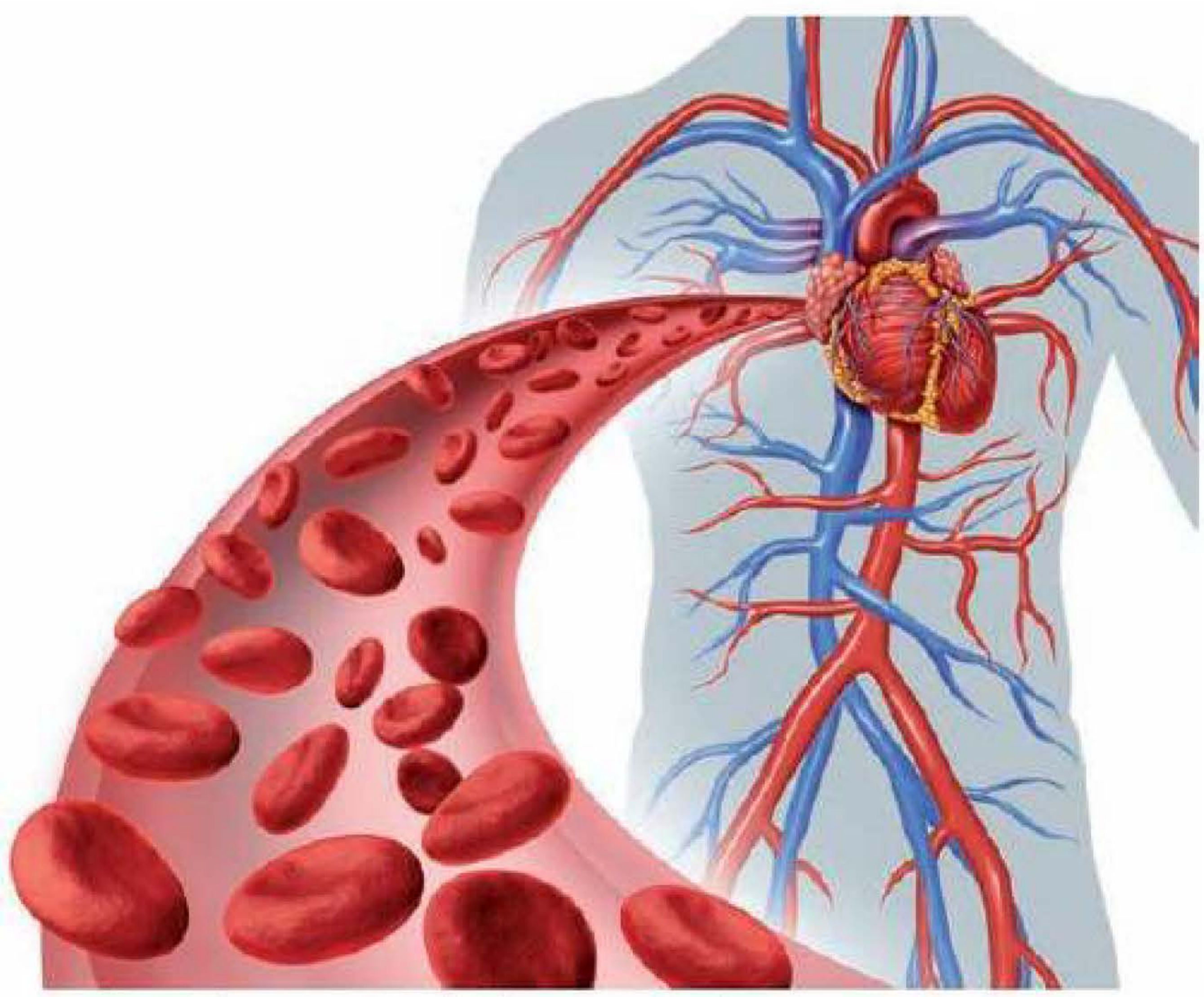


Figure 3.18 The human circulatory system

ACTIVITY: DIY circulatory system

ATL

- Creative-thinking skills: Use visual diagrams to generate new ideas; make unexpected connections between ideas; apply existing knowledge to generate new ideas

Your task is to **design** an organ system for the body that does the following things:

- **picks up oxygen, glucose and other nutrients, and circulates them around the body**
- **supplies oxygen, glucose and other nutrients to the cells**
- **gets rid of waste products from cells and takes them to areas for export out of the body.**

So you need to invent a circulatory system!

You need to **draw** a diagram of your design, and add labels to show how it works.

Things to think about ...

a) Getting oxygen into the body

- **What vessels will pick up oxygen, and where will they be located?**
- **How thick will these vessels be?**

Hint

What will speed up the diffusion of oxygen into them?

- **What substance will they contain to carry the oxygen?**
- **What other features of these vessels will speed up the diffusion of oxygen into them? (Why would this be important?)**

b) Getting glucose into the body

- What vessels will pick up glucose, and where will they be located?
- How thick will these vessels be?

> *Hint*
> *What will speed up the diffusion of glucose into them?*

- What substance will they contain to carry the glucose? Will this be the same as the substance that carries the oxygen?

c) Moving glucose, oxygen and other nutrients, to where they are needed

- What structure will pump the substances needed by the body to where they are needed? What would it look like, and where would it be located? We will explore this important organ further on pages 69–71.

d) Vessels under high pressure

- The organ you have designed in (c) above will have to move the nutrients needed by the cells over large distances (to the head and to the furthest parts of the body – hands and toes). The liquid carrying the nutrients will, therefore, have to be under *high* pressure going away from this organ.
- What features will the vessels carrying liquid away from this organ have to have to deal with this high pressure?

> *Hint*
> *Think of adaptations that any vessel under high pressure would have to have.*

e) Delivering the nutrients to the cells

- Once the nutrients arrive at the cells, how will the nutrients get into the cells?
- What vessels will carry the nutrients to the cells? (Will they be the same as those in (d) above – or do the adaptations of the vessels under high pressure mean that they cannot be used to deliver nutrients all the way to the cells?)

f) Vessels under low pressure

- Once the liquid carrying the nutrients has passed through the tissues which need them, the liquid will have lost much of its pressure. (Think of a big river that has split into lots of smaller ones – the speed of the river slows down, due to friction and other reasons.)
- What adaptations will the vessels of your circulatory system have now? How will they deal with the lower pressure, and stop the liquid they contain flowing backwards?
- Where will these vessels deliver the liquid back to?

◆ Assessment opportunities

- ◆ In this activity you have practised skills that are assessed using Criterion A: Apply scientific knowledge and understanding to solve problems.

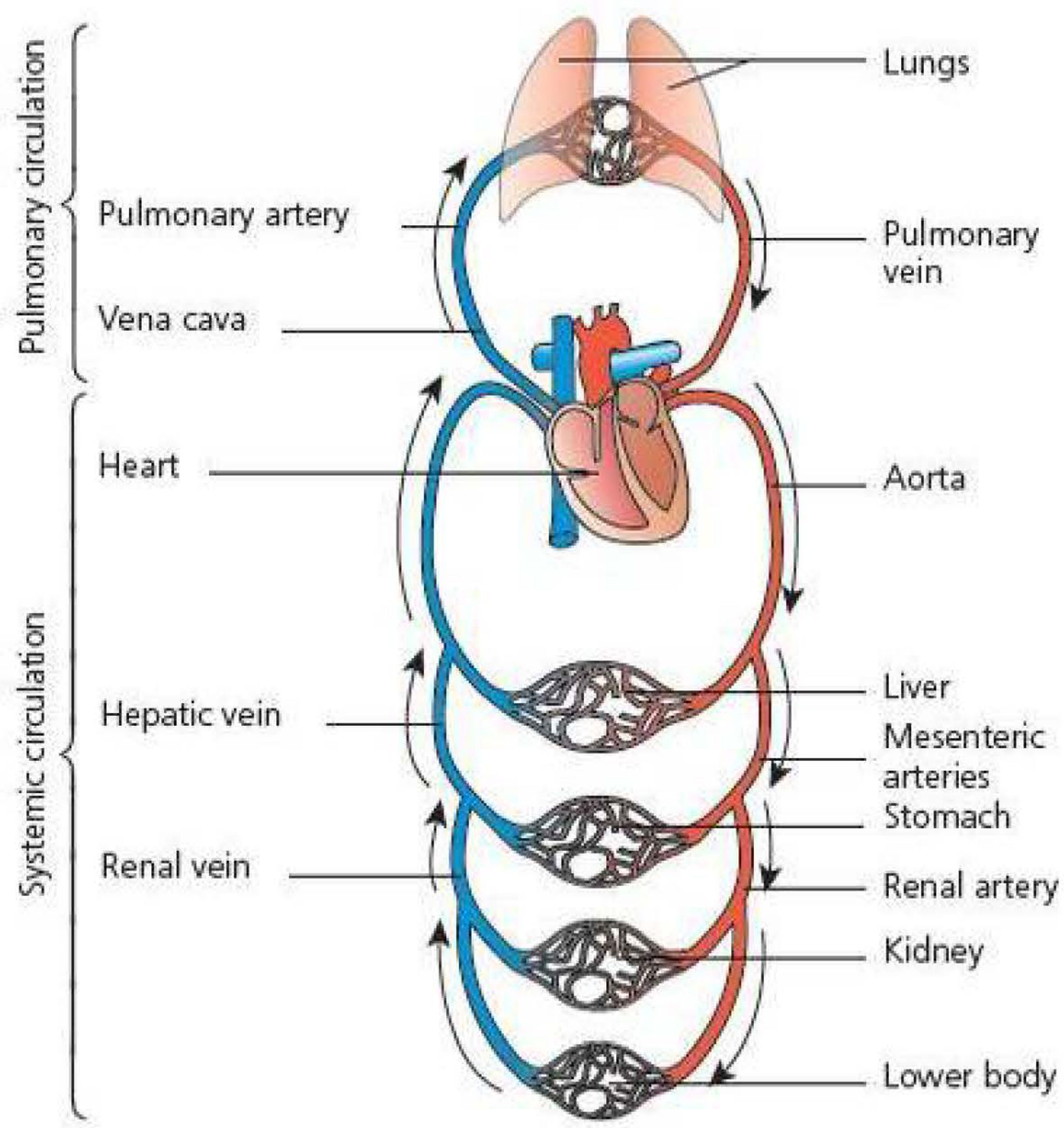


Figure 3.19 The circulatory system

Facts about blood vessels:

- **Arteries** carry blood at high pressure away from the heart.
- Arteries absorb the heart beat (which we can feel in our pulse) – their contents increase and decrease in pressure as the heart contracts and relaxes.
- **Capillaries** supply nutrients and oxygen to the cells by diffusion. They carry away waste products from the cells.
- **Veins** carry blood from the capillaries back to the heart, under low pressure.
- Veins do not have increases and decreases in pressure and are adapted to stop blood from flowing backwards, due to the low pressure. Veins have valves that stop the blood flowing backwards.

ACTIVITY: The blood vessels

ATL

- Critical-thinking skills: Draw reasonable conclusions and generalizations

Using the information above, identify the following blood vessels, and explain your choices to your neighbour.

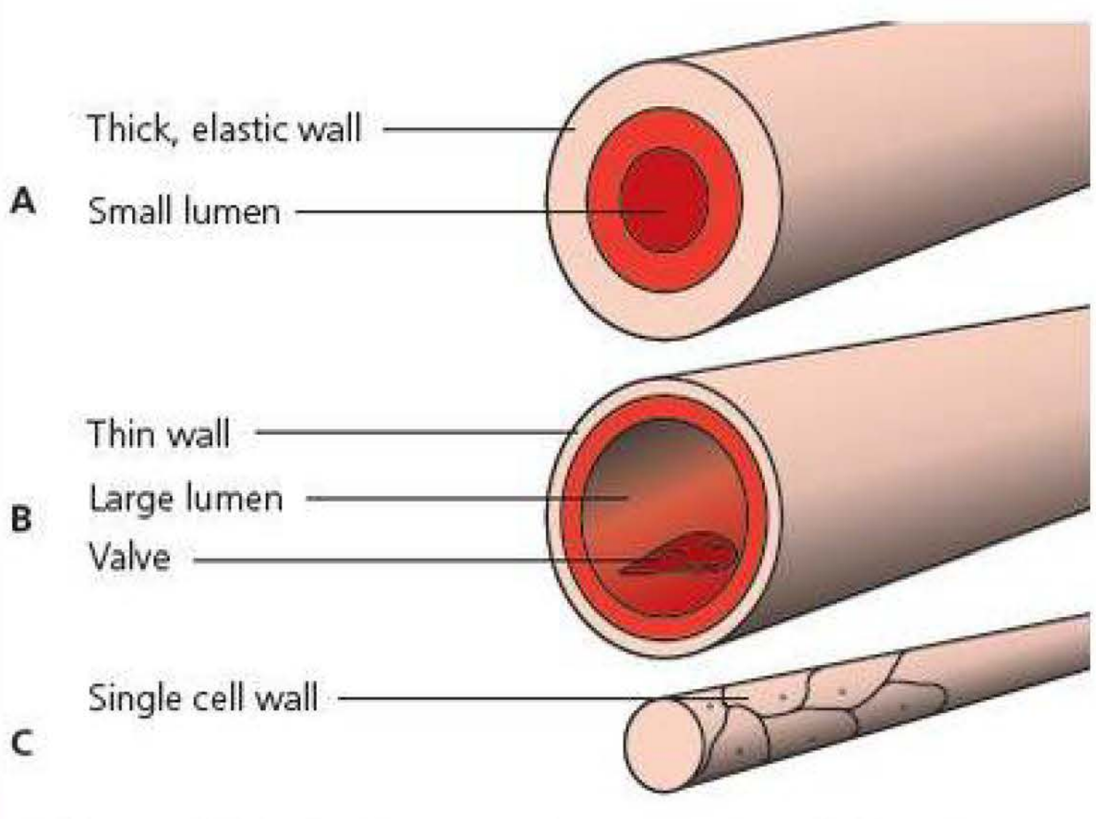


Figure 3.20 Differences between the different blood vessels

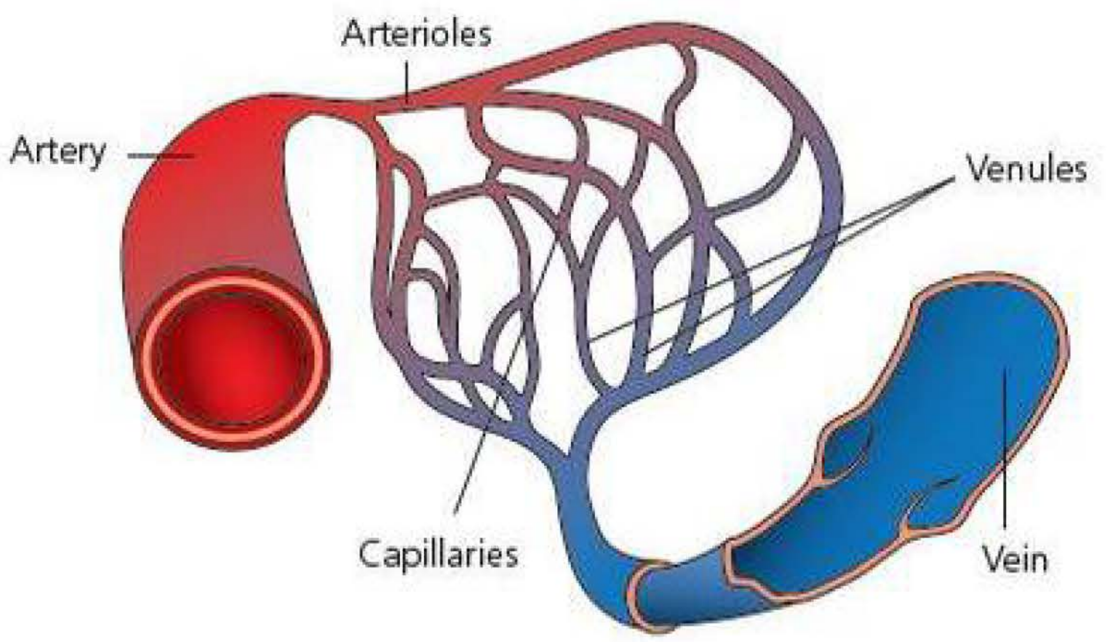


Figure 3.21 The blood vessels of the circulatory system

Explore the circulation of blood around the body further here: www.kscience.co.uk/animations/blood_system.htm

◆ Assessment opportunities

- In this activity you have practised skills that are assessed using Criterion A: Apply scientific knowledge and understanding to solve problems.

WHAT IS THE STRUCTURE AND FUNCTION OF THE HEART?

We have already investigated the role of the circulatory system, and how it is adapted to its role. Now let's look more closely at the organ that is central to the working of the circulatory system – the heart!

The heart is a double pump that pushes blood first to the lungs under low pressure, and then to the rest of the body under high pressure.

The heart contains two types of chamber:

- The **atria** – receive blood into the heart
- The **ventricles** – push blood to lungs and rest of the body.

Heart valves, as in the veins, prevent blood from going the wrong direction.

ACTIVITY: The heart

■ **Figure 3.22** Thinking about the heart

ATL

- Creative-thinking skills: Apply existing knowledge to generate new ideas
- Information literacy skills: Access information to be informed

COLOUR–SYMBOL–IMAGE

Find a source of information about the function of the heart (this may be in a book, on the Internet or in a magazine). As you read about the heart, make notes of things that you find interesting, important, or insightful. When you finish, choose three of these items that most stand out for you.

- **For one of these, choose a *colour* that you feel best represents or captures the essence of that idea.**
- **For another one, choose a *symbol* that you feel best represents or captures the essence of that idea.**
- **For the other one, choose an *image* that you feel best represents or captures the essence of that idea.**

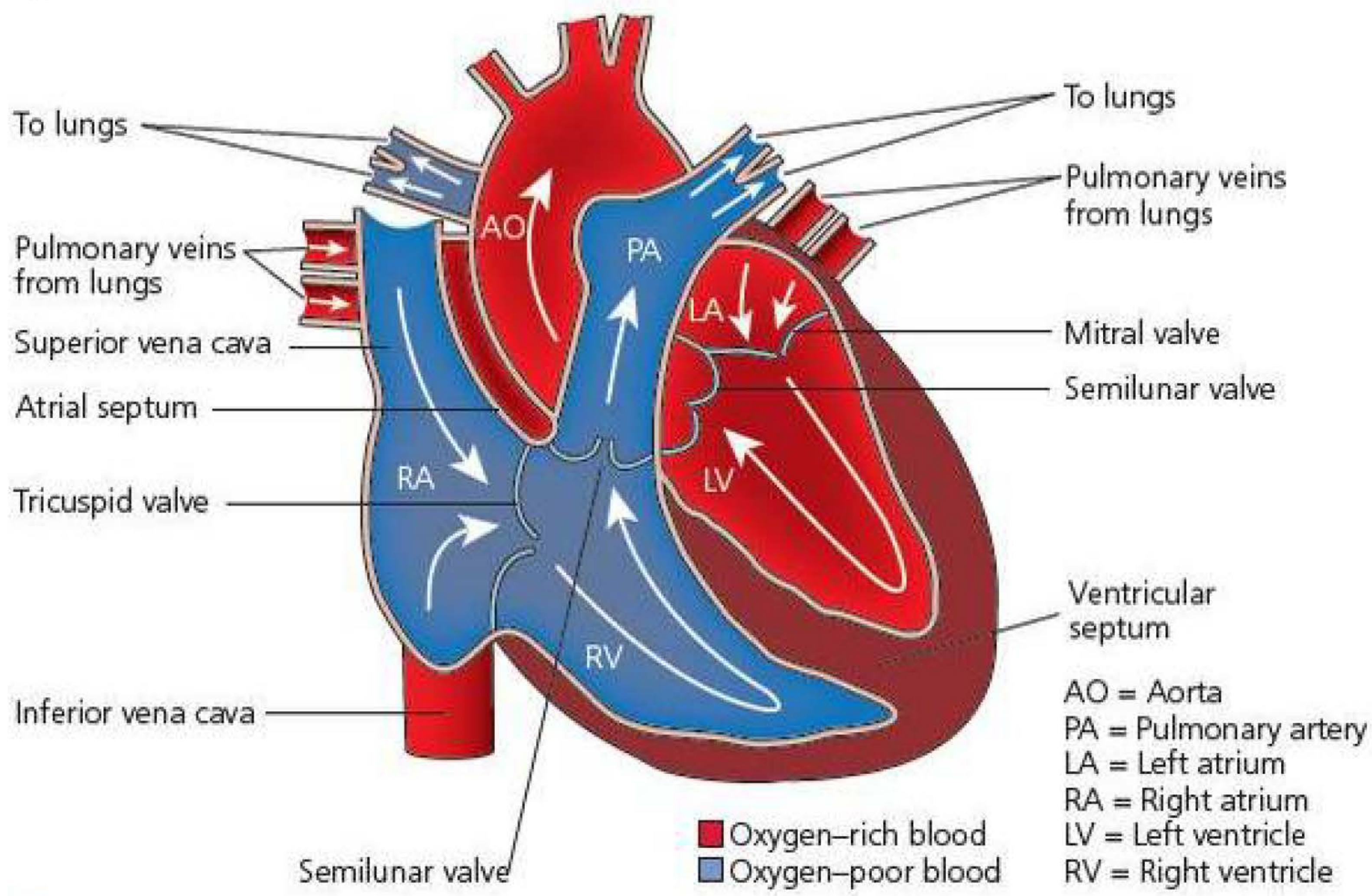
With a partner or group first share your colour and then share the item that it represents. Say why you choose that colour as a representation of that idea. Repeat the sharing process until every member of the group has shared his or her colour, symbol and image.

Your colour, symbol and image may each focus on different roles that the heart plays. The heart:

- **pumps blood to lungs and to the rest of body**
- **allows blood to be pumped to lungs at lower pressure than it is pumped to the rest of the body**
- **keeps oxygenated blood (from lungs) separate from deoxygenated blood (from the rest of body)**
- **maximizes the efficiency of oxygen delivery to tissues**
- **makes sure blood travels in one direction through the body.**

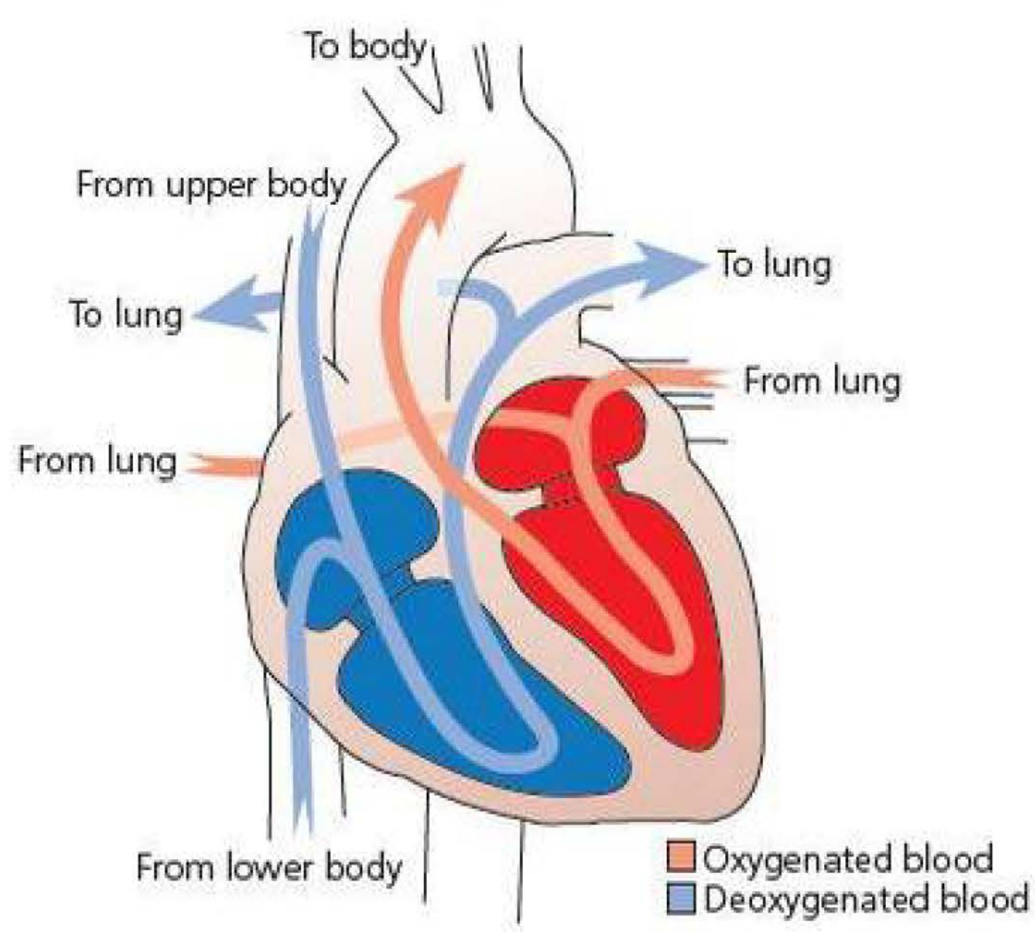
Now watch how the heart contraction moves blood through the heart here: **www.kscience.co.uk/animations/heart.htm**

Figure 3.23 shows a labelled and annotated heart.



■ **Figure 3.23** The anatomy of the heart

The heart ensures that each cell in the body receives a constant supply of oxygen and food, and has waste products removed such as urea and carbon dioxide.



■ **Figure 3.24** Blood flow through the heart

EXTENSION

What controls the contraction of the heart? Use these search terms: **pacemaker**, **SAN**, **AV node**, **electrical activity**.

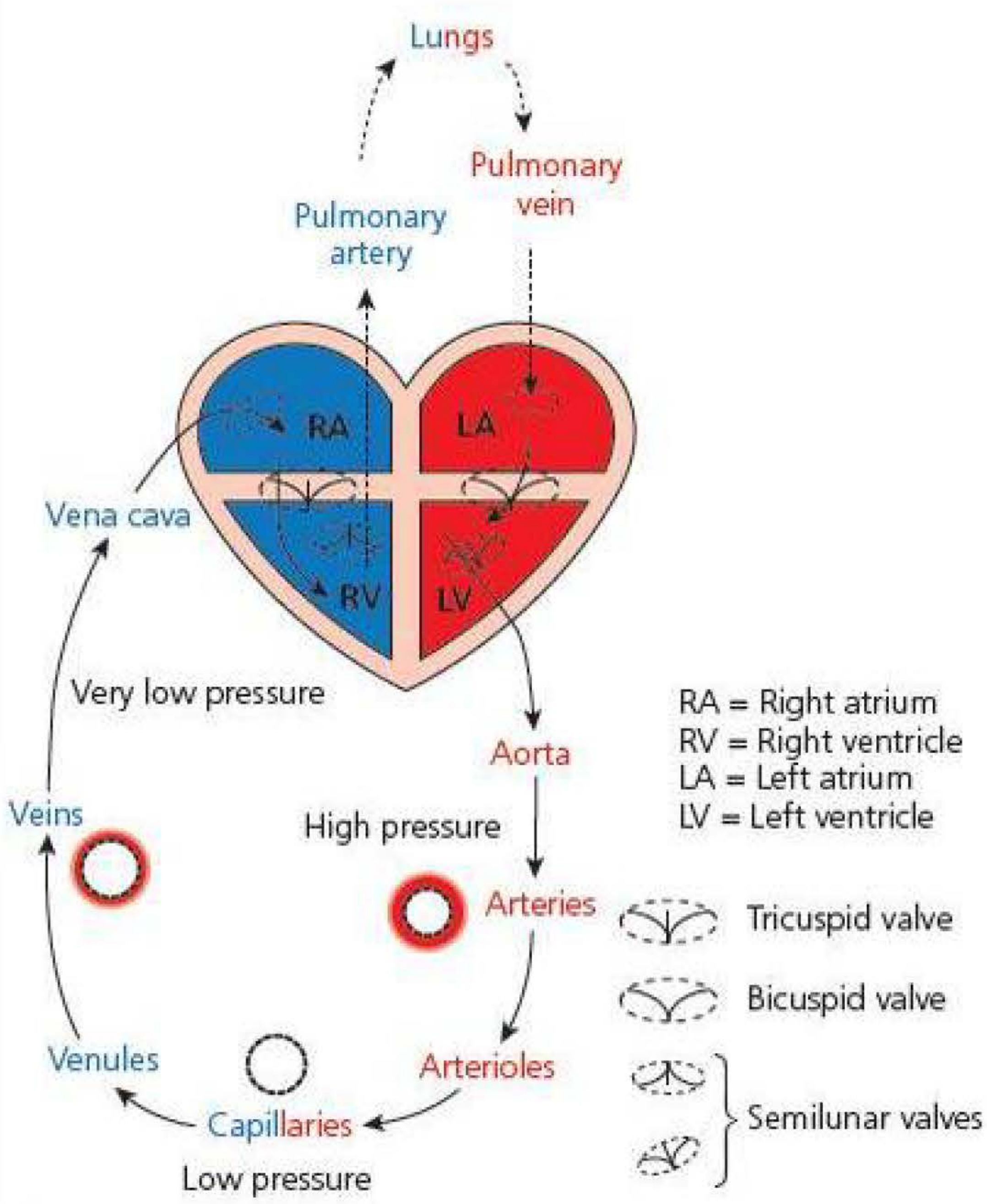
Practise labelling the heart here: **www.kscience.co.uk/animations/heart_labelling.htm**

REVIEW

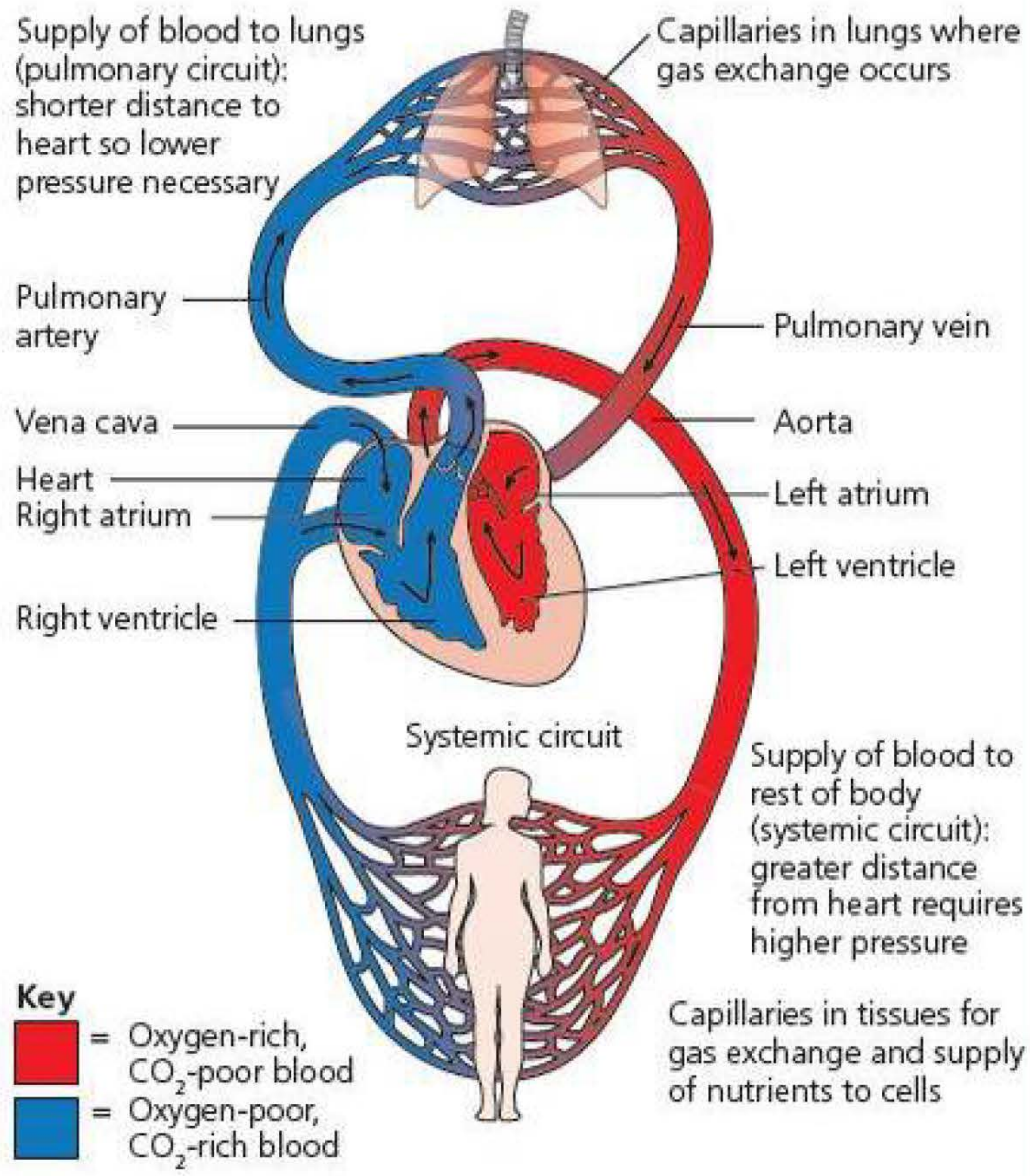
- **How do nutrients and oxygen reach the cells of the body?**
- **How do the three different blood vessels, arteries, capillaries and veins, vary in structure and function?**
- **Draw and label a diagram of the heart. Explain how blood passes from the heart to the lungs, back to the heart, and then to the rest of the body.**

REVIEW

Look at the following two diagrams:



■ **Figure 3.25** The passage of blood through the heart



■ **Figure 3.26** Blood supply to and from the heart

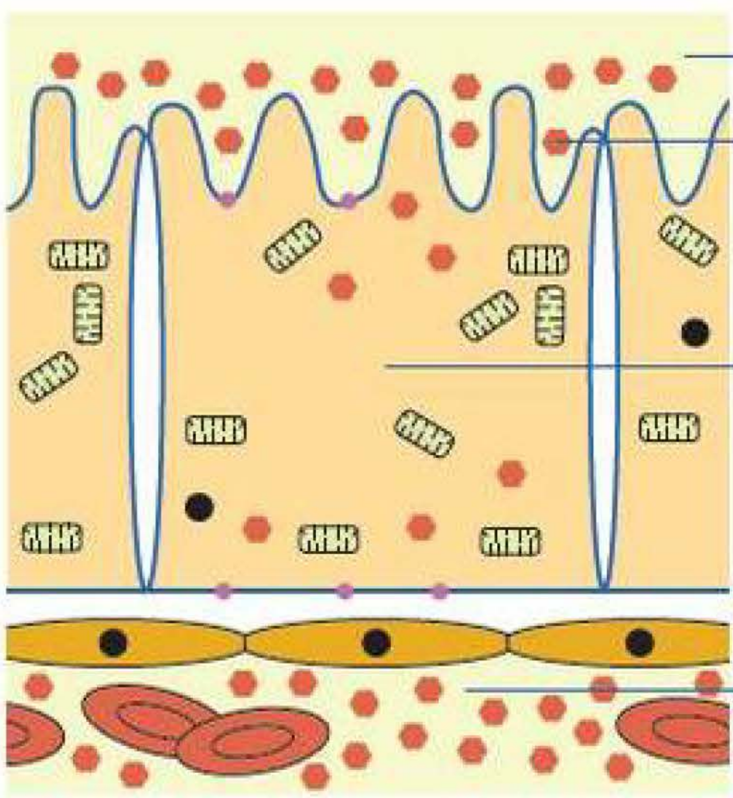
- **What have you learnt about how substances are transported around an organism?**
- **What have you learnt about how the structure of the circulatory system is related to its function?**
- **What have you learnt about the structure and function of the heart?**

What processes are involved in movement and transport?

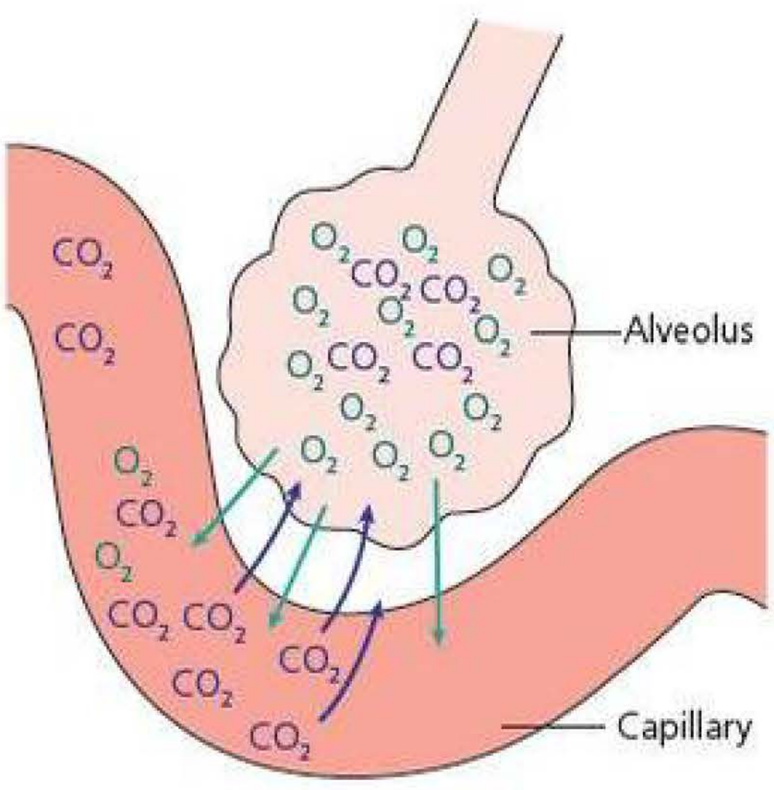
HOW DO SUBSTANCES MOVE IN AND OUT OF CELLS?

Substances must move from the intestines and lungs into the blood. Carbon dioxide must move from the blood into the alveoli. How does this happen?

Look carefully at the following two diagrams:



■ **Figure 3.27** Movement of glucose from lumen of small intestine to epithelial cell and on into blood



■ **Figure 3.28** Movement of carbon dioxide from blood, and oxygen into blood at alveolus

These diagrams show how molecules move from high to low concentration – this is called **diffusion**. Through random movement, more molecules are going to move from a higher concentration to a lower one than vice versa.

Oxygen moves from the alveoli in the lungs into the blood, and carbon dioxide from the blood into the alveoli (this is known as gas exchange). In the intestine (gut), food molecules such as glucose move from the lumen (the space in the middle of the intestine where the food moves) into the cells lining the gut (epithelial cells) and then into the blood.

Look again at the lower part of Figure 3.27. There is a higher concentration of glucose in the blood than in the epithelial cells. How can glucose move from the cells into the blood? The answer lies in a different way in which molecules can move, called **active transport**. Active transport moves molecules from lower to higher concentration (i.e. against their concentration gradient) – this needs energy from **respiration**.

Active transport is a process in cells that moves substances against a concentration gradient, from lower to higher concentration. This process requires energy from respiration.

Imagine you are trying to push a cart up a hill – you will need a lot of energy to get to the top!

■ **Figure 3.29** Active transport requires energy

There is a further way in which molecules are moved – **osmosis**. We will investigate this in the following activity.

ACTIVITY: Osmosis

ATL

- Critical-thinking skills: Use models to explore complex systems

Osmosis is the diffusion of water through a partially permeable membrane. Because water is very important to living things, we give the movement of water into and out from cells a special name. The cell membrane is partially permeable because it lets some molecules through freely but not others.

Look at the following diagram. Can you **describe** and **explain** what is happening?

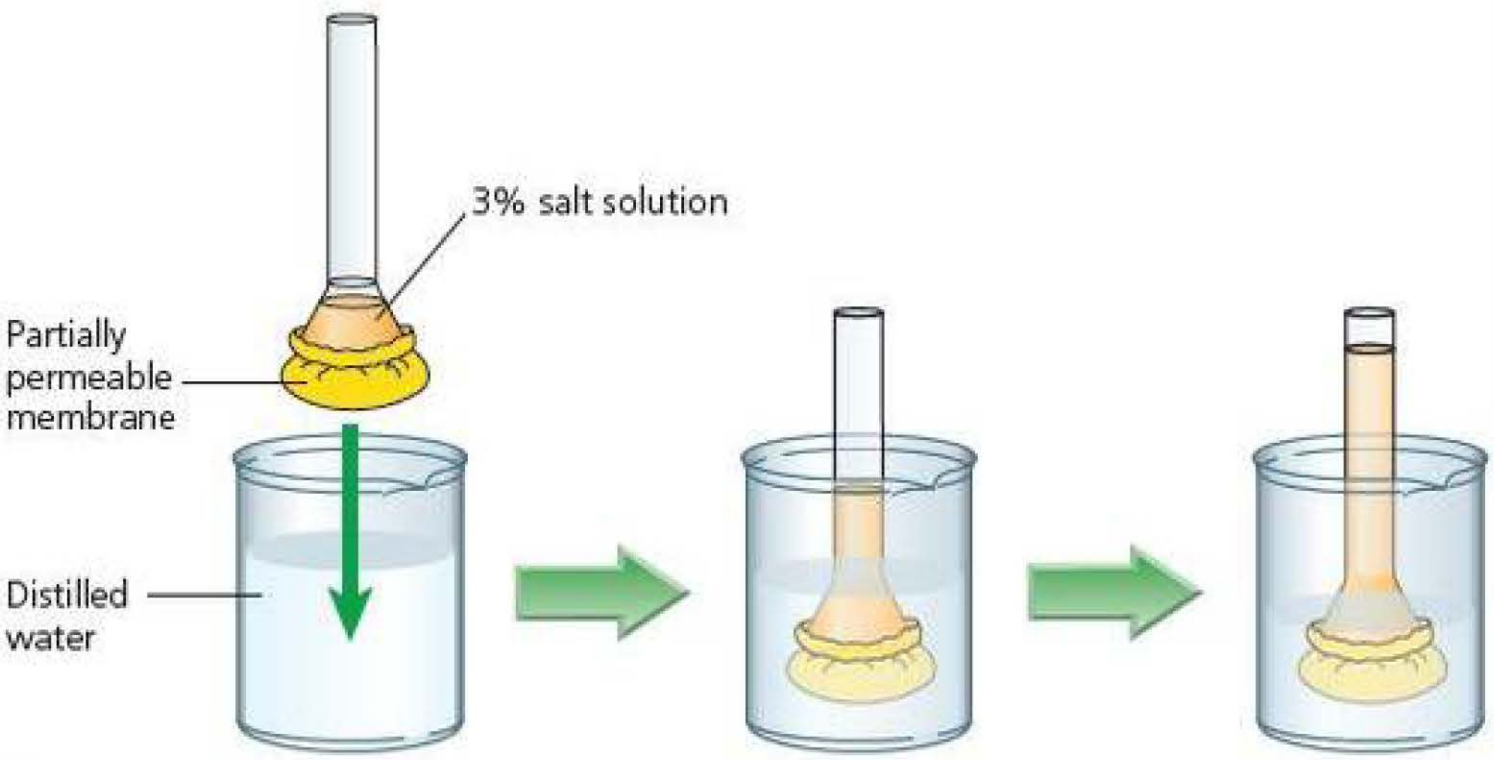


Figure 3.30 An osmometer. The partially permeable membrane could be visking tubing

The water can pass through the partially permeable membrane because it is small enough to fit through the pores in the membrane, but the salt cannot as it is too big.

- **How does this model what happens in cells?**
- **What would happen if you put an animal cell in pure water?**

Assessment opportunities

- In this activity you have practised skills that are assessed using Criterion C: Interpret data and explain results using scientific reasoning.

DISCUSS

Describe to your neighbour what is happening in the following diagrams:

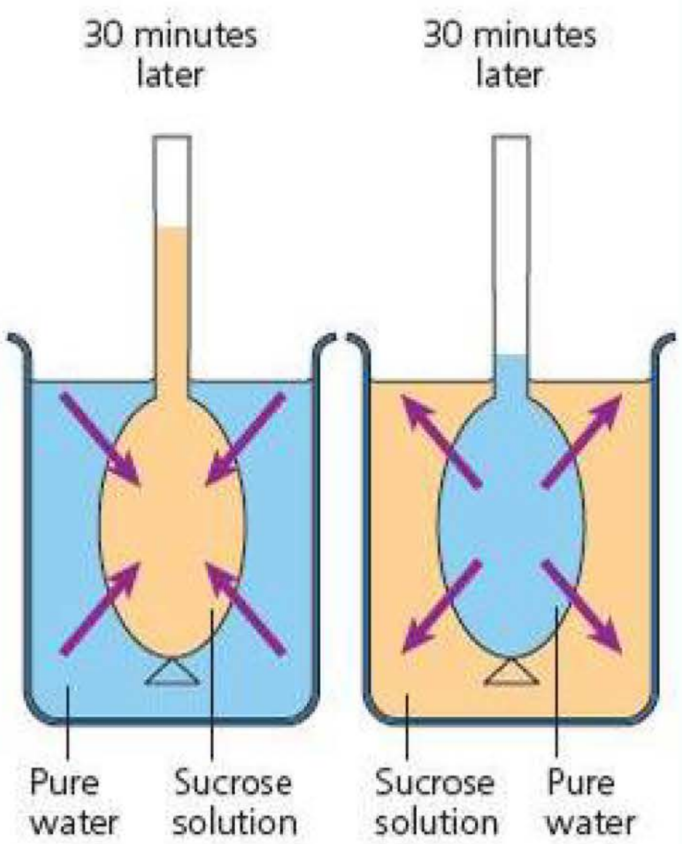


Figure 3.31 Osmosis in action

Complete the following diagram by adding similarities and differences between the three processes:

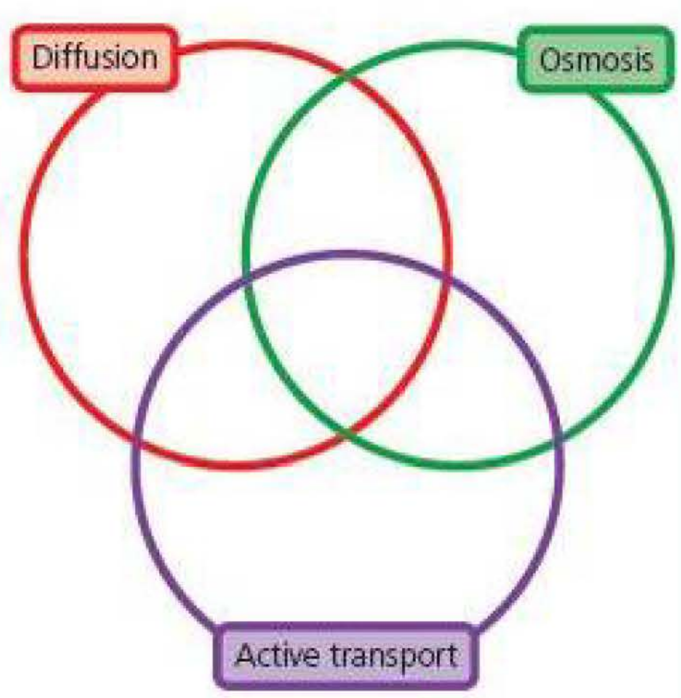


Figure 3.32 Comparing diffusion, osmosis and active transport

SUMMARY REFLECTION

- **What have you learnt about how substances move in and out of cells?**
- **What processes are involved in movement and transport?**
- **What are diffusion, osmosis and active transport?**
- **What have you learnt about the process of osmosis? How is it different to diffusion?**

Why do the conditions within organisms need to be kept in balance?

WHAT IS HOMEOSTASIS?

Your body needs to keep itself within strict limits – if the conditions stray outside these limits then your health, and ultimately your life, may be in danger.

Keeping conditions balanced within the body is called **homeostasis**.

The following factors must be kept in balance:

- temperature
- pH
- water levels in blood and fluids surrounding tissues
- sugar levels in blood
- CO_2 levels in blood.

The following activity gets you to think about why you must keep conditions constant within your body.

Temperature and pH must be kept constant to ensure that enzymes have the optimum conditions to work in and do not **denature**.

Carbon dioxide, when dissolved in blood, lowers the pH and creates an acidic environment. The carbon dioxide must, therefore, be removed by breathing it out.

Too much or too little water in the blood creates osmotic effects – water will either move into cells in the blood (too much water) causing them to burst, or move out of cells (too little water) by osmosis. Either can be damaging for the body.

Your blood sugar level must be constant because too much sugar means that there is a lower water concentration in the blood, and so water moves into the blood from the tissues leading to the body becoming dehydrated. Respiration in cells needs a regular supply of glucose in the right quantities – too much sugar can be as serious as too little.

ACTIVITY: Keeping conditions constant

ATL

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

Discuss the following with your partner:

1. Why must temperature be kept the same? Use your knowledge of enzymes (pages 40–45) to **explain** why.
2. How is temperature kept constant? Think about:
   a. What happens when you get too hot?
   b. What happens when you get too cold?

   Search terms: vasodilation, vasoconstriction, sweat, shivering, piloerection.
3. Why must the pH of your blood be kept constant? Use your knowledge of enzymes to **explain** why.
4. Why must the water level in your blood be kept constant? Use your knowledge of osmosis (page 73) to help you.
5. Why must the sugar level in your blood be kept constant? Use your knowledge of respiration (pages 28–32) and osmosis to **explain** why.

Analyse and **evaluate** the knowledge you have learnt in this chapter about how organisms sustain themselves. **Apply** this understanding to make scientifically supported judgements about how organisms keep their internal environment constant.

Assessment opportunities

- This activity can be assessed using Criterion A: Describe and explain scientific knowledge.

How is sugar level controlled?

- After a meal, digested sugar enters the blood.
- Higher blood-sugar level is detected by the **pancreas**.
- The pancreas releases the hormone **insulin**.
- Insulin travels around the body in the blood.
- At muscle and liver cells, insulin instructs cells to store glucose as glycogen.
- The blood sugar level returns to normal.

A second hormone is used if blood-sugar levels are too low. **Glucagon** instructs cells to break glycogen down into glucose.

Many **homeostatic** mechanisms use hormones in this way.

Explore further here: **www.abpischools.org.uk/page/modules/diabetes/diabetes4.cfm**

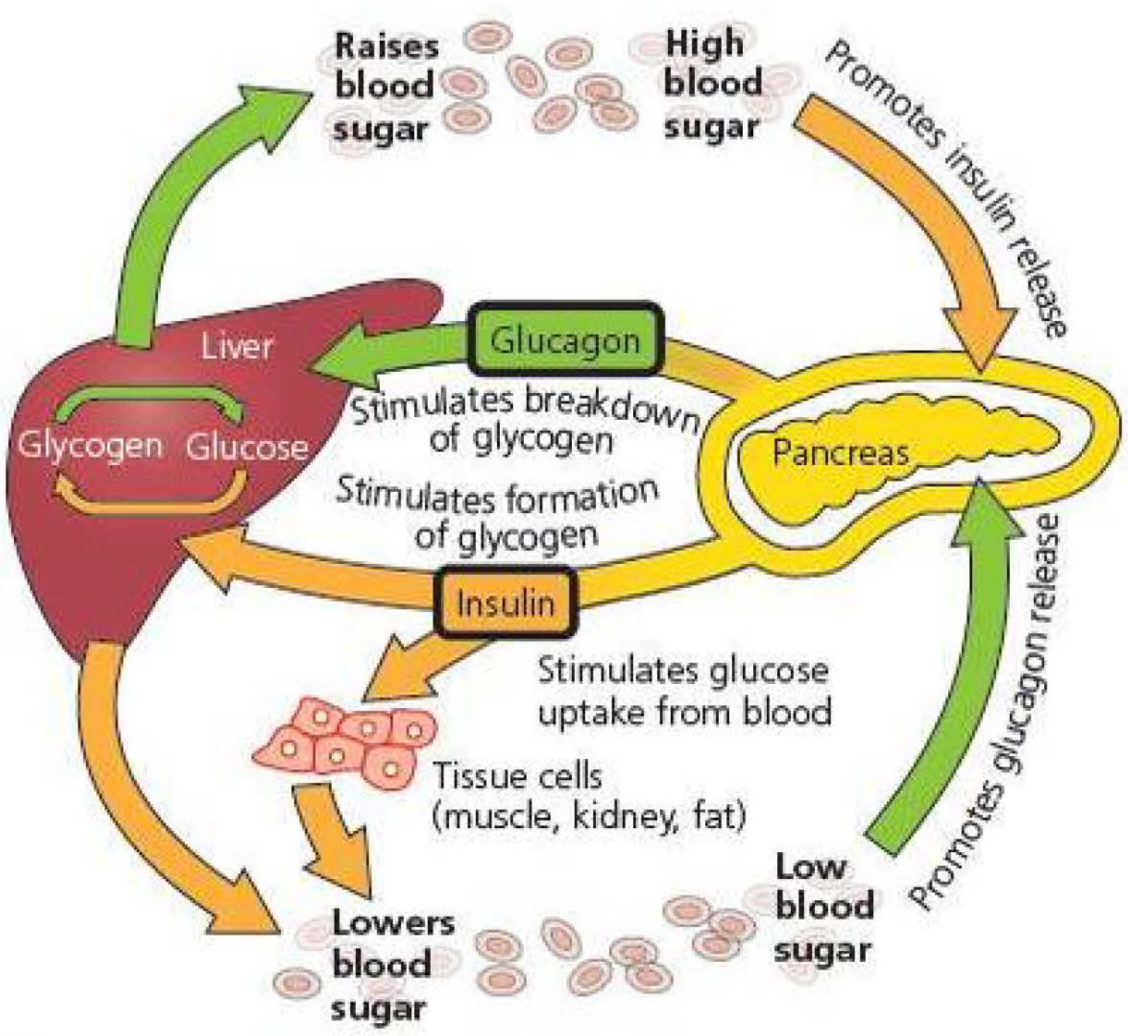


Figure 3.33 Insulin and glucagon control sugar levels in the blood

EXTENSION

How does the kidney filter urea from the blood and control water levels in the body? Explore further here: **www.kscience.co.uk/animations/kidney.htm**

EXTENSION

How does the body regulate temperature? Find out about the thermoregulatory homeostatic mechanisms: **vasodilation**, **vasoconstriction**, **sweating**, **shivering**, **piloerection**.

How do poikilothermic (cold-blooded) organisms regulate their temperature?

Produce a summary poster of how thermoregulation works.

SUMMARY REFLECTION

- **What have you learnt about homeostasis?**
- **Why do the conditions within organisms need to be kept in balance?**

REVIEW

Describe and **explain** how and why the following conditions in the body must be controlled:

- **temperature**
- **pH**
- **water levels in blood and fluids surrounding tissues**
- **sugar levels in blood**
- **CO_2 levels in blood.**

How do elements essential for life cycle between the environment and organisms?

WHAT IS THE CARBON CYCLE?

All elements in living things, such as carbon, oxygen and hydrogen, **cycle** between the physical environment and the biotic (i.e. living) part of **ecosystems** (i.e. the **community**). Without such cycling, nutrients would end up in dead organisms, faeces and waste, and not get returned to living matter.

In this section we will investigate how two elements – carbon and nitrogen – cycle.

ACTIVITY: Investigating the carbon cycle

ATL

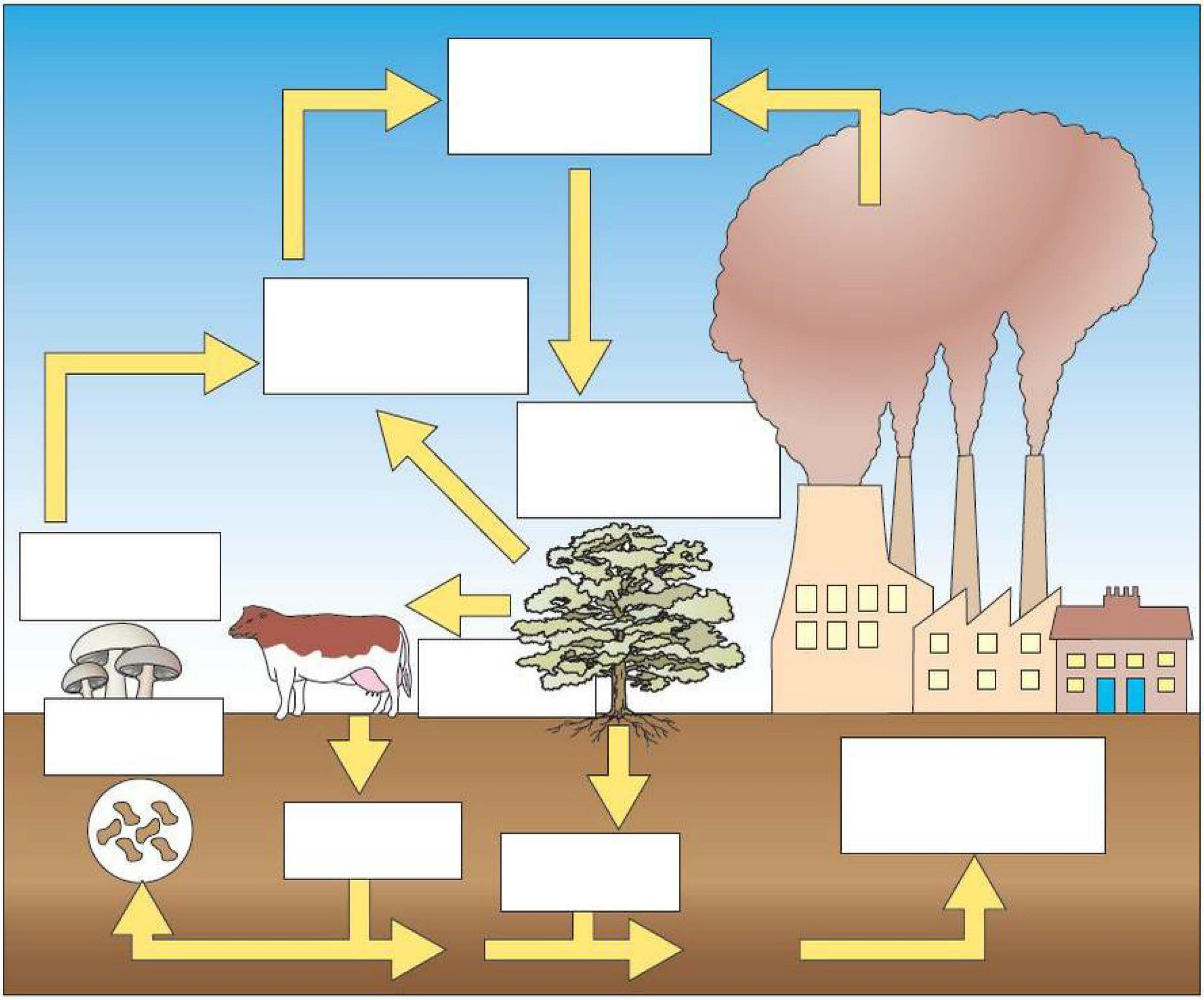
- Creative-thinking skills: Apply existing knowledge to generate new ideas

Think about the following:

- **What biological molecules contain carbon? (Remind yourself on pages 56–57.)**
- **What process releases carbon dioxide from living things? (See pages 30–31 if you need help here.)**
- **What process takes in carbon dioxide and converts it into glucose? (Reminder on pages 33–34.)**
- **How does carbon pass from one organism to the next in a food chain?**
- **Bacteria, fungi and other decomposers feed on dead organisms and waste material (such as faeces). How would these organisms return carbon into the atmosphere?**
- **Under the right conditions, carbon in dead organisms is locked up in coal, oil, gas and other fossil fuels. High pressure and incomplete decay lead to the production of such fossil fuels over thousands of years. How is the carbon in these materials being returned to the atmosphere?**

Now complete the diagram on the next page.

Words to use: respiration, photosynthesis, combustion, carbon dioxide, decomposition, consumption/eaten by



■ **Figure 3.34** The carbon cycle

EXTENSION

- What role does limestone play in the carbon cycle?
- Can you find out how much carbon is stored in each of the reservoirs in which it is found (for example, the ocean, fossil fuels, the atmosphere, sedimentary rock, the Earth's mantle)?
- How are human activities affecting the carbon cycle?

◆ Assessment opportunities

- ◆ In this activity you have practised skills that are assessed using Criterion A: Describe and explain scientific knowledge.

ACTIVITY: The nitrogen cycle

ATL

- Information literacy skills: Access information to be informed

Your task in this activity is to find out about the nitrogen cycle and make your own summary diagram to show how nitrogen moves from the atmosphere and into living things, and how it is then returned to the physical environment.

Find out about the nitrogen cycle using these search terms: **decomposers**, **nitrogen-fixing bacteria**, **nitrifying bacteria**, **denitrifying bacteria**, **ammonia**, **nitrite**, **nitrate**.

Help is also available here: www.classzone.com/books/ml_science_share/vis_sim/em05_pg20_nitrogen/em05_pg20_nitrogen.swf

You will find that the whole nitrogen cycle is driven by four types of bacteria – but which bacteria does what, and how do they link together to make a cycle?

EXTENSION

- How do waterlogged soils affect the nitrogen cycle?
- Why do carnivorous plants, **pitcher plants**, **sundew**, **Venus flytrap** exist?

Assessment opportunities

- In this activity you have practised skills that are assessed using Criterion A: Apply scientific knowledge and understanding to solve problems.

WHAT IS THE NITROGEN CYCLE?

As we have seen earlier in the chapter (pages 56–57), nitrogen is needed in living things to make protein. Organisms have difficulty in using nitrogen gas directly from the atmosphere – it is a very unreactive gas and only one group of bacteria have evolved the ability to use nitrogen directly to make other compounds.

DISCUSS

Discuss with your neighbour what you found out about the nitrogen cycle. Check your understanding using the following figure:

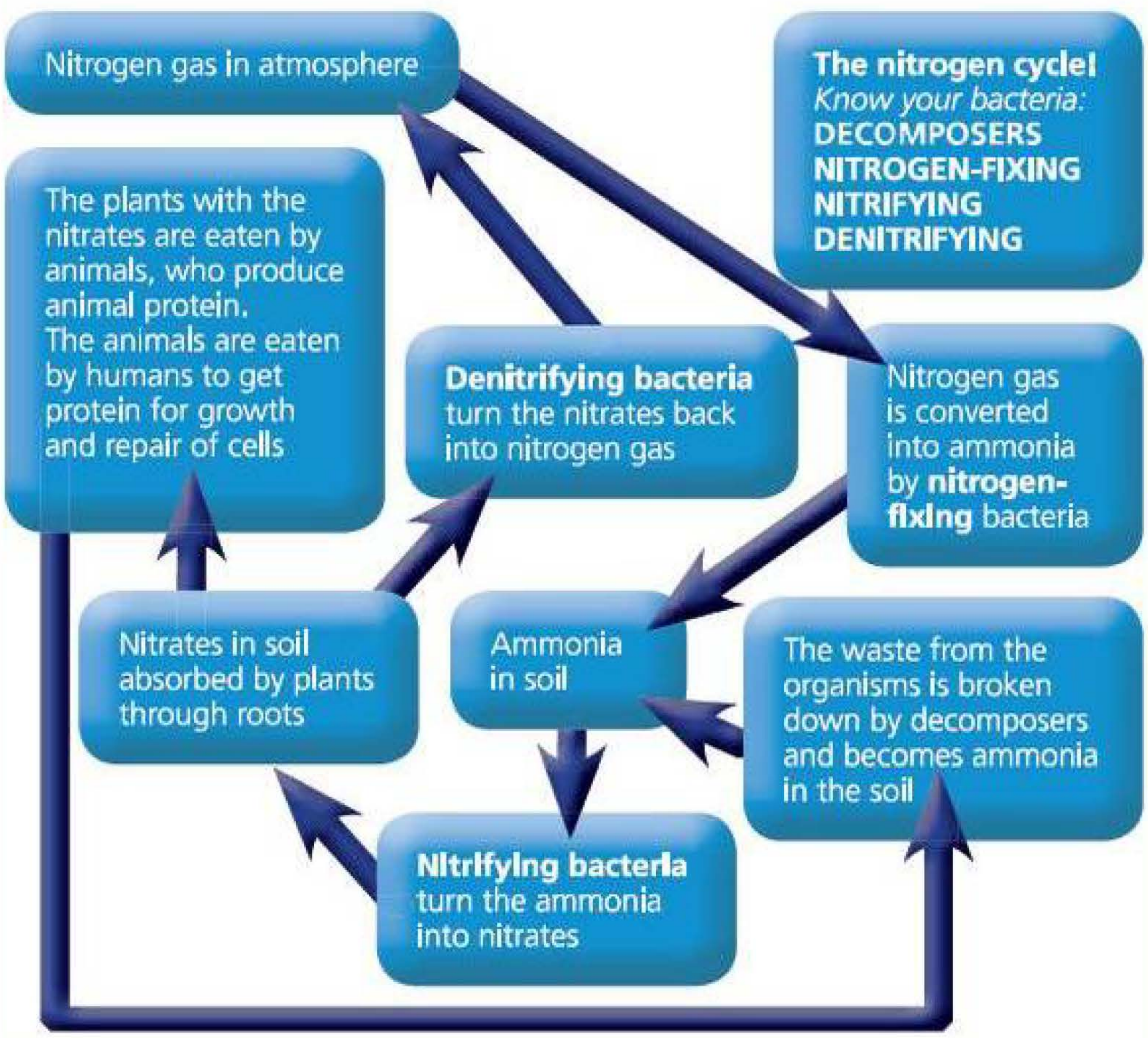


Figure 3.35 The nitrogen cycle

Are there dangers in using drugs to control weight?

In this chapter we have investigated how a healthy diet provides the body with all the nutrients it needs to function properly. Some people have metabolic conditions that mean that they put on weight and can become overweight. Other people may become obese because they have an unhealthy diet, where the amount of energy they consume in their food is not balanced by the amount of energy they expend.

There are many diets available to help people lose weight. There are also legal drugs that people can take to aid weight loss. These drugs can:

- suppress appetite (people feel less hungry so eat less)
- inhibit fat absorption in the intestine (less fat is absorbed into the blood and, hence, into cells)
- increase cell metabolism (so more food is broken down in cells to release energy).

THINK–PUZZLE–EXPLORE

Figure 3.36 Pharmaceutical drugs can be used to aid weight loss. Examples of such drugs include orlistat (Alli or Xenical), sibutramine (Meridia) and lorcaserin (Belviq)

ATL

- Communication skills: Use a variety of media to communicate with a range of audiences; Negotiate ideas with peers and teachers

In small groups, research **weight-control drugs**, and record your findings. Which people are generally prescribed these drugs, and why? Should overweight people, in general, have access to these drugs? Are there dangers in using these drugs?

www.drugs.com/article/prescription-weight-loss-drugs.html

www.nhs.uk/Conditions/Obesity/Pages/Treatment.aspx

Consider what 'legal' means and why some drugs are legal but others are not.

In your group, prepare a presentation of what you have found. The presentation should educate the public about these drugs – their use and possible abuse. Should people use legal drugs to try to control their weight?

Allocate roles in your group. Communicate together and with your teacher to assess the information and weigh up the evidence.

Aim to use a variety of media in your presentation – for example, as well as the presentation itself (which could be a PowerPoint) you could also have hand-outs available so that people can take away and read the information you have provided. Make the information visually interesting, and be aware of the sensitive nature of the material you will be talking about.

Assessment opportunities

- This activity can be assessed using Criterion A: Describe and explain scientific knowledge and understanding and Criterion D: Discuss and evaluate the implications of science to solve a specific problem.

REVIEW

Brainstorm a list of at least 12 questions about the topic. Use these question-starts to help you think of interesting questions:

- **Why ...?**
- **How would it be different if ...?**
- **What are the reasons ...?**
- **Suppose that ...?**
- **What if ...?**
- **What if we knew ...?**
- **What is the purpose of ...?**
- **What would change if ...?**

Review the brainstormed list and star the questions that seem most interesting. Then, select one or more of the starred questions to discuss for a few moments.

- **What new ideas do you have about the topic that you didn't have before?**

What have you learnt about yourself as a knowledgeable scientist? How have you developed and used conceptual understanding, and explored knowledge across a range of disciplines?

Take action: Food choices

- Diet can be affected by personal and cultural choices. Some people choose to be vegetarian as they do not believe it is right to eat animals. Other people's diets are influenced by their religion, training regime for sport or health issues.
- Any diet must ensure that a healthy balance of nutrients is taken into the body.
- Using the information you have learnt from this chapter, plan an advertising campaign to ensure healthy eating within your school or community. Your campaign needs to make sure that:
  - it **explains** what is meant by a healthy diet
  - it **explains** that food needs, such as energy intake, vary from person to person
  - there is a range of dietary choices available and that these will depend on personal preferences, beliefs and culture.
- Decide within your class the best way of promoting your message. This could be a poster campaign, information on a website, leaflets and brochures, and so on.
- **Explore further ...**

  www.nhs.uk/livewell/goodfood/pages/eight-tips-healthy-eating.aspx

  www.healthyeating.org/Portals/0/Documents/Tip%20Sheets/CulturalFoodGuide.pdf

  www.jamieoliverfoodfoundation.org.uk/
- Write up your findings as a fully referenced report, evaluating your sources and the effectiveness of your campaign. Make sure that your report is supported by materials (such as posters, leaflets, etc.) produced for your project.

Assessment opportunities

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

SOME SUMMATIVE PROBLEMS TO TRY

Use these problems to apply and extend your learning in this chapter. These problems are designed so that you can evaluate your learning at different levels of achievement in Criterion A: Knowledge and understanding.

THESE PROBLEMS CAN BE USED TO EVALUATE YOUR LEARNING IN CRITERION A TO LEVEL 1–2

1 **State** the seven components in a balanced diet.

2 **State** the elements found in proteins.

3 a **Suggest** why snacking on chocolate, crisps and soft drinks is an unsuitable diet for children who are not very active.

  b **Suggest** the health problems that might develop if children have too much fat in their diet.

THESE PROBLEMS CAN BE USED TO EVALUATE YOUR LEARNING IN CRITERION A TO LEVEL 3–4

4 **Outline** the role of digestion in the body.

5 Three different foods were tested for different food groups. The following results were found:

Food sample	Test	Result
Food 1 	Iodine solution	Orange/brown
	Benedict's solution	Blue
	Biuret test	Purple/lilac
	Paper test	Greasy mark present
Food 2 	Iodine solution	Blue/black
	Benedict's solution	Blue
	Biuret test	Blue
	Paper test	No change
Food 3 	Iodine solution	Orange/brown
	Benedict's solution	Orange precipitate
	Biuret test	Blue
	Paper test	No change

Which food groups were present in each food sample? **Justify** your answers using evidence from the results given.

THESE PROBLEMS CAN BE USED TO EVALUATE YOUR LEARNING IN CRITERION A TO LEVEL 5–6

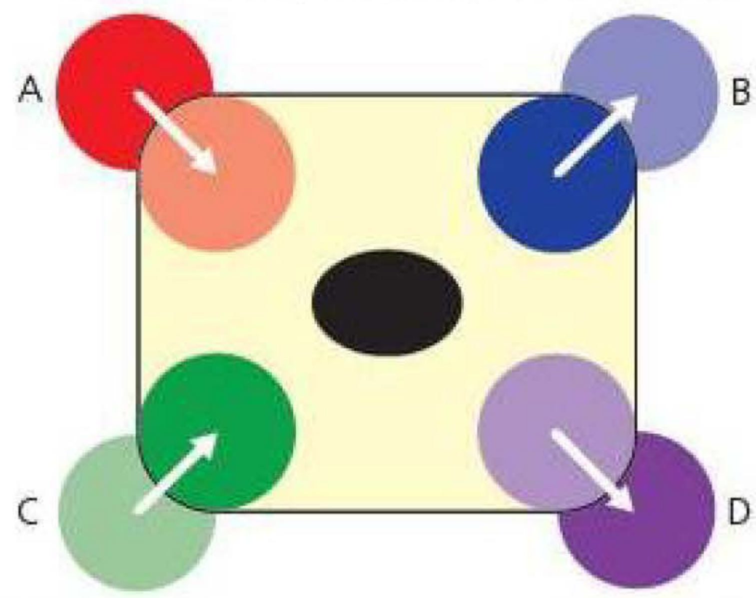
6 a **Describe** two ways in which the mouth can break down starchy foods.

  b **Describe** how the liver helps to digest fats.

  c **Describe** one role of bile other than helping to digest fats.

7 **Describe** how oxygen from the air reaches cells in our body.

8 The following diagram shows four ways in which molecules may move into and out of a cell. The dots represent the concentration of the different molecules.



■ **Figure 3.37** Movement of molecules into and out from a cell

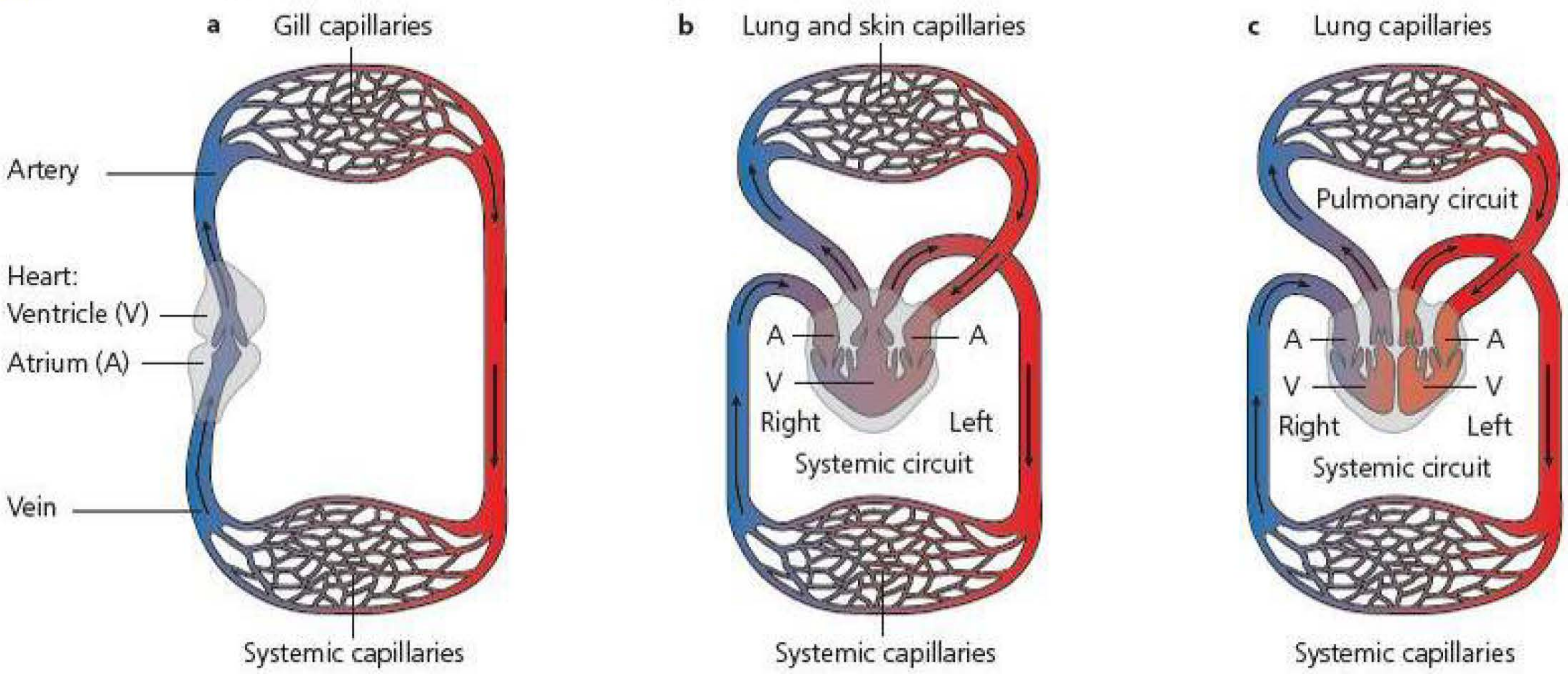
  a Which arrow represents movement of oxygen molecules?

  b Which arrow represents movement of carbon dioxide?

  c Which arrow represents the active transport of glucose molecules?

9 **Describe** the differences between arteries, capillaries and veins.

10 The following diagram shows the circulatory systems of three different animals:



■ **Figure 3.38** The circulatory systems of **a** fish, **b** amphibians and **c** mammals

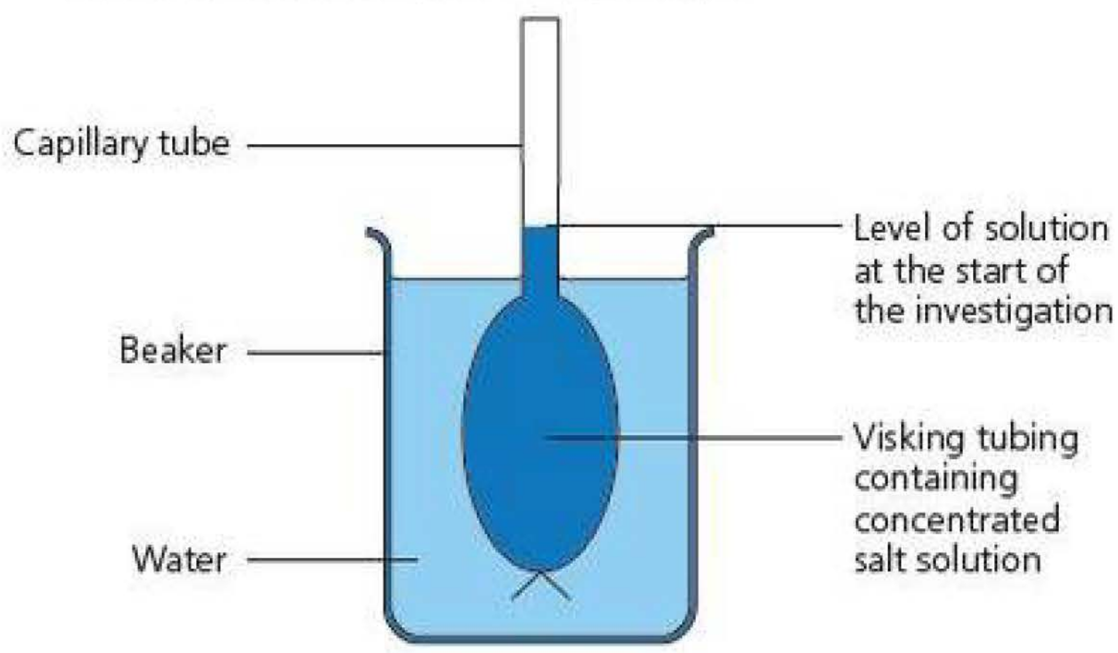
a **Describe** the differences between the three different circulatory systems.

b **Suggest** what is meant by 'systemic' capillaries.

c **Suggest** the advantages of having a mammalian heart compared to an amphibian or a fish heart.

THESE PROBLEMS CAN BE USED TO EVALUATE YOUR LEARNING IN CRITERION A TO LEVEL 7–8

11 An experiment was set up to investigate osmosis. The following equipment was used:



■ **Figure 3.39** Investigating osmosis

a What is osmosis?

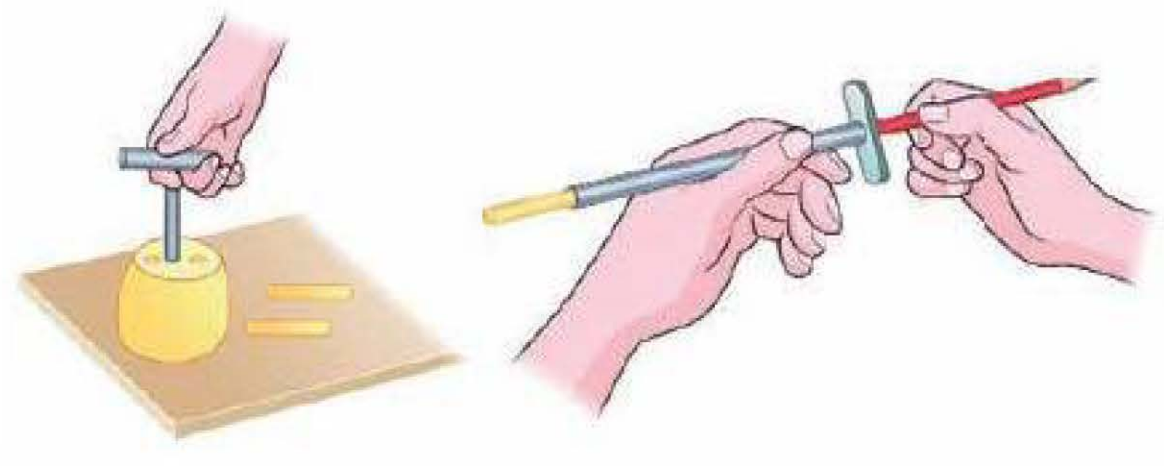
b **Describe** and **explain** what will happen to the level of solution in the capillary tube during the experiment.

c Red blood cells were put into different concentrations of salt solution. Figure 3.40 shows the appearance of the blood cells after 10 minutes.

i Using your knowledge of osmosis, **suggest** reasons for the appearance of the cells in each solution, A, B and C.

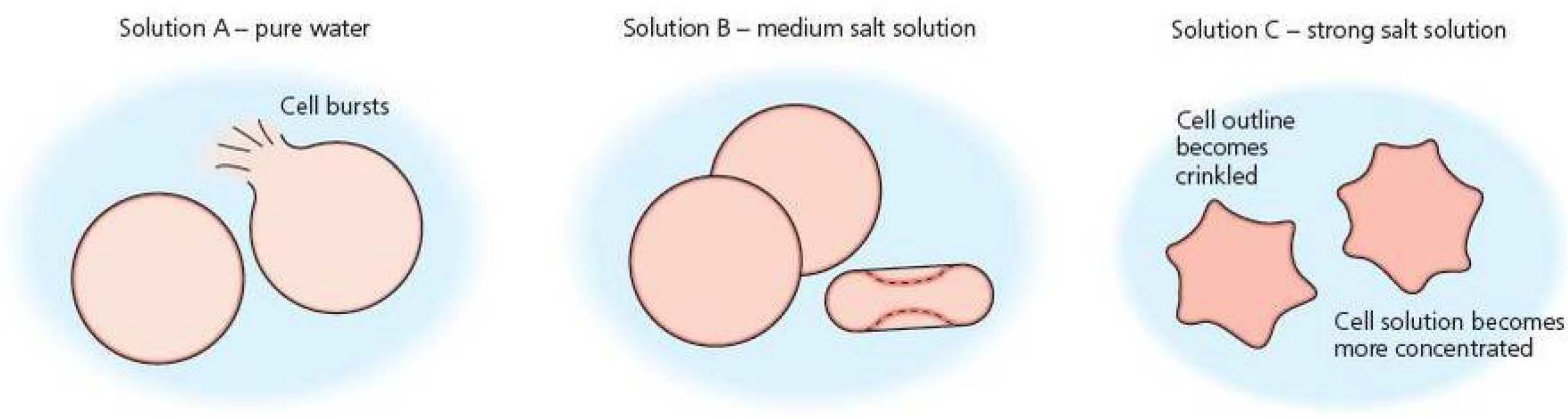
ii **Explain** the appearance of a plant cell placed in a solution of pure water.

12 An experiment was carried out to investigate osmosis in potatoes. Chips were removed from a potato (Figure 3.41).

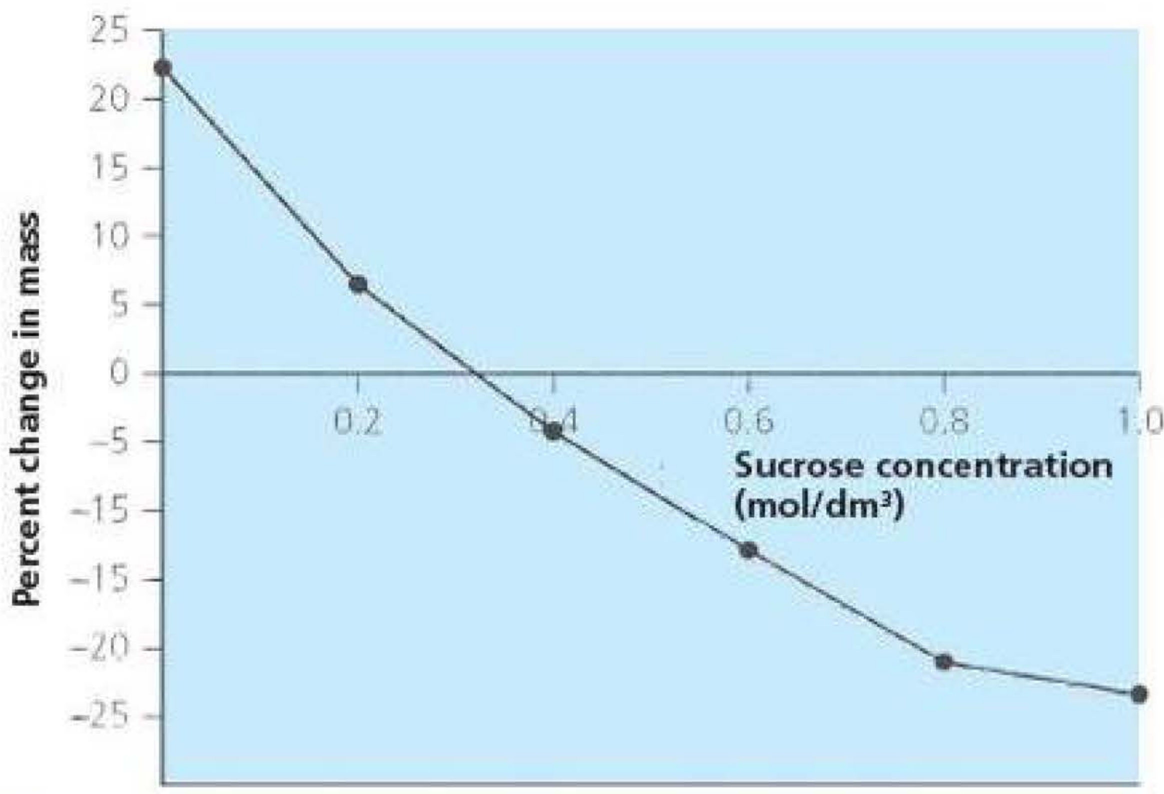


■ **Figure 3.41** Preparing potato chips for osmosis experiment

The chips were cut to 30 mm in length and the mass of each recorded. Each chip was placed in a different concentration of sucrose solution, from 0.0 to 1.0 mol dm^{-3}. After 40 minutes, the chips were removed and re-weighed. The percentage change in mass was calculated for all chips (the change in mass divided by the original mass, multiplied by 100). A graph was plotted showing percentage change in mass against sucrose concentration (Figure 3.42 overleaf).



■ **Figure 3.40** Red blood cells in a range of different concentrations of salt



■ **Figure 3.42** Graph showing percent change in mass of potato chips at different sucrose concentrations

a **Describe** and **explain** the results shown in Figure 3.42.

b **Evaluate** the experiment.

   i How could the reliability have been improved?

   ii What were the limitations of the experiment?

   iii How would limitations have affected the accuracy of the result?

   iv How could the experiment have been improved to reduce these limitations and improve accuracy?

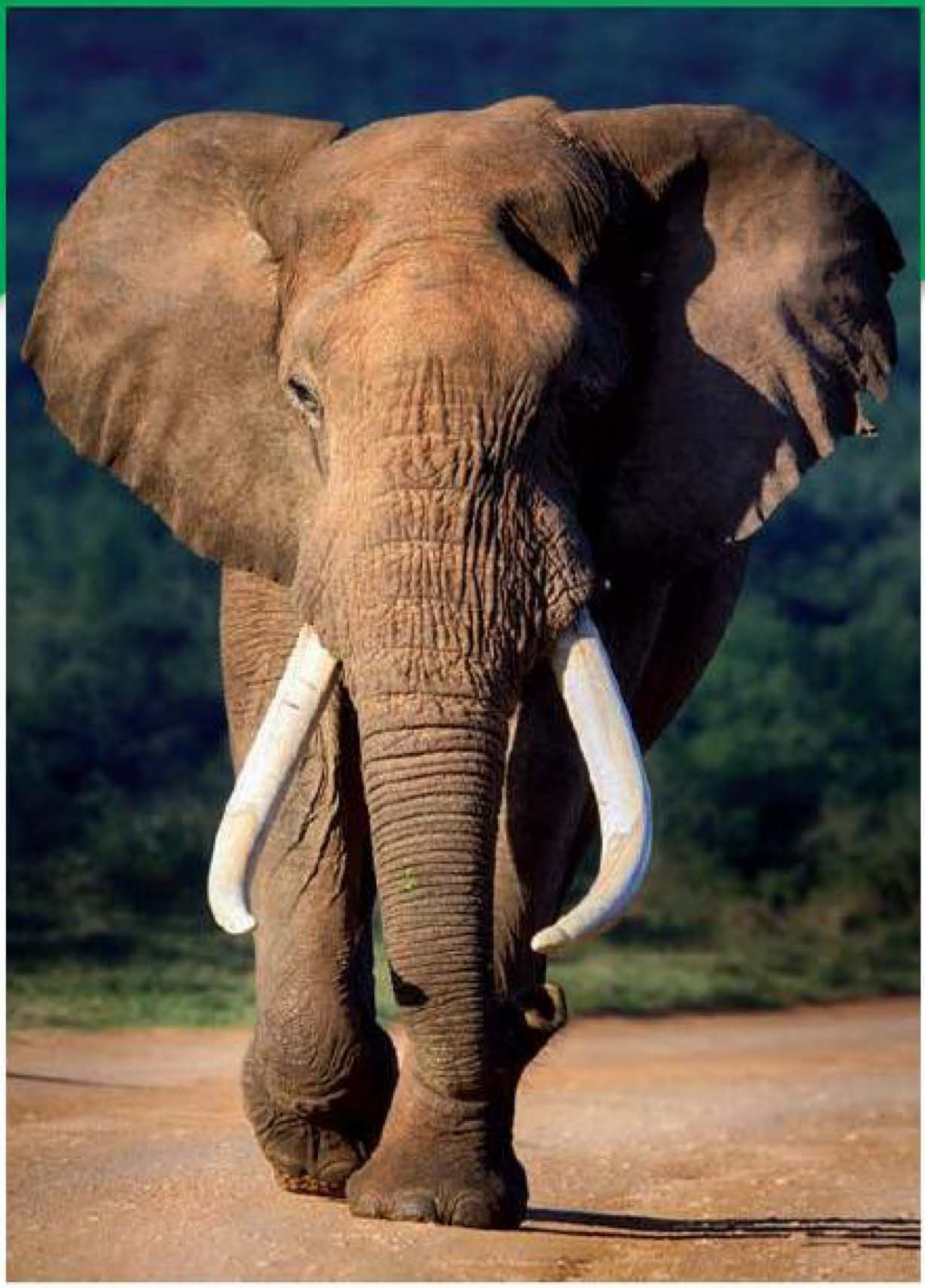
Reflection

In this chapter we have explored how the body can achieve a balanced diet, and how the nutrients we need reach our cells. We have seen how elements present in our food and bodies cycle between the environment and living matter. We have discussed how oxygen is absorbed and transported to cells, and how waste products are removed, so that a state of balance can be maintained in the body. We have applied our knowledge to discuss whether people should use drugs to control their weight, and how we can promote healthy eating in our local community. We have learnt how to develop and use conceptual understanding, and focused on the role of knowledge in scientific endeavour.

<table>
<tr><th colspan="6">Use this table to reflect on your own learning in this chapter</th></tr>
<tr><td>Questions we asked</td><td>Answers we found</td><td colspan="4">Any further questions now?</td></tr>
<tr><td>Factual: What nutrients do organisms need to survive? What occurs during the process of digestion? What occurs during the process of gas exchange? How are substances transported around an organism? How do substances move in and out of cells? What are diffusion, osmosis and active transport? What is homeostasis? How do elements essential for life cycle between the environment and organisms?</td><td></td><td colspan="4"></td></tr>
<tr><td>Conceptual: What processes are involved in movement and transport? Why do the conditions within organisms need to be kept in balance?</td><td></td><td colspan="4"></td></tr>
<tr><td>Debatable: Should people use drugs to try to control their weight?</td><td></td><td colspan="4"></td></tr>
<tr><td rowspan="2">Approaches to learning you used in this chapter</td><td rowspan="2">Description – what new skills did you learn?</td><td colspan="4">How well did you master the skills?</td></tr>
<tr><td>Novice</td><td>Learner</td><td>Practitioner</td><td>Expert</td></tr>
<tr><td>Critical-thinking skills</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Creative-thinking skills</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Communication skills</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Transfer skills</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Information literacy skills</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Collaboration skills</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Learner profile attribute(s)</td><td colspan="5">How did you demonstrate being knowledgeable in this chapter?</td></tr>
<tr><td>Knowledgeable</td><td colspan="5"></td></tr>
</table>

4 What issues do larger organisms face?

The size of organisms determines their **distribution in space and time**, and the **form** and **function** of specialized structures in larger organisms **develop** from their **relationships** with the **environment**.



■ **Figure 4.1** An African elephant – an example of a (very) large organism

CONSIDER AND ANSWER THESE QUESTIONS:

Factual: In what ways are organisms adapted to the environment they live in? What structures do larger organisms have in order to efficiently exchange nutrients, gases and waste with their environment? What are the adaptations or specialized features of cells, tissues, and organs that increase surface area?

Conceptual: How does the size of an organism determine its needs for energy and nutrients? What role does surface area : volume ratio play in determining the efficiency of transfer of substances into and out of organisms? How does the shape of an organism help adapt it to the environment it lives in? How does the behaviour of an animal help adapt it to the environment it lives in?

Debatable: How important is it to protect endangered animals? How can the design of conservation areas, and zoos, help meet the needs of larger animals and support their survival?

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

IN THIS CHAPTER, WE WILL …

- **Find out** how the size of an organism plays an important role in its relationship with the environment, and issues they face as they get bigger.
- **Explore** how different animals and plants are adapted to the environment they live in.
- **Take action** by planning how endangered large animals, such as elephants and tigers, can be protected in the wild or in zoos, so as to meet their needs and support survival.

■ **Figure 4.2** A selection of plants and animals. How are they adapted to their respective environments?

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

- Critical-thinking skills
- Creative-thinking skills

● We will reflect on this learner profile attribute …

- Thinker – you will have opportunity to develop as a thinker through various critical-thinking activities.

◆ Assessment opportunities in this chapter …

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

KEY WORDS

adaptation
behavioural
implications
physiological
specialized

In the examples shown in Figure 4.2, each organism is adapted to its **environment**, allowing them to survive often in extreme conditions. **Adaptations** can be physical features such as size and shape, **behavioural** characteristics such as how an animal lives with others in its group, or **physiological** adaptations which involve the function of the organism's body, such as temperature regulation. Can you identify the different adaptations for each organism? What about other adaptations that you may not be able to see in the photos?

In the last chapter we explored how animals maintain a constant environment in their bodies – the process known as **homeostasis**. Adaptations in animals enable them to maintain homeostasis, even in extreme environments. Organisms that are adapted to specific environments are known by certain terms, such as species of plants adapted to dry conditions which are known as **xerophytes** (from 'xero' which means dry, and 'phyte' which means plant).

In Chapter 7 we will explore the work of nineteenth-century scientist–adventurer Charles Darwin. He made the link between animal adaptations and species' survival, and what happens to species when their environment changes. In order to survive and reproduce, an organism must be perfectly adapted to their surroundings – if not then it will not survive and pass on its genes to the next generation (something we will look at further in Chapter 6).

WHAT MAKES YOU SAY THAT?

ATL

- Critical-thinking skills: Draw reasonable conclusions and generalizations

What's going on?

Choose an organism, and find a photo of it that clearly shows its adaptations.

http://waynesword.palomar.edu/lmexe10b.htm

Describe the way of life that the organism is adapted to (for example, 'adapted to life in the desert' if it is a camel). **List** all the environmental factors that may affect the organism (such as a regular supply of water if it is a plant, or temperature if is an animal living at the North or South Pole).

What do you see that makes you say that?

Now **describe** and **explain** the features that adapt the organism to its environment (for example, the hump on a camel that stores fat and which can be broken down to release energy and a source of water). Aim for at least five different adaptations. What features can you describe and explain that enable them to overcome the environmental factors you have listed?

Alternatively, for this activity, you could choose to talk about an organ from within an organism, such as the heart or eye (Figure 4.3 and Figure 4.4).

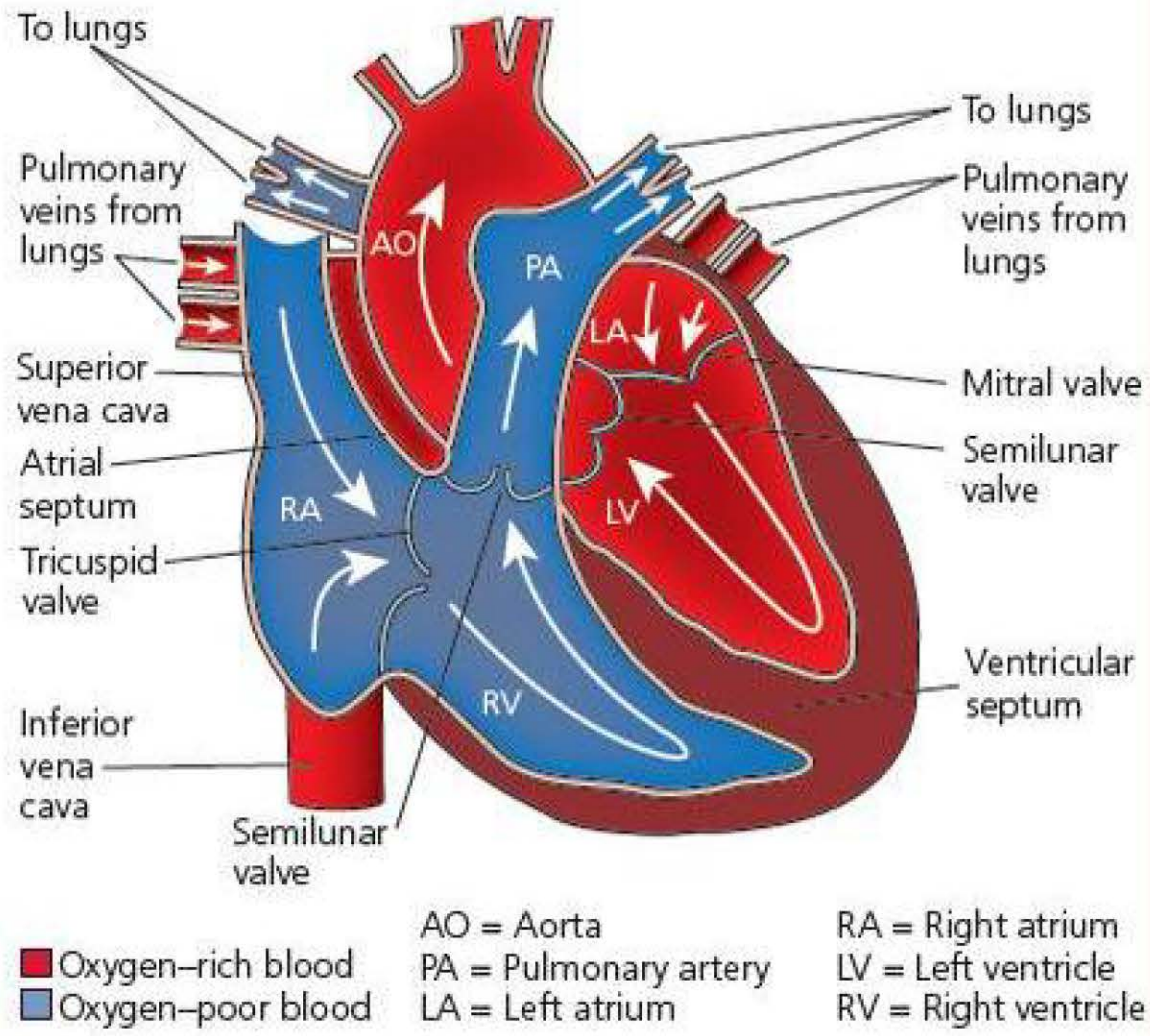


Figure 4.3 The human heart

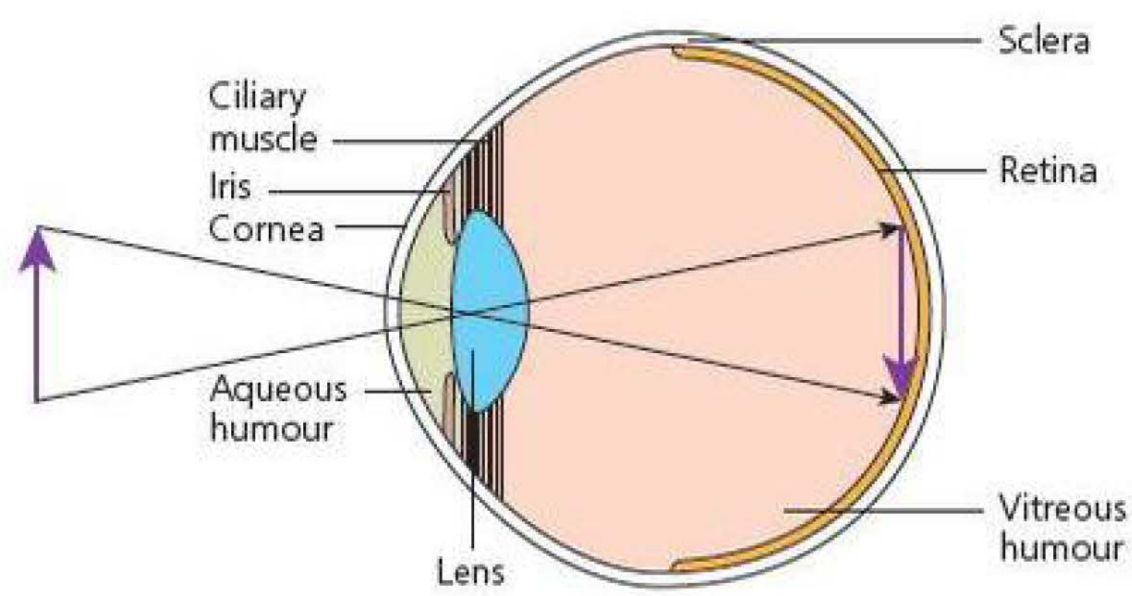


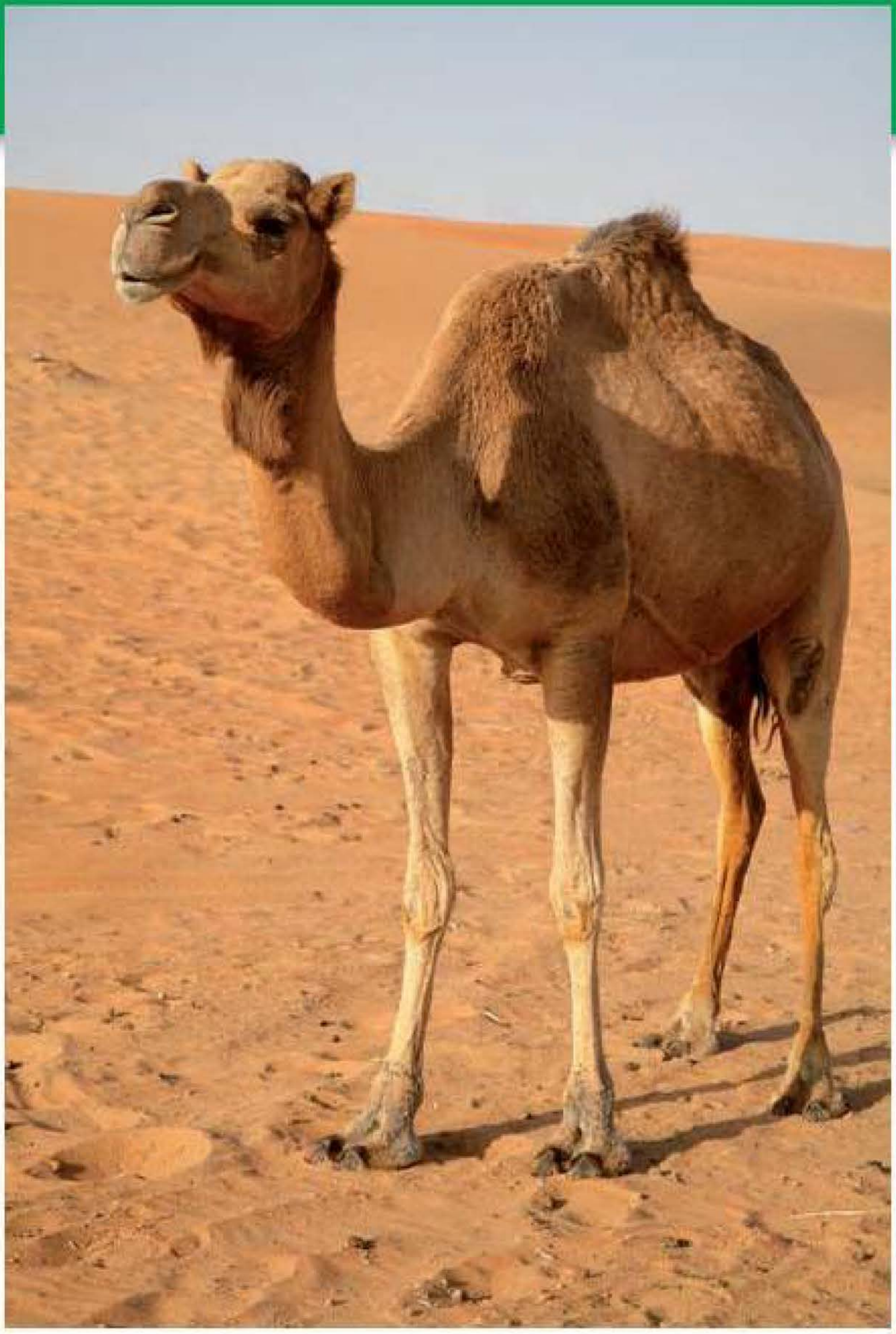
Figure 4.4 The human eye

- **What's going on? What is the role of the organ in the body?**
- **What do you see that makes you say that? What adaptations can you see in the organ that enable it to fulfil its function?**

Assessment opportunities

- In this activity you have practised skills that are assessed using Criterion A: Apply scientific knowledge and understanding to solve problems.

The environment that an organism is adapted to can include many different factors – temperature, the availability of water, the amount of sunlight, food – depending on the type of organism and the way it lives. Adaptations may be outwardly visible, such as the hump (or humps) on camels (one hump on a dromedary and two on a bactrian). Other adaptations are hidden within the body: think of the four–chambered heart in mammals that separates oxygenated and deoxygenated blood and enables oxygen-rich blood to be delivered to all cells, for example (see Chapter 3), or the retina cells at the back of the eye that enable us to see (see Chapter 8).



■ **Figure 4.6** Dromedary camel

■ **Figure 4.5** Bactrian camel

■ **Figure 4.7** A humpback whale and her calf. How is a whale adapted to its environment?

What specialized structures do larger animals have inside their bodies? How do they help animals survive?

SPECIALIZED STRUCTURES IN LARGER ANIMALS

Two essential ingredients needed for survival are food and oxygen (as we explored in Chapter 2). What adaptations do animals have to increase the rate at which these life-giving substances can be taken into the body?

THINK–PAIR–SHARE

ATL

- Critical-thinking skills: Draw reasonable conclusions and generalizations

Look at the four figures shown here. How is each organ adapted to increase the rate of movement of substances, such as food or vital gases (oxygen in animals and carbon dioxide in plants) into the organism? Pick one of the organ systems. Think about explanations yourself, then share them with your neighbour, and finally feed your ideas back to the class.

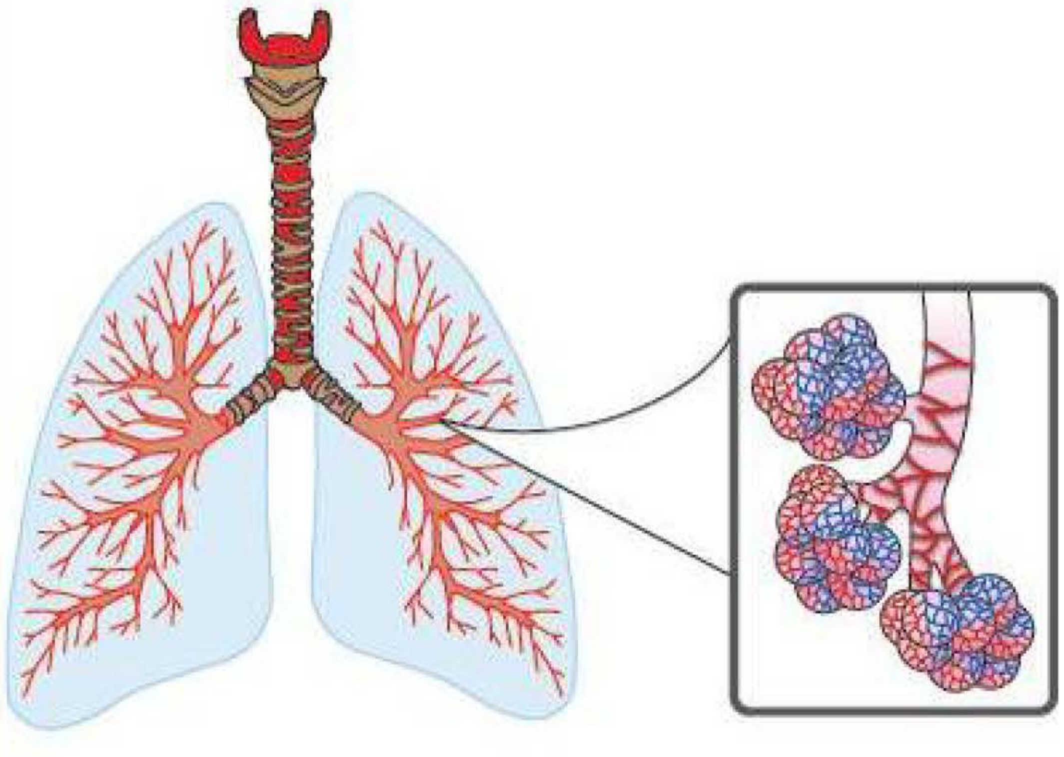


Figure 4.8 Human breathing system

- What key substance is provided by the lungs, needed by all cells to survive?
- What waste product is removed by the lungs, which if left in the blood would decrease the pH of the blood?
- Remind yourself of the structure of the breathing system in humans: can you name all the different parts?

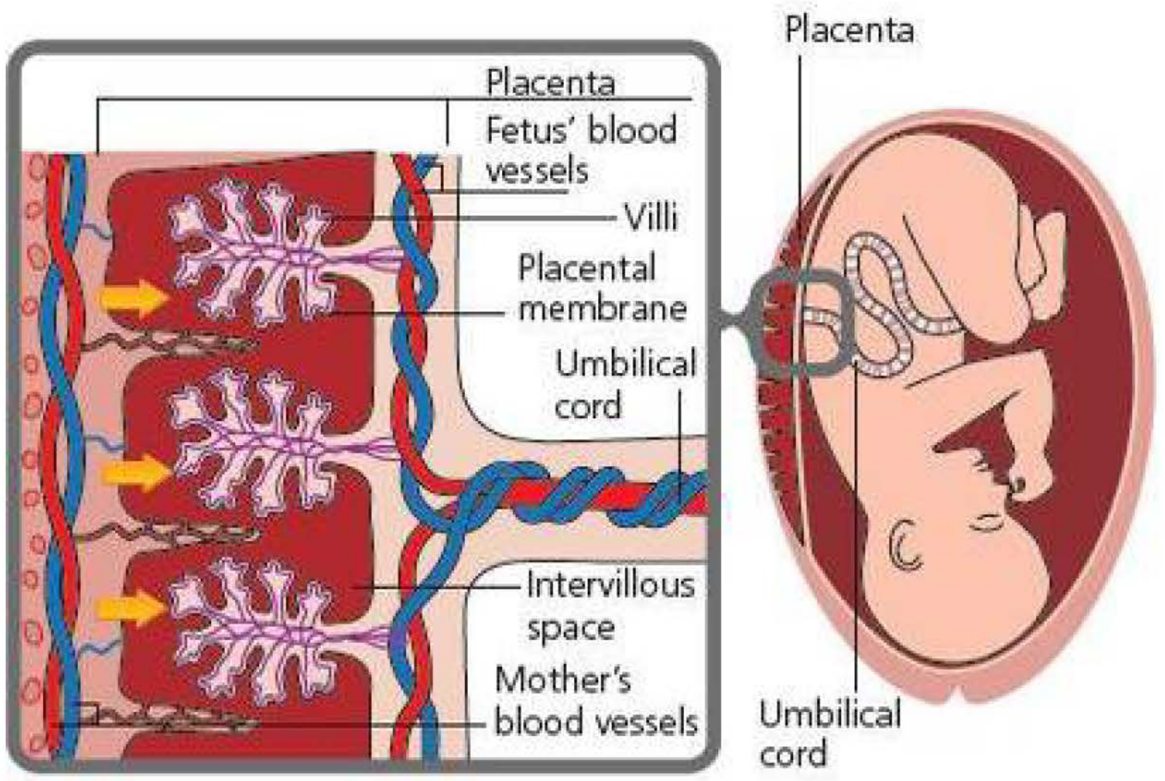
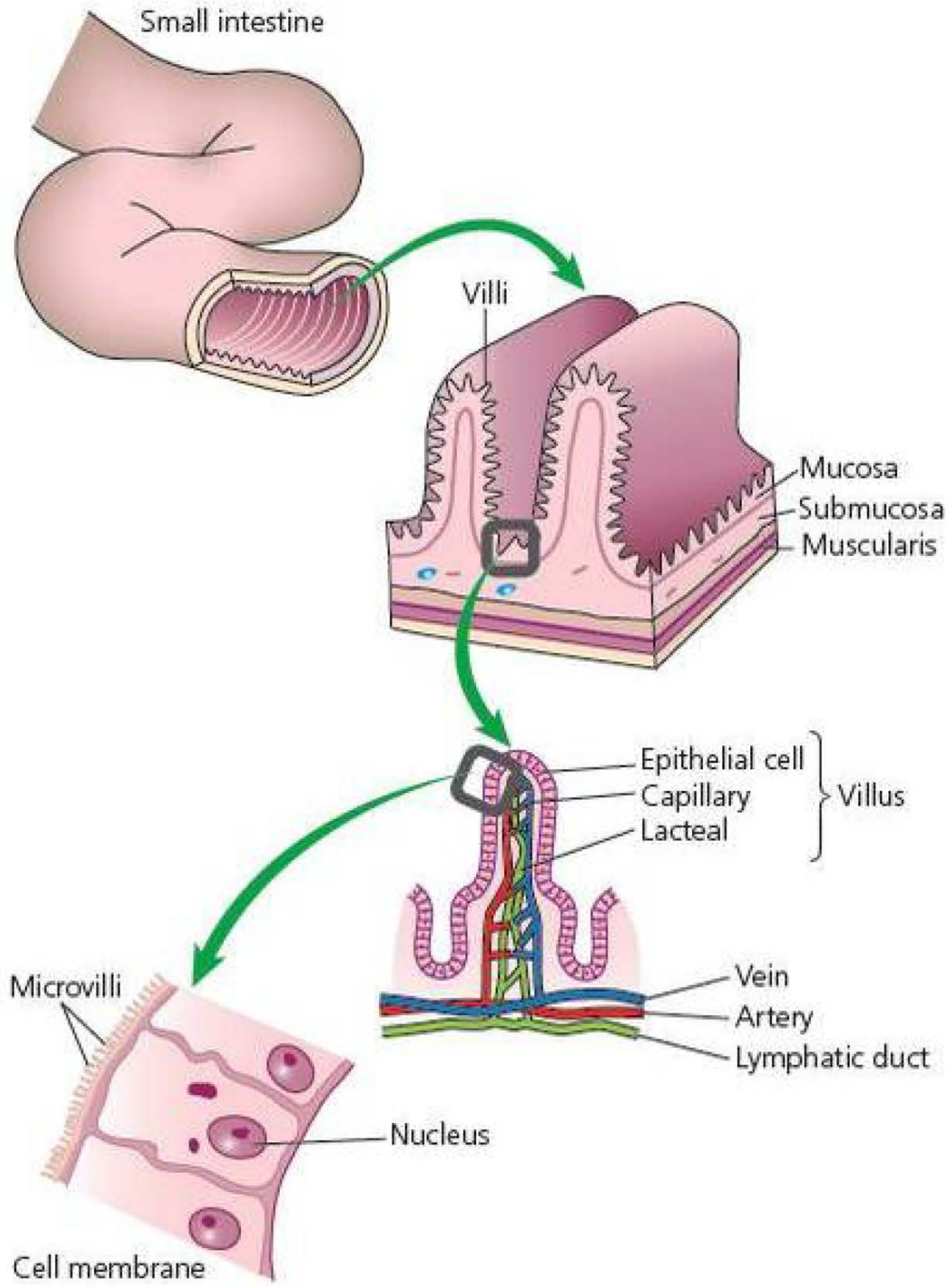


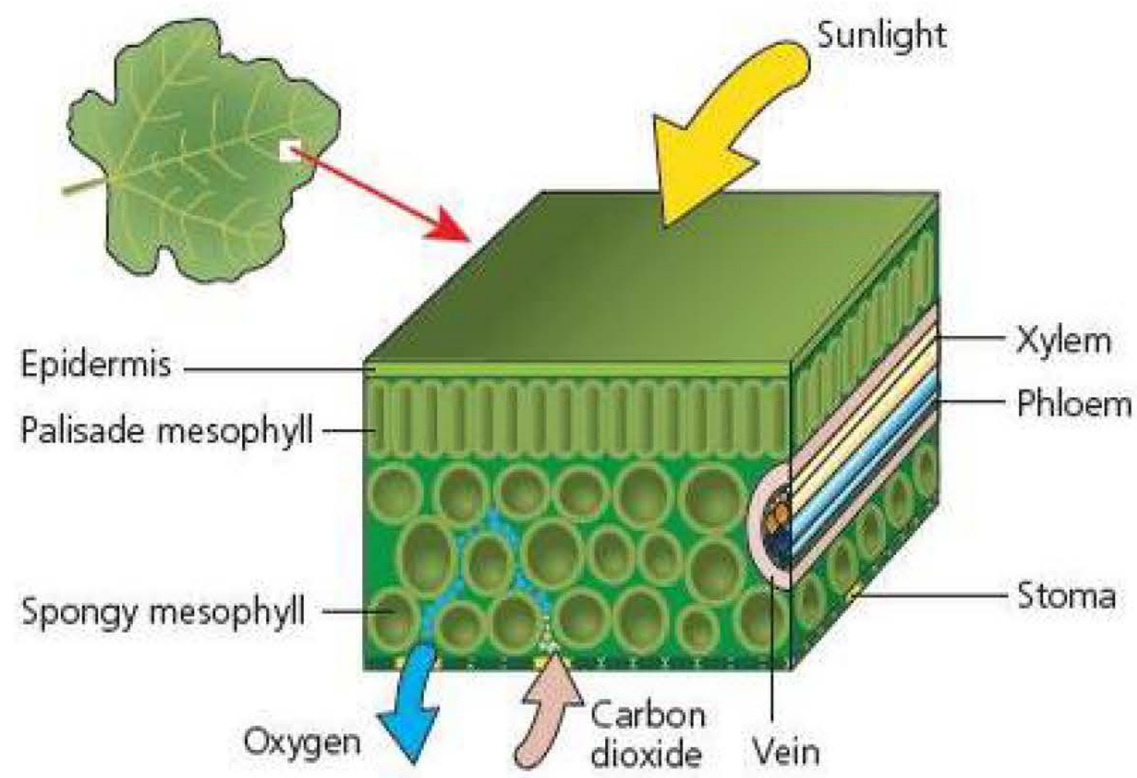
Figure 4.9 The placenta

- The placenta grows from the embryo and implants itself in the uterus (womb) of the mother: what role does it play for the embryo?
- Look carefully at the shape of the placental membrane (which absorbs food and oxygen from the mother): why is it highly folded in this way?
- What substances does the placenta remove from the embryo? (Think about waste products that must be removed from the body because they are toxic.)



■ **Figure 4.10** The small intestine

- **Look carefully at the lining of the small intestine, through which digested food is absorbed into the blood. What are villi? What essential adaptation do they have to increase the rate of absorption?**
- **Now look carefully at the cells that line the intestine on the surface of the villi – what adaptations do they have?**



■ **Figure 4.11** The structure of a leaf

- **The leaf has several different layers – what do you think each of these layers is for?**
- **Carbon dioxide, needed for photosynthesis, enters the leaf through stomata (plural of stoma), and oxygen leaves. There are airspaces between the cells in the spongy mesophyll layer that increase the surface area for diffusion of gases.**
- **Why are these adaptations needed? There is one common feature in all four organs that enable the organism to survive – can you identify what it is?**
- **All these adaptations are found in larger organisms, not smaller ones such as single-celled amoeba – why is this?**

◆ Assessment opportunities

- In this activity you have practised skills that are assessed using Criterion A: Apply scientific knowledge and understanding to solve problems.

How can the rate of movement of molecules be increased?

WHAT FACTORS SPEED UP THE RATE OF DIFFUSION?

Diffusion is the movement of **molecules** from higher to lower **concentration**. Think of an air-freshener that you spray into a room – it takes several seconds for the scent to reach all parts of the room, as the particles spread out from the can from a higher to lower concentration (concentration is a measure of number of molecules per unit volume).

ACTIVITY: What factors speed up the rate of diffusion?

Air-freshener

Stand at one corner of your classroom during a lesson. Spray air-freshener into the room. Who can smell the air-freshener first? What happens to the smell of air-freshener eventually? Can you **explain** your observations?

■ **Figure 4.12** Air-freshener diffusing through air

Potassium permanganate

Put a few crystals of potassium permanganate into a glass or Petri dish containing water. Watch what happens to the purple molecules of potassium permanganate. What happens to the purple colour eventually?
How could you speed up the rate at which the purple colour reaches all parts of the glass/Petri dish? Can you **explain** your observations?

■ **Figure 4.13** Potassium permanganate diffusing through water

Adding more crystals to the water would speed up the rate at which the purple reaches all parts of the container. This is because there is a greater difference in concentration between the area where the crystals were added and the rest of the water, and also because the greater number of crystals would have a greater surface area compared to only a few. Distance is also important – the students nearest to the air-freshener will smell the scent first as it has less distance to travel.

As we have already seen in Chapter 3, organisms need a variety of different substances to keep functioning, and to maintain life processes. Oxygen and glucose are needed for cellular respiration, and a variety of nutrients are needed to sustain metabolic processes.

Various factors speed up the rate at which substances can move into organisms. What are these factors? Think about the structures you have explored on pages 90–91 (the lungs, placenta, intestine and leaf) and the features that make them efficient at the job they do.

A fast rate of diffusion can be achieved by:

- increasing surface area
- decreasing the thickness of the diffusion surface
- maintaining a concentration gradient.

A concentration gradient is needed so that molecules can move from a higher to lower concentration. For example, in the lungs, oxygen is removed from the alveoli by the blood which maintains the difference between the oxygen concentration in air in the alveoli and the blood oxygen concentration.

A small diffusion distance is needed as the thicker the surface, the longer it will take for molecules to cross it. For example, there is a small distance between the mother's blood and that of the embryo, ensuring that the embryo gets food and oxygen quickly enough.

The larger the surface area, the faster molecules can move into (or out from) an organism. For example, the folds in the lining of the small intestine (the villi) allow digested food molecules to move into the blood at a rate that is fast enough to maintain life processes. Further folds on the membranes of the cells lining the intestine (**microvilli**) further increase the surface area.

Why do organisms need these **specialized** structures? Small animals do not have lungs/intestines/placenta, and microscopic plants do not need specialized leaf structures. What is it about larger organisms that make these specialized structures essential?

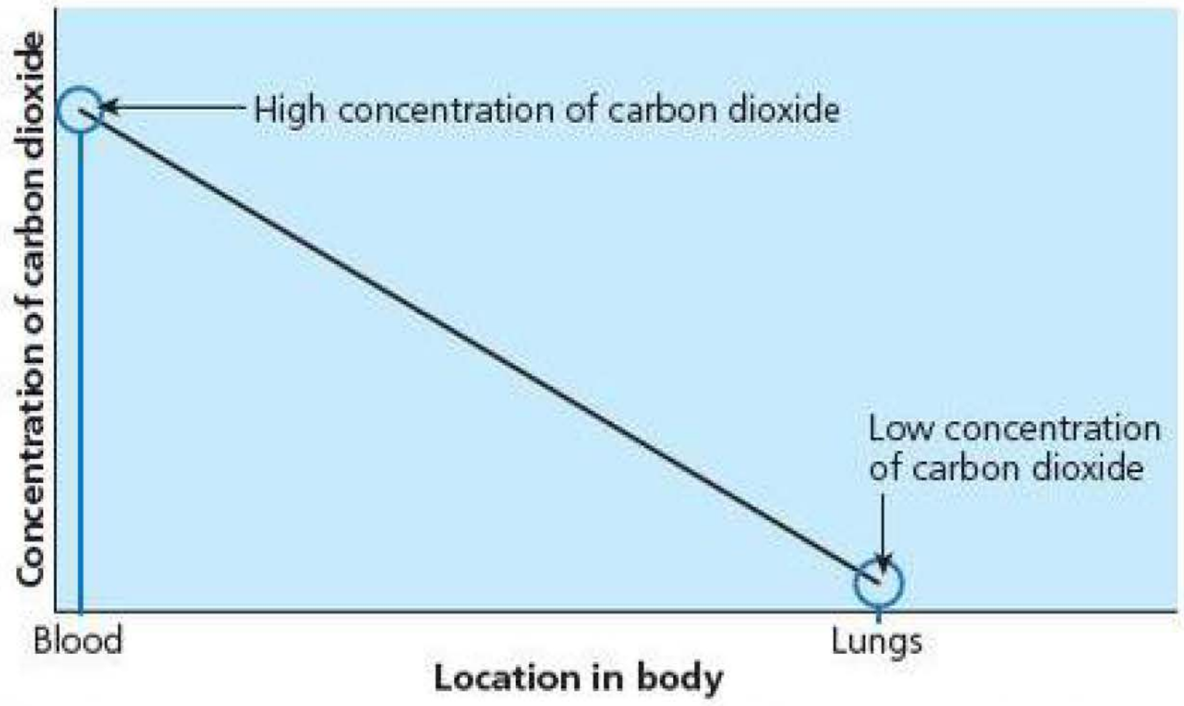


Figure 4.14 The concentration gradient in alveoli allows carbon dioxide to diffuse from the blood

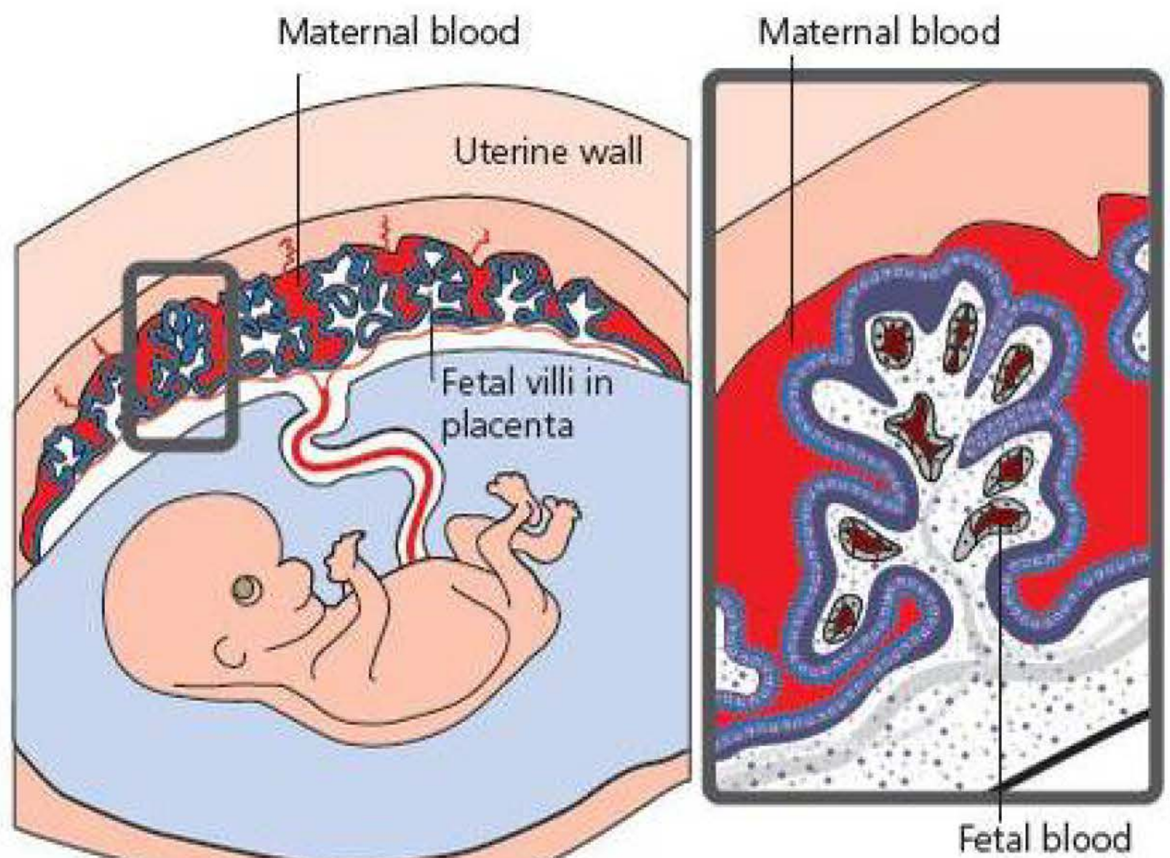


Figure 4.15 There is a short distance between maternal blood and fetal blood

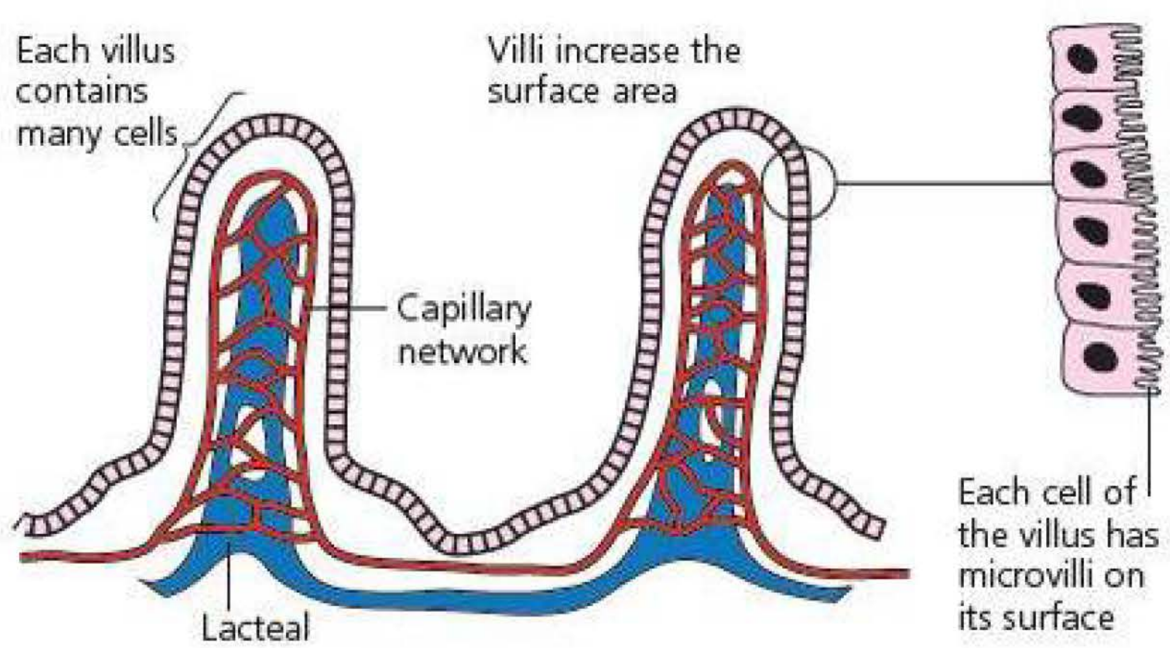


Figure 4.16 How villi and microvilli increase surface area in the small intestine

What is 'surface area : volume ratio' and why is it important to living things?

ACTIVITY: What happens to the surface area and volume of objects as they increase in size?

ATL

- Critical-thinking skills: Evaluate evidence

In this activity you will collect and **present** data relating to **surface area : volume ratio**.

Imagine that the three cubes below represent three different sized animals (it is easier to use these rather than real animals): let's investigate what happens as they increase in size …

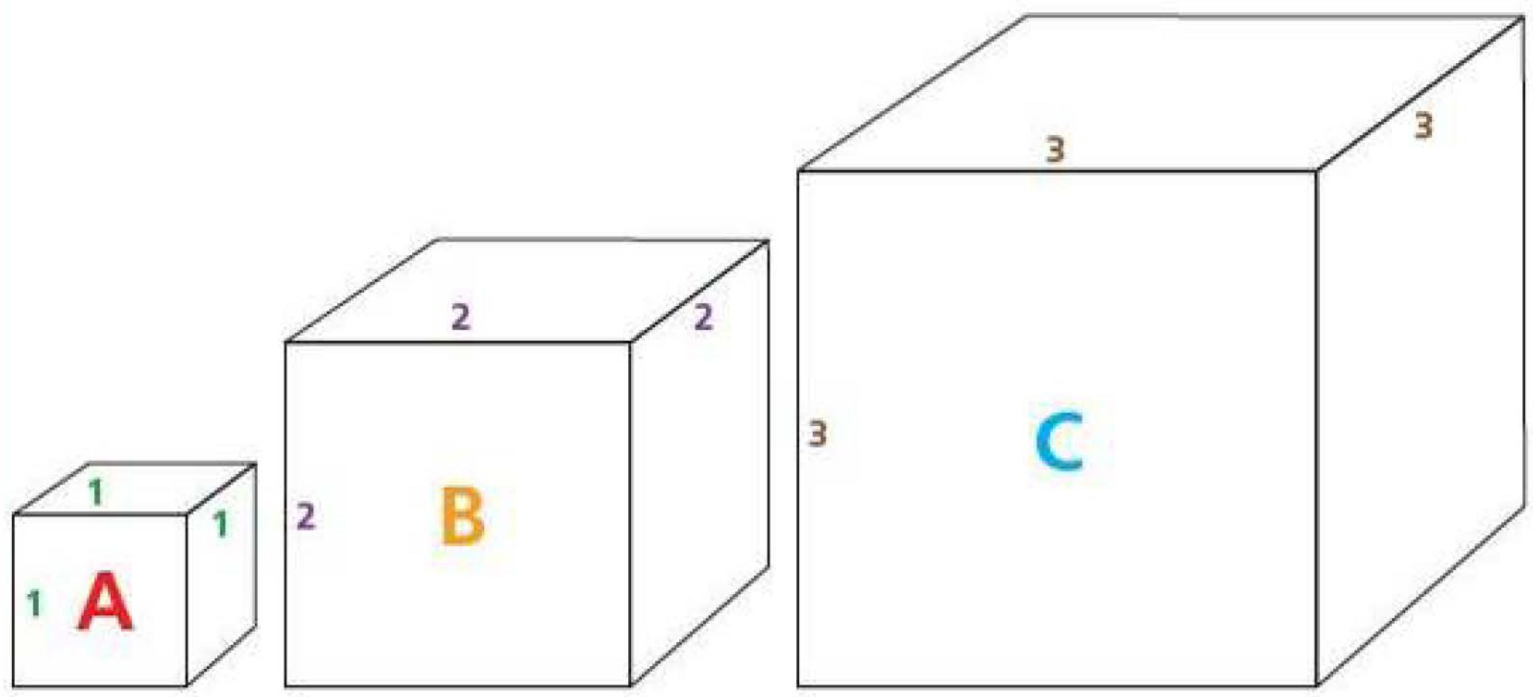


Figure 4.17 Three cubes representing animals of different sizes

1 **Work out the surface area of each cube. (Can you see why we are using cubes rather than real animals now?) Think of each cube spread out flat (see Figure 4.18 below) and the surface of each square added together to work out the total surface area.**

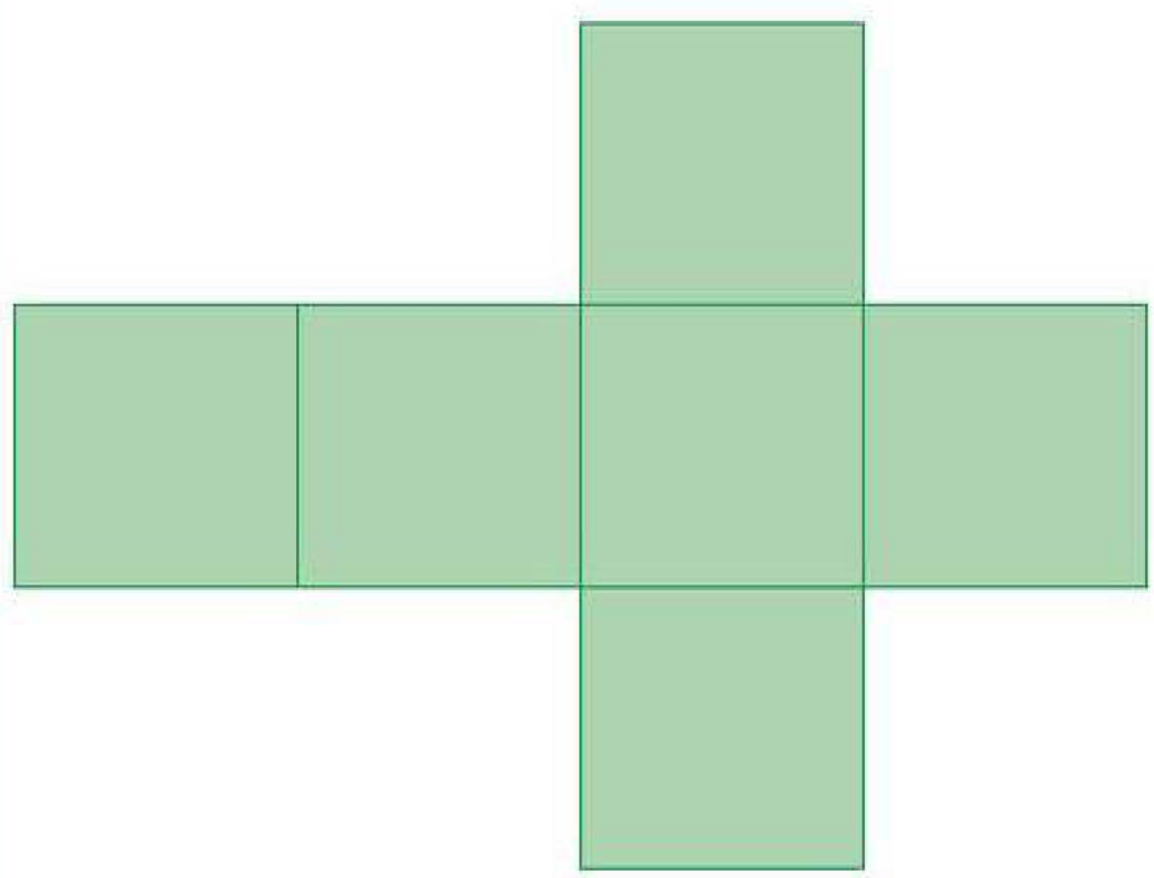


Figure 4.18 A 2D plan of a cube

2 Now work out the volume of each cube, by multiplying the width by the breadth by the depth (i.e. block A has a volume of $1 \times 1 \times 1 = 1\,cm^3$).
3 Finally, divide the surface area by the volume to work out the 'surface area : volume ratio'). Copy and complete Table 4.1.

Table 4.1 What happens as a block increases in size?

Block	Surface area of block/cm^2	Volume of block/cm^3	Surface area : volume ratio (surface area/volume)
A	$(1 \times 1) \times 6 =$	$1 \times 1 \times 1 =$	
B	$(2 \times 2) \times 6 =$	$2 \times 2 \times 2 =$	
C	$(3 \times 3) \times 6 =$	$3 \times 3 \times 3 =$	

The relationship between two variables may not be obvious – visual diagrams can help to reveal unexpected connections and create new ideas and avenues for further inquiry.

4 Imagine now a fourth block, 10 cm × 10 cm × 10 cm. Calculate the surface area : volume ratio of this block.
5 Now **sketch** a graph showing the relationship between size and surface area : volume ratio. Extrapolate your graph out to larger dimensions. What happens to the ratio as the block continues to get larger? Is it a linear relationship (i.e. a straight line)? If it is not a linear relationship, what does this tell you?

- What association have you found between surface area and volume as organisms increase in size?

Science is all about inquiry – but how do we know what questions to ask? Scientific inquiry often starts with some **preliminary observations** which lead us to make a **hypothesis** about how things work. We can then design an investigation to test the predictions we make.

Assessment opportunities

- In this activity you have practised skills that are assessed using Criterion C: Present data; Interpret data and explain results using scientific reasoning.

ACTIVITY: The effect of size and surface area on the movement of molecules

ATL

- Critical-thinking skills: Evaluate evidence

1 Take a 4 cm length of agar jelly with a cross-sectional area of 2 cm^2. The jelly has been made with phenolphthalein indicator which is an indicator that turns colourless in the presence of acid: the indicator stains the jelly pink. Cut the agar block in half to create two 2 cm^3 cubes (one of these cells will be called cell A). The cubes represent model cells, which will be used to investigate how quickly material can diffuse throughout the cell. Cut the other 2 cm^3 cube in half to create a cell 2 cm^3 by 2 cm^3 by 1 cm^3 (cell B). Cut the remaining block in half so that you have a 2 cm^3 by 1 cm^3 by 1 cm^3 cell (cell C) and the remaining part in half again (cell D). Cut the final piece in half to create cell E so that you have five cells of different sizes in total.

■ **Figure 4.19** Apparatus for experiment into rate of diffusion compared to cell size

2 Place the five models cells, each of a different size, in 1 M hydrochloric acid (make sure you are wearing eye protection). As the acid diffuses into the agar 'cells' the indicator will lose its colour and turn colourless. The acid represents essential materials needed by the cell for metabolic reactions – the faster the substances reach all parts of the cell, the more likely the cell is to survive.

Safety: Wear eye protection when handling the acid. Wash your hands after the experiment.

Hypothesis

Formulate and **explain** a testable hypothesis using correct scientific reasoning.

Predict what will happen to each model cell. Which will show the fastest rate of diffusion? Which will show the slowest rate of diffusion? What do you think will happen to the surface area : volume as the blocks increase in size?

Carry out the experiment

Observe what happens to the model cells. Time how long it takes for each cell to turn completely clear. Compare the results and record your data in a table.

Repeat the experiment to improve reliability; take care cutting the cubes to ensure your results are accurate. How could you improve the precision of the experiment?

reliability Results are repeated so that a mean can be calculated, and any results that do not fit the overall pattern of data can be identified as anomalous.

precision The number of decimal places that can be reliably measured. For example, if a digital balance can measure to two decimal places then this is the precision that can be recorded in a results table.

3 **Calculate** the surface area, volume and surface area : volume ratio for each agar block. You need at least five values for the independent variable.

Observe the changes that occur as the blocks increase in size by measuring the time taken for each block to change colour.

Accurately **interpret** your data and **explain** your results using correct scientific reasoning.

Evaluate the validity of your hypothesis based on the outcome of the investigation.

Evaluate the validity of the method based on the outcome of the investigation.

Explain improvements or extensions to the method that would benefit the investigation.

Explain, using the results from the experiment, why single-celled organisms can never become very big.

Explain, using the results from the experiment, why cells are the size they are.

Predict, using the results from the experiment and your own knowledge, what cells can do when they become too large.

◆ Assessment opportunities

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

As organisms increase in size their surface area : volume ratio decreases.

As objects increase in size, their volume increases at a faster rate than their surface area (as we have seen). This means that larger organisms have a smaller surface area compared to their size. Living things depend on the constant exchange of nutrients, gases and waste with their environment – smaller organisms can achieve this across their surface without the need for specialized structures, as the surface area is very large compared to their size. Larger organisms need specialized structures to increase the surface across which vital materials can be taken into their body, and wastes removed.

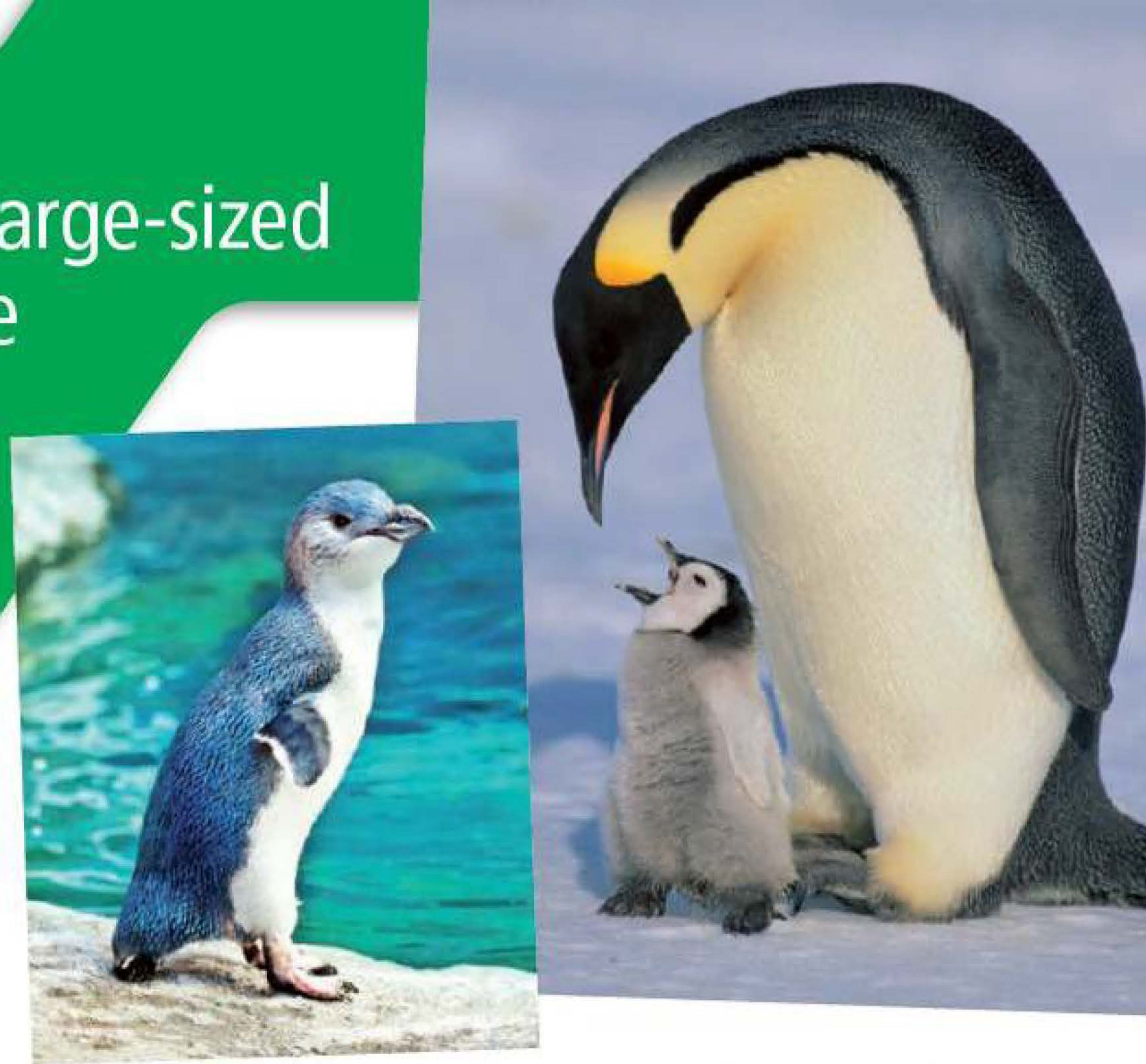
The issue of surface area relative to size also determines the size that cells themselves can be. What happens to a cell as it increases in size? Why might this create problems for the survival of the cell?

I USED TO THINK …, BUT NOW I THINK …

Reflect on what you have learnt so far …

- **Summarize the implications that an increase in size has for organisms.**
- **Has your understanding about how organisms are adapted to their environment changed as a result of what you have studied so far this chapter? Summarize in a few sentences, if this is the case, how your thinking has changed.**

When is having a large-sized body an advantage and when is it a disadvantage?



■ **Figure 4.20** A fairy penguin (height = 41 cm) and an emperor penguin (height = 1.3 m)

BEING BIG – A PROBLEM OR A SOLUTION?

Not all penguins live in cold environments. The fairy penguin lives on the coasts of Australia and New Zealand. Look at the two photos in Figure 4.20: the fairy penguin (left) and the emperor penguin (right). The emperor penguin is much larger than the fairy penguin. Why do you think this is?

THINK–PAIR–SHARE

ATL

- Creative-thinking skills: Make unexpected connections between ideas; Generate new ideas

■ **Figure 4.21** Big dog, small dog

Imagine you go to live at the South Pole, and want to take a dog with you. Predict which dog in Figure 4.21 would be best suited to these conditions. Why is this? Imagine you go somewhere to live that is hot, such as the Sahara. Predict which dog would be best suited to these conditions. Why is this?

Compare the optimal **habitat** for the two dogs. Use your knowledge of the effect of size on surface area:volume to **explain** your observations.

Assessment opportunities

- In this activity you have practised skills that are assessed using Criterion B: Formulate a testable hypothesis and Criterion C: Interpret data and explain results using scientific reasoning.

ACTIVITY: How body size affects the rate of heat loss from animals

ATL

- Critical-thinking skills: Evaluate evidence

Fairy penguins can be up to 41 cm in length. Emperor penguins are, in contrast, the largest species of penguin, with male adults reaching up to 1.3 m and weighing 45 kg. The emperor lives in Antarctica and is large, and the fairy penguin lives in Australia and New Zealand and is small. This experiment investigates the advantage of having a larger body size and mass in cold environments.

You will **measure** the rate of heat loss in two beakers, representing the emperor (large beaker) and fairy penguins (small beaker). Predict which beaker will lose heat the most quickly.

1. Take two glass beakers, one 500 ml and the other 100 ml.
2. Fill the two beakers with hot water (as near to 75 °C as possible). 75 °C is used because it is much higher than room temperature.
3. Immediately start recording the temperature in each beaker with the thermometer. Record the temperature in each beaker every minute for 15 minutes. If you have data-logging equipment use it to record your data.
4. **Plot** graphs of the results. Make sure the graphs are properly labelled.
5. Did your results match your prediction? **Explain** why one beaker had a slower rate of heat loss than the other, using your knowledge of surface area : volume ratio. Which environment would this penguin live in?

Safety: Take care handling the hot water.

Figure 4.22 Penguin experiment

Assessment opportunities

- In this activity you have practised skills that are assessed using Criterion B: Formulate a testable hypothesis and Criterion C: Interpret data and explain results using scientific reasoning.

The photos in Figure 4.23 show pairs of animals from different parts of the world. Both bears and foxes are found in both warm/temperate environments and also cold/northern environments. The sun bear (upper left) is found in the rainforests of Southeast Asia, and is the smallest bear species. The polar bear (bottom right) is the largest bear species, and is found in the Arctic Circle. The European (or 'red') fox (bottom left) is found throughout northern hemisphere, from Europe through to North Africa, Central America and Asia. The Arctic fox (top right) is native to the Arctic Circle.

Look carefully at the photos in Figure 4.23. How are the animals adapted to the environment they live in? Think about their size and shape – how do these factors adapt them for cold or warmer conditions?

Write down as many adaptations for each animal as you can think of, and the reasons for each adaptation. Do this now.

Many Arctic animals, such as the polar bear, have white fur made of hollow hairs, which act as camouflage and trap warm air next to the skin. Sunlight is transmitted down the hairs to the bear's black skin, which absorbs the light and changes it to heat. But if you look carefully at these animals, you will also see that the shapes of the animals are different depending on where they are found in the world. Why is this? How does shape help them adapt to their environment?

Larger animals found in warmer environments find it difficult to lose heat. They can get round this by increasing their surface area, by having large ears (the African elephant is a good example of this – see Figure 4.1) or spending much of the day in water (the hippopotamus only emerges from rivers once the hot sun has set, feeding on grass in the savannah during the cool of the night).

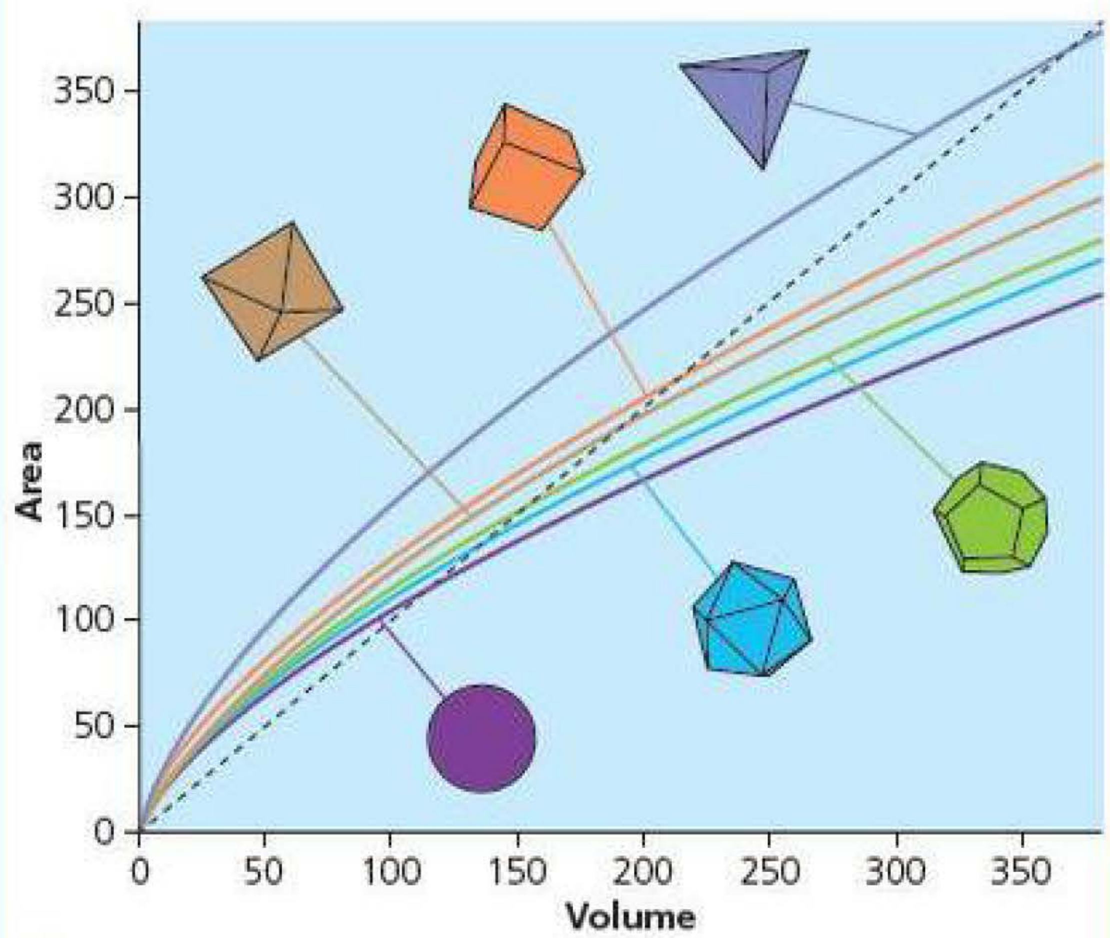
Larger animals need greater amounts of food and energy to support their metabolism. More cells mean more nutrients. This can be an issue for larger animals. However, smaller animals, because they lose more heat, have to have a relatively high metabolic rate (rate of respiration) to sustain life processes – what issues does this raise for them?

■ **Figure 4.23** Foxes and bears from different environments

Which body shape is best for living in cold environments?

THINK–PAIR–SHARE

Figure 4.24 shows the relationship between the volume and surface area of different three-dimensional shapes.



■ **Figure 4.24** Graphs of surface area against volume for different solid shapes

Compare the curve for the sphere with the curve for the pyramid. Which has the greatest ratio? Which has the smallest ratio? Use this information to identify the optimum shape for animals in cold environments.

◆ Assessment opportunities

- In this activity you have practised skills that are assessed using Criterion B: Formulate a testable hypothesis and Criterion C: Interpret data and explain results using scientific reasoning.

HOW DOES SHAPE AFFECT SURFACE AREA : VOLUME RATIO?

An animal with a small surface area : volume ratio is well adapted to cold environments as it will lose heat more slowly than other animals.

Body shape is an important adaptation in animals. We have already seen how surface area to volume ratio decreases with increasing volume – this is shown again in the graph of different shapes (left). Surface area decreases for rounder shapes, and increases with shapes such as cubes and pyramids. But what effect does this have on animals, or even plants come to that? Look again at the animals in Figure 4.23. Are the animals from warmer environments the same shapes as those from the North and South Poles? What shape are the animals from the ice and snow-covered habitats? Which shape would minimize their surface area compared to their volume, reducing heat loss and increasing chances of survival? Angular or spherical?

The body shape of animals in colder environments is adapted to minimize heat loss. Legs, ears and tail tend to be shorter, which also helps to conserve heat. For example, compared with the red fox, the Arctic fox has a rounder body, thicker fur, shorter legs and tail, as well as a shorter muzzle and ears. Having a lower surface area for their size, by being rounder in shape, means that animals such as the emperor penguin and polar bear lose less heat compared to their relatives from warmer climates. As we can see, the best shape for an animal in cold environments would be a perfect sphere! This isn't a very practical shape for a bird that swims, but the shape of a penguin is fairly close to this.

Critical-thinking skills: Identifying similarities and differences between things is a good way to see 'patterns' and connections – and these help us to understand the bigger picture.

ACTIVITY: How animal behaviour can improve the chances of survival

ATL

- Critical-thinking skills: Evaluate evidence

1 Take eight test tubes. These will represent individual penguins (in the same way that we used beakers to model penguins in the Activity on page 99).
2 Set up one test tube by itself, and the remaining seven test tubes into a bundle, held by an elastic band.

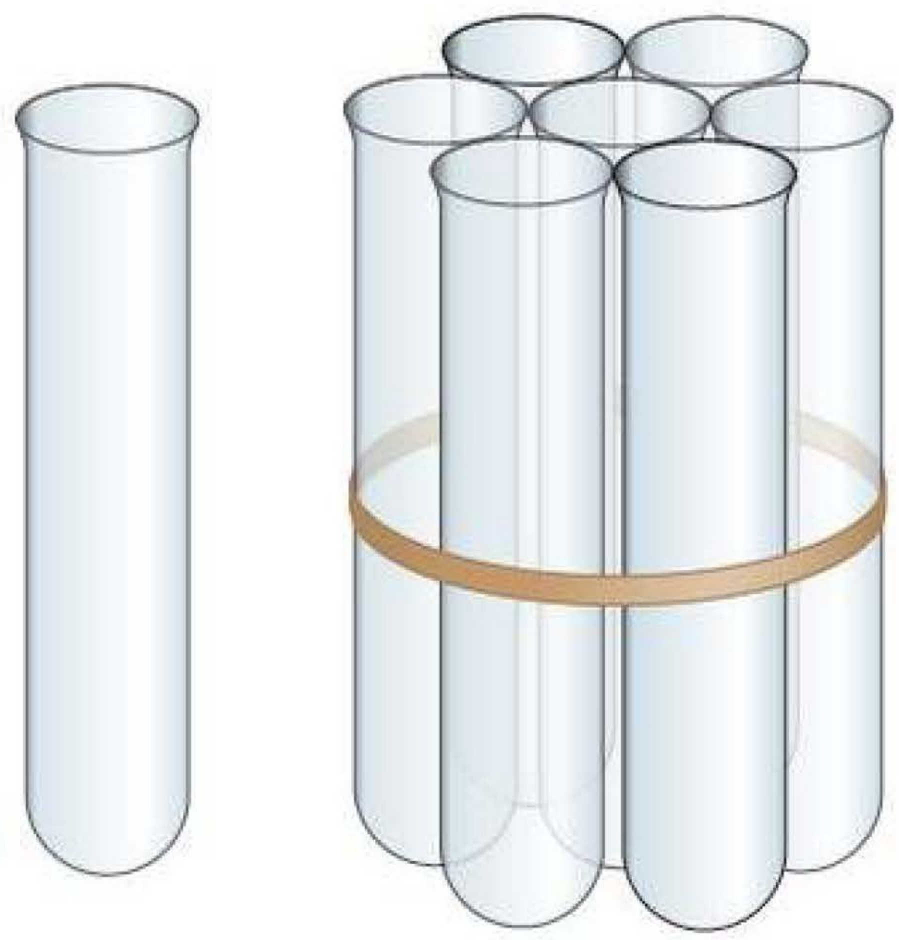


Figure 4.25 Penguin-huddling experiment

3 Put water that has just boiled into each test tube. Fill each test tube two-thirds full. **TAKE CARE** with the hot water.
4 Immediately put a thermometer into the central test tube in the huddle, one at the edge of the huddle, and one in the solitary tube.
Predict which penguin will lose the most heat, and which will lose the least heat.
5 Record the temperature for 15 minutes. Do this for the test tube on its own, the one in the middle of the huddle and one at the edge of the huddle.
6 **Plot** the data for each of the three penguins on a graph. **Explain** what is shown. Use what you have learnt about surface area : volume ratio to **explain** why the huddle lost less heat than the solitary penguin.

Hint

The huddle acts like one large organism – its larger size means that it has a lower surface area compared to its volume and therefore loses less heat.

Information literacy skills: Processing data and reporting results are essential skills in scientific research.

Safety: Take care handling the hot water. Ask your teacher to fill the test tubes. Remain standing throughout the experiment in case of spillages.

Assessment opportunities

- In this activity you have practised skills that are assessed using Criterion B: Formulate a testable hypothesis; this activity can be assessed using Criterion C: Interpret data and explain results using scientific reasoning.

Huddling in emperor penguins reduces heat loss. The male emperor endures a 115-day ordeal, during which he courts, mates and incubates an egg without eating a single meal. Along with this, he has to cope with wind-chill temperatures reaching down to minus 60°C. The males conserve their energy by huddling together to keep warm. Emperor penguins have to face freezing winds (called katabatic winds), which blow off the polar plateau and intensify the cold. Huddling cuts the heat loss by as much as 50%, and enables males to survive the long incubation fast since the warmer they are, the longer their fat lasts.

As we have seen above, the large huddle has a lower surface area : volume ratio than a solitary penguin, so that less heat is lost. This shows that animal behaviour can also be related to the concept of surface area relative to size, as well as the other issues we have explored in this chapter.

! Take action

- As well as issues concerning surface area : volume ratio, large animals often live in habitats threatened by human activities, and face extinction as a result. In this chapter we have examined how animals are adapted to the environment in which they live. Habitats that are being encroached on by human activities, such as deforestation, mining or hunting, suffer damage as a result. Animals that live in these degraded habitats can no longer survive, and so become endangered.

■ **Figure 4.26** Sumatran tiger

- News article: 'Sumatran tigers on the brink of extinction':

  www.worldwildlife.org/press-releases/sumatran-tiger-on-brink-of-extinction

- Read about illegal trade in wildlife here:

  www.worldwildlife.org/threats/illegal-wildlife-trade

- Many top predators are under threat – a recent study has shown that out of 31 predator species, three-quarters are in decline, including cheetahs, leopards, polar bears, tigers, giant otters and many species of wolf. Habitat loss through human disturbance is one of the main reasons why these large animals are under threat, combined with hunting and exploitation by humans.

- News article: 'How the threat to lions, leopards and wolves endangers us all' (*Guardian* newspaper, January 2014):

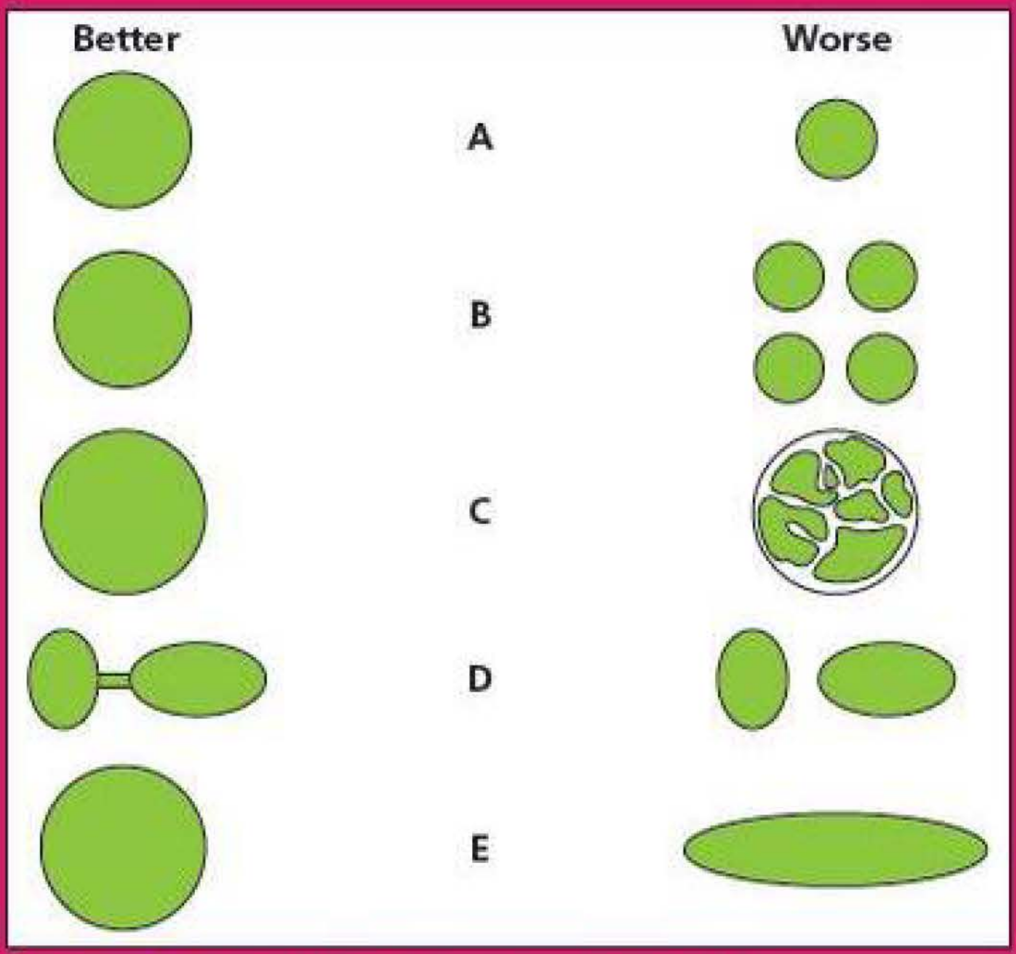
  www.theguardian.com/environment/2014/jan/26/endangered-species-carnivores-extinction

- Animals can be protected in their natural habitat (*in situ* conservation) or in artificial environments such as zoos (*ex situ* conservation).

- Protected areas contain habitats that endangered animals are adapted to, and ensure that species have the necessary space to survive. Read about the design of protected areas here (go to the section titled 'Conserve Natural Areas According to Ecological Principles'):

  www.extension.org/pages/31821/conservation-subdivision:-design-phase-patch-size-and-shape-of-conserved-open-spaces#.VCfi8mddXww

- Reserve design considers the spatial arrangement of the habitats needed by the species, as well as how the species will respond through time.



■ **Figure 4.27** The shape and size of reserves, as well as how they are connected together, is important in designing a protected area

- Read about how zoos can help protect endangered animals here:

  www.zsl.org/conservation-initiatives/conservation-breeding

- As well as conserving animals in the wild and in zoos, trade in endangered animals (either whole animals or body parts) can be prevented by countries cooperating with one another. Read about this here:

  www.cites.org/

ACTIVITY: How can large animals be best protected?

Choose an animal that is under threat of **extinction** using one of these sites:

www.wwf.org.uk/wildlife/

www.iucnredlist.org/

Find out about ways in which the species can be protected. Use science to **explain** how the scientific solutions would work, for example one based on the area required by the animal to survive relating to its reproductive capacity, population size, and habitat requirements. Which ways do you think would work best for the species you have selected? You must think about the pros and cons of *in situ* and *ex situ* conservation. Could CITES (Convention on International Trade in Endangered Species of Wild Fauna and Flora – an organization helping to control the trade in endangered species) play a role in protecting your species?

Here is an example of how one species of large mammal is being protected:

www.worldwildlife.org/species/elephant

Write your research findings in the form of a report to the government, and make a recommendation at the end: what are the best ways, in your view, for improving the chances of survival of your endangered animal? Make sure you use science to **explain** how the scientific solutions would work.

◆ Assessment opportunities

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

WHAT ISSUES DO LARGER ORGANISMS FACE?

As organisms increase in size their surface area does not increase at the same rate as their mass or volume: this not only affects how big cells can be, but also explains why larger animals need specialized structures such as lungs and intestines. In order to maintain themselves and sustain life, food and oxygen needs to be taken into cells and wastes removed (Chapter 3). Surface area : volume explains why cells can't simply get bigger and bigger, as above a certain size they would not be able to absorb fast enough all the substances they need to survive – this is why tissues and organs (Chapter 1) are needed, built out of many millions of individual cells, in larger organisms. It explains why leaves are flat and animals in colder environments have a rounder body shape than their relatives in warmer climates.

In the next chapter, we will be considering how artificial and naturally occurring factors affect human health. Some illnesses affect the functioning of the human body by reducing the surface area of certain organs – meaning that the substances needed by the body cannot be absorbed fast enough. We will see how surface area, in relation to the volume of living things, can explain the causes of certain illnesses, in addition to the various issues we have explored in this chapter.

c **Interpret** the data to make a judgement as to why flatworms (phylum Platyhelminthes) do not need specialized surfaces for absorbing oxygen or food into their bodies.

SOME SUMMATIVE PROBLEMS TO TRY

Use these problems to apply and extend your learning in this chapter. These problems are designed so that you can evaluate your learning at different levels of achievement in Criterion A: Knowing and Understanding.

THIS PROBLEM CAN BE USED TO EVALUATE YOUR LEARNING IN CRITERION A TO LEVEL 1–2

1 Using what you have learnt in this chapter, try to improve your explanations for the effect that shape has on surface area : volume ratio.

The table below shows five objects that gradually become flatter. Object 1 is a cube, which is then gradually flattened more and more (objects 2–5). The original cube is made thinner and thinner while maintaining the original volume. Find out what happens to the surface area and surface area : volume ratio as the box is flattened by completing the table below.

a **State** the relationship between surface area and volume as organisms increase in size.

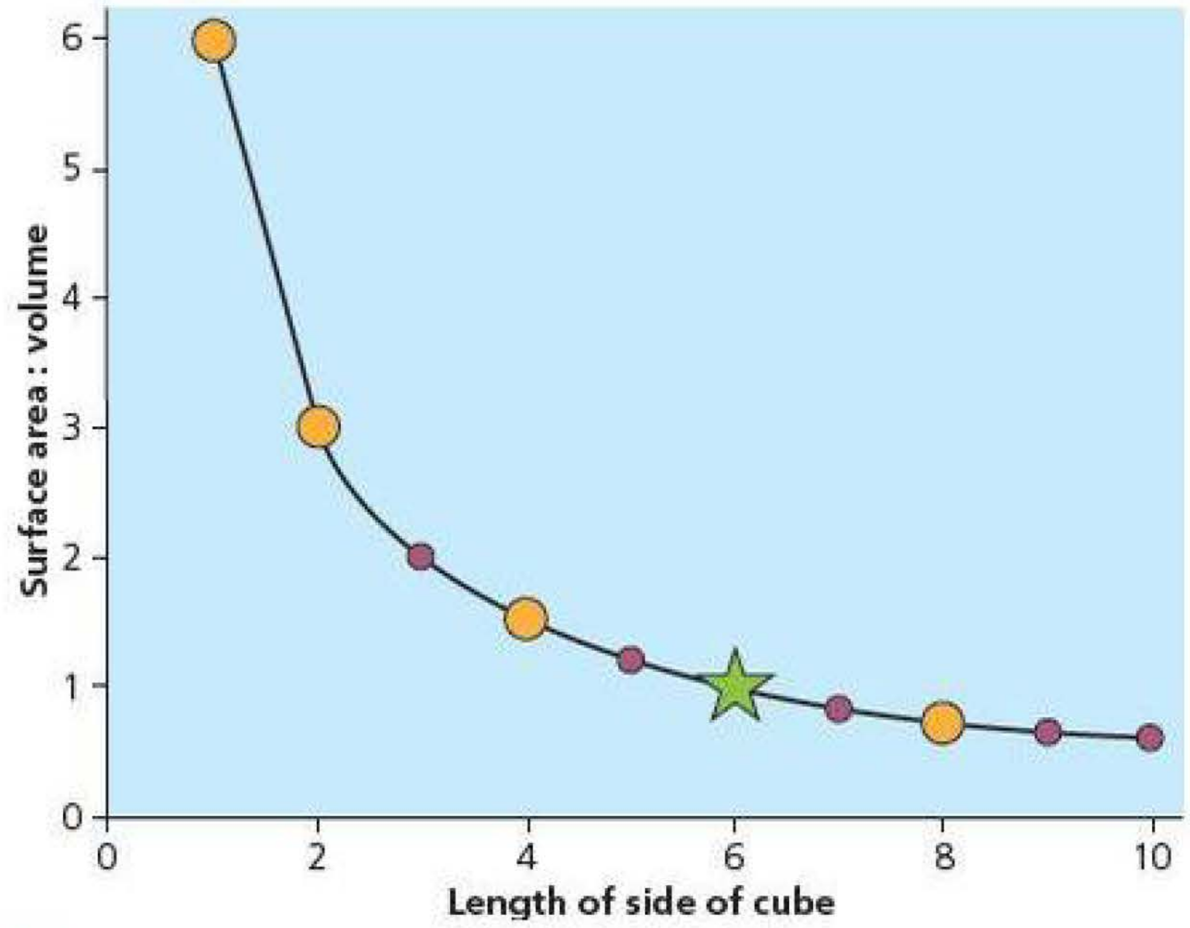
b Using the data in the table, **suggest** a solution that explains why surface area increases even though the volume of the animals stays the same.

■ **Table 4.2** What effect does flattening an object have on its surface area : volume ratio?

Object number	Height (mm)	Length (mm)	Width (mm)	Surface area (mm^2)	Volume (mm^3)	Surface area : volume ratio
1	4	4	4	192	256	
2	2	8	4	224	256	
3	1	8	8	320	256	
4	0.5	16	8	560	256	
5	0.25	16	16	1056	256	

THIS PROBLEM CAN BE USED TO EVALUATE YOUR LEARNING IN CRITERION A TO LEVEL 3–4

2 The graph below shows the relationship between surface area : volume ratio and the size of an object.



■ **Figure 4.28** The relationship between size and surface area : volume ratio

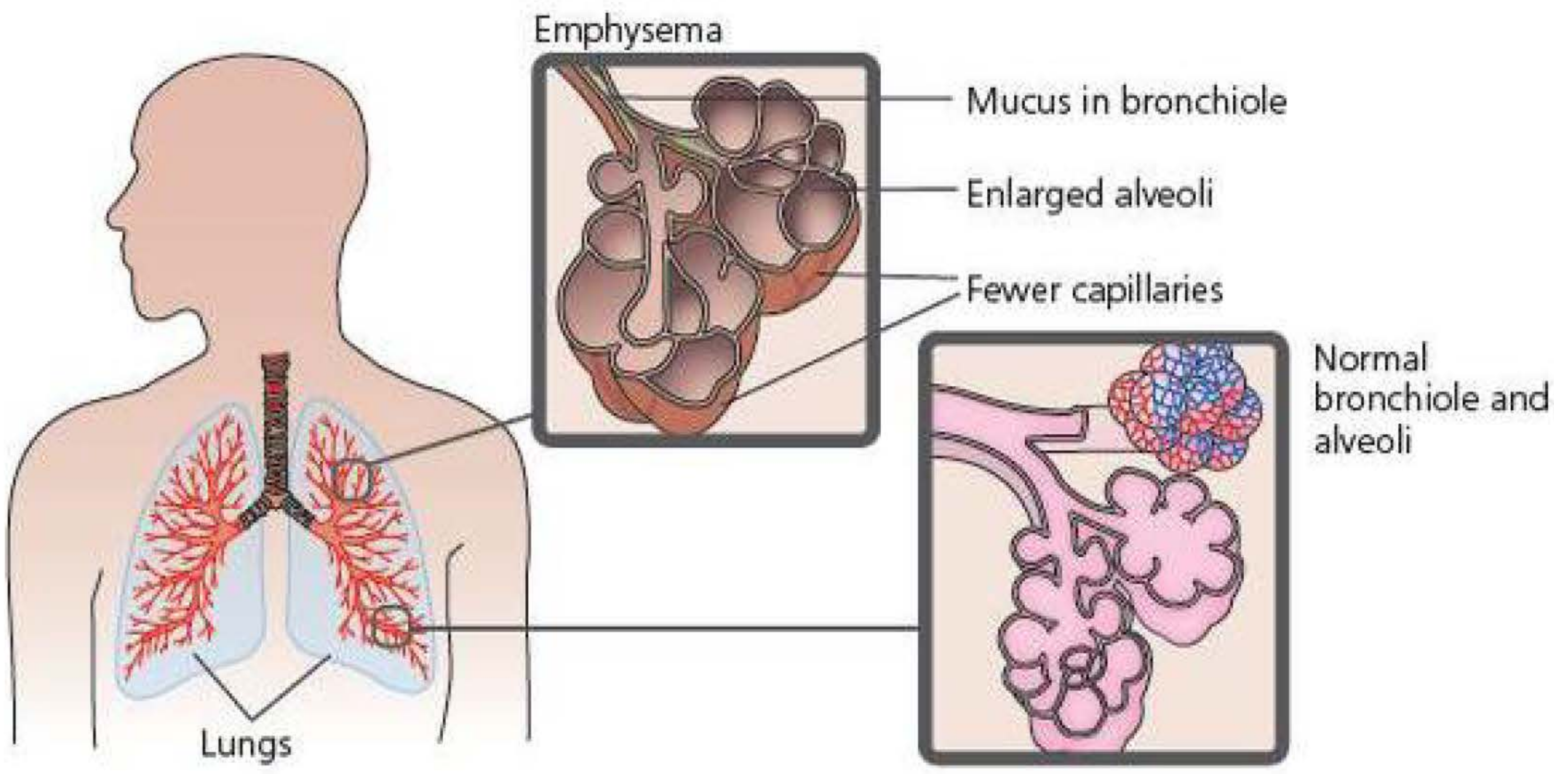
a **Outline** the relationship between surface area : volume and the size of an object.

b **Apply** your knowledge of surface area and volume to **explain** the relationship between surface area : volume ratio and the size of an object shown in the graph.

c **Interpret** the data to make a scientifically supported judgement to **explain** how surface area : volume ratio limits cell size.

THIS PROBLEM CAN BE USED TO EVALUATE YOUR LEARNING IN CRITERION A TO LEVEL 5–6

3 The following diagram shows the gas exchange surfaces (alveoli) of a healthy person and someone with a disease called emphysema. Emphysema can be caused by cigarette smoking over a long period of time. Persistent coughing by the smoker, and damage from chemicals in the cigarette tar, damage the walls of the alveoli.



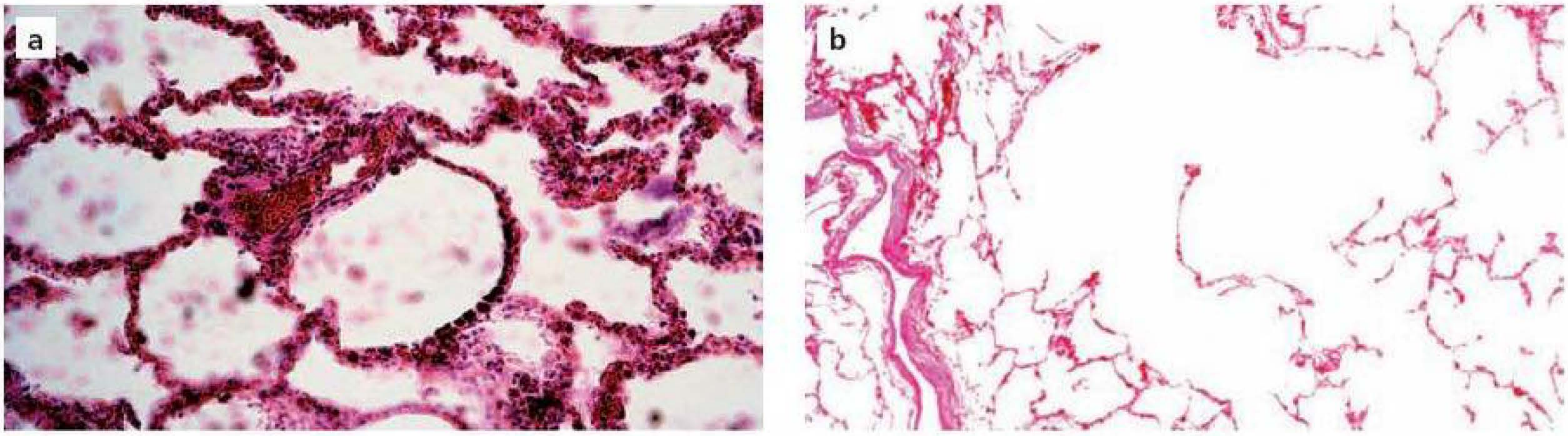
■ **Figure 4.29** Healthy and affected alveoli in someone with emphysema

Figure 4.30 shows slides made from sections of lungs taken from a healthy person (left) and someone with emphysema (right).

a **Describe** how the structure of the alveoli of a healthy person relates to their function.

b **Describe** the difference between healthy alveoli and those from a person with emphysema.

c How would the differences you have observed affect the person with emphysema (i.e. what symptoms would they show)? **Analyse** the photos so you can make a scientifically supported judgement.



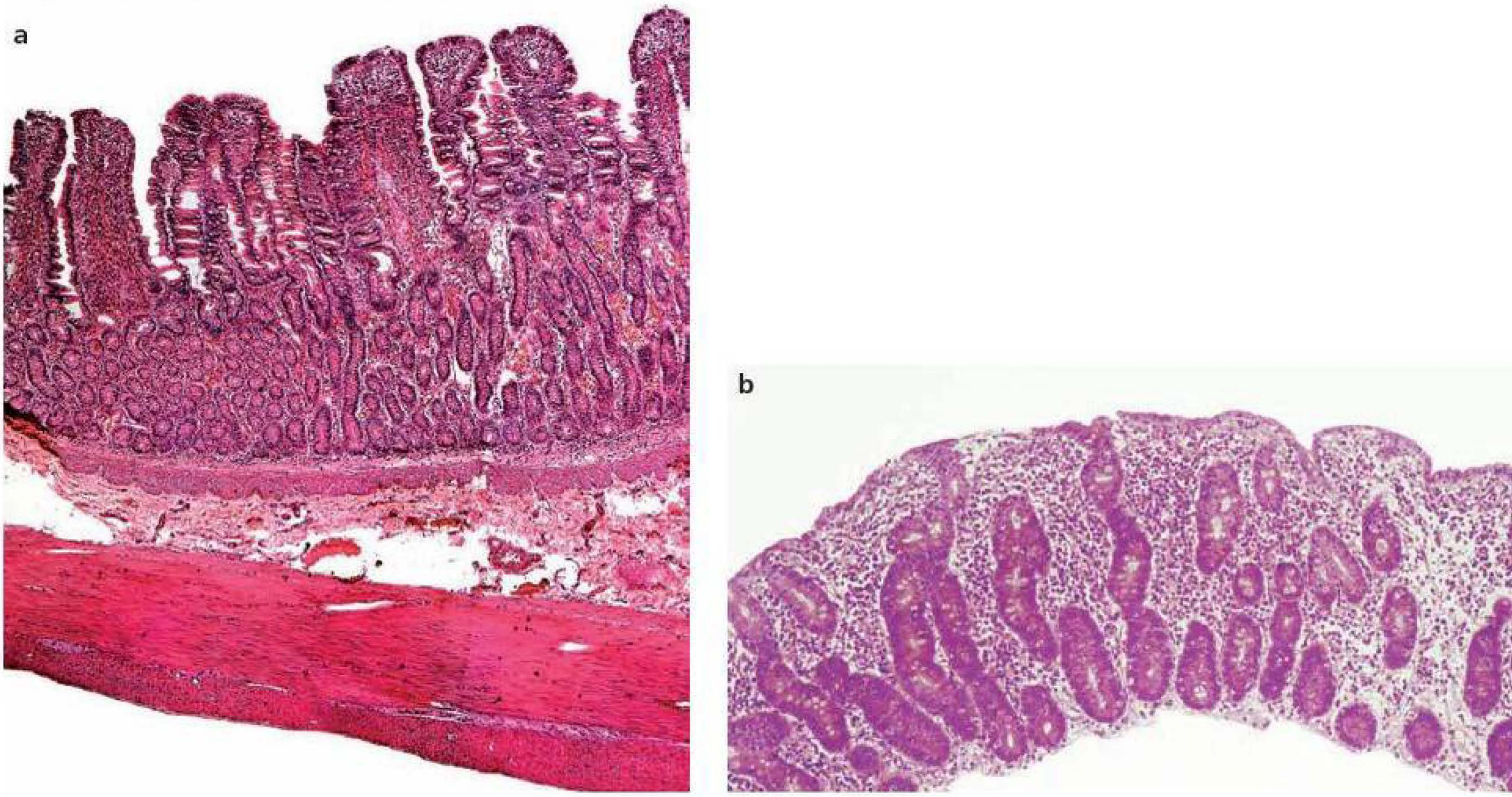
■ **Figure 4.30** (a) Alveoli of a healthy person, (b) alveoli of someone with emphysema

THIS PROBLEM CAN BE USED TO EVALUATE YOUR LEARNING IN CRITERION A TO LEVEL 7–8

4 Look at Figure 4.31 below, showing the small intestine of a healthy person (left) and someone with an illness called coeliac disease (right).

Coeliac disease is caused when a person is allergic to gluten – an immune response, in reaction to any gluten in the food eaten, causes the defence mechanisms to attack the person's own gut tissue.

Analyse the information you have been given about coeliac disease to make a scientifically supported judgement about the symptoms you would expect a person with coeliac disease to show.



■ **Figure 4.31** (a) The small intestine of a healthy person, (b) someone with coeliac disease

Reflection

In this chapter we have seen how size affects the way that organisms interact with their environment. We have explored how many scientific phenomena, such as cell size, the shape of animals in different environments, and huddling behaviour in emperor penguins, can be explained using the concept of surface area : volume ratio. We have explained why larger animals need specialized structures such as lungs and intestines in order to maintain body processes. We have had opportunity to develop as a thinker through various critical-thinking activities.

<table>
<tr><th colspan="6">Use this table to reflect on your own learning in this chapter</th></tr>
<tr><td>Questions we asked</td><td>Answers we found</td><td colspan="4">Any further questions now?</td></tr>
<tr><td>Factual: In what ways are organisms adapted to the environment they live in? What structures do larger organisms have in order to efficiently exchange nutrients, gases and waste with their environment? What are the adaptations or specialized features of cells, tissues, and organs that increase surface area?</td><td></td><td colspan="4"></td></tr>
<tr><td>Conceptual: How does the size of an organism determine its needs for energy and nutrients? What role does surface area : volume ratio play in determining the efficiency of transfer of substances into and out of organisms? How does the shape of an organism help adapt it to the environment it lives in? How does the behaviour of an animal help adapt it to the environment it lives in?</td><td></td><td colspan="4"></td></tr>
<tr><td>Debatable: How important is it to protect endangered animals? How can the design of conservation areas, and zoos, help meet the needs and support the survival of larger animals?</td><td></td><td colspan="4"></td></tr>
<tr><td rowspan="2">Approaches to learning you used in this chapter</td><td rowspan="2">Description – what new skills did you learn?</td><td colspan="4">How well did you master the skills?</td></tr>
<tr><td>Novice</td><td>Learner</td><td>Practitioner</td><td>Expert</td></tr>
<tr><td>Critical-thinking skills</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Creative-thinking skills</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Learner profile attribute(s)</td><td colspan="5">How did you demonstrate your skills as a thinker in this chapter?</td></tr>
<tr><td>Thinker</td><td colspan="5"></td></tr>
</table>

5 What factors affect human health?

Human health is a **consequence** of the **relationships** and **interactions** between biological processes in our bodies, our lifestyles and the **conditions we live in**.

■ **Figure 5.1** Neighbourhoods in Corfu, Greece (left), and Santiago, Chile (right)

CONSIDER AND ANSWER THESE QUESTIONS:

Factual: What must happen inside the human body in order to for us to be healthy? What are external conditions that contribute to our health?

Conceptual: How are biological processes in our bodies, the conditions we live in and our lifestyles related so that their interactions have consequences for our overall health?

Debatable: What does it mean to be healthy? Do you think access to health care and a healthy lifestyle are rights or privileges?

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

IN THIS CHAPTER, WE WILL ...

- **Find out** how different types of living conditions and environments influence human health and how diseases can spread within a population.
- **Explore** different types of disease and the mechanisms our bodies have to maintain or re-establish our health.
- **Take action** by raising awareness of strategies that will support and improve human health.

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

- Communication skills
- Media literacy skills
- Critical-thinking skills
- Transfer skills
- Organization skills
- Information literacy skills

KEY WORDS

disease
host
welfare

● We will reflect on this learner profile attribute …

- Reflective – thoughtfully consider how the condition of our surroundings, our lifestyle and our natural tendencies impact on our health; and discuss what options we have and what decisions we can make to improve our health and that of others.

◆ Assessment opportunities in this chapter:

- ◆ Criterion C: Processing and evaluating
- ◆ Criterion D: Reflecting on the impacts of science

THINK–PAIR–SHARE




■ **Figure 5.2** 'Health' can have many forms

What do we consider to be 'healthy'?

Think about someone who you would describe as really 'healthy'. This person could be you, someone you know personally (like one of your parents) or someone you have only seen or heard about (like an athlete). Ask yourself, 'What is it that makes me think this person is healthy?' Fill in your ideas in a table, like this one:

The healthy person is:		
Physical characteristics that make me think this person is healthy	**Actions** this person does that make me think s/he is healthy	**Other things** about this person that make me think s/he is healthy

Pair up with a partner. Share your lists with each other. Compare your lists to **identify** what is similar and different in your ideas about a healthy person.

Next, combine the ideas you agreed on in order to try and write one 'big idea' of what makes a person healthy. Put your 'big idea' into one sentence and complete this sentence: 'A person is healthy when …'.

Finally, share your ideas with the class, so that everyone's 'big ideas' can be written down in a common learning place. You will go back to reflect on and add to these 'big ideas' as you learn more about the factors affecting human health.

What is health?

When was the last time you were sick enough to stay home from school? How did you feel? Maybe you had a headache or stomach-ache or sore throat, or some combination of all three. Maybe your body felt sore or you had a fever. Probably, you felt tired and the only thing you wanted to do was stay in bed or lie on the sofa.

What did you do to feel better? Did you drink some tea and just rest? Or did you go to the doctor to get some medicine? Or were you so sick that you had to go to the hospital for treatment?

Whatever the case, you were probably not very happy when you were sick, and were relieved on the day you started to feel better. It happens to everyone … everyone gets sick at some time or another. But the big question is … *why*? Why do we get sick? Why do we have a fever or headache or stomach-ache? Why do some people get sick often and others only rarely? Why do people in some parts of the world suffer from frequent, serious disease, while in other parts of the world people generally live healthy lives? Why do some illnesses come and go quickly with hardly any symptoms, while others last a long time – even a lifetime – and can even cause death?

In this chapter, we will look for answers to these questions and more. We will explore what factors contribute to health, and we will consider the role of governments and leaders in order to ensure their citizens are healthy. We will use our knowledge and understanding about health in order to develop strategies and suggestions for improving health, which we will share with others because, as the saying goes, 'He who has health has hope; and he who has hope has everything'.

Figure 5.3 How do you know you are 'sick'?

THE WORLD HEALTH ORGANIZATION

The World Health Organization (WHO) is part of the United Nations system; it is a worldwide authority that provides leadership and support for health and health-related matters in different countries and regions around the world.

Just like many countries and large organizations, the WHO has a constitution in which its values and principles for leadership are outlined. Read the preamble of the WHO's constitution, where you will find the WHO's definition of and expectations for health:

CONSTITUTION OF THE WORLD HEALTH ORGANIZATION

THE STATES Parties to this Constitution declare, in conformity with the Charter of the United Nations, that the following principles are basic to the happiness, harmonious relations and security of all peoples:

- Health is a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity.
- The enjoyment of the highest attainable standard of health is one of the fundamental rights of every human being without distinction of race, religion, political belief, economic or social condition.
- The health of all peoples is fundamental to the attainment of peace and security and is dependent upon the fullest co-operation of individuals and States.
- The achievement of any State in the promotion and protection of health is of value to all.
- Unequal development in different countries in the promotion of health and control of disease, especially communicable disease, is a common danger.
- Healthy development of the child is of basic importance; the ability to live harmoniously in a changing total environment is essential to such development.
- The extension to all peoples of the benefits of medical, psychological and related knowledge is essential to the fullest attainment of health.
- Informed opinion and active co-operation on the part of the public are of the utmost importance in the improvement of the health of the people.
- Governments have a responsibility for the health of their peoples which can be fulfilled only by the provision of adequate health and social measures…

Is access to health care and a healthy lifestyle a right or a privilege?

ACTIVITY: WHO said what?

ATL

- Communication skills: Read critically and for comprehension
- Critical-thinking skills: Formulate factual, topical, conceptual and debatable questions

In this activity, you will critically and actively read the preamble of the constitution of the WHO. You will **identify** which of the expectations for health can be addressed using science or scientific developments, and share your ideas.

Instructions for critical and active reading:

- Identify, and highlight or underline the WHO's definition of 'health'.
- Use the Connect–Extend–Challenge table (Table 5.1) to focus your attention and write down and **organize** your thoughts while reading.

After the active and critical reading …

- In pairs, compare your notes:
  - Did you identify the same definition for health?
  - In what similar and different ways did you Connect–Extend–Challenge?
- Use your 'wonderings' from your Challenge notes to write one or more debatable question(s).

With the class:

- Share your ideas with the class, and add to the list of 'big ideas' about health.
- Share your debatable question(s) for discussion now or later on in the class.

By the end of the chapter:

- Take the role of a journalist for a weekly science column and write an editorial column about the expectations for health that are in the WHO's constitution.
  - **Explain** WHO's expectations for health and the ways in which science is used to address these.
  - **Evaluate** the impacts of cultural, economical, environmental, ethical, moral political and social factors on the implications of applying science to address the WHO's expectations for health.
  - Consistently **apply** scientific language and cite your sources.

Assessment opportunities

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

Table 5.1 Connect–Extend–Challenge

While reading the preamble of WHO's constitution, there were …	Notes from reading	
Ideas that **CONNECT** to science or scientific developments	*Expectations for health*	*How science can be used to meet the expectations*
Ideas that **EXTEND** my original ideas about health	I used to think that health is …	… but now I think 'health' can also be …
Ideas that **CHALLENGE** my way of thinking or make me wonder more about health	I don't quite understand these ideas: I wonder:	

■ **Figure 5.4** Going to hospital in Vietnam, Ghana and the United States

EXTENSION

ATL

- Media literacy skills: Locate, organize, analyse, evaluate, synthesize and ethically use information from a variety of sources and media
- Communication skills: Read critically and for comprehension

Do countries value and put as much emphasis on health as the WHO? How many countries do you think include in their constitutions provisions for the health, or welfare, of their citizens?

You and your classmates can do some research to find out. You can find the constitution of many different countries translated to English and available online in PDF. Then, you can do a quick word search in the constitution to find out if or how often the constitution refers to the government's role in the health or welfare of its people.

Here's how:

- Open the search engine of your choice.
- Type in the name of the country you are interested in, followed by the words *constitution pdf*. For example, if you are interested in learning about Turkey, you would type into the search bar *Turkey constitution pdf*.
- Once you have found the constitution, do a word search for 'health' and then for 'welfare'. To search for a word, if you are using a Mac, hold down the 'command' and 'f' keys at the same time; if you are on a PC, hold down the 'CTRL' and 'f' keys. When the word-find search bar opens, type in the word you are looking for. The word-find search bar will tell you how many times the word appears in the document, which you will find highlighted in the text; scroll through to locate the words. If the word is not present in the document, the search bar will say 0 or will be blank.

What did you find? Share the results with your class. What do your findings tell you about the importance of health and welfare in different countries around the world?

DISCUSS

- To what extent do you agree or disagree with the WHO's definition of health as '… a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity'?
- How do you feel about statement that 'Governments have a responsibility for the health of their peoples which can be fulfilled only by the provision of adequate health and social measures …'? Do you agree or disagree?
- In what ways can science and scientific developments be applied and used to address the issue of public health as it is discussed in the WHO's constitution?

What happens inside our body for us to be healthy? What external conditions contribute to our health?

MICRO-ORGANISMS

■ **Figure 5.5** A drop of water

A simple drop of water; you consume thousands of drops of water just like this every day, totalling millions in your lifetime.

Have you ever stopped to think about what is in each drop of water that you drink? Of course, it is made up of hydrogen and oxygen atoms bonded together, but there is more.

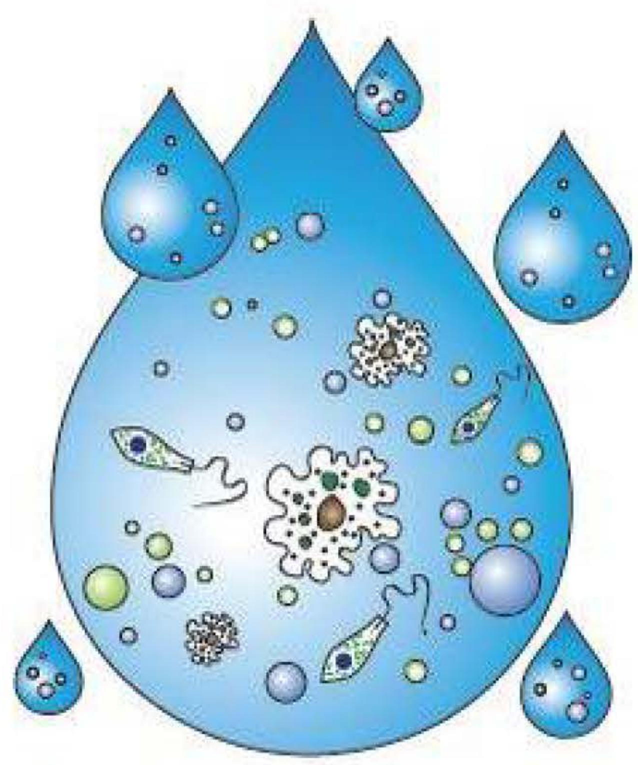
Water often contains many dissolved minerals that our body cells use to perform the cellular functions which give us energy and help us grow. But there are also tiny **micro-organisms** floating and living in each drop of water we consume.

In addition to being found in water, micro-organisms cover literally every surface of everything that surrounds us … they cover the top of your desk, your kitchen table, your toothbrush, your plate, money and even the food you are eating. Micro-organisms are floating in the air we breathe in and out throughout our lives. Our own bodies are even covered by and filled with micro-organisms – in fact, believe it or not, we have more single-celled micro-organisms living on and in our bodies than we have of our own body cells!

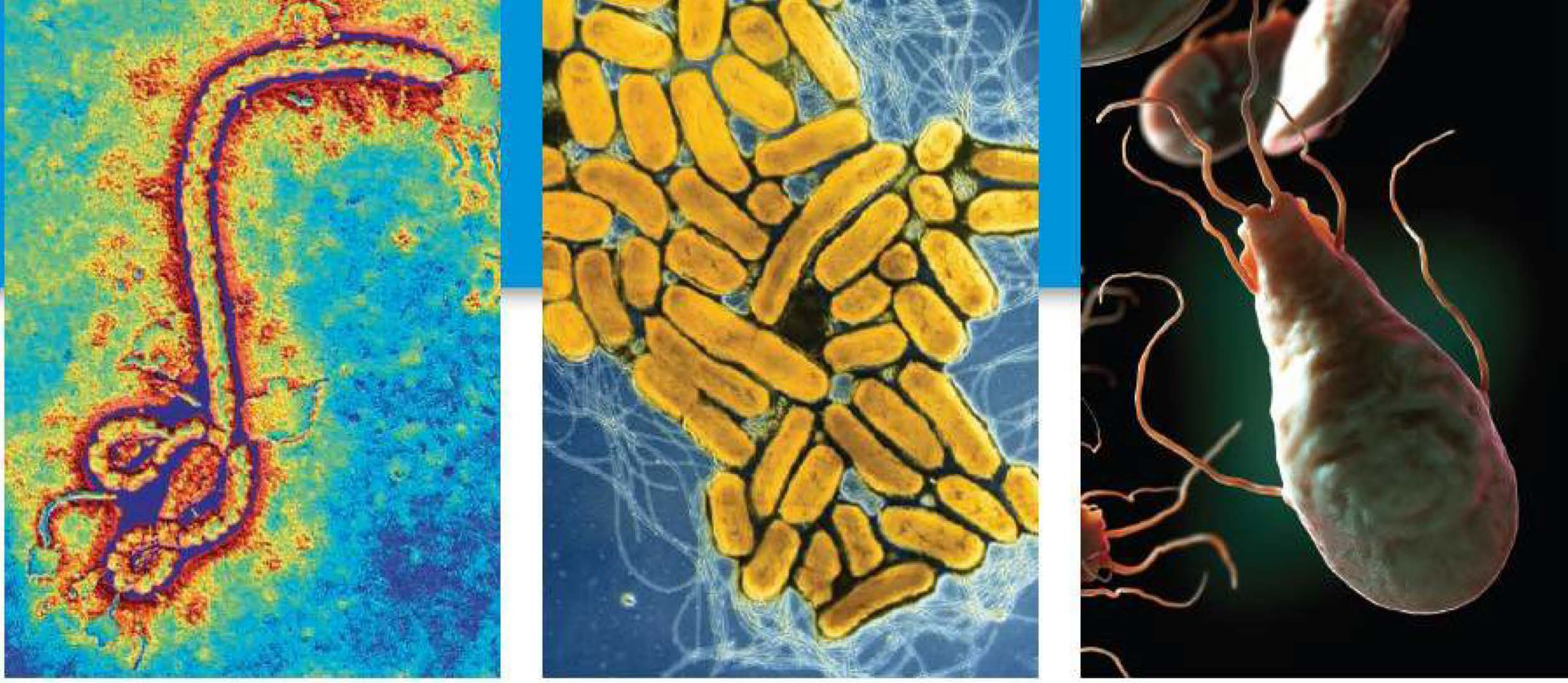
■ **Figure 5.6** Bottled water usually contains dissolved minerals

But, before you get nervous, it is important to know that the majority of those micro-organisms are harmless or even benefit our body; in fact, many of these micro-organisms on and in our bodies are single-celled **bacteria** that contribute to our health by protecting us from harmful micro-organisms and helping us to digest our food.

The harmless bacteria pass into and out of our bodies without us ever knowing; the beneficial bacteria (sometimes referred to as 'probiotics' since 'pro' means 'in favour of' and 'biotic' means 'living things') are actually necessary components of our digestive system because they ensure we break down foods and make the nutrients in our food available, so that we can be well-nourished and healthy.



■ **Figure 5.7** Most water contains thousands of micro-organisms



■ **Figure 5.8** These pathogens can cause disease if they find their way into the human body. From left to right: Ebola virus, cholera bacteria and Giardia protozoa

Pathogens

Bacteria and viruses

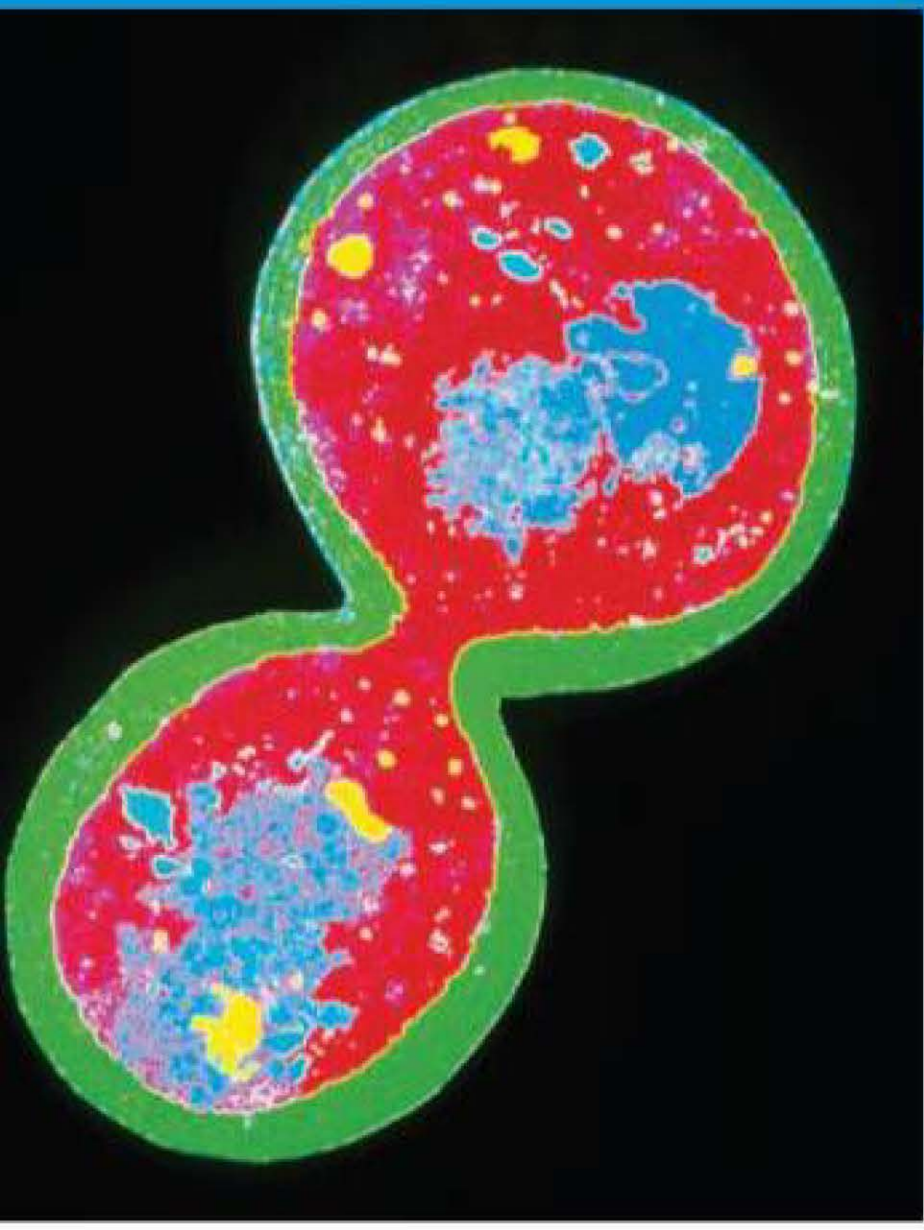
Some of the micro-organisms that surround us can be harmful to our body and health; these types of harmful micro-organisms are known as **pathogens** (from *'pathos,'* meaning 'disease' or 'suffering' and *'-gen,'* meaning 'giving rise to'); they are bacteria, **viruses** or **parasites** which can use or destroy our body cells for their own survival, while causing diseases that make a person feel ill.

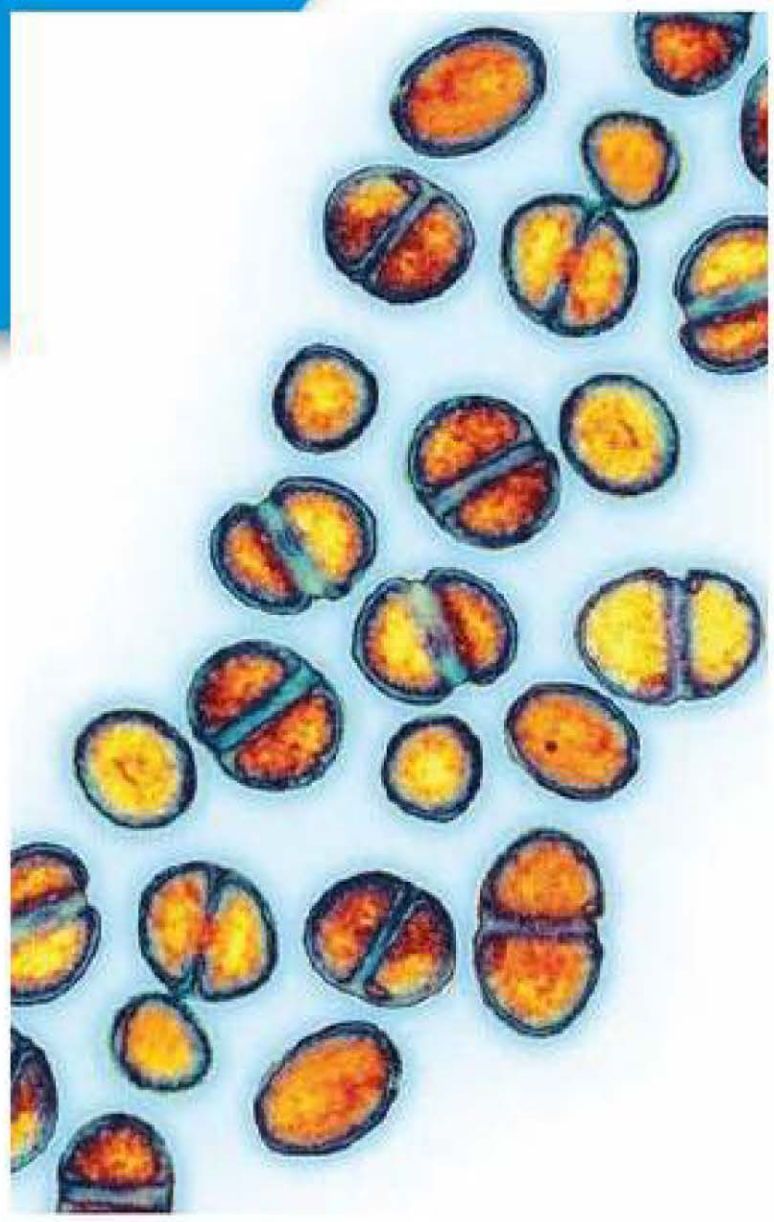
What happens that causes us to feel ill when those disease-causing pathogens enter our bodies? We will take a closer look at that now.

Like other organisms, micro-organisms need a place to live with the temperature, amount of water and balance of nutrients that are appropriate for them to survive and reproduce. For many micro-organisms, including pathogens, inside the human body is the perfect environment: normal body temperature (between 36 and 37 °C) and the dissolved substances in our blood and cells create an ideal habitat for them to carry out all of their life functions … you can imagine the pathogens like people on a warm summer beach holiday with a non-stop buffet, well-rested and enjoying themselves with the nice weather and delicious food!

Micro-organisms enter our bodies from openings such as the mouth, eyes, nose or an open cut. Micro-organisms get access through these body openings in many different ways, including in the water we drink, the food we eat, the air we breathe, or from our hands. If the micro-organisms are able to pass through some of the barriers to micro-organisms in our body, such as nose hairs, sticky mucus covering our eyes and mouth and nose, and stomach acid, they find themselves in this warm and food-filled 'holiday' environment, and it is very easy for them to live and reproduce. Soon, in these perfect living conditions, the number of micro-organisms multiplies very quickly and they circulate throughout the body along with the blood and other body fluids. If, as we mentioned before, these micro-organisms are of the harmless or beneficial variety, we do not even notice they are there. However, if these micro-organisms are of the pathogenic sort, a disease may start to develop and we may feel ill.

■ **Figure 5.9** Just like people, microbes have ideal conditions in which to grow and reproduce

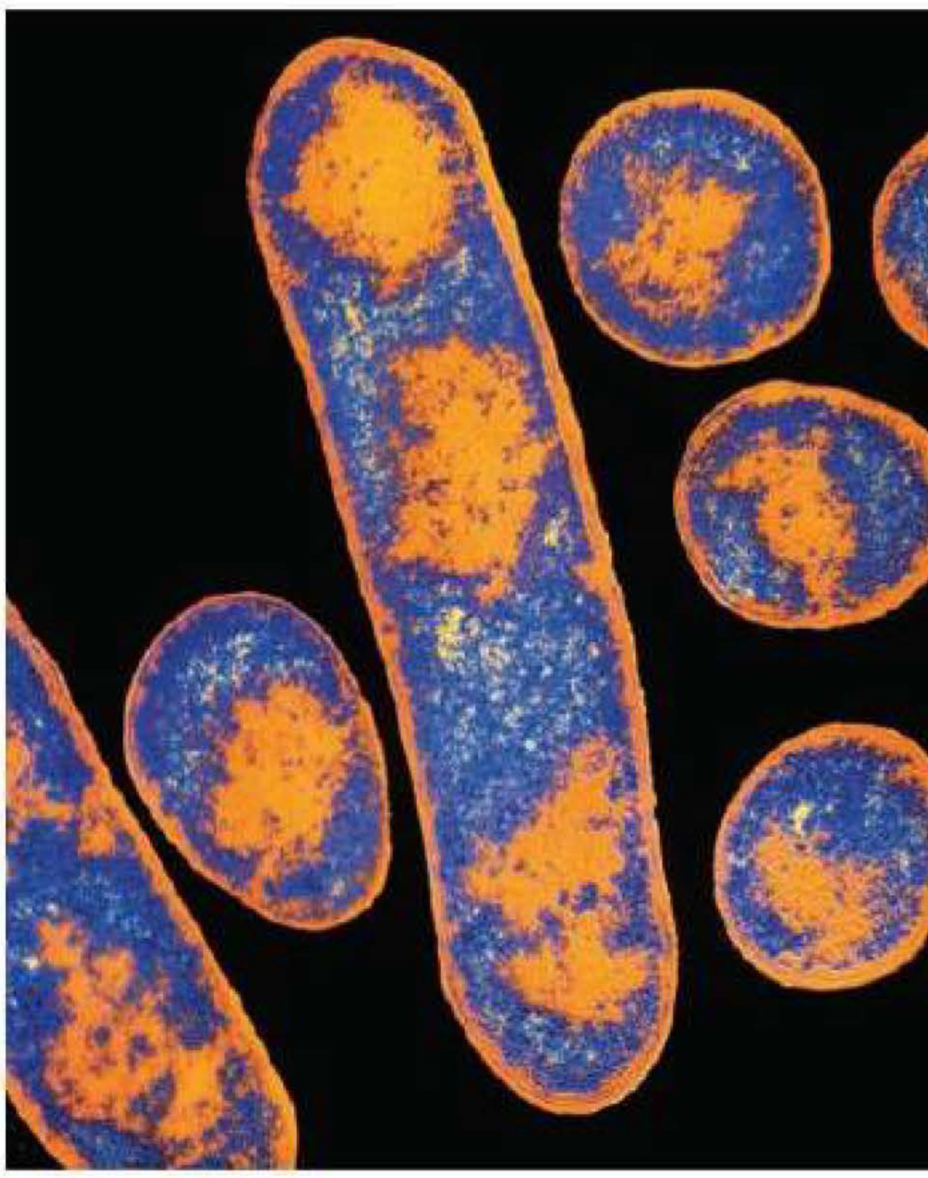




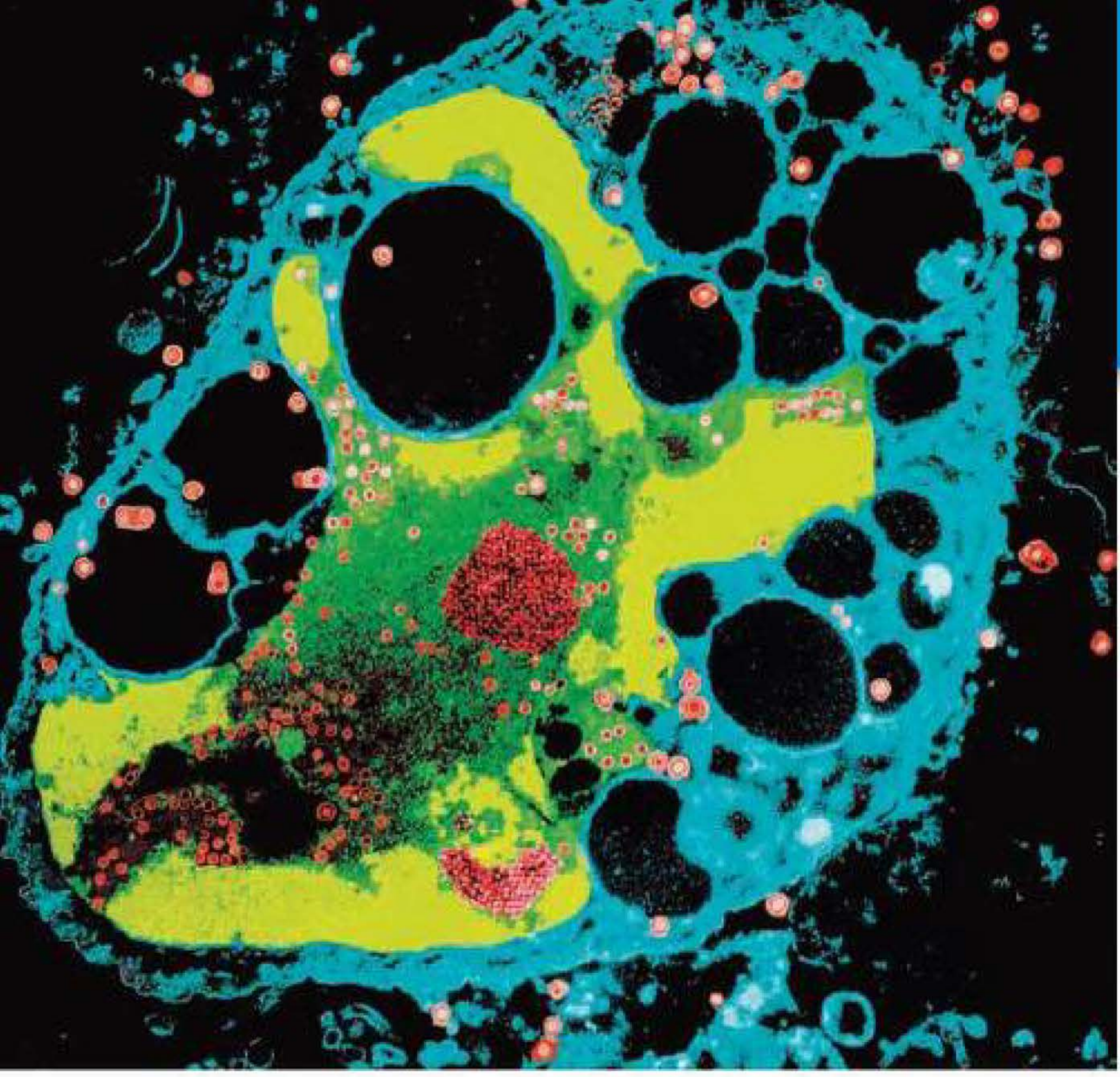
■ **Figure 5.10** Micro-organisms, such as these yeast cells (left) and MRSA bacteria cells (right) reproduce asexually, doubling their cellular contents and dividing as in mitosis

Why, you might be wondering, do we feel ill as a result of having these pathogenic micro-organisms growing inside us? It is because some of them, such as bacteria, produce and release waste materials, in a similar way to how humans and other living things produce and release waste. Some of the waste materials that pathogenic bacteria produce and then release into our body are toxins – small amounts of 'poison' that enter body cells, damaging or killing our healthy body cells, and making us feel unwell in the process.

Other pathogens, such as viruses, make us feel ill for another reason. Viruses do not contain all of the components or mechanisms necessary for reproduction. For that reason, viruses are not capable of reproducing on their own; instead, they must enter into other healthy cells and take over the reproductive mechanisms of those cells. When this happens, the healthy **host** cells use their own cellular components to assemble new viruses. Soon, the host cells fill with the newly assembled viruses, until the host cell no longer can support its own needs for survival. At this point, the host cells burst open, releasing all of the newly formed viruses. Therefore, during a viral infection, our body cells that host the virus die when they burst open and release the copied viruses; in addition, all of the copies of the virus are now inside the body, ready to infect and get copied by nearby body cells, which will also die in the process.

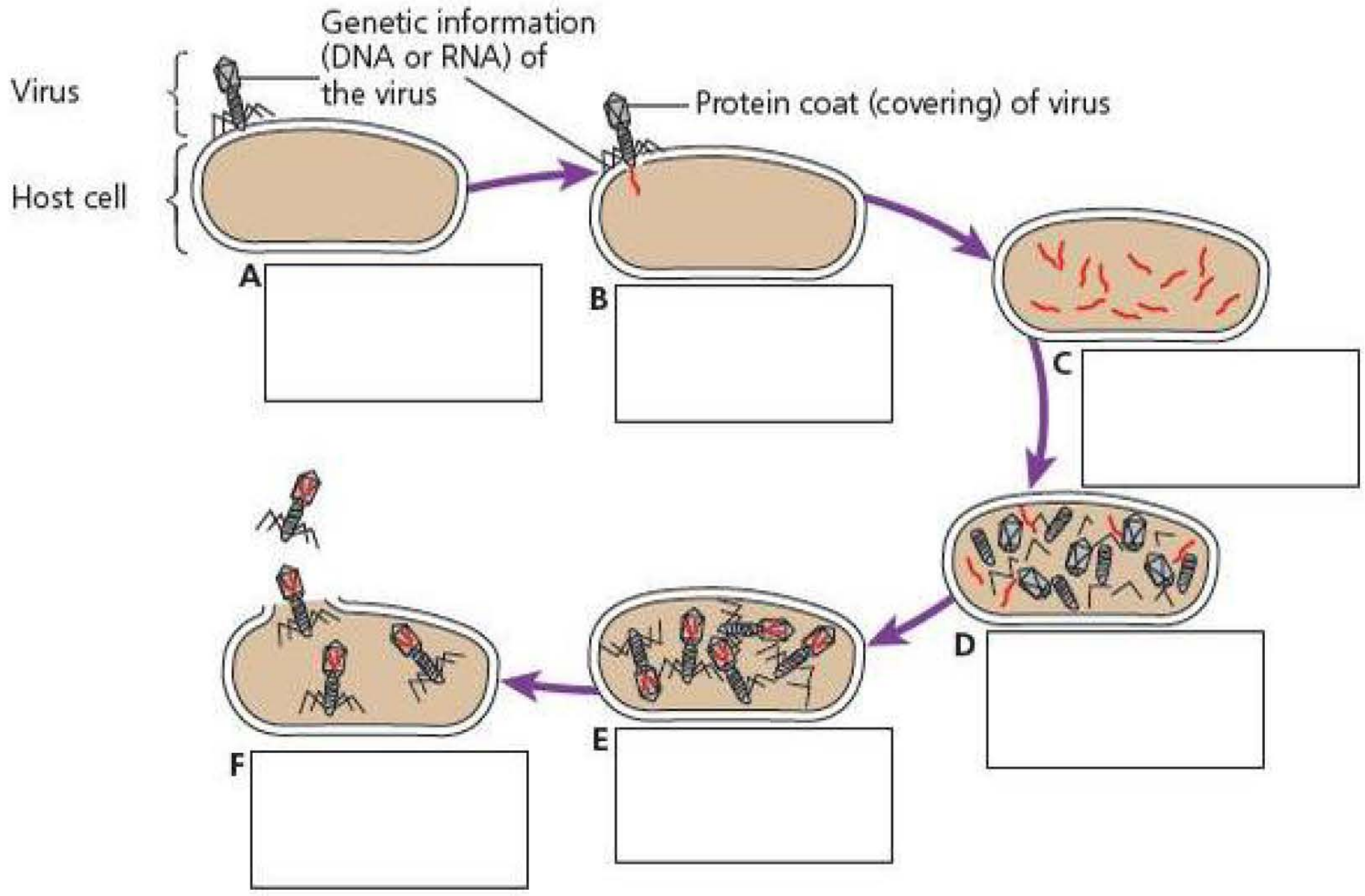


■ **Figure 5.11** *Clostridium botulinum* is a type of bacterium that produces a toxin that can cause disease in humans. It grows in canned foods that have not been appropriately preserved, and produces a toxin that causes botulism poisoning, resulting in serious food poisoning or even death. The exotoxins produced by *C. botulinum* are also used in the injections for Botox treatments



■ **Figure 5.12** We can see in this *Herpes simplex* virus infection the red-coloured *Herpes* virus entering into, being copied by and breaking out of the host cell

■ **Figure 5.13** The HIV particles are 'budding' or growing off from their host cell after they have taken over the genetic and functional 'machinery' of the host cell. This process will kill the host cell and will lead to thousands of copies of the virus being released into the human body



■ **Figure 5.14** A summary of the way in which a virus is replicated by its host cell

Parasites

Parasites have different ways of making us feel ill. Because parasites may be single-celled micro-organisms such as amoebas, or larger, multicellular organisms such as worms, their interactions with the host body cells differ widely. However, the end result is that the parasite uses the host as a source of nutrients, depriving the host of the substances it needs for its own survival.

ACTIVITY: A virus infection

■ ATL

■ Critical-thinking skills: Use models to explore complex systems

In pairs, **discuss** what is happening in each stage of Figure 5.14. Write down the stages of infection next to each letter in the figure.

■ **Figure 5.15** These virus particles (illustrated in green) are suited for the conditions provided by the host cells in the lungs; as the lung cells make copies of and release more of the virus into the lung tissue, it causes the human host to produce phlegm and cough in an attempt to rid the body of the viral invaders

The living conditions of pathogens

Different pathogens have different specific requirements for their ideal living conditions, for example, the lungs the intestines or inside the ear. Depending on where the pathogens have taken up residence, the symptoms you experience from the infection result from the damage or death to the cells that host the pathogens. For example, the host cells for rhinovirus (the virus that leads to the common cold) are found in our nasal sinuses or lungs, which is why we have a stuffed up nose as a result of the cold virus.

Other symptoms when you are ill come from your body's defence system, called the immune system, in its attempt to regain the balance of healthy body cells to pathogenic cells – a balance which the body begins to lose when the pathogens start to rapidly grow and reproduce. You might recall from Chapter 3 that the balance of conditions within our body is called homeostasis, and that the body makes automatic adjustments or changes in order to try and re-establish balance when different factors cause an imbalance.

ACTIVITY: Symptoms of illness

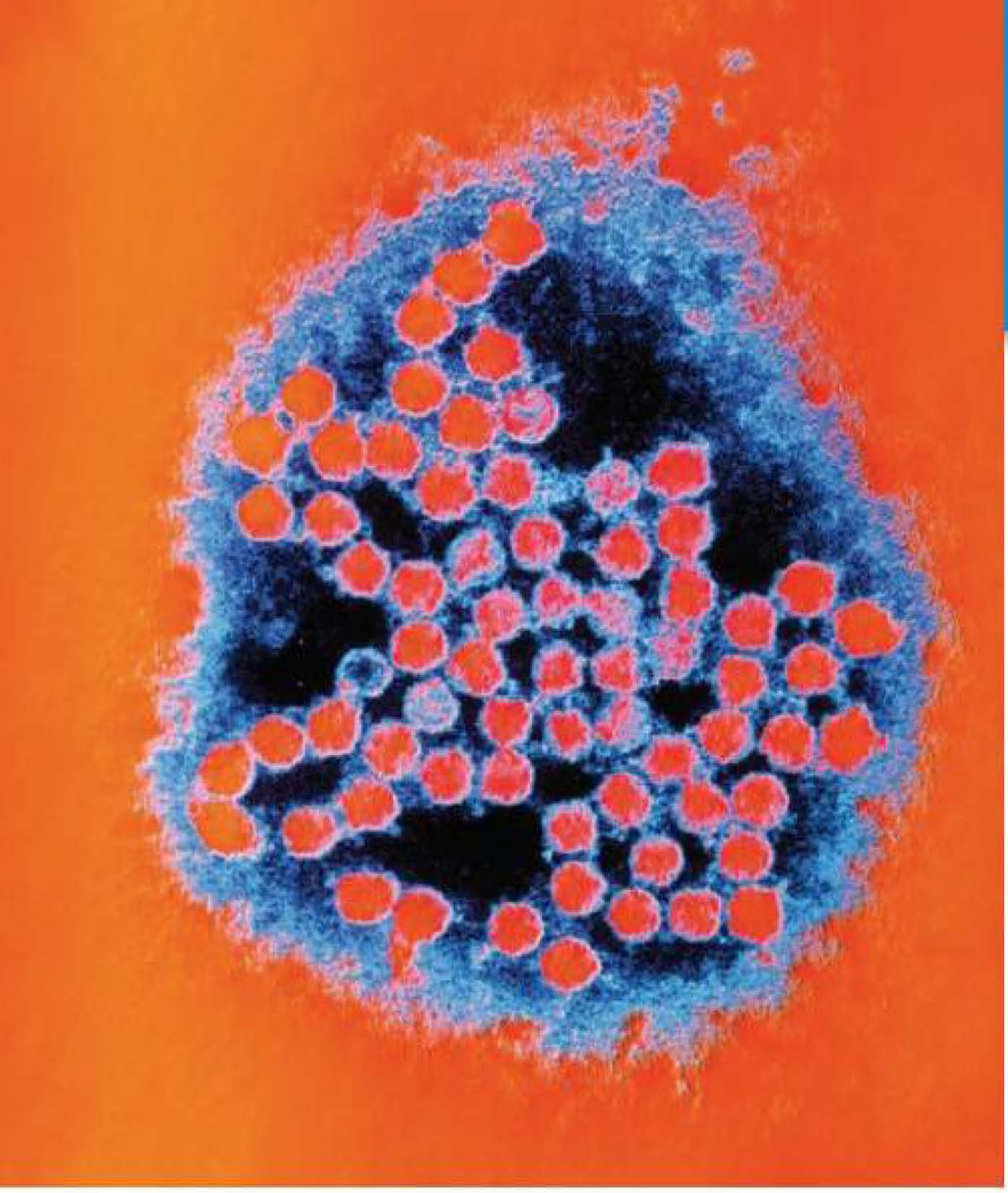
ATL

■ Communication skills: Make inferences and draw conclusions

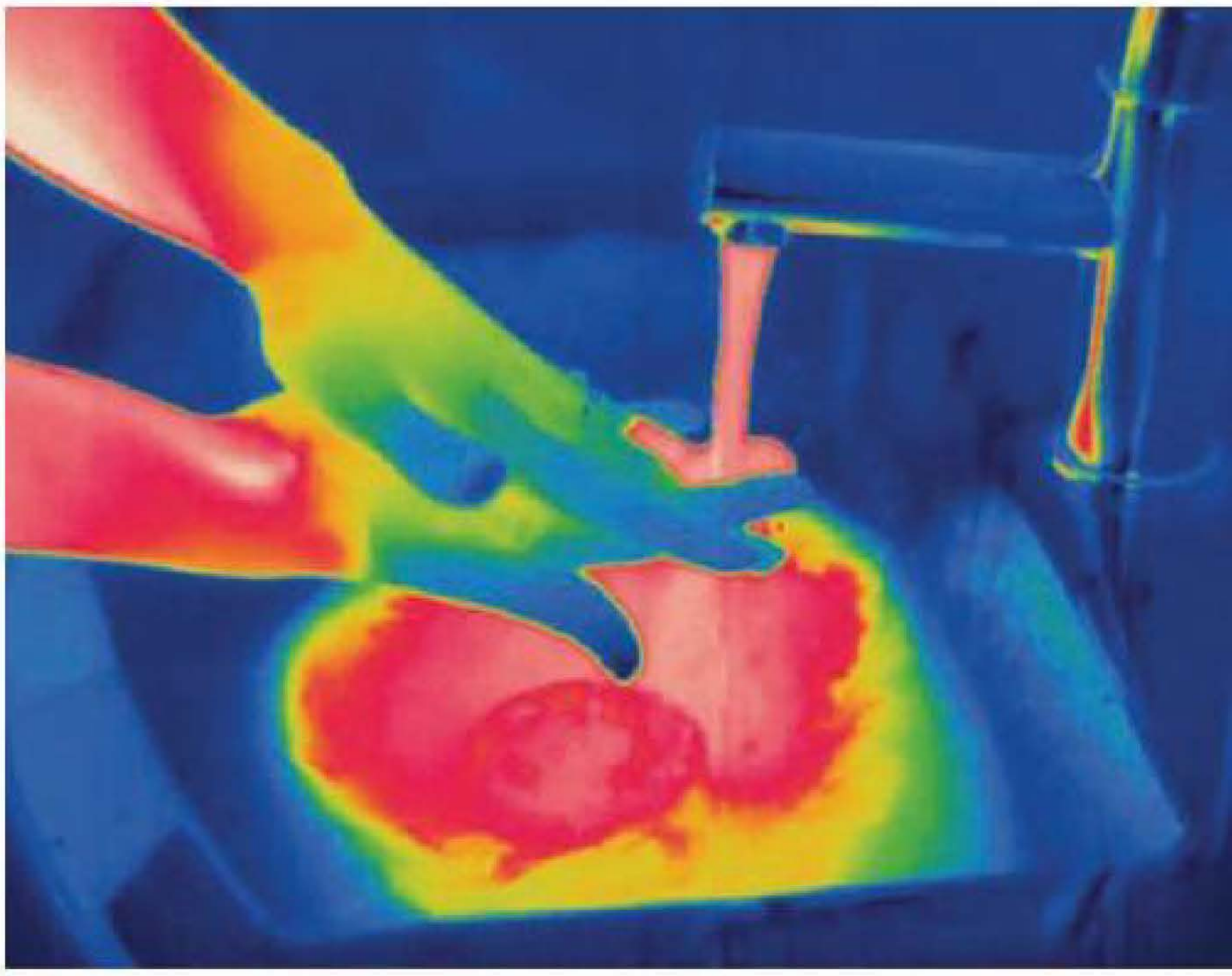
Think about some common symptoms when you feel ill, and **suggest** some reasons for the symptoms that result from infections by pathogens. Copy the table below and fill in Column B with your inferences, and then share with a partner, and the class.

Add three rows to the bottom of the table and enter some other symptoms you have experienced when you were ill, and **suggest** explanations for those symptoms as well. Read page 121 and then fill in Column C with what you have learnt.

A Symptoms	B Inferred explanations for symptoms (before reading)	C Biological explanations for symptoms (after reading)
Fever		
Runny nose		
Sneezing		
Coughing		
Diarrhoea or vomiting		



■ **Figure 5.16** These rhinoviruses have been replicated within the cells of the upper respiratory system; they cannot live in the acidic conditions of the stomach, so they will only infect cells in the sinuses or lungs, resulting in the symptoms we associate with the common cold



■ **Figure 5.17** The effect of heat on pathogens is the reason why we should wash our hands or dishes with warm or hot water and why surgical equipment is cleaned by putting it in a type of 'oven' before being used for surgery. This thermal image shows hot water (coloured in red) coming out of the tap while a surgeon is washing his hands

WHAT HAPPENS INSIDE YOUR BODY WHEN YOU ARE ILL?

Your body responds to the presence of pathogens by trying to make the inside of your body a less appealing place for the pathogens to be; if we go back to the beach holiday analogy, now think of a place that is cold and rainy and that does not offer any meals. If you were on a beach holiday under those conditions, you would not want to stay there very long, and, in fact, you *could not* stay very long if there was no food – the same is true for pathogens when they find themselves in an environment that does not have the correct temperature or a source of nutrients.

Therefore, the symptoms your body produces when you have an illness is the way your body tries to make itself as uninviting as possible for the pathogens. Each symptom you experience is your body trying to damage or kill the pathogens, prevent the pathogen from reproducing, or rid itself of the pathogen all together.

Let's consider again the symptoms in the table the Activity on page 120 in order to identify the reason we experience those symptoms when we are ill.

First, a fever is a response to the presence of the pathogens (or even other foreign substances) in your body. It is your body's attempt at making your internal environment too hot for the pathogens to live and reproduce because, as the temperature increases above 37 °C, pathogens become less efficient at performing life-sustaining cellular processes, and will eventually die.

■ **Figure 5.18** This leg wound is infected; we can see evidence of the immune system hard at work in the production and build-up of white blood cells that are coming out of the injury

When the cells of your immune system identify pathogens in your body, the immune-system cells release a chemical that is like a signal. The chemicals produced by the immune-system cells, as well as the toxins produced by the pathogens, circulate to different organs in your body, including to your brain. When the chemicals from the pathogens and immune-system cells get to your brain, they are detected by a part of your brain called the hypothalamus. One of the jobs of the hypothalamus is to regulate body temperature in response to different stimuli. So, when the hypothalamus detects these chemicals, it responds by 'turning up the heat' in your body, and you develop a fever.

The sticky mucus and phlegm that the cells in your nose and lungs produce are your body's way of trapping pathogens before they fully enter the body. When you sneeze, cough or blow your nose, all of those pathogens that were caught by the mucus or phlegm end up in the tissue or air, instead of in your body. In addition, the phlegm and mucus our body produces contain **antibodies**, which are molecules produced by specialized cells, called white blood cells, in the immune system. In response and in order to fight off invading pathogens, your body produces more white blood cells, which, in turn, produce more antibodies.

So, the more pathogens there are in your body, the more white blood cells, mucus and phlegm your body produces, so that you have more antibodies and sticky traps available to protect you from disease-causing micro-organisms. In addition, this increased level of white blood cell production is an important strategy to protect you in the future, because some of the white blood cells are known as 'memory cells'. Their job is to circulate in your body, ready to immediately produce antibodies in the case of a future infection.

When you have diarrhoea or vomit, though it is unpleasant, it is your body trying to make itself less welcoming to pathogens because your digestive system becomes more acidic. In addition, you are physically and actively removing the pathogenic micro-organisms from your body.

However, sometimes despite your body's best efforts, your defence mechanism – the immune system – is not strong enough on its own to protect you from pathogens and re-establish homeostasis. In some of these cases, a doctor might prescribe **antibiotics**. Antibiotics, which literally means 'against living things,' are substances that damage, destroy or kill certain types of cells; specifically, antibiotics target certain types of bacterial cells.

Many antibiotics are found in nature; for example the popular antibiotic penicillin originates from a type of mould. Even more antibiotics, however, are developed and mass-produced by scientists in research and pharmaceutical laboratories. Antibiotics are developed to target and damage or destroy different types of bacterial cells and, therefore, can be effective only in treating diseases caused by bacterial infections. This means that, if a parasite or virus causes a disease, antibiotics will not be an effective treatment for eliminating the pathogens that cause the disease. In these types of parasitic or viral infections, doctors may prescribe medicines that help to reduce the symptoms of the infection so you feel better while your body is trying to fight the disease.

EXTENSION

What role does luck play in important scientific developments? Is all scientific advancement the result of carefully planned and detailed investigations? Try doing an Internet search using the words Penicillin discovery to learn how chance played a role in one of the most important, life-changing discoveries in science and medicine.

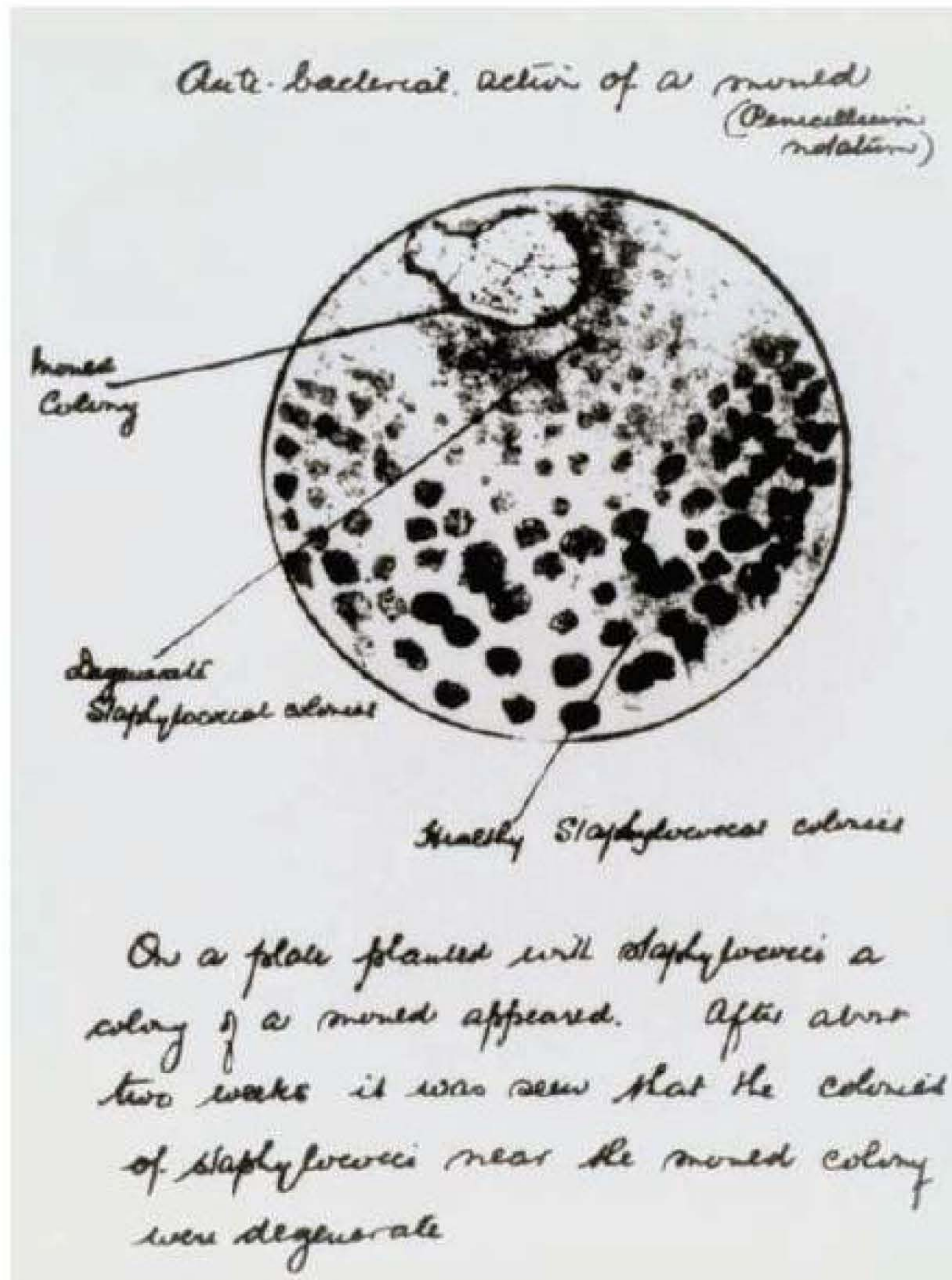


Figure 5.19 Alexander Fleming's sketch and notes about the antibacterial effect of the fungus *Penicillium notatum* growing on a Petri dish with *Staphylococcus* bacteria. This 'accidental' discovery led to the development of the first antibiotic, penicillin

EXTENSION

How would you feel if a trusted doctor in your town took you into his office one day, scratched your arm, rubbed in some pus from some open sores on another patient's arm, kept you under observation for a few days, and then, after noticing you seemed healthy, rubbed the scratches on your arm with some pus from the sores of *a third* patient who was sick with a deadly disease?

Would you believe that that was very much the way in which the first **vaccine** was tested? In fact, in the late 1700s a British doctor named Edward Jenner used an unknowing young boy as a 'human guinea pig' to test his theory that exposing people to a small amount of a less serious disease, in this case cowpox, could prevent them from getting a more serious disease, smallpox.

Figure 5.20 Jenner infecting James Phipps with cowpox in order to test his theory that the boy would not later get smallpox

To learn more about Jenner's approach to developing vaccines, try searching for **Edward Jenner smallpox**. How do you think his methodology would be received today?

Links to: History

Have you studied the history of medicine and health in your History class? Think about how medicine and health have developed over time, and how these factors have impacted on human life and societies. For example, you might want to consider how the development of medicines, such as antibiotics, and mobile medical treatments have impacted on soldiers and the outcomes of war. Or, perhaps, you could explore the role that exposure to and spread of certain diseases, such as smallpox, had on colonization in the 'New World'.

Figure 5.21 A historical satirical cartoon depicting people getting the smallpox vaccine. What can you infer about the way people felt about the smallpox vaccine from studying this cartoon?

WHAT IS THE BODY'S RESPONSE TO PATHOGENIC INVADERS?

You may, at this point, be wondering about vaccinations. What are they and how do they work? To understand how vaccines work, we have to understand your body's natural response to pathogenic invaders.

As we learnt before, your body's immune system produces antibodies in order to protect you from pathogens after they have entered your body. We have also learnt that some of those antibodies – the memory cells – stay in your body in order to fight off future pathogenic invaders and prevent the disease from developing. This process of fighting off a current, or 'primary', infection while establishing a protection mechanism from future, or 'secondary', infections is a powerful one. The human body is, indeed, well adapted and well equipped to protect itself from many harmful things.

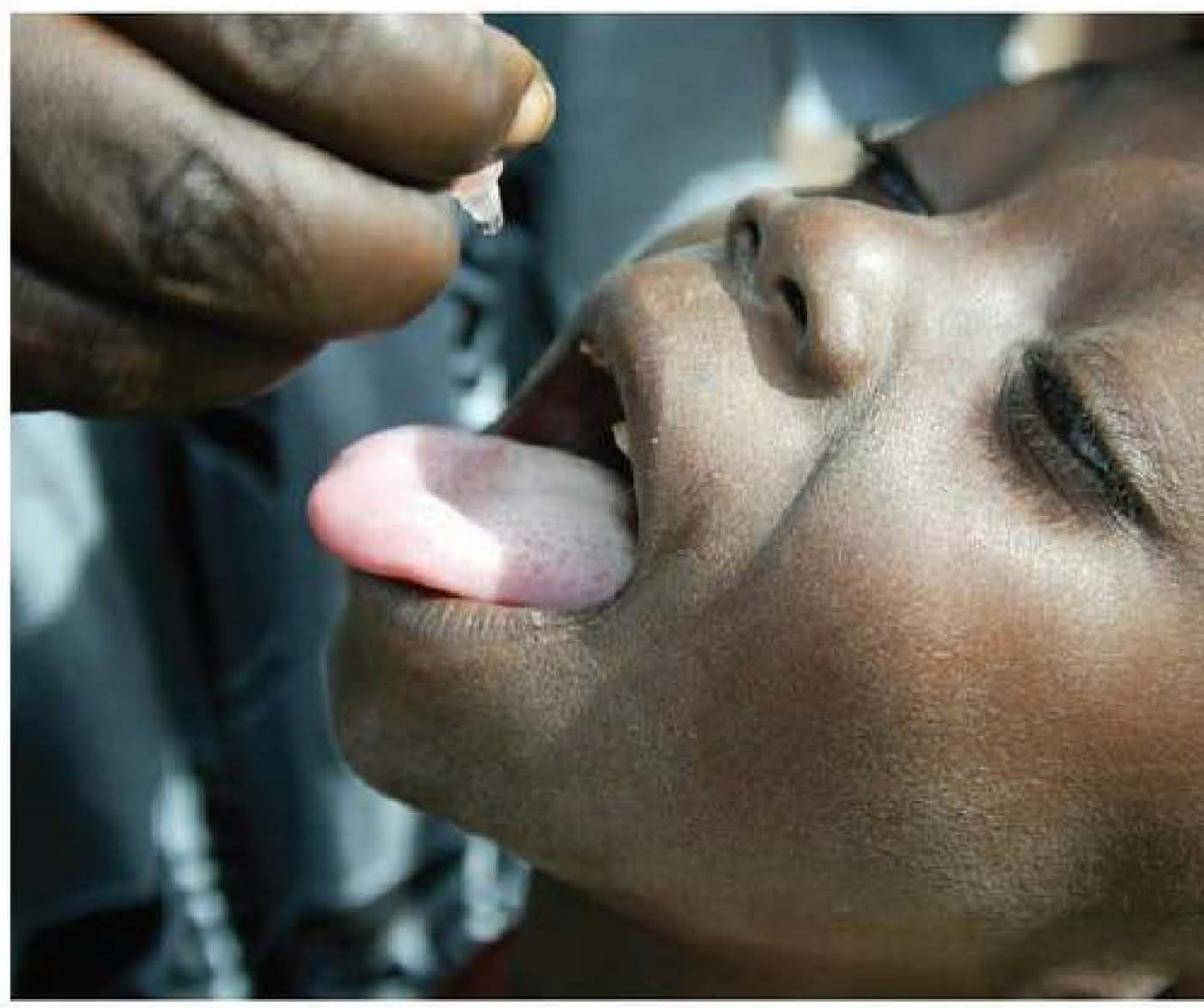
However, as you have probably heard on the news, or perhaps even experienced personally, there are many common diseases, such as measles, hepatitis and some types of flu, as well as some types of rare but serious diseases such as Ebola, that are caused by pathogens that are able to reproduce (or be copied) so quickly in your body, and have such serious symptoms, that your body's immune system and antibodies have very little chance of protecting you. To make matters more complicated, some of these pathogens either do not respond to treatments such as antibiotics, or respond very slowly. In these cases, the pathogens can be so destructive to our body cells that they cause life-long damage to body organs, or even, if the symptoms are severe enough, death.

Vaccines

Vaccines, therefore, have been developed and are used to prevent disease by acting as a 'trigger' for your body's production of antibodies and memory cells, without being exposed to or infected by the living pathogen. This is because vaccines contain dead or fragments of viral or bacterial pathogens; these dead or fragments of pathogens are enough to stimulate your immune system into producing the antibodies and memory cells. That way, just like in the natural immune response, the memory cells will be waiting in your body, ready to protect you from the invading pathogens should you be exposed to them, and should they try to enter your body.

Vaccines have proven to be effective in preventing individuals from getting ill, as well as in reducing or completely eliminating the presence of a disease in certain areas or populations. For example, the polio disease, caused by poliovirus, was once a widespread and much-feared disease because it causes paralysis and death in children and adults. However, as of 2015, it has been eradicated, or eliminated from, all but three countries in the world. This near-complete eradication is due to large-scale and worldwide efforts to vaccinate (or 'immunize') children and adults from the virus.

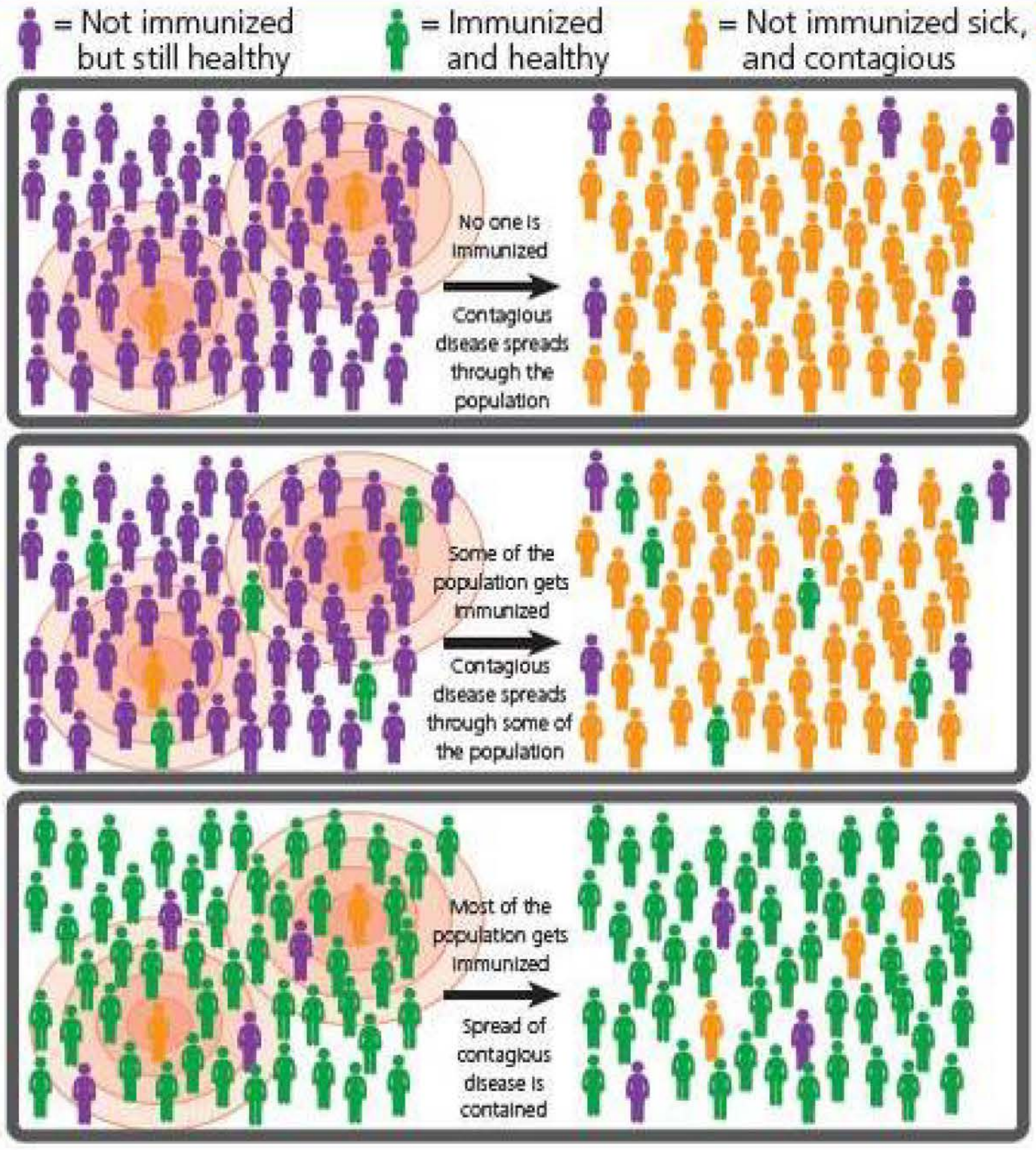
Despite the safety and widespread success of vaccines, doctors have established some guidelines and suggestions for who should get which vaccines and when. For example, doctors recommend that babies and children get different vaccines at different times during infancy and childhood. This is recommended because, even though new-born babies have received some protective antibodies from their mothers during the last weeks of pregnancy, their immune systems are still in development; the vaccination schedule is designed to help protect babies from the diseases they are most likely to be exposed to and that are most likely to cause immediate or long-term health complications. Furthermore, if a baby is exposed to a virus before he or she is vaccinated, there is more of a chance that the baby would get sicker than an adult because the baby's undeveloped and immature immune system would not respond quickly or strongly enough.



■ **Figure 5.22** Vaccines are often administered through an injection, though they may also be given by drops directly in the mouth

EXTENSION

To learn more about poliovirus and the progress that has been made towards its complete, worldwide eradication, trying searching for **global polio eradication**.



■ **Figure 5.23** Vaccination (Immunization) scenarios

ACTIVITY: Controlling the spread of disease

ATL

- Critical-thinking skills: Draw reasonable conclusions and generalizations; Use models to explore complex systems and issues

Look at Figure 5.23. What do you notice about the spread of the disease in each scenario? Jot down some notes.

Now complete this sentence in a detailed, bulleted list, 'From the information in this diagram, I understand that in order to avoid an uncontrollable spread of a disease …'

Compare your 'understandings' with those of your partner. How do they compare? In what ways are your ideas similar? In what ways are they different? In what ways do you or your partner understand the information in the figure in a different way after discussing?

You may be wondering if it is necessary for 100% of a population to get vaccinated in order to prevent a virus from spreading to a large portion of the population, in what is known as an 'epidemic.' Let's take a look at Figure 5.23 to answer that question.

Figure 5.23 illustrates the principle of herd immunity. According to this principle, it is not necessary for 100% of a population to be vaccinated; however, the majority of the population must be vaccinated in order to be able to contain and prevent an uncontrolled spread of the disease.

THINK–PAIR–SHARE

Take a moment to pause and consider the Statement of Inquiry for this chapter that has been guiding the learning through this topic. From what you have learnt so far, what aspects of human health can you **identify** as coming from the internal environment as opposed to the external environment?

Copy the table below and write your ideas in it. **Discuss** your ideas with a partner. An example has been done for you.

Human health is a relationship between …	
Factors in the internal environment (natural bodily processes)	**Factors in the external environment (conditions of and resources available in our surroundings)**
You develop a fever.	The only water for drinking comes from a water hole where clothes are also washed.

How do our surroundings, bodily processes and lifestyle choices interact and have consequences for our health?

HOW DO DISEASES GET TRANSMITTED?

As we discussed in the previous section, the pathogenic micro-organisms in our surroundings can have an effect on our internal health if they are able to reproduce and spread in our bodies. But what are some other examples of interactions and the relationship between what is going on outside our body, what is going on inside our body and our health? Also, how much do our surroundings actually affect our health? And do different conditions in our surroundings have different effects on our health? We are going to explore these questions in more detail in this section.

Before looking at how our surroundings may influence our health or the presence of disease, we must first become familiar with different types of disease. Some types of diseases, such as those that come from the presence of pathogenic micro-organisms in our bodies, are said to be **communicable** or infectious, which means the pathogens spread from person to person.

Airborne transmission

Some types of pathogens that cause communicable diseases can travel through the air, such as when a person coughs or sneezes while ill, causing the pathogenic bacteria cells or viruses to spread from the infected person's mouth and nose through the air, and land on a surface or on another person, they gain access to the other person's body. Communicable diseases that spread in this way are easily *transmitted*, or passed from person to person, because air constantly surrounds and enters our bodies and these so-called 'airborne' pathogens can survive for hours while floating in the air or after landing on a surface. Some examples of diseases that pass in this way are the common cold, flu and strep throat.

DISCUSS

In pairs, **discuss** and then write down some of your ideas in response to the following question: Considering what we have learnt about where pathogens are found and what we can do in order to protect ourselves from or to recover from a pathogenic infection, in what ways might where a person lives (such as their home, city, country) influence their health?

You could answer using the following phrasing: 'I think where a person lives can influence their health because ...'

Transmission via bodily fluids

Other types of communicable diseases are transmitted when the body fluids, such as blood, saliva, vomit or faeces, of an infected person – or animal – enter an uninfected person's body through direct contact with openings in the body, such as the mouth, nose, eyes or through an open cut.

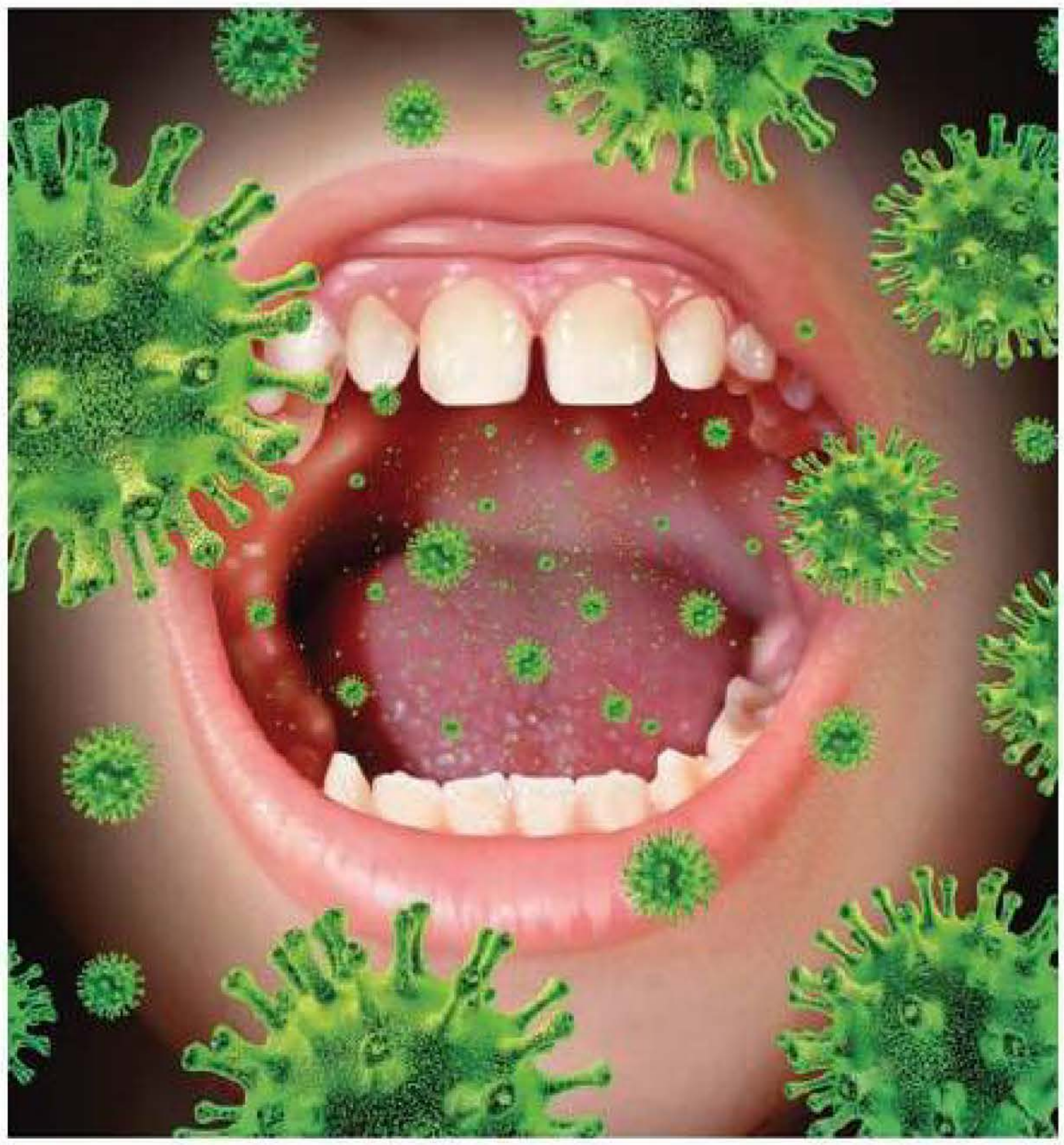


Figure 5.24 Some diseases are communicable, and can easily spread as bacteria or viruses travel through the air

These types of communicable diseases do not spread as easily as those caused by airborne pathogens, simply because we are less likely to come into direct, physical contact with the body fluids of another person or animal. Sometimes people develop diseases from these types of pathogens when they eat food that has been contaminated with pathogens, such as *Salmonella*, a type of bacterium that can be found on raw or undercooked meat, poultry and eggs, and *E. coli*, a type of bacterium which comes from consuming contaminated beef, milk, produce or water.

Two other very serious diseases that are communicable through direct contact with body fluids are those that are caused by the human immunodeficiency virus (HIV) and the Ebola virus. Though the viruses that cause HIV and Ebola can be very quickly copied once they are inside the human body, and both diseases have caused many deaths, members of the medical and scientific communities have acknowledged that the consequences and spread of these diseases are less than if these diseases were spread by airborne pathogens. For example, an Ebola outbreak that started in 2014 had serious and deadly consequences for the people who contracted, or caught, the disease. Thousands of people in the West African countries of Guinea, Liberia and Sierra Leone, as well as individuals in other countries, died from the Ebola virus; however, doctors agree that, if Ebola were an airborne pathogen, the results would have been even more devastating, perhaps even causing a *pandemic*, or worldwide, outbreak.

DISCUSS

Now that scientists have been able to map out all of the genes that make up the human **genome**, or genetic sequence, the possibility exists for doctors and scientists to be able to target and modify the genes that cause inheritable diseases.

What are your thoughts on this? To what extent do you think it is okay for parents to ask their doctors to identify and change the genetic sequences of their children?

Here are some suggestions to have a thoughtful discussion with your partner and the class:

- **First brainstorm a list of possible *negative* medical, social, economic or ethical consequences or outcomes of identifying and modifying the genetic sequence of one's future offspring.**
- **Then brainstorm a list of possible *positive* medical, social, economic or ethical consequences or outcomes of identifying and modifying the genetic sequence of one's future offspring.**
- **Try to name, with a reason that *supports* or *explains* your opinion, which possible consequences or outcomes may outweigh the others.**

Remember, questions like these are not easy to answer, but they are questions that you may face as you get older and have to make decisions that affect your life and those around you. Keep in mind there are no 'right' or 'wrong' answers to questions like these – that's part of the reason why they are so hard to answer! But, even if you really are not sure of how you feel, asking questions, talking about and reflecting on uncomfortable or challenging topics is a good way to practise being reflective and a thinker.

Inherited or genetic diseases

Other types of diseases are not spread from person to person through the air or fluids, but, instead, are inherited or **genetic** disorders. These **inheritable** or **genetic diseases**, such as Huntington's disease, haemophilia and sickle cell anaemia, are not caused by pathogenic micro-organisms, but, instead, occur due to the 'instructions' coded into our DNA, or genetic information.

Because the symptoms and characteristics of these diseases are literally part of our DNA, the only way for them to be transmitted is if the genes that code for the disease are passed from generation to generation in a family, similar to the way in which the traits for hair colour or height can be passed along within a family.

Just as you cannot do anything to change the *true* colour of your hair or make yourself *actually* taller, there is nothing we can do with medical treatments available at this time to stop people from developing diseases they have inherited in their DNA. Instead, just as people can use dye to change the *appearance* of their hair or put on high-heeled shoes to *seem* taller, people who have inherited certain diseases can use medicine or make adjustments to their lifestyles to prevent or decrease the symptoms of inheritable diseases.

EXTENSION

Learn more about the history of and recent outbreaks of the Ebola virus by visiting the Centers for Disease Control website: www.cdc.gov/vhf/ebola/

Autoimmune, lifestyle and mental health disorders

In addition to communicable and inheritable diseases, some diseases are considered to be **autoimmune diseases**. Autoimmune diseases, such as Type I **diabetes**, Crohn's disease and multiple sclerosis, are not always well understood in the medical community. Doctors know that autoimmune diseases are caused when our *own* immune system (hence *auto*immune) recognizes our own body cells as foreign cells or dangerous pathogens, and then begins to damage and destroy our *own* body cells, just like the immune system normally does to actual pathogenic cells. However, the reason *why* people's immune systems start fighting against them is not completely understood. For that reason, it is often difficult to predict who will develop an autoimmune disease and how to manage it.

Some diseases, such as Type II diabetes, certain types of **cancer** (for example lung cancer) and a form of liver disease called cirrhosis, can be linked to people's lifestyle or behaviour. These diseases can develop as a result of such factors as obesity coming from excessive intake of calories; lack of exercise; smoking; and excessive consumption of alcohol. Although the development of diseases such as Type II diabetes, lung cancer and cirrhosis are not only or entirely linked to behaviour or lifestyle, the chance of a person developing one or more of these diseases has been shown to increase as a result of these behaviours and lifestyles.

Another type of disorder is connected to mental health. The prevalence of mental-health disorders, including depression, eating disorders, post-traumatic stress disorder and addictive disorders, among many others, varies greatly depending on a variety of factors. Some mental health illnesses are inheritable, whereas others are connected to traumatic experiences, brain damage from a serious accident, abuse, or living under stressful conditions.

At this point, take some time to reconsider the 'big ideas' about health that you and your class wrote down at the start of the chapter. With the new information you have learnt, what can you add to the list?

With this information about different types of diseases, we will now take a look at the prevalence, or number of cases, of different types of diseases around the world. From the information in these graphs, we will be able to suggest some consequences of people's surroundings on their health.

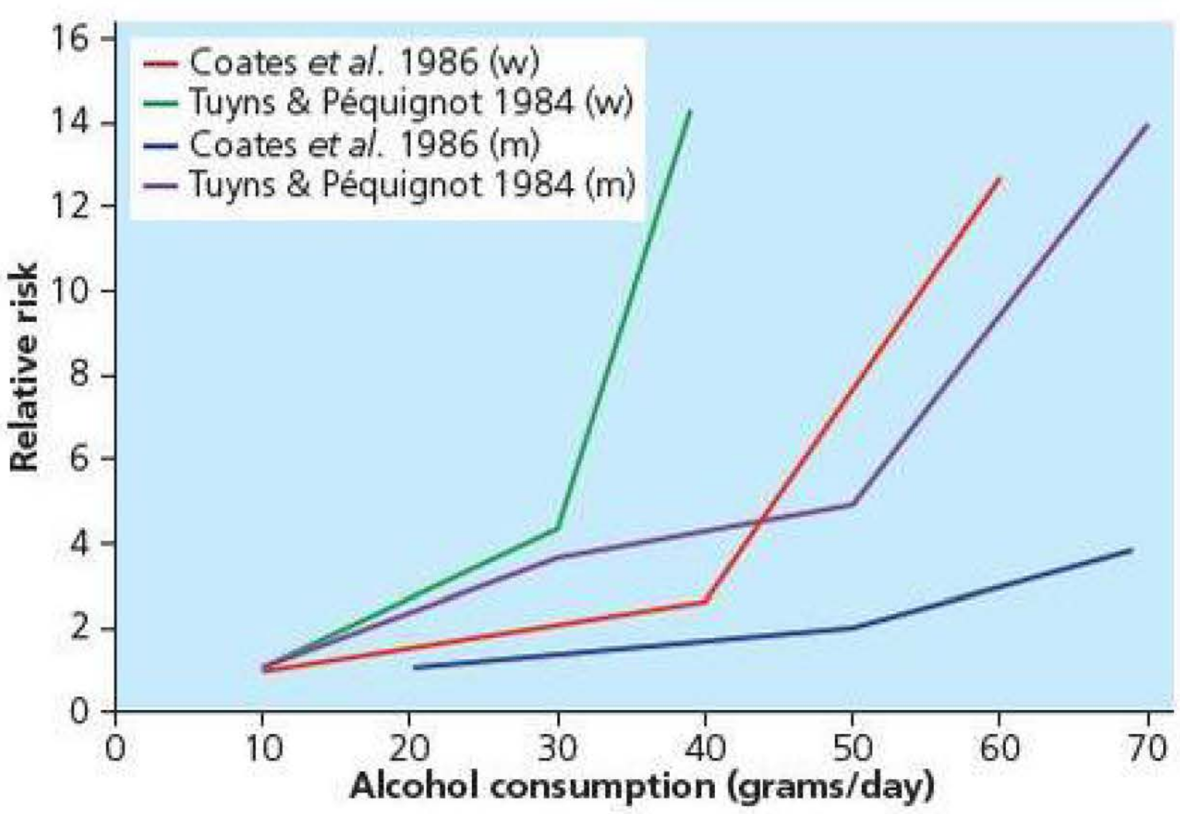


Figure 5.25a Alcohol consumption and risk of developing cirrhosis of the liver in men (m) and women (w). What pattern do you notice? Do you consider this to be a strong correlation? Explain why you think this.

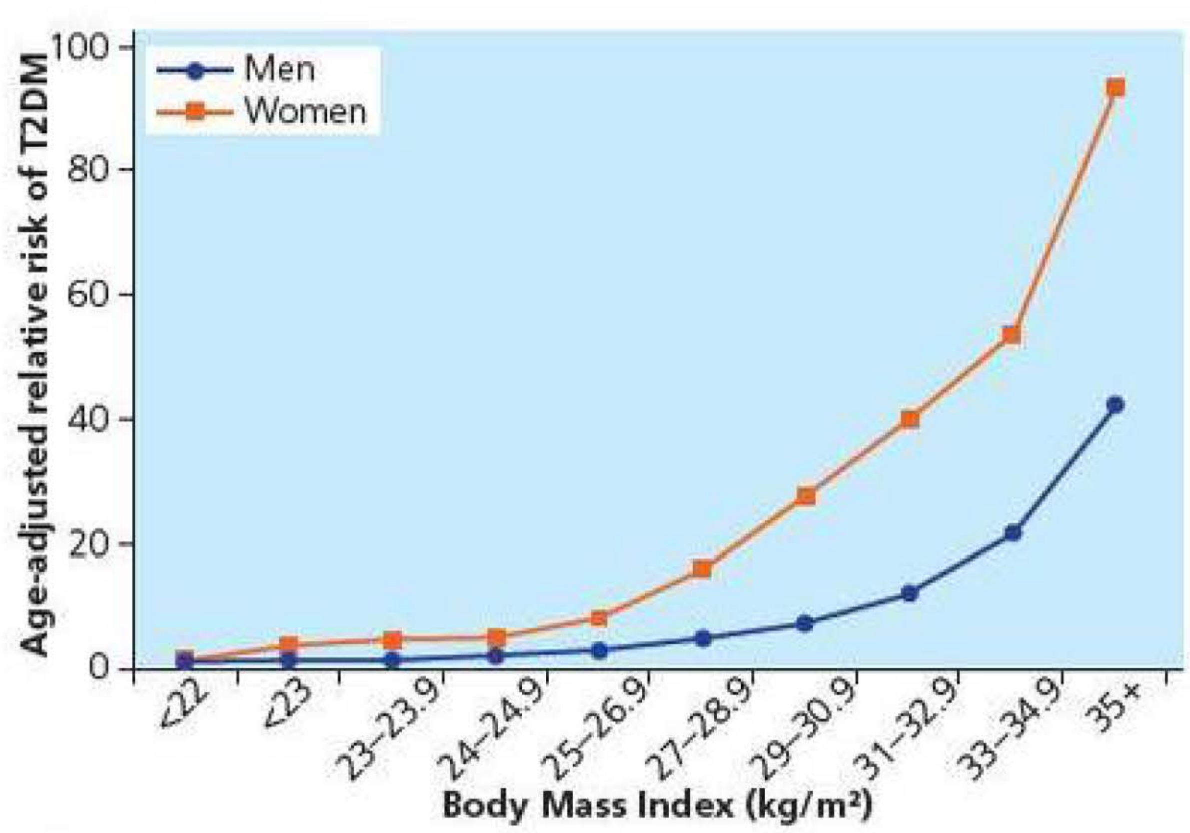


Figure 5.25b The correlation between body mass index (BMI) and Type II diabetes (T2DM). What trend do you notice?

ACTIVITY: Mapping types of diseases

ATL

- Organization skills: Use appropriate strategies for organizing complex information

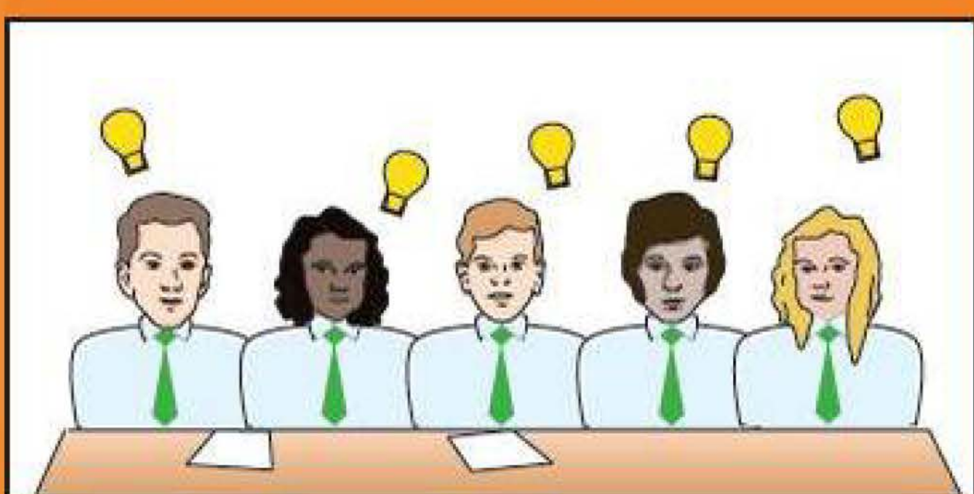
Before continuing, take some time to **organize** the information about different types of diseases you have just read about. To do this, you can use a thinking routine designed to help you generate, sort, connect, and elaborate on the big ideas.

Here are the steps for you to do on your own or with a partner and then share with the class.

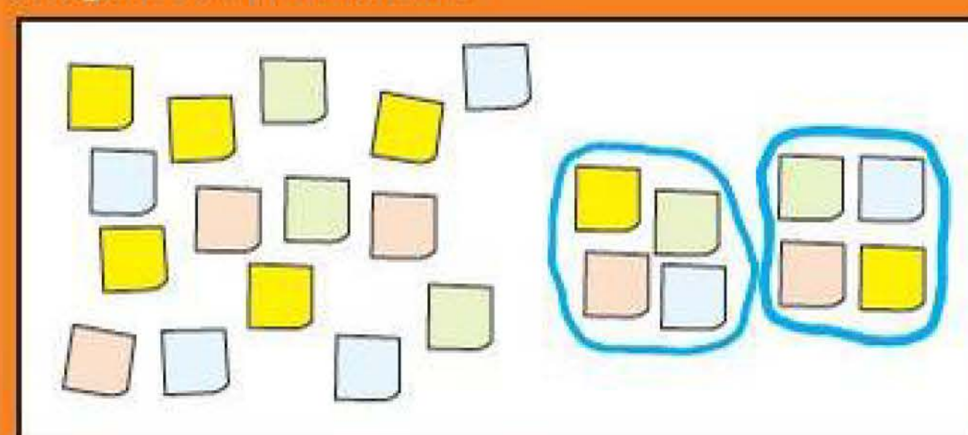
EXTENSION

Are you interested in the symptoms and treatment for the diseases mentioned in this section? Search for them on reputable websites, such as the World Health Organization (www.who.org) and the Centers for Disease Control (www.cdc.gov).

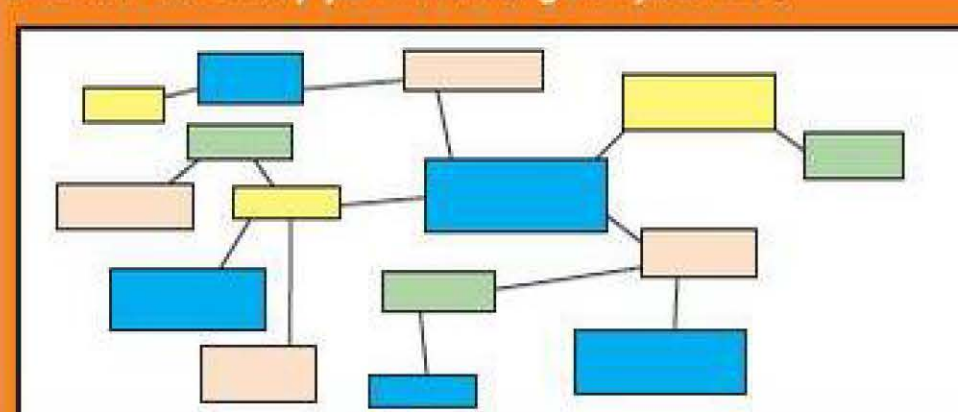
Step 1: **Generate** (think about and write down) a list of all the types of diseases, as well as any examples and important scientific words related to the diseases. You can think of this as making a 'vocabulary list' of all the important words for this section. It is helpful to brainstorm this list with a partner or as a whole class. You can generate your list on a piece of paper, on your electronic device, or on sticky notes.



Step 2: **Sort** or **separate** the words into different categories or groups. Each category or group should have words that represent some sort of relationship or connection to a different type of disease. You may want to sort the words by colour-coding or making lists. Please note: there is not one 'right' way to sort the words, and you may find that some words can easily go in more than one category. Again, talking with your classmates can help to identify different categories of information.



Step 3: **Connect** the words within and between categories by drawing lines or arrows. You could use a piece of blank paper to draw a 'mind map' or 'concept map' so that it is easier to show the connections between the ideas. If you used sticky notes, you can stick them on a large piece of paper or on a white board to draw lines between the ideas. You could also make a table if you prefer.
Try explaining the connections out loud to your partner in order to clarify your thinking for yourself.



Step 4: **Elaborate** or **explain** the connections between the words. For example, write a sentence or phrase on the connecting lines in order to say in what way(s) the ideas are connected. You may also want to write a paragraph or make a voice recording to summarize the connections between all of the words.

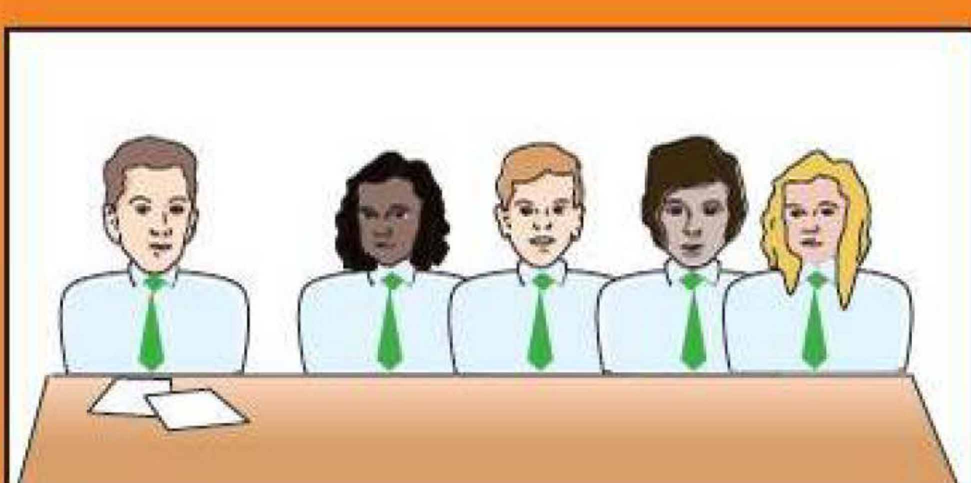


Figure 5.26 Thinking routine – Generate, Sort, Connect, Elaborate

ACTIVITY: Disease around the world

ATL

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

In this activity, you will **analyse** several different graphs that depict different trends in disease in different areas of the world. You will look at and analyse trends in:

- **mortality (deaths) from lung cancer (Figure 5.27, page 134)**
- **diagnosed clinical (treated by a doctor) depression (Figure 5.28, page 135) and**
- **mortality from infectious diseases (Figure 5.29, page 135).**

You will notice that each graph is of a different style. Scientists regularly present the results of their investigations in graphs (as do you when you do your own investigations). Because we are often confronted with the graphical representations of scientific findings in our day-to-day lives as well, in order to be well-informed and to avoid being misled, it is important that you are able to analyse and form conclusions about information that is presented in all different types of graphs.

To do this activity, you and your class and teacher can decide if each student will analyse each graph, or if you will divide up the graphs and discuss the different trends in groups.

There now follows a series of questions. The questions have been designed in order to help you thoroughly analyse, understand and form conclusions on the information that is shown by the graph or chart. The questions are a guideline for the data analysis that you will eventually be able to do on your own, after you have practised several times.

1. **Using the information in the title and any information on the graph or chart, what does the graph/chart show us? In other words, what is the goal or purpose of the graph/chart? Imagine that you are the scientist who collected the data for this graph or chart – what is your reason for making it? You should also discuss in what ways the different types of graphs (such as line or bar graphs) or charts (such as pie charts or histograms) allow scientists to explain or demonstrate different types of information. It is important that you use your own words, so *do not* just re-write the title here. Your response should be in the form of a few sentences that briefly explain the overall purpose of the graph.**
2. **What type of disease(s) does the graph show (communicable, inheritable/genetic, behaviour- or lifestyle-based, mental health-related)?**
3. **What are the 'units' of the graph, or what is the graph measuring? For example, does the graph show the percentage of people with a certain disease? Does the graph show the number of people with a certain disease?**
4. **What is the minimum and maximum number for the graph? This question is particularly important for Figure 5.27.**

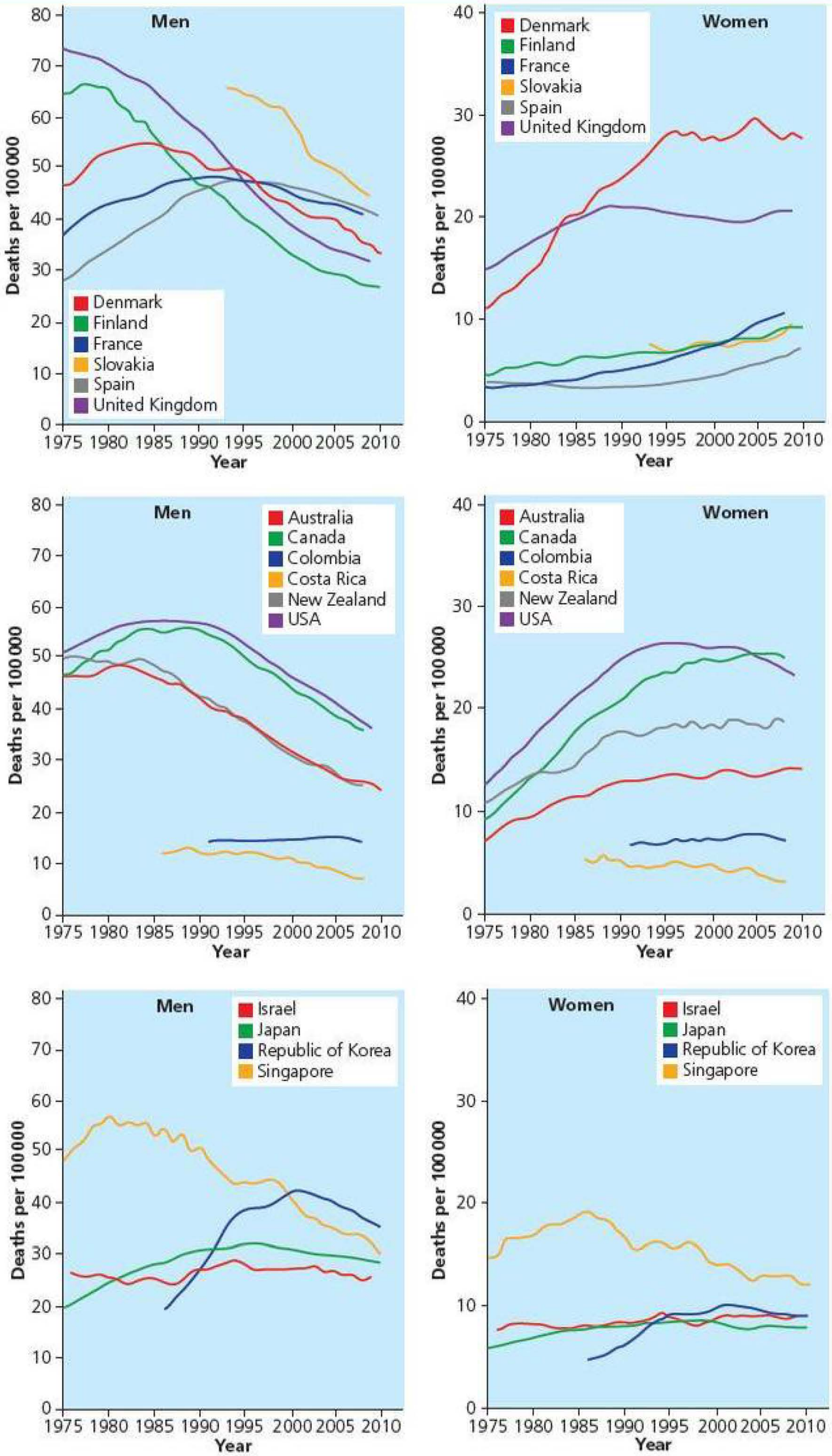
5 What patterns do you notice in the graph? At this point, you should respond only with what you see; do not give explanations or tell 'why'. Answer these sentences to help you:
   a Where/when do you notice the highest number of people with the disease(s) shown in the graph?
   b Where/when do you notice the lowest number of people with the disease(s) shown in the graph?
   c Where/when do you find the maximum number of people with the disease(s) shown in the graph?
   d Where/when do you find the minimum number of people with the disease(s) shown in the graph?
   e Where/when do you notice a sharp or sudden or very clear difference between the number of people with the disease(s) shown in the graph?
   f Where/when do you notice a small or slight or subtle difference between the number of people with the disease(s) shown in the graph?
   g Where/when do you notice strong contrasts in health trends between neighbouring countries?

For the next questions, it is important to reflect on the factors that might influence the patterns or trends that you recognized in the graphs. You can consider *cultural*, *economic*, *environmental*, *ethical*, *moral*, *political* and *social* factors.

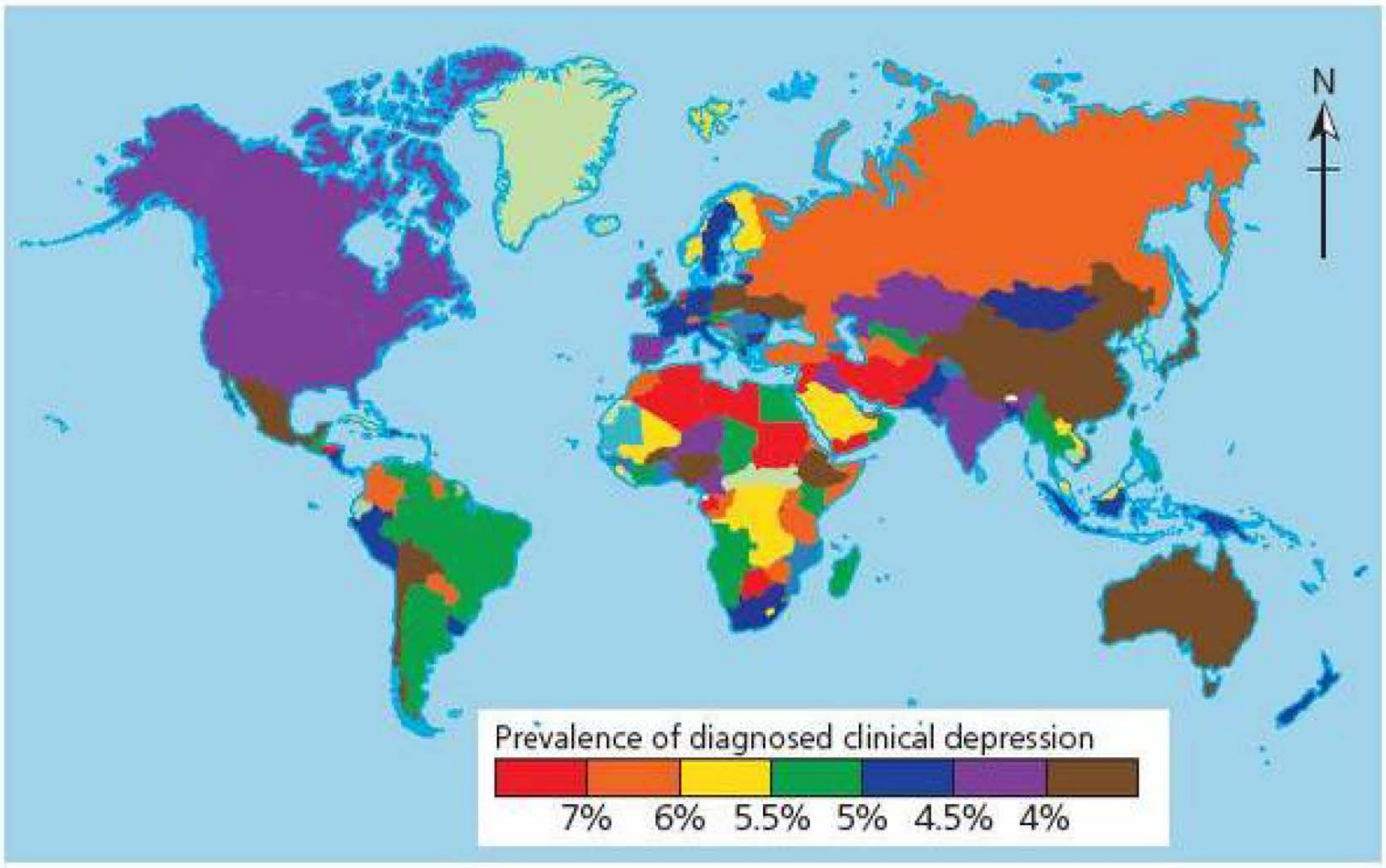
6 By using your background or general knowledge, perhaps from other classes or things you have seen in the news or experienced personally, what can you hypothesize or **suggest** as a reason for the trends you see in the graph? At this point, you can try to give an explanation and refer to things that are 'unseen' or 'not shown' directly on the graph – try using words like *because, so, for this reason* ….
7 What are some things you need to research before you form a conclusion about the data? In other words, what are some questions that you need answered before you can form a conclusion? Using reputable resources for health information, do an Internet search to find answers or additional information for your questions.
8 After doing your research, what additional information did you find in response to your questions?
9 Using the information from your research, as well as the trends you noticed in the graphs and what you have learnt about how science is applied to prevent, manage and treat disease, what conclusions can you form about the trends and tendencies shown in the graph? At this point, you can try to give an explanation and refer to things that are 'unseen' or 'not shown' directly on the graph – try using words like *because, so, for this reason* ….
10 What might be some reasons *other than the biological factors that affect health* that contribute to the patterns and trends you see? For example, cultural, economic, environmental, ethical, moral, political or social factors. In particular, it could be interesting to consider why it is that some neighbouring countries have very different trends in health.

◆ Assessment opportunities

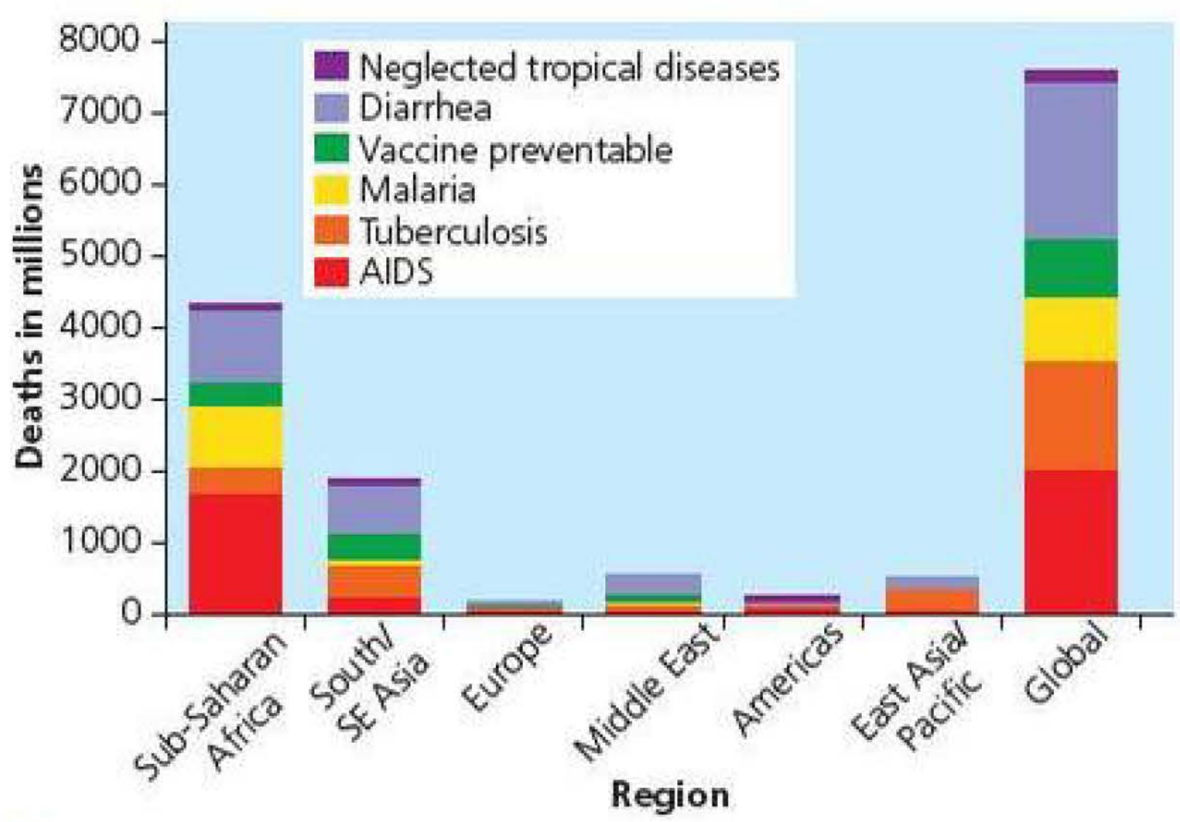
- This activity can be assessed using Criterion C: Processing and evaluating data, strands i. Present collected and transformed data, and ii. Interpret data and explain results using scientific reasoning, and Criterion D: Reflecting on the impacts of science.



■ **Figure 5.27** Trends in mortality (deaths) from lung cancer in selected countries per 100 000 (standardized by age)



■ **Figure 5.28** Diagnosed clinical depression



■ **Figure 5.29** Mortality from infectious diseases

EXTENSION

Are there other diseases in which you are interested in the patterns of their prevalence? Or what about disease patterns of men compared to women?

Try doing an Internet search to find out. You can search for the name of disease, followed by the words 'graph' or 'prevalence'. You can also do an image search instead of a web search; if you do that, be careful that the image or graph you see is actually for the disease you are interested in learning more about.

By analysing graphs of the prevalence of different diseases in different regions around the world, we can see that there are some relationships between a person's surroundings and behaviours and their internal health.

What are your thoughts about these patterns? Do you think they are permanent characteristics, or trends that can change over time? What makes you say that?

Links to: Individuals and Societies

There is an interdisciplinary link related to the key concepts of systems and global interactions for Individuals and Societies.

In this chapter, we are exploring the relationship between where people live – their surroundings – and their health. We have seen that trends in health vary as conditions and daily life experiences vary. We also read in the constitution of the WHO that, 'The enjoyment of the highest attainable standard of health is one of the fundamental rights of every human being without distinction of race, religion, political belief, economic or social condition'. This concept of **equity** is often explored in Individuals and Societies, and the question of how access to services and goods depends on income and wealth is debated.

LIFE EXPECTANCY

We have noticed that the patterns for disease are not the same for everyone, everywhere. In particular, the graphs show that depending on where in the world people are living, they may be more or less likely to develop different diseases.

As we will see in the Activity below another factor that varies greatly around the world is life expectancy. **Life expectancy** refers to how long people, on average, live. Life expectancy is often used as a quantifiable, or numerical, representation of health.

ACTIVITY: An animated look at life expectancy over the years

ATL

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

In addition to the information you learnt from the graphs about the patterns of disease around the world (Figures 5.27–5.29), you can find an animated representation of life expectancy (or lifespan) over the past 200 years by searching in your search engine or youtube.com for the following: **Hans Rosling's 200 Countries, 200 Years, 4 Minutes – the Joy of Stats**.

1 **Watch the video in order to complete the table and add to your understanding of health around the world.**

According to what you have noticed in and concluded from the graphs and Hans Rosling's animation, what are some factors related to living environment and health that you can suggest?

2 **Work with a partner to suggest some factors, as well as a justification for your suggested factors. Record your ideas in a copy of the table below.**

3 **Draw some conclusions, and consider and complete this sentence with your ideas: 'In general, the pattern and relationship between income and life expectancy is …'.**

According to the way in which Hans Rosling shared the data, measuring human health can be reduced to a comparison between life expectancy and income.

4 **What are your thoughts about the relationship between life expectancy and income? From what you have seen and learnt, to what extent do you agree that income is the biggest factor affecting health?**

Table 5.2 Hans Rosling's 200 Countries, 200 Years, 4 Minutes – the Joy of Stats: Identifying patterns in income and life expectancy

Country	Pattern related to income	Effect on life expectancy (lifespan)

Remind yourself of the Statement of Inquiry for this chapter. We have learnt about some of the physical or biological aspects of health, and through looking at and analysing graphs, we have identified some patterns in health in different regions of the world. In addition, we have learnt that there is a strong positive correlation between income level and life expectancy, which is one of the indicators of health.

Life expectancy correlates with other factors that are linked to a person's surroundings, or where he or she lives.

ACTIVITY: The relationships between health and where you live

ATL

- Critical-thinking skills: Use models to explore complex systems; identify trends
- Information literacy skills: Access information to be informed and inform others
- Communication skills: Make inferences and draw conclusions

With a partner or as a class, brainstorm a list of factors that vary from country to country or region to region which make you wonder about their impact on life expectancy. For example, maybe you wonder about the relationship between trends in the number of physicians available in different regions and life expectancy. How about having access to clean water or sanitary facilities? How might they relate to life expectancy in different parts of the world?

Once you have brainstormed a list of factors, go to the Google Public Data website to create datasets and graphs that demonstrate the relationship between life expectancy and each one of the factors. You can select different World Development Indicators to graph against life expectancy. These indicators may be the same as the factors you brainstormed or different. You can also choose which regions or countries to compare, and you can select to graph the data as a scatterplot, which you can then 'play' to see the trends since 1990.

When you are making your graphs, be sure to consider carefully whether to put 'life expectancy' on the *x*- or *y*-axis; in other words, in the graphs that you are creating, is life expectancy the independent or dependent variable?

After you have created your graphs, compare them with those that your classmates have created. What do you notice? What can you conclude?

Organize the information in the graphs into a table (see below), and **discuss** the patterns with your class.

Assessment opportunities

- This activity can be assessed using Criterion C: Processing and evaluating data, strands i. Present collected and transformed data, and ii. Interpret data and explain results using scientific reasoning.

Table 5.3 Patterns and relationships between life expectancy and World Development Indicators

World Development Indicator	Pattern or trend that the graph shows	Relationship between geography and health that the graph suggests




■ **Figure 5.30** How do our surroundings affect our health?

Now that we have found evidence to support our Statement of Inquiry, we will look further into the biological relationship between surroundings or living environment and health.

■ **Table 5.4** Biological relationships between types of diseases and living environment

Type of disease	Biological relationship with surroundings or living environment
Communicable	Because pathogens can often be eliminated or reduced by appropriate sanitation, including washing with warm water and soap, communicable diseases tend to spread more in living environments where people have limited or no availability to hot, running water and soap. The spread of communicable diseases occurs more quickly and easily when people are living in more densely populated areas or homes. Antibiotics help to treat diseases and vaccines help to prevent the spread of diseases; however, the availability and affordability of antibiotics and vaccines differs greatly in different areas of the world.
Inheritable or genetic	In more some areas of the world there may be less genetic diversity among the population, which can contribute to the passing on of genetic diseases from parents to offspring.
Behaviour or lifestyle-based	Eating a diet high in saturated fats, processed foods and animal products; smoking; consuming excess alcohol; and taking drugs have a negative impact of the function of internal organs and blood flow. For example, the kidney and liver both function to break down the things we consume, and then help the body to get rid of the wastes that come from the toxic substances that sometimes make up the food we eat, liquids we drink, air we breathe, and drugs (both legal and illegal) we take. If we consume many products which have components that are toxic for our body, the kidneys and liver have to work 'overtime' in order to neutralize or eliminate the toxins from our body. In addition, a diet that is high in saturated fats can contribute to blockages in blood vessels, which can slow or reduce blood flow through the body. Products which have components that are toxic for the body tend to be more highly processed and contain large quantities of sugar, such as packaged or fast food. Also, when we eat and digest animal products such as red meat or cheese, the body has to process more toxic substances than after we eat plant products, such as grains or seeds. In addition, products that contain addictive substances, such as coffee, alcohol, tobacco and drugs, have more toxic substances than products that do not contain addictive substances. A sedentary lifestyle in which a person gets little exercise and, in fact, moves very little throughout the day, can contribute to obesity as well as increase the risk of problems with heart, liver, and kidney health.
Mental-health disorders	Mental health is linked to the functioning of the **nervous system**. The nervous system responds to events and situations in our surroundings, which cause different organs or parts of the nervous system to release chemicals, such as hormones or neurotransmitters. In some people, there is not an appropriate balance between the release or recognition of hormones and neurotransmitters. Stress is closely linked to mental-health disorders such as depression. Stress can be related to financial insecurity, emotional insecurity, unemployment, social inequality and the presence of other health issues. Experiencing conflict is linked to mental-health disorders, including post-traumatic stress disorder and depression. Some examples of conflict that people experience are being in an abusive relationship; experiencing or participating in war; and living in a high-crime area.

! Take action

ATL

- Communication skills: Use a variety of media to communicate with a range of audiences
- Media literacy skills: Locate, organize, analyse, evaluate, synthesize, and ethically use information from a variety of sources and media
- Transfer skills: Combine knowledge, understanding, and skills to create products or solutions

! Use your understanding about the factors related to health in order to create a campaign of scientifically researched and supported healthy-living strategies or suggestions. Consider the following in your campaign:

- Who is the target audience of your campaign? For example, are the strategies in your campaign more applicable for people in urban areas of more or less economically developed countries? Or are your strategies more useful for those living in rural areas? Or maybe your campaign will focus on a portion of a larger population, such as teenage girls in more economically developed nations.
- What are the health concerns related to your target audience? For example, will you focus on communicable diseases, or perhaps mental-health issues? Or do you want to develop your campaign about a specific health concern, such as vaccinations?
- Why does the target audience need to know about the information in your campaign? In other words, be sure that the message of your campaign is relevant to the lives of your target audience.
- What scientific information do you want your target audience to know? In other words, what scientific information about human health will you share through your campaign? Remember, your campaign will be more credible and influential if you include references to scientific data as evidence and support for the strategies you suggest.
- What did you do to be sure that the information you share in your campaign is valid and scientifically supported? You can include more trustworthy information if you use information that is:
    - searched on scholarly databases, such as **jstor.org**, or search engines, such as **scholar.google.com**
    - from websites of *official commercial organizations* (.com web addresses), *non-profit organizations* (.org), *government organizations* (.gov), or *educational facilities* (.edu)
    - from websites that have been recently updated
    - from websites free of spelling errors or unreadable fonts
    - recently published
    - peer reviewed or cited by other scientists or in other scientific publications
    - based on recent data that comes from a single study in a governmental organization, educational facility, or peer-reviewed journal.
- What is the best way for the information of your campaign to reach your target audience? What environmental, economic, social, moral or cultural factors do you need to consider when developing your campaign? For instance, if your target audience lives in a rural area of a less economically developed country, would a social networking campaign be the most effective way of spreading your message?
- What can you do to correctly cite and give credit to your sources of information? To use appropriate citation formats, you can do an Internet search for '*citation generator*' to find websites that will create the citation for you, or maybe you can download a citation app on your smart phone or computer to do the same. To be sure that you are following the principles of academic honesty, try doing an Internet search of '**avoiding academic dishonesty**;' follow the suggestions provided by the educational facilities, usually universities, that come up in the search results.

Assessment opportunities

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

SOME SUMMATIVE PROBLEMS TO TRY

Use these problems to apply and extend your learning in this chapter. These problems are designed so that you can evaluate your learning at different levels of achievement in Criterion A: Knowledge and understanding.

THESE PROBLEMS CAN BE USED TO EVALUATE YOUR LEARNING IN CRITERION A TO LEVEL 7–8

1 You are visiting a friend for a week during a school holiday. A few days into your visit, you begin to feel ill. You develop a sore throat, headache and fever. You are also feeling tired and a bit achy. His parents are away so you do not have a way to get to the doctor until late the next day.

a **Explain** the biological reasons for why we feel and experience different symptoms when we are ill.

You and your friend decide to look up your symptoms online. After visiting a couple of different websites, you and he think that you might have strep throat. However, you and your friend are not sure, because it seems it may also be the flu.

All of the websites you visit say that you should drink plenty of water, rest a lot and gargle with warm salt water, and some of the websites say that you should take an 'over the counter' medicine to reduce your fever.

Your friend tells you that a few weeks ago, he had also been sick with the same symptoms. His doctor did a test for strep throat and then prescribed him antibiotics. Because he was feeling better a few days after taking the antibiotics, your friend didn't finish the prescription; he offers you the rest of the pills since they helped him feel better so quickly.

b **Analyse** the information in the scenario to **evaluate** your options. To do this you should:

i **state** the circumstances when taking antibiotics is appropriate

ii **identify** some reasons for the suggestions on the websites based on what you know and understand about pathogens and illnesses

iii **outline** the strengths and limitations of using your friends' antibiotics

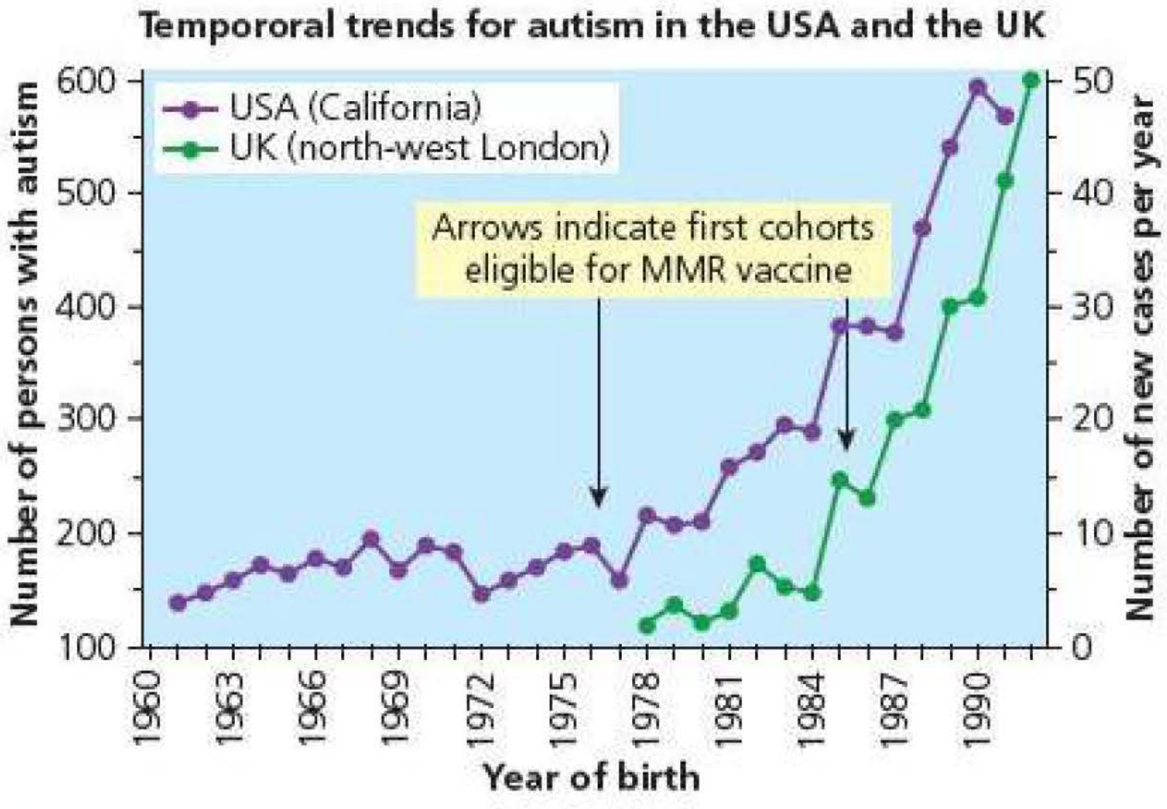
iv **outline** the strengths and limitations of following the suggestions from the websites.

c **Apply** your scientific knowledge and understanding about disease and illness and **discuss**, using scientific evidence, what you should do to feel better until your friend's parents return the next day and can take you to the doctor.

2 Imagine that the older brother of a friend of yours, whose wife will soon be having a baby, is trying to decide whether or not they should get the baby vaccinated. He says he doesn't understand why people are still getting vaccines for things like measles, mumps and rubella, because 'no one gets them any more'.

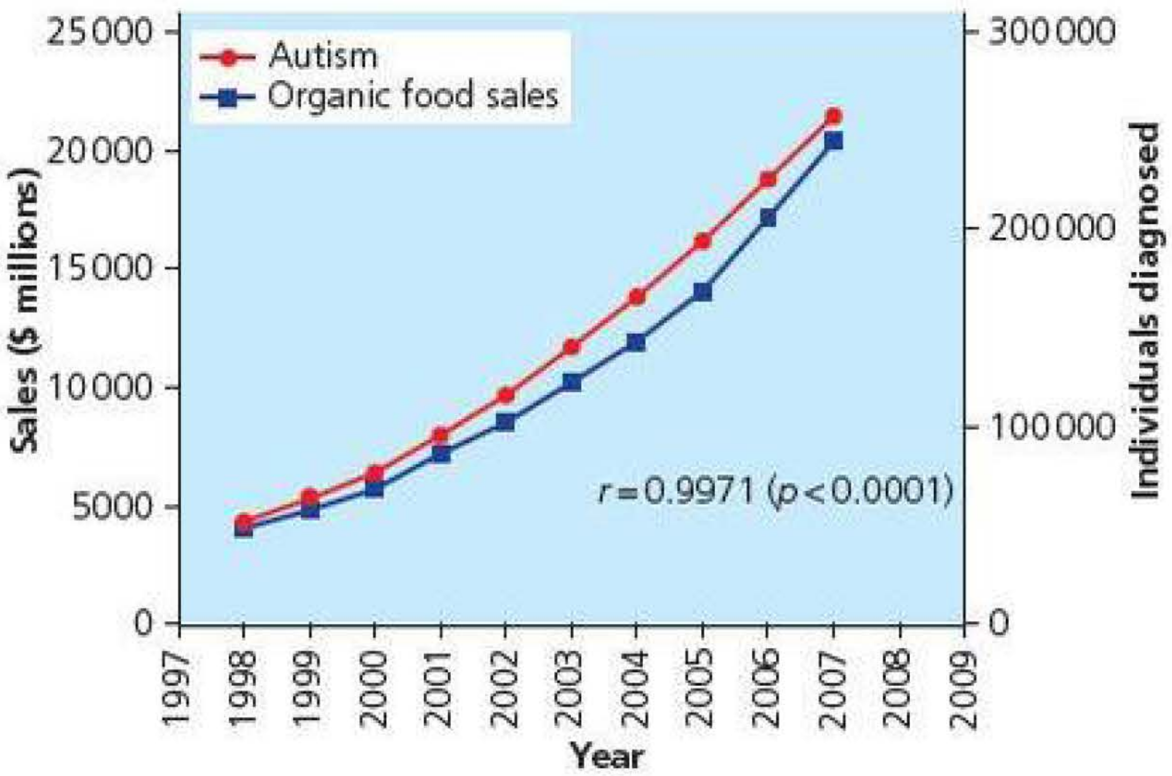
a Use your knowledge of vaccines and how illnesses are spread to **explain** to your friend's brother how vaccines work to prevent and protect people from the spread of certain diseases.

After you explain how vaccines work, the brother says he has heard there is a link between vaccinations and autism. He points out this graph he saw online:

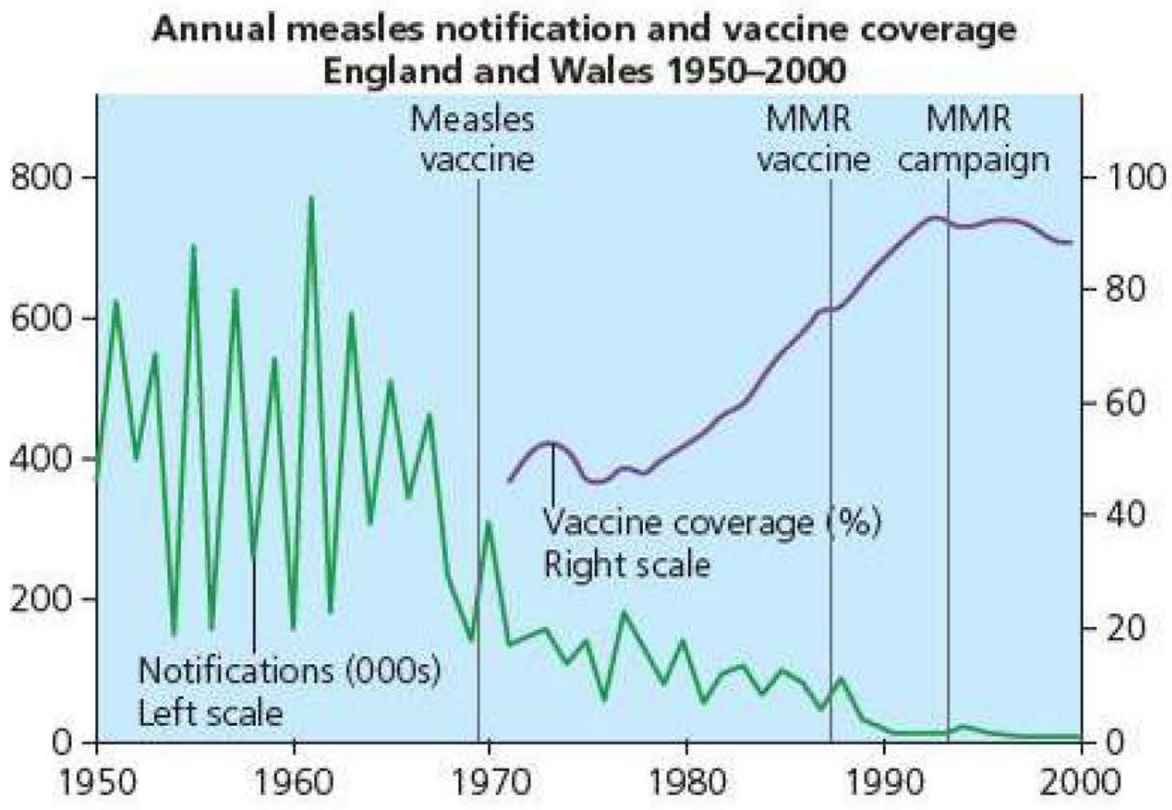


■ **Figure 5.31**

Then, your friend, who thinks his brother should get the baby vaccinated, shows you these two other graphs from different websites:



Sources: Organic Trade Association, 2011 Organic Industry Survey, U.S. Department of Education, Office of Special Education Programs, Data Analysis System (DANS), OMB 1820–0043: 'Children with Disabilities Receiving Special Education Under Part B of The Individuals with Disabilities Act'



Source: Public Health England

■ **Figure 5.32**

b **Analyse** and **evaluate** the data in the graphs to make a scientifically supported judgement about the efficacy of vaccinations and the cause of autism. To do this, for each graph you should:

i **identify** the sources of the data, if any

Hint

Look at the 'small print' under the x-axis.

ii **evaluate** the sources of data (how reliable, trustworthy and relevant is the source?)

iii **identify** the variables on the *x*- and *y*-axes

iv **summarize** the relationship between the variables

v **outline** the strengths and weaknesses of the information provided in each graph

vi **discuss** to what extent these graphs demonstrate the efficacy of vaccinations, and to what extent they demonstrate a link or cause of autism.

A few weeks after this conversation, you are back at your friend's house. The brother is there again, and has said that they have been thinking about another option instead of vaccinating their baby. After talking about what you told him last time about vaccines and how they work, they thought they could bring the new-born baby out to the mall and other public places to expose her to as many 'germs' as possible. That way, the brother says, the baby will build up her own defences and will not need antibiotics.

c **Evaluate** the two methods the brother is considering to protect his baby from the possibility of contracting diseases like measles, mumps, and rubella: getting a vaccination or exposing the new-born to people who are possibly infected with different pathogens.

d **Apply** what you know and understand about the immune system and vaccinations to **suggest** the better option for protecting their baby.

3 The tendency of different types of diseases varies in different areas of the world.

a **Explain** some of the trends, tendencies or patterns of disease that can be understood through the data and statistics available through organizations such as the WHO.

b There are many different examples of diseases that are prevalent in less economically developed nations compared to more economically developed nations. Using specific examples in your response, **explain** this tendency.

According to the resources at **www.water.org**:

> Although access to drinking water has improved, the World Bank estimates that 21% of communicable diseases in India are related to unsafe water. In India, diarrhea alone causes more than 1,600 deaths daily ... Hygiene practices also continue to be a problem in India. Latrine usage is extremely poor in rural areas of the country; only 14% of the rural population has access to a latrine. Hand washing is also very low, increasing the spread of disease.

c **Apply** your knowledge and understanding of how diseases spread and how they can be prevented to offer some possible solutions to the problems that exist in India relation to access to water and the spread of disease.

In the constitution of the WHO, it states, 'The extension to all peoples of the benefits of medical, psychological and related knowledge is essential to the fullest attainment of health'.

d **Discuss** the relationship between people's living conditions or surroundings and health.

e Using scientific examples to support your position, **discuss** the principle in the above statement that the 'fullest attainment of health' depends on providing all people with 'medical, psychological and related knowledge.'

Reflection

In this chapter we have seen that 'health' can mean many different things. Health can be influenced by the presence of pathogens in our body, inheritable diseases, lifestyle and behaviour, and mental illness. Moreover, we have seen that human health is a function of not only the biological processes that occur inside our bodies, but also of the conditions that surround us wherever we live. Being healthy is a result of how well the body is able to maintain a healthy balance, or homeostasis. However, the degree to which our bodies can maintain or re-establish homeostasis is influenced by external factors including the conditions of our living environment.

<table>
<tr><th colspan="6">Use this table to reflect on your own learning in this chapter</th></tr>
<tr><td>Questions we asked</td><td>Answers we found</td><td colspan="4">Any further questions now?</td></tr>
<tr><td>Factual: What must happen inside the human body in order for us to be healthy? What are external conditions that contribute to our health?</td><td></td><td colspan="4"></td></tr>
<tr><td>Conceptual: How are biological processes in our bodies, the conditions we live in, and our lifestyles related so that their interactions have consequences for our overall health?</td><td></td><td colspan="4"></td></tr>
<tr><td>Debatable: What is 'health'? Is access to health care and a healthy lifestyle a right or a privilege?</td><td></td><td colspan="4"></td></tr>
<tr><td rowspan="2">Approaches to learning you used in this chapter</td><td rowspan="2">Description – what new skills did you learn?</td><td colspan="4">How well did you master the skills?</td></tr>
<tr><td>Novice</td><td>Learner</td><td>Practitioner</td><td>Expert</td></tr>
<tr><td>Communication skills</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Media literacy skills</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Critical-thinking skills</td><td></td><td></td><td></td><td></td><td></td></tr>
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<tr><td>Organization skills</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Information literacy skills</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Learner profile attribute(s)</td><td colspan="5">Reflect on the importance of being reflective for your learning in this chapter.</td></tr>
<tr><td>Reflective</td><td colspan="5"></td></tr>
</table>

6 How do characteristics pass from one generation to another?

Your **identity** and **relationships** with other people are determined by genetic factors: scientific **evidence** has led to **models** that help to understand observed **patterns** of inheritance.

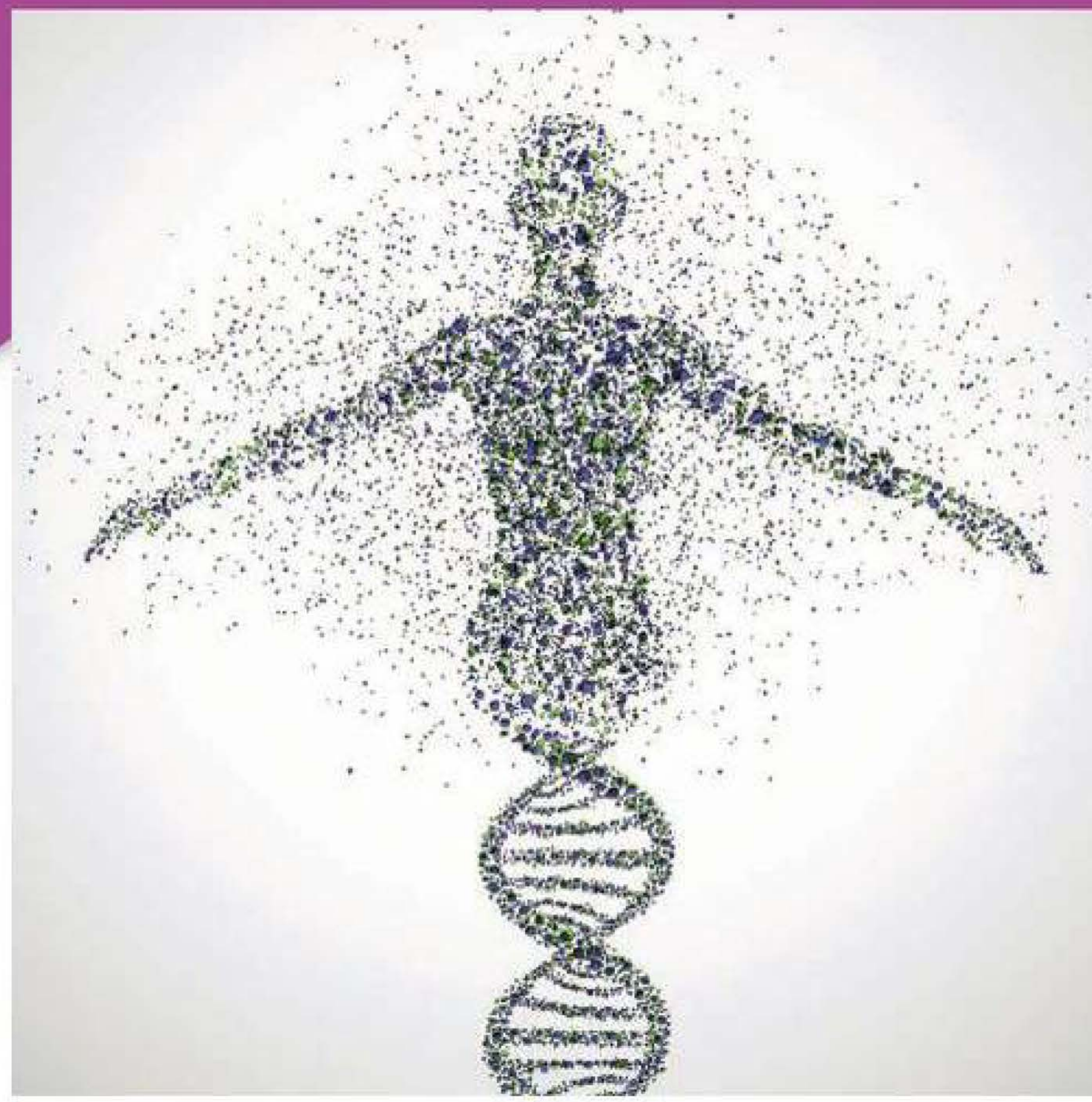


Figure 6.1 DNA codes for the characteristics that determine individual characteristics and identity

CONSIDER AND ANSWER THESE QUESTIONS:

Factual: What is DNA? In what way is DNA the basis for inheritance and evolution? Who was Gregor Mendel and what work did he do to show how characteristics are inherited? What are alleles? What is asexual and sexual reproduction? How do single-celled organisms reproduce? What is mitosis? How do multicellular organisms reproduce? What different life cycles exist?

Conceptual: What does the structure of DNA reveal about its function? How does the genetic code produce physical characteristics? To what extent does the genetic code determine the identity of a person?

Debatable: Does the end justify the means in science – were Watson and Crick correct to use Rosalind Franklin's data without her permission? Were Mendel's results too perfect? To what extent should humans manipulate human reproduction or genetic characteristics?

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

IN THIS CHAPTER, WE WILL …

- **Find out:**
  - how DNA is the basis of inheritance;
  - how DNA determines our identity and relationships with others.
- **Explore** how models and experiments reveal the structure and nature of DNA.
- **Take action** by exploring whether specific genes should be artificially selected to make 'designer babies'.

KEY WORDS

characteristics	heredity	replication
cross-breed	inheritance	variation
generation	offspring	

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

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

We will reflect on this learner profile attribute …

- Open-minded – critically appreciating our own personal history, and seeking a range of points of view.

Assessment opportunities in this chapter:

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

LIFE STORY: HOW THE DNA STRUCTURE WAS DISCOVERED

Figure 6.2 James Watson

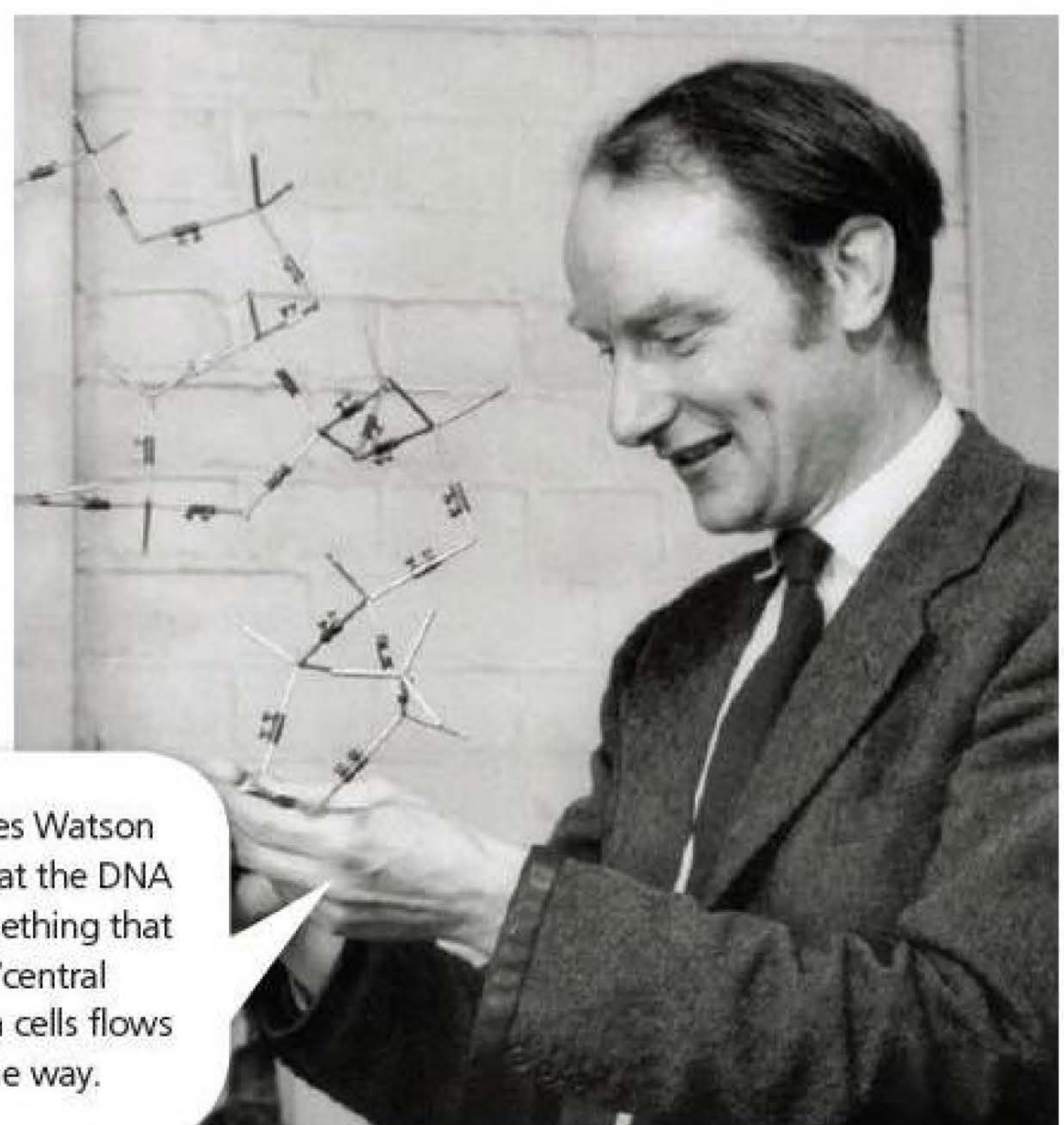
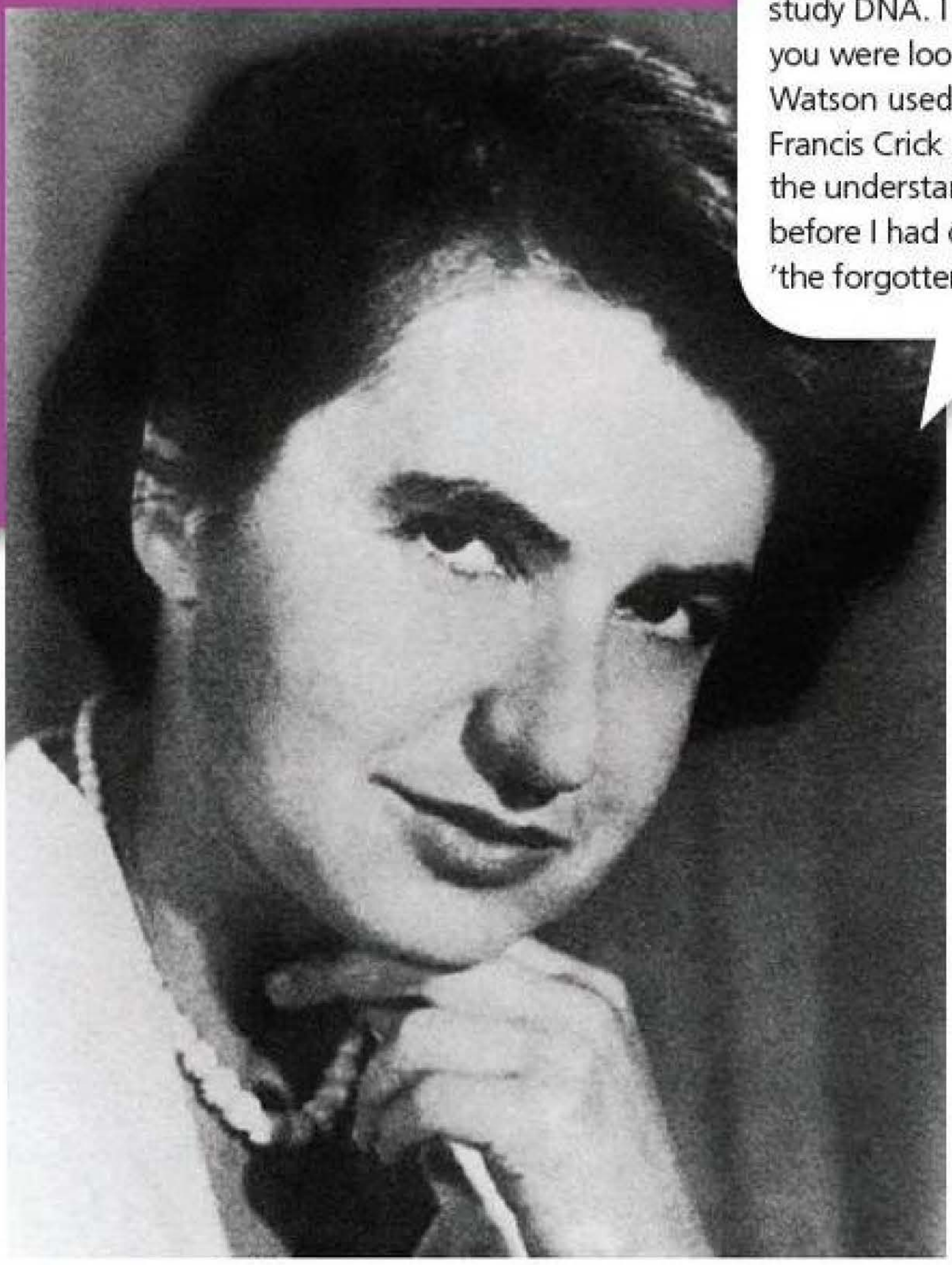
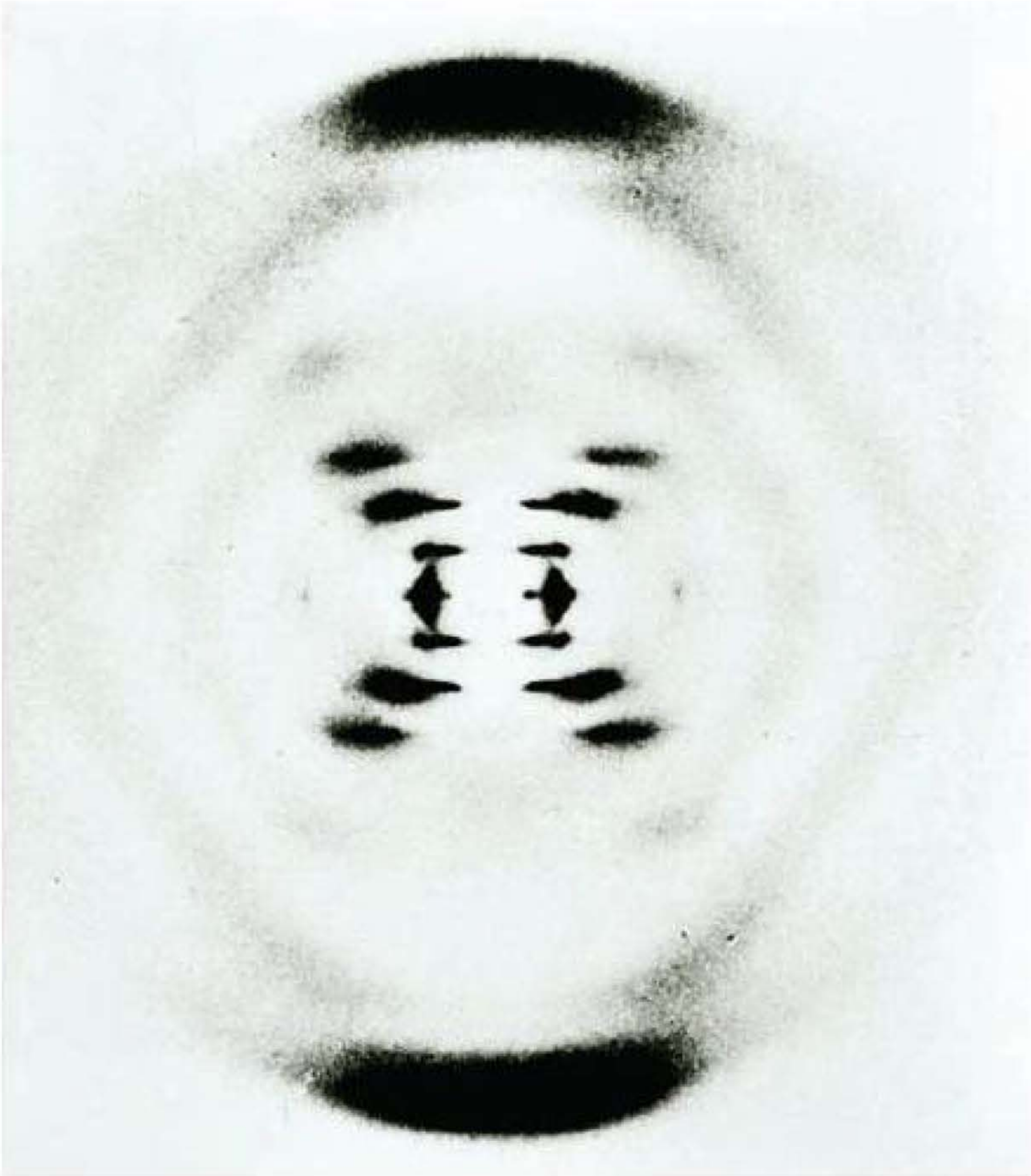


Figure 6.3 Francis Crick

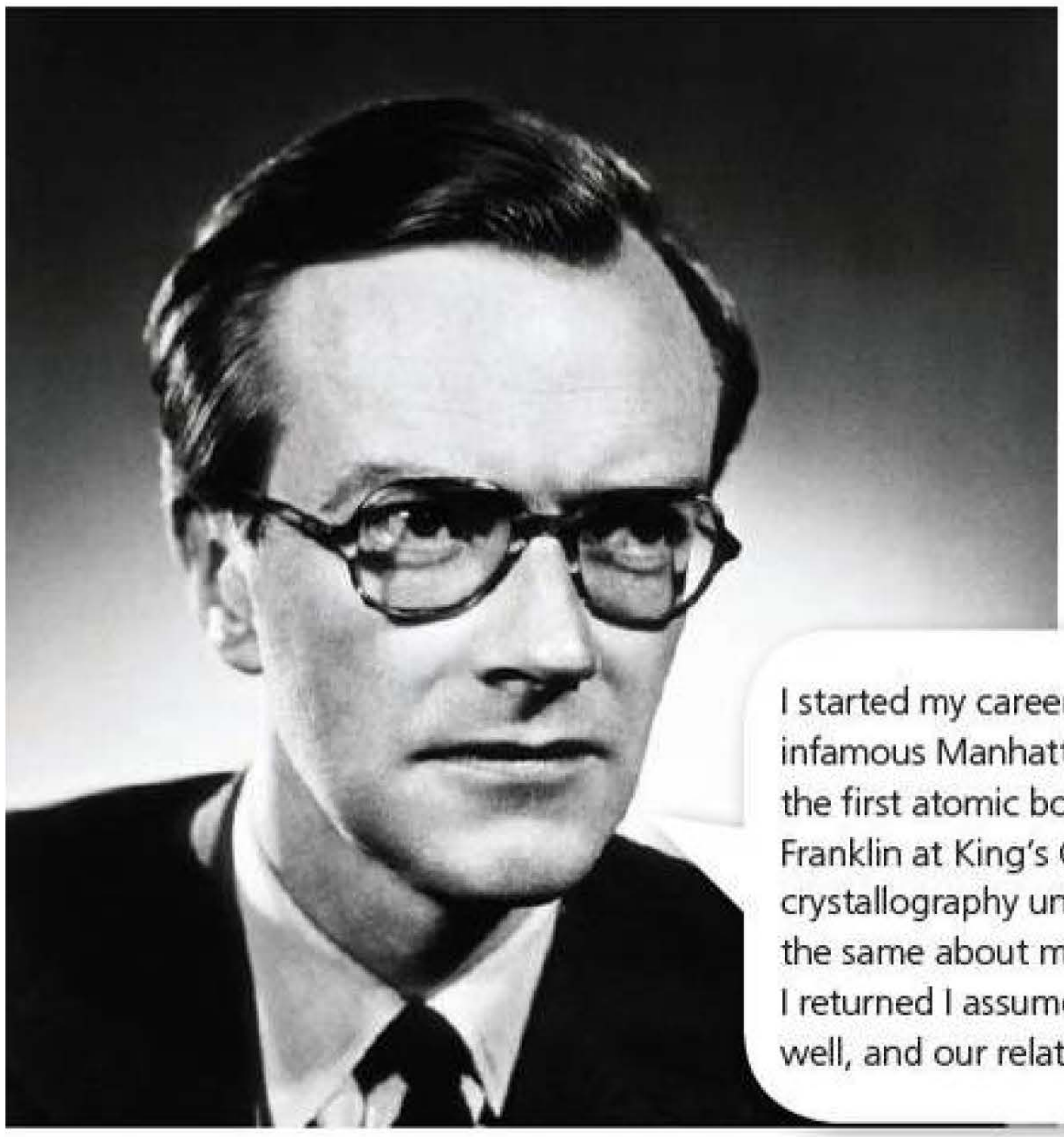
I was a British chemist and X-ray crystallographer who used X-ray diffraction to study DNA. I produced photographs of DNA that showed (if you knew what you were looking for!) that the molecule was made of a double helix. James Watson used one of these photos (without my permission!) to help him and Francis Crick develop their DNA model. Although I made critical contributions to the understanding of DNA structure, Watson and Crick published their model before I had completed my research, and so today I am sometimes referred to as 'the forgotten woman of DNA'.



■ **Figure 6.4** Rosalind Franklin



■ **Figure 6.5** X-ray diffraction photo of DNA taken by Rosalind Franklin in 1953, the year in which Watson and Crick discovered DNA's structure, aided by Franklin's work. The image results from a beam of X-rays being scattered onto a photographic plate by the DNA. Various features about the structure of the DNA can be determined from the pattern of spots and bands. The cross of bands indicates the helical nature of DNA



I started my career as a nuclear physicist, but was put off this after working on the infamous Manhattan Project (the research and development project that produced the first atomic bombs during the Second World War). I worked alongside Rosalind Franklin at King's College, London, who had been employed to improve the X-ray crystallography unit. I found her very difficult to work with (but she probably felt the same about me!). I had been on holiday when she was first arrived, and when I returned I assumed she had been taken on as my assistant – she did not take this well, and our relationship did not improve from that point!

■ **Figure 6.6** Maurice Wilkins

ACTIVITY: Researching DNA and how science is done

ATL

- Information literacy: Evalute information sources based on their appropriateness to tasks

In this activity you will:

- **access information to be informed and inform others**
- **make connections between different sources of information**
- **evaluate and select information sources based on their appropriateness to the task**
- **create references and citations, use footnotes/ endnotes and construct a bibliography according to recognized conventions.**

Specifically, you will:

- **learn about how the structure of DNA was discovered (how and by whom)**
- **discuss what the discovery tells us about how science is done.**

Breaking it down, you need to:

- **write an essay on how the structure of DNA was discovered**
- **use the keywords opposite to help you search for information**
- **include information about the structure of DNA (what it looks like and what it is made from)**
- **include information about the scientists who helped lead to its discovery, as well as the two scientists who first published the structure of DNA in 1953**
- **write about what you think the discovery tells us about how science is done**
- **remember that your work will be marked on content, presentation and effort**
- **plan your time carefully, allocating time for reading and then writing**
- **reference your work and include a bibliography.**

How science is done

The story of how the structure of DNA was discovered reveals a lot about how science is done. The study of science is based on the scientific method. An explanation (theory) is based on evidence (observations) and can be used to make a prediction. The theory remains the current theory until a new experimental fact contradicts it. Then the theory is modified, or changed to a new theory that fits the facts – until a new fact is discovered that disproves this theory, and so on.

The discovery of the structure of DNA had many false starts, until the correct structure was discovered (in 1953). The scientists that published the structure of DNA first got all the credit for its discovery – even though other scientists were also working on the structure at the time and had contributed to its discovery.

Key words

People: **Erwin Chargaff**, **Alfred Hershey**, **Martha Chase**, **Rosalind Franklin**, **Maurice Wilkins**, **James Watson**, **Francis Crick**.

Scientific words: **adenine**, **thymine**, **guanine**, **cytosine**, **double helix**, **X-ray diffraction**.

Useful sites:

Learn Genetics: **http://learn.genetics.utah.edu/**

Video: **www.youtube.com/ watch?v=sf0YXnAFBs8**

Referencing: There are many different ways of referencing (i.e. recording references used when writing an essay). A popular method is the Chicago style of citation: **www.chicagomanualofstyle.org/home.html**.

EXTENSION

The global context for this chapter is Identities and relationships, and the focus for the Learner profile is Open-minded. With these in mind, research further about the role of women in science. Use Rosalind Franklin as your starting point, and then find out about other significant women scientists and the roles they played. Perhaps you would like to give a talk to your class/year group about changing roles and perceptions of women scientists through time?

What does the structure of DNA reveal about its function?

WHAT IS DNA?

DNA (deoxyribonucleic acid) is a molecule common to all life on Earth. It contains the code that determines the shape and structure of living things. The discovery of the structure of DNA was one of the biggest breakthroughs in science. Scientists could then understand how organisms reproduce and pass on their **characteristics** to **offspring**.

When James Watson and Francis Crick completed their model of DNA, they announced that they had 'discovered the secret of life'. Once the structure of DNA was known, it was clear (immediately to Watson and Crick, and later to other scientists) how it could divide and replicate, copying itself from one **generation** to the next and so passing on the information it contained.

But what is DNA? DNA is also a macromolecule (page 56), made up from repeating units of a smaller building block. The building blocks of DNA are **nucleotides**, made up themselves from three parts: a phosphate, a sugar (deoxyribose) and a base.

There are four different **bases**: **adenine**, **cytosine**, **thymine** and **guanine**. Each base has a different shape. The bases make a four-letter 'alphabet' – the order of the bases in the DNA determines the **genetic code**, which determines the characteristics of the organism.

The phosphate and sugar from one nucleotide join with other nucleotides to form a long chain – two of these chains join together to form a DNA molecule (a double helix), held together by the bases (see Figure 6.9). The sugar and phosphates form the 'backbone' of the DNA, with the bases making the genetic code.

What do you notice about the bases in Figure 6.9? How do you think this helps in DNA **replication**?

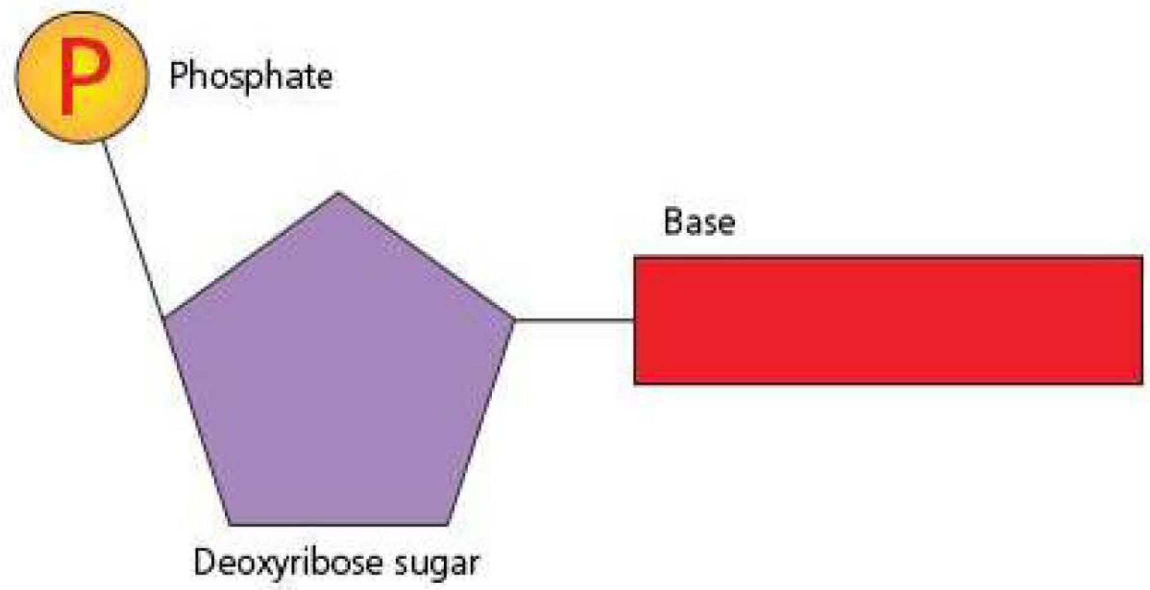


Figure 6.7 A nucleotide – the building block of DNA

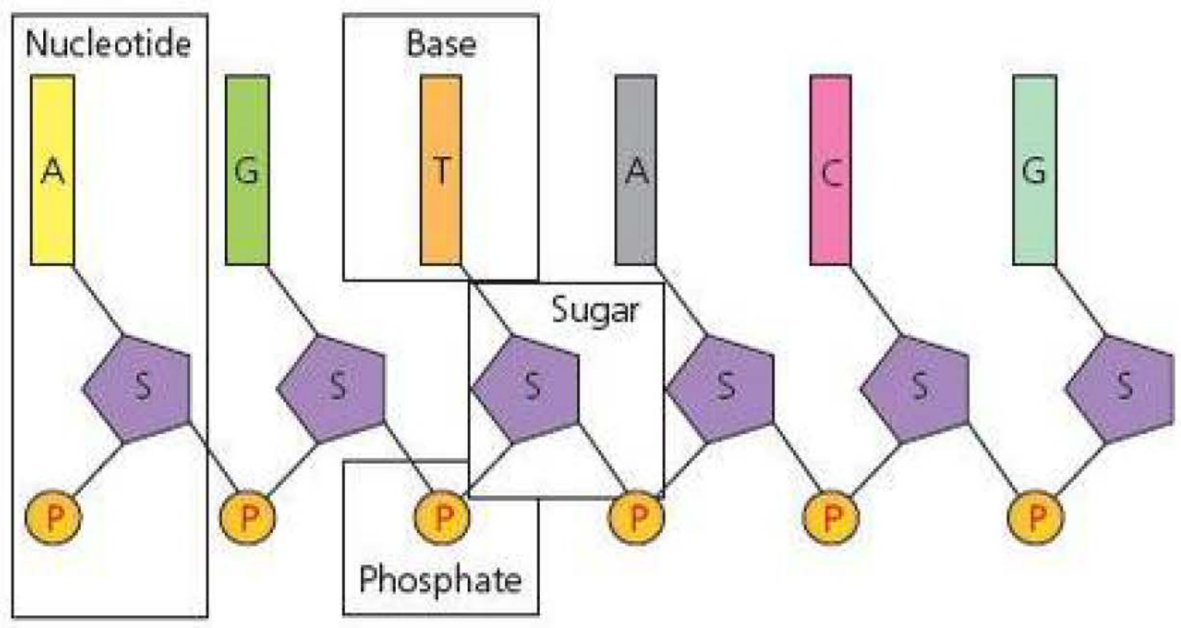


Figure 6.8 A chain of nucleotides make up a macromolecule. Two of these join together to make a double helix (DNA). The sugar and phosphates make the backbone of the DNA, and the bases contain the genetic code

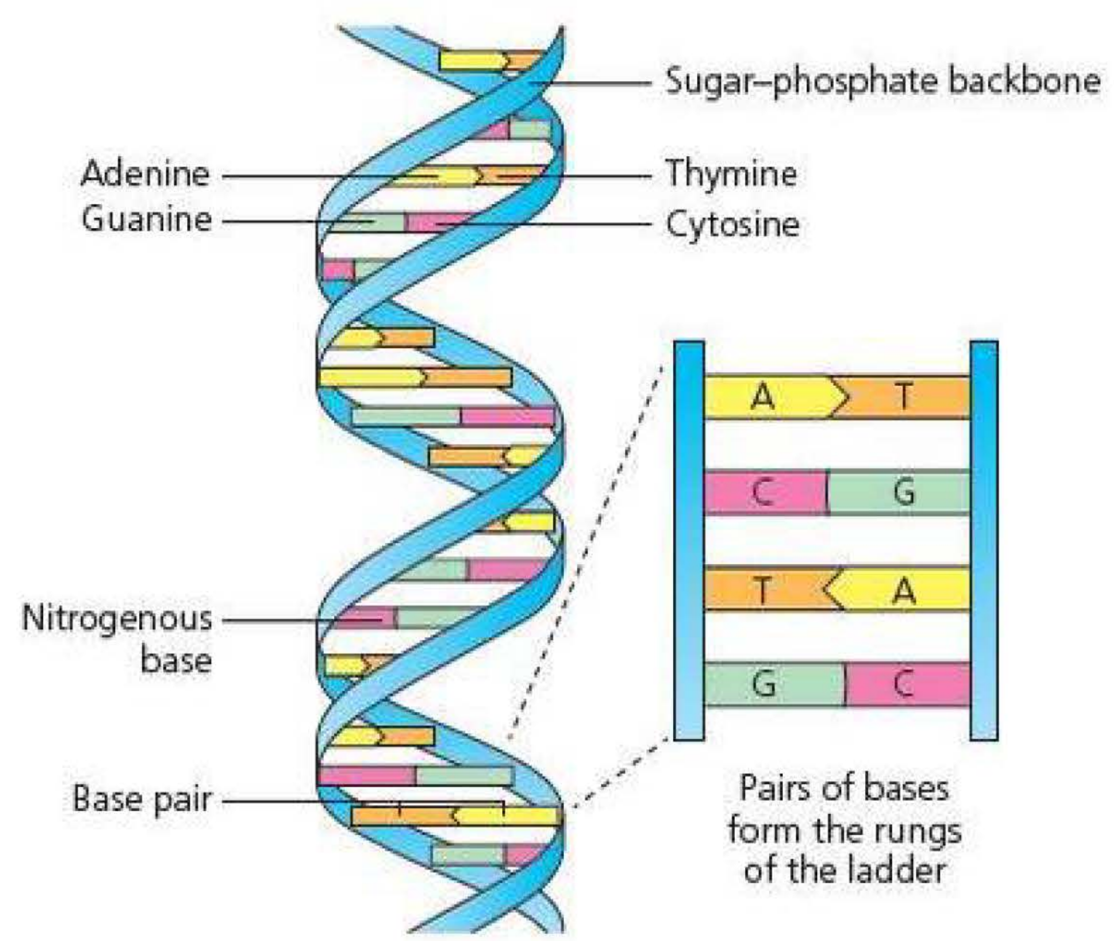
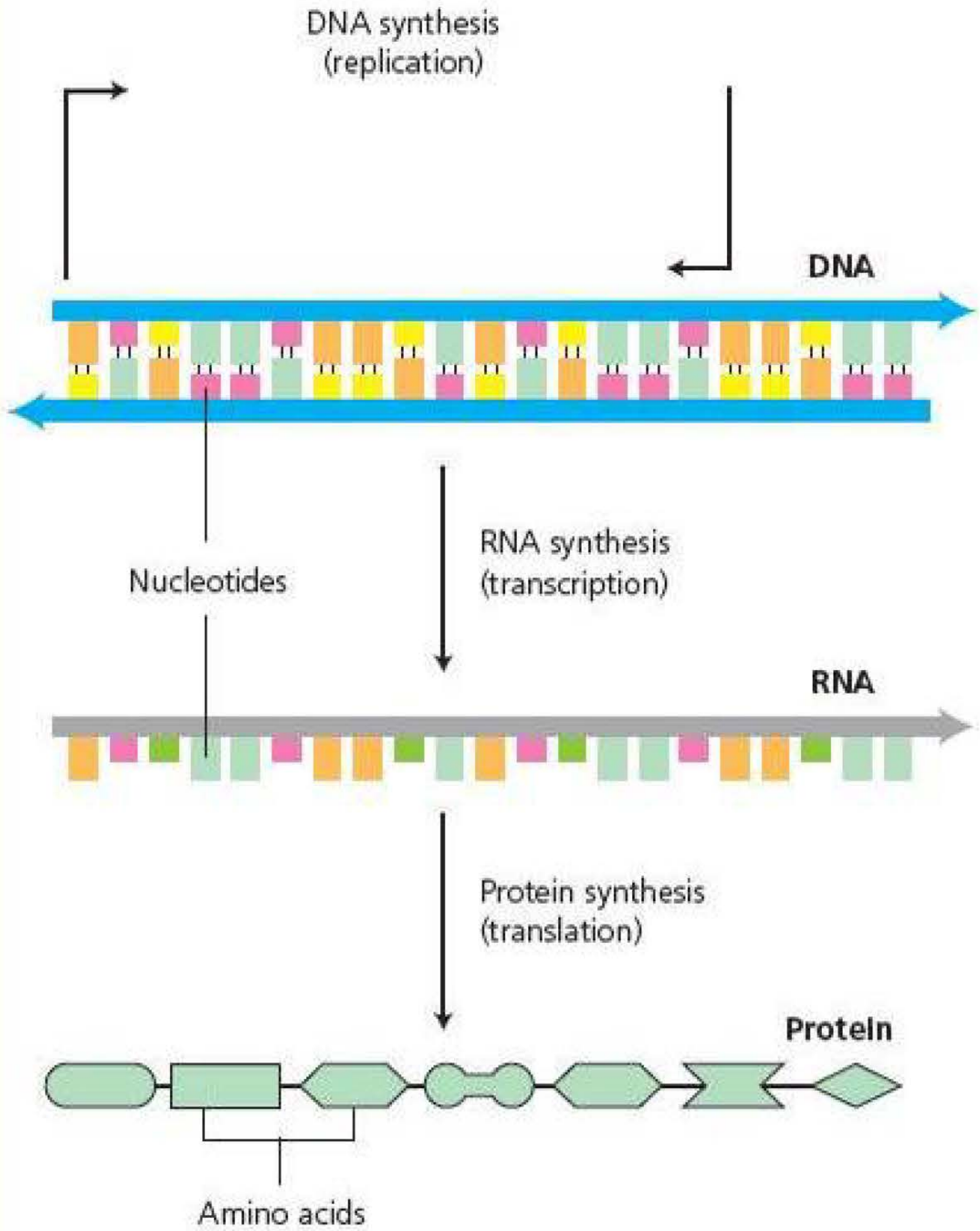
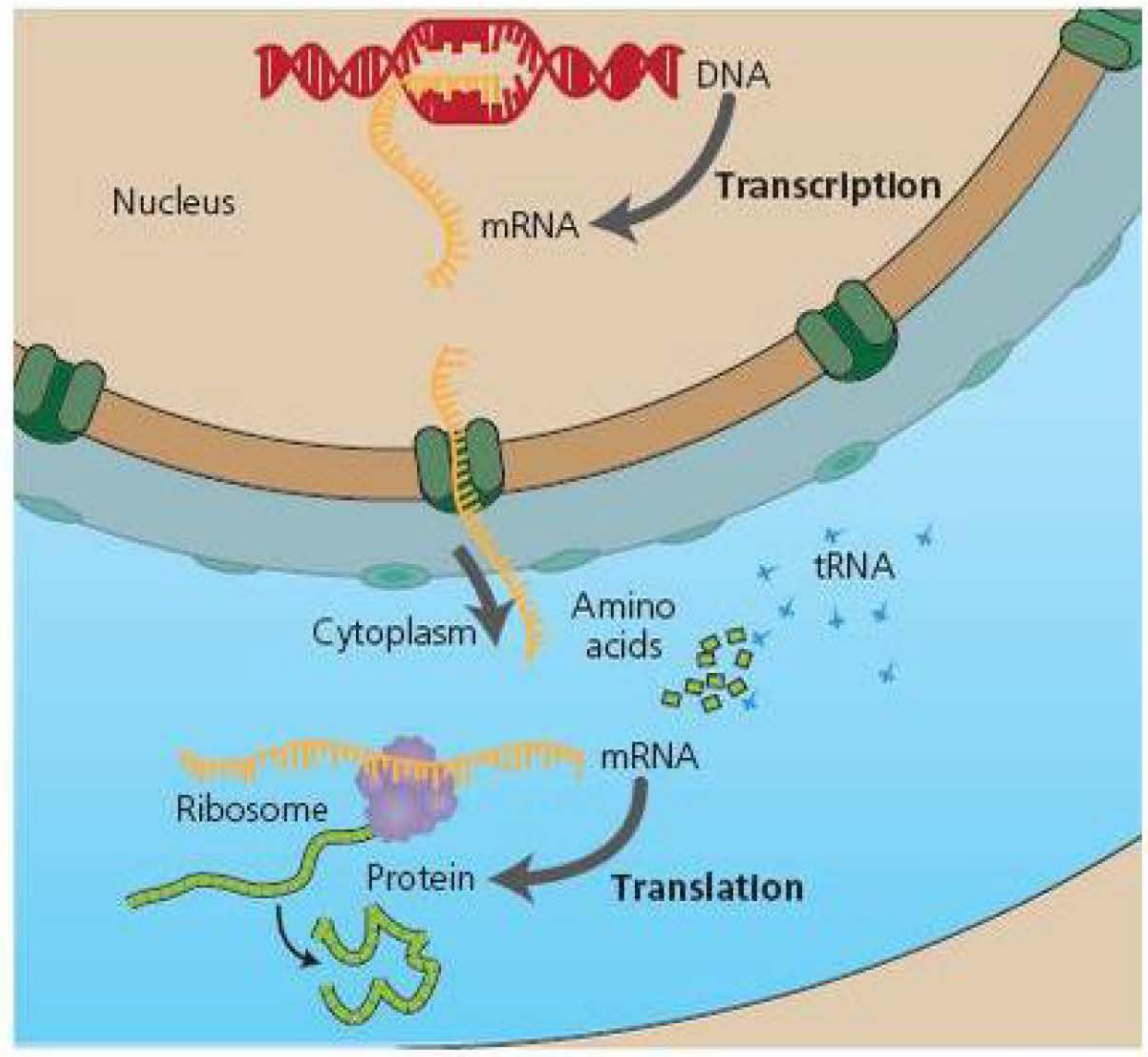


Figure 6.9 The DNA double helix

EXTENSION: How does DNA code for proteins?



■ **Figure 6.10** The 'central dogma' of biology developed by Francis Crick: DNA codes for RNA, which in turn codes for proteins. RNA is a messenger molecule that copies the genetic code from DNA (this is called transcription). The RNA travels from the nucleus to ribosomes in the cytoplasm where it is 'decoded' and read by the ribosomes to make protein (this is called translation). The order of the bases on the RNA determines which protein is made



■ **Figure 6.11** Transcription and translation being carried out in the cell

DNA codes for proteins in the following way:

- DNA in the nucleus unwinds and 'unzips' – the bases are exposed.
- A copy of the genetic code is taken – the molecule that does this is called mRNA (messenger RNA) – this is called transcription. (*Why do you think it is called this?*)
- mRNA travels out from the nucleus.
- The mRNA genetic code is 'read' at a ribosome – the order of the bases determines the order in which amino acids are assembled together to make a protein. This process is called translation. (*Why do you think it is called this?*)

DNA is often seen as a slightly mysterious substance. It is straightforward, however, to remove DNA from cells and to see it at first hand. In the following practical you will extract the DNA from a fruit – with the skills you learn you could extract the DNA from any cell, including your own.

ACTIVITY: Extract DNA from kiwi fruit

ATL

- Organization skills: Use technology effectively and productively

Figure 6.12 Kiwi fruit – ideal for DNA extraction

You will need:

- **Boiling tube**
- **Glass stirring rod**
- **Absolute alcohol**
- **Filter funnel and filter paper**
- **Salt**
- **Two beakers (250 ml)**
- **Washing-up liquid**
- **Knife**
- **Chopping board**
- **Kiwi fruit**
- **Hot water bath (60 °C)**
- **Ice bath**
- **Pipettes**
- **Bent wire**
- **Measuring cylinders (10 ml)**
- **Top pan balance**

What you need to do:

1. **Chop up half a kiwi fruit.**
2. **Half fill a beaker with hot tap water (60 °C). Add salt (about 10 g) and stir until the salt has dissolved. Mix in about 6 ml of washing-up liquid.**
3. **Add the chopped kiwi fruit to this mixture. Stand the beaker in the water bath (60 °C) for 10 minutes, continuing with stirring and mashing the kiwi fruit.**
4. **Transfer this mixture in the beaker to the ice bath, leave for 5 minutes. Continue stirring and mashing.**
5. **Filter the mixture into a cold boiling tube.**
6. **Use about 10 ml of the filtrate (remove any bubbles there are on the surface of the liquid). Add about 15 ml of absolute alcohol. Add the alcohol very gently down the side of the tube so that it sits on top of the salt solution and kiwi mixture. Do not shake the tube – keep it still to get a good yield of DNA. The DNA appears as white strands entangled at the interface of the two liquids.**

Think carefully about why you may be carrying out each of the procedures above.

Safety: Wear eye protection and wash your hands at the end of the experiment. Avoid inhaling the fumes from the alcohol.

Interpret each of the stages in the DNA extraction to **explain** how each stage helps to release DNA from the cell. For example, why is salt added to the mixture? Why is alcohol added? You will need to carry out research to find explanations for each part of the process.

Assessment opportunities

- In this activity you have practised skills that are assessed using Criterion C: Interpret information and explain results using scientific reasoning.

In this activity we have used a scientific technique to extract DNA from the nucleus of living tissue.

In any scientific experiment, it is important to *explain* why something has happened, not just *describe* the outcome:

- The detergent in the washing-up liquid breaks down the fatty membranes of the kiwi cells – this allows the DNA to come out of the cell. The warmth speeds up this process.
- The salt binds to the DNA and dissolves in the water, but it cannot dissolve in the alcohol. This causes the DNA (and salt) to be precipitated – the cold step helps this precipitation process.

DISCUSS

Discuss with your neighbour the following questions:

- **Does the end justify the means in science – were Watson and Crick correct to use Rosalind Franklin's data without her permission?**
- **What does Watson and Crick's behaviour tell you about academic honesty?**

Now share your ideas with the rest of the class.

EXTENSION: Academic honesty

Hold a debate in your class about academic honesty. The proposal could be 'The scientific process depends on scientific dishonesty'.

ACTIVITY: Make your own model of DNA

ATL

- Critical-thinking skills: Use models to explore complex systems

In this activity your task is to solve the problem of how to make a model of DNA. You will **apply** scientific knowledge to make a model that is scientifically accurate. You can use any material to do this:

- **Pipe-cleaners and beads (different colours can represent the different bases, and the sugar–phosphate backbone)**
- **Candy (such as liquorice, gummy bears) and tooth picks to hold the candy in place**
- **Clay (for a more permanent model)**
- **Origami (check out www.yourgenome.org/activities/origami-dna)**
- **Styrofoam balls**

Inspiration can be found here: www.wikihow.com/Make-a-Model-of-DNA-Using-Common-Materials

Make sure that your bases pair up. In the DNA double helix, adenine always pairs with thymine, and cytosine with guanine. This *base pairing* ensures that when the DNA replicates, an exact copy is made.

In this activity we have used models to explore the structure of a molecule that is fundamental to life.

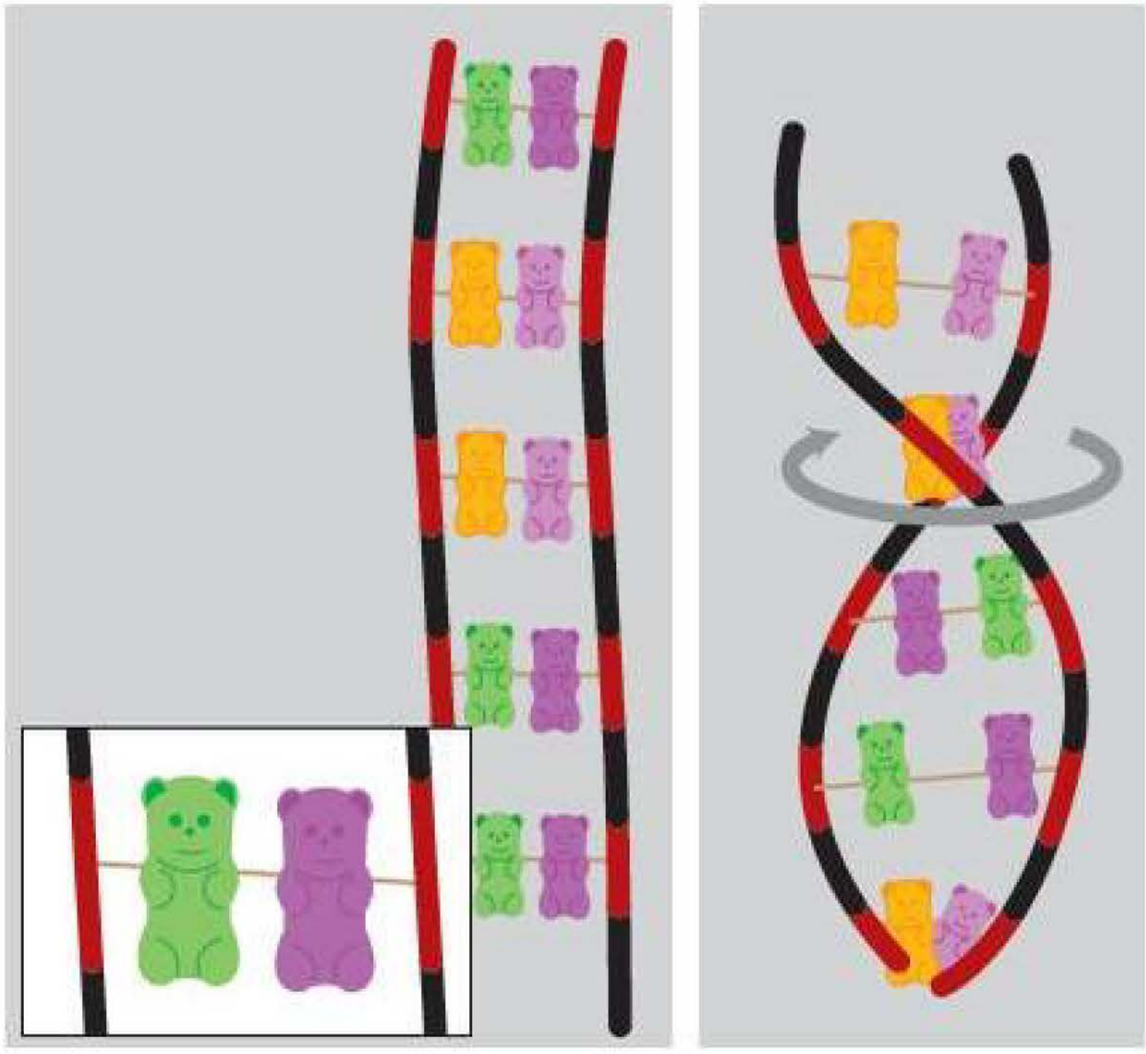


Figure 6.13 Making a DNA model from candy. Two colours of liquorice make the sugar and phosphate backbone that make up the double helix, and gummy bears form the bases (each of the four bases is a different colour)

Assessment opportunities

- In this activity you have practised skills that are assessed using Criterion A: Apply scientific knowledge to solve problems.

In what way is DNA the basis for inheritance and evolution? What are alleles?

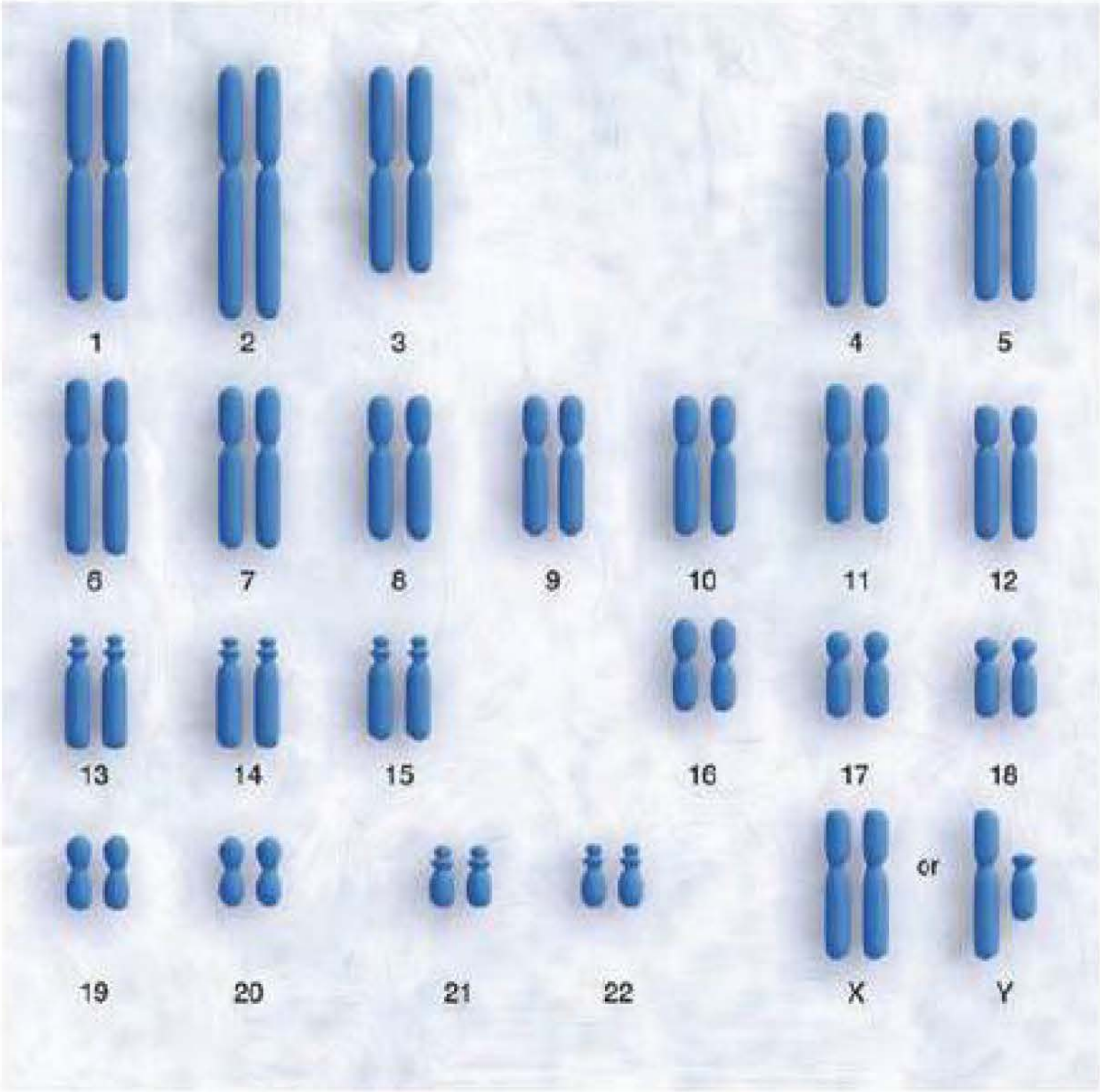
WHAT ARE GENES?

Each cell in an organism contains the molecule DNA, which is a set of instructions for particular characteristics in a species. The DNA in cells is not stored as one long molecule, but is divided into several individual lengths called **chromosomes**. Humans have 23 different chromosomes.

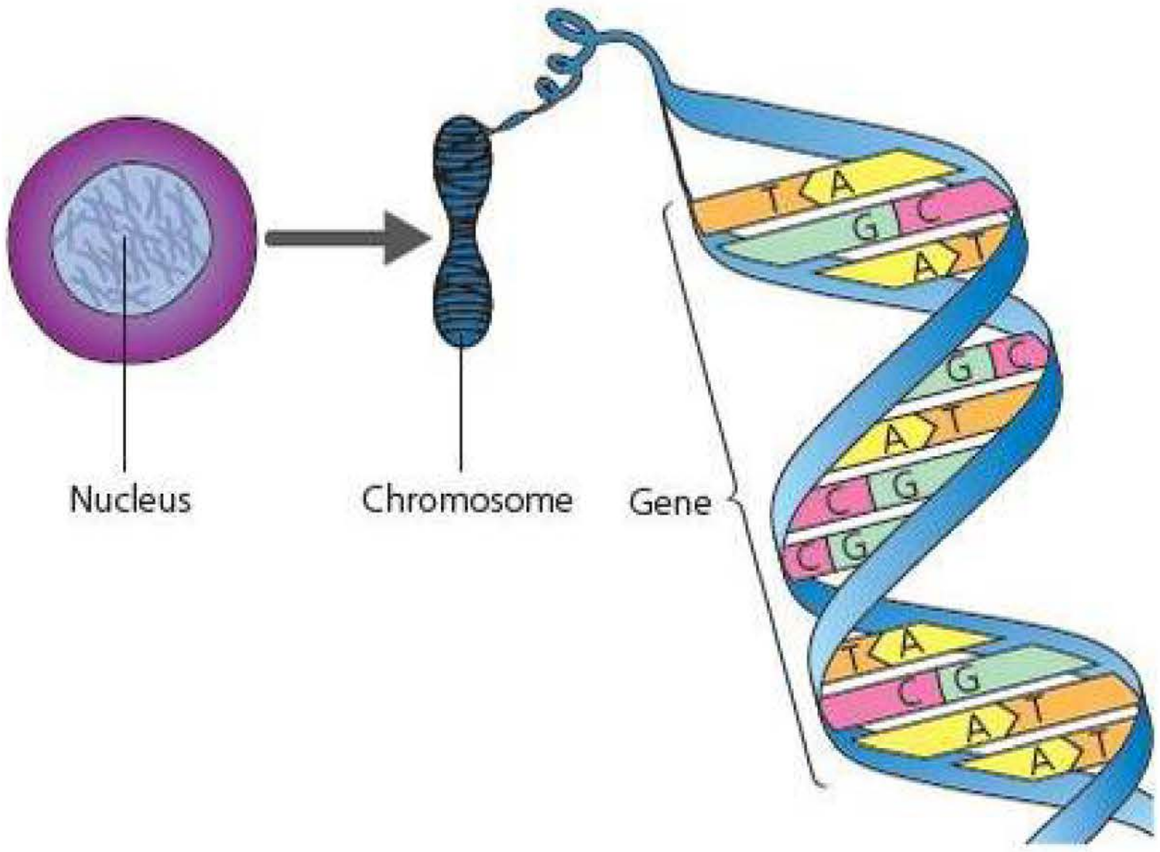
Each chromosome contains lengths of genetic code that determine different characteristics – these lengths of code are called **genes**. A gene is the unit of **inheritance**, passed down from one generation to the next.

So, to recap:

- **Nucleus**: contains chromosomes made from DNA
- **Chromosome**: a linear strand of DNA
- **Gene**: a section of a chromosome that codes for a particular protein.



■ **Figure 6.14** Humans have 23 different chromosomes. Chromosomes occur in pairs – one from each parent. Each chromosome has a different set of genes



■ **Figure 6.15** Each cell contains a nucleus which controls the activities of the cell. Each nucleus contains lots of threads of DNA called chromosomes – these carry information which controls how your body works and what you look like. A gene is a length of DNA that codes for a specific characteristic, such as eye colour

ACTIVITY: What happens if the genetic code changes?

ATL

- Critical-thinking skills: Analyse complex concepts and synthesize them to create new understanding

What happens if one letter in a sentence is changed? Suppose, for example, 'The cat sat on the mat' becomes 'the cat sat on the rat'? One letter has been changed, but the meaning of the sentence is completely different. The same happens with DNA (which contains a 4-letter rather than a 26-letter alphabet) – changes to the genetic code can change the protein produced by a gene.

A **mutation** is a change in the DNA of an organism. The change may or may not result a change to the physical characteristics (or phenotype) of the organism.

Mutations that occur in a **gamete** (**sperm** or **egg**) can be passed to the next generation, whereas mutations that occur in body (or 'somatic') cells may be harmless or may result in a disease such as cancer.

Mutations can result in DNA being copied incorrectly. **Mutagens** can also cause mutations. Examples of mutagens include:

- X-rays
- ionizing radiation
- chemicals (for example, the tar from cigarettes).

A point mutation is a change in one base in the genetic code. It can be the result of:

- the change of one base to a different base (often caused by the DNA being copied incorrectly) – this is called a **substitution** mutation.
- the **insertion** of an additional base into the DNA
- the **deletion** of a base from the DNA.

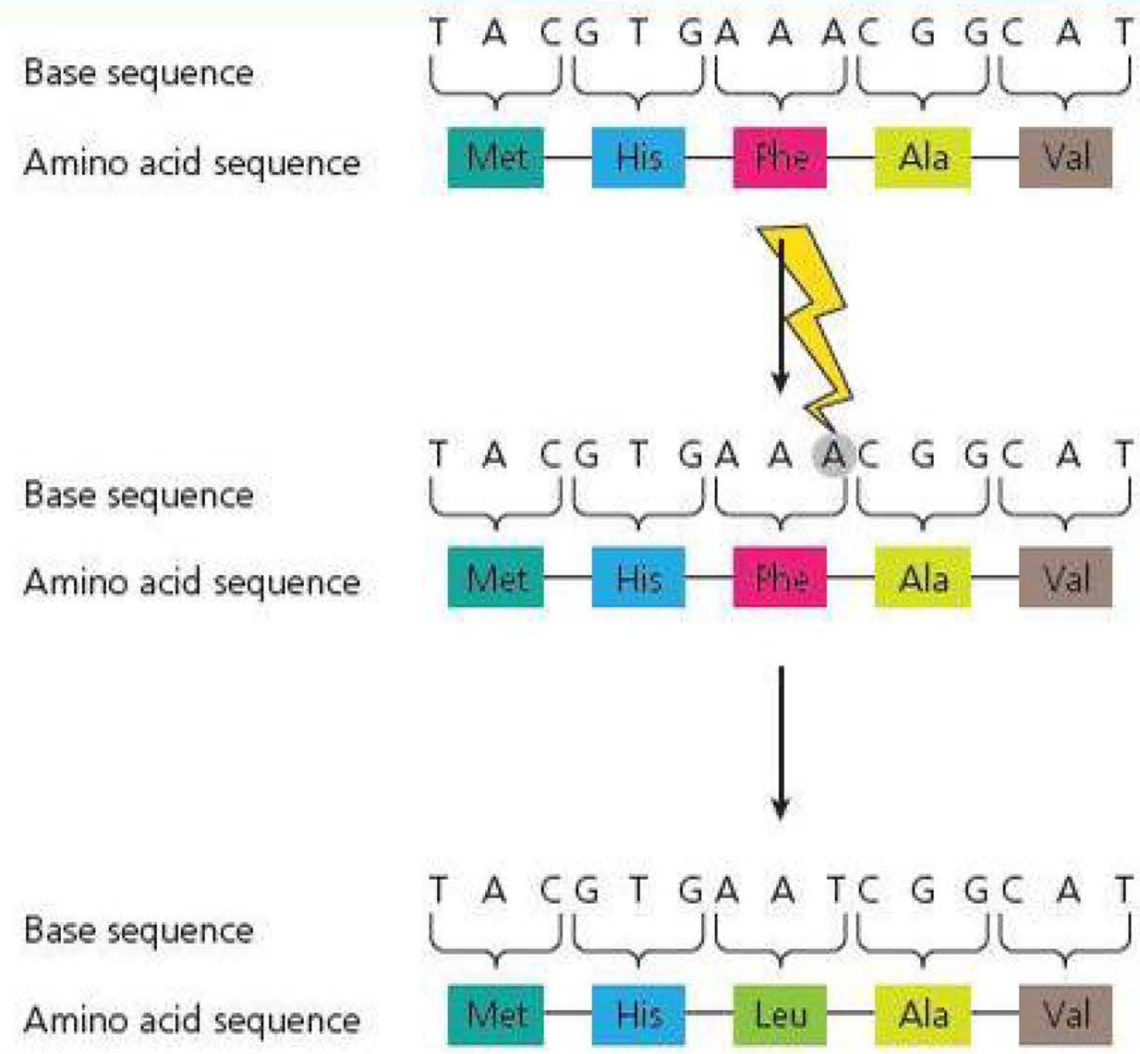


Figure 6.16 A substitution mutation. What is happening here, and what is the effect?

Because bases work in triplets (threes) to determine which amino acid is needed in a protein, an addition or deletion can have a profound effect. The deletion or insertion of a base results in what is called a 'frameshift' (Figure 6.17).

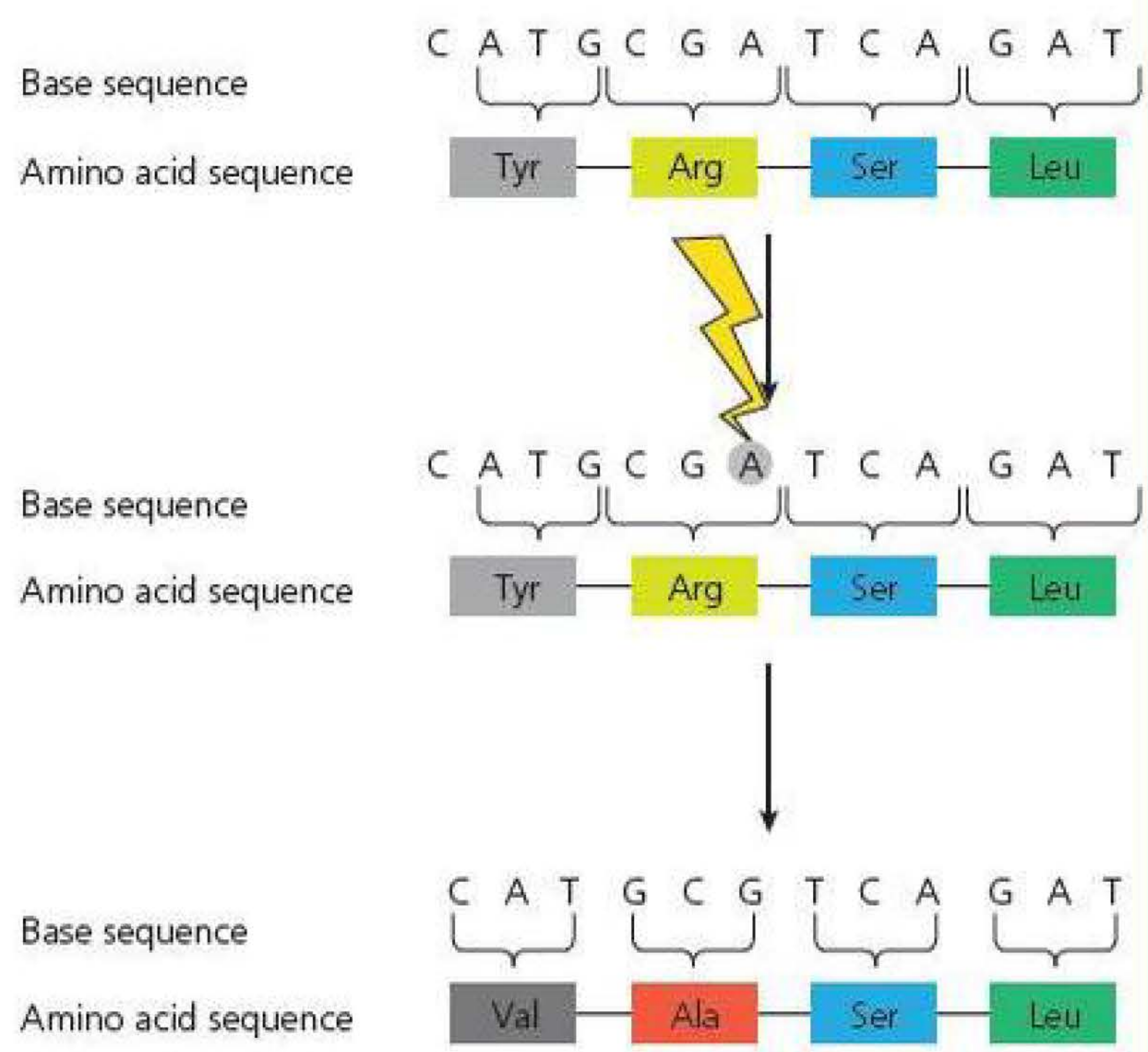


Figure 6.17 Base deletion resulting in a 'frameshift'. The base 'A' is removed, resulting in all bases before it to the left moving forward one place. Because bases work in threes, the first two amino acids in the sequence change – this would result in a different protein to the original

Some changes result in 'nonsense', so the changed genetic code cannot be read and has no meaning (in these cases the mutated DNA will probably not be replicated and will be terminated). If the change results in a different meaning to the sentence (i.e. results in a different amino acid being coded for), then this mutation is called a 'missense' mutation (shown in Figures 6.16 and 6.17, page 153).

Look at the following types of mutation. What types of mutation are being illustrated, and what would the results be?

the red dog bit the tan cat

the red mog bit the tan cat

Example 1

the red dog bit the tan cat

the red hog bit the tan cat

Example 2

the red dog bit the tan cat

the red rdo gbi tth eta nca

Example 3

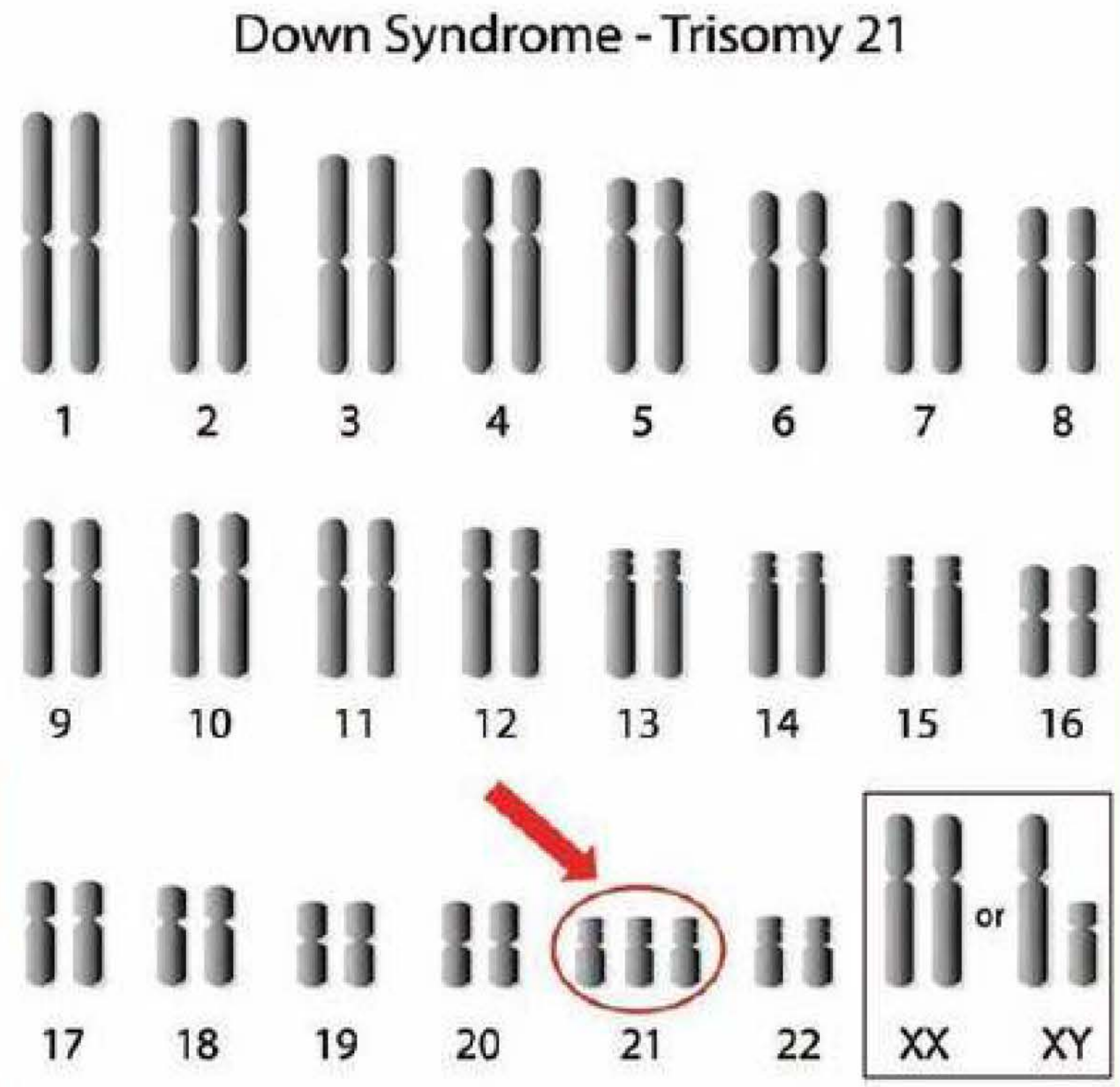
the red dog bit the tan cat

the red ogb itt het anc at_

Example 4

■ **Figure 6.18** Different types of mutation – what is being shown in each example?

Other mutations result in whole chromosomes being lost or repeated during cell division. Down syndrome, for example, is the result of one whole extra chromosome 21, the result of faulty cell division in an egg or sperm.



■ **Figure 6.19** Down syndrome is the result of an extra chromosome

■ **Figure 6.20** An extra chromosome causes Down syndrome. The extra one comes from a cell division in the production of sperm or egg

Mutations can create different versions of the same gene. For example, at some point in the past everyone had brown eyes – a mutation caused a different pigment to develop in the iris of the eye, leading to people with blue eyes. Different forms of the same gene are called **alleles**.

So, a person has two genes for each characteristic:

- One gene comes from each parent.
- Each gene comes in different forms.
- Different forms of the same genes are called alleles.
- Mutations can cause changes in genes, leading to new alleles and new **variation**. Mutations can also lead to genetic diseases.

Read about mutations here: **http://learn.genetics.utah.edu/content/variation/mutation/** and here: **www.sciencegeek.net/Biology/FlashPPT/Mutations/**

Watch the following tutorial about different types of mutation and their effects: **http://evolution.berkeley.edu/evolibrary/article/mutations_01**

Now look at the following data:

Table 6.1 Changes in incidence of Down syndrome with age of mother

Maternal age	Incidence of Down syndrome	Maternal age	Incidence of Down syndrome	Maternal age	Incidence of Down syndrome
20	1 in 2000	30	1 in 900	40	1 in 100
21	1 in 1700	31	1 in 800	41	1 in 80
22	1 in 1500	32	1 in 720	42	1 in 70
23	1 in 1400	33	1 in 600	43	1 in 50
24	1 in 1300	34	1 in 450	44	1 in 40
25	1 in 1200	35	1 in 350	45	1 in 30
26	1 in 1100	36	1 in 300	46	1 in 25
27	1 in 1050	37	1 in 250	47	1 in 20
28	1 in 1000	38	1 in 200	48	1 in 15
29	1 in 950	39	1 in 150	49	1 in 10

Plot a graph of these data. (You will need to convert the incidence values into a number you can plot – how will you do this?) **Interpret** the data and **explain** the results using scientific reasoning.

Assessment opportunities

- This activity can be assessed using Criterion C: Accurately interpret data and explain results using scientific reasoning.

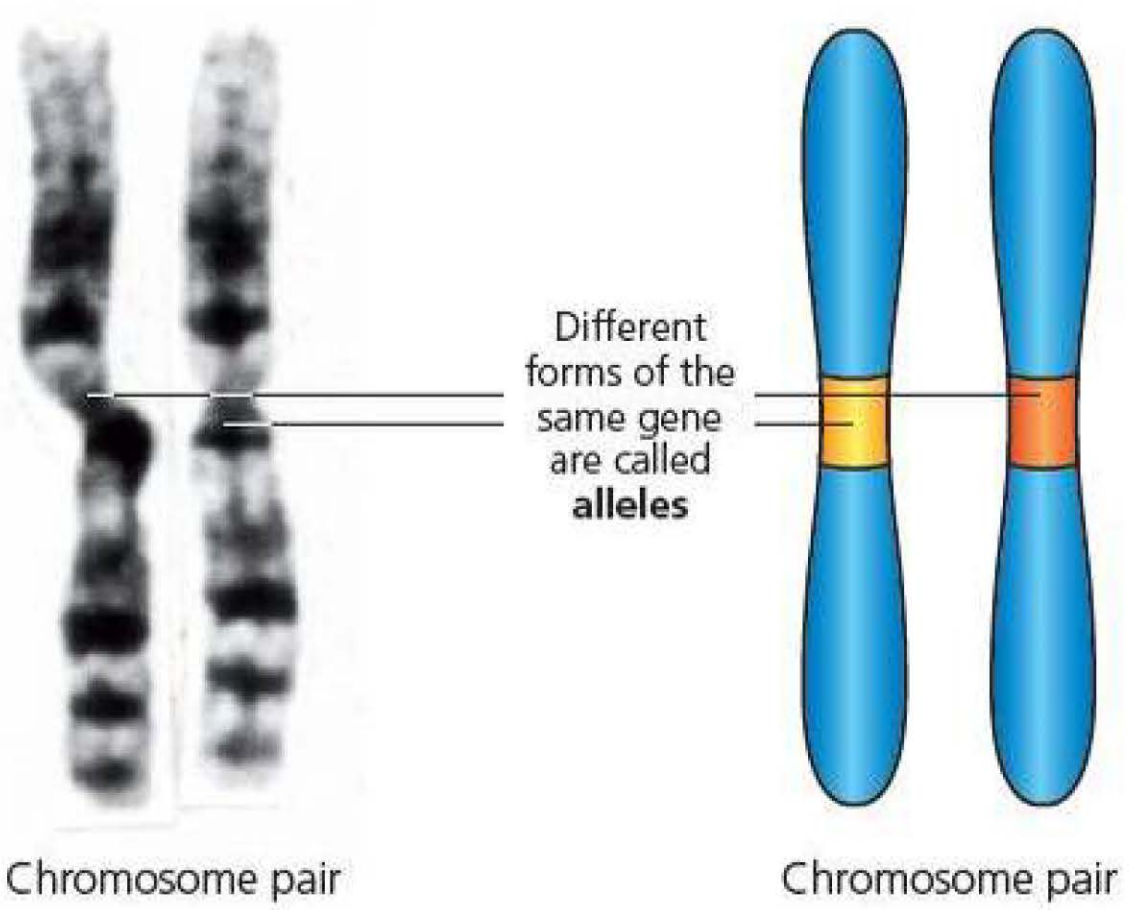


Figure 6.21 Different forms of the same gene are called alleles

SUMMARY REFLECTION

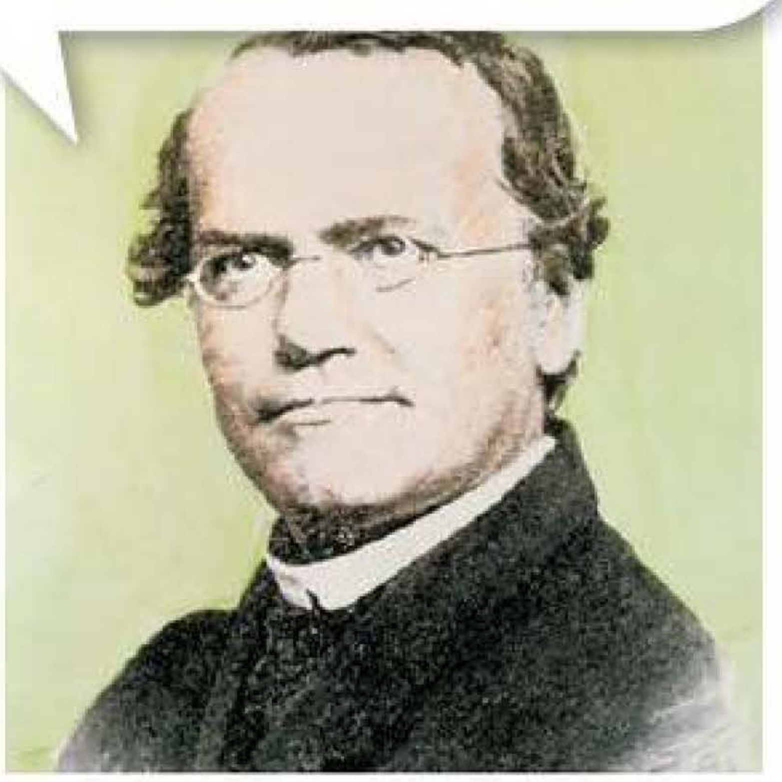
- What have you learnt about how DNA is divided into genes?
- What have you learnt about how DNA is the basis for inheritance and evolution?
- What have you learnt about alleles, and how they are formed?

REVIEW

- Define the following terms: nucleus, chromosome, DNA, gene, allele.
- Describe the cause and effect of gene mutations.
- What different types of mutation exist? Outline three.

How does the genetic code produce physical characteristics?

I was born in 1822 in what is now the Czech Republic and was christened Johann Mendel. My father, Anton, was a peasant farmer but his health and livelihood were shattered by a falling tree when I was 16. My father couldn't afford to send me to school or university, and so the Church was my only route to an education. I became an Augustinian friar, taking the name 'Brother Gregor'. I have become known as the father of genetics because of my pea plant experiments established many of the rules of heredity.



■ **Figure 6.22** Gregor Mendel

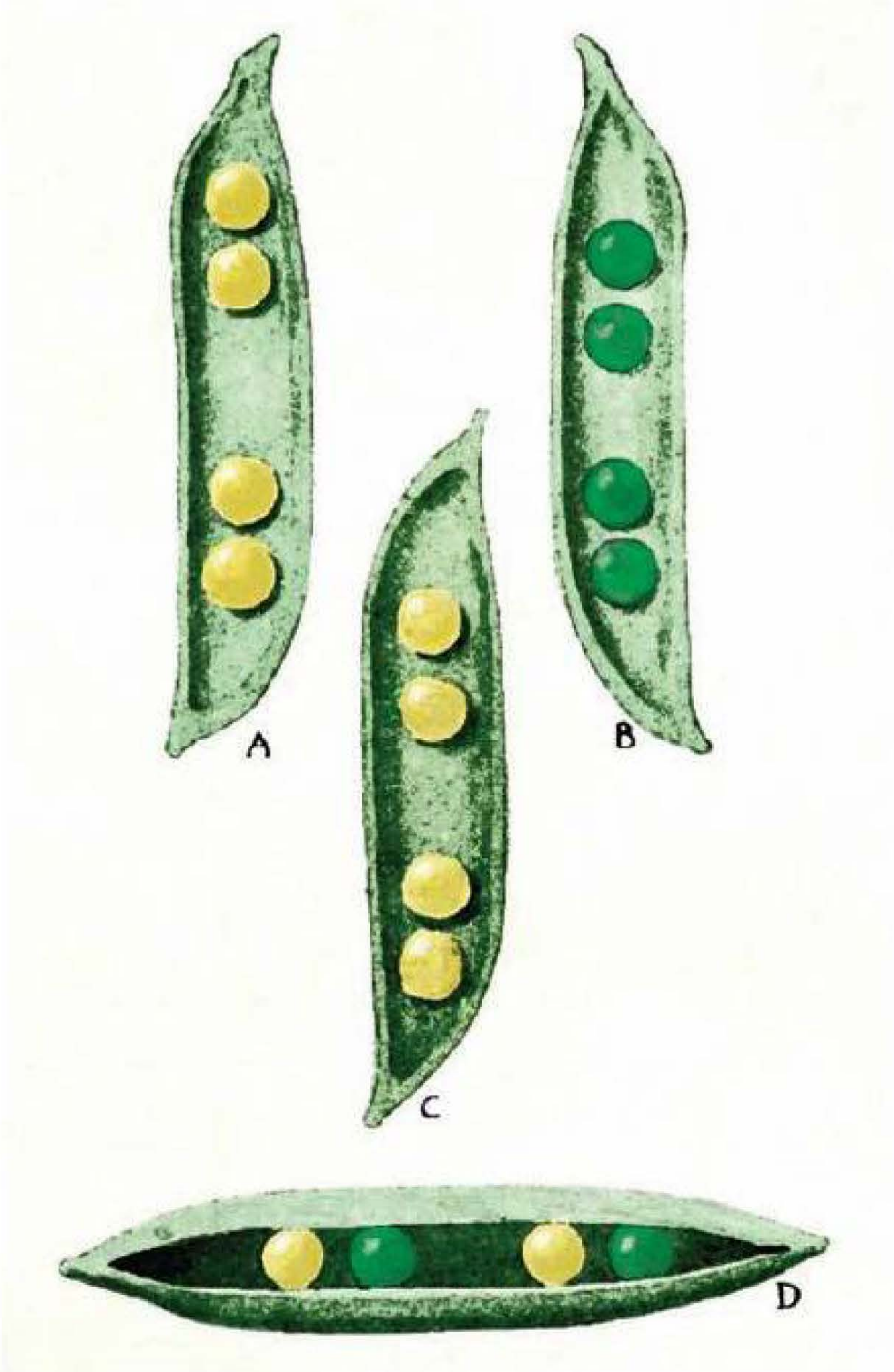
WHO WAS GREGOR MENDEL AND HOW DID HE SHOW CHARACTERISTICS ARE INHERITED?

Genetic crosses

How do characteristics get passed down from one generation to the next? A monk called Gregor Mendel made the first discovery of the laws of **heredity**, at a time when chromosomes had not yet been observed or genes detected.

How did people think that inheritance worked before Mendel came along?

People didn't really know how inheritance worked but they thought that it must work by 'blending' (a bit like mixing paints of different colours). For example, if a tall person has children with a short person, their genes will be 'blended' and the children will be of medium height. This seemed to work with several characteristics such as height and skin colour. However, it was an inadequate explanation of other characteristics such as eye colour (how can you have one sibling with blue eyes and another with brown eyes?). However, scientists (for example Charles Darwin) didn't have any other explanation apart from the 'blending' hypothesis.



■ **Figure 6.23** Mendel's peas. Historical artwork of the peas (*Pisum* sp.) used by Gregor Mendel (1822–1884) in his experiments. He cross-bred peas that produced yellow (A) and green (B) peas. This produces a generation in which the peas are all yellow (C). This is because the colour of the peas is controlled by an allele in which yellow colour is dominant. An allele is a pair of genes that have different effects on the same characteristic, for instance controlling pea colour. By breeding the C generation peas together, Mendel found that the next generation had a mixture of pea colours (D). The ratio of yellow to green peas was 3:1. His work formed the basis of genetic theory

What experiments did Mendel carry out?

He **cross-bred** different types of pea plant in the gardens of the monastery. In total he planted 30 000 plants over eight years. He crossed rounded seed pods with wrinkled ones, yellow peas with green peas, tall stems with dwarf stems and so on.

What were Mendel's conclusions?

In every case, the offspring were just like the parent plant, for example they were all tall. Then, when he allowed this offspring generation to interbreed, he found that dwarf plants reappeared in the next generation. This occurred in a 3:1 ratio with 3 tall plants to 1 dwarf plant. He found the same results with lots of different characteristics and lots of different species of plant (such as fuchsias and maize). In other word, 'blending' wasn't taking place. Mendel argued that 'factors' (what we now call 'genes') were being passed on to the next generation. Some of these factors were being hidden and then reappearing in the next generation.

Were Mendel's results too perfect?

Mendel obtained excellent results, such as 14 949 tall plants to 5010 dwarf plants, giving a ratio of 2.98:1. Remember, Mendel was a good mathematician and he probably knew what results to expect. Some scientists have argued that his results are suspiciously excellent!

What happened to Mendel's discoveries?

In 1866 Mendel published his work clearly in *The Proceedings of The Brunn Society for Natural Science*, a scientific journal which found its way into all the best libraries. He also sent his results and his ideas to a professor of botany in Munich (Karl-Wilhelm Nageli). However, Nageli replied with polite but patronising letters. The professor didn't grasp the significance of Mendel's work. Mendel's work remained unrecognized and he gradually lost interest in his gardens as he rose to the position of Abbot. Then, three different scientists (Hugo de Vries, Carl Correns and Erich von Tschermak) all independently re-discovered Mendel's work in 1900 and realised how important it was. In 1903 a scientist called Walter Sutton realized that chromosomes behave just like Mendel's 'factors'.

ACTIVITY: Ethics and scientists' responsibilities

ATL

- Information literacy skills: Access information to be informed
- Critical-thinking skills: Revise understanding based on new information

On page 151 you discussed the ethics of Watson and Crick's use of Rosalind Franklin's DNA data, and the role of academic honesty in the scientific process. Some scientists have questioned Mendel's data and have suggested that it is too good to be true.

Read more about **ethical behaviour in science** and the **responsibilities** scientists have.

Analyse and evaluate your sources of information.

Discuss the following questions with your neighbour:

- **To what extent are scientists responsible for their actions?**
- **To what extent should scientists follow an ethical code of conduct?**
- **Should there be a universal ethical code for scientists?**

Now share your ideas with the whole class.

Assessment opportunities

- This activity can be assessed using Criterion A: Analyse and evaluate information to make scientifically supported judgements.

Chromosomes come in pairs, one from each parent. In 1918, the biologist Ronald Fisher realized that Mendel's results could be used to support Charles Darwin's ideas of evolution (see Chapter 7). 'Mendelism', said Fisher, 'supplied the missing parts of the structure erected by Darwin'.

Find out more about Mendel and his experiments here: **www.wiley.com/college/test/0471787159/biology_basics/animations/mendelianInheritance.swf**

The likely offspring of two parents can be determined using genetic diagrams. These Punnett squares (named after the scientist who developed them) work out the probability that a given offspring will be produced.

allele Different versions of the same gene (one from the father, one from the mother).

recessive Hidden by a dominant allele. An allele that affects an animal's appearance only if it is present in the homozygous state.

dominant An allele that always shows through. An allele that causes the homozygous form and the heterozygous form to look the same as each other.

homozygous Two identical alleles for a particular characteristic in each cell.

heterozygous Two different alleles for a particular characteristic in each cell.

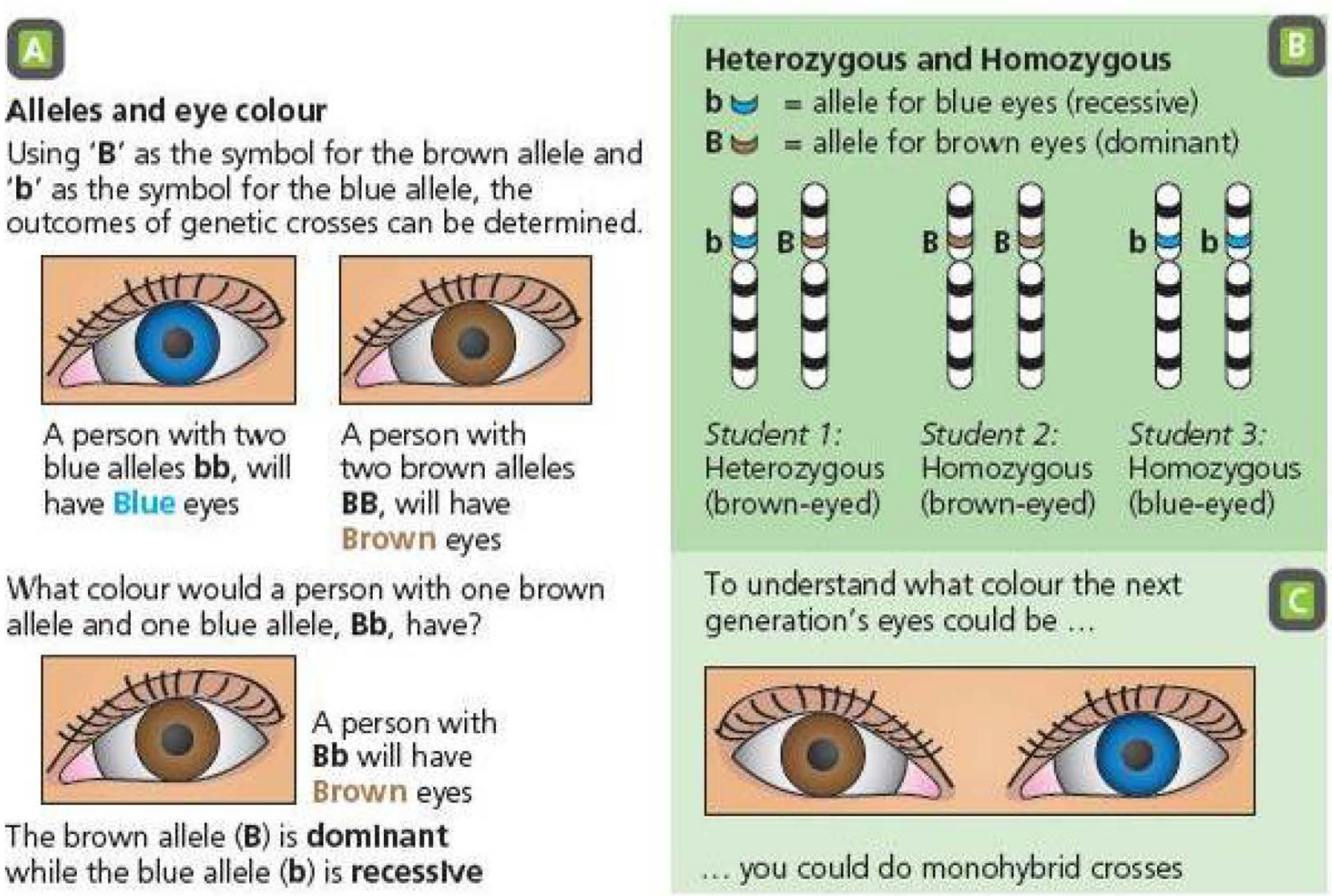
genotype The 'genetic makeup' of a person – the genetic information in the cell.

phenotype What you look like – the outward effect of the genetic code on the body.

phenotypic traits Physical characteristics.

The terms above help to describe genetic diagrams, which show the possible outcomes of genetic crosses. Remember, each gene is found in pairs in each cell, because you have two of each chromosome (one from each parent).

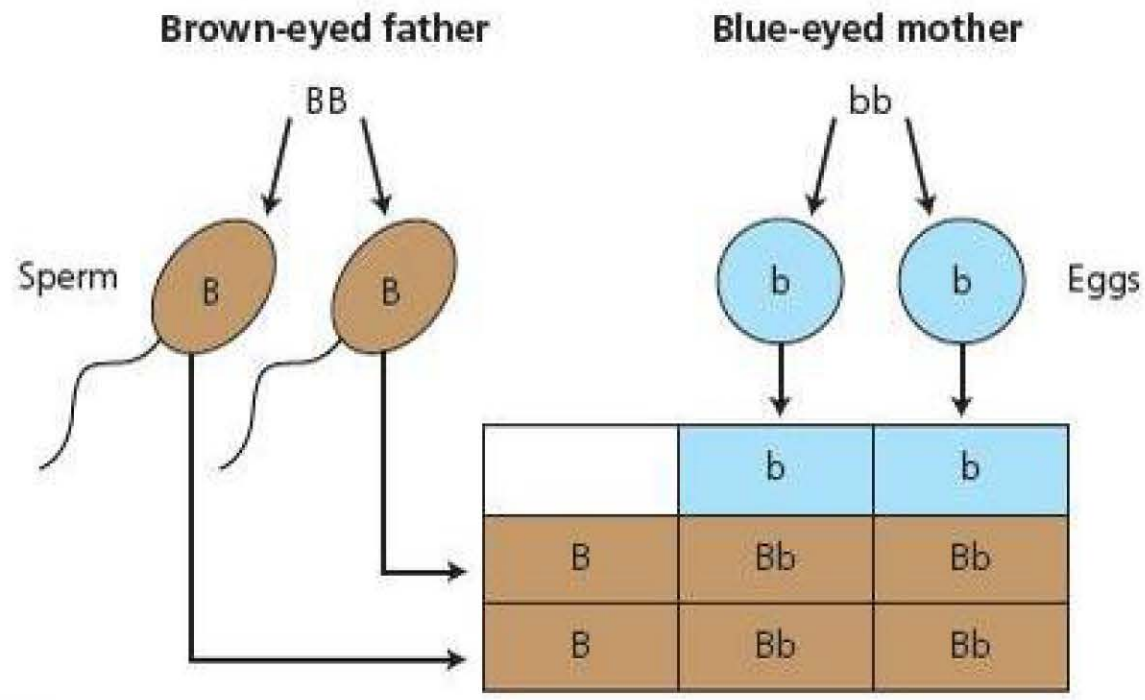
Take the example of eye colour (Figure 6.24).



■ **Figure 6.24** Determination of eye colour

Monohybrid crosses show the possible combinations of how one characteristic can be inherited.

The Punnett square shows the genotypes of two gametes produced by **meiosis**, for both parents. The rest of the square shows the genotypes of offspring, depending on which sperm fertilizes which egg (Figure 6.25).



■ **Figure 6.25** How a Punnett square is set out

EXTENSION

The monohybrid crosses explored here are simple genetic crosses using only one gene. In reality, many genetic crosses are more complex than this, involving more than one pair of genes. Other genes do not follow a simple 'recessive/dominant' relationship and are more complex. Find out about these other types of genetic cross: **dihybrid cross**, **co-dominance**, **incomplete dominance**, **sex-linkage**.

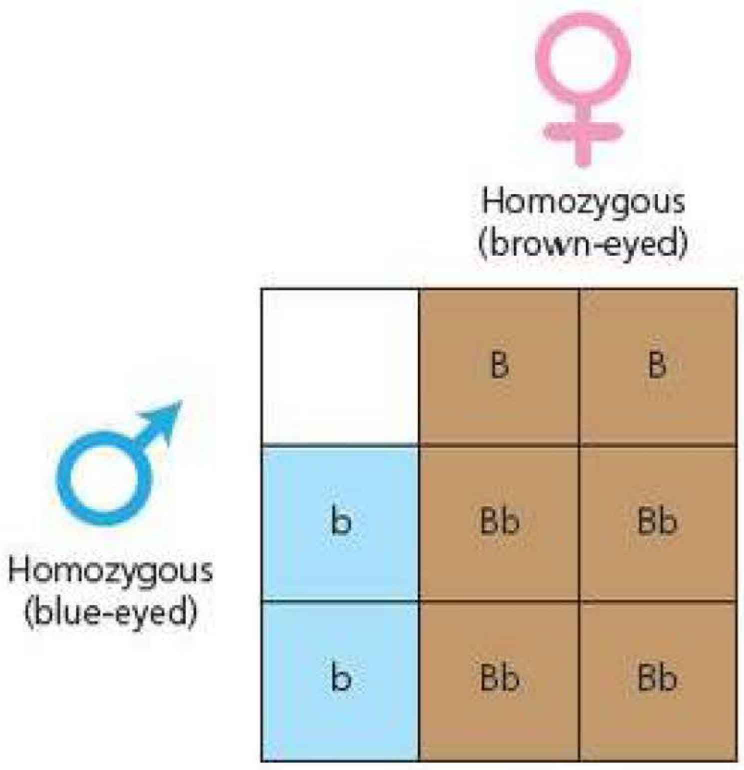
Produce a fact sheet on each type of genetic cross.

EXTENSION

Find out more about Mendel's experiments here: www.sumanasinc.com/webcontent/animations/content/mendel/mendel.html

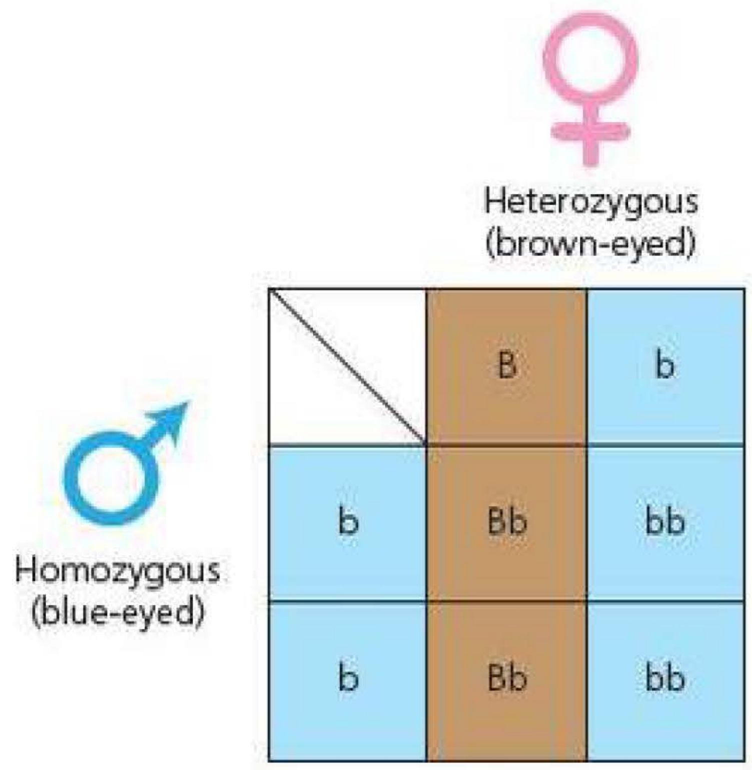
For eye colour, these are the possibilities:

1 If both parents are homozygous:



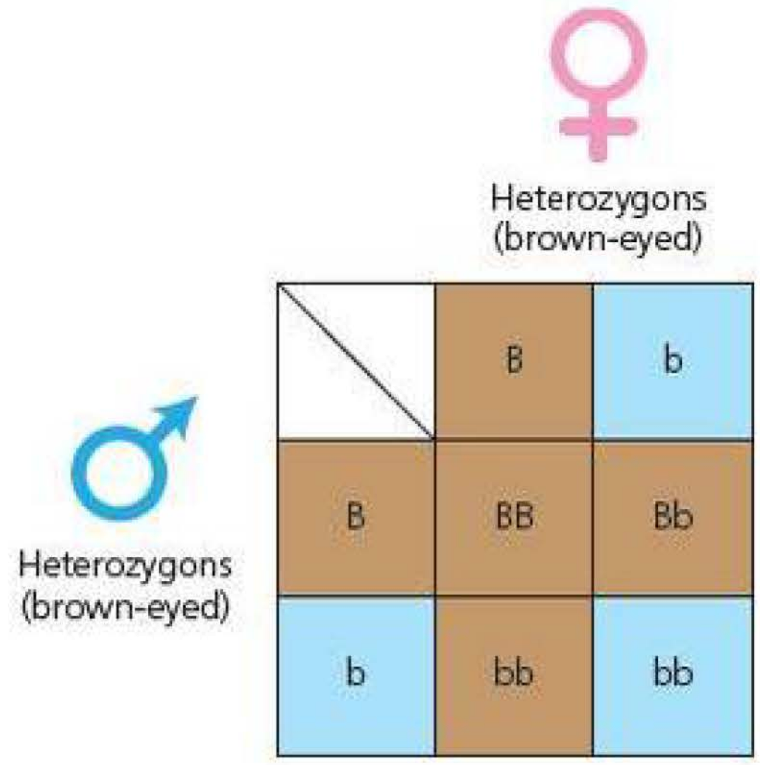
■ **Figure 6.26** Eye colour: cross between two homozygous parents

2 If one parent is heterozygous and one homozygous recessive:



■ **Figure 6.27** Eye colour: cross between one heterozygous parent and one who is homozygous recessive

3 If both parents are heterozygous:



■ **Figure 6.28** Eye colour: cross between two heterozygous parents

Mendel was the first to notice that if both parents are heterozygous, offspring are produced in the ratio 3:1 (three with the dominant characteristic and one with the recessive).

It is now time to practise genetic crosses yourself!

ACTIVITY: Practising genetic crosses

■ ATL

- Critical-thinking skills: Interpreting data

Access these sites to find out about how the results of genetic crosses between two individuals can be worked out:

www.dnalc.org/view/16192-Animation-5-Genetic-inheritance-follows-rules-.html

www.siskiyous.edu/class/bio1/genetics/monohybrid_v2.html

Now carry out some genetic crosses yourself, using these sites:

www.execulink.com/~ekimmel/mendel1a.htm

www.zerobio.com/drag_gr11/mono.htm

◆ Assessment opportunities

- In this activity you have practised skills that are assessed using Criterion A: Apply scientific knowledge to solve problems.

In this activity we have developed a hypothesis about potential outcomes of genetic crosses and checked these using software programs.

How do single-celled organisms reproduce? What is mitosis?

■ **Figure 6.29** Asexual reproduction in a spider plant – new plants are created at the tips of leaves

WHAT IS ASEXUAL AND SEXUAL REPRODUCTION?

There are two types of reproduction: asexual and sexual.

In **asexual reproduction** there are no gametes (eggs and sperm) and no fertilization. Cells undergo **mitosis** (see below) and a structure which breaks away from the main body is formed: this structure grows into a new creature.

All offspring produced by asexual reproduction are genetically identical.

Sexual reproduction is the production of offspring from two parents using gametes (egg and sperm). The cells of the offspring have two sets of chromosomes (one from each parent). Sexual reproduction involves two stages:

- Meiosis – the special cell division that makes gametes with half the number of chromosomes (one set).
- **Fertilization** – the fusion of two gametes to form a zygote (back to two sets of chromosomes).

We will explore the process of meiosis in Chapter 7.

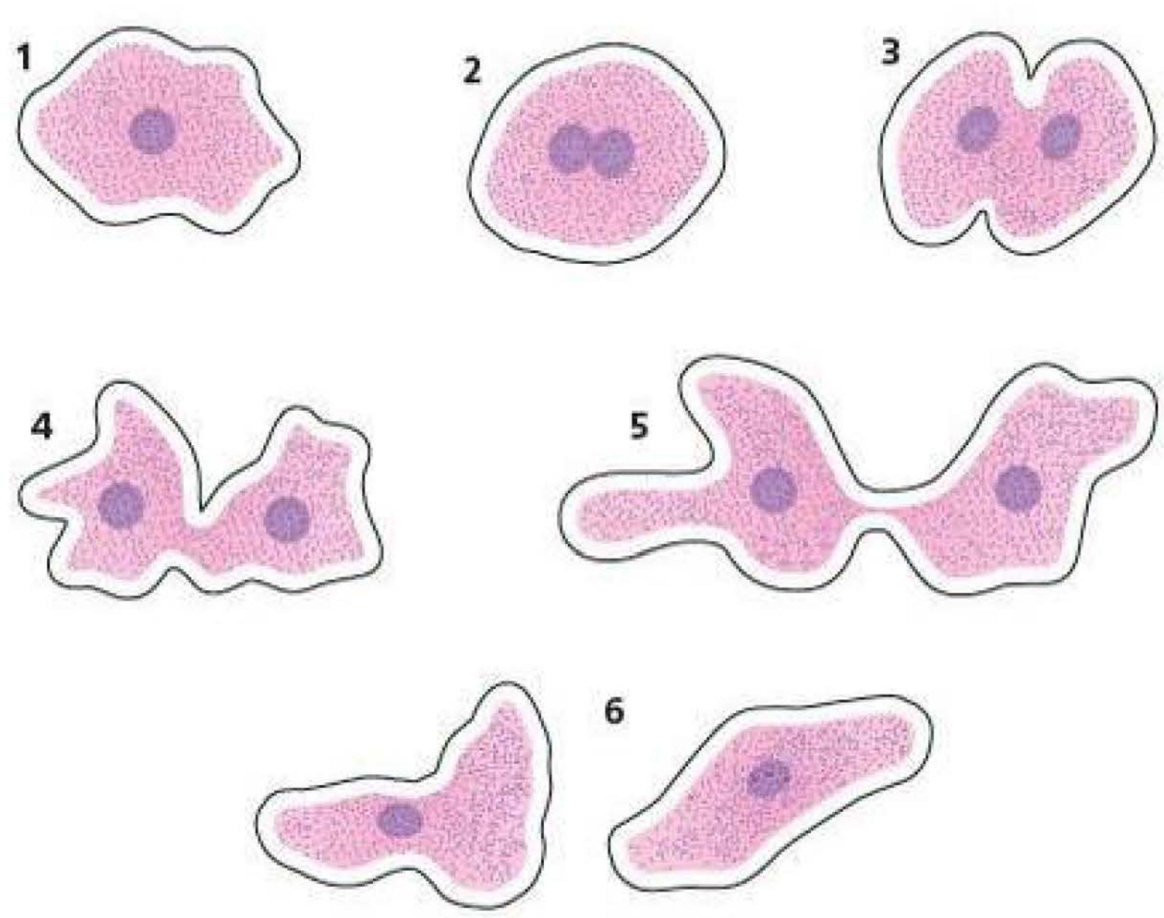
In sexual reproduction, DNA from one generation is passed to the next by gametes.

Sexual reproduction is a source of genetic variation, when DNA from a mother is 'shuffled' with DNA from a father. It involved the random fusion of gametes, which also leads to variation (any sperm can fertilize the egg). Variation is therefore produced by combining genes in different combinations in the gametes, and by random fusion of gametes (something we will come back to in the next chapter).

Single-celled animals tend to reproduce asexually as they cannot have specialized reproductive organs. A yeast cell (Chapter 1, page 16), for example, simply divides in two to reproduce.

■ **Figure 6.30** A yeast cell reproducing asexually

And here is asexual reproduction in amoeba:



■ **Figure 6.31** Asexual reproduction in an amoeba

ACTIVITY: Exploring mitosis

ATL

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

Mitosis is cell division that leads to two identical cells. It is used in our bodies for growth, repair and to replace worn-out cells. Some organisms can use it to reproduce (asexual reproduction).

In this activity you will carry out a 'thought experiment' – use your powers of observation, and knowledge of DNA, to work out how mitosis happens. You may want to brainstorm ideas with your neighbour, or in small groups!

1 **Cells contain single-stranded chromosomes. During mitosis, two new cells are created, each containing an identical set of chromosomes. Why do the new cells need to contain identical copies of the original chromosomes?**

2 **What do you think has to happen to each single-stranded chromosome before mitosis can take place? (Use your knowledge of DNA structure to help you answer this question – what can DNA do to create copies of itself?)**

Figure 6.32 shows plant cells undergoing mitosis (stages go from left to right):

3 **Now look at the following diagram of the stages of mitosis. Can you work out what is going on, and why?**

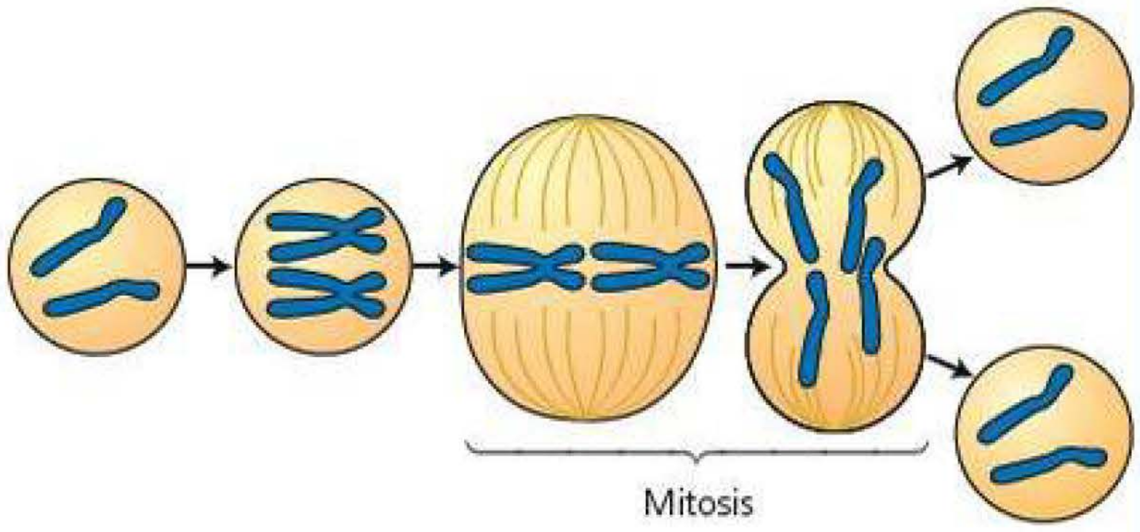


Figure 6.33 The stages of mitosis

4 **Discuss your observations and conclusions with your neighbour. Do they agree with you?**

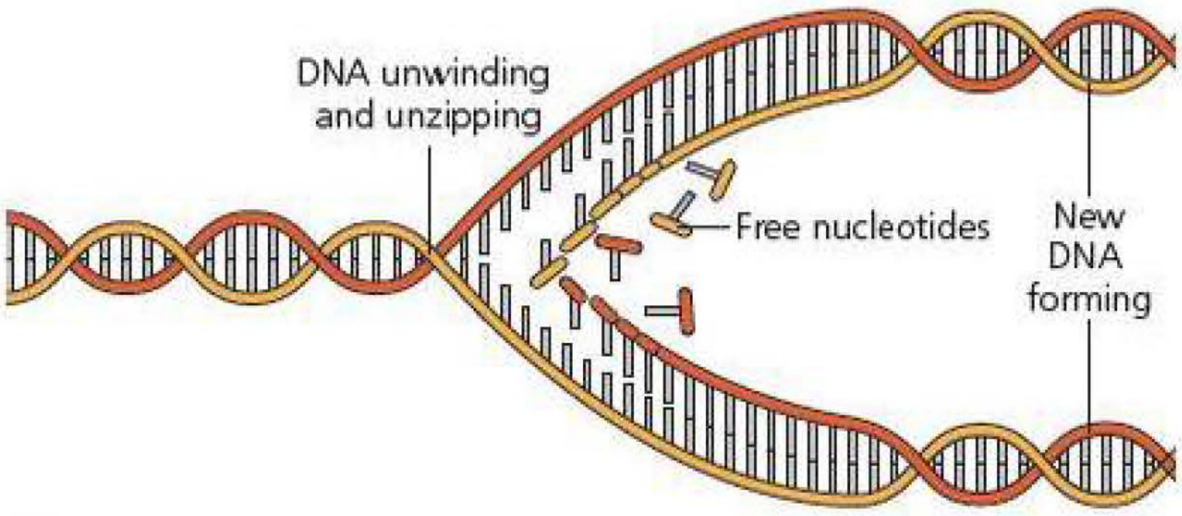
Assessment opportunities

- In this activity you have practised skills that are assessed using Criterion A: Apply scientific understanding to solve problems in unfamiliar situations.

In this activity we have used our skills of observation and our understanding of biology to work out how mitosis takes place.

Figure 6.32 Mitosis in plant cells

Before cells divide, each chromosome must copy itself to produce two identical strands.

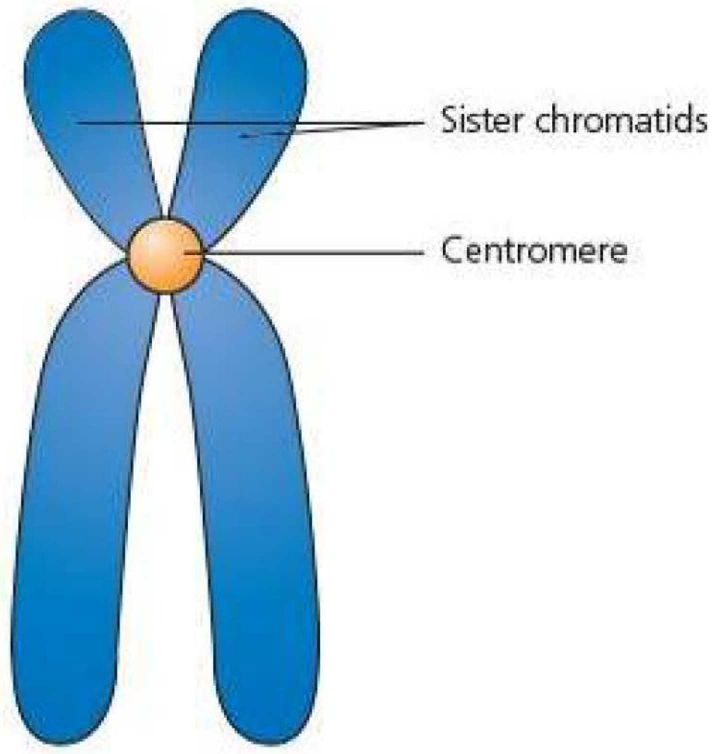


■ **Figure 6.34** DNA replication

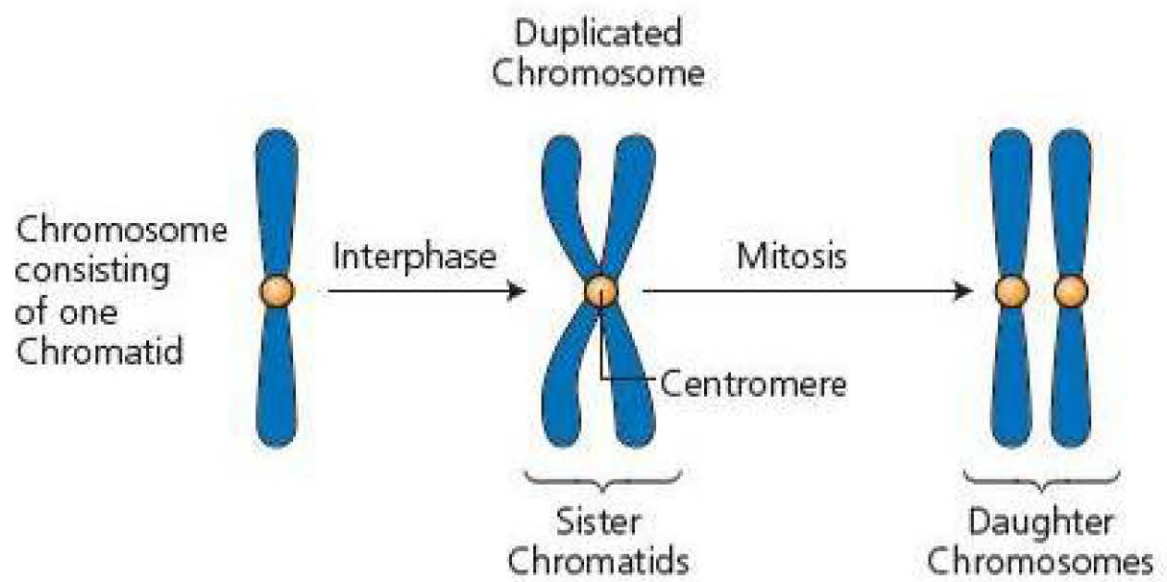
This DNA replication occurs in a stage of the cell cycle called **interphase**.

The process produces double-stranded chromosomes. Each strand is called a **chromatid**. Chromatids are held together by a protein structure called a **centromere**.

■ **Figure 6.35** Double-stranded chromosome before cell division

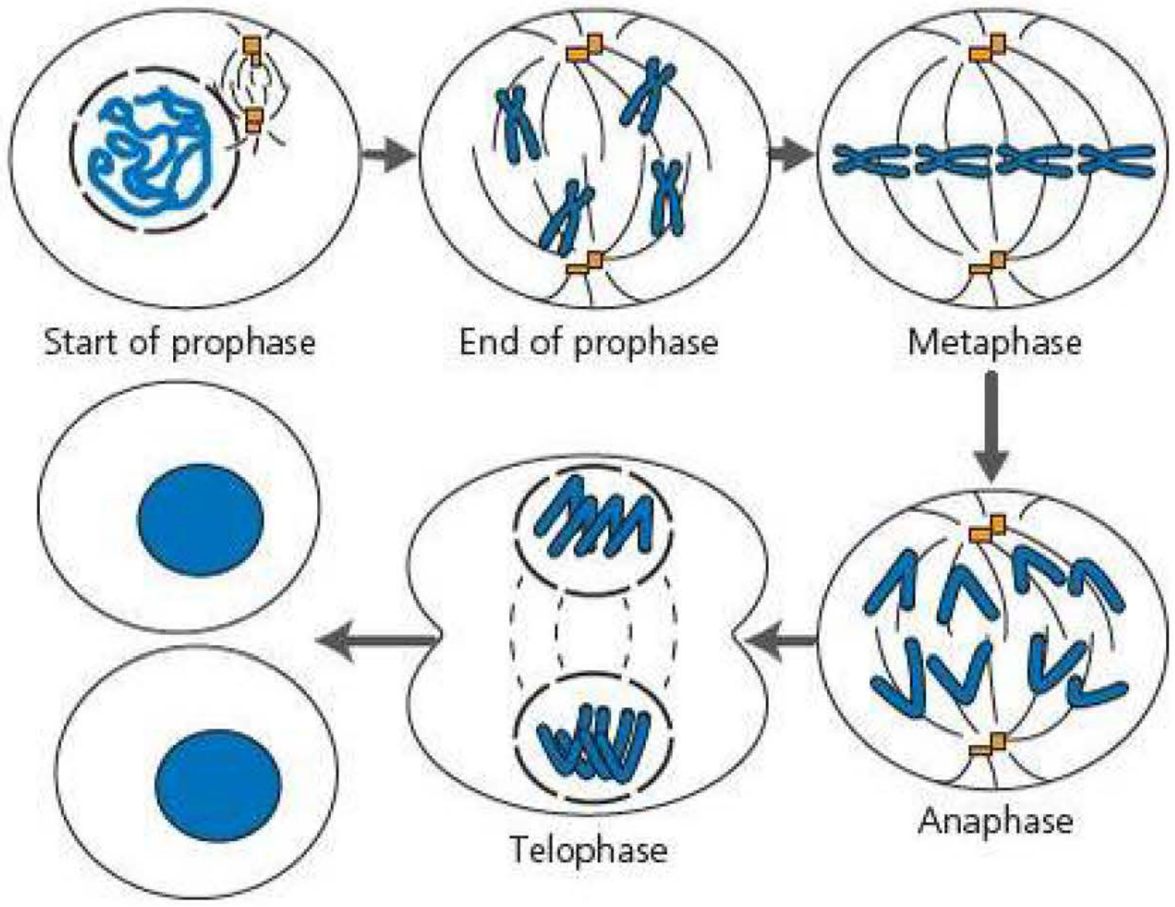


During mitosis, each double-stranded chromosome reverts to being single-stranded, with one copy of each chromosome ending up in each of the two new cells.



■ **Figure 6.36** Changes in chromosomes during interphase and mitosis

Mitosis can be divided into four separate stages: **prophase**, **metaphase**, **anaphase** and **telophase**.



■ **Figure 6.37** The stages of mitosis. Only four chromosomes are shown to make the process clearer – in human cells there are 46 chromosomes

1 **Prophase**. Chromosomes become shorter and fatter (they condense) so they are easier to move around. The chromosomes become visible as distinct threads. The nuclear membrane breaks down so that the chromosomes can move freely within the cell. A series of protein fibres (called the spindle) are formed that attach to the centromere of each chromosome.
2 **Metaphase**. The chromosomes line up in the centre of the cell (the 'equator'). They are moved into place using the spindle fibres.
3 **Anaphase**. The spindle fibres contract and separate the chromatids, which are pulled to opposite ends of the cell.
4 **Telophase**. The nuclear membrane reforms and the chromosomes unwind so they can carry out their function once more.

Following mitosis (i.e. nuclear division) the cytoplasm divides in two, separating the two cells (this is called **cytokinesis**).

During mitosis, one cell has become two, with each daughter cell a genetically identical copy of the original parent cell.

REVIEW

- **What are the differences between sexual and asexual reproduction?**
- **What is interphase?**
- **What are the stages of mitosis? What happens at each stage, and why?**
- **What is cytokinesis?**
- **Why is mitosis important?**

SUMMARY REFLECTION

Reflect on what you know about the differences between sexual and asexual reproduction. The following table will help with this:

Table 6.2 Comparing sexual and asexual reproduction

Feature	Sexual reproduction	Asexual reproduction
Common in bacteria		✓
Plants do it	✓	✓
Most animals do it	✓	
Needs two parents	✓	
Needs only one parent		✓
Gametes made	✓	
Cell fusion involved	✓	
No cell fusion involved		✓
Variety in offspring	✓	
Offspring are clones		✓

- **What have you learnt about how single-celled organisms reproduce?**
- **What have you learnt about mitosis?**

What different life cycles exist?

■ **Figure 6.38** Asexual reproduction in plants

HOW DO MULTICELLULAR ORGANISMS REPRODUCE?

Multicellular organisms can reproduce sexually or asexually, although the more complex ones tend only to be able to reproduce sexually.

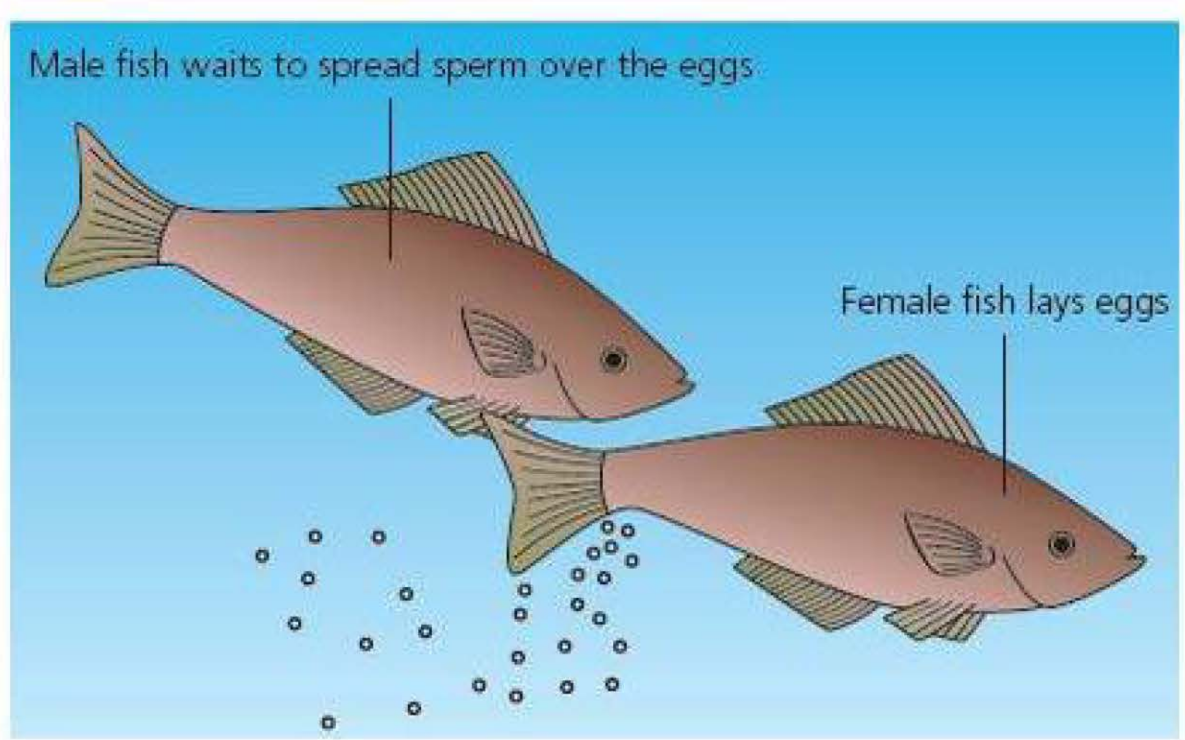
Plants reproduce sexually when they need to create variation in their offspring (for example if the environment is changing and they need to adapt to these changes), and asexually when the conditions are not changing and all offspring can be identical.

■ **Figure 6.39** Asexual reproduction in hydra. Hydra reproduces asexually by budding off a daughter polyp (as seen on left). The mouth of the hydra (upper centre) is surrounded by tentacles which it uses to capture small items of food which float past on the current. Food particles are passed to the mouth for ingestion. Waste is also eliminated out of the mouth

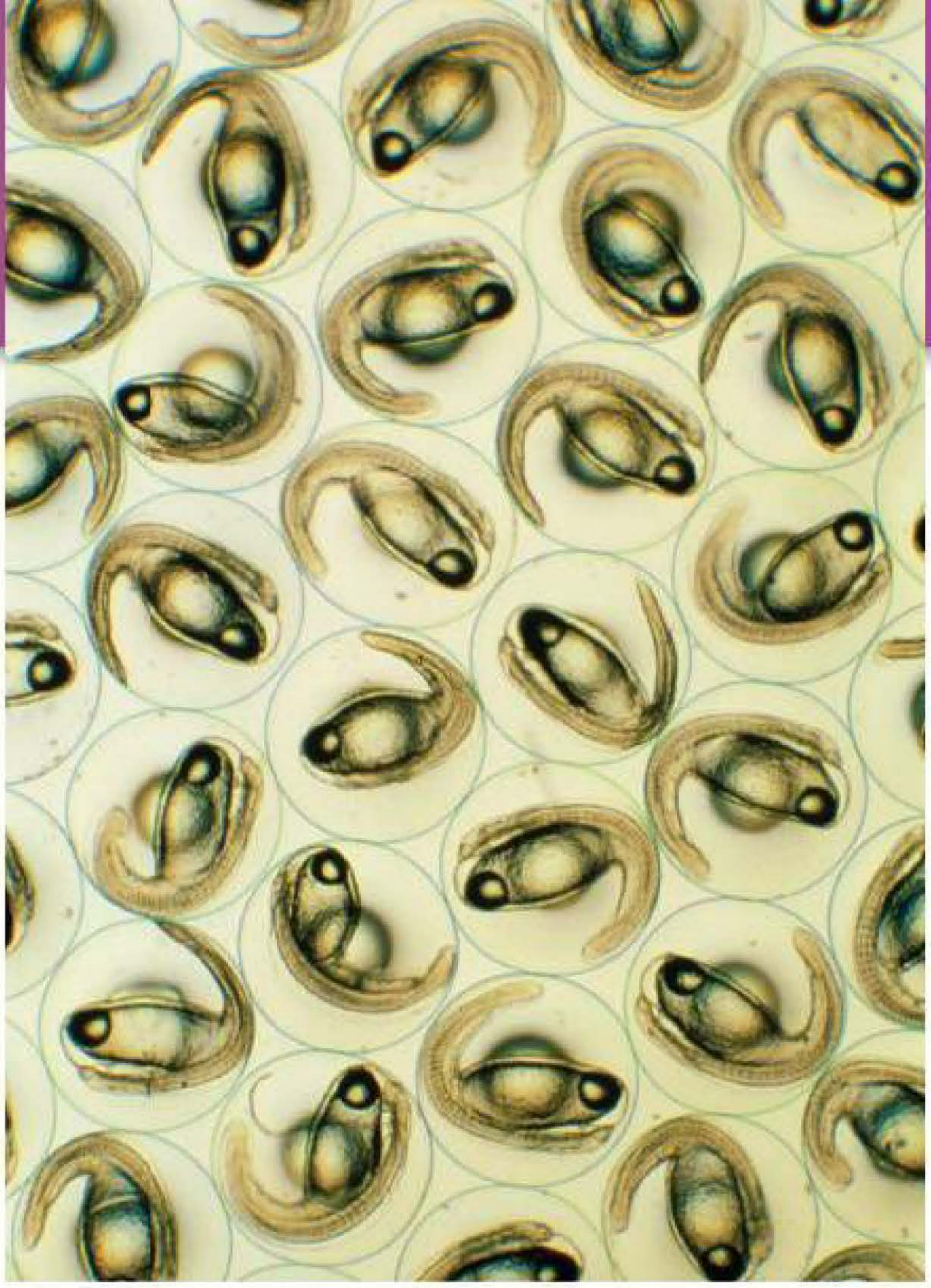
Examples of asexual reproduction in plants include the production of runners (as in strawberries) which grow in to **clones** of the parent plant, bulbs that can divide and produce clones, and tubers (such as potato) that can split to produce several genetically identical new plants.

Some animals can reproduce asexually, for example many insects such as greenfly, and aquatic hydra.

Sexual reproduction is a much more complex process than asexual reproduction. Some animals reproduce through external fertilization in which the males and females release their gametes into the water (for example many species of fish – the process is called spawning). Most animals on land reproduce through internal fertilization, in which the males ejaculate sperm into the bodies of the females.



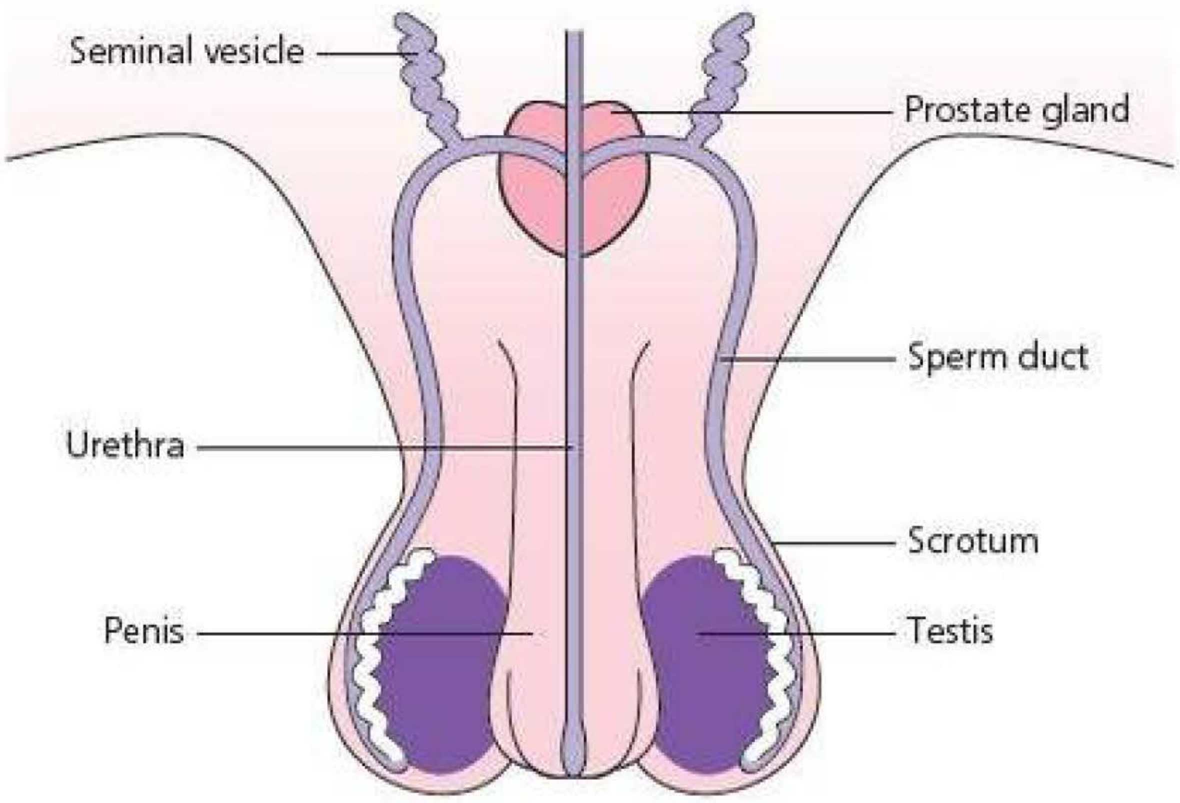
■ **Figure 6.40** Spawning in fish. External fertilization can happen in aquatic animals because the gametes can reach each other in the water



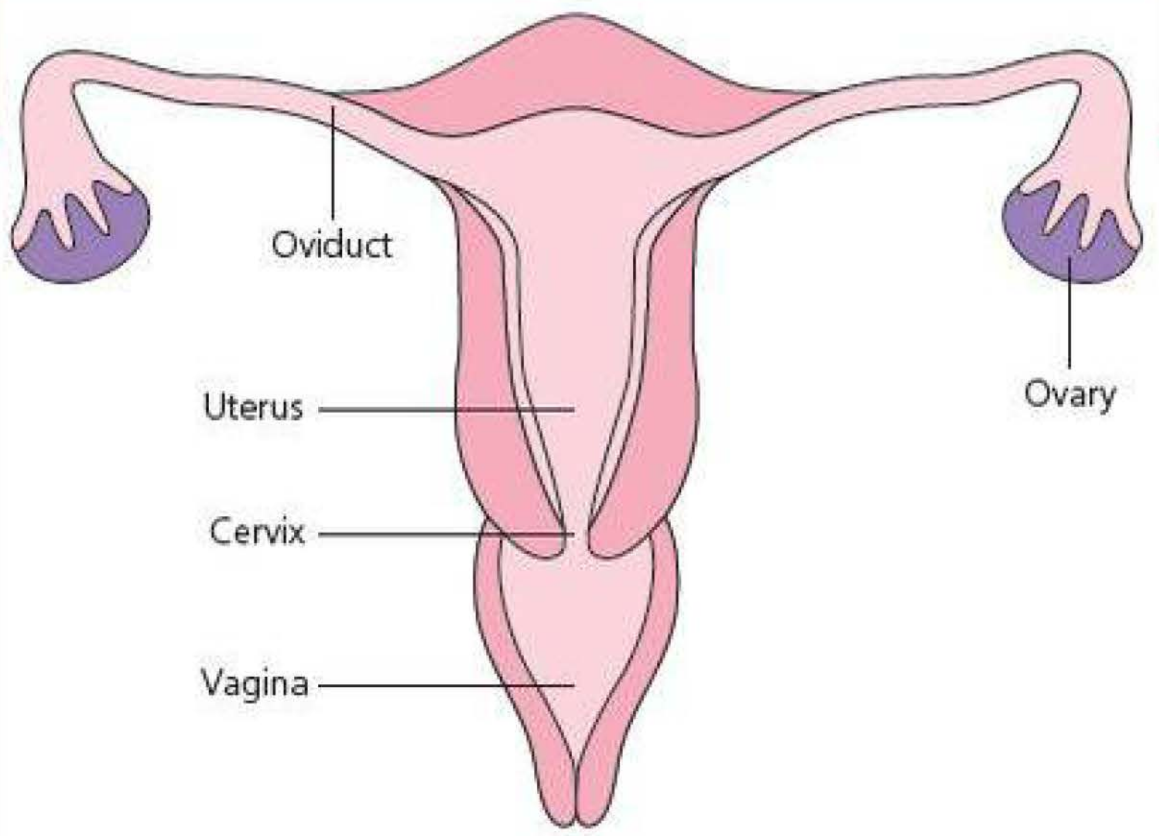
■ **Figure 6.41** Glass eel eggs. The eggs have been released into water and fertilized by sperm. The eggs are transparent and the developing embryos can be seen within them. The glass eels (*Anguilla japonicum*) migrate to spawn in the Pacific Ocean west of the Mariana Islands. The adults die after spawning

Human reproduction

Organisms carrying out sexual reproduction have highly specialized reproductive organs that ensure the gametes from the male can reach the gamete of the female.



■ **Figure 6.42** Male reproductive organs



■ **Figure 6.43** Female reproductive organs

Gametes from each sex are adapted to the job they have to do, and so are very different from each other.

■ **Table 6.3** Differences between egg and sperm

Egg	Sperm
Bigger	Smaller
Cannot move on its own	Can move on its own (has tail)
Has large food store	Does not have food store
Not many produced	Many produced

1 Sperm are produced in the testes by meiosis.
2 During sexual intercourse they pass down the sperm duct (Figure 6.42) and are mixed with fluid from the seminal vesicles to produce semen.
3 The semen is ejaculated into the woman's vagina and travels towards the Fallopian tubes (oviduct).
4 One ovum is released every month into a Fallopian tube, at which point it may be fertilized by sperm.
5 The zygote (fertilized egg) will develop into an embryo and implant itself in the lining of the uterus.
6 The embryo then develops a placenta which allows the embryo to receive materials such as food and oxygen from its mother.
7 The amnion develops around the embryo, and it secretes amniotic fluid, which acts as a shock absorber for the embryo.
8 When the embryo becomes recognisably human we call it a fetus.

In vitro fertilization (IVF) is a process by which an egg is fertilized by sperm outside the body, and can be used in infertility treatment.

■ **Figure 6.44** Monarch butterfly freshly emerged from cocoon

SUMMARY REFLECTION

- **What have you learnt about how multicellular organisms reproduce?**
- **What different life cycles exist?**

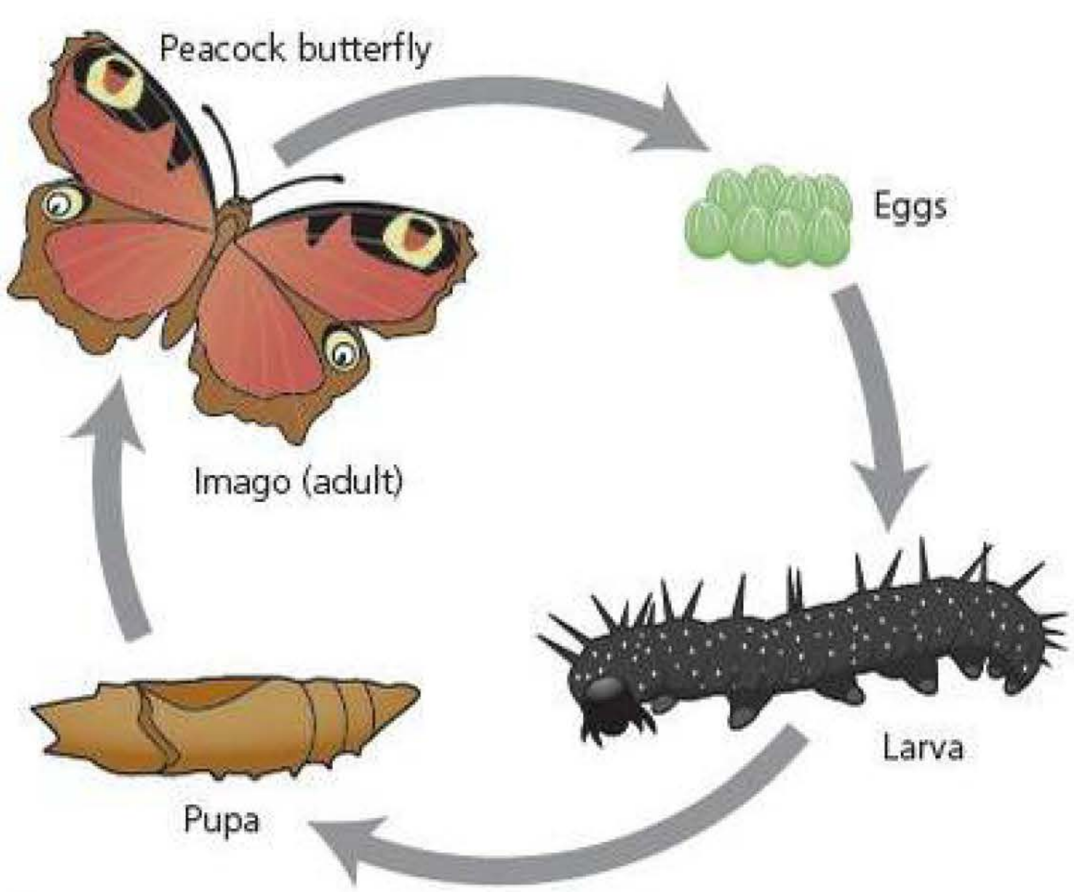
A **life cycle** is a period involving one generation of an organism through means of reproduction, whether through asexual reproduction or sexual reproduction. In the next activity you will find out about different life cycles.

ACTIVITY: Life cycles

ATL

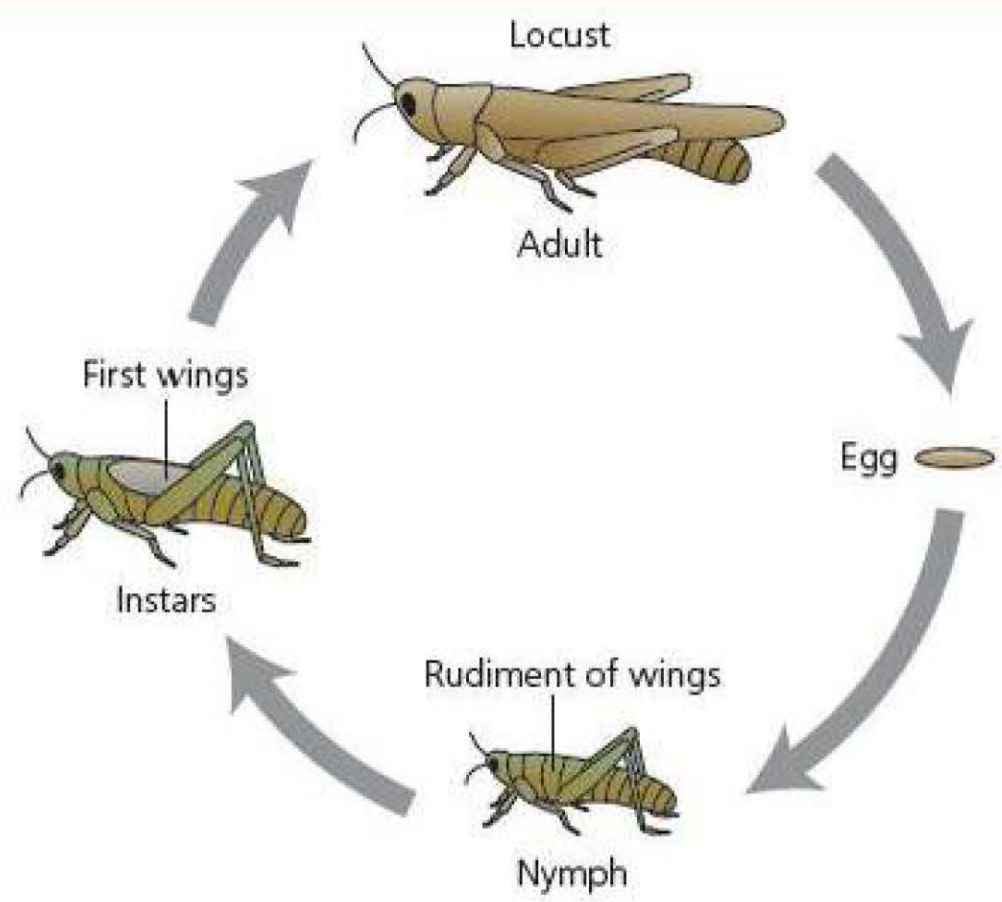
- Information literacy skills: Access information to be informed

Look at Figures 6.45 and 6.46. What different life cycles do they show?



■ **Figure 6.45** Life cycle of a butterfly

Vertebrates also show a variety of different adaptations to their life cycles. Look at Figures 6.47 and 6.48 opposite – what adaptations do they show?



■ **Figure 6.46** Life cycle of a locust

Produce a summary poster showing the variety of different life cycles that exist in animals. Use the following search terms to help find information: **incomplete metamorphosis**, **complete metamorphosis**, **placenta**, **amnion**, **marsupial**.

You can also use the information on this page and previous pages.

Assessment opportunities

- In this activity you have practised skills that are assessed using Criterion A: Describe and explain scientific information.

Figure 6.47 Emperor penguin sitting on egg

Figure 6.48 Kangaroo mother with young (joey)

DISCUSS

- In a small group, **discuss** the different life cycles that exist. How are they adapted to different organisms' ways of life?
- What have you learnt in this chapter about the scientific evidence that has improved our understanding of genetics?
- How does genetic information generate the characteristics of an organism?
- How are inheritable characteristics passed from one generation to another?
- To what extent do genetic characteristics determine the identity of an individual?
- What have you learnt about yourself as an open-minded learner? In what ways in this chapter have you critically appreciated your own personal history, and sought a range of points of view?

! Take action: Opportunity to apply learning through action …

Designer babies

! In this chapter we have looked at how genetic information is passed from one generation to the next, and how this information codes for physical characteristics. If we know which gene codes for which characteristic, in theory specific genes could be artificially selected to make 'designer babies'.

! Find out more about the issue of designer babies. To what extent is the science already available? Search terms: designer baby, genetic engineering, genetic diseases, gene therapy, human genome, reprogenics.

! **Discuss** with your neighbour the following question: To what extent should humans manipulate human reproduction or genetic characteristics? Now **discuss** the question within the whole class.

! Individually or in groups produce a poster or fact sheet that covers the following points:

- **Explain** ways in which science is already applied to address genetic problems (gene therapy).
- **Discuss** and **evaluate** the implications of using science and its applications to select specific genes in fertilized eggs in order to produce 'designer babies'.
- Consistently **apply** the scientific language you have learnt in this chapter to communicate understanding clearly and precisely.
- **Document** your sources of information completely.

Assessment opportunities

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

SOME SUMMATIVE PROBLEMS TO TRY

Use these problems to apply and extend your learning in this chapter. These problems are designed so that you can evaluate your learning at different levels of achievement in Criterion A: Knowledge and understanding.

THESE PROBLEMS CAN BE USED TO EVALUATE YOUR LEARNING IN CRITERION A TO LEVEL 1–2

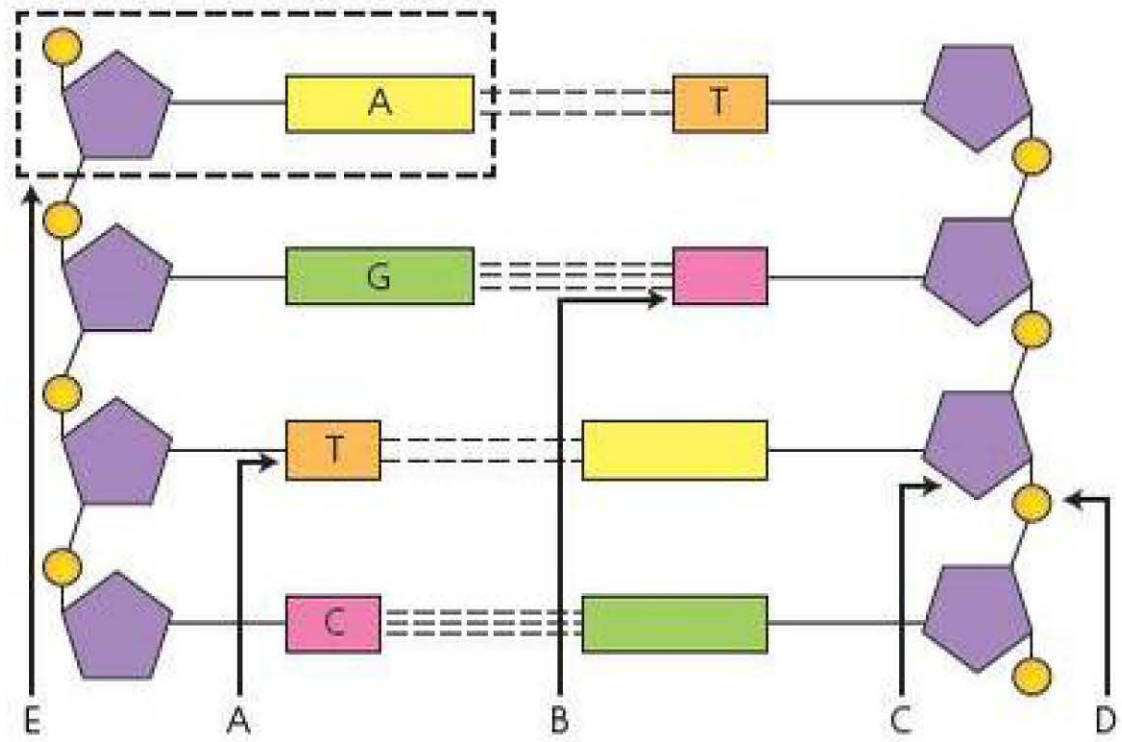
1 The following passage describes inheritance. Complete the passage by writing a suitable word or words in each space.

A gene is a section of a double-stranded molecule known as _______________________________.

This molecule is found within the ____________________ of the cell, contained in threadlike structures called ____________________. The two strands form a double helix linked by a series of paired bases. The base adenine is always linked to ________________ and the base cytosine is always linked to ________________________.

Sometimes the genetic material of a cell changes: this is known as a _______________. These changes occur very rarely but their incidence can be increased by ____.

2 This diagram represents part of a molecule of DNA:

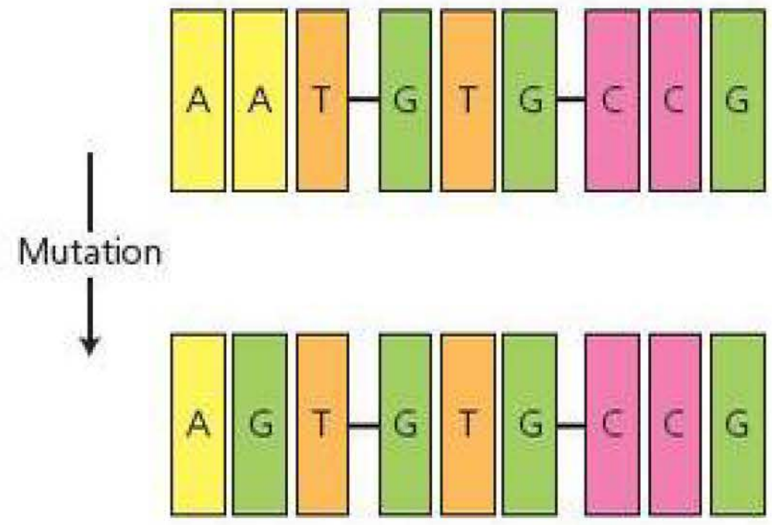


■ **Figure 6.49** The structure of DNA

Name the labelled parts A, B, C, D and E.

THESE PROBLEMS CAN BE USED TO EVALUATE YOUR LEARNING IN CRITERION A TO LEVEL 3–4

3 The following diagram shows a section of DNA before and after a mutation:

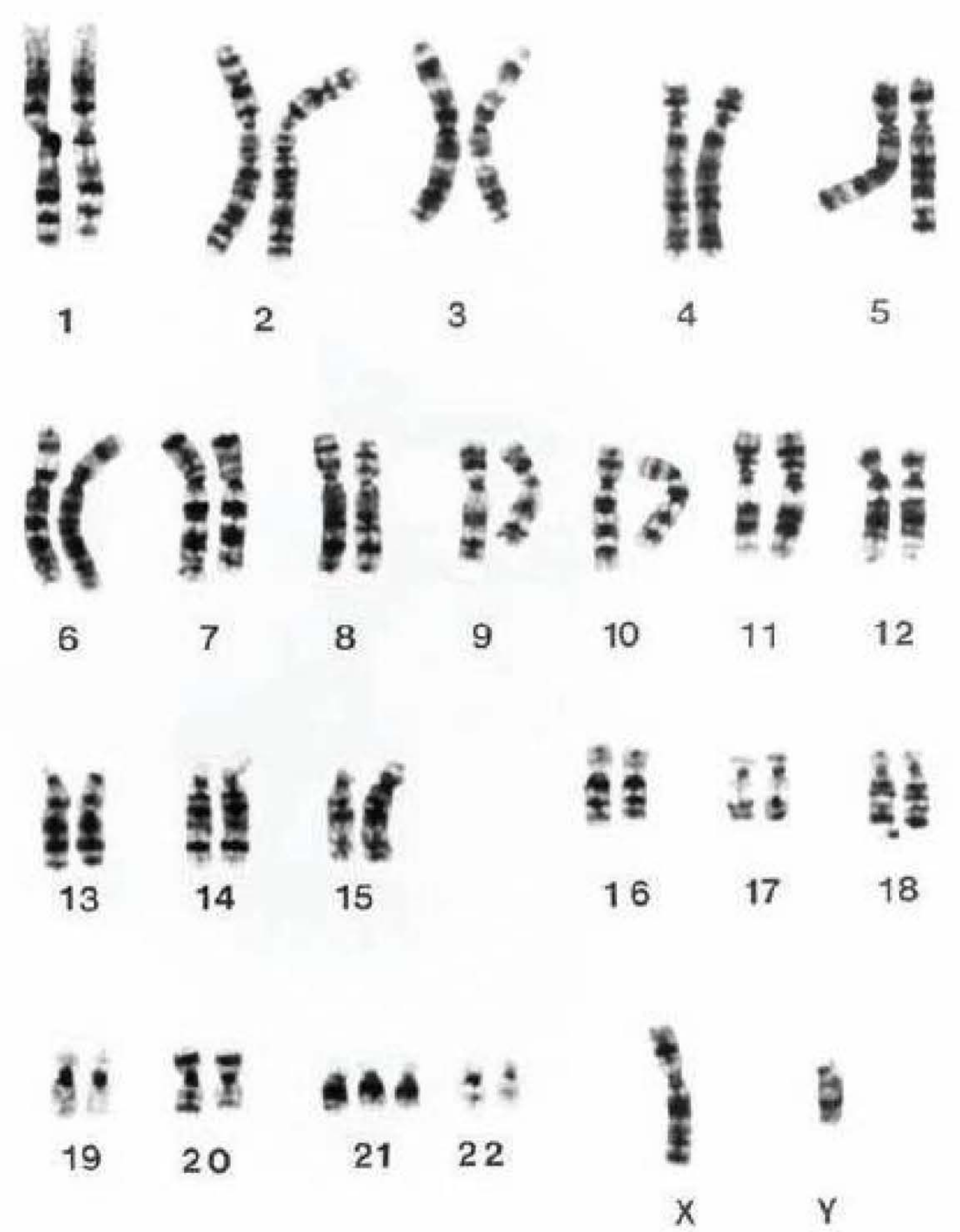


■ **Figure 6.50** DNA mutation

a **Suggest** what factor may have caused the mutation.

b Using your knowledge of the role of DNA in cells, **outline** the effect that the mutation could have on the organism.

4 Some mutations result in whole chromosomes being lost or repeated during cell division. Figure 6.51 shows a cell where a chromosome mutation has occurred.



■ **Figure 6.51** Cell with a chromosome mutation

a **State** the number of the chromosome where the mutation has taken place.

b **Outline** the possible cause of the mutation.

THESE PROBLEMS CAN BE USED TO EVALUATE YOUR LEARNING IN CRITERION A TO LEVEL 5–6

5 a **Describe** the difference between asexual and sexual reproduction.

b Copy and complete the following table using ticks and crosses to indicate presence/absence of different features:

Feature	Sexual reproduction	Asexual reproduction
Common in bacteria		
Plants do it		
Most animals do it		
Needs two parents		
Needs only one parent		
Gametes made		
Cell fusion involved		
No cell fusion involved		
Variety in offspring		
Offspring are clones		

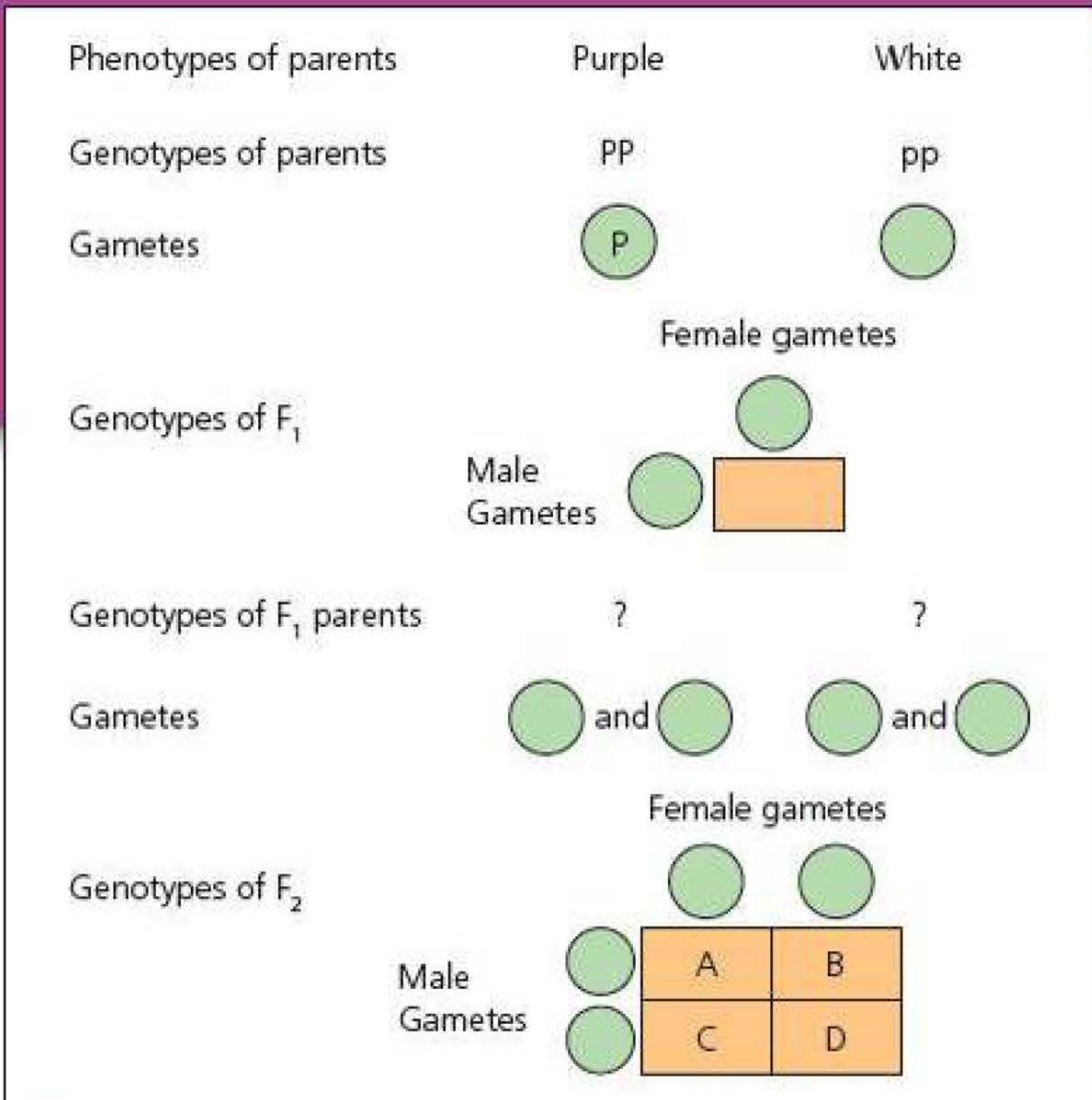
c **Describe** the process of mitosis using diagrams to illustrate your answer.

7 a What is a gene?

b What is an allele?

c A pea plant has a single pair of alleles that control flower colour.

■ **Figure 6.52** Pea plants have flowers of different colours. This photo shows a pea (*Pisum* sp.) with a purple flower



■ **Figure 6.53** Inheritance in pea plants

The allele for purple flowers is dominant to the allele for while colour. Figure 6.53 shows the result of a cross between a pure-breeding purple pea plant and a pure-breeding white flower. P = dominant allele for purple flower, p = recessive allele for white flower.

i Complete the genetic diagram shown in Figure 6.53.

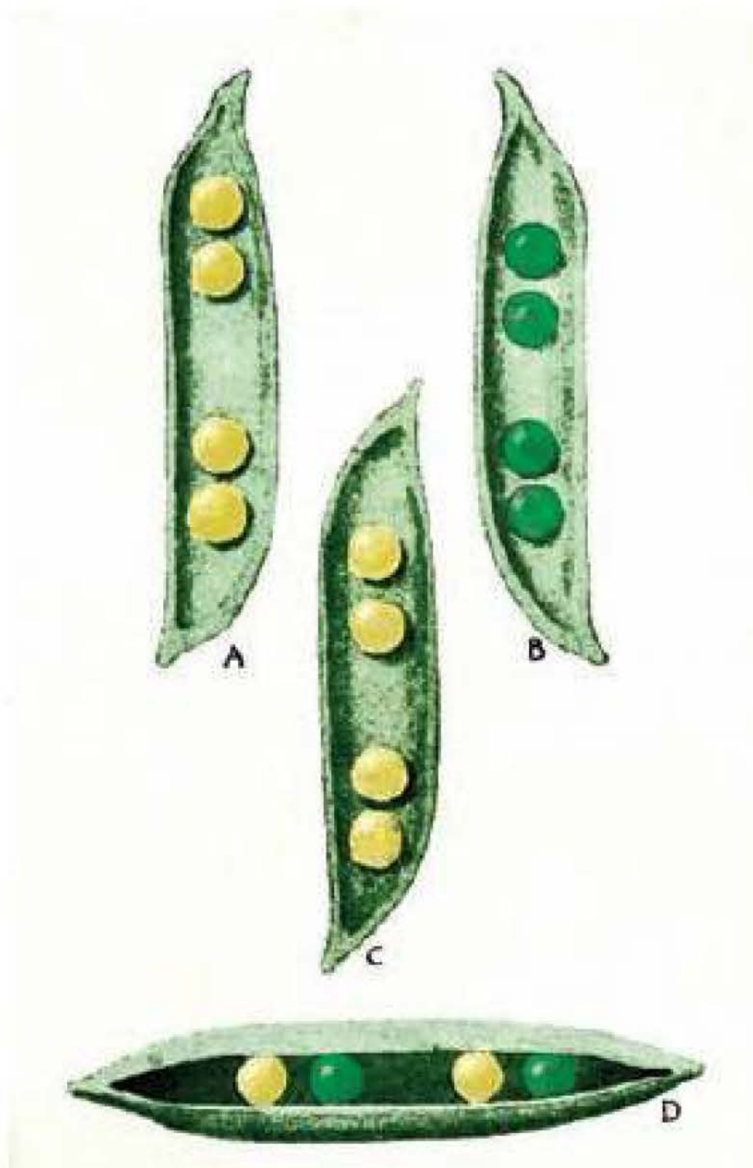
ii What are the colours for the flowers of A, B, C and D?

iii **Suggest** what is meant by 'pure breeding'?

THIS PROBLEM CAN BE USED TO EVALUATE YOUR LEARNING IN CRITERION A TO LEVEL 7–8

8 a Many plants can carry out both asexual and sexual reproduction. Compare asexual reproduction and sexual reproduction. **Explain** the advantages and disadvantages of both types of reproduction.

b Gregor Mendel was a monk who carried out research on pea plants to investigate how organisms inherited characteristics from one generation to the next. Pea plants carry out sexual reproduction. Between 1856 and 1863 Mendel grew and analysed some 29 000 pea plants. Different pea plants showed different characteristics, such as yellow or green peas.



■ **Figure 6.54** Mendel's peas. Historical artwork of the peas (*Pisum* sp.) used by Gregor Mendel (1822–1884) in his experiments into heredity

i **Explain** how pea plants can produce different coloured peas.

ii When Mendel cross-pollinated a pure-breeding parent plant that only produced yellow peas with a pure-breeding parent plant that only produced green peas, he found that the first offspring generation (F_1) always produced yellow seeds. **Explain**, using genetic diagrams, Mendel's results.

iii Mendel cross-pollinated the F_1 generation to produce a F_2 generation. He repeated the experiment and combined his results. He found that 705 yellow peas were produced and 224 green peas. **Analyse** these results, and **explain**, using genetic diagrams, the observed ratio between green and yellow peas.

iv Mendel carried out more experiments using other characteristics, such as flower colour and whether peas were round or wrinkled. In each experiment, his data almost perfectly matched expected results. **Evaluate** Mendel's experiments using your knowledge of genetics and experimental design.

Reflection

In this chapter we have explored how scientific evidence, and the use of models, have improved the understanding of genetics. We have seen how genetic information generates the characteristics of an organism, and how inheritable characteristics are passed from one generation to the next. We have discussed the extent to which genetic characteristics determine the identity of an individual, and the degree to which humans should be able to manipulate human reproduction or genetic characteristics. We have learnt about our role as an open-minded learner, considered how to critically appreciate our own personal history, and have sought a range of points of view to explore issues raised in this chapter.

<table>
<tr><th colspan="6">Use this table to reflect on your own learning in this chapter</th></tr>
<tr><td>Questions we asked</td><td>Answers we found</td><td colspan="4">Any further questions now?</td></tr>
<tr><td>Factual: What is DNA? In what way is DNA the basis for inheritance and evolution? Who was Gregor Mendel and what work did he do to show how characteristics are inherited? What are alleles? What is asexual and sexual reproduction? How do single-celled organisms reproduce? What is mitosis? How do multicellular organisms reproduce? What different life cycles exist?</td><td></td><td colspan="4"></td></tr>
<tr><td>Conceptual: What does the structure of DNA reveal about its function? How does the genetic code produce physical characteristics? To what extent does the genetic code determine the identity of a person?</td><td></td><td colspan="4"></td></tr>
<tr><td>Debatable: Does the end justify the means in science – were Watson and Crick correct to use Rosalind Franklin's data without her permission? Were Mendel's results too perfect? To what extent should humans manipulate human reproduction or genetic characteristics?</td><td></td><td colspan="4"></td></tr>
<tr><td rowspan="2">Approaches to learning you used in this chapter</td><td rowspan="2">Description – what new skills did you learn?</td><td colspan="4">How well did you master the skills?</td></tr>
<tr><td>Novice</td><td>Learner</td><td>Practitioner</td><td>Expert</td></tr>
<tr><td>Organization skills</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Critical-thinking skills</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Creative-thinking skills</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Information literacy skills</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Learner profile attribute(s)</td><td colspan="5">Reflect on the importance of being open-minded for your learning in this chapter.</td></tr>
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7 How have different forms of life arisen?

Species change over time through interactions with their environment: the evolution of humans has impacted global biodiversity in ways that may not be sustainable.

■ **Figure 7.1** Galápagos Tortoises, Galápagos Islands, Ecuador. These tortoises helped Charles Darwin develop his theory of evolution by natural selection

CONSIDER AND ANSWER THESE QUESTIONS:

Factual: What is speciation? What occurs during meiosis? What effects do genetic mutations have on the survival of species?

Conceptual: How can we understand and know about events and processes that occurred many years ago and over a long period of time? How have changes in habitats led to the development of new species? What occurs during the process of natural selection? How do changes in the genetic code lead to phenotypic variation? How have changes within cells led to the development of new species? How are species interrelated? How can scientists work out how closely related species are?

Debatable: To what extent have humans and their lifestyles driven the evolution of other species? To what extent is the use of antibiotics in farming benefitting or harming human health?

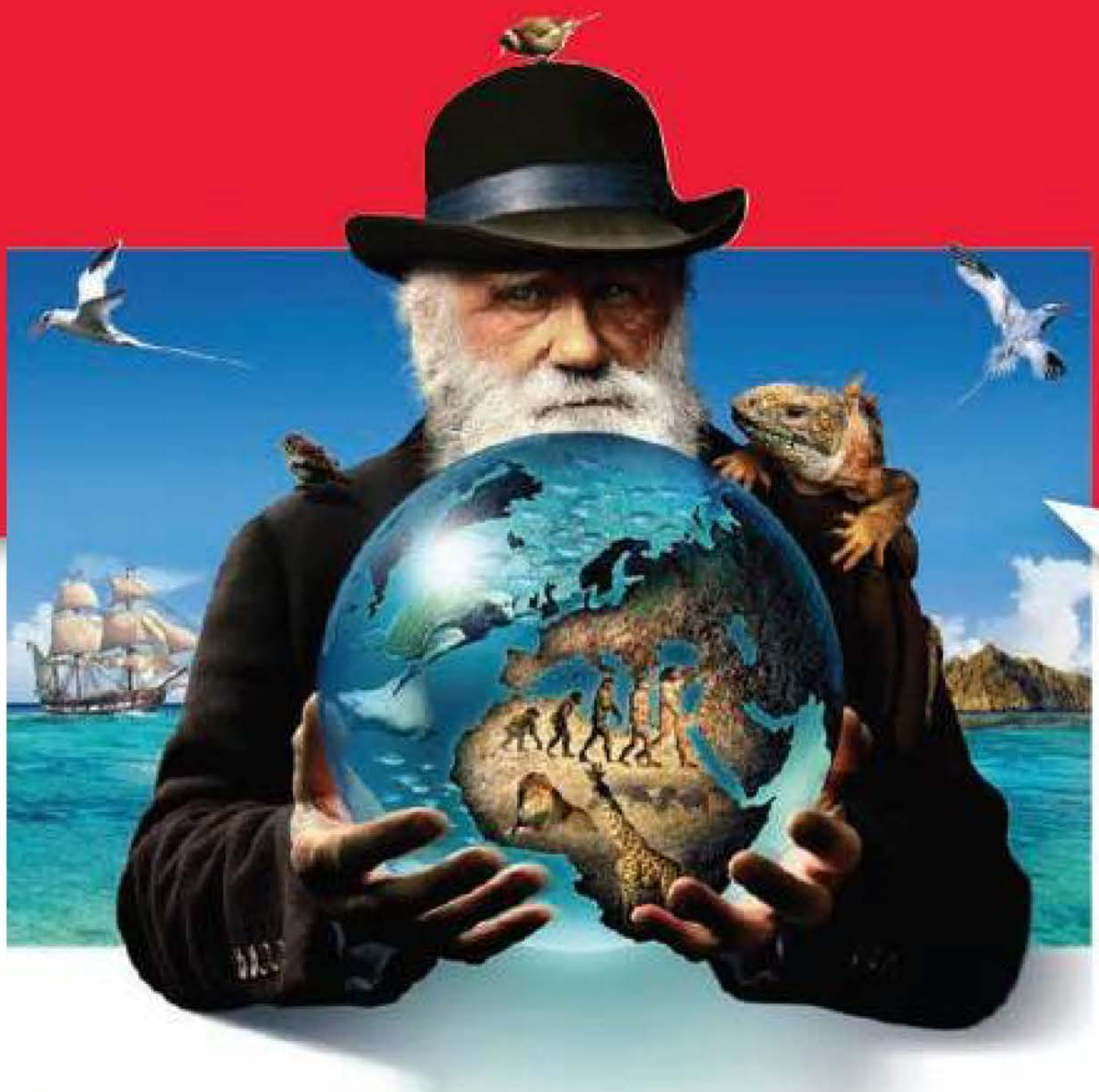
Now **share and compare** your thoughts and ideas with your partner, or with the whole class.

IN THIS CHAPTER, WE WILL …

- **Find out:**
  - how life on Earth has evolved over millions of years;
  - about the evidence for evolution and how new species are formed.
- **Explore** the mechanisms of natural selection and speciation.
- **Take action** by campaigning to protect an endangered animal at risk of extinction.

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

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



■ **Figure 7.2** Charles Darwin and HMS *Beagle* (left)

My name is Charles Darwin. My father wanted me to be a priest and I began training at Cambridge University – when I showed my displeasure at this career choice he suggested medicine, which I studied at Edinburgh before giving up on that too. My father was not pleased! My real interest was in natural history, and so when I saw an opportunity to pursue these interests while employed as gentleman's companion to the Captain of HMS *Beagle*, I leapt at the chance. My father eventually gave me his grudging approval, and so in 1831 I set sail as naturalist on HMS *Beagle*. This incredible journey lasted 5 years, and provided the fieldwork for my famous book *On the Origin of Species By Means of Natural Selection* which was published in 1859. I described it as a 'brief abstract' – I had intended it to be longer! To say that it caused 'a bit of a stir' is something of an understatement!

We will reflect on this learner profile attribute …

- **Reflective – thoughtfully considering the world and your own ideas and experiences.**

Assessment opportunities in this chapter:

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

KEY WORDS

ancestral	isolation
comparative	selection
distribution	speciation
evolved	sustainable

Today, it is generally accepted that present-day **species** have arisen by change from **ancestral** forms of life. By '**evolution**' we mean the gradual development of life over very long periods of time (i.e. geological time), from its earliest beginnings to the **diversity** of organisms we know about today, both living and extinct. Evolution is the development of new types of living organism from ones that already exist through the gradual build-up of **genetic** differences. Charles Darwin developed the theory of evolution by **natural selection**, which explains how changes in species can occur through **variation** and **selection** (see page 184 for further details; you will explore the theory over the next few pages). It has been said that '*Nothing makes sense in biology without evolution*': this is because the theory links all aspects of Biology and forms a framework for study, in the same way that the periodic table in Chemistry does.

SEE–THINK–WONDER

Put yourself in the mind of Charles Darwin. Look at Figures 7.3 to 7.6 that show different objects – each was observed by Darwin and helped him develop his theory of evolution.

For each figure, think what might be going on or what a relevant observation might be. Back up your interpretation with reasons. Think about what this makes you wonder about the object.

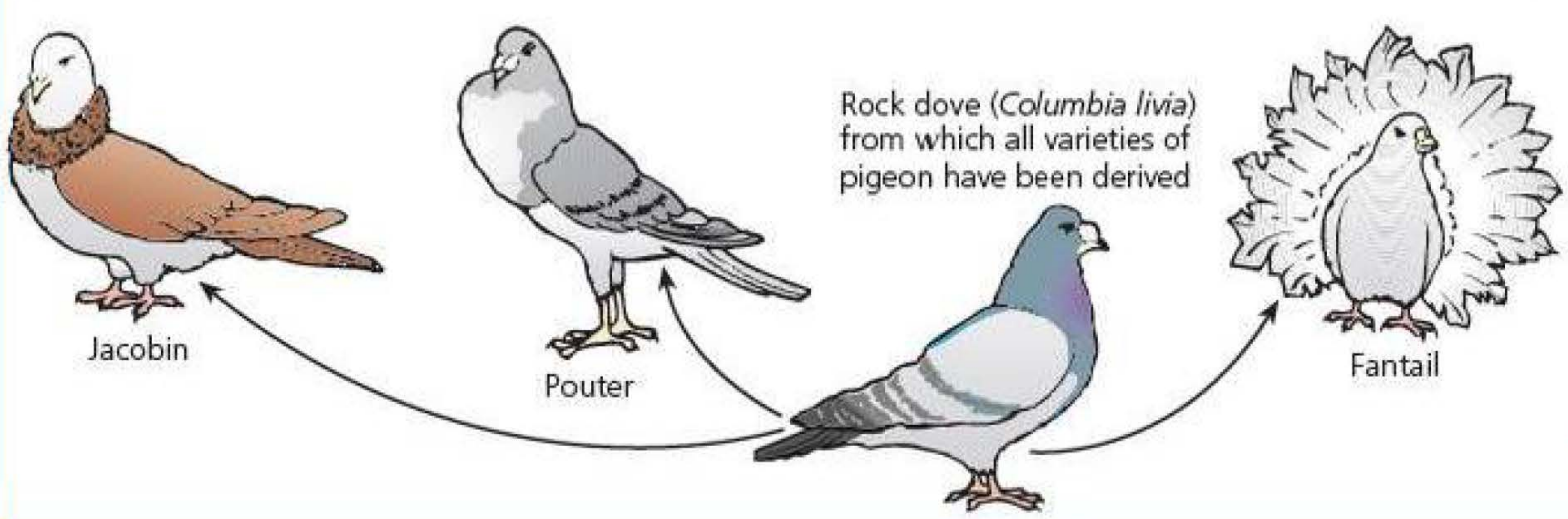
So, in this activity you see, think and wonder (it helps if you do these all at the same time, for each figure):

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

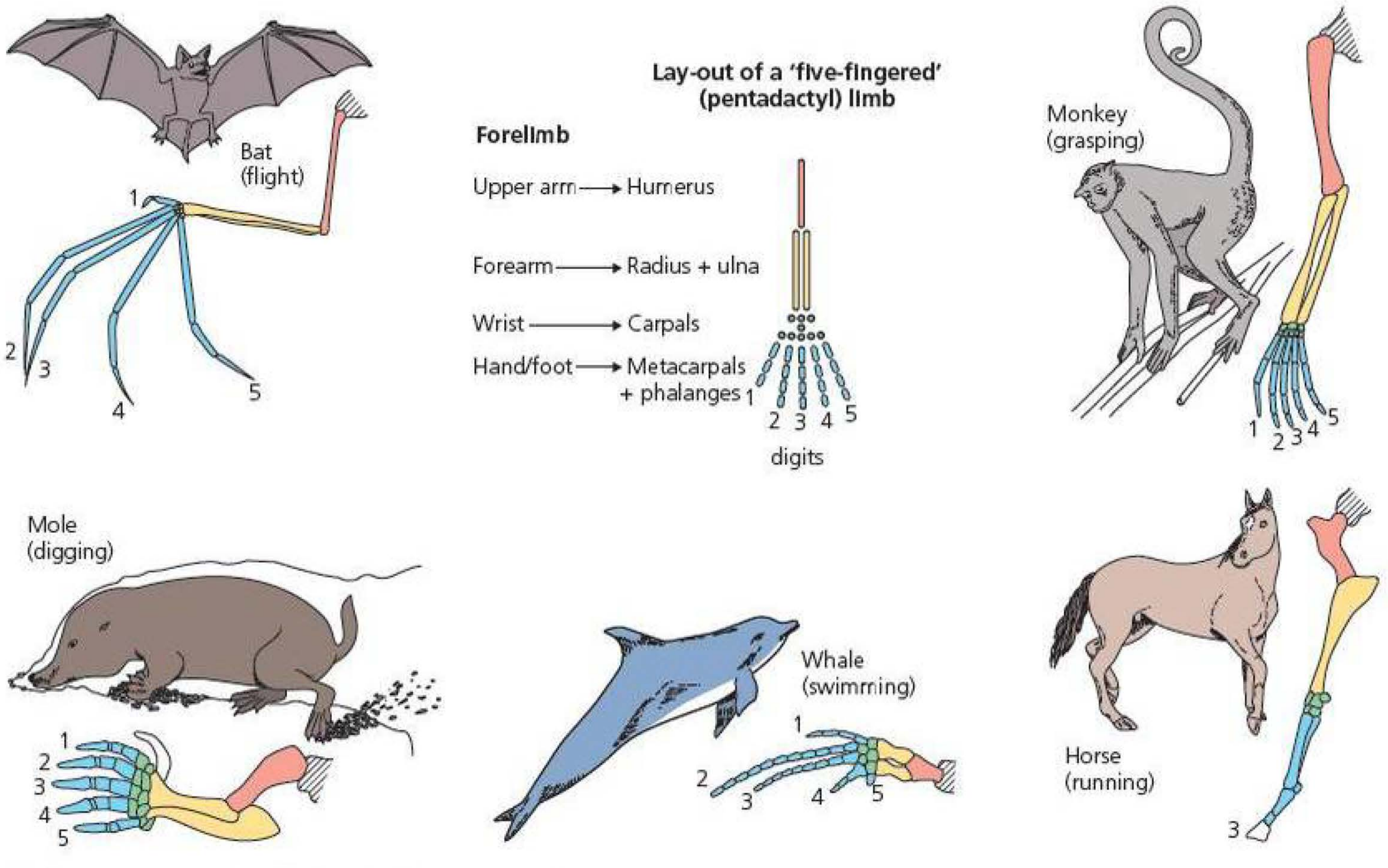
Write down your ideas on paper. You will need to start separate sentences with 'I see ...', 'I think ...', 'I wonder ...'. Share your ideas with a small group, and then with the whole class.

■ **Figure 7.3** Fossil layers

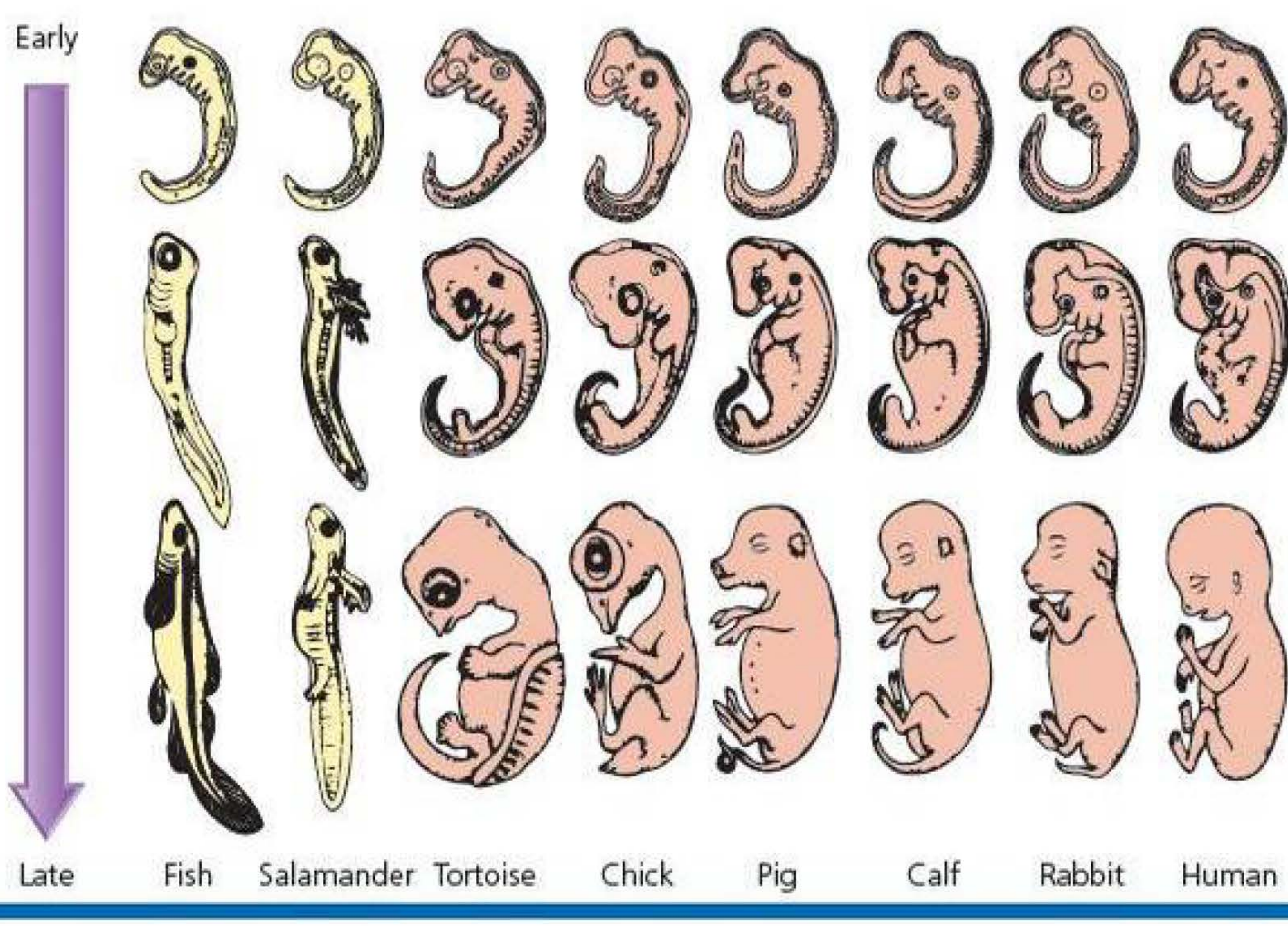
From his breeding of pigeons, Darwin noted that there were more than a dozen varieties that, had they been presented to an ornithologist as wild birds, would have been classsified as separate species.



■ **Figure 7.4** Selective breeding in pigeons



■ **Figure 7.5** The forelimbs of different vertebrates



■ **Figure 7.6** Vertebrate embryos, from early to late stages of development

What is the evidence for evolution?

■ **Figure 7.7** A fossil ammonite

HOW CAN WE UNDERSTAND EVENTS AND PROCESSES THAT OCCURRED MANY YEARS AGO?

Evidence for evolution comes from many sources, including from the study of **fossils**, from **artificial selection** in the production of domesticated breeds (see Chapter 11, page 283), from studies of the **comparative anatomy** of groups of related organisms, and from the geographical **distribution** of species.

Fossils allow us to understand and know about events and processes that occurred many years ago and over a long period of time. Fossilization is an extremely rare, chance event. Predators, scavengers and bacterial action normally break down dead plant and animal structures before they can be fossilized. Of the relatively few fossils formed, most remain buried or, if they do become exposed, are overlooked or accidentally destroyed.

Despite being such a rare event, numerous fossils have been found – and more continue to be discovered all the time. If the fossil, or the rock that surrounds it, can be accurately dated (using radiometric dating techniques, which measure naturally occurring radioactive substances such as carbon-14 in relation to the amount of carbon-12), we have good evidence of the history of life.

ACTIVITY: History of life on Earth

ATL

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

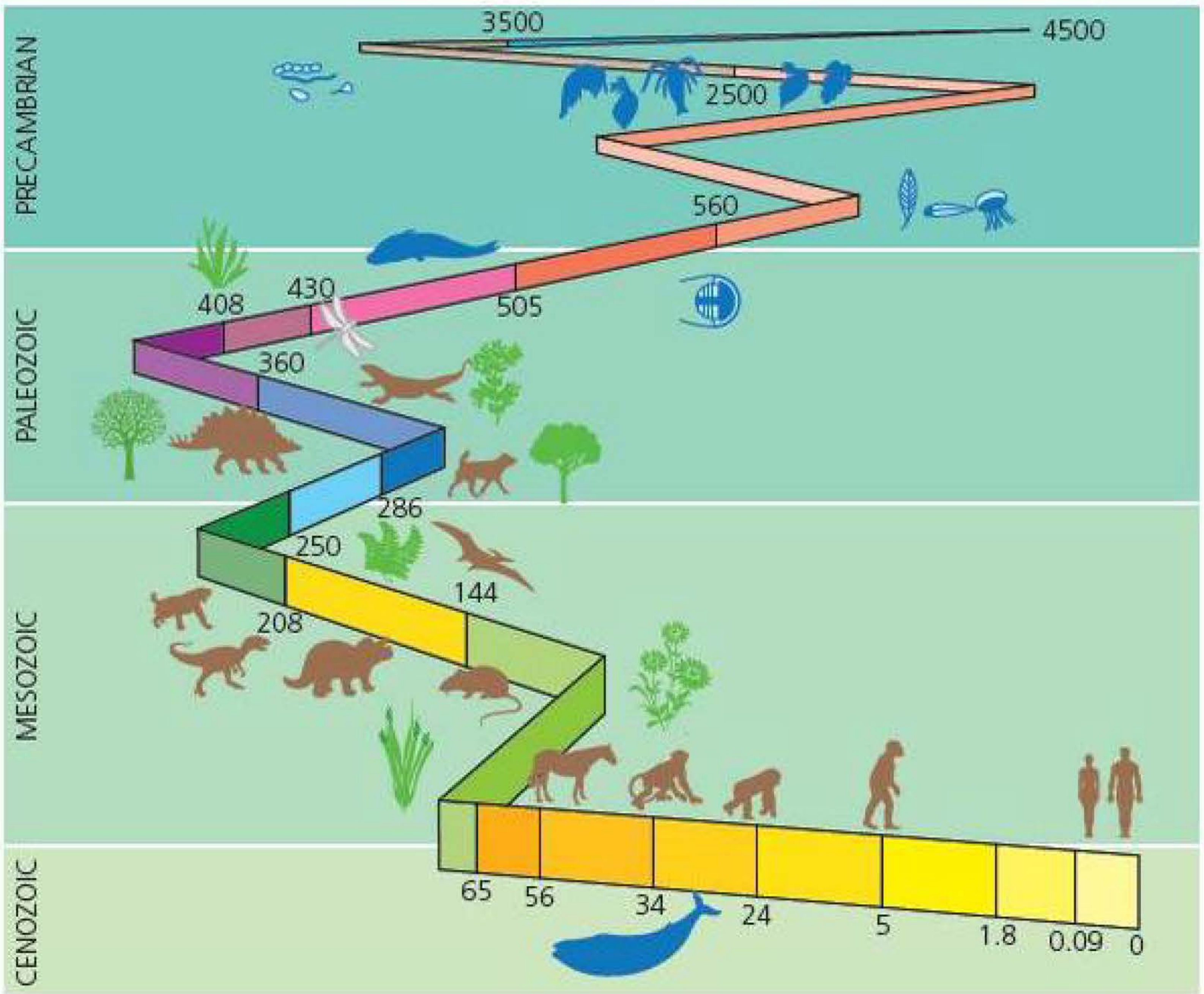
Your task is to produce a poster that summarizes the following information:

- How are fossils formed?
- Trace how one group of organisms have **evolved** through time (the horse and the whale are good examples to use: www.amnh.org/exhibitions/past-exhibitions/horse/the-evolution-of-horses and http://ocean.si.edu/ocean-videos/evolution-whales-animation)
- What do fossils tell us about evolution through space and time? Make sure you compare fossil records and geology on different continents. Use these search terms: **geology**, **fossilization**, **sedimentation**, **plate tectonics**, **continental drift**, **biogeography**.

Now produce a timeline that summarizes the history of life on Earth. You should aim to include the following key events:

- 3500 million years ago: First signs of life – bacteria
- 900 million years ago: The first complex cells
- 550 million years ago: First multicellular plants appear (liverworts and mosses)
- 420 million years ago: First animals came out of water to live on land
- 245 million years ago: First tiny mammals appeared with the dinosaurs on Earth
- 65 million years ago: Dinosaurs became extinct [*why did this happen?*]
- 3.9 million years ago: The appearance of the early ancestors of humans (*Australopithecus afarensis*)
- 120 000 years ago: *Homo sapiens* first evolved.

Use these search terms: **evolution of life**, **fossils**, **extinction**, **first life**.



◆ Assessment opportunities

◆ This activity can be assessed using Criterion A: Describe and explain scientific information.

■ **Figure 7.8** A timeline of life

■ **Figure 7.9** Dinosaur extinction – the bones of a *Tyrannosaurus rex* with early mammals hiding in the skeleton

■ **Figure 7.10** Reconstructions of *Australopithecus afarensis* specimens

EXTENSION: The evolution of life

What was the first life on Earth like? Many of the clues come from the conditions found at the time – the organism must have been adapted to these conditions.

In this activity you will use your knowledge of the early Earth atmosphere, and different types of respiration (Chapter 1), to **design** the earliest forms of life on Earth. You will show how changes in the atmosphere would have resulted in the development of different forms of life, and **explain** how multicellular organisms may have first evolved.

You need to **draw** diagrams of your organisms (for each one of the stages 1–3 below), and add labels to show how their metabolism (e.g. respiration/photosynthesis) would have worked. Can you give names to your creations?

Things to think about …

1 First life

   a The atmosphere on the early Earth was high in carbon dioxide, but very low in oxygen: what form of respiration would these early forms of life have used?

   b What would they have looked like (one cell, more than one cell, colour, shape, size, etc.)?

2 What came next?

   a The first forms of life could not make their own food – they had to find food. Later on, other organisms evolved which *could* make their own food. How would they have done this?

> Hint
> What organisms do you know about which make their own food, i.e. glucose?

   b What would they have looked like? (size, colour, etc.). What form of respiration would they have used?

> Hint
> They found oxygen **poisonous**!

   c What would these organisms have done to the atmosphere of Earth? How would the atmosphere of Earth have changed?

3 Changed atmosphere?

   a New life would have arisen with the changing atmosphere – what form of respiration would this form of life have used?

   b What advantages would this type of metabolism have given the new forms of life?

> Hint
> How much energy could they now release from glucose compared to early life? Would this have had any implications for the **size** they could become?

   c What would they have looked like (one cell, many cells, size, shape, etc.).

Draw and **label** each of these *three* forms of life. Perhaps you could draw them as a family tree, from the earliest to the most developed?

SUMMARY REFLECTION

- What have you learnt about how we can understand and know about events and processes that occurred many years ago and over a long period of time?
- What have you learnt about how fossils are formed?
- What have you learnt about how fossils are used to show how life has evolved?
- What have you learnt about the history of life on Earth?

DISCUSS

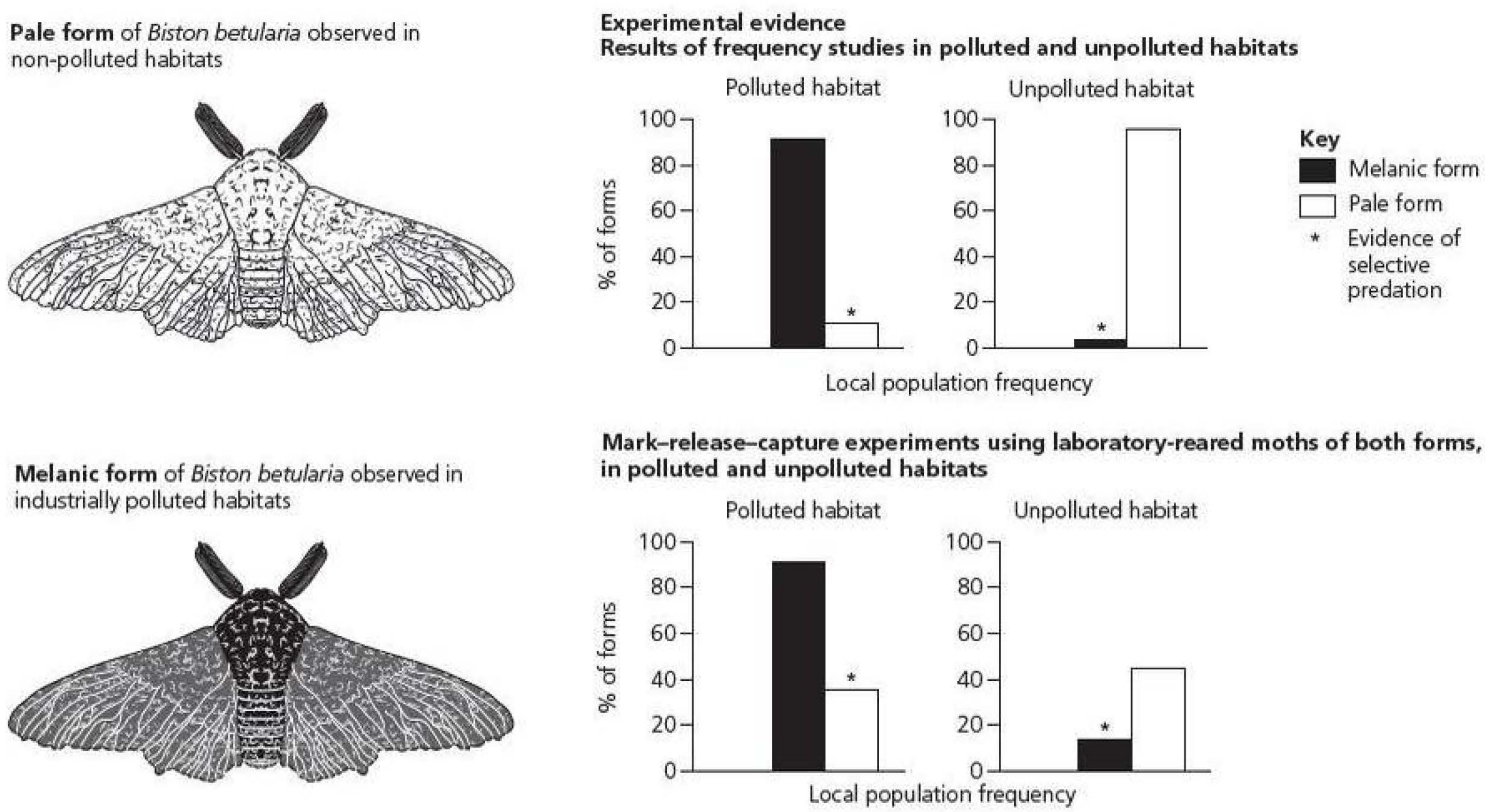
- **Explain** to your neighbour how fossils are formed.
- **Discuss** in a small group about how life has evolved on Earth, and the evidence for this.

What examples of natural selection are there?

WHAT OCCURS DURING THE PROCESS OF NATURAL SELECTION?

During the Industrial Revolution in Britain, in the early part of the nineteenth century, air pollution by gases (such as sulfur dioxide) and soot was distributed over the industrial towns, cities and surrounding countryside. Here, lichens and mosses on tree trunks were killed off and these surfaces were blackened. The numbers of dark varieties of some 80 species of moth increased in these habitats in this period. This rise in proportion of darkened forms is known as industrial melanism.

The dark-coloured (melanic) form of the peppered moth *Biston betularia* tended to increase in these industrialized areas, but their numbers were low in unpolluted countryside, where pale, speckled forms of moths were far more common (Figure 7.11). The melanic form was effectively camouflaged from **predation** by insectivorous birds in sooty areas, and became the dominant species.



■ **Figure 7.11** The peppered moth – an example of natural selection

ACTIVITY: Natural selection games

ATL

- Critical-thinking skills: Evaluate evidence and arguments

For each of the following activities **formulate** and **explain** a hypothesis. Explain your hypothesis using correct scientific reasoning.

Peppered moths

■ **Figure 7.12** The peppered moth, *Biston betularia*

Carry out your own investigation of the peppered moth using this site: http://peppermoths.weebly.com/

Summarize what you have found out on a postcard-sized piece of paper. Share your ideas with your neighbour – write any change to your ideas on the reverse of the postcard.

The natural selection of candy

- Take a bowl and fill it with jelly beans of different colours, including black (these are representing individuals in a population, and the bowl is the habitat of the population).
- Work out the proportion of black candy to coloured candy.
- At the beginning of the lesson, tell the others in your class that the black candy does not taste good (they are representing poisonous animals in a population).
- During the lesson other students can take candy from the bowl.
- At the end of the lesson work out the proportion of black candy to coloured candy left. What do your results tell you?

Alternatively, you could put a bowl with nuts, raisins and M&Ms in front of your class. Say nothing. After a while, observe which food has been eaten and which has survived.

Worms in the yard

- Take 100 cocktail sticks and colour half green and half red. These will represent a population of worms.
- Drop the sticks in long grass.
- Collect as many sticks as you can in one minute. What do your results tell you?

Design your own experiment to demonstrate natural selection

- What will you use as your model organisms?
- What adaptations will your model organisms **demonstrate** to ensure that some are more likely to survive to the next generation than others?
- How will you ensure your results are reliable?
- How will you **analyse** your data?
- What would you predict the outcome to be of your experiment? Do your results confirm your prediction?

◆ Assessment opportunities

- This activity can be assessed using Criterion B: Formulate a testable hypothesis and explain it using scientific reasoning and Criterion C: Interpret data and explain results using scientific reasoning.

ACTIVITY: Explanation game

ATL

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

Darwin's finches – what do you notice? Explain …

Darwin famously studied the Galápagos finches. Look carefully at Figure 7.13.

First **identify** something interesting about the finches shown in the figure. Write a sentence beginning 'I notice that ...'.

Following that observation, begin a sentence that starts : 'Why is it that way?' or 'Why did it happen that way?' What conclusions do you reach from studying the feature you have identified (put yourself inside Darwin's head …)?

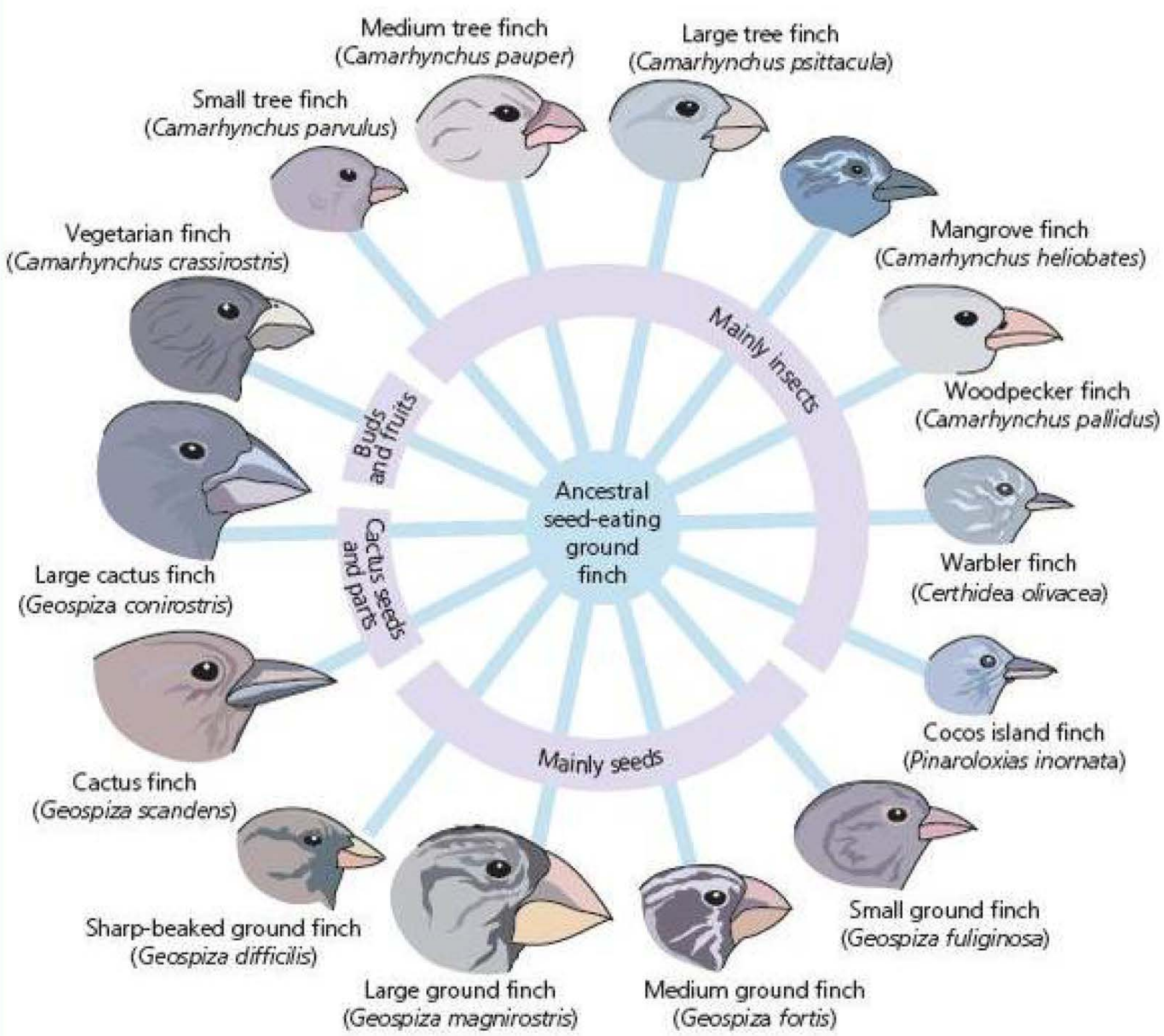


Figure 7.13 Speciation in Galápagos finches; this process is known as adaptive radiation

Information

The Galápagos Islands were created by rising magma from breaks in the Earth's crust ('hot spots').

■ **Figure 7.14** The Galápagos Islands lie 1000 km west of the mainland of Ecuador

- **Volcanic islands were formed as a plate moved over the hot spots.**
- **An ancestral finch colonized the islands from mainland South America.**
- **Different populations of the finch became isolated on different islands.**
- **They adapted to the different conditions found on each island (see Figure 7.13).**
- **Galápagos finches have undergone speciation to fill many of the niches on these volcanic islands and they now are very different from the original mainland South American finch.**

Can you find other examples of island species which have evolved to be different from their mainland counterparts, for example Hawaiian honeycreepers?

Why do you think that Darwin's theory of evolution by natural selection was only gradually accepted? What other theories have there been for evolution? Research Lamarck.

New evidence from DNA research and the emergence of resistant organisms helps to support Darwin's theory of evolution through natural selection (see page 193).

The evolution of beaks can be explored further using the activity on this site:

www.stem.neu.edu/programs/re-seed/activities-and-labs/natural-selection-bird-beak/

EXTENSION

Consider natural selection of *Geospiza fortis*, a ground finch on the Galapágos island of Daphne Major.

Look at the following graph – **describe** and **explain** what you see.

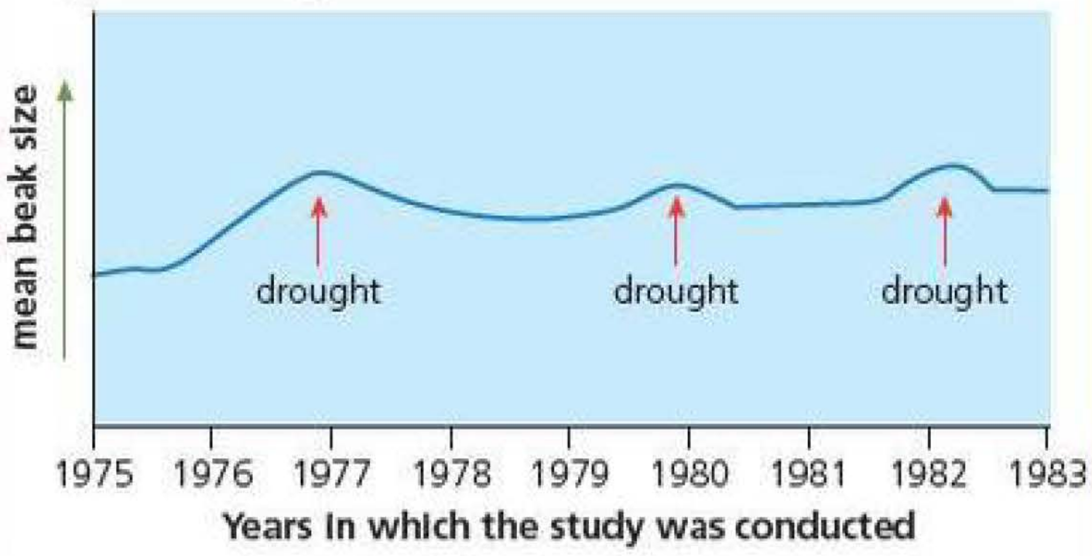


Figure 7.15 Change in mean beak size in *Geospiza fortis* populations on Daphne Major, 1975–1983, provides evidence of natural selection

On Daphne Major, the medium ground finch (*Geospiza fortis*) tends to feed on small tender seeds, which are available in abundance in wet years. During long dry periods (as occurred in 1977, 1980 and 1982), once the limited stocks of smaller seeds had been eaten, the surviving birds were those that could feed on larger, drier seeds which are more difficult to crack open. It was discovered that in periods of drought the average beak size increased (Figure 7.15).

Investigate this further on the following site:

www.explorelearning.com/index.cfm?method=cResource.dspDetail&ResourceID=404:

This is an interactive animation exploring how the thickness of birds' beaks varies according to rainfall on an isolated island.

During his travels around the globe, and in particular during his visit to the Galápagos Islands, Charles Darwin noted that all species showed tremendous variation (that each individual was slightly different from others in the population). He also noticed that populations produced many more individuals than could survive, due to limited resources. He noted that there was a 'struggle for existence'. On returning to the UK, and after carrying out more extensive research, Darwin developed his 'theory of evolution by natural selection':

- Individuals within a population show variation.
- Populations produce more offspring than needed to replace them – large number of offspring leads to overpopulation.
- The population size remains constant, however.
- Resources such as food are limited.
- There is competition between individuals for food, mates, etc.
- There is a 'struggle for existence' and many individuals die.
- Individuals best adapted to their environment survive.
- These successful organisms are more likely to breed and pass on their genes to next generation.
- This continues over many generations.

If the environmental conditions change then evolution occurs, the animals and plants change and may, over millions of years, form new species.

When the environment changes, new opportunities for species are generated. The **niche** of a species is everything about where and how it lives – what it eats, how it reproduces, its habitat, and so on. Each species has a unique niche, and so as a population moves into new environments the niche can change. As the niche changes, so does the species.

Darwin had observed that humans can select for different breeds of animals (e.g. pigeons – see page 174), and that if this 'artificial selection' could lead to new varieties then there was no reason why, given sufficient amounts of time, that nature could not select for new species (hence '*natural* selection'). This theory revolutionized the way that scientists viewed nature, and formed the bedrock on which the study of Biology is built.

■ **Figure 7.16** Illustration of Charles Darwin observing Galápagos tortoise (*Geochelone nigra*), with HMS *Beagle* in the background

SUMMARY REFLECTION

- **What have you learnt about how species evolve?**
- **What have you learnt about how new theories in science develop?**

REVIEW

- **Outline Darwin's theory of evolution by natural selection.**
- **How did Darwin come to his conclusions?**
- **What is the difference between 'artificial selection' and 'natural selection'?**
- **Give three different examples of evidence for natural selection.**

How have changes in habitats led to the development of new species?

species A group of organisms that can mate and produce young that are themselves able to breed and have their own young.

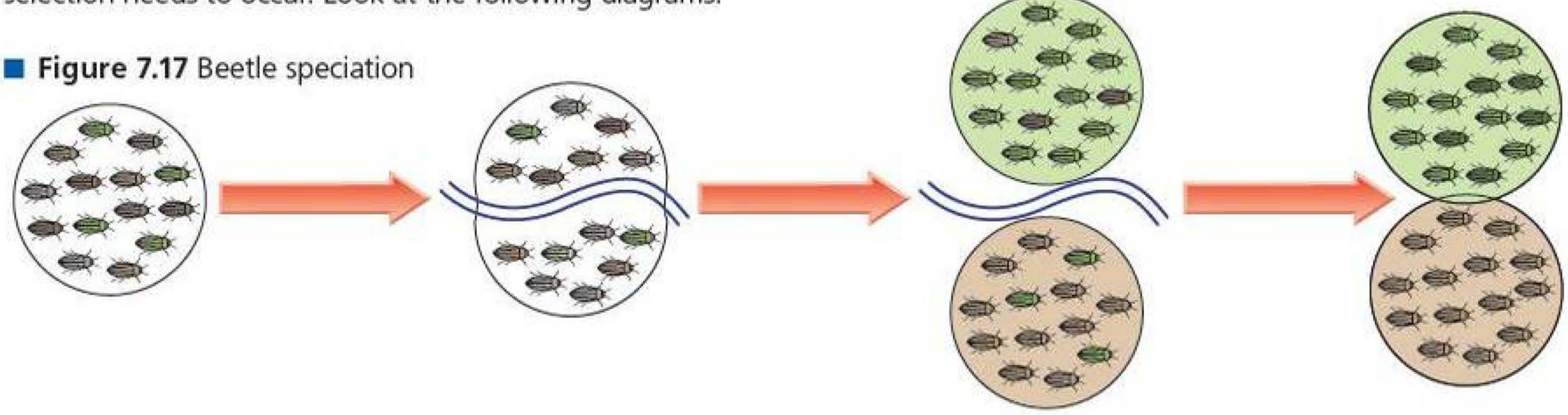
speciation The process by which new species form; natural selection works with isolating mechanisms to produce new species.

gene pool All the different types of gene (i.e. all the alleles – Chapter 6) in a species.

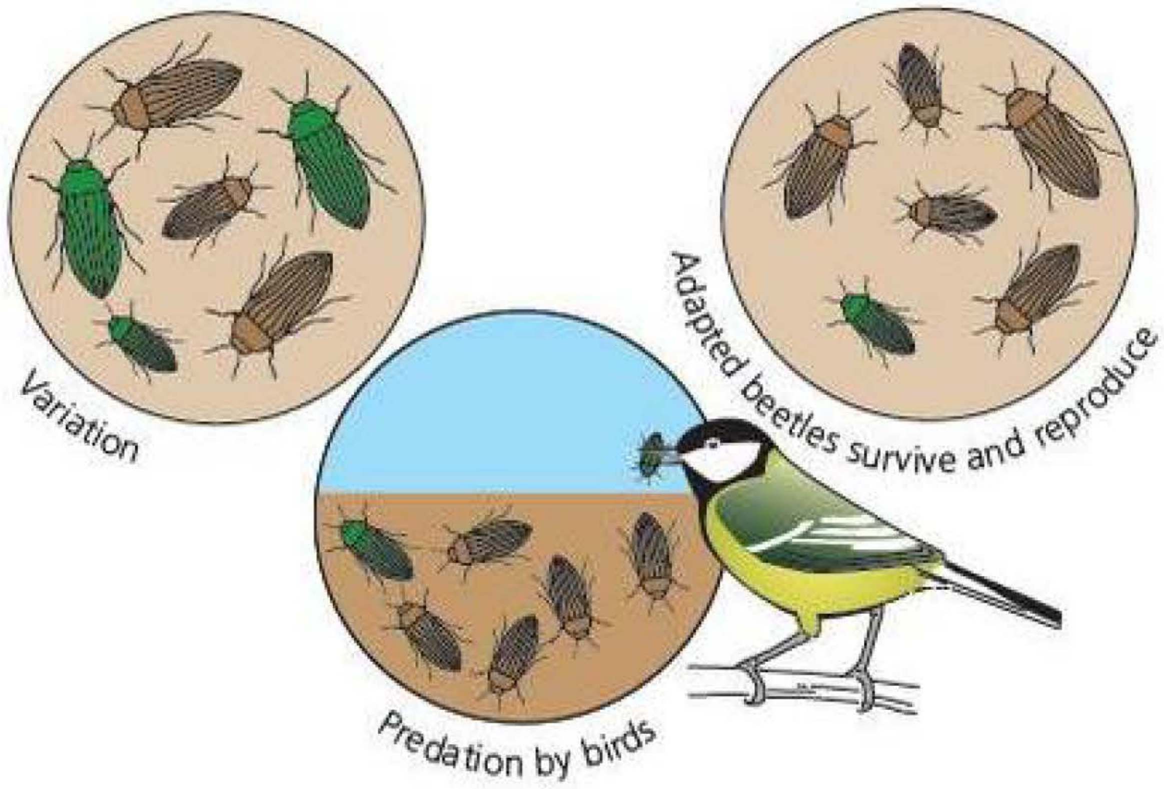
WHAT IS SPECIATION?

For a new species to form, something else as well as natural selection needs to occur. Look at the following diagrams:

■ **Figure 7.17** Beetle speciation



■ **Figure 7.18** Predation pressures on beetles



Something has happened to separate the initial population of beetles into two isolated populations – in this case a river has formed over thousands of years, but the **isolation** could equally be due to a mountain range being created through movement of the Earth's plates, or some other barrier. The environments on either side of the barrier are different, and so there are different selection pressures (individuals to the north of the river are given an advantage by having a green colouration, matching their habitat which is covered by lush vegetation; individuals to the south of the river are given an advantage by having a brown colour as their habitat is arid with more exposed earth – Figure 7.17).

Without the barrier, the two populations would continue to mix and exchange genes – this would maintain the variety present in the initial population but not allow new species to evolve. The barrier, by separating populations, isolates the **gene pools** of two populations so they can no longer interbreed and exchange genes (they become **reproductively isolated**) – this means that over time, through the process of natural selection, adaptive genes are selected and others lost and so the two gene pools change and evolve. Eventually the two gene pools are so different that even if the two populations come back together (if the river dries up, for example) the individuals from each population cannot interbreed – the two populations have become different species.

Isolation, combined with natural selection, leads to speciation. Space, as well as time, is therefore important in the evolution of new species.

■ **Figure 7.19** Mountains can isolate populations and lead to speciation, as well as rivers, seas and other barriers

REVIEW

- **What is needed, in addition to natural selection, for new species to form?**
- **What different barriers can form that lead to populations becoming isolated? Think of at least three.**
- **What is meant by 'reproductive isolation'?**
- **How can species evolve within the same geographical area?**

SUMMARY REFLECTION

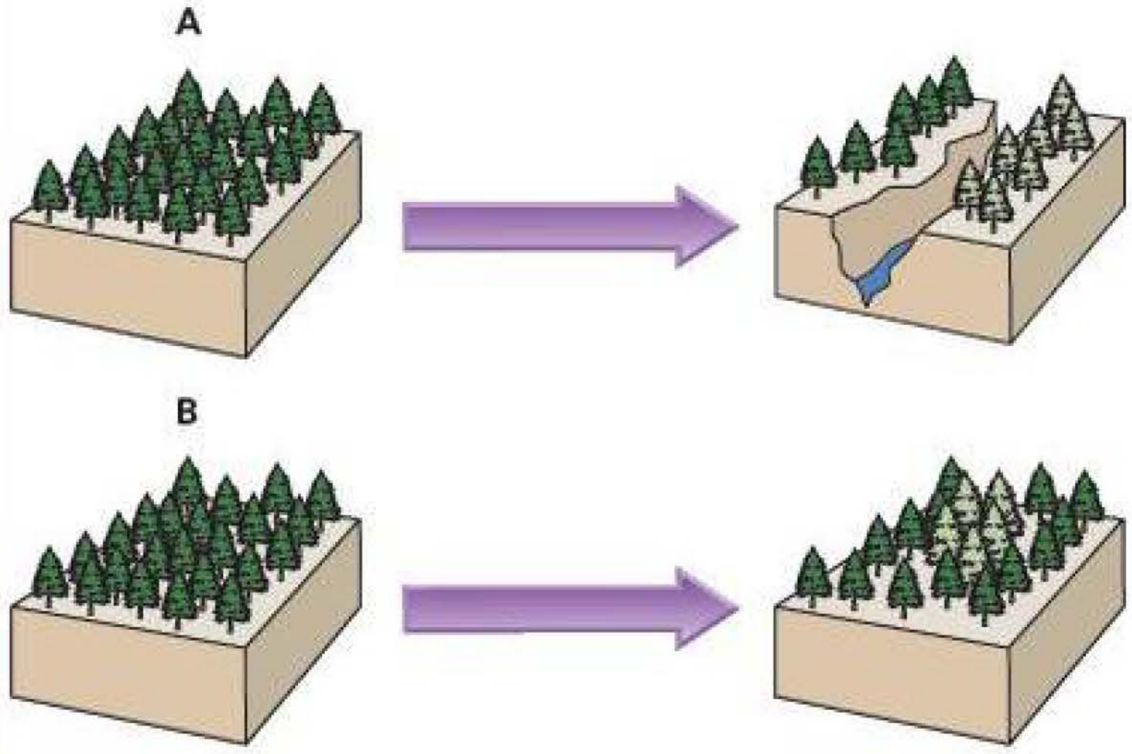
- **What have you learnt about the evolution of new species that you did not know before?**
- **What have you learnt about how changes in habitats lead to the development of new species?**

ACTIVITY: Different means of speciation

ATL

- Creative-thinking skills: Apply existing knowledge to generate new ideas
- Information literacy skills: Access information to be informed

Look at the following diagrams:



■ **Figure 7.20** Different types of speciation

- **Describe** and **explain** what has happened in Figure A.
- **Describe** and **explain** what has happened in Figure B (use your knowledge of what leads to new species to inform your answers).

As well as geographical barriers, such as mountain ranges and rivers, populations can also become isolated within the same ecosystem. Think of as many different ways that populations could become isolated within the same geographical area – how many different environmental factors are there in a forest ecosystem, for example, and how could these lead to populations becoming isolated and evolving differently?

Research: allopatric speciation, sympatric speciation, environmental gradient, diurnal/nocturnal.

Assessment opportunities

- In this activity you have practised skills that are assessed using Criterion A: Analyse and evaluate information to make scientifically supported judgements.

What is meiosis? How do changes in the genetic code lead to variation?

HOW HAVE CHANGES WITHIN CELLS LED TO THE DEVELOPMENT OF NEW SPECIES?

ACTIVITY: What happens during meiosis?

ATL

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

Look at the following diagrams carefully:

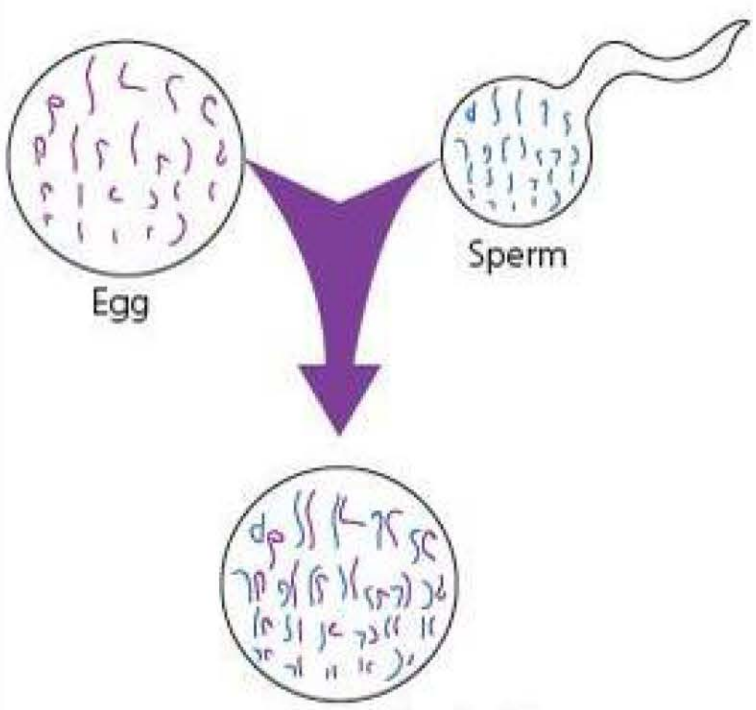


Figure 7.21 Chromosomes in gametes and fertilized cell (zygote)

- **What is the difference between the zygote and gametes (egg and sperm)?**
- **What do you think has happened to the gametes to produce the cells you see?**
- **Why do you think this has happened?**

In this activity we have used our skills of observation and our understanding of biology to work out how meiosis takes place.

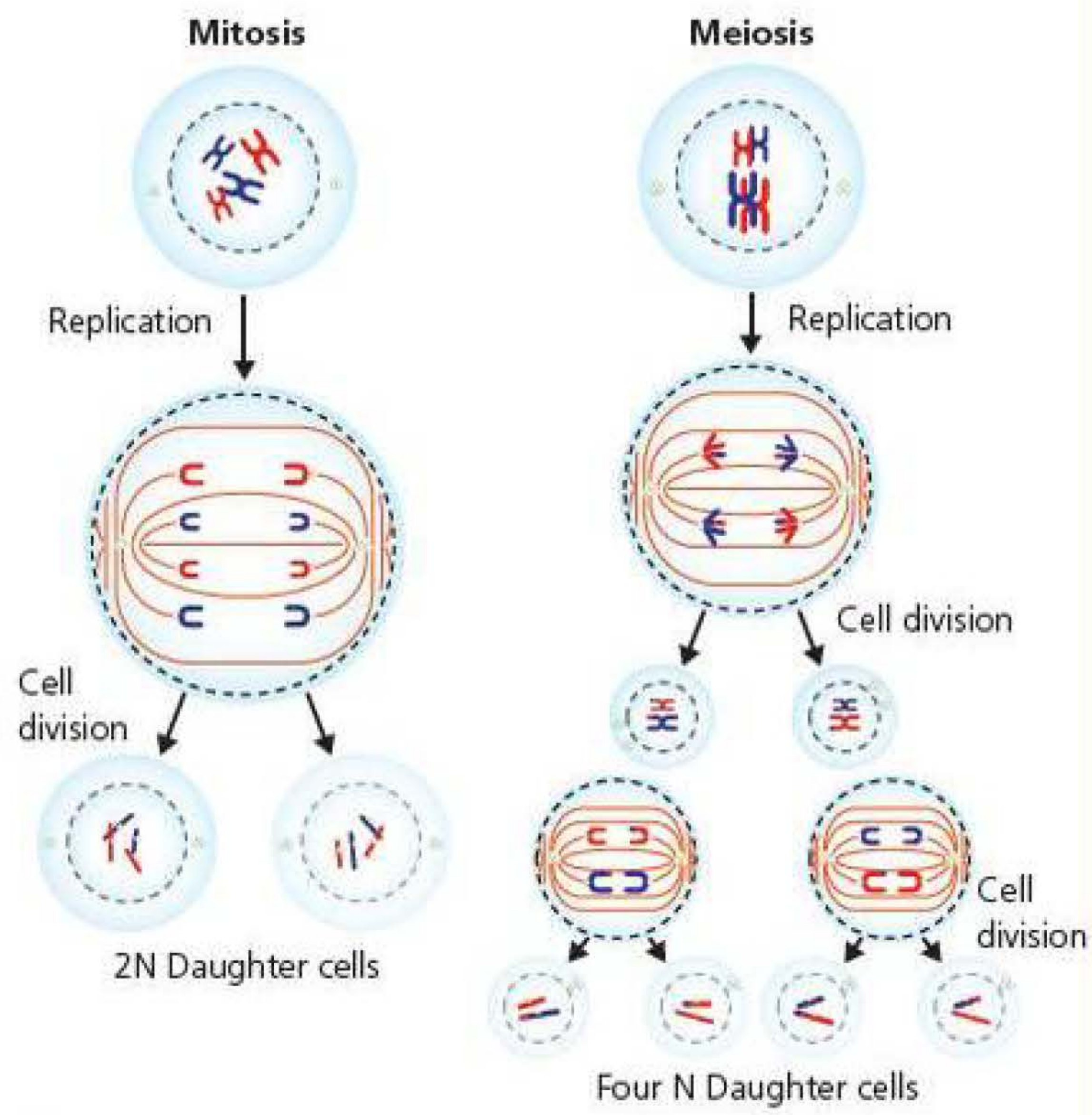
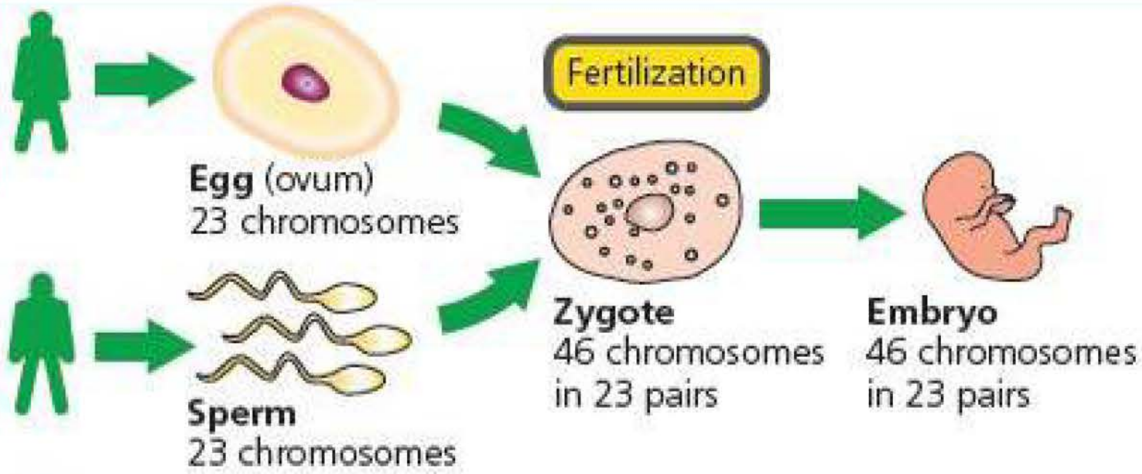


Figure 7.22 Comparing mitosis and meiosis

- **Describe and explain what has happened to the chromosomes during meiosis.**
- **In what ways does mitosis differ from meiosis?**
- **Create a table that compares mitosis with meiosis – what are the similarities and differences?**
- **How does meiosis lead to variation? Look carefully at what is happening to the chromosomes and come to your own conclusions.**

Assessment opportunities

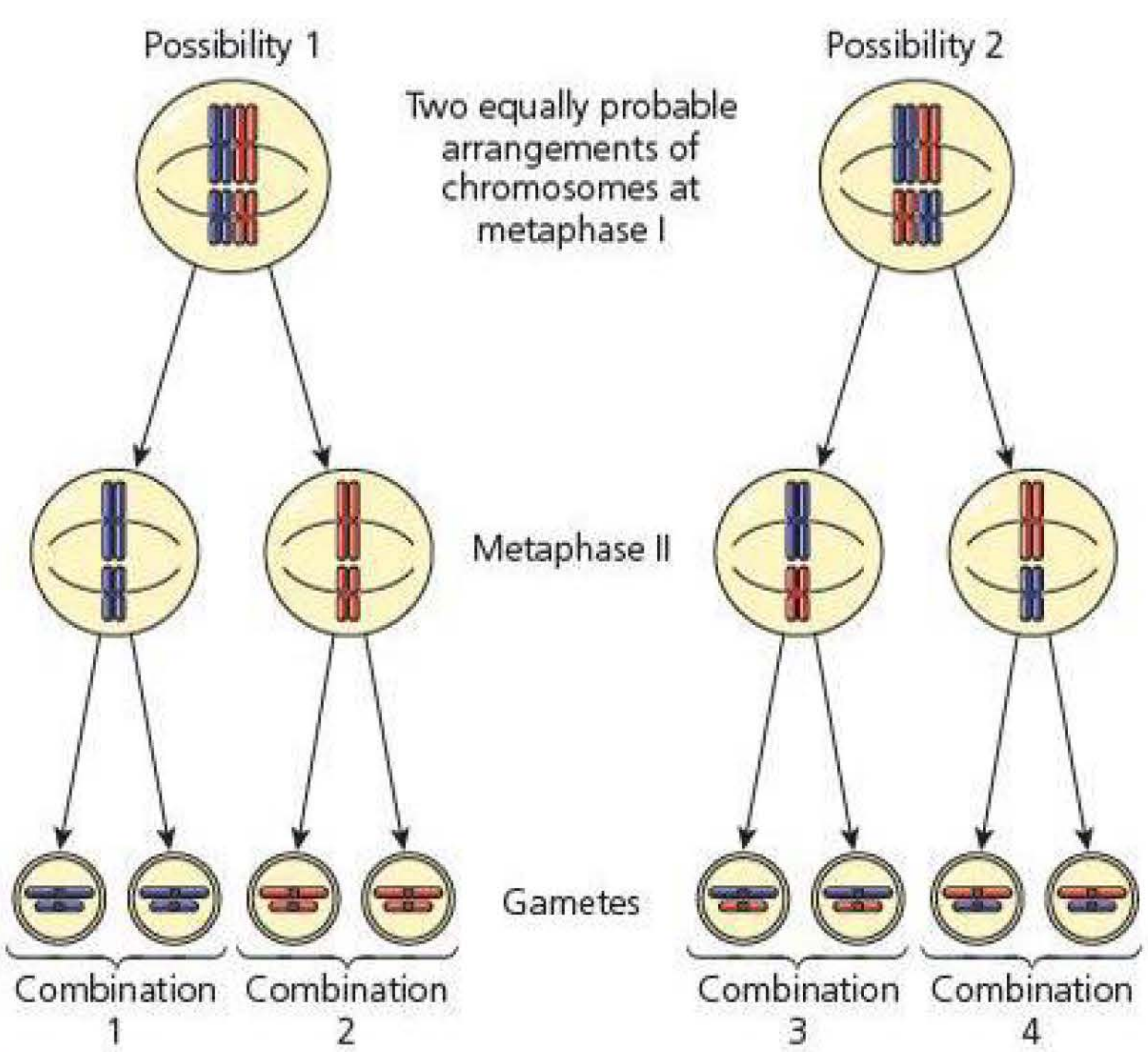
- In this activity you have practised skills that are assessed using Criterion A: Apply scientific knowledge and understanding to solve problems in unfamiliar situations



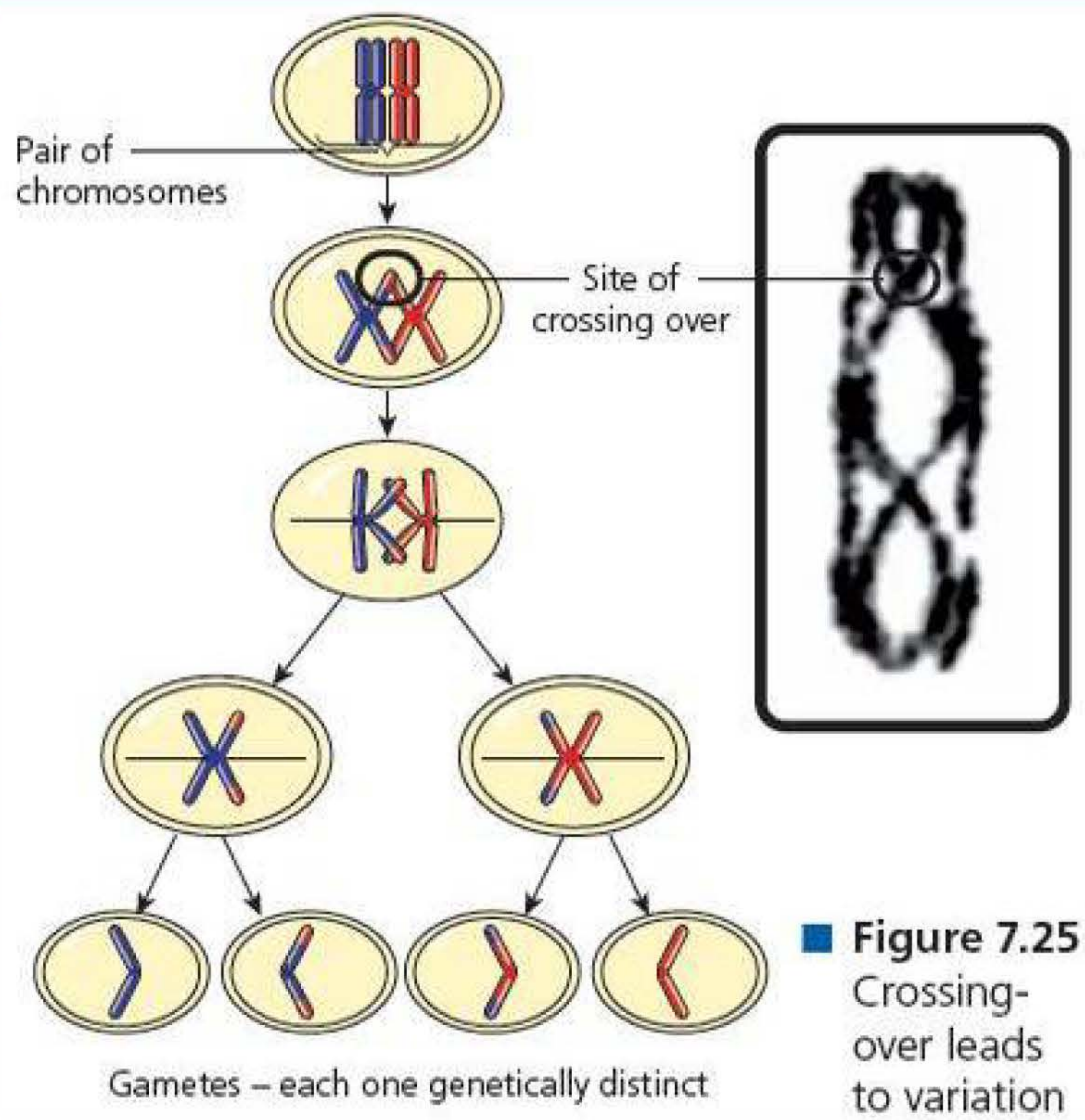
■ **Figure 7.23** Meiosis maintains the number of chromosomes in the cells of offspring so not leading to a doubling of the number that would occur otherwise. Body cells have two of each chromosome (one from each parent) – these cells are known as **diploid**. Gametes have one of each chromosome (are **haploid**)

Meiosis is cell division used in **sexual reproduction** (Chapter 6). It produces **gametes** that fuse at **fertilization** to form a **zygote**. It leads to variation. As we saw in Chapter 6, the number of **chromosomes** needs to halve in gametes so that the original chromosome number is maintained in body cells.

In the last activity you carried out a 'thought experiment' – you used your powers of observation, and knowledge of DNA, to work out how meiosis happens. You also compared meiosis with mitosis – in what ways are they similar, and in what ways are they different? You may have brainstormed ideas with your neighbour, or in small groups to come to a conclusion.



■ **Figure 7.24** Random assortment of maternal and paternal chromosomes leads to variation



■ **Figure 7.25** Crossing-over leads to variation

Meiosis enables the number of chromosomes to be maintained from one generation to the next. It does this by halving the number of chromosomes in gametes (so that they have one set of chromosomes rather than two).

Meiosis also leads to variation of offspring through **random assortment** of parental chromosomes (Figure 7.24).

Another source of variation is **crossing-over**, whereby genetic material (**alleles**) from one chromosome is exchanged for those of its pair (Figure 7.25).

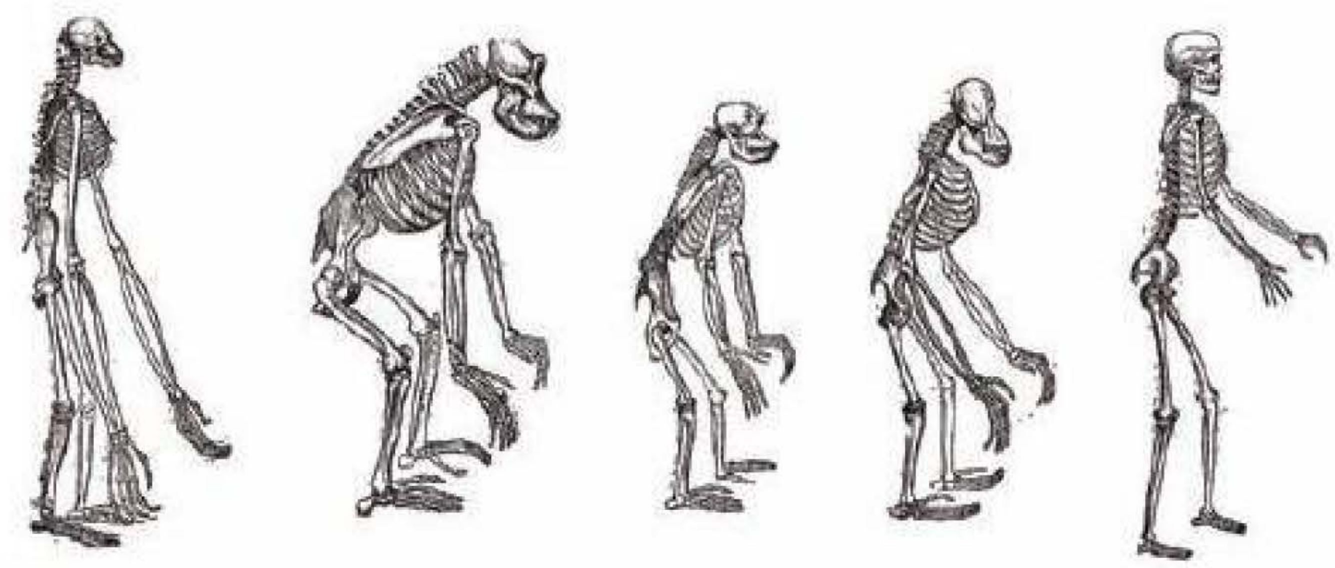
In summary, meiosis leads to:

- The maintenance of chromosome number in body cells from one generation to the next by halving the number of chromosomes: i.e. cells go from diploid to haploid.
- Variation through:
  - random assortment of chromosomes
  - crossing-over
  - the fact that any sperm can fertilize any egg cell (this is important as all gametes are genetically different to each other – which gametes fuse together at fertilization determines the genetic makeup of the offspring and therefore its identity).

SUMMARY REFLECTION

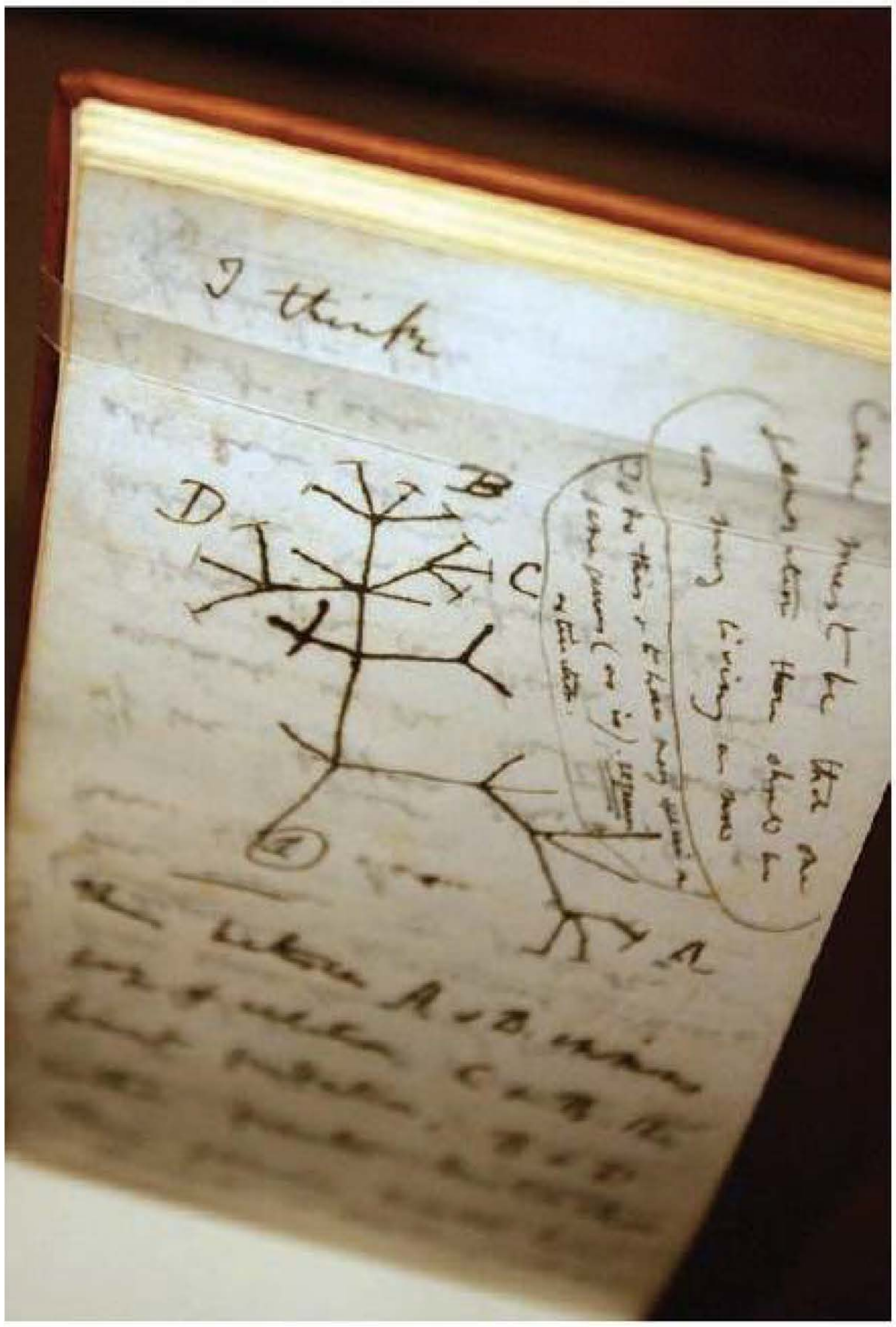
- **What have you learnt about how changes within cells lead to the development of new species?**
- **What occurs during meiosis – can you describe and explain the events?**

How can scientists work out how closely related species are?



■ **Figure 7.27** Comparison of great ape skeletons

Darwin drew the following sketch in one of his notebooks that he used to record his thoughts and ideas (a reflection diary):

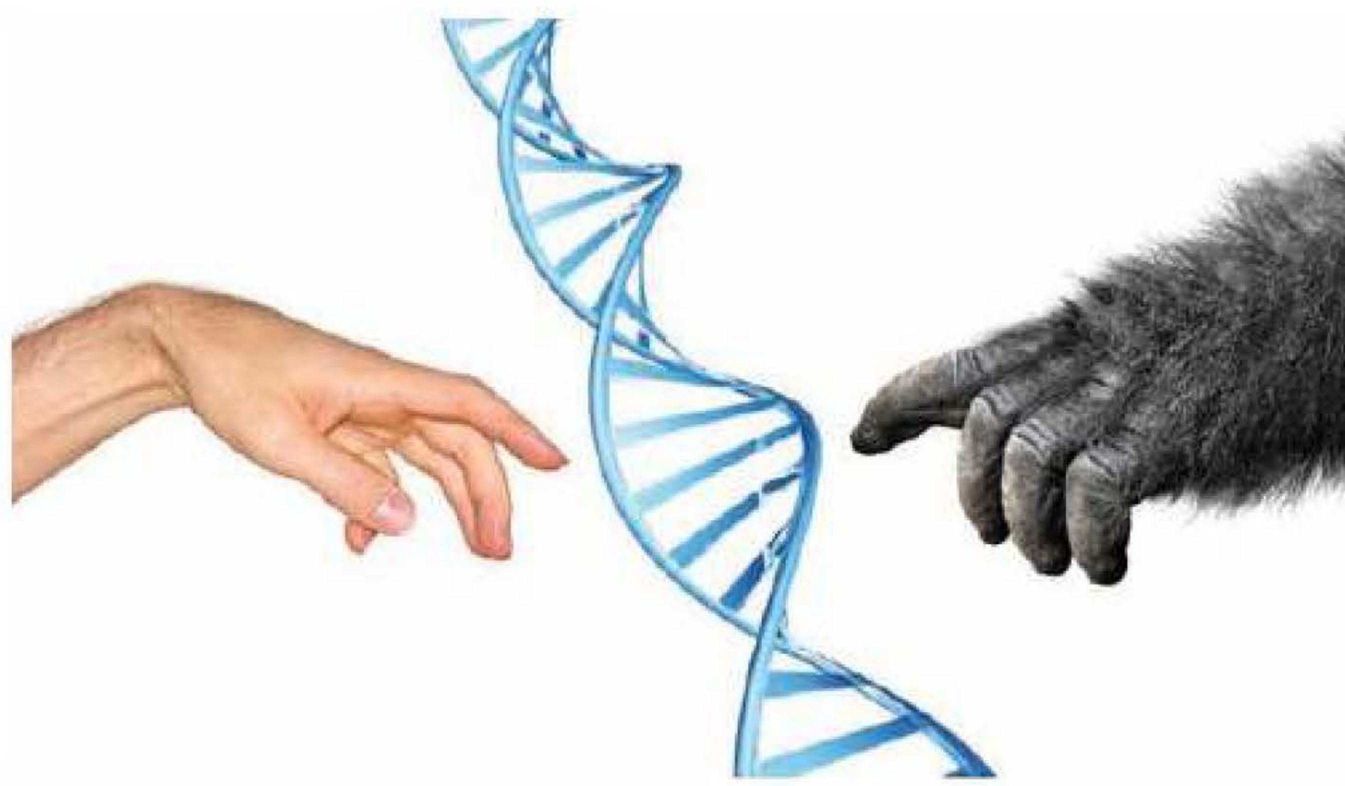


■ **Figure 7.26** Charles Darwin's vision of 'descent with modification' from his 'B' notebook

The diagram shows a tree-like structure. What do you think Darwin was trying to represent here?

We have seen earlier in this chapter how fossil remains and other evidence (such as anatomical similarities) provide evidence about how species are related. The skeletons of the apes (Figure 7.27), for example, show that the gibbon (left of figure), gorilla, chimpanzee, orang-utan and human (right of figure) are related and share a **common ancestor** (an ancestor species they all share), and suggest how evolution has adapted them to different environments and lifestyles.

The best evidence for evolution, however, lies in the molecule of life that all species share – DNA (Chapter 6).

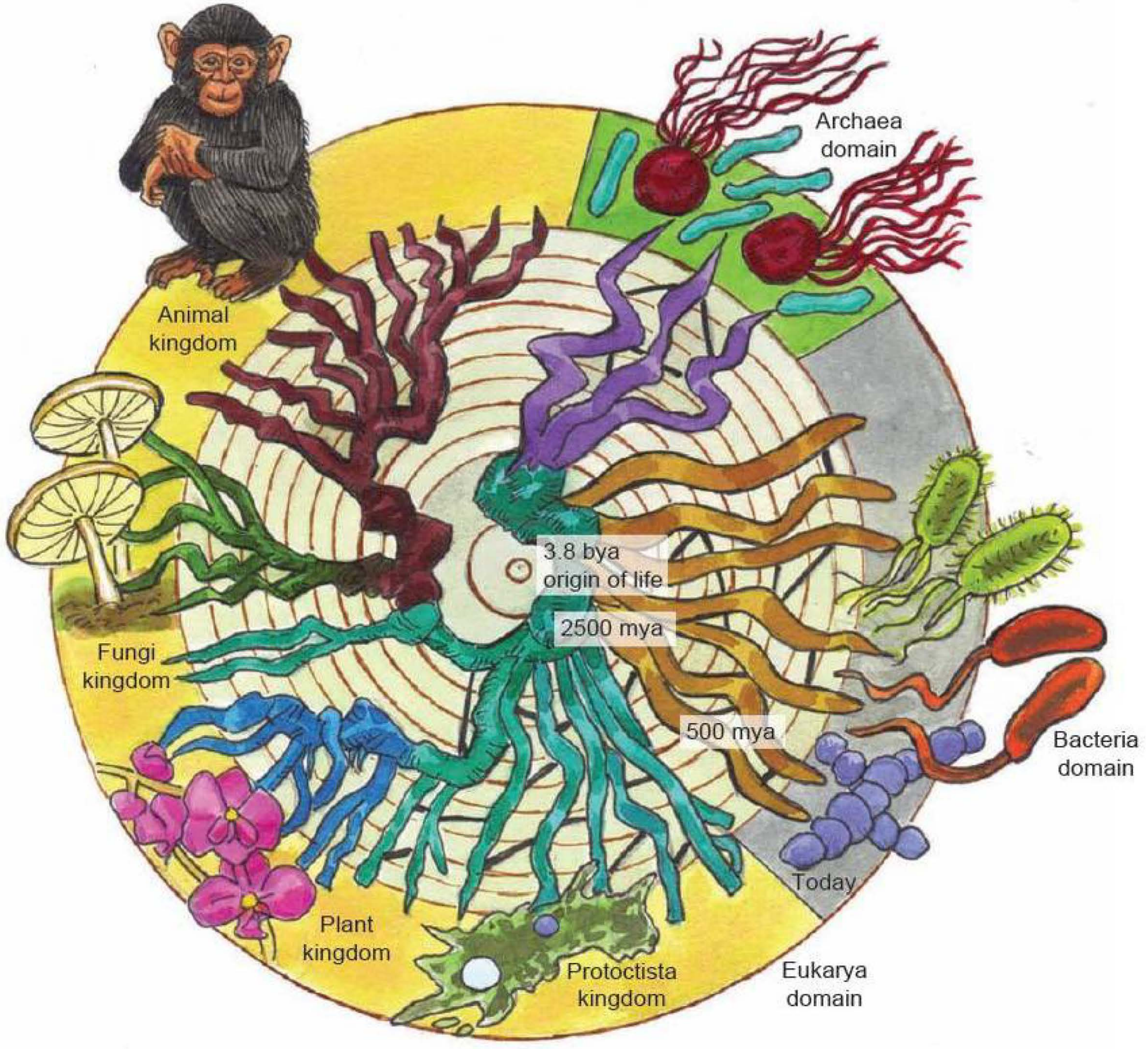


■ **Figure 7.28** DNA links all life by a common thread

DNA can be used to work out similarities and differences between species – species with very similar genes will be closely related, whereas those with very different DNA will be only distantly related (don't forget, all life on Earth is ultimately related to each other as we share a common ancestor 3.8 billion years ago).

■ **Figure 7.29** Scientist examining DNA sequences. Each group of four strips represents the nucleotide sequence of AGCT (adenine–guanine–cytosine–thymine; see Chapter 6). Scientists can now use computers to compare DNA sequences from different organisms to study how similar they are

From this information, evolutionary trees can be created (Figure 7.30) that show the interrelation of all life, and when different groups evolved.



■ **Figure 7.30** The tree of life – showing the five kingdoms and how DNA evidence indicates that all share a common ancestor ca. 3.8 billion years ago (bya). DNA evidence also indicates when different groups evolved

ACTIVITY: The tree of life

ATL

- Information literacy skills: Access information to be informed and inform others
- Media literacy skills: Seek a range of perspectives from varied sources

In this activity you will seek a range of perspectives from varied sources (such as Internet, books, magazines, video).

Use the following sites to explore the 'tree of life':

www.wellcometreeoflife.org/ The Wellcome Trust's superb Tree of Life site. David Attenborough explores the evolutionary links between all living things. Includes an interactive tree of life (see below), where relationships between all branches of the tree can be explored.

www.wellcometreeoflife.org/interactive/ Interactive tree of life, from the Wellcome Trust.

www.onezoom.org/ Another visual presentation of the interrelation between all species, created by a group at Imperial College, London.

You can find your own sources of information on **tree of life**, **evolutionary links**, **ancestor species**.

Each source will present the tree of life in a different way. Which source have you found the most useful in representing the relationship between species?

- Choose one group to explore in detail. What can you learn about how this group is related to the rest of life on Earth?
- **Present** your research as a poster to inform others about what you have found.

Assessment opportunities

- In this activity you have practised skills that are assessed using Criterion A: Analyse and evaluate information to make scientifically suppoted judgements.

In this activity we have used the latest visualization software to appreciate the variety of life on Earth and see how connections are made on the tree of life.

Because DNA mutates and changes through time, the rate of this change can be used to estimate when different species or groups evolved on Earth. DNA evidence can be used to create detailed diagrams that show the interrelation of groups (Figure 7.31).

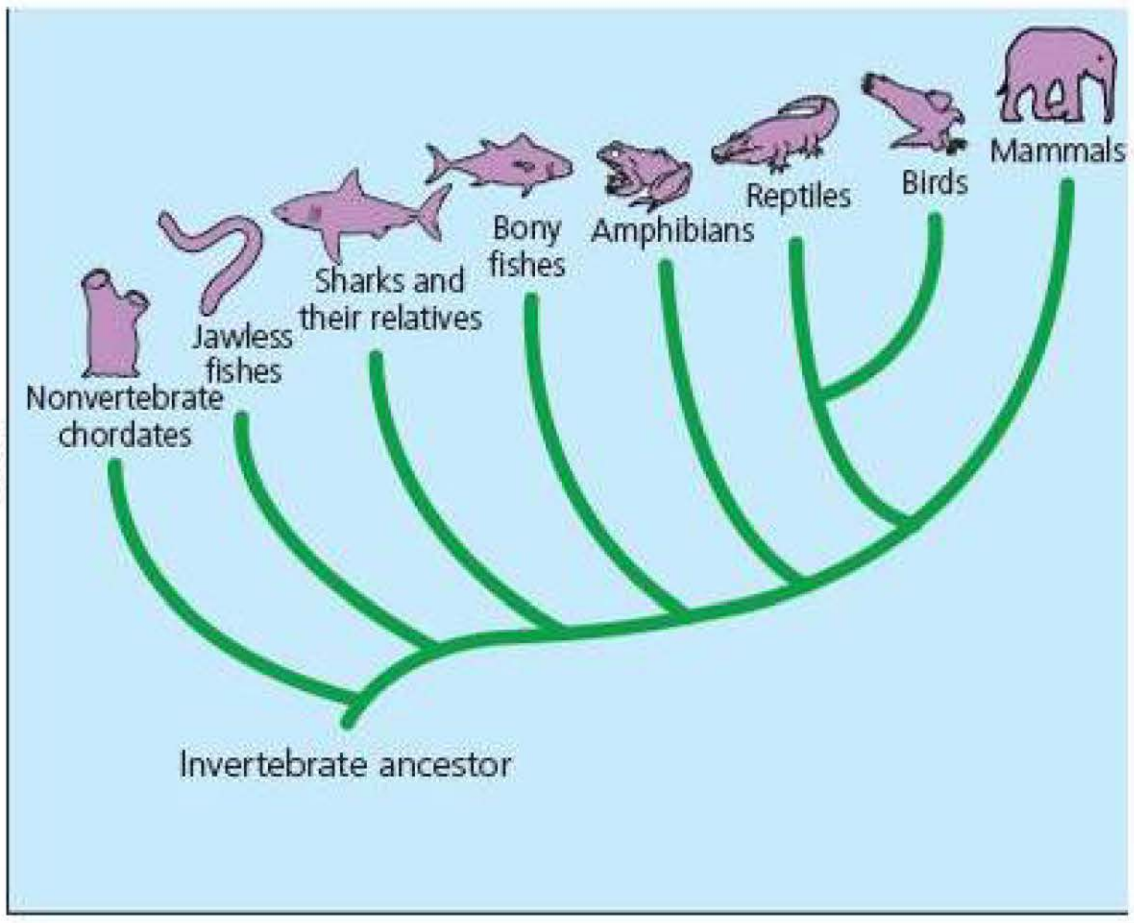


Figure 7.31 The relationship between vertebrate groups through time

SUMMARY REFLECTION

- What have you learnt about how species are interrelated?
- What new ideas have you found out about the way in which scientists work out whether species are closely related or not?

DISCUSS

- Why can DNA be used to work out how closely related species are?
- **Discuss** in a group why DNA represents the best tool for classifying species and working out the relationship between organisms. Why is it better than the other methods you have looked at (e.g. fossils and anatomical similarities)?

What effects do genetic mutations have on the survival of species?

HOW HAVE HUMANS DRIVEN THE EVOLUTION OF OTHER SPECIES?

Bacteria and evolution

- **Mutations** occur frequently in **bacteria**.
- Bacteria reproduce very quickly.
- Bacteria can cause illness.
- Bacteria are killed by **antibiotics**.
- Some bacteria mutate and become **resistant** to the antibiotics.
- These bacteria survive, reproduce and pass on the resistance.
- Today we have some resistant bacteria which cannot be treated by antibiotics.
- People die from the infection unless their own immune system saves them.

ACTIVITY: Superbugs

ATL

- Critical-thinking skills: Draw reasonable conclusions

Describe and **explain** *in your own words* what you can see in this diagram:

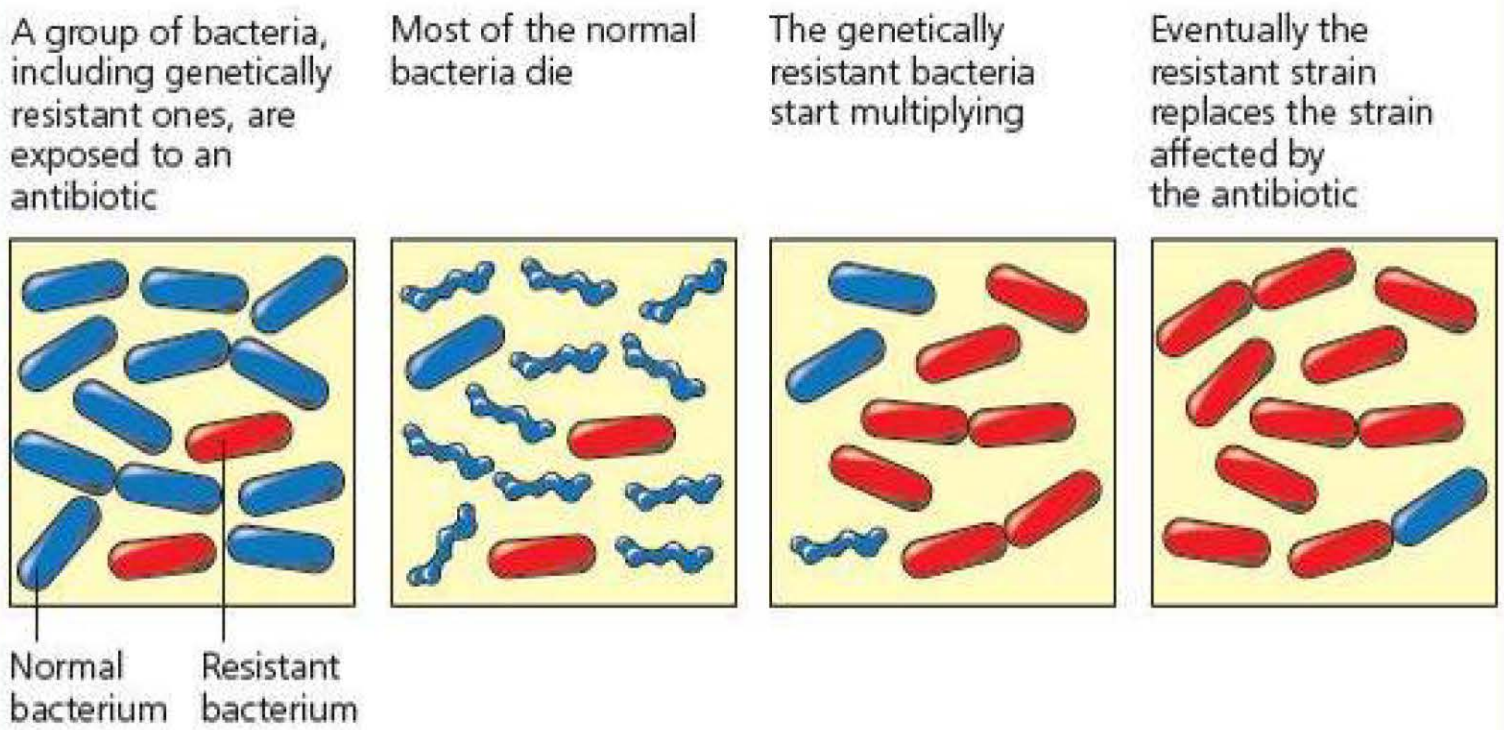


Figure 7.32 The evolution of antibiotic resistance in bacteria

- **Explain how this is an example of natural selection.**
- **Now explore the evolution of antibiotic resistance on this site:** **www.sumanasinc.com/scienceinfocus/sif_antibiotics.html – animation showing the evolution of antibiotic resistance in bacteria.**
- **To what extent is the use of antibiotics in farming benefiting or harming human health? Read the following and come to your own conclusions:**

www.nature.com/news/rules-tighten-on-use-of-antibiotics-on-farms-1.9761

www.fda.gov/forconsumers/consumerupdates/ucm378100.htm

www.ciwf.org.uk/our-campaigns/antibiotics-health-crisis/

Assessment opportunities

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

In this activity we have used our knowledge of natural selection to explain how superbugs evolve, why they are a threat to health systems, and how this problem can be addressed.

The evolution of antibiotic resistance in bacteria can be summarized as follows:

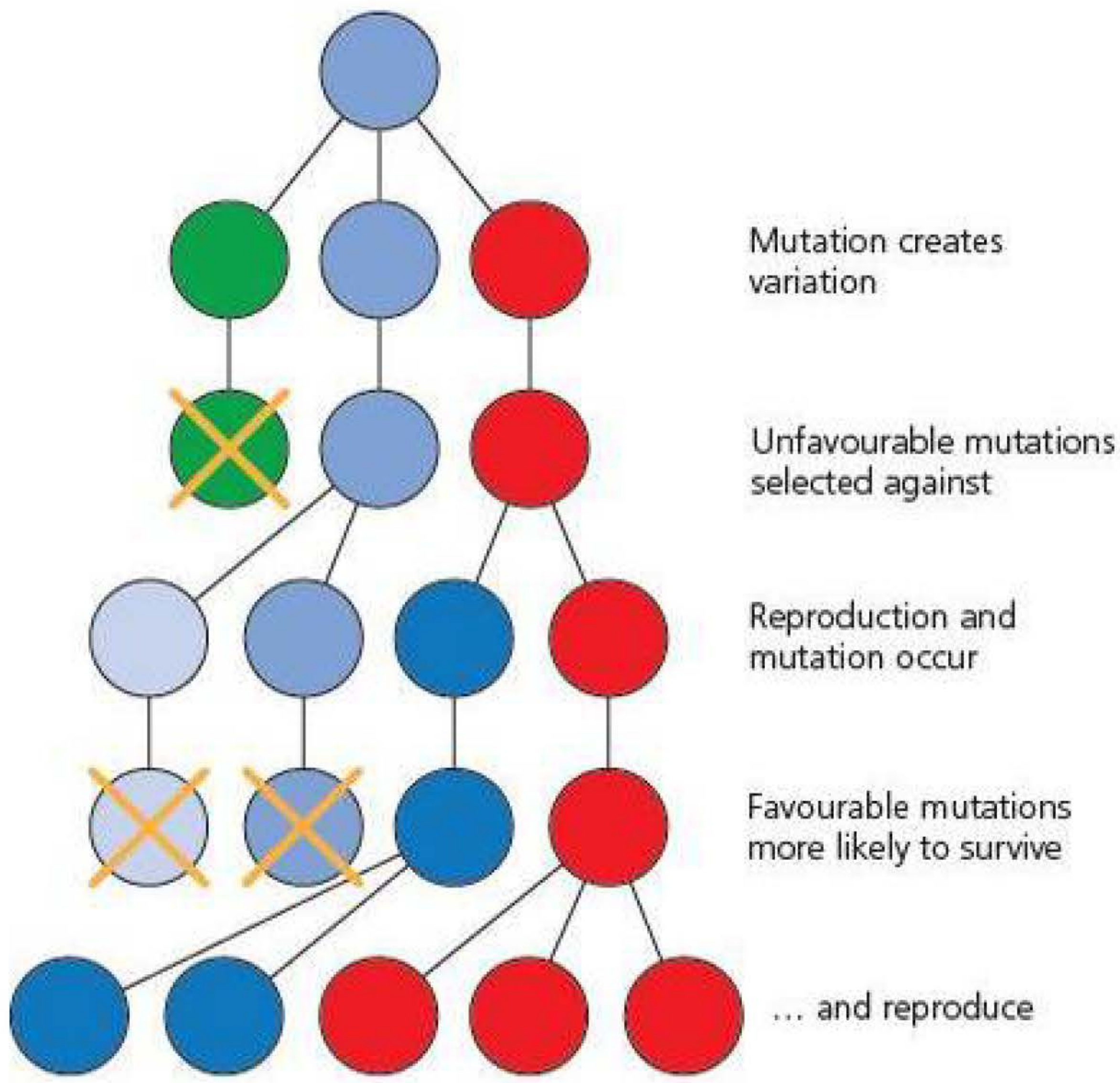


Figure 7.33 Mutations lead to natural selection

Mutations, as well as sexual reproduction (through meiosis), therefore lead to variation and evolution by natural selection.

SUMMARY REFLECTION

- **What have you learnt about how humans and their lifestyles (i.e. excessive use of antibiotics to treat bacterial infections) have driven the evolution of other species?**
- **What have you learnt about how the use of antibiotics in farming is benefitting or harming human health?**

EXTENSION: Species loss caused by human activities

As well as the evolution of new species, the advent of humans on Earth has led to the irreversible loss of species (extinction).

What examples of human-forced extinction have occurred (or indeed are in the process of happening)? How do we know that these extinctions were caused by humans rather than other causes?

In the past, mass extinctions (where 75 per cent or more of all species on Earth went extinct) have been caused by natural events. How many mass extinctions have occurred in the past, and what were their causes?

What is meant by the '6th mass extinction'? What is its cause?

DISCUSS

Do you think that antibiotics are being overused? What is the problem with using antibiotics excessively? What does your neighbour think, and the rest of your group? The following sites will provide you with information to discuss:

http://antibioticawareness.ca/?page_id=14

www.cdc.gov/features/getsmart/

www.who.int/mediacentre/factsheets/fs194/en/

- **What have you learnt in this chapter about how species change through time and space?**
- **How can the evolution of species be explained by species' interactions and adaptations to their environment?**
- **What is the evidence for evolution?**
- **To what extent have humans and their lifestyles driven the evolution of other species?**
- **What have you learnt about yourself as a reflective learner during this chapter? What have you learnt about how you consider the world and your own ideas and experience? Have your own ideas about the origin of life of Earth 'evolved' during this chapter?**

Take action: Opportunity to apply learning through action …

Figure 7.34 Some 65 million years ago, the impact of an asteroid with the Earth provoked one of prehistory's greatest mass-extinctions, when it wiped out the dinosaurs and many other species

Extinction is forever

- Life on Earth, as we have seen in this chapter, has evolved over million years. Changes humans are making to the planet, however, are putting this life at risk. Between 200 and 2000 species may be going extinct every year. There have been periods in the past when the Earth has lost at least 75 per cent of all species – these mass extinction events were caused by natural disasters (the dinosaurs were wiped out, as you probably know, when a giant asteroid hit the Earth – see Figure 7.34). There have been five mass extinctions in the past, and it is possible that a sixth mass extinction is happening at the moment – not the result of natural events but due to us – but we will not know for sure until it is too late.
- We will further explore how the evolution of one species (humans) has impacted the rest of biodiversity on Earth, and whether these effects are **sustainable** or not, in Chapter 10.
- Many charities and individuals campaign and raise funds to preserve animals (and plants) at risk from extinction.
- In your class, choose an animal you want to protect, and then work out a strategy for how you can best help in this species' survival. You may want to:
  - work with a conservation charity, such as WWF, to help protect the animals
  - have an event within your community to raise money to fund conservation work
  - produce posters or leaflets to raise awareness of the plight faced by your animal
  - write to the governments who are responsible for the protection of the animal to encourage them to take the right actions.
- At the end of your campaign hold an assembly for your school or college to tell the rest of your community about your actions.
- Make sure you:
  - Focus on how science is applied and used to address the species' survival (e.g. captive breeding; behavioural studies of the animal in the wild so that it can be properly be understood and conserved). **Explain** ways in which science is applied.
  - **Discuss** and **evaluate** the implications of using science to conserve your species (e.g. the need for captive breeding in zoos – what ethical issues are there regarding keeping animals in zoos?).
  - Consistently **apply** scientific language to communicate your understanding clearly and precisely.

Explore further …

http://wwf.panda.org/about_our_earth/biodiversity/biodiversity/

www.iucnredlist.org/

www.tusk.org/index/uk

www.unep-wcmc.org/

Assessment opportunities

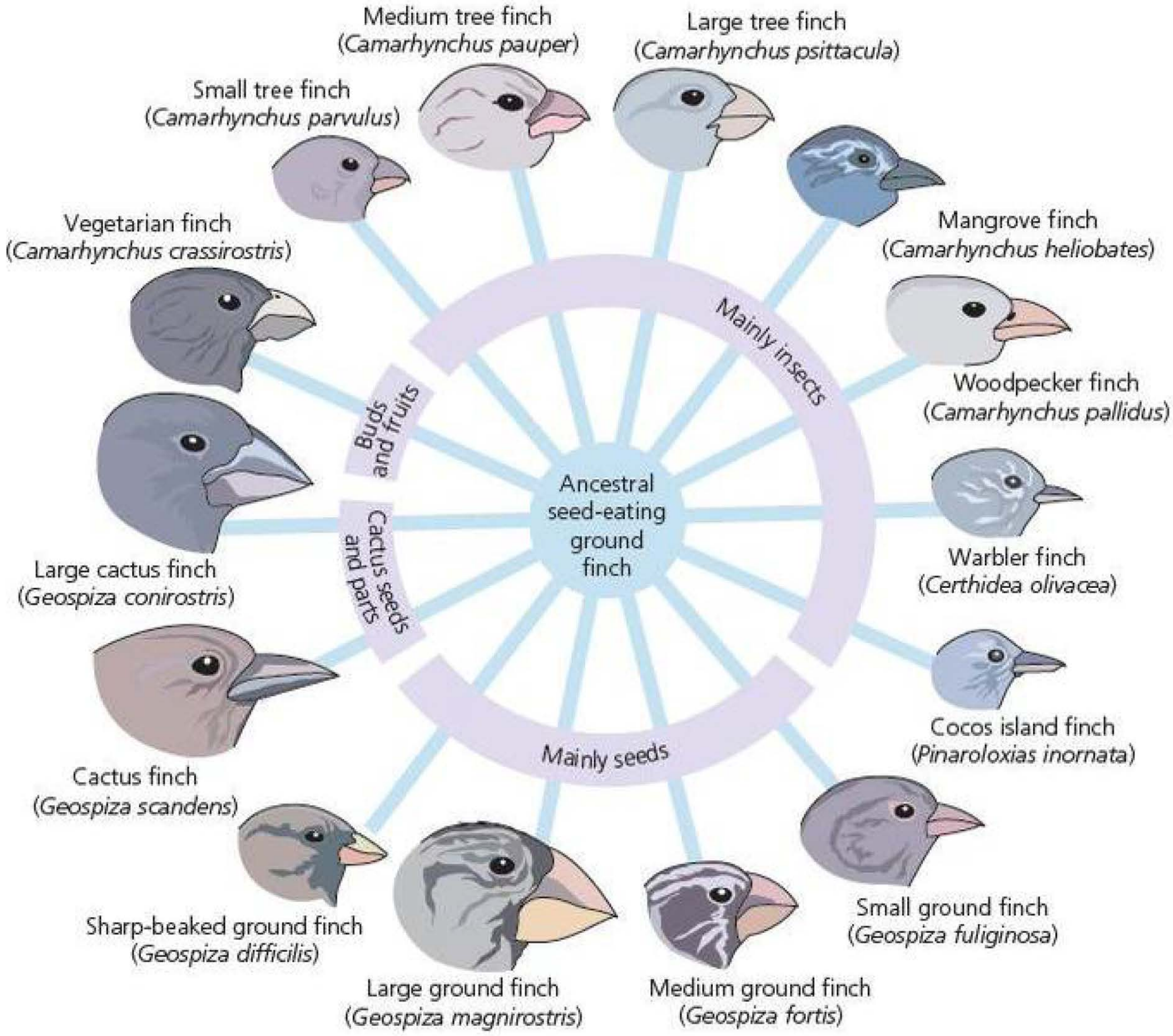
- This activity can be assessed using Criterion D: Reflecting on the impacts of science.

SOME SUMMATIVE PROBLEMS TO TRY

Use these problems to apply and extend your learning in this chapter. These problems are designed so that you can evaluate your learning at different levels of achievement in Criterion A: Knowledge and understanding.

THIS PROBLEM CAN BE USED TO EVALUATE YOUR LEARNING IN CRITERION A TO LEVEL 1–2

1 a **State** what is meant by the term 'evolution'.
  b **State** what is meant by the term 'natural selection'.
  c i **Suggest** how the finches of the Galápagos Islands provide evidence for evolution by natural selection (Figure 7.35).
   ii **State** four other examples of evidence for evolution.

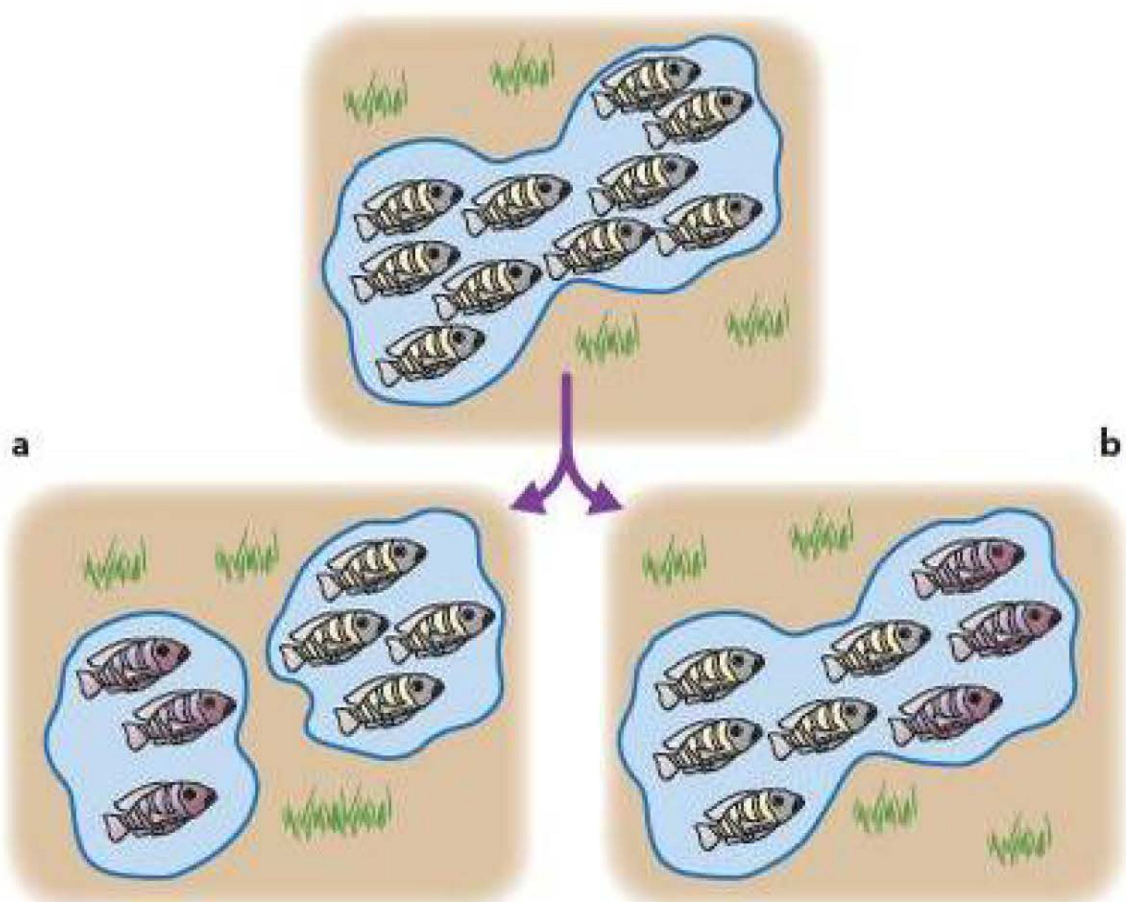


■ **Figure 7.35** Evolution in the Galápagos finches

THIS PROBLEM CAN BE USED TO EVALUATE YOUR LEARNING IN CRITERION A TO LEVEL 3–4

2 Cichlids are freshwater fish found in Africa.

■ **Figure 7.36** A yellow cichlid fish



■ **Figure 7.37** Speciation in fish

a **Outline** what is meant be the term 'speciation'.

b **Outline** the mechanism for speciation shown in Figure 7.37a.

c **Outline** the mechanism for speciation shown in Figure 7.37b.

d Africa contains many different species of cichlid. Lake Malawi alone contains as many as 850 different species of cichlids. **Suggest** why so many different species of cichlid fish are found in Africa.

THESE PROBLEMS CAN BE USED TO EVALUATE YOUR LEARNING IN CRITERION A TO LEVEL 5–6

3 In Hong Kong, a total of 22 936 new patients were infected by one of three major superbugs during 2013. The three superbugs were: Extended-Spectrum Beta-Lactamase (ESBL), Methicillin-Resistant Staphylococcus Aureus (MRSA) and Carbapenem-Resistant Acinetobacter baumannii (CRA).

Potential killers
Top three superbugs in hospitals
Multi-drug resistant organisms (MDRO)

	New patients 2011	New patients 2013	Change
ESBL	11 613	12 510	+8%
MRSA	6 571	7 793	+19%
CRA	1 697	2 633	+55%
Total	**19 881**	**22 936**	**+15%**

■ **Figure 7.38** Changes in superbugs in Hong Kong hospitals between 2011 and 2013

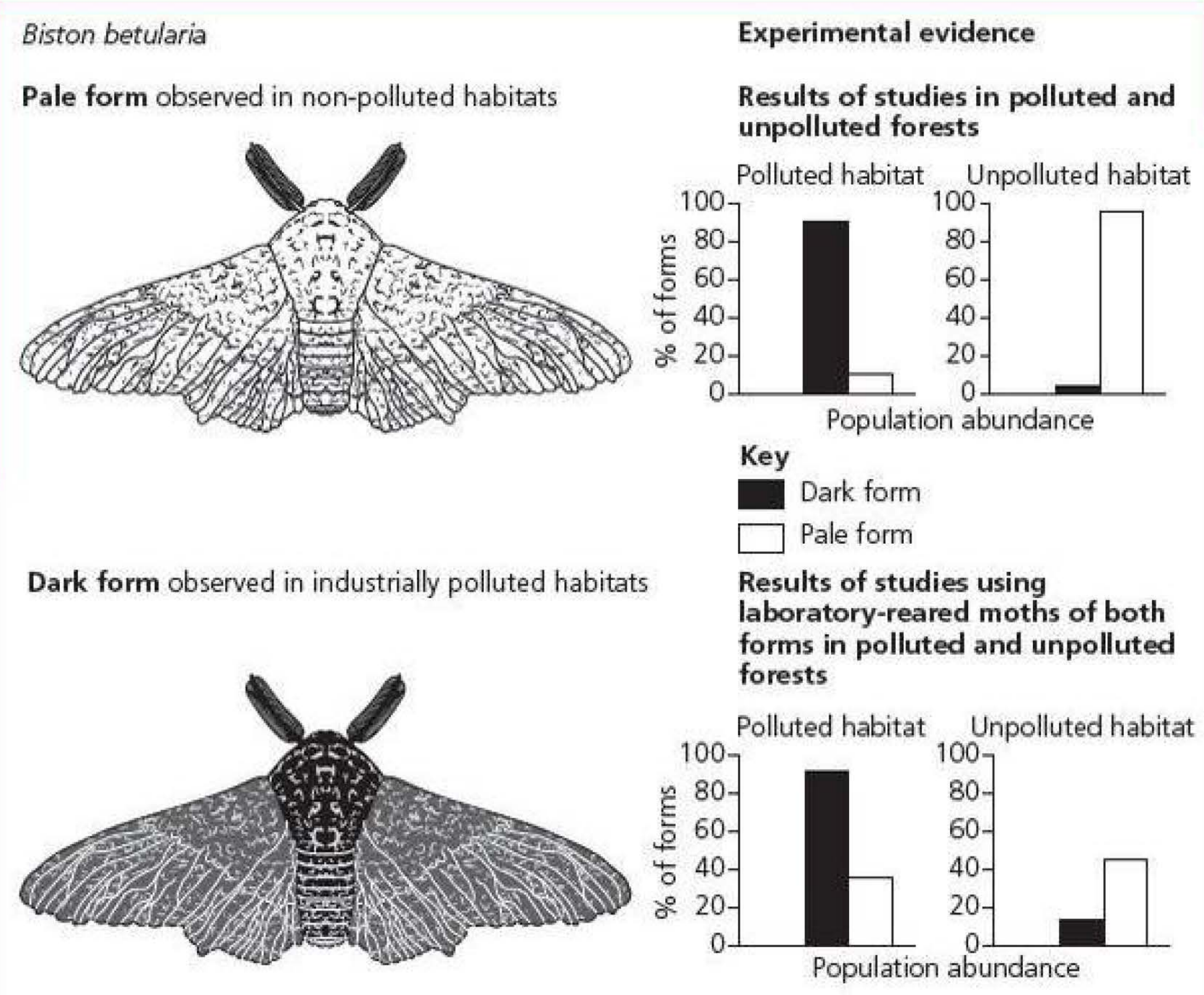
a **Describe** what is meant by the term 'superbug'.

b **Describe** how superbugs have evolved.

c **Analyse** the data in Figure 7.38.

i **Describe** the differences in the number of cases recorded for each superbug in 2011. **Suggest** reasons for the differences recorded.

ii Compare and contrast the change in incidence for each superbug between 2011 and 2013. **Suggest** reasons for the differences recorded.



■ **Figure 7.39** *Biston betularia* and its two forms

5 *Biston betularia* is a moth found throughout the United Kingdom. It occurs in two forms: pale and dark.

a **Suggest** how the dark form could have arisen.

b Compare the results from the polluted and unpolluted forest.

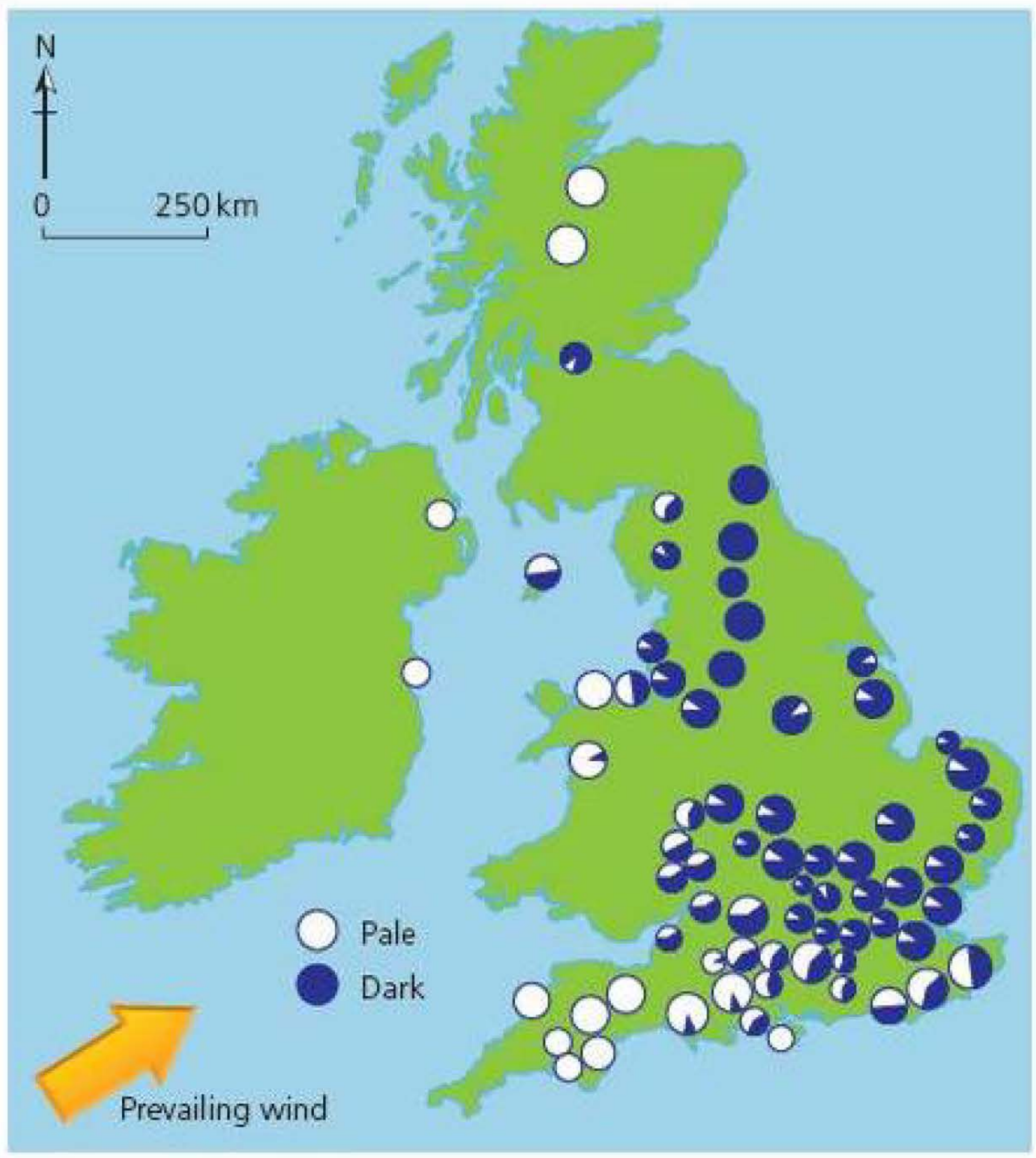
c **Suggest** reasons for the different population abundances of pale and dark forms:

i in polluted forests

ii in unpolluted forests.

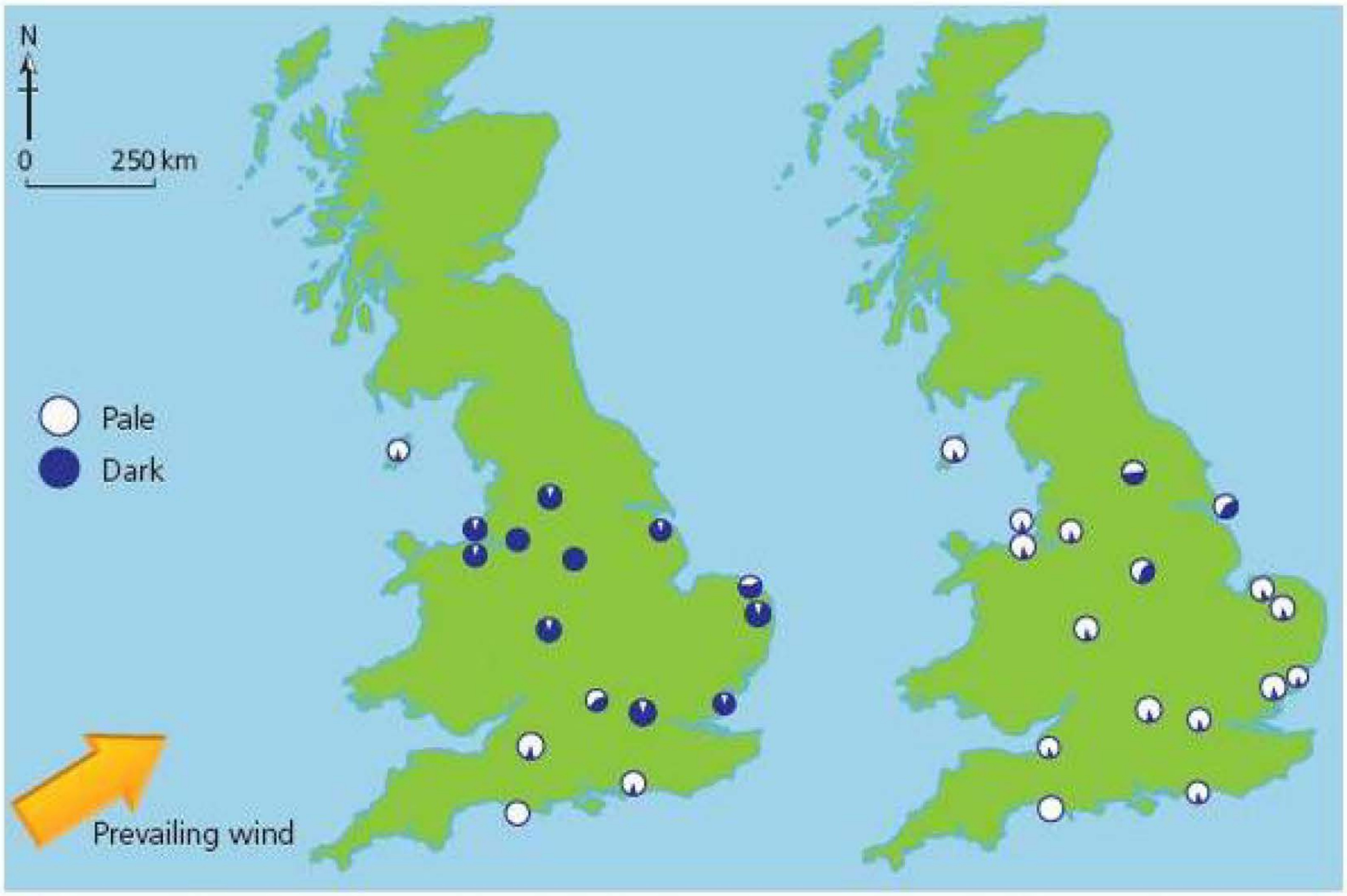
Figure 7.40 shows the distribution of pale and dark forms throughout the UK and Ireland.

d **Suggest** reasons for differences in the distribution in pale and dark forms.



■ **Figure 7.40** The distribution of pale and dark peppered moths, *Biston betulana*, throughout the UK and Ireland

Figure 7.41 shows changes in the abundance of each form of *Biston betularia* between 1956 and 1996.



■ **Figure 7.41** The geographic distribution of dark and pale forms of peppered moths in the UK based on a 1956 survey (left map) and one carried out in 1996 (right map)

e **Suggest** reasons for the changes in the abundance of the dark and pale forms between 1956 and 1996.

THIS PROBLEM CAN BE USED TO EVALUATE YOUR LEARNING IN CRITERION A TO LEVEL 7–8

6 Sickle cell anaemia is a genetic disease that affects red blood cells. People with the disease have sickle-shaped red blood cells that do not carry oxygen and can block capillaries.

■ **Figure 7.42** A sickle cell (left) and a normal red blood cell (right)

Malaria is an infectious disease of humans and other animals caused by a parasitic protoctistan called *Plasmodium*. Mosquitos carry the parasite from one host to another. Female mosquitos require blood to survive and when they feed they inject the malarial parasites into the blood.

■ **Figure 7.43** A female mosquito feeding

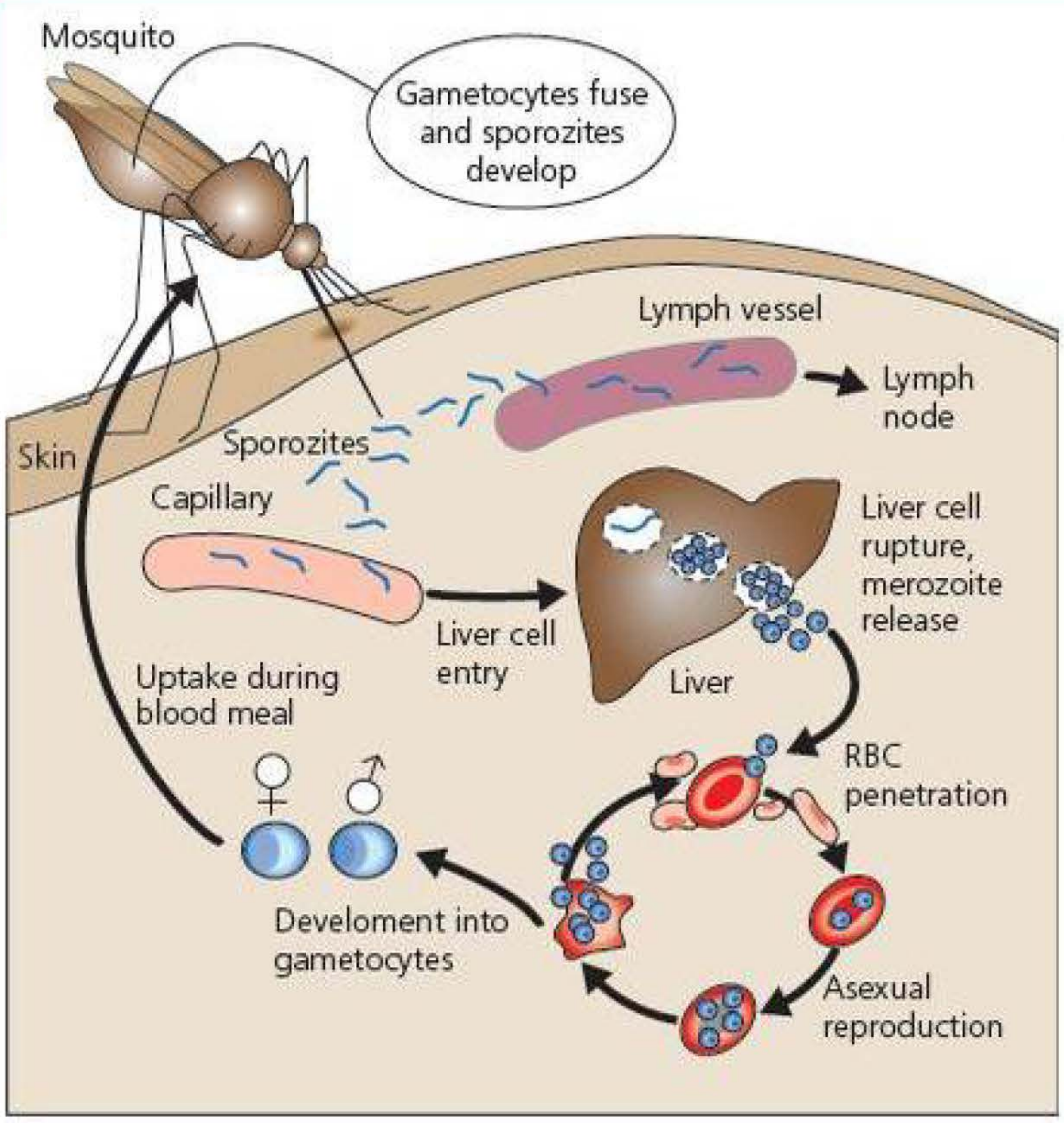


Figure 7.44 The life cycle of the *Plasmodium* parasite

Plasmodium have a complex life cycle with a series of different stages.

The malarial parasite require normal red blood cells to complete its life cycle.

a Sickle cell anaemia is caused by a change in one base of DNA. **Explain** how this causes a change in the hemoglobin protein.

The allele for sickle-cell hemoglobin is rare in many parts of the world but more common in areas of Africa.

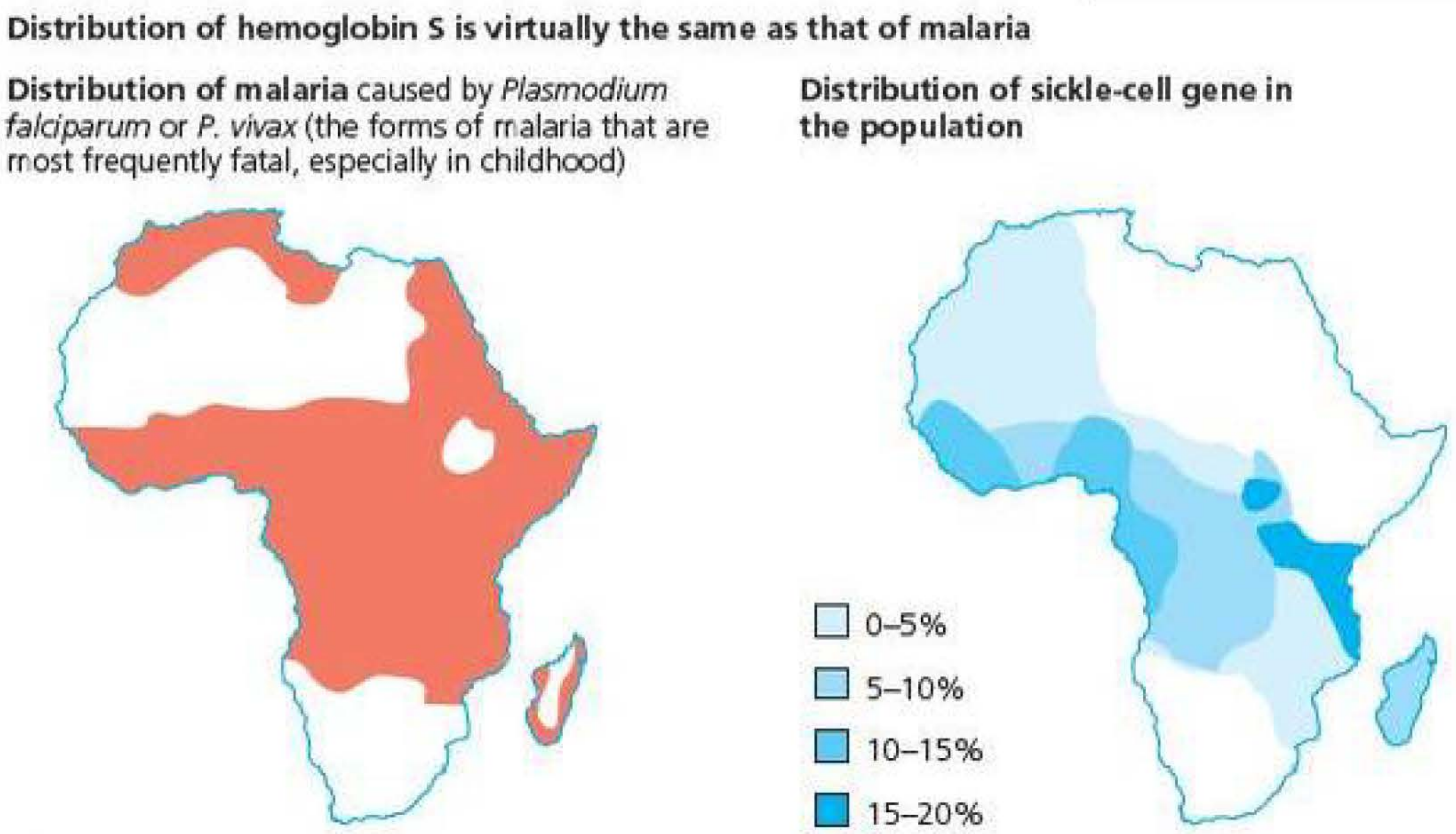


Figure 7.45 The distribution of malaria and sickle-cell gene in Africa

b Using the information in Figures 7.44 and 7.45, **suggest** why the sickle-cell allele is more common in parts of Africa than other areas.

c **Select** and **evaluate** the evidence from the maps that explains the distribution of the sickle-cell allele and the resistance to malaria in parts of Africa.

d Sickle-cell anaemia is an example of variation in humans.

  i **Explain** how meiosis produces variation.

  ii Compare mitotic cell division with cell division by meiosis.

Reflection

In this chapter we have found out about how species change through time and space, and seen how the evolution of species results through species' interactions and adaptations to their environment. We have explored the evidence for evolution, and the extent to which humans and their lifestyles have driven the evolution of other species. We have explained how new species evolve through the process of natural selection and speciation. We have learnt about our role as a reflective learner by considering the world through our own ideas and experiences.

<table>
<tr><th colspan="6">Use this table to reflect on your own learning in this chapter</th></tr>
<tr><td>Questions we asked</td><td>Answers we found</td><td colspan="4">Any further questions now?</td></tr>
<tr><td>Factual: What is speciation? What occurs during meiosis? What effects do genetic mutations have on the survival of species?</td><td></td><td colspan="4"></td></tr>
<tr><td>Conceptual: How can we understand and know about events and processes that occurred many years ago and over a long period of time? How have changes in habitats led to the development of new species? What occurs during the process of natural selection? How do changes in the genetic code lead to phenotypic variation? How have changes within cells led to the development of new species? How are species interrelated? How can scientists work out how closely related species are?</td><td></td><td colspan="4"></td></tr>
<tr><td>Debatable: To what extent have humans and their lifestyles driven the evolution of other species? To what extent is the use of antibiotics in farming benefitting or harming human health?</td><td></td><td colspan="4"></td></tr>
<tr><td rowspan="2">Approaches to learning you used in this chapter</td><td rowspan="2">Description – what new skills did you learn?</td><td colspan="4">How well did you master the skills?</td></tr>
<tr><td>Novice</td><td>Learner</td><td>Practitioner</td><td>Expert</td></tr>
<tr><td>Critical-thinking skills</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Creative-thinking skills</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Information literacy skills</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Media literacy skills</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Learner profile attribute(s)</td><td colspan="5">Reflect on the importance of being reflective for your learning in this chapter.</td></tr>
<tr><td>Reflective</td><td colspan="5"></td></tr>
</table>

8 How are organisms adapted to survive?

Organisms are more likely to survive when they are adapted to **interact** with **their surroundings** and respond to **changes** in their **environment**.

Figure 8.1 Organisms are most successful when they are able to perceive and respond to changes in their surroundings

CONSIDER AND ANSWER THESE QUESTIONS:

Factual: In what ways do organisms interact with their environment? In what ways do organisms respond to changes in their surroundings?

Conceptual: How does perceiving and responding to changing conditions of their environment contribute to the survival of organisms living there?

Debatable: To what extent should people use artificial or chemical means to support the survival of organisms when and where the organisms are not naturally adapted to live?

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

IN THIS CHAPTER, WE WILL …

- **Find out** how humans and other organisms are adapted to respond to changes in our and their surroundings.
- **Explore:**
  - the interconnectedness between organisms' adaptations and their survival in the place and time they are living;
  - how different organisms interact in their environment and respond to the changing conditions in their surroundings.
- **Take action** by designing vegetable gardens that are well-suited for growing in different cities, different neighbourhoods of the same city, or in your own school or neighbourhood at different times of the year.

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

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

● We will reflect on this learner profile attribute …

- Balanced – you will have opportunity to become more balanced as you learn about your body's and other organisms' natural responses to changing situations.

◆ Assessment opportunities in this chapter:

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

A *fable* is a story that uses characters from nature to tell the readers a *moral*, or lesson, for life. To start thinking about the important ideas and messages in this chapter, read the fable 'The Oak and the Reed'. This has been translated into English from Greek, and was originally told by Aesop, an ancient Greek storyteller who lived around 620–564BCE. Then look carefully at Figure 8.2, and use both the written fable and the illustration to respond to the questions.

THE OAK TREE AND THE REED

A reed got into an argument with an oak tree. The oak tree marvelled at her own strength, boasting that she could stand her own in a battle against the winds. Meanwhile, she condemned the reed for being weak, since he was naturally inclined to yield to every breeze. The wind then began to blow very fiercely. The oak tree was torn up by her roots and toppled over, while the reed was left bent but unharmed.

Aesop's Fables. *A new translation by Laura Gibbs. Oxford University Press (World's Classics): Oxford, 2002*

■ **Figure 8.2** The oak tree and the reed

THINK–PAIR–SHARE

- What do you see in Figure 8.2 that connects to or helps to illustrate the fable?
- What is different between the oak and the reed?
- What happened to the oak? What happened to the reed? Why did these things happen?
- What is the *moral* of the story? In other words, what is the lesson for life (in one sentence) that this fable teaches us?
- What do you think the connection between this fable and our chapter about adaptations might be?

KEY WORDS

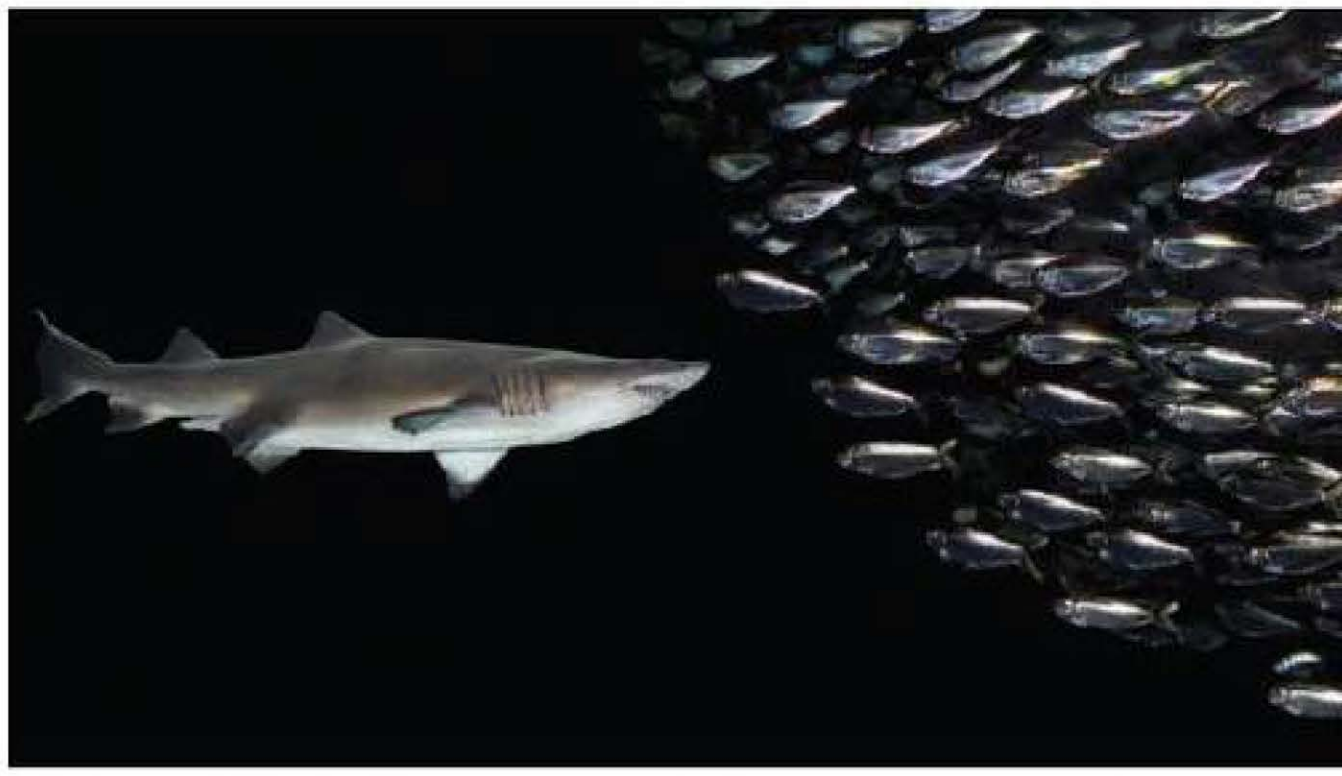
hormones	stimulus
nervous system	tropisms
neurons	

In what ways do organisms interact with their environment?

■ **Figure 8.3** Cacti and ferns are both plants, but they grow in very different conditions

What makes an organism suited to live in its environment? How can it be possible that some organisms thrive in conditions that seem impossible – or at least dangerous – to live in? For example, why is it that one plant, such as a cactus, can survive in a hot, dry desert while another plant, such as a fern, thrives only in a cool, damp forest?

Or, why do some animals live together in a large community, like these sardines and herring (right), while others spend most of their lives alone or in a small group, like this shark?

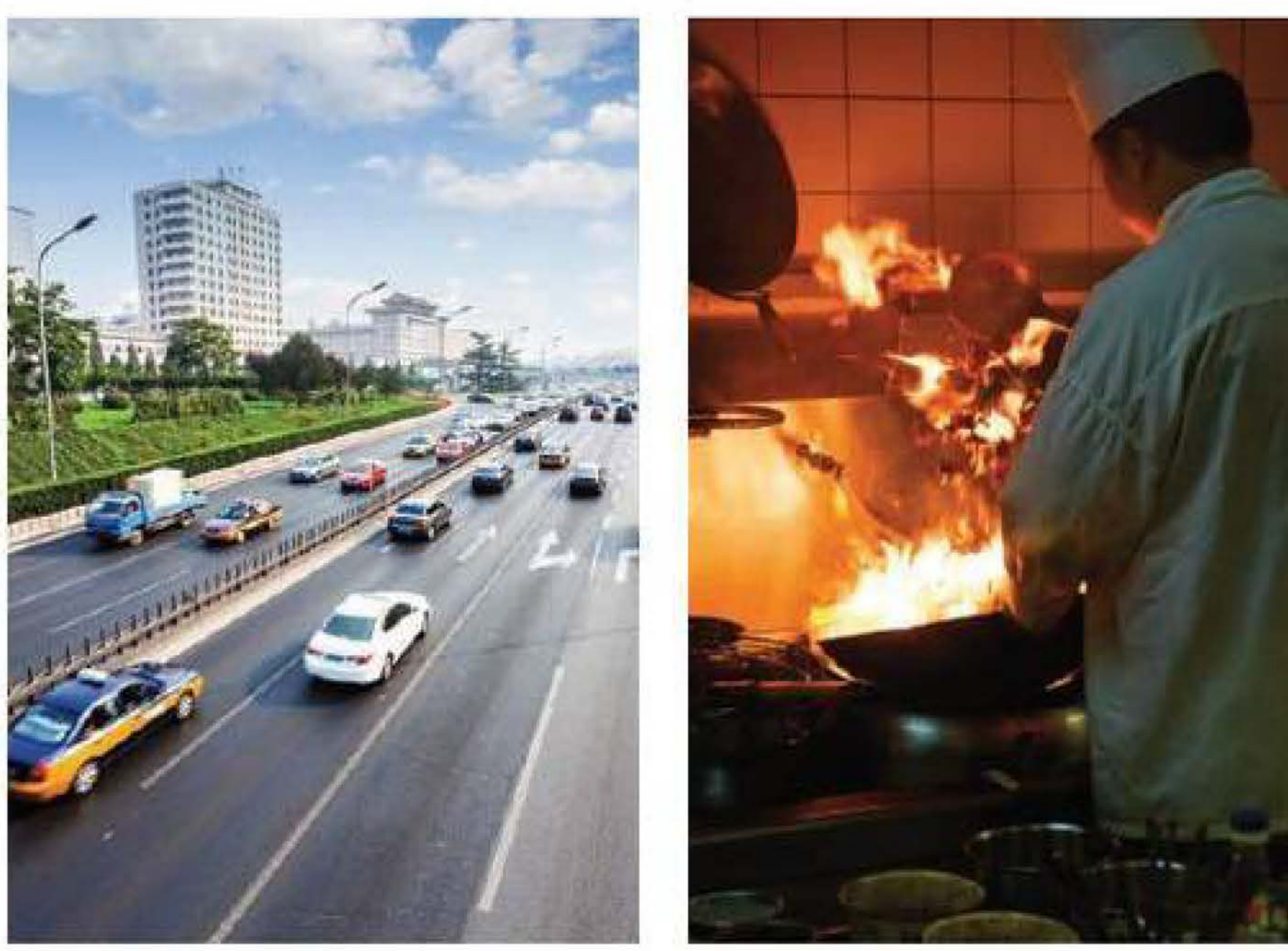


■ **Figure 8.4** Sharks are solitary while sardines and herring swim in large groups

Or, thinking about humans – how is it possible that we are able to cross busy streets, speed cars down a highway, or chop up food and cook over a fire thousands of times during our lives and (usually) not get hurt?

It is, of course, because organisms have evolved over time and in different settings to be *adapted* to live in and respond to their environment, just as we saw in Chapter 7. Through the processes of natural selection and evolution, different species have passed along different traits as result of their suitability for survival in the time and place the organisms are living. These traits that make organisms well suited to live in their habitat are called **adaptations**.

But what are some of those adaptations that contribute to the survival of humans, other animals and plants in different places and at different times? In this chapter, we will look at some of the challenges that all organisms face as their living conditions change through time – either through the course of a day, or year after year – and how their adaptations allow them to respond to those challenges, increaseing their chances of survival. We will also look at how humans have been able to manipulate some organisms and their adaptations in order to meet the needs and wants of the growing human population.



■ **Figure 8.5** Humans are adapted to function in a wide variety of situations, allowing us to participate in diverse activities

ACTIVITY: For every action there is a reaction

ATL

- Organization skills: Use appropriate strategies for organizing complex information

Science includes a lot of information! There are many facts, terms, concepts and skills that you need to know in order to understand the concepts and apply science to your daily life. Tables are a great way to keep yourself organized and systematically sort information to look for patterns or find unique characteristics.

For this activity, you will work with a partner to complete the activities listed in column A. You will copy the table and fill in columns B, C and D for each of the activities. Share your ideas for columns C and D with your partner, and write down any scientific suggestions that seem appropriate for each activity.

A	B	C	D
Activity	Response	Possible reason for the response	Where and when this response might be useful in 'real life'
1 Look closely at your partner's eyes, observing the pupil, the black area in the middle of the coloured part. Then, have your partner close his or her eyes for 15 seconds. What do you notice about the pupils when the eyes are re-opened?			
2 Ask your partner to sit with his or her legs crossed, so that the leg can swing freely. Hit the leg just below the knee with the side of your hand.			
3 Have your partner hold a clear piece of acetate or thin wire screen in front of his or her face. Then, throw the cotton ball at the person.			
4 Have your partner carefully turn around in a circle for about 20 seconds. Look closely at his or her eyes when she or he begins to turn around, while spinning, and immediately after stopping. If you have a stool that spins, you could also try spinning while seated.			

Scientists depend on keen skills of **observation** in order to identify patterns and form conclusions from their investigations. In addition, making observations of natural phenomena is often the starting point for questions that lead to experiments and discoveries.

In what ways do organisms respond to changes in their surroundings?

■ **Figure 8.6** If we touch something hot, we automatically respond by dropping whatever it is we are holding

REFLEXES

A **reflex** is an automatic and involuntary response to a **stimulus**. A reflex can be thought of as an immediate adaptation to a sudden change in our surroundings.

ACTIVITY: Stimuli and reflexes

Discuss each of the following stimuli with your partner and how you might normally respond. Copy the table and fill in the usual responses to the stimuli in the 'Examples of responses' column.

Examples of stimuli	Examples of responses
The Sun is shining brightly into your eyes.	
You put your hands under the tap to wash your hands and very hot water comes out.	
You take a mouthful of milk that has gone sour.	
You walk into a bakery at lunchtime and the air is filled with the smell of baking bread.	
You are walking down the street when an ambulance speeds down the street with its sirens on and stops at the intersection in front of you.	
Using these examples, I understand that a **stimulus** (pl. stimuli) is …	

Imagine this … you are in your kitchen cooking soup on the stove in a metal pot. The soup has been bubbling for a couple of minutes, so you think it is ready. You turn off the burner, reach for the metal handle, pick up the pot, and … *ouch*! Now, there is a big mess in the kitchen because you dropped the hot pot and soup spilled everywhere. But why would you drop the pot like this? Why wouldn't you just put the pot carefully down so you wouldn't have anything to clean up?

You dropped the pot because it is a reflex to do so. Because reflexes are automatic, 'unthinking' actions that happen immediately in response to what happens around us, to us, and even inside us, they help us avoid potentially dangerous or life-threatening results. Reflexes are examples of adaptations that allow us to interact with and respond to our surroundings to aid in our survival.

Of course, we have all experienced these automatic, uncontrollable – and sometimes embarrassing – actions, like sneezing loudly while your classmates are quietly working, or shivering when it is cold out, or jumping when someone behind you says 'Hello!' How can we do this? How can we act without even thinking? Don't we control our bodies and what we do? And, while the answer to that last question is yes, we use our brains to make decisions and take actions, there are also times when the thinking part of the brain is simply not involved in the action process. The process of forming a thought would be too slow, and, so our muscles act before we make a thoughtful decision to react or not.

We are able to respond without thinking to what goes on around us because we have sense organs with specialized cells that allow us to perceive changing conditions, and then send 'instant messages' through our body in order to cause an appropriate response. But how are we able to notice these changes? To where do we send the instant messages? And how are we able to respond so quickly?

To begin to answer these questions, we will next learn more about our sensory organs that are responsible for hitting the 'send' button for the instant message. Then, we will take a closer look at the path the instant messages must follow for us to respond quickly and appropriately.

THINK ABOUT IT!

ATL

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

Finding the connections between personal experiences and scientific concepts helps us to better understand and apply our learning. Use the information from what you read, see and talk about in addition to what you have experienced in your day-to-day life in order to copy and complete the table below. A portion of the table has been filled in as an example.

Sense organs	Associated sense	Examples of stimuli the sense organs perceive	Examples of associated responses
Nose 	Smell	Bread baking Rotten meat	Mouth watering Crinkling nose; pushing food away
Mouth 			
Ears 			
Eyes 			
Skin 			

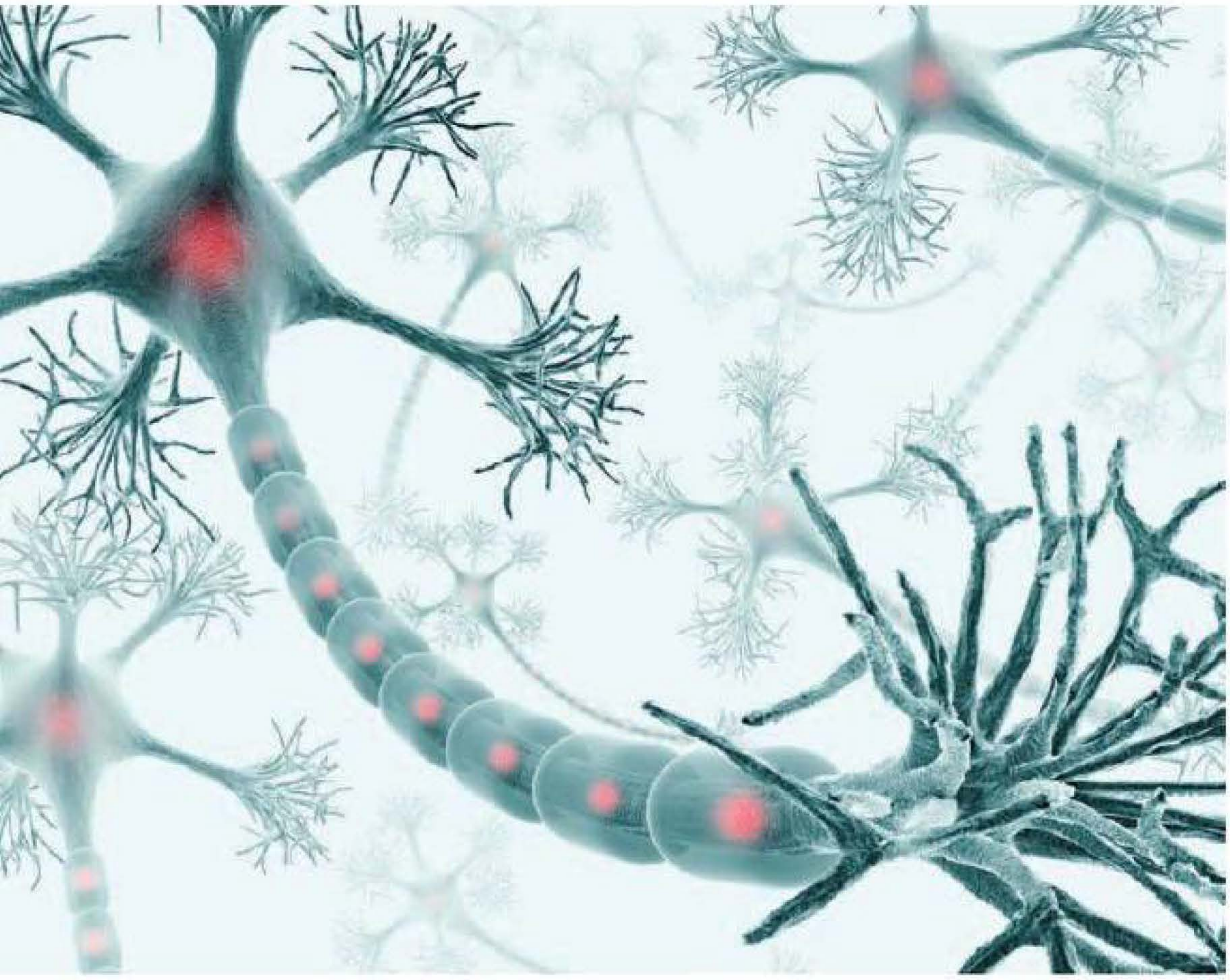
RECEIVING STIMULI

Now that we have thought about some of stimuli to which our bodies respond, as well as the types of responses we have, let's learn how and why we actually have those responses. We'll look at the example mentioned earlier, of dropping the hot metal pot full of soup.

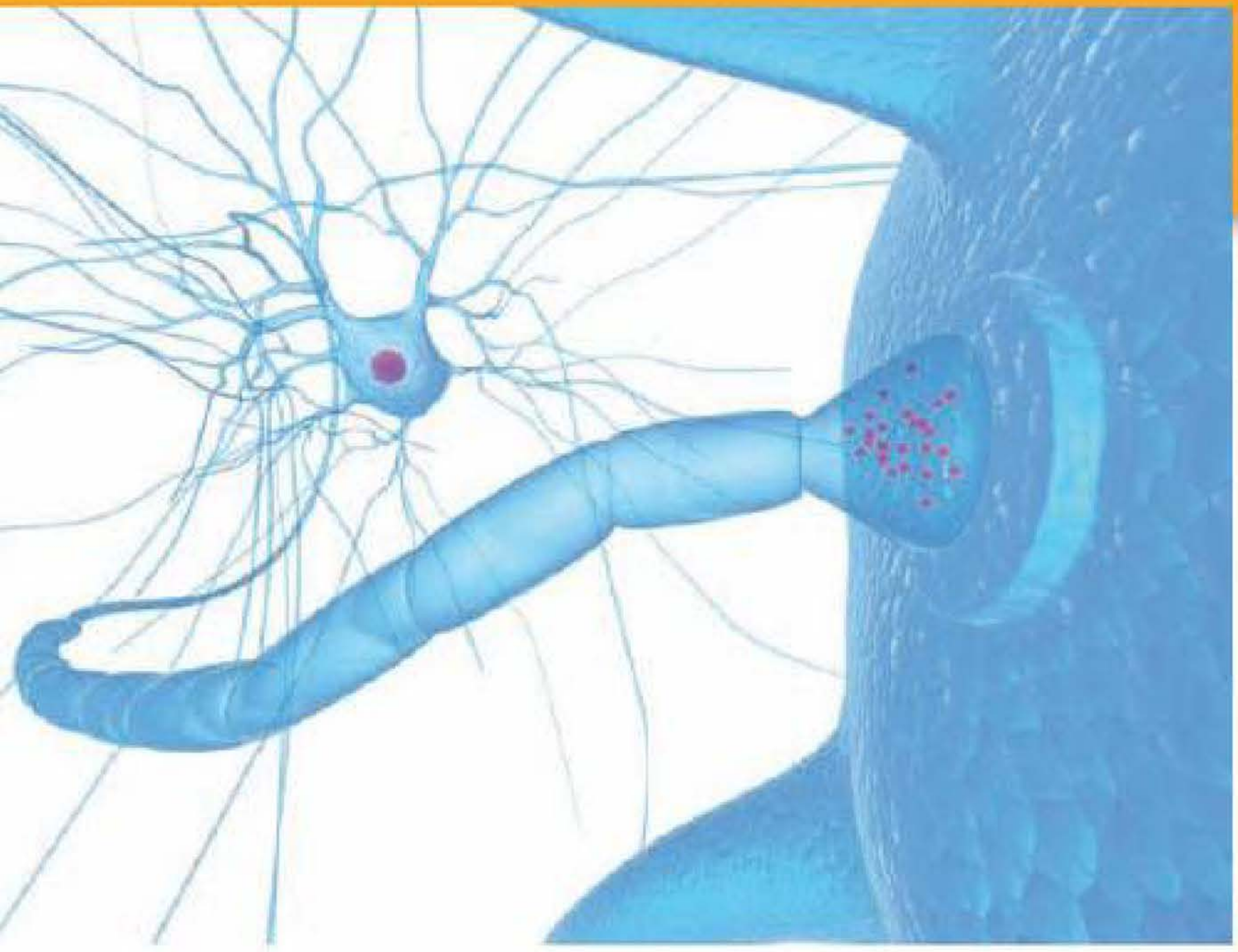
The response begins in the fingertips, where cells called **sensory neurons** are stimulated by the high temperature they sense. The sensory cells in your fingertips contain **thermoreceptors**, which means the skin cells on the fingertips are specialized in order to detect and send information about extremes in temperature.

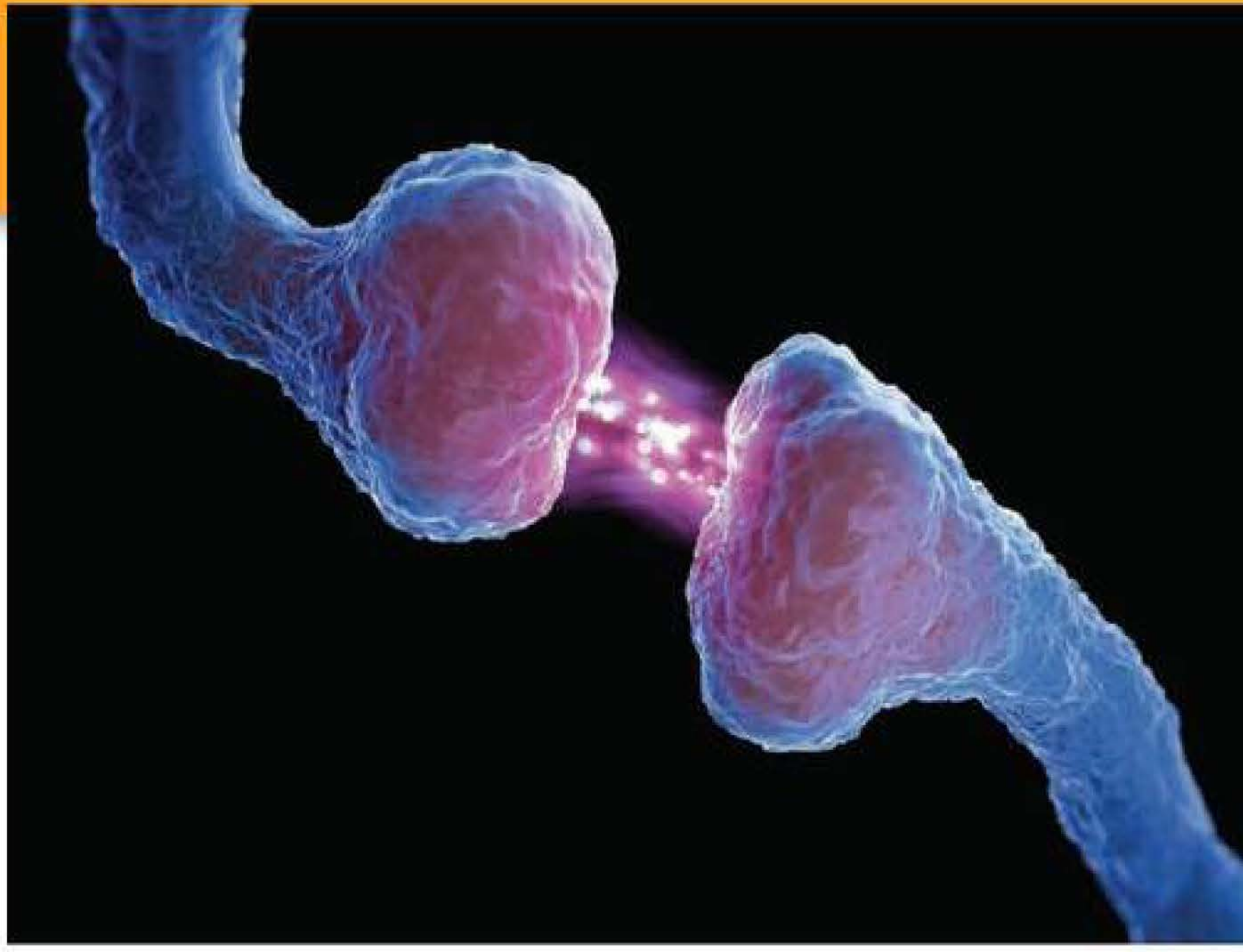
When the thermoreceptors in your fingertips detect 'extreme heat' as you touch the pot, they are activated to initiate a signal, called a nerve impulse or action potential, along the length of the sensory neuron. When the nerve impulse gets to the end of the sensory neuron, it causes chemicals called neurotransmitters to be released from the sensory neuron, which float across a small gap towards neighbouring **neurons**, where the neurotransmitters function to trigger a continuation of the 'extreme-heat' nerve impulse in the next neurons.

As you can see in Figure 8.7, the neuron cell body is surrounded by branch-like structures called dendrites, where the stimulus, in this case extreme heat, is perceived; extending from the cell body is the axon, which you can compare to an extension cord that carries the nerve impulse. At the end of the axon is the axon terminal, which synapses, or adjoins with, the neighbouring neurons, separated by the small gap known as the synaptic cleft.



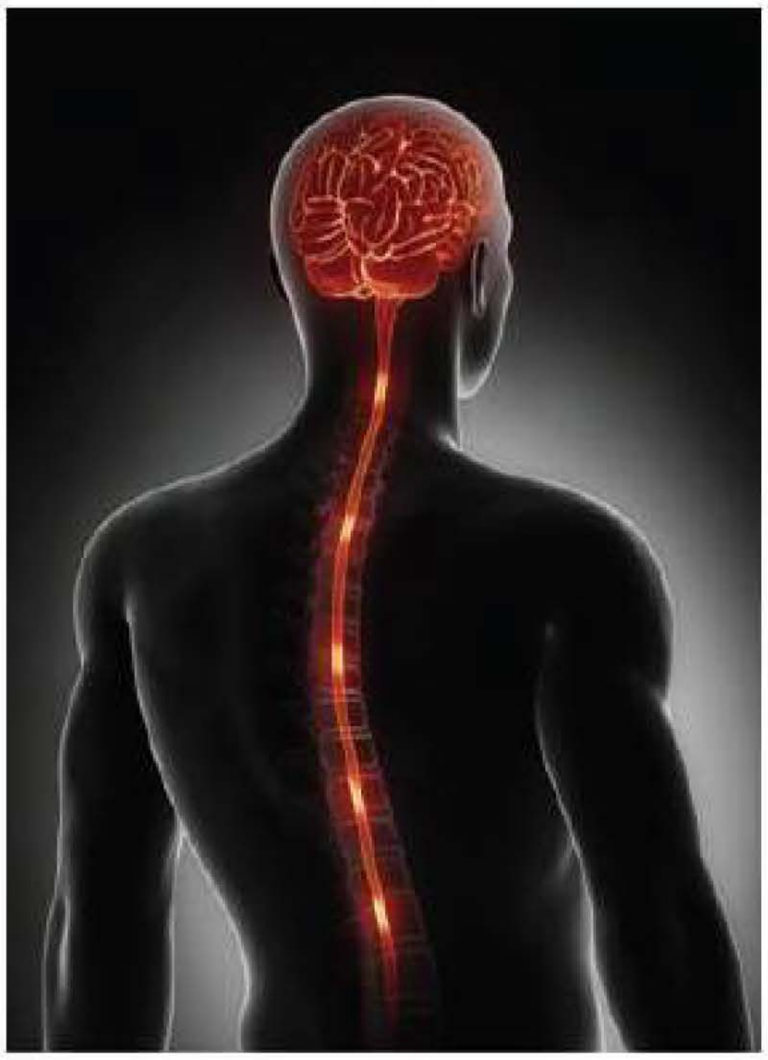
■ **Figure 8.7** An illustration of a neuron, showing the dendrites, cell body, axon and axon terminal





■ **Figure 8.8** Illustrations depicting the synapse between two neurons, with the neurotransmitters passing from one neuron to the next, so that the nerve impulse is carried along through the nervous system

When the 'extreme-heat' nerve impulse travels across the synaptic cleft into the neighbouring neurons, the message of 'extreme heat' travels continuously, rapidly, automatically, and non-stop along all of the sensory neurons in the **peripheral nervous system** through your hand, up your arm, and to your **spinal cord**, which is part of your **central nervous system** (CNS). Because your spinal cord is part of your central nervous system, it has the ability to command action in your body, without you having to use your brain to think about or make a decision to do so.



■ **Figure 8.9** The brain and spinal cord make up the central nervous system, and the nerves that extend off of the spinal cord make up the peripheral nervous system

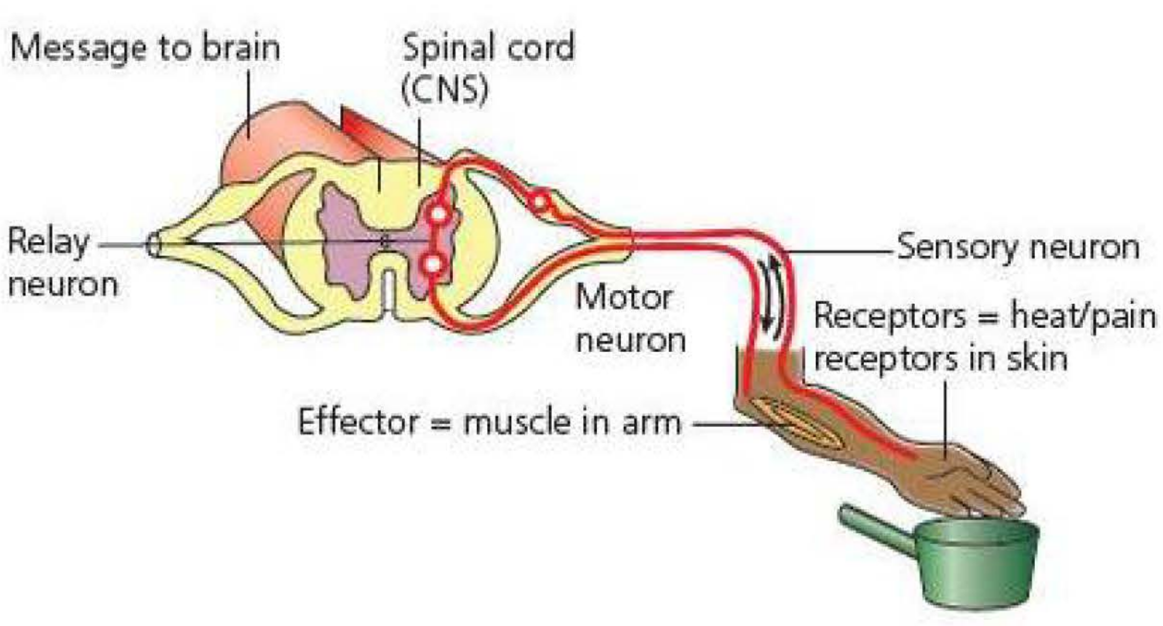
DISCUSS

Before we continue with what happens to the 'extreme-heat' nerve impulse, pause for a moment to talk with your partner about the shape of the neuron. How does the shape, or form, of the neuron complement its function? How might the job of sending messages throughout the body be different if the shape of neurons were different?

■ **Figure 8.10** Relay neurons pass along the message of the nerve impulse between sensory and motor neurons

In the spinal cord, the 'extreme-heat' nerve impulse travelling along the sensory neurons reaches **relay neurons**. Relay neurons function to *relay*, or pass, the nerve impulse from the **sensory neurons** to the **motor neurons**.

The relay neuron also acts as a translator, to change the 'extreme-heat' message from the sensory neurons to a 'relax-forearm-and-hand-muscles' message in the motor neurons. Just as the sensory neurons synapse with other sensory neurons, the motor neurons synapse with each other to form a chain of neurons, extending from the spinal cord and down along the arm and hand. The motor neurons also synapse with muscle cells in your arm and hand, so when the 'relax-forearm-and-hand-muscles' nerve impulse gets to the end of the motor neuron and travels to the muscle cells, the nerve impulse causes the muscle cells in your forearm and hand to relax, and you drop the pot.



■ **Figure 8.11** A nerve impulse travelling along the spinal reflex arc allows us to quickly respond to a situation that may cause injury or harm

We can summarize this chain of events in this way:

1 Sensory neuron receptors perceive stimulus.
2 Stimulus travels along the sensory neurons in the nerve impulse.
3 The nerve impulse reaches the spinal cord.
4 The nerve impulse travels to the relay neurons.
5 Relay neurons pass nerve impulse to motor neurons.
6 Motor neurons carry nerve impulse to muscle cells.
7 Muscle cells (effectors) respond to nerve impulse.

This chain of events is similar in all types of reflex responses. The things that change are the types of receptors in the sensory neuron, the neurotransmitter that is released between neurons, and the type of effector cell and effector response. In addition to thermoreceptors, some other types of sensory neurons include:

- **photoreceptors**, which respond to changes in light
- **chemoreceptors**, which respond to changes in chemicals associated with odours, tastes, and dissolved substances in the blood
- **mechanoreceptors**, which respond to changes in pressure or touch
- **sonoreceptors**, which respond to changes in sound.

In some stimulus–response systems, the stimulus comes from your internal body environment instead of the external environment. For example, your body cells need access to a form of sugar (glucose) in order to produce energy for them (and your body) to function; but what if it has been a long time since you last ate and there is not any more glucose readily available in your blood?

Links to: Physics

Many of our receptor cells are stimulated by changes in light or sound waves. Through studying physics, we can understand how sound and light waves travel in order to trigger a nerve signal in our bodies.

In this case, chemoreceptors that are sensitive to blood-sugar levels are activated and send a nerve impulse to your brain, which receives the 'low blood-sugar' message. The brain then sends messages to your pancreas to release glucagon, which is a **hormone**, or chemical messenger that travels through your blood, and signals your liver to break down stored carbohydrates into sugar that your cells can use for energy.

Figure 8.12 This figure shows the location of the pancreas in the digestive system. When the nervous system is stimulated by low blood-sugar levels, a signal is sent to the pancreas so that it releases glucagon, a hormone which helps to make glucose available in the blood

ACTIVITY: Making sense of it all

ATL

- Organization skills: Use appropriate strategies for organizing complex information

You have just read about types of sensory receptor cells. Use the information, your prior knowledge, and inferring skills to copy and complete the first table below. Compare your responses with those of your classmates and class, adding to your thoughts any new ideas. Part of the table has been filled in as an example.

Sensory receptor cells and their locations

Sensory receptor	Location in the body	Stimulus
Thermoreceptors	Fingertips; skin	Touching something hot or cold
Photoreceptors		
Mechanoreceptors		
Chemoreceptors		
Sonoreceptors		

Before we go on to learn about different types of adaptations, remind yourself of our Statement of Inquiry. As you continue with this chapter, it is important to think about the Statement of Inquiry and look for situations that exemplify the big idea represented in it.

Use the second table below to help you **identify** and **organize** the information from the chapter so that it makes a connection to the Statement of Inquiry. Part of the table has been filled in for you as an example and to get you started, but you should add your own ideas and examples. Start off with what you have learnt so far about how we respond to changes in our surroundings; you will be reminded to come back to this table and add to it as you continue with the chapter.

Statement of Inquiry reminder:

Organisms are more likely to survive when they are adapted to interact with their surroundings and respond to changes in their environment.

Stimulus: Conditions in the environment/surroundings	Response/Adaptation	How the response/adaptation supports survival
Hot metal pot	Thermoreceptors in hand are activated so that sensory neurons send signal to spinal cord. Motor neurons extending from the spinal cord to your arm and hand signal the muscles to relax and you drop the pot.	If you don't drop the pot, you will burn your hand.

How do perceiving and responding to stimuli contribute to survival?

ADAPTING TO STIMULI

Although we have talked about human adaptations of response to their surroundings, other organisms, big and small, also perceive and respond to changing conditions. Tables 8.1 and 8.2 summarize some examples of how some different organisms are adapted to receive information from and respond to their environment. It is important to note that, even though all organisms are equipped with mechanisms to help them adjust to variable conditions, depending on what 'type' of organism they are (such as a protist, plant or animal) and their complexity, different organisms have different ways of sensing and responding to their surroundings. For example, plants do not have a nervous system or neurons, but within their cells they have proteins that are stimulated or activated by stimuli in a way similar to the way in which animals' sensory receptor cells are activated.

ACTIVITY: Almost by magic

Read the information in the tables. Then copy the tables and complete the empty sections with your partner or as a class.

■ **Table 8.1** Responding to the environment: Animals

Organism	Stimulus	Type of receptor
Planaria 	Dissolved chemicals	Chemoreceptors
Bats 	Echos	Sonoreceptors
Snakes 	Body heat of nearby animals	Thermoreceptors

■ **Table 8.2** Responding to the environment: Plants

Organism	Stimulus	Type of receptor
Plants 	Direction of sunlight	Photoreceptor
Plants 	Insects landing on leaves	Mechanoreceptor
Plants 	Force of gravity	Mechanoreceptors

ATL

■ Critical-thinking skills: Draw reasonable conclusions and generalizations

Response	When this might be found in nature	Why this response/adaptation supports survival
Chemoreceptors in the front end of planaria are stimulated by different chemicals dissolved in the water surrounding the planaria. The planaria move either toward or away from the dissolved chemicals.	Planaria move toward higher concentrations of dissolved nutrients in their surrounding water.	
Sonoreceptors in the bats' ears are stimulated by the sound waves in the bats' surroundings. The bat adjusts direction and style of flying depending on the intensity and direction of the sound waves.	Bats use echolocation to identify the size and location of different objects in their surroundings. To do this, bats produce a high-pitched sound while flying and wait for the sound waves to bounce off nearby objects and return, as an echo, to the bat. Sonoreceptors send signals about the sound waves of the echo to the bats' brain, which uses the signals to determine how big the objects are, where they are located, and whether they are moving or stationary.	
Theremoreceptors in the 'pit organs' of snakes are stimulated by subtle changes in environmental temperature caused by nearby animals. Snakes use this information to adjust the direction and nature of their movements.		

Response/Growth patterns	When this might be found in nature	Why this response/adaptation supports survival
Phototropism: photoreceptor proteins in leaves are stimulated by the sunlight. The plant releases **hormones**, which causes the plant to change the direction it is growing so it grows toward the light.	As plants grow around each other, they block each other's direct exposure to the sunlight. Plants change the direction and angle in which they grow so they can get access to more sunlight.	
Thigmotropism:		
Gravitotropism: mechanoreceptor proteins in root cells perceive the direction of the force of gravity, and grow in the same direction; mechanoreceptor proteins in shoots perceive the direction of the force of gravity, and grow in the opposite direction.		

ACTIVITY: Seeing is believing

ATL

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

Organisms are constantly interacting with their environment, and it is possible to design and conduct experiments to learn more about in what ways, why and how they respond. Behavioural biologists study the ways in which animals respond to different conditions in their environment. Often, behavioural biologists spend many years 'in the field' observing their research subjects, such as primates or birds, in order to be able to identify responses and behaviours. For example, Jane Goodall spent decades in the rainforest observing and studying chimpanzees to understand more about how they are adapted for success in their environment.

In contrast, other behavioural biologists set up experiments in the laboratory, where they carefully alter and control conditions to observe how the organisms, such as rodents or insects, respond to the changes. Plant biologists also carefully observe how plants respond to different and changing stimuli in the environment, both in the field and in the laboratory.

With this activity, you will have the opportunity to practise the research skills of a behavioural biologist by designing, and perhaps carrying out, an investigation about behaviour. To do this, decide whether you would like to practise the skills of an animal behavioural biologist or a plant biologist, and you can choose which organism's responses to stimuli you would like to observe.

For example, would you like to see how different insects respond to different smells or sounds? Or maybe you are interested to see how a plant's roots grow in zero gravity? Perhaps you would like to learn if a cat depends more on its sense of sight or sense of smell in order to locate food …

Once you have decided the subject of your research, think about the type of stimuli and response you would like to investigate. Then, **design** an investigation into your chosen organism's response to the stimuli. Remember, ethical treatment of living things is part of being a good scientist; therefore, you must be sure to design an investigation that avoids any harm or damage to living things. You can use the investigation-design guidelines (below) in order to help you design the investigation.

Depending on the subject of your investigation and the nature of your investigation, you may be able to actually carry out the investigation and collect your own data. Speak with your teacher about the possibilities of conducting your experiment, which could help you in selecting school-appropriate test subjects and materials.

Investigation-design guidelines

Problem or question for investigation:

Hypothesis:

Variables:

Type of variable	What will be manipulated	Rationale	How to manipulate
Independent			
Dependent			
Controlled			

Materials:

List all the materials and equipment you will use.

Quantity	Materials/ Equipment	Description of the equipment (if necessary)

Method:

Control group:

Special considerations:

Data:

Numerical data: raw/processed data table(s)

Visual data: graph(s)

Conclusion:

Evaluation and improvements:

Limitation of the method	Explanation of limitation	Suggestion for improvement

Works cited or bibliography:

Assessment opportunities

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

EXTENSION

ATL

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

Some organisms live in extreme conditions, and therefore have very unusual adaptations to perceive and respond to their environment. Conduct an Internet search for examples of organisms, including insects, fish, plants, reptiles, amphibians or mammals, which have unique, specialized structures or sensory receptors that aid in their survival.

Share your examples with your classmates – who found the most bizarre or unusual adaptation?

Figure 8.13 This triplewart seadevil fish has a bioluminescent lure that it uses to attract prey in its habitat. It is an adaptation for survival in the dark, deep-sea waters where it lives

ACTIVITY: In the field

ATL

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

As we have discussed, organisms must be constantly interacting with various factors in their environments, and they have different adaptations to help them successfully and appropriately respond to the stimuli.

In the pictures of animals in the savannah (Figure 8.14), there are many different factors, or conditions, that affect the survival of the plants, animals and other organisms living there.

First, **list** factors or conditions you see in the pictures that affect survival of the different organisms. For example, we can see a watering hole with variety of mammals, including giraffes and elephants, as well as different birds. We can also see that the ground looks hard and dry, with brown, barely living grass.

Then, using your background or prior knowledge from things you have previously seen, learnt or researched about this habitat, **list** factors or conditions that you do not see (but you think might also be there) that would also affect the survival of the organisms living there. For example, although you may not see any insects in the photo, you know that there are likely to be many mosquitoes on and around the animals.

Now, compare your list with your partner. Is there anything you can add to their list? Is there anything you can add to your list? Work together in order to create one list of factors that everyone agrees on.

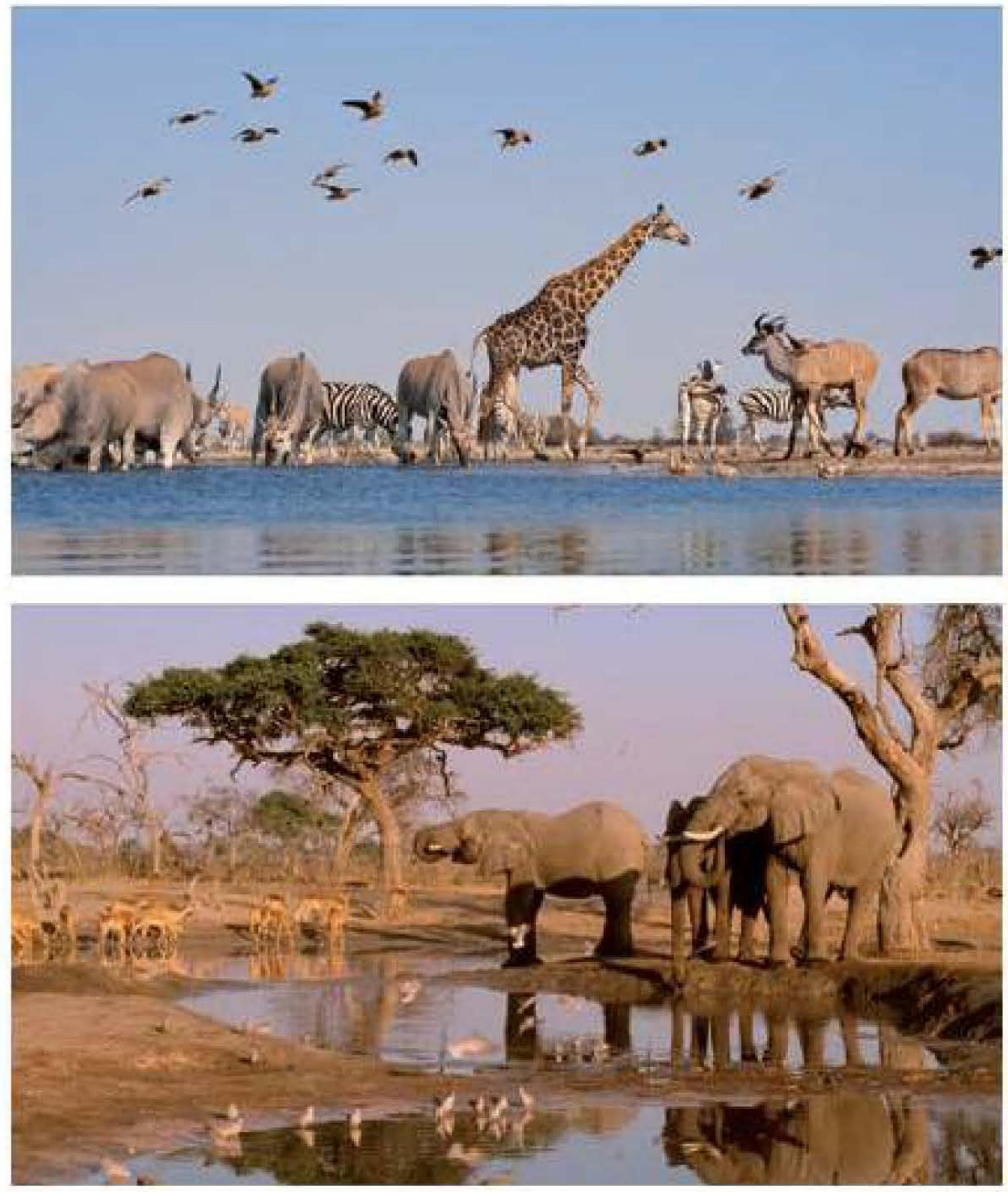


Figure 8.14 Animals living in the savannah are adapted to life in a hot, dry climate

Look at your group's list of the factors affecting the survival of the organisms in the savannah. As a group, decide if each factor describes something that is *living* or *not living*. Write the letter 'L' next to each factor you agree describes something living, and the letters 'NL' next to each factor you agree describes something non-living.

FACTORS AFFECTING SURVIVAL

As we know from personal experience, as well as from our observations in the last activity, some of the factors with which living things interact in their environment are living, and some are non-living. The scientific term for the living factors is **biotic**, whereas the non-living factors are **abiotic**. In order to be successful in their environment, the cellular receptors and body structures that organisms have are such that the organisms respond to stimuli in ways that make life-supporting substances more accessible and life-saving actions more immediate.

ACTIVITY: It's a factor of life

ATL

- Communication skills: Use a variety of organizers for academic writing tasks

Using examples from the previous activity as well as what you know about other environments, such as beaches, rainforests, coral reefs and city parks, generate a list of factors that affect survival.

Then, create a table or other organizer to categorize the factors as either abiotic ('non-living') and biotic ('living').

■ **Figure 8.15** Habitats such as beaches, rainforest, coral reefs and city parks all have particular abiotic and biotic factors to which the organisms living there must adapt

Links to: Individuals and Societies

The concept of global interactions focuses on connections between individuals and communities, as well as the ways in which people use and manage their resources. As we are adapting to changes in climate and land distribution, the ability to interact effectively within and beyond our communities is becoming more relevant than ever.

Take action

ATL

- Transfer skills: Apply skills and knowledge in unfamiliar situations; Combine knowledge, understanding and skills to create products or solutions

! As cities spread, arable farmland shrinks and global climates change, having enough food to support the growing human population is an increasing concern. In addition, as the premise of 'think globally, act locally' becomes more popular, many people are trying to reduce their 'food miles' by purchasing and consuming more local products. One suggestion of how to reduce a possible future food shortage, as well as how to increase accessibility to locally grown produce, is to develop new strategies for higher yield urban farming or community and personal gardens.

! Imagine that you are a city or town planner, and you have been hired by your school to **design** a gardening strategy to sustainably grow some of the produce consumed by the members of the school community during the school year.

! To do this, you will have to:

- Use your knowledge and understanding from this chapter to **explain** how plants receive stimuli and respond to their environments.
- **Identify** the characteristics and needs of plants that would be well-adapted for the environment of your school.
- Research the availability and prices of the plants you have identified as being well-adapted to your school environment.
- Develop a strategy for how the school could sustainably grow the plants you identified in your research; include suggestions about the strategies and responsibilities of students and the equipment that will be needed to maintain the gardens.
- **Analyse** and **evaluate** the feasibility of growing the plants; in other words, consider the possible strengths and weaknesses in your suggested strategies, and to what extent might these impact on the feasibility of creating sustainable gardens at school.

Assessment opportunities

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

SOME SUMMATIVE PROBLEMS TO TRY

Use these problems to apply and extend your learning in this chapter. These problems are designed so that you can evaluate your learning at different levels of achievement in Criterion A: Knowledge and understanding.

THESE PROBLEMS CAN BE USED TO EVALUATE YOUR LEARNING IN CRITERION A TO LEVEL 7–8

1 Sometimes, when people experience extreme physical trauma, such as a severe injury resulting from a car accident, they go into 'shock'. While they are 'in shock', they report feeling no pain and interact with others quite normally. One of the reasons people in shock do not feel pain is because the brain is signalled to release a group of neurotransmitters called endorphins. When endorphins are released, they bind to neurotransmitter receptors in the brain.

a **Describe** how the *form* (or structure) of neurons matches (or is well-suited for) their *function* of sending information about stimuli and responses throughout the body.

b **Explain** why a person who has just severely cut his finger while chopping wood for a fire might not even notice that he is seriously injured and bleeding, whereas a person who gives himself a paper cut might yell out, drop the paper, and shake his hand around for relief.

c Scientists claim that the production of and effects of endorphins have had an evolutionary advantage for humans and have allowed humans to dominate their environments.

i **Evaluate** the claim that endorphins have had a positive impact on human adaptations and evolution.

ii **Discuss** the possibility that endorphins can be a disadvantage for human survival.

Researchers have found by conducting blood tests and brain scans that prolonged exercise, such as participating in endurance sports like long-distance running, results in the release of endorphins.

A friend of yours decided to train for a half-marathon. The other day, she told you that she is concerned about her training, because she has to walk after about 45 minutes of running because her legs feel too achy to continue. She has not had any injuries, but she says she simply feels 'sore.'

d **Apply** your scientific knowledge and understanding about pain perception and neurotransmitters such as endorphins to **design** a scientifically supported, healthy training schedule that will allow her to increase her running distance while preventing long-term injuries.

2 Marine shrimp have a very poor sense of sight. They do not navigate through the water by visual stimuli; instead, they rely on and respond to other types of stimuli in their surroundings.

■ **Figure 8.16** Common marine shrimp in a rock pool

Marine shrimp use receptor cells in their antennae to detect stimuli in their surroundings. As a result of the different stimuli they receive, marine shrimp are able to locate tiny particles of dissolved food, avoid dissolved substances that are toxic to the shrimp, and move around structures or other organisms that are in the water.

a **Explain**, based on the above information, which type(s) of receptor cells you would expect to find in the antennae of marine shrimp, and which type(s) of receptor cells you would not expect to find.

b **Explain** how the type(s) of receptor cells in the antennae of marine shrimp support their survival.

c Based on your answers to (a) and (b), **discuss**, using specific examples of receptor cells, why marine shrimp may have evolved to have more of certain types (or a certain type) of receptor cells and fewer of other types.

d **Apply** your knowledge and understanding of receptor cells, the perception of stimuli, and biotic and abiotic factors that affect survival to **design** an a plan for shrimp farmers to determine a scientifically supported and reliable means to raise and support larger populations of larger shrimp.

3 Mosses are small plants that grow without flowers or true roots. They usually grow in damp and shady areas. Observations of moss growing in nature and under laboratory conditions show that moss tends to grow in the direction of light and in the opposite direction to gravity.

Figure 8.17 A moss plant in nature showing growth in the opposite direction to gravity and toward the light. Experiments show that moss grown under laboratory conditions grows with the same patterns

Research done in the space station laboratories show that plants, such as these rice and mustard plants (*Arabidopsis*), tend to grow in a random and disorderly way when under 'microgravity' conditions.

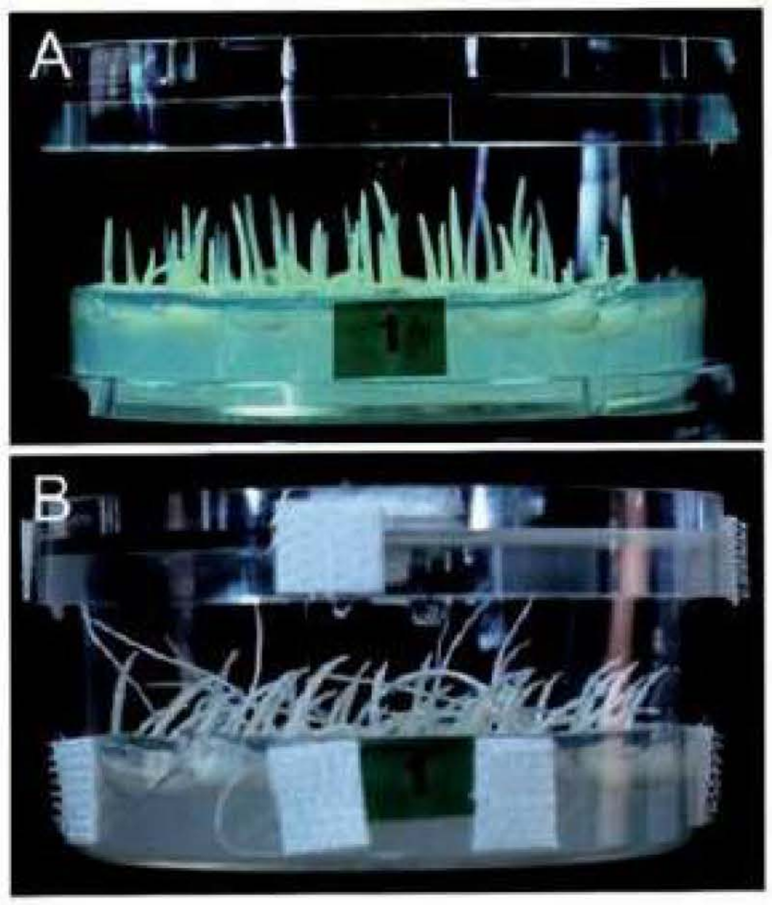
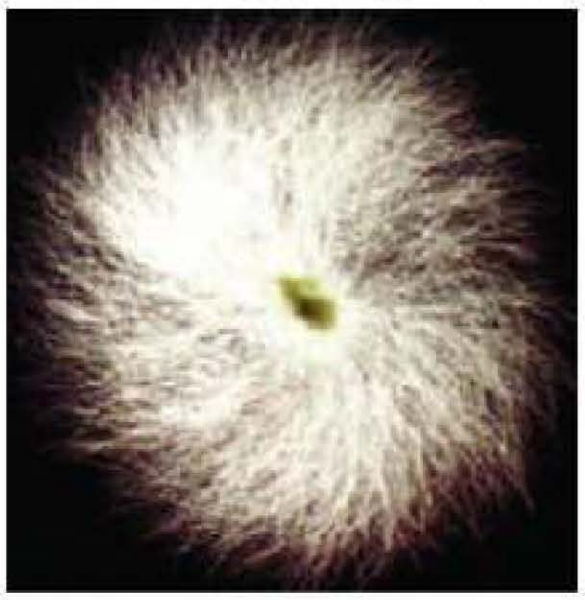


Figure 8.18 These photos show the random growth patterns typical of plants growing in microgravity. We can see that, in microgravity conditions, stems grow in different directions, including downward toward the roots

In 2003, scientists discovered the remains of an experiment on moss plants that was started on the space shuttle Columbia before it exploded in space. The moss plants were grown in dark containers on the space shuttle. Before the shuttle was destroyed, the astronauts on board treated the moss plants with a chemical which stopped the growth of the plants.

When the remains of the shuttle were found in Texas in the United States, some of the moss samples had survived. The samples showed that the moss with no light or gravity grew in soft, stringy, spirals.



■ **Figure 8.19** The soft spirals of moss growing in microgravity without light

a **Explain**, based on the above information, the types of receptor proteins found in moss, rice, and mustard plants.

b **Explain**, based on the above information, the growth patterns that moss, rice, and mustard plants exhibit .

Scientists are not fully certain why the moss growing in darkness in microgravity display this type of spiral growth pattern. Some believe that growing in this way is a primitive and efficient growth pattern, allowing the plant to spread out and avoid growing over itself.

c **Evaluate** the above claim and **explain** to what extent you agree or disagree.

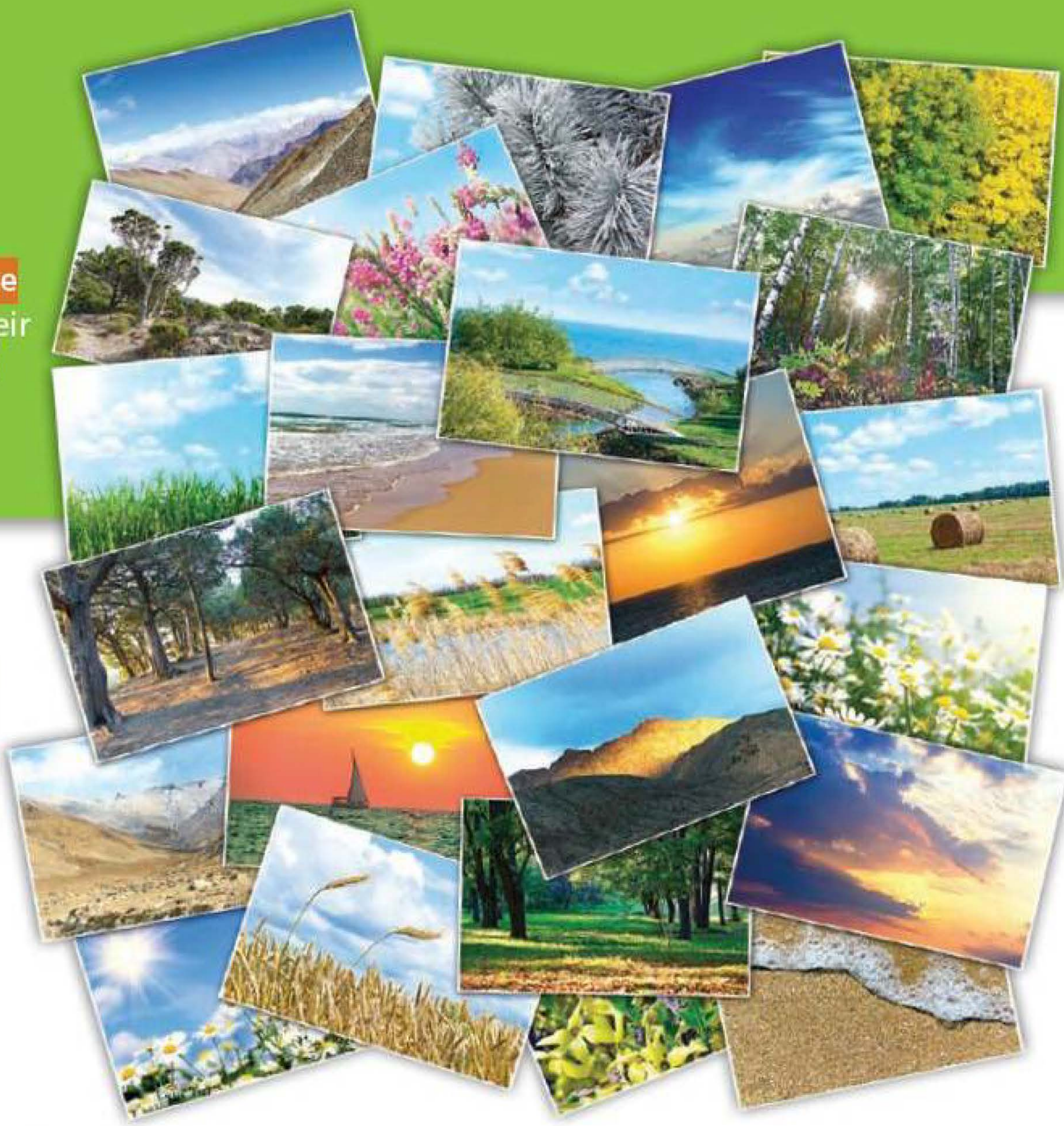
Reflection

In this chapter, we have learnt that all living things – from the largest mammals to the smallest micro-organisms – are constantly interacting with their environment. Life depends on an organism's ability to perceive the surrounding conditions and respond appropriately. These adaptations have been shaped by natural selection and evolution, and are, in part, responsible for the great diversity of living things that covers the planet Earth.

Use this table to reflect on your own learning in this chapter					
Questions we asked	Answers we found	Any further questions now?			
Factual: In what ways do organisms interact with their environment? In what ways to organisms respond to changes in their surroundings?					
Conceptual: How does perceiving and responding to changing conditions of their environment contribute to the survival of organisms living there?					
Debatable: To what extent should people use artificial or chemical means to support the survival of organisms when and where the organisms are not naturally adapted to live?					
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					
Information literacy skills					
Transfer skills					
Creative-thinking skills					
Critical-thinking skills					
Learner profile attribute(s)	Reflect on the importance of being balanced for your learning in this chapter.				
Balanced					

9 How do species interact?

Ecosystems can be in balance when the species sharing their habitat have interconnected and sustainable functions and roles.



■ **Figure 9.1** Life depends on the interactions between all different living things, in all different habitats, at all different times

CONSIDER AND ANSWER THESE QUESTIONS:

Factual: What are the interconnected roles and functions of different species that contribute to maintaining balance in an ecosystem?

Conceptual: How do changes or shifts in species' functions and roles, or interactions between species, influence the balance and stability of an ecosystem?

Debatable: To what extent should people interfere with or influence the interactions between different species in an ecosystem in order to try to extend and improve human life?

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

IN THIS CHAPTER, WE WILL ...

- **Find out** what happens to an ecosystem when the natural conditions are modified.
- **Explore:**
  - the ways different species interact in ecosystems around the world;
  - the interactions of species that make up the local ecosystem.
- **Take action** by identifying, advocating for, and making a small change in our daily habits that will have a positive impact on a local ecosystem.

■ **Figure 9.2** Organisms in ecosystems interact in many different ways

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

- Reflective skills
- Information literacy skills
- Creative-thinking skills
- Organization skills
- Communication skills
- Transfer skills

● We will reflect on this learner profile attribute …

- Caring – in particular, what does it mean to be caring when interacting with others? Do other animals show caring, or is it a trait unique to humans? What are some ways that caring is shown?

◆ Assessment opportunities in this chapter:

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

Carefully look at the living things in the ecosystem that is pictured in Figure 9.2. What do you Notice–Think–Wonder? Copy and fill in Table 9.1 with your ideas.

Remember: anything that you see in the picture is what you '*notice*'; your ideas or possible explanations for what you see are what you '*think*'; and your questions or things you want to know more about are what you '*wonder*'.

■ **Table 9.1** Notice–Think–Wonder chart

When I look carefully at the living things in this ecosystem, I …		
Notice	Think	Wonder

KEY WORDS

commensalism	habitat
competition	mutualism
ecosystem	parasitism
food chain/web	predator type

How do organisms interact?

Life is all around us. From the biggest mammals walking on the ground or swimming in the sea, to the smallest micro-organisms floating unnoticeably in the air around us, we are constantly surrounded by and in contact with many different types of living things.

So, how is it that so many different types of living things – plants, large animals, insects, bacteria – are able to live side-by-side without destroying each other? We all breathe the same air and drink the same water and have many other similar needs; so what is it about the way different living things interact that allows all of us not only to *survive*, but actually *thrive* in each other's presence?

In this chapter, we will explore this perhaps contradictory idea: that living things do not just 'get by' while living among other organisms, but, instead, depend on balanced interactions with each other in order to meet their needs for life. We will also take a look at what happens when those interactions become out of balance, due to either natural or artificial factors.

ACTIVITY: No 'Paine' no gain

ATL

- Reflective skills: Consider ethical, cultural and environmental implications

In the 1960s, Robert Paine, an ecologist at the University of Washington in the United States, conducted an experiment to determine the effect of predators on the stability of an ecosystem. He, and other ecologists at the time, wondered if the removal of an important 'top' **predator** from an ecosystem would have a positive impact on the ecosystem, and result in a greater variety of species, and a healthy and stable ecosystem; or if the absence of the top predator would have a negative impact on the organisms, resulting in fewer species and an unbalanced and unhealthy ecosystem.

■ **Figure 9.3** Predators are consumers that hunt, kill and eat other animals as their source of food

In order to answer these questions about the impact of top predators on the health of an ecosystem, Paine studied the species' interactions on the rocky shoreline of Washington. For his experiment, Paine removed the top predators from a portion of the rocky shoreline. The top predator that he removed and returned to the ocean was a type of starfish, *Pisaster ochraceus*, which preys, or feeds on, other organisms, such as snails, mussels and barnacles, that live in the ecosystem. In the area of the shoreline next to the removal site, he left the ecosystem in its original state as a control group, with the top predator starfish still feeding on the other species.

■ **Figure 9.4a** *Pisaster ochraceus* is the top predator in the tide pools of the rocky coastlines where it lives

■ **Figure 9.4b** Mussels, snails and barnacles make up part of the diet of *Pisaster*

For the next 10 years, Paine kept the experimental area of the ecosystem free from any *Pisaster* that migrated there. Throughout the time of the experiment, he made observations and collected data about the numbers and types of different species that lived in the experimental area, and compared that to his observations and data from the control area. His results surprised and impressed not only him, but many members of the scientific community. Indeed, his findings and conclusions about the role of top predators in an ecosystem have formed the foundation of ecological principles on species interactions.

So, what is your hypothesis? Considering that a healthy ecosystem is one that has a diverse variety of species interacting, what impact do you think removing top predators has on an ecosystem? Will removing top predators help the ecosystem to be more diverse, stable, and healthy, or will removing the top predators make the ecosystem less diverse, unbalanced, and unhealthy? In this activity, you will process some of Paine's data and **present** it in a graph. You will then be able to **analyse** the results to **determine**, as Paine did, the impact that top predator removal has on the ecosystem.

- **Will removing top predators help the ecosystem to be more diverse, stable and healthy, or will removing the top predators make the ecosystem unbalanced and unhealthy? What makes you say that? Write your ideas down, and share with your partner or the class.**

■ **Table 9.2** Average number of species per year in coastal ecosystems with *Pisaster* present and with *Pisaster* removed

Year	Number of species	
	With *Pisaster*	Without *Pisaster*
1963	17.0	18.0
1964	17.5	13.0
1965	17.8	7.5
1966	18.0	2.5
1967	18.2	2.5
1968	19.0	2.5
1969	19.5	2.0
1970	19.8	2.0
1971	19.9	1.5
1972	20.0	2.0
1973	20.1	2.5
Average		

Use the data in Table 9.2 (page 225) to make two graphs to:

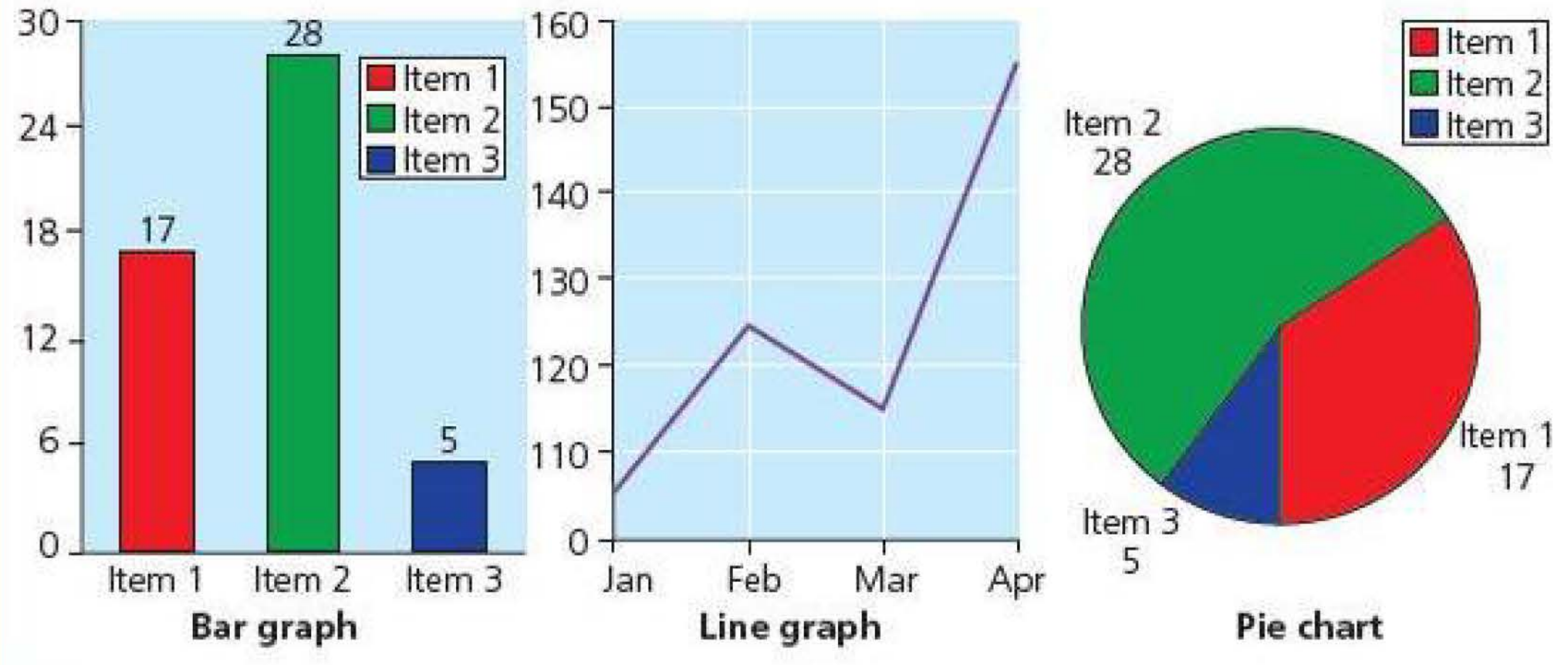
- **show the pattern in the number of species from 1963 to 1973**
- **compare the average number of species in the two areas by the end of the experiment.**

Here are some guidelines to help you in making your graphs.

Before you begin, decide which type of graph you should make in order to best show the relationships in the data.

Some questions to consider in deciding the type of graph are:

- **Which is the best type of graph (from Figure 9.5) to show:**
  - **a trend over time**
  - **a percentage or fraction of a whole and**
  - **an average of final results?**
- **What does the data (Table 9.2) from Paine's experiment on *Pisaster* show? There can be more than one correct answer.**
  - **a trend over time**
  - **a percentage or fraction of a whole or**
  - **an average of final results**
- **Therefore, what type of graph(s) should you create in order to:**
  - **show pattern in the number of species from 1963 to 1973**
  - **compare the average number of species in the two areas by the end of the experiment?**
- **What will you put on the *y*-axis? Remember, the *y*-axis should be the dependent variable, or the 'results' that are counted, measured, or calculated in the experiment.**
- **What will you put on the *x*-axis? Remember the *x*-axis can be the independent variable, or the factor the experimenter changes or manipulates; or, the *x*-axis can show the time during which the results are being recorded.**



■ **Figure 9.5** Types of graphs and charts

After you make your graphs, answer and **discuss** these questions:

- **What is the effect of removing *Pisaster* from the rocky shoreline ecosystem? What data from the graphs supports your answer?**
- **Does removing *Pisaster* result in more or less species diversity? What data from the graphs supports your answer?**
- **Does removing *Pisaster* result in a more or less stable ecosystem? What data from the graphs supports your answer?**
- **What can you conclude about the effect of top predators on an ecosystem? Do they contribute to or take away from the diversity, stability, and health of an ecosystem?**
- **How does your hypothesis compare to the results of the experiment? Was your prediction and reasoning correct or incorrect? Why?**
- **How effective was Paine's method in determining the effect of removing a top predator from an ecosystem? In other words, what aspects of Paine's experiment made his results reliable or 'trustworthy'? What might he have done differently to improve the experiment?**

◆ Assessment opportunities

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

In this activity we have practised the skill of processing data and reporting the results. We used a summary of Paine's data to make graphs and interpret the meaning of the results. We then shared our understanding of the results with the class.

SUMMARY REFLECTION

We have processed and analysed data from a foundational experiment in the field of community ecology. We have seen how removing a top predator from an ecosystem can result in an ecosystem that is less diverse, less stable and less healthy.

EXTENSION

ATL

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

Paine conducted his experiments many years ago. What have experiments shown since then? Is there more support for and examples of the crucial role top predators have in maintaining a balanced ecosystem? Perhaps you can research about your local ecosystem to learn if there have been any investigations about species interactions in the natural areas where you live.

Can you find more current studies and information about the role of predators in ecosystems? Use these search terms: top predator, role, ecosystem.

DISCUSS

With your partner or the class, **discuss** the following:

- **How do the findings from Paine's and others' research compare to your predictions of the effect of top predators?**
- **Why might the top predator have such an impact on the ecosystem? Suggest some reasons.**

What are the interconnected roles and functions that contribute to a balanced ecosystem?

As we understand from our prior learning and reading about Paine's experiment, different species have different roles or 'positions' in an ecosystem. These roles or 'positions' are largely based on their feeding needs and habits. For example, as was mentioned in the information about Paine's experiment, animals such as *Pisaster* that prey (or hunt and feed on) on other animals are called predators; the animals that are eaten by the predators, such as mussels and barnacles, are called **prey**. In addition, there are other organisms called **producers**, such as seaweed or plants, because they create (or produce) their own 'food' by harnessing energy from their surroundings, and are eaten by many organisms in the ecosystem. Therefore, we can say that one of the functions of prey and producers is to provide a source of food and energy in an ecosystem, whereas one of the functions of predators is to eat other organisms and keep their population sizes in balance. These interactions of eating and being eaten make up what is known as a **food chain** or **food web** in an ecosystem.

Of course, this principle of eating or being eaten in an ecosystem is not so simple. Take a moment to consider an ecosystem with which you are familiar. Maybe it is a **terrestrial** (land) ecosystem such as a deciduous forest, rainforest or grassland; or maybe it is an **aquatic** (water) ecosystem, such as a coral reef, river or marsh. Now, think about this: do the predators only eat other animals? Or do they eat plants, too? Do the animals that are prey only eat plants? Or can they eat animals as well? In other words, can predators also be prey, and can prey also be predators?

Figure 9.6 Deciduous forests, tropical rainforests, grasslands, coral reefs, rivers, and marshes are all examples of ecosystems

The answer to all of these questions is both yes and no.

Let's take a closer look at a unique ecosystem located in Yellowstone National Park in the United States in order to see what happens in a real ecosystem. The Yellowstone ecosystem is made up of mountains, grasslands and forests; a variety of large and small **fauna** (animals), such as deer mice, wolves, grizzly bears, elk and bison; various birds, reptiles, amphibians and insects; and **flora** (plants), such as pine trees, aspen trees, sagebrush and many different kinds of grasses and wildflowers. In the next activity, you will read a list of facts about the eating habits of different species at Yellowstone, and use this information to fill in a sample food web. This activity will help you answer the questions in the previous paragraph, as well as the factual inquiry question, 'What are the interconnected roles and functions of different species that contribute to maintaining balance in an ecosystem?'

Figure 9.7 Yellowstone National Park is located in the northwest corner of the state of Wyoming in the United States

ACTIVITY: Eat or be eaten (or maybe both)

ATL

- Organization skills: Use appropriate strategies for organizing complex information

Scientists use many different ways to organize and make sense of what they observe, investigate and understand. For example, scientists identify and organize the patterns in which organisms interact in different ecosystems.

One of the tools that scientists use to categorize and organize the interactions between organisms in an ecosystem is a food web. A food web refers to the network or connections between what organisms eat in an ecosystem. In a food-web diagram, the *producers* (plants) and *consumers* (animals) are drawn or written in, with arrows to connect the organisms that are *eaten* with the organisms that are *eating*. Depending on the diversity of the ecosystem, a food web can be very simple with few connections, or very complicated with many connections.

To practise making a food web, use the facts about some of the organisms living in Yellowstone (below) and the food-web template (Figure 9.8) to create a food web for the Yellowstone ecosystem. A portion of the food web has been done for you as an example. Follow the example to help you fill in the remainder of the food web. Remember, use arrows to connect the organism that is eaten to the organism that is eating (organism eaten → organism eating).

Note that in this food web there may be some different ways to fill in the template as you move left to right on each level, but not as you move up and down between levels. Also, you can choose simply to write in the names of the organisms to fill in the food-web template, or use your computer to put pictures of the organisms in the food web.

- **Elk eat quaking aspen.**
- **Mayflies and trout eat green algae.**
- **Bison, deer mice and bighorn sheep eat grey willow.**
- **Trout eat mayflies.**
- **Red-tailed hawks, coyotes and grizzly bears eat deer mice.**
- **Grizzly bears, grey wolves and coyotes eat elk.**
- **Coyotes and grey wolves eat bison.**
- **Grey wolves eat bighorn sheep.**
- **Grizzly bears and osprey eat trout.**
- **Bald eagles eat osprey.**
- **Grey wolves eat bald eagles.**

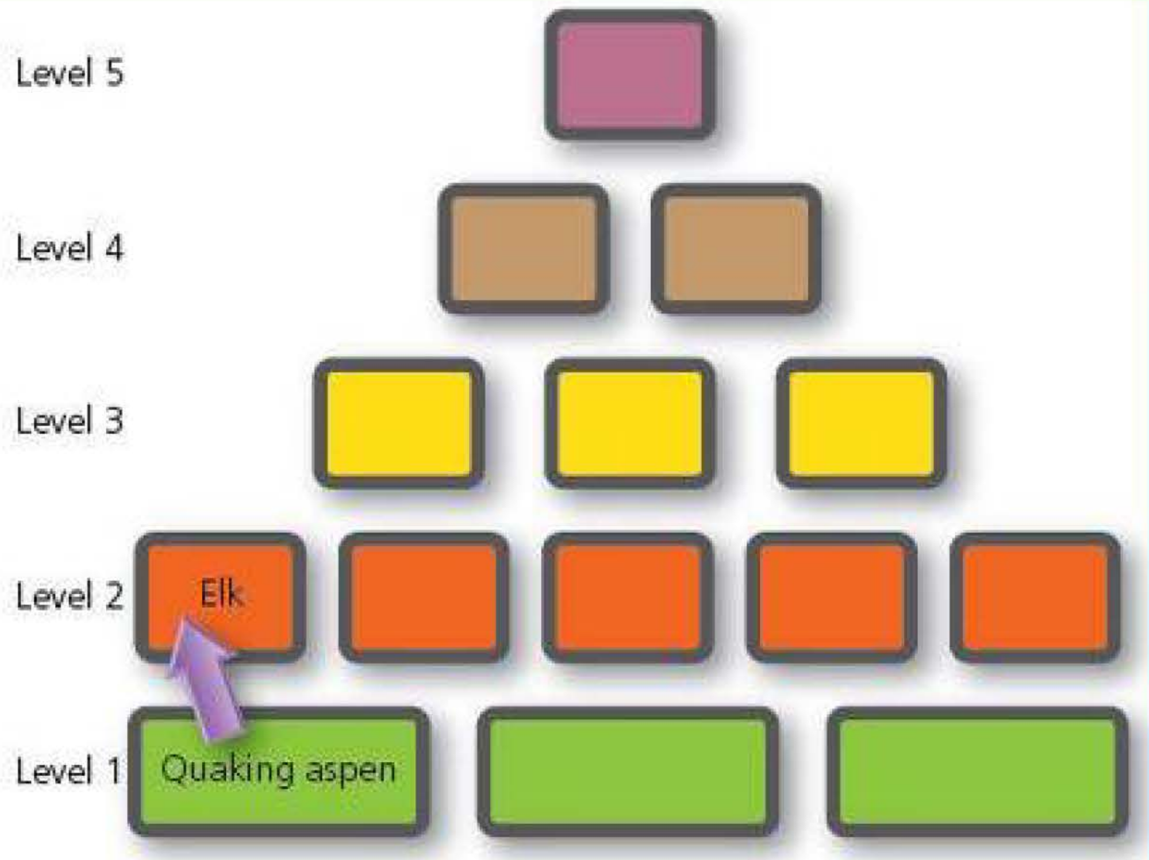


Figure 9.8 Food-web template for Yellowstone ecosystem

When you have finished your food web and compared it with those of your classmates, make a list of the general patterns between organisms in the food web, using the heading 'Some patterns I notice about the interactions between the organisms in a food web'.

In this activity we have used the food web as a model to explore and make generalizations about a complex system and to understand the interactions between organisms in an ecosystem.

EXTENSION

ATL

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

Can you construct a food web for another ecosystem? To begin, think of an ecosystem you are either familiar with or interested in. It could be a large ecosystem, such as a rainforest, or a small ecosystem, such as a pond or tide pool.

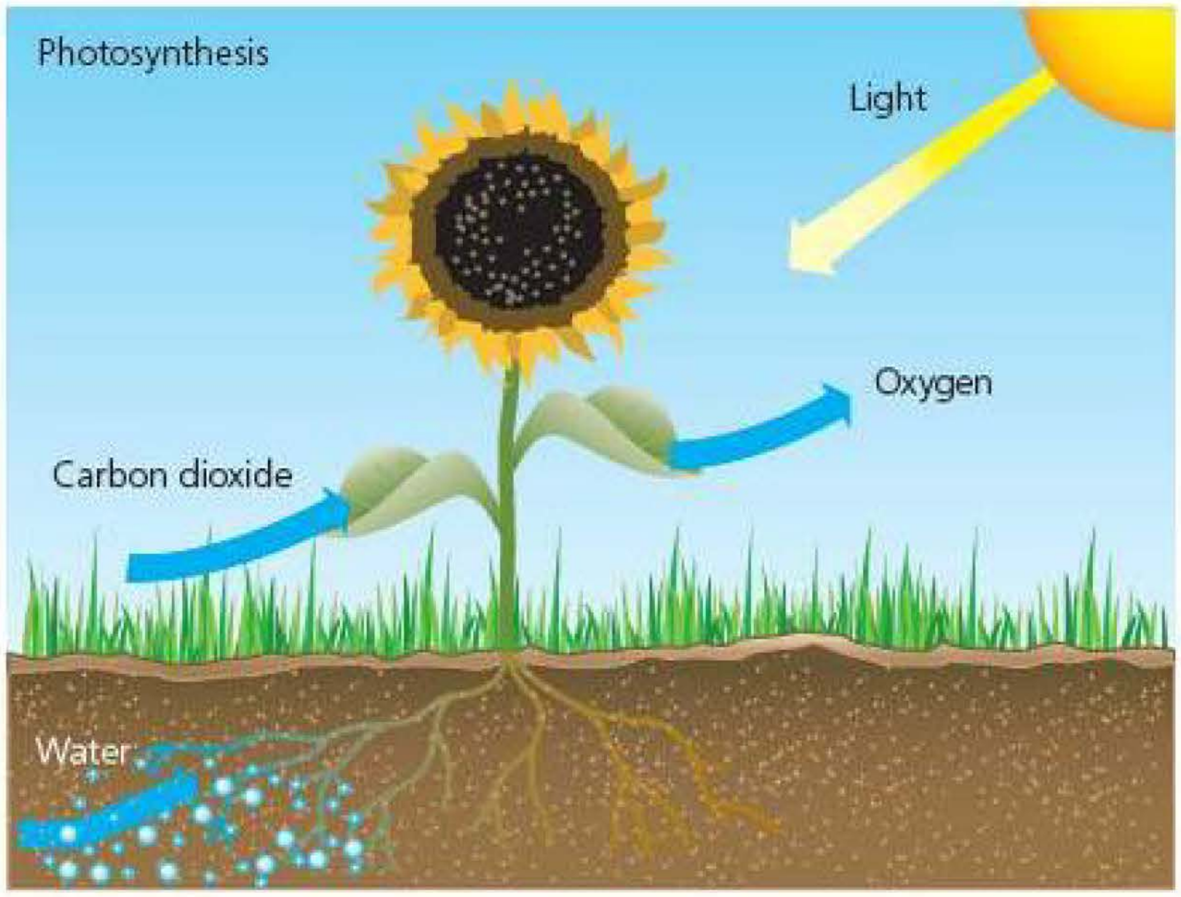
Then do an Internet search for the producers, primary consumers, secondary consumers and maybe tertiary and quaternary consumers in the ecosystem of your choice. For example, you could type **rainforest producers** or **rainforest primary consumers** in your search bar. Arrange the organisms you learn about from your search in the levels as we did for the Yellowstone ecosystem, and draw in arrows to show what is eaten and what is eating.

Alternatively, you can search for an already constructed food web for your ecosystem of choice by simply typing in the ecosystem followed by the words food web. For instance, to find the food web of the rainforest, you can type **rainforest food web** in the search bar.

What do you notice about the interactions between organisms in the ecosystem you researched and the Yellowstone ecosystem? In what ways are they similar? How do they differ?

FLOW OF ENERGY

Through the previous activity, we see that producers (plants) make up the foundation of the food web. The producers have a very important role in the ecosystem, because they are the only organisms that are able to convert inorganic molecules (from carbon dioxide) and light energy from the Sun – which animals are not able to use as an energy source – into a form of chemical energy – sugars – that animals *can* use for energy (Figure 9.9). The fact that plants have the ability to convert light energy into chemical energy in the process of photosynthesis is vital for the survival of all organisms on the planet, because sunlight is the original source of energy for the planet.

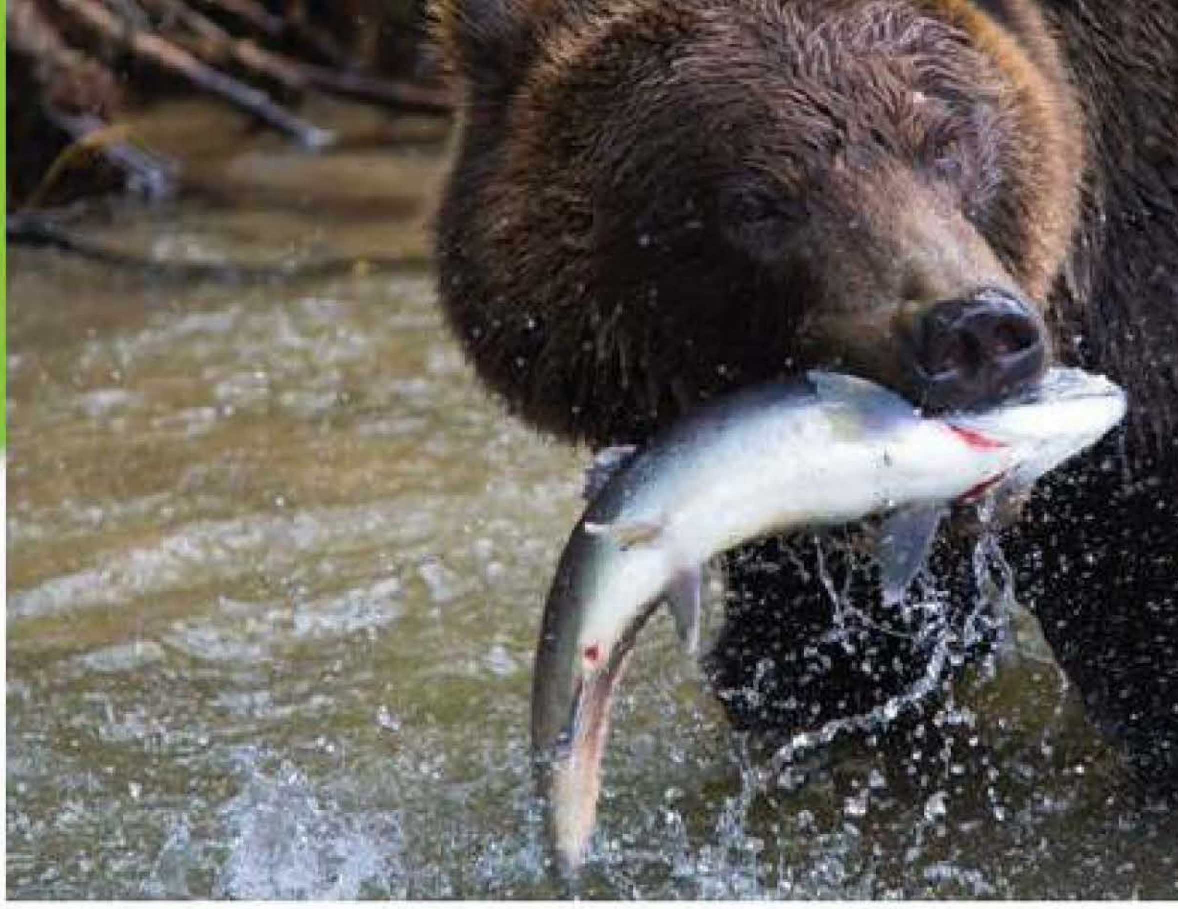


■ **Figure 9.9** Just like the energy available in flour is not usable to us until we chemically transform it during the baking process, the energy available in the Sun is not usable to us until plants transform it during the photosynthesis process

Interestingly, in ecosystems such as those deep below the surface of the ocean, where the energy of the sunlight does not reach, microscopic organisms use a process called **chemosynthesis** (Figure 9.10) instead of photosynthesis. In the process of chemosynthesis, the chemosynthetic microbes convert inorganic molecules and heat energy from geothermal vents that consumers cannot use into forms of chemical energy that consumers can use.

■ **Figure 9.10** Bacteria and other micro-organisms that live in the deep sea and far away from the energy from sunlight, use the energy from thermal vents to transform inorganic molecules into organic molecules in the process of chemosynthesis

■ **Figure 9.11** Green plants and a rabbit are examples of producers and primary consumers



■ **Figure 9.12** Salmon and a brown bear are examples of secondary and tertiary consumers

MEMBERS OF A FOOD WEB

The animals that eat plants are **primary consumers** (primary means first). Primary consumers are important to an ecosystem because, by eating the producers, they help to control the population size of the producers. This helps to ensure that the producers have sufficient access to sunlight, water, space and other **resources** so they can continue to grow, develop and reproduce. This 'weeding out' that occurs from feeding also ensures that a variety of producers can live in an ecosystem, not just those that grow very tall or very fast. In turn, this further benefits the ecosystem because not all primary consumers can eat the same types of plants (compare yourself to a cow – even though you can eat many plants, such as spinach or lettuce, if you tried to eat grass, it would make you sick; cows, however, are happy to eat grass as their main source of food), so the greater the variety of producers, the greater the variety of primary consumers.

Pause now and label the organisms in your food web that are *producers* and *primary consumers*.

Animals that eat primary consumers are **secondary consumers** … and the animals that eat secondary consumers are **tertiary consumers** (tertiary means third) … and the animals that eat tertiary consumers are **quaternary consumers** (quaternary means fourth). In a similar way to the primary consumers, the secondary, tertiary and quaternary consumers function to control the populations of the organisms they eat. Keeping the population of animals an appropriate size is important so that, like plants, animals have sufficient access to the food, water and space they need to live and reproduce, and that no one variety or species has an advantage. As soon as one species has an advantage and it is very easy for that species to survive and reproduce, other species are at a disadvantage and the ecosystem becomes less diverse and less balanced.

Pause now and label the organisms in your food web that are *secondary*, *tertiary* and *quaternary consumers*.

The importance of having a diverse and balanced ecosystem in order for the ecosystem to be healthy has been mentioned a couple of times in this section. But why is it that an ecosystem with a variety of different species is healthier than an ecosystem with only a few species? Maybe it will help to compare an ecosystem with a football league. In a football league, there are teams and players with different skills, strengths and weaknesses. Although there are tendencies for certain teams and players to play better or win more than others, all teams in the league have a chance of winning at any particular match – that is why it is fun and exciting to play and watch. In addition, there are rules and regulations to ensure that no one team or player has an unfair advantage over the other teams and players.

Now imagine the situation if the players of *one* team were given access to better equipment, better coaches, water during the matches and more time to rest between games, but the players of all the other teams were given damaged equipment, poor coaches, no water during the matches and little time between matches. Instead of having exciting, competitive football matches, with members of each team having a chance to win, there would be boring, predictable matches with the better-equipped team winning each time.

DISCUSS

With your partner or the class, **discuss** the analogy of the interactions between players and teams in a football league with the interactions between organisms in an ecosystem.

- **What do the different components of the football league analogy represent in an ecosystem? Some things to consider when making connections are the players; better-equipped team; less-equipped teams; access to equipment, coaches, water, and rest time; winning the matches; and fans no longer watching the matches.**
- **Why is it important for an ecosystem to have a variety of organisms in order for the ecosystem to be balanced and healthy?**

Before long, the better-equipped team would have out-competed all of the other teams. If that pattern continued, after a while, the fans of the less-equipped teams would get tired of seeing their teams lose … they would stop watching on television and stop paying to go to the matches. And, if there is no money, there is no more football league. If there is only one team that could win, it leads to a lack of diversity, and a lack of balance that eventually makes the whole system collapse.

As we can see in the food web, some consumers eat only plants; these types of consumers are known as **herbivores** (herb = plant, and -ivore = eater). Other consumers eat animals as well as plants, and are known as **omnivores** (omni = all, and -ivore = eater). Consumers that eat only animals are known as **carnivores** (carn = meat or flesh, and -ivore = eater). Remember, animals that eat other animals can also be called predators; the predator(s) that are at the top of the food web are also known as *top predators*.

Pause now and label the organisms in your food web that are *herbivores*, *omnivores*, and *carnivores*. Also label the *top predator*.

The different levels on the food web are called **trophic** (meaning *feeding* or *nutrition*) **levels**. Producers (plants) make up trophic level 1, and animals make up all of the other trophic levels, starting with trophic level 2. Some more simple ecosystems might have only three trophic levels, whereas other, more diverse or complex ecosystems, such as the Yellowstone ecosystem, can have four or five trophic levels. Notice that trophic level 2 can be composed of herbivores or omnivores, and trophic levels 3 and higher can be composed of omnivores or carnivores.

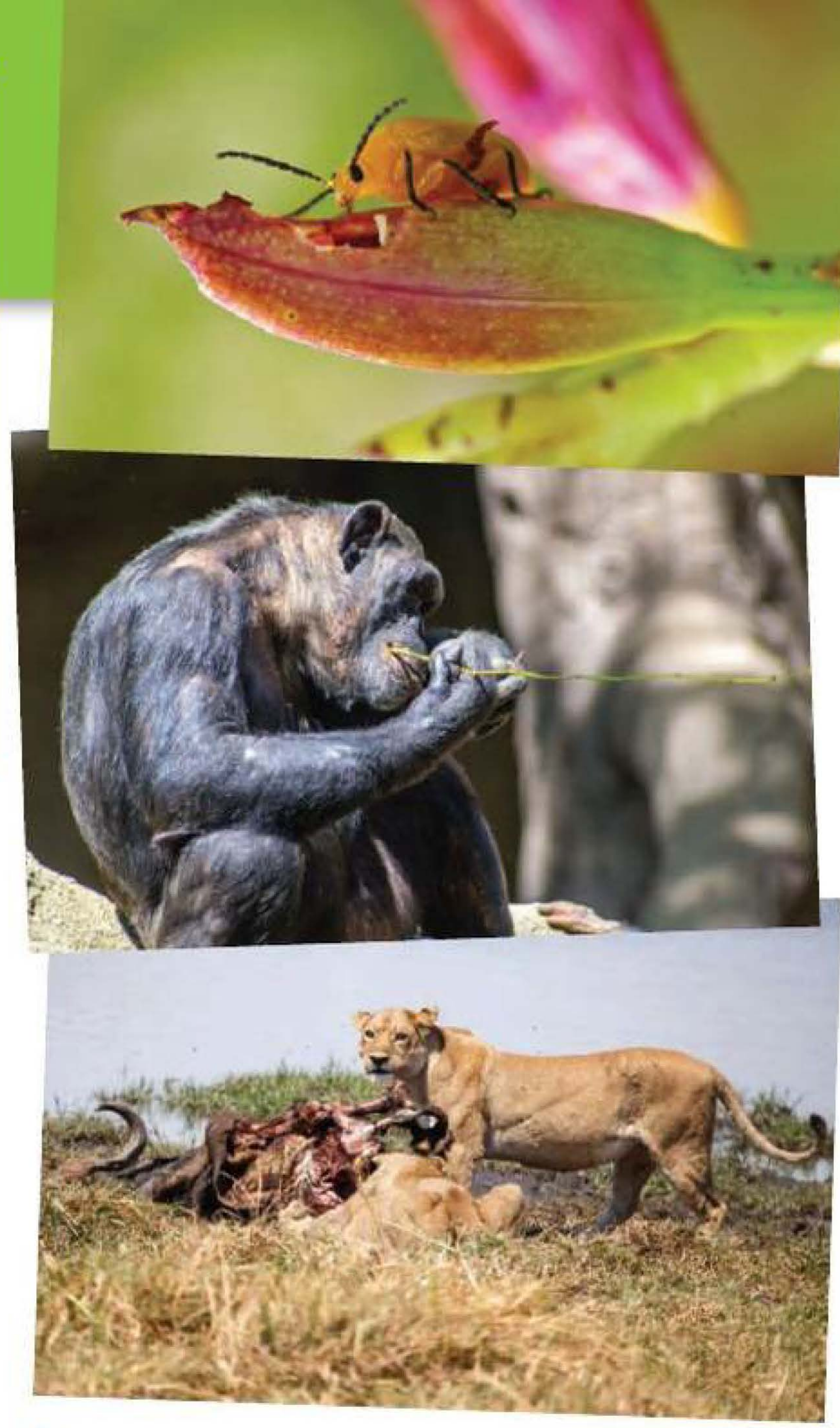
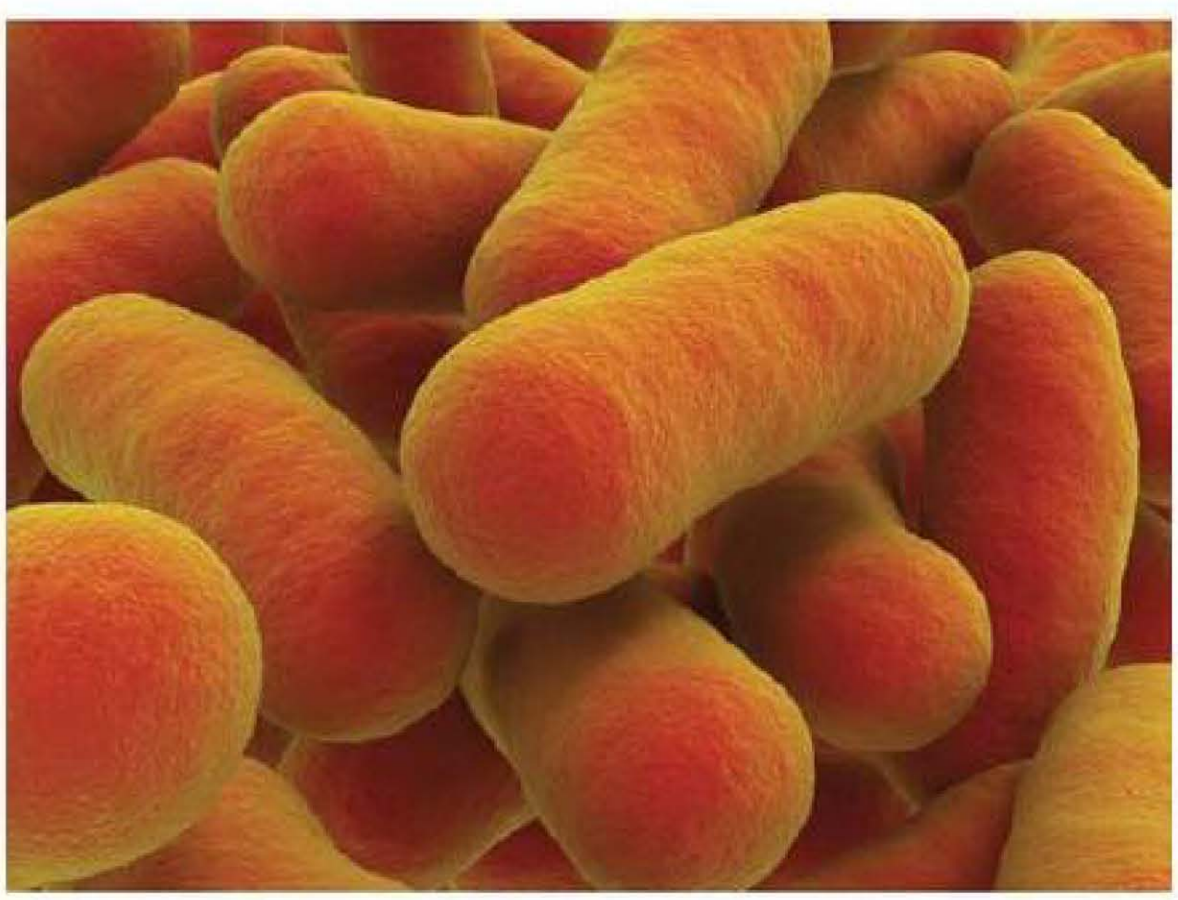


Figure 9.13 Examples of herbivores, omnivores and carnivores

Pause now and label the *trophic levels* on the Yellowstone ecosystem food web.

At this point, you might be wondering, who eats the top predators? Or, what happens to the animals and plants that die and but are not eaten? We know that the world is not filled with top predators like grey wolves and lions and *Pisaster*, and we also know that the once an animal or plant dies, it does not stay there forever. So why is this?

It turns out there are (often 'invisible') members of the food web that hold a very important job. Just as consumers have the important job of keeping the numbers of living plants and animals under control by feeding on them, another category of organisms, called **decomposers**, have the crucial role of keeping the number of dead plants and animals under control by breaking down dead organisms.



■ **Figure 9.14** Mushrooms, moulds and bacteria are all examples of decomposers known as saprotrophs

The most important members of the decomposers are fungi (such as mould and mushrooms) and bacteria; these organisms are known as **saprotrophs**, and they break down dead plant and animal tissue through the process of chemical digestion. Though these tiny organisms do not 'eat' the dead plants and animals for energy as animals do, they are able to use the products of chemical digestion as nutrients to perform their life functions. We often cannot see saprotrophs, but these microscopic members of every ecosystem work busily to break down the remnants of plants and animals.

The more 'visible' members of the decomposers are the **detritivores**, such as worms and maggots, and the **scavengers**, such as vultures and hyenas. Unlike saprotrophs, detritivores and scavengers are animals, and they eat dead plants or the remnants and leftovers of animals that died by natural causes or that were hunted by predators. Similar to the saprotrophs, the detritivores and scavengers help to keep their ecosystems free of dead plant and animal tissue.

■ **Figure 9.15** Worms and maggots are examples of the decomposers known as detritivores

ACTIVITY: A web of information

ATL

- Creative-thinking skills: Practise visible thinking strategies and techniques
- Organization skills: Use appropriate strategies for organizing complex information

In this section, we have learnt a lot about the organisms that make up an ecosystem, and the roles that these organisms have in order to keep the ecosystem in balance.

Whenever we are exposed to a lot of information and new words, it can be challenging to make connections between or remember the important concepts. In order to help in this process, it can be helpful to use a thinking routine designed to help you generate, sort, connect and elaborate on the big ideas.

Figure 9.16 shows the steps for you to do on your own or with a partner and then share with the class.

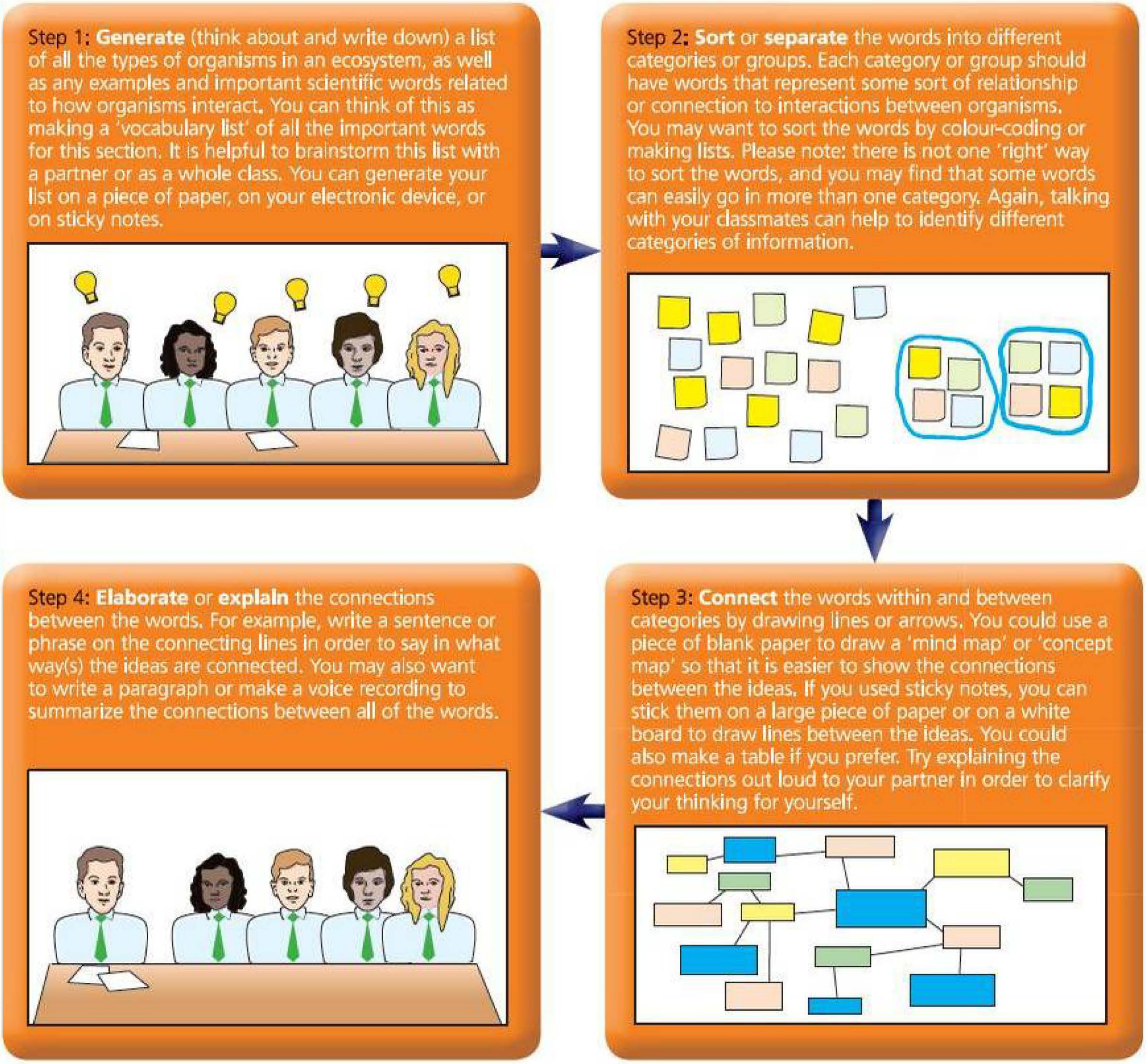


Figure 9.16 Thinking routine – Generate, Sort, Connect, Elaborate

How do changes in species' functions and interactions influence the balance in an ecosystem?

APPROACHES TO EATING

We have learnt about the roles and functions different species have within an ecosystem. We know that ecosystems are made up of different 'eaters' which, through their feeding habits, help to keep the populations of the organisms they eat under control. These interactions are natural and uncontrollable; the organisms are programmed by their DNA to interact with other organisms in a certain way. These organisms do not choose what to eat in the way that we do. (Elk don't think, 'Hmmm. What do I want for breakfast today? Hey! I think some aspen sapling leaves would be a good treat.') Instead, it is a natural instinct within the animal, coupled with its physical characteristics, that drive what and how they eat.

These pictures show some examples of interactions in ecosystems that are driven by the natural instinct and need for food. Make some notes on the interactions you notice between the named organisms. You will use your notes to construct a table to summarize different types of interactions between species.

In Figure 9.17a, the elk is eating the aspen tree saplings; in other words, the aspen saplings are the food source for elk. (Look back at the previous section to see where the elk and aspen are in the food web.) Elk are herbivores, so this interaction is called **herbivory**. Similarly, in Figure 9.17b, we can see the grey wolves are hunting the elk; we can infer that the wolves will kill and then eat the elk. (Look back at the previous section to see where the grey wolves and elk are in the food web.) Grey wolves are predators, so this interaction is called **predation**.

Until this point, the interactions we have focused on have all been about food. But is everything about eating? Does everything in an ecosystem come down to kill or be killed?

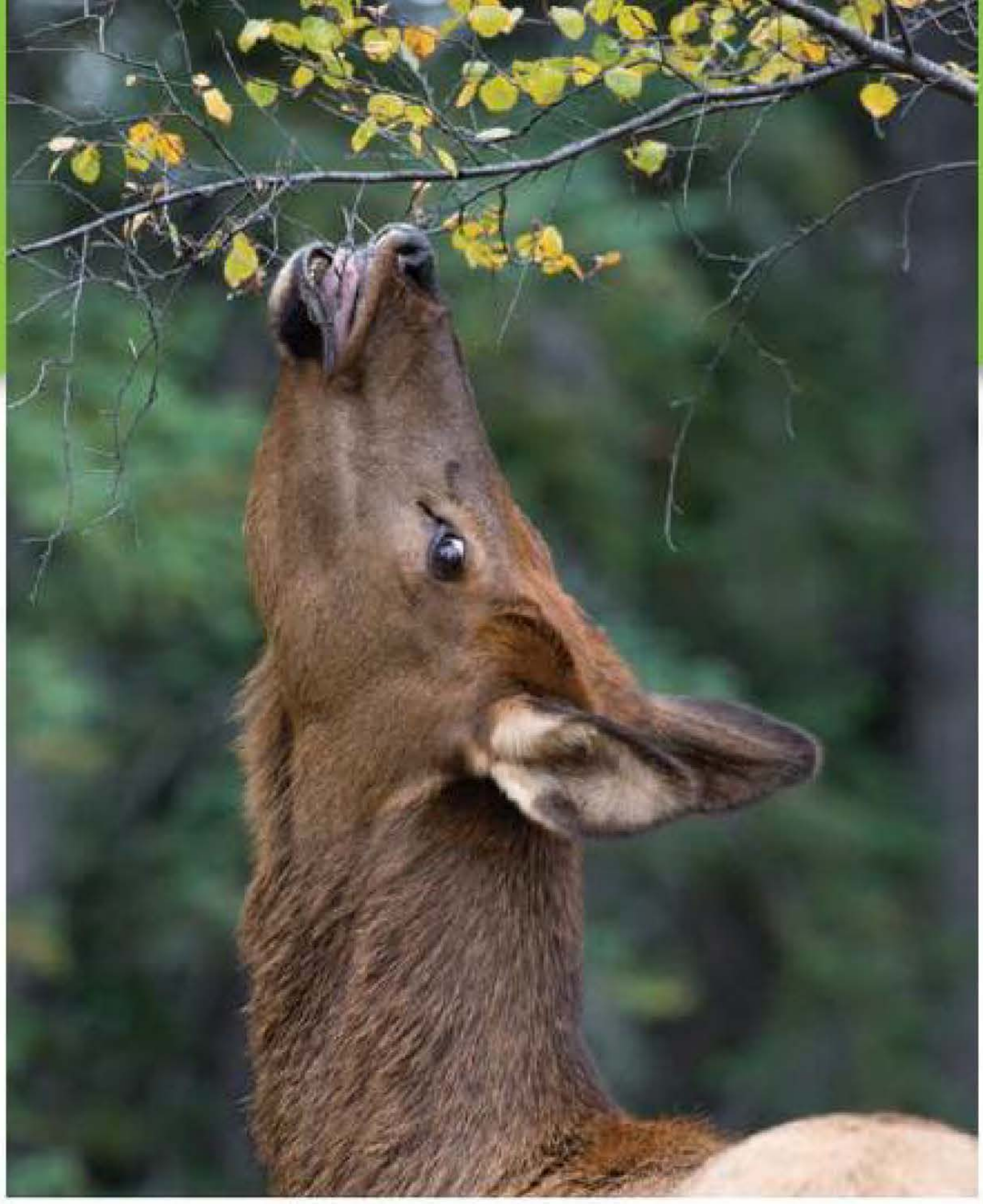


Figure 9.17a Elk eating leaves from an aspen tree sapling

Figure 9.17b Wolves hunting for and preying upon an elk

Are there any examples of 'I'll scratch your back if you scratch mine' in an ecosystem? Do animals ever help each other out, or is it each one for itself?

In the next activity, you look again at different species in the Yellowstone ecosystem, and read about the different ways in which these species interact. You will use that information to identify trends in the interactions to determine which species benefit from the interactions, and which species are at a disadvantage.

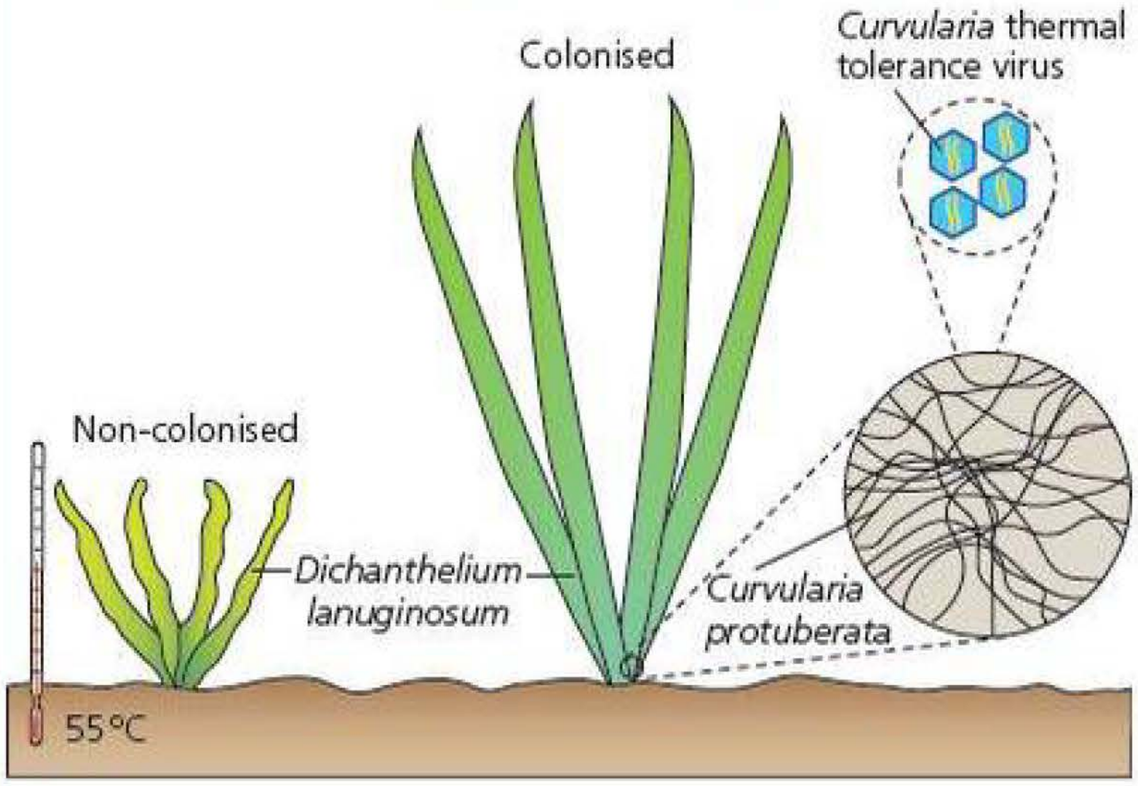
ACTIVITY: Enemies, friends and strangers

■ ATL

- Communication skills: Make inferences and draw conclusions

For each of the 'snapshots' of species interactions, observe the organisms carefully and read the information. Then, use your observations and the written information to fill in the table of interactions.

Dichanthelium lanuginosum or 'panic grass'



■ **Figure 9.18** Panic grass

Dichanthelium lanuginosum, or 'panic grass', is a unique plant because it is able to grow in soil temperatures that are much higher than those in which most other plants can grow. In fact, because Yellowstone has geothermal (thermal = hot) soils, the soil temperature where panic grass grows is consistently above 50 °C. Panic grass is able to grow in these extreme temperatures because of a fungus, *Curvularia protuberata,* which lives on the grass's roots and helps the grass get access to more water. *Curvularia protuberata* is a fungus that needs plants as a source of food. In addition, a virus called *Curvularia* thermal tolerance virus, which is naturally adapted to survive in very hot conditions, lives in and depends on the fungus for a place to live and means to reproduce. In exchange for living and reproducing in the fungus, the virus is able to 'pass on' its ability to survive in extreme heat. As a result, the fungus is able to survive in the extreme heat and the panic grass can tolerate life in the hot soil.

Organism	Does the relationship have a positive (+), negative (–) or neutral (N) effect on the organism?	What makes you say that?
Dichanthelium lanuginosum (panic grass)		
Curvularia protuberata (fungus)		
Curvularia thermal tolerance virus		

Catbirds

■ **Figure 9.19** Catbird eggs

Catbirds are songbirds that make their nests and lay their eggs in trees or shrubs that are covered in many branches and leaves. In Yellowstone, catbirds nest in willow trees, which provide the catbirds with protection and 'camouflage' for their eggs and offspring. Catbirds do not eat the willow trees; they just build their nests there and eat berries from trees and bushes that grow near the willow trees.

Organism	Does the relationship have a positive (+), negative (–) or neutral (N) effect on the organism?	What makes you say that?
Catbird		
Willow tree		

➤

Sarcoptes scabiei

■ **Figure 9.20** Wolf with mange

In the Yellowstone ecosystem, wolves and coyotes get a skin infection called mange from a mite (small insect) called *Sarcoptes scabiei*. The mites dig down into the skin cells of the coyotes and wolves, causing them to have itchy, allergic reactions. The coyotes and wolves bite and chew their own skin, causing them to bleed and to be more sensitive to other types of infections. The mites use the coyotes and wolves for a place to live, reproduce, and have access to nutrients; in the process, the mites cause the coyotes and wolves to get sick, weak and sometimes even die.

Organism	Does the relationship have a positive (+), negative (–) or neutral (N) effect on the organism?	What makes you say that?
Wolves and coyotes		
Sarcoptes scabiei (mite)		

SYMBIOTIC RELATIONSHIPS

Through the previous activity, we can see that in addition to just eating other organisms for food, living things require different types of interactions with other living things in order to survive. **Symbiosis** literally means living together, and it is the scientific word to refer to the fact that different species do not live separately or independently from one another, but, instead, have many different types of interactions with other species throughout their lives.

As we have seen from the previous activity, these symbiotic relationships can be harmful or helpful, or somewhere in between. Table 9.3 summarizes the different types of symbiotic relationships between living things; use the descriptions and your notes from the activity to copy and complete the 'Example' column.

■ **Table 9.3** Summary table of symbiotic relationships

Relationship	Description of the relationship	Effect on the members of the relationship	Example Use the information from the previous activity to fill in the examples
Parasitism	The **parasite** depends on the **host** in order to survive. Without the host, the parasite cannot live. The parasite uses the host as a source of food or shelter. The parasite harms, weakens and sometimes kills the host as a result of their interactions.	+ effect for one member; – effect for the other member(s)	Parasite(s): Host(s):
Commensalism	One organism uses another organism to help in its survival, but has no negative effect on the other individual. In other words, the interaction benefits one organism while doing neither harm nor good to the other organism.	+ effect for one member; no effect on the other member (s)	Benefited organism(s): Unaffected organism(s):
Mutualism	All the interacting organisms depend on and benefit from each other. No individual in the relationship can survive without the other, but no individual is doing harm to the others.	+ effect for both/all members	Benefited organism(s):

Copy and complete Table 9.4 by using smiley and sad faces to represent the situation for the different species in each of the symbiotic relationships.

■ **Table 9.4** Visual summary of symbiotic relationships

Species 1	Species 2	Symbiotic Relationship
		Parasitism
		Commensalism
		Mutualism

In addition to symbiotic and feeding relationships, there are other types of natural interactions between species, which we can see in Figure 9.21a and Figure 9.21b overleaf. Look carefully at the pictures. What do you notice about the interactions between the named species? Why do the species interact in these ways? What are the results of the interactions? Do any of the species benefit from the interactions? Are any of the species harmed from the interactions?

■ **Figure 9.21a** Grey wolves confronting each other

■ **Figure 9.21b** Brown bear confronting a grey wolf

In Figure 9.21a, we see the grey wolves are fighting each other. It is not clear why they are fighting, but in ecosystems where food, water, territory and possible mates are limited, it is necessary for members of the same species to fight for their share. In fact, if the resources are very limited or there are very few possible mates in an ecosystem, the 'losing' individual might die from lack of resources or be killed while fighting for a mate. This type of fighting between individuals in the same species is called **intraspecific competition**, or competition within one species.

In addition to individuals within the same species fighting for limited resources, we can see in Figure 9.21b that individuals from different species can fight for food, water and territory, or to protect their young from predators. Here, the brown bear is threatening the grey wolf. Again, we cannot see why the bear is aggressive toward the wolf, but because the bear and wolf are of different species, we call this type of interaction **interspecific competition**.

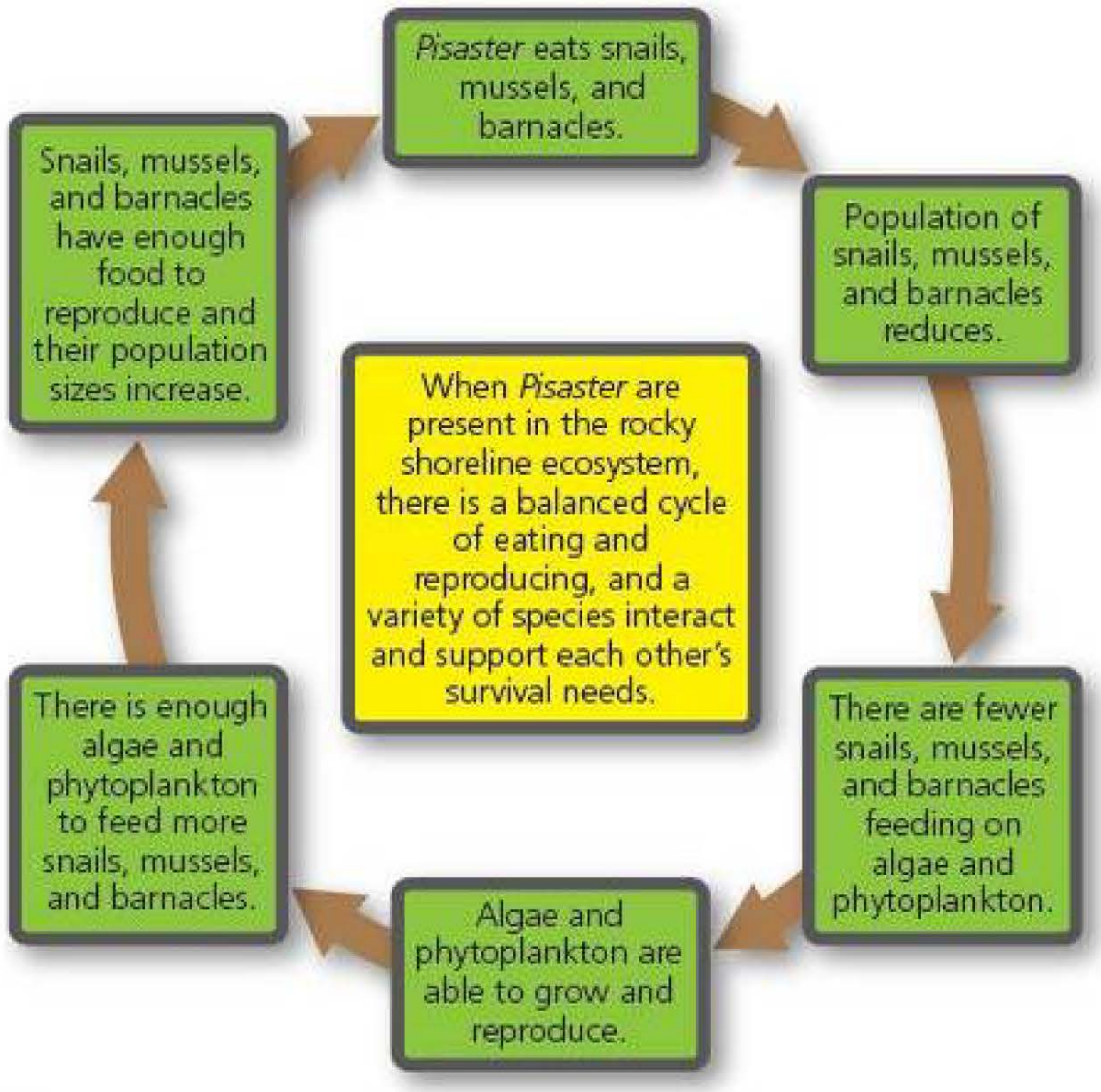
All of the pictures in this section show that some individuals and species can have a powerful influence on the survival of not only other individual organisms, but also on whole species. Let's use Table 9.5 to help organize and summarize the different types of species interactions we have learnt about.

KEYSTONE SPECIES

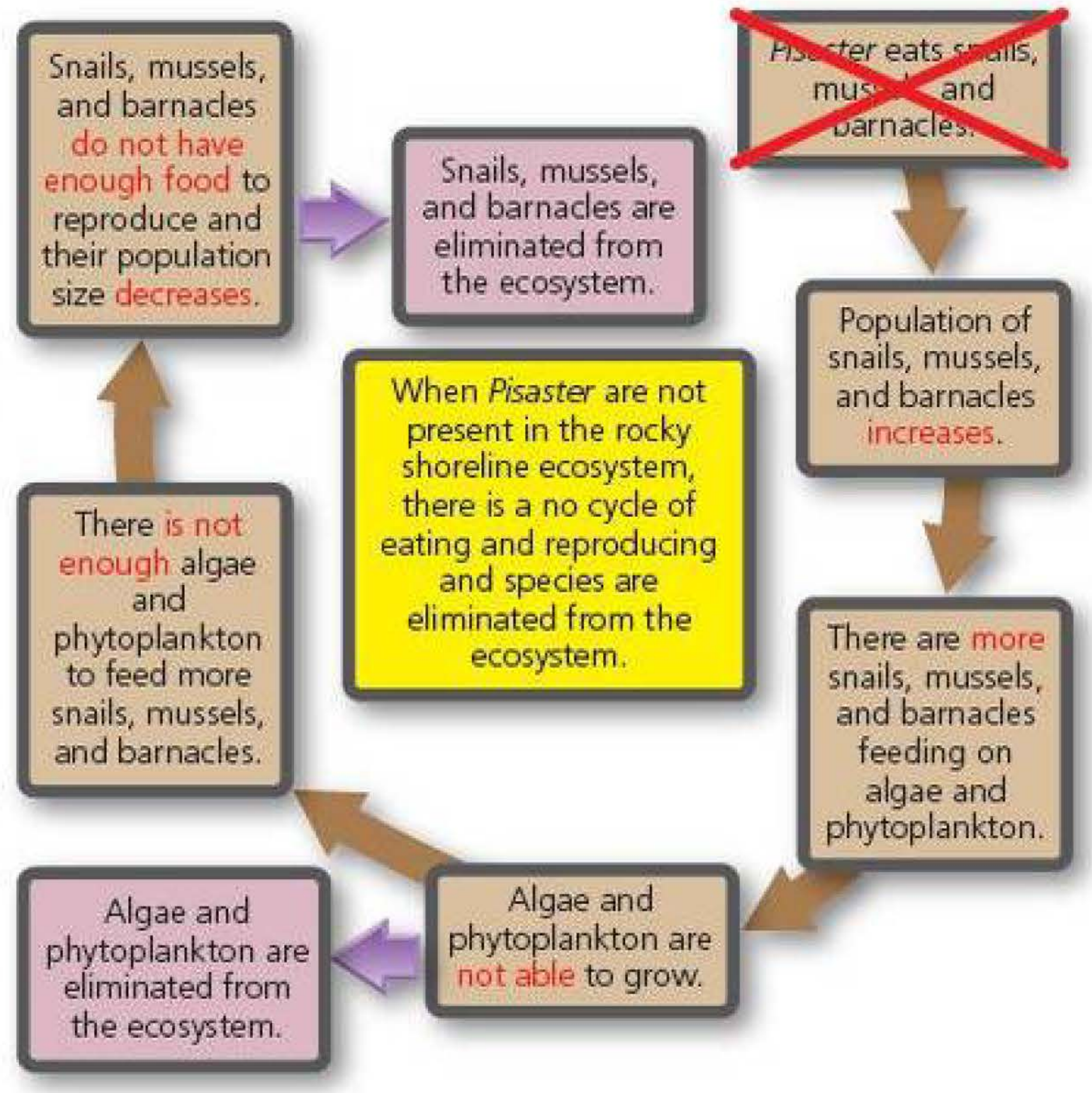
At this point, let's go back to our conceptual inquiry question, 'How do changes or shifts in species' functions and roles, or interactions between species, influence the balance and stability of an ecosystem?' and Paine's experiments and claims about the role of a top predator in maintaining the stability of an ecosystem. We saw from processing and graphing Paine's data that removing the top predator, *Pisaster*, from the rocky shoreline ecosystem resulted in an unbalanced ecosystem with less species diversity. But why did that happen? Let's first take a look at the interactions of some of the organisms in a healthy, balanced rocky shoreline ecosystem (Figure 9.22).

■ **Table 9.5** Table of observations of species interactions

Interacting species	Summary of interactions	Reason for the interaction	Result of the interaction	Name of interaction
Panic grass, *Curvularia protuberata*, and *Curvularia* thermal tolerance virus				
Catbirds and willow trees				
Sarcoptes scabiei and grey wolves				
Elk and aspen tree saplings				
Elk and grey wolves				
Grey wolves				
Brown bear and grey wolves				



■ **Figure 9.22** Interactions in a healthy rocky shoreline ecosystem



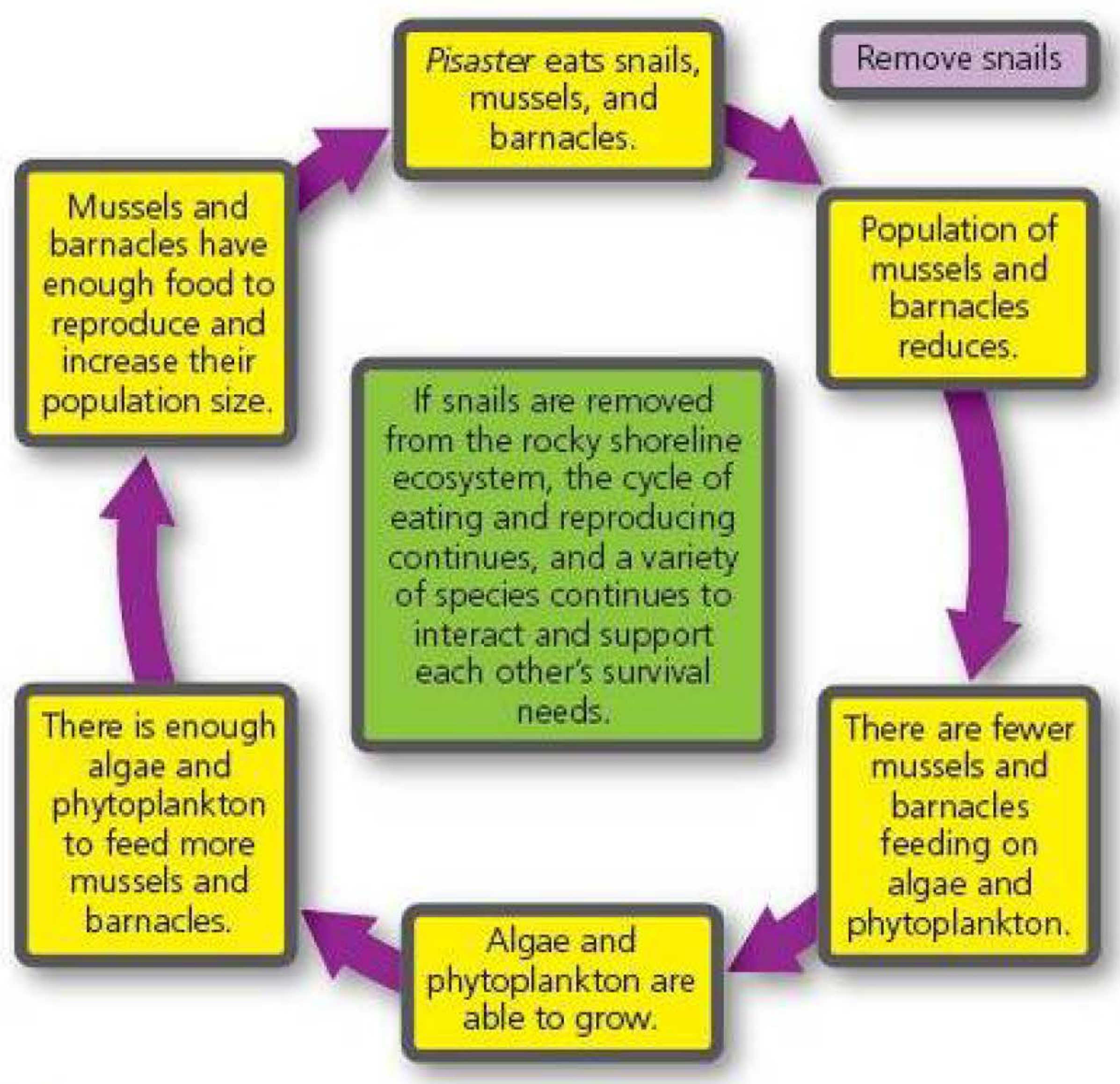
■ **Figure 9.23** Interactions in the rocky shoreline ecosystem after removing *Pisaster*

■ **Table 9.6** Summary table of organisms in a rocky shoreline ecosystem

Trophic level(s)	Organism(s)	Role in food web	Type of 'eater'
1	Green algae Phytoplankton	Producers	N/A – makes own food
2	Barnacles Mussels	Primary consumers	Herbivores; detritivores
2–3	Snails	Primary–secondary consumers	Omnivores
3–4	*Pisaster*	Secondary–tertiary consumers	Carnivores

So, what happens if *Pisaster* is removed, as Paine did in his experiment? Figure 9.23 demonstrates the outcomes over time when *Pisaster* is removed.

But what if Paine had removed another species from the ecosystem? What would happen then? Would the ecosystem still be in balance? Take a look at Figure 9.24 to see the effect on the ecosystem if Paine had removed snails instead of *Pisaster*.



■ **Figure 9.24** Interactions in the rocky shoreline ecosystem after removing snails

As we can see, removing snails does not cause the balance of the ecosystem to be disrupted. Try it on your own, and you will find that the removal of any one other species will not cause the ecosystem to collapse in the way that removing *Pisaster* does.

Paine called species like *Pisaster* – species on which the health, balance and diversity of an ecosystem depends – **keystone species**, because the 'keystone' is the stone in a stone arch that holds the arch together.

Each ecosystem has its own keystone species: a species, often but not always a top predator, that is necessary in order to maintain a healthy balance of species and interactions. Beavers are the keystone species in a wetland ecosystem; prairie dogs are the keystone species in a grassland ecosystem; and grey wolves are the keystone species in the Yellowstone ecosystem.

There are many factors that may cause a disruption to the natural balance and interactions between organisms in an ecosystem. Paine and his scientific research demonstrate one example of how an ecosystem can be disrupted due to the death or removal of some organisms from the ecosystem.

■ **Figure 9.25** In architecture, the keystone (shown in white) is necessary to maintain the integrity and shape of an arch

Some other historic and current examples are:

- powerful storms, such as tornadoes, hurricanes or monsoons
- the overhunting of animals, such as bison or racoons, for food or fur
- the killing of predators, such as bear, lions and wolves, that are considered dangerous to human settlements
- geological events, such as earthquakes, volcanic eruptions and tsunamis
- the accidental poisoning of plants and animals due to chemicals from farming and industry.

As we can see, some of these factors are natural, and uncontrollable, while others result from human decisions and actions. With your partner or the whole class, sort the factors into natural or human-initiated factors, and add some of your own ideas; then, write your thoughts for why the disruption could have negative consequences on the balance of the ecosystem. Finally, offer some suggestions to lessen the damage to the ecosystem's balance.

■ **Table 9.7** Table of factors that affect the interactions and balance of ecosystems

Event/factor	Natural or human-initiated factor	Possible negative consequences	Suggestions to reduce the damage to the ecosystem
Powerful storms			
Overhunting			
Killing predators			
Geological events			
Accidental poisoning			

To what extent should people interfere with interactions in ecosystems to improve human life?

HUMAN IMPACTS

The Statement of Inquiry says 'ecosystems can be in balance when the species sharing their **habitat** have interconnected functions and roles'. So it is important to reflect and discuss the role of humans in the interactions between organisms and the balance of ecosystems.

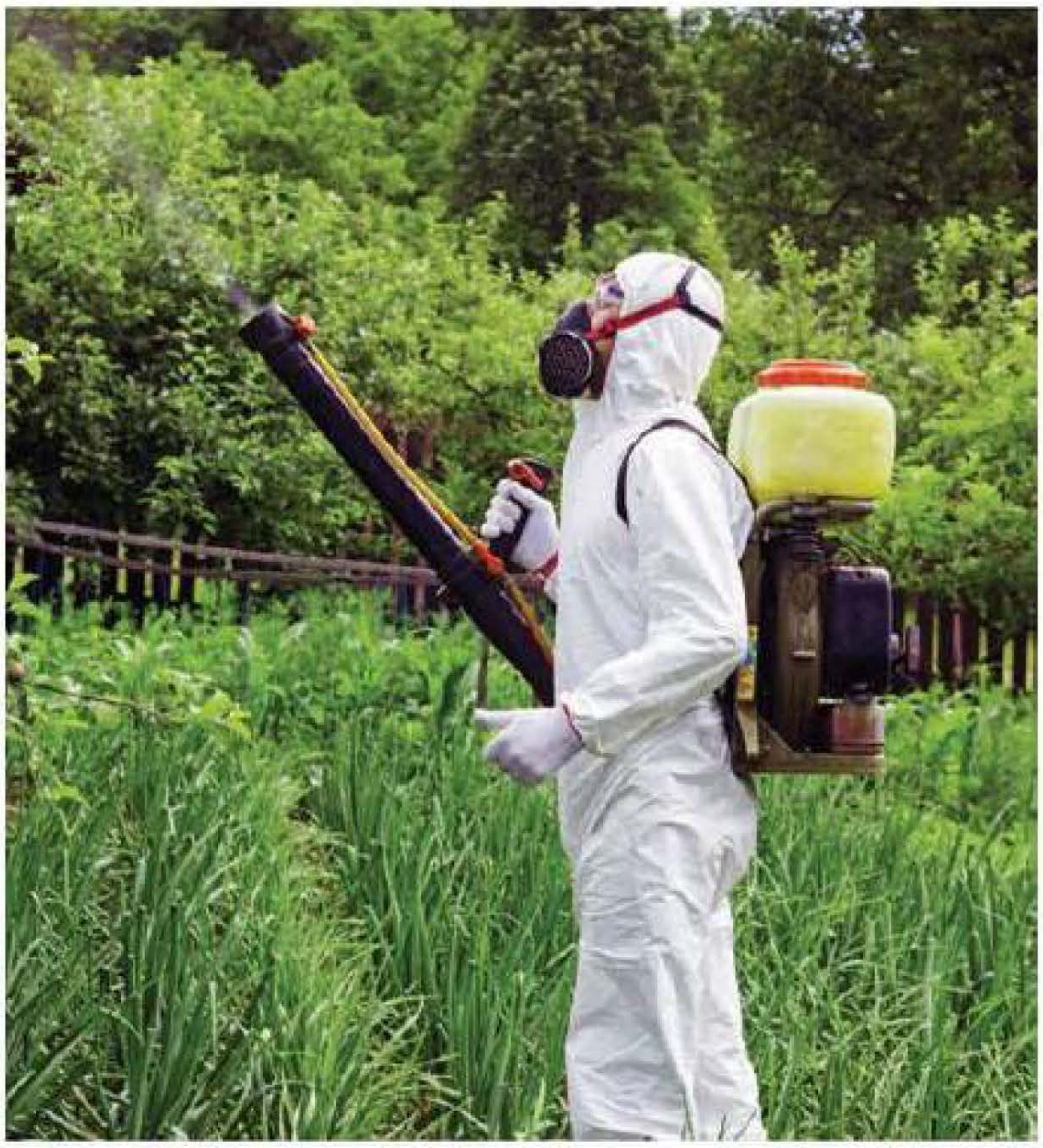
As human territory and influence expand around the world, humans have taken several steps that have interfered with or influenced the interactions between different species. For example, we have introduced domesticated animals into ecosystems where such animals were previously unknown. One example of where this has happened is on the Galápagos Islands, off the coast of Ecuador. The isolated islands have a unique and delicate ecosystem. The introduction of goats and dogs had a profound effect on the balance of food supply for the native animals. This is because a new herbivore (goats) and carnivore (dogs) suddenly entered into the food web.

We can also consider farming as another way in which humans influence interactions between animals for human benefit. For example, humans manipulate the reproduction of cows, chickens, pigs and fish in order to meet the demand for meat products. In addition, some farmers use pesticides in order to poison or kill the insects or other 'pests', such as mice or insects, that feed on and damage their crops.

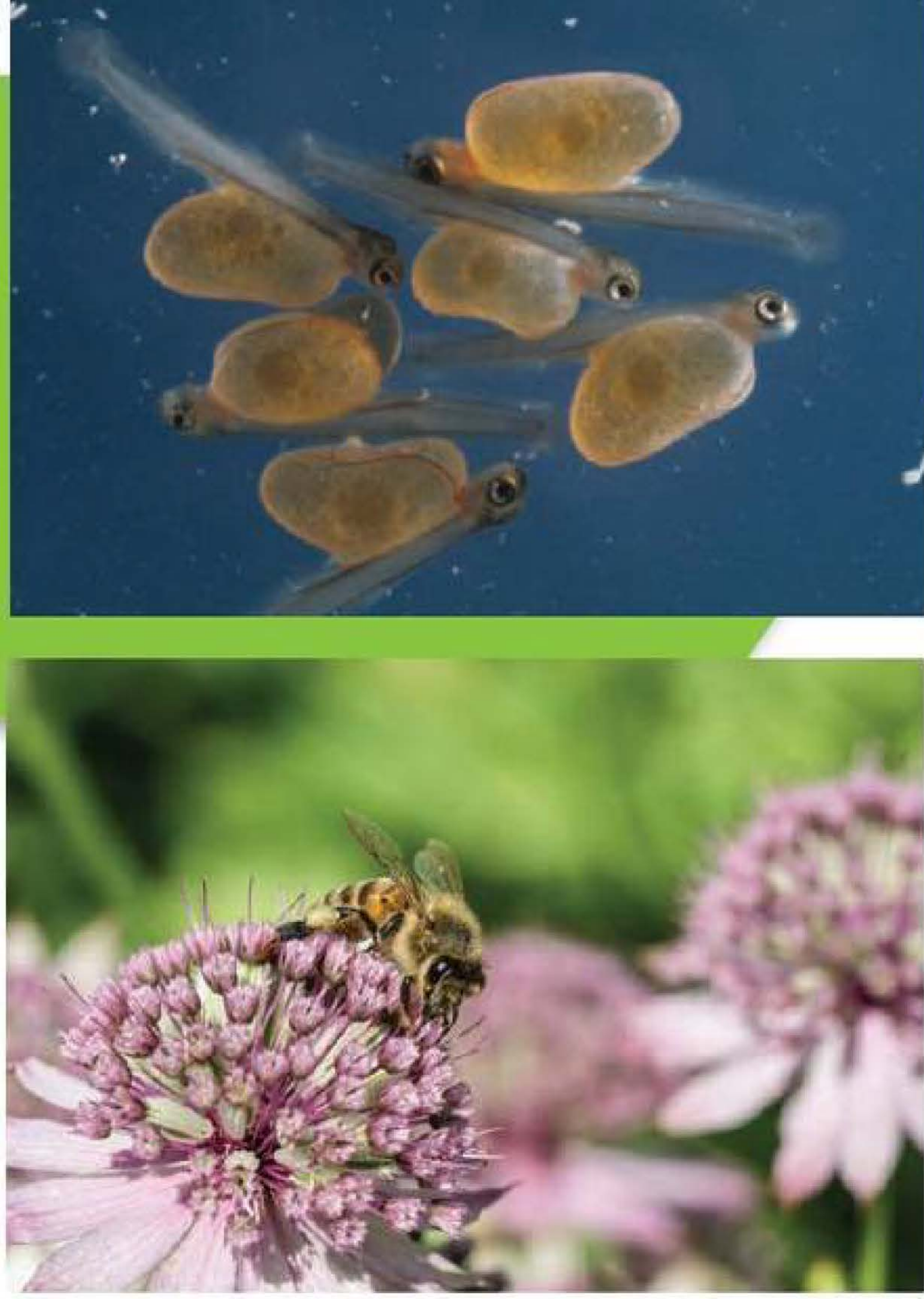
■ **Figure 9.26a** An airman from the US army stationed in the Galápagos Islands during WWII feeding his goat

Other organisms in the food web may then eat these poisoned insects or rodents, and the toxins are passed along, causing deaths higher up the trophic levels. Farmers say they do this in order to produce more crops and to keep supplies up and prices down.

■ **Figure 9.26b** Today, herds of feral (wild, non-native) goats roam the Galápagos Islands, competing with the native species, such as this tortoise, for territory, water and food



■ **Figure 9.27** Farmer in full protective gear spraying pesticide



■ **Figure 9.28** Organisms at different trophic levels in a food web, such as these baby salmon and bees, are affected by the use of pesticides and other chemicals that farmers use to manipulate the growth of their crops

DISCUSS

Using these examples, as well as those mentioned in the previous section, such as hunting, **discuss** with your partner and class your opinion in response to the debatable question: *To what extent should people interfere with or influence the interactions between different species in an ecosystem in order to try to extend and improve human life?* Remember to use scientific explanations about the interactions of living things in order to support your point of view.

In this chapter, we have explored how organisms interact with each other in order to establish a balanced ecosystem. How do these interactions in nature compare with what we as humans do in our day-to-day lives in order to interact and find balance with each other and in our roles?

! Take action

■ ATL

■ Transfer skills: Combine knowledge, understanding and skills to create products or solutions

! Consider ways in which your daily actions affect the interactions between living things. Perhaps some products you buy and use come from companies that disrupt the interactions between the organisms that live in the ecosystems surrounding their factories. Or maybe the impact on organisms comes after you throw the product away.

! List some things you use regularly, and research on the science behind how those items are produced and what happens after we dispose of them.

! **Explain** the ways in which the production or disposal of these products may interfere with natural interactions that occur within an ecosystem to keep it in balance.

- ◆ Consider these questions: which products can we reduce or stop using? Is there a more eco-friendly product from a more eco-friendly company? Are there alternatives for disposal that are now possible due to scientific developments?

! **Explain** the ways in which scientific knowledge and understanding of interactions in an ecosystem can be used and applied to provide suggestions or alternatives for producing and disposing of products in a more eco-friendly way.

! **Discuss** and **evaluate** some of these science-based suggestions or alternatives for producing and disposing of more eco-friendly products:

- ◆ How might cultural, economic, environmental, ethical, moral, political or social factors interact with the implementation or impacts of these science-based suggestions and alternatives?

! **Present** your findings to raise awareness of the suggestions, and alternatives. Imagine the difference if more people bought and used products that are less disruptive to the balance of healthy ecosystems.

! Remember to consistently **apply** scientific language so you can communicate your understanding clearly and precisely and document all of your sources completely.

◆ Assessment opportunities

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

SOME SUMMATIVE PROBLEMS TO TRY

Use these problems to apply and extend your learning in this chapter. These problems are designed so that you can evaluate your learning at different levels of achievement in Criterion A: Knowledge and understanding.

THESE PROBLEMS CAN BE USED TO EVALUATE YOUR LEARNING IN CRITERION A TO LEVEL 7–8

1 In the United States, there is debate about whether grey wolves should be on the list of endangered species. If unlisted, in some states people could legally shoot and kill wolves in an unrestricted way. Some environmental groups have issue with this, and would like to see the grey wolf continue to be listed as an endangered species so that it is not legal to kill them.

a Grey wolves are top predators in their ecosystem. **Explain,** using examples, the role that top predators have in maintaining a balanced ecosystem.

One of the claims of those who would like to keep grey wolves de-listed is that there is a large enough population of wolves, and that some wolves are entering into human-populated areas. There are also claims that wolves are threatening the population of big game, such as elk and therefore the wolf population needs to be controlled by hunting.

b Use your knowledge and understanding of species interactions in order to **evaluate** the claims of those who would like to remove grey wolves from the list of endangered species.

c **Discuss** the strengths and limitations of both removing grey wolves from the endangered species list and keeping them on.

d **Apply** your knowledge and understanding of the role of top predators in an ecosystem to **design** a plan to manage and monitor grey wolf populations and the effects of reducing wolf populations through hunting.

2 We often think of 'ecosystems' as being large areas of land or water, where different plants and animals live and interact. However, ecosystems can be small and closed, where there are only a few types of organisms interacting in specific and specialized ways. In these specialized ecosystems, the interactions and balance between the organisms are still essential to maintain a healthy state.

One of these specialized ecosystems is in the digestive tract of humans. In fact, the intestines of humans are filled with different bacteria that thrive with the resources and conditions of their intestinal habitat.

We often refer to these bacteria as 'probiotic bacteria'. This is because 'pro' means 'good' or 'in favour,' and these bacteria that inhabit our intestines are good for us. We depend on them to make nutrients available for our cells by breaking down foods, such as fruits and vegetables, for which our bodies do not produce digestive enzymes. Without these probiotic bacteria, much of the nutrients in plant-based food would be unusable to us, and would quickly pass out of our bodies in diarrhoea. The probiotic bacteria depend on us for a living space (our intestines) and an energy source (the undigested food particles that make it to our intestines).

People sometimes try to strengthen this balance of probiotic bacteria in our intestines by consuming '*probiotics*'. They do this by eating fermented foods, such as yogurt, kefir, sauerkraut and kimchi, which are rich in probiotic bacteria, or by taking probiotic pills. Other people also try to increase their consumption of the types of foods, known as '*prebiotics*', which are not easily digestible by humans, such as whole grains, onions and bananas, but which are a good source of nutrients for probiotic bacteria.

a **Explain** the type of symbiotic relationship that people have with the probiotic bacteria living in our intestines.

We also depend on probiotic bacteria because they help to prevent pathogenic (disease-causing) bacteria from establishing colonies in our digestive tract. Because there are so many probiotic bacteria living in our intestines, it is difficult for the pathogenic bacteria to have access to the living space and food sources necessary to take up residence.

b **Explain** the type of interaction that the probiotic bacteria have with pathogenic bacteria that enter our intestines.

Sometimes when pathogenic bacteria do enter our digestive systems, they either outnumber or are stronger than the probiotic bacteria that are living there, and the pathogenic bacteria gain access to resources and begin to reproduce and kill or damage our intestinal or other body cells. When this happens, the pathogenic bacteria are able to use our body to their benefit and we become sick.

c **Explain** the type of relationship that people have with the pathogenic bacteria living in our intestines.

Imagine a friend of yours is going on vacation to a country that does not have a very good system of water purification. She is concerned that she will get sick while she is there. She is considering taking antibiotics (bacteria-killing medicine) as a precaution. She has also read about probiotic and prebiotic foods, and is thinking about consuming these to protect herself.

d **Discuss,** using your scientific knowledge and understanding of relationships and interactions between organisms in their ecosystem, the benefits or limitations of taking antibiotics or consuming probiotics and prebiotics as a means of protecting oneself from future illness.

e **Apply** your knowledge and understanding of relationships and interactions between organisms in their ecosystem to **design** a scientifically supported approach for your friend to try and maintain a healthy digestive system while on holiday.

Reflection

In this chapter, we have seen that all organisms depend on other organisms in order to survive. In a healthy ecosystem, there is a cycle of interactions that results in shifts and adjustments that allow the ecosystem to stay in balance. Like a person walking on a tightrope, constantly making small adjustments in position to stay balanced, the interactions between species in an ecosystem are never static; they are constantly changing and adjusting to support the needs of all that make a positive contribution.

<table>
<tr><th colspan="6">Use this table to reflect on your own learning in this chapter</th></tr>
<tr><td>Questions we asked</td><td>Answers we found</td><td colspan="4">Any further questions now?</td></tr>
<tr><td>Factual: What are the interconnected roles and functions of different species that contribute to maintaining balance in an ecosystem?</td><td></td><td colspan="4"></td></tr>
<tr><td>Conceptual: How do changes or shifts in species' functions and roles, or interactions between species, influence the balance and stability of an ecosystem?</td><td></td><td colspan="4"></td></tr>
<tr><td>Debatable: To what extent should people interfere with or influence the interactions between different species in an ecosystem in order to try to extend and improve human life?</td><td></td><td colspan="4"></td></tr>
<tr><td rowspan="2">Approaches to learning you used in this chapter</td><td rowspan="2">Description – what new skills did you learn?</td><td colspan="4">How well did you master the skills?</td></tr>
<tr><td>Novice</td><td>Learner</td><td>Practitioner</td><td>Expert</td></tr>
<tr><td>Reflective skills</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Information literacy skills</td><td></td><td></td><td></td><td></td><td></td></tr>
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<tr><td>Learner profile attribute(s)</td><td colspan="5">Reflect on the importance of caring for your learning in this chapter.</td></tr>
<tr><td>Caring</td><td colspan="5"></td></tr>
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10 How do the choices people make affect the environment?

As a result of the choices that humans make, the **environment** has undergone and will continue to undergo **change**. Humans have the ability to understand the consequences of their actions and to act to restore **balance** in ecosystems and work towards a **sustainable** future.

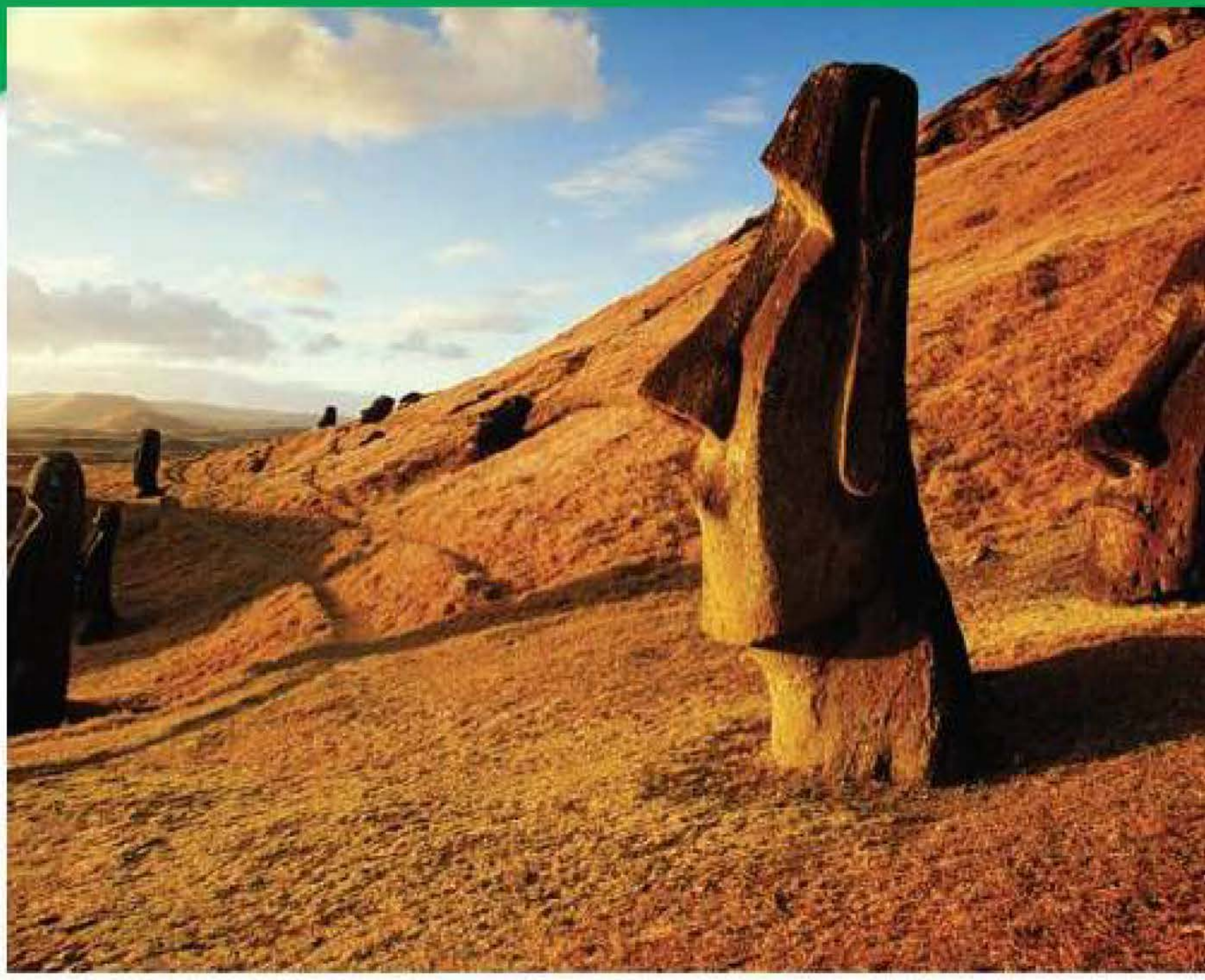


Figure 10.1 Easter Island statues

CONSIDER AND ANSWER THESE QUESTIONS:

Factual: How has human population growth changed over the last 12000 years? In what ways do humans influence or change different habitats? What is pollution? What is global warming? In what ways do humans overexploit natural resources? In what ways do humans try to protect nature and natural resources?

Conceptual: Why has population growth changed? What impact has human disturbance had on natural systems? How is pollution harming the environment? What are the effects of climate change? How do human lifestyles determine the health of different ecosystems? How do conservation efforts support the health of different ecosystems?

Debatable: To what extent does the possibility of economic growth justify the overexploitation of natural resources? Should governments create laws that require people to alter their behaviour in order to mitigate the negative effects of human lifestyles?

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

IN THIS CHAPTER, WE WILL ...

- **Find out:**
  - how the effects of human disturbance can be measured;
  - how human population growth has put increasing demands on the planet.
- **Explore** how the choices people make affect the environment.
- **Take action** by making our school or college more sustainable.

KEY WORDS

emission	introduced	resource
environmental	overexploit	sustainability
exploitation	pollutants	

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

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

We will reflect on this learner profile attribute …

- Balanced – recognizing our interdependence with others and with the world in which we live.

THE LESSONS OF EASTER ISLAND

We think that the society we live in will be here forever. But experience from societies in Earth's past indicates that this may not necessarily be the case. 'Societal collapse' is the fall or disintegration of human societies, and has occurred regularly in human history. Two reasons why a society may collapse are **environmental** problems and failure to adapt to environmental issues. Environmental problems that have traditionally led to societal collapse include: **deforestation** and habitat destruction; soil problems (erosion, salinization (the process by which water-soluble salts accumulate in the soil) and loss of soil fertility); water management problems; **overhunting** (on land and in water); and the effects of **introduced species** on **native species**.

In his book *Collapse*, ecologist Jared Diamond talks about the collapse of the society that lived on the remote Easter Island. The island is about 117 km² in area and is situated about 3700 km west of the Chilean coast. It is one of the most remote inhabited islands in the world. It was colonized by Polynesian people in 700 CE and the population peaked at 12 000 around 1600 CE. The famous statues (moai) found on the island (see Figure 10.1) speak of a sophisticated culture – one that could carve huge rocks and move them around the island. The population is now about 4000. What caused the dramatic reduction in the island's population? Diamond believes that deforestation of the island destroyed the **resource** base the people depended on, and asks the questions 'How could the Easter Islanders have deforested their **environment**? What did they say when they were cutting down the last palm tree? Didn't they see what they were doing?' The total deforestation may be related to the statues: trees were used to move the moai, and removal of the trees led to soil erosion, landslides, crop failures and famine.

What do these past collapses tell us about our own society? Are we affecting our environment in such a way that we are undermining the resources on which our societies depend? **Sustainability** is living within the means of nature, so if humanity's actions are non-sustainable then by definition they cannot be maintained: do you think that our current use of the environment is **sustainable**? **Sustainable development** meets the needs of the present without compromising the ability of future generations to meet their own needs: do you think that the human race will be able to achieve this?

Other societies that have collapsed include: Maya in the Yucatan, the Anasazi, Fertile Crescent society, Angor Wat and Great Zimbabwe. Archaeologists have shown us that there were environmental problems underlying many of these past collapses. Choose one of these case studies to research and find out which environmental problems contributed to the collapse. Produce a presentation to show to the rest of your class.

There are four new factors that may contribute to the weakening and collapse of present and future societies: **climate change** caused by human activities; build-up of **pollutants** in the environment; energy shortages; full human use of the Earth's photosynthetic capacity.

Why has population growth changed?

■ **Figure 10.2** Human population growth

HOW HAS HUMAN POPULATION GROWTH CHANGED OVER THE LAST 12 000 YEARS?

For most of the history of Earth, natural processes have influenced and shaped life. More recently, one species – *Homo sapiens* – has been the dominant influence on Earth's **ecosystems** (as we began to explore in Chapter 7). Early humans lived in balance with nature, as hunter–gatherers, and had little impact on their environment. Populations were low in numbers and people lived off the land. As humanity spread from Africa, becoming farmers and clearing land to grow crops, the impact of *Homo sapiens* on the planet grew.

The development of settled agriculture represents one of the most significant changes in human history, and enabled human populations to start growing. This period, known as the Neolithic ('new stone age') revolution, began in the 'fertile crescent' in the Middle East about 10 000 years ago, and changed forever the way that humanity interacts with the environment.

In recent times, humanity's tremendous growth in population, from mere millions in the Neolithic period to over 7 billion today has put even more pressure on the Earth's natural systems.

Following the development of agriculture, human populations became settled in growing communities. During the Industrial Revolution, increased access to energy further fuelled population growth. The world's population doubled between 1804 and 1922, 1922 and 1959, 1959 and 1974. It is, therefore, taking less and less time for the population to double. In the twentieth century growth became exponential (exponential means increasingly rapid growth).

Other factors have contributed to an increase in human population:

- better healthcare
- more nutritious food
- cleaner water
- better sanitation.

The biggest increase in population is in economically developing countries (LEDCs) rather than in more economically developed countries (MEDCs). High infant-death rates increase the pressure on women to have more children, and in some agricultural societies parents have larger families to provide labour for the farm and as security for the parents in old age. Lack of access to contraception, through education or medical services, also leads to increased birth rates.

The impact of exponential growth is that enormous amounts of extra resources are needed to support growing populations (for food, housing, clothing). However, resource use in many LEDCs is much less than the resource consumption in MEDCs where population growth rates are much lower.

ACTIVITY: Plotting population growth since 10 000BCE

ATL

- Information literacy skills: Access information to be informed and inform others; Collect and analyse data

Tables 10.1 and 10.2 show populations data from 10 000BCE to 2011. Table 10.1 shows data from 10000BCE up to the late medieval period, and Table 10.2 from the early Renaissance period up to 2011.

On graph paper, **plot** population size against time (as measured by year). Note that the dates are not evenly spaced and so you must work out a scale on your *x*-axis that allows you to plot dates over a 12 000 year period.

- **Explain** the shape of the graph you have plotted.
- **Explain** why human population has increased rapidly from the early eighteenth century onwards.
- Early measurements of human population size are estimates. Why is this?
- What key events were happening in the years shown in Tables 10.1 and 10.2? Use the following website as a starting point: http://na.unep.net/geas/newsletter/images/Jun_11/Figure1.png
- When will the world population reach 8 000 000 (8 billion)? What about 9 billion? Extrapolate your graph to estimate these dates.
- What are the long-term projections for world population beyond 2050? Why are these patterns predicted?
- Find out about milestones in world population, including the current world population, here: www.worldometers.info/world-population/#milestones

THINK–PAIR–SHARE

- What do you think is responsible for the rise in human population numbers?
- What impact is human population growth having on the environment?

Now share your ideas with your neighbour. Does the rest of the class agree?

Assessment opportunities

- This activity can be assessed using Criterion C: Present and interpret data and explain results using scientific reasoning.

In this activity we have practised extrapolating the best-fit line of a graph to predict future population growth.

Table 10.1 Global human population size from 10 000BCE to the late medieval period

Year	10 000BCE	8000BCE	6500BCE	5000BCE	3000BCE	2000BCE	1000BCE	400BCE	1CE	1200CE
Population size (millions)	5	5	7.5	12.5	14	27	50	162	285	405

Table 10.2 Global human population size from the early Renaissance to 2011

Year	1500	1804	1927	1960	1974	1987	1999	2011	?	?
Population size (millions)	443	1000	2000	3000	4000	5000	6000	7000	8000	9000

SUMMARY REFLECTION

What have you learnt about how human population growth has changed over the last 12 000 years? Why has population growth changed?

REVIEW

Create a table that summarizes key changes in human population growth over the past 12 000 years. Highlight the periods when human population increased from 1 to 2 billion, 2 to 3 billion, and so on. What historical events were happening at the time and what led to the population growth?

What impact has human disturbance had on natural systems?

DISCUSS

What does 'A HIPPO' stand for? **Describe** and **explain** to your neighbour what each letter stands for. What examples can you provide to help you **explain** each of the human threats to natural systems? Can your neighbour think of different examples? Make a joint list of all the ideas you have come up with.

ACTIVITY: A HIPPO

ATL

- Creative-thinking skills: Make unexpected connections between objects or ideas

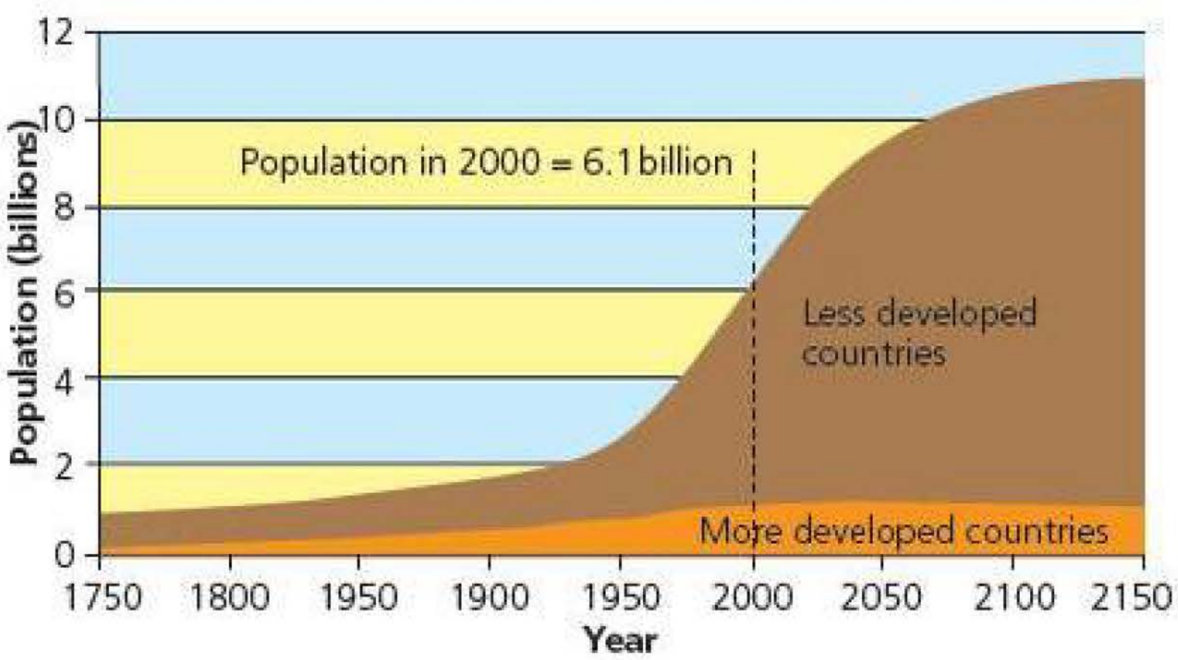
Look at the following photos, each of which represents one of the reasons why natural systems are being disturbed:

■ **Figure 10.3** Fields before harvest at summer

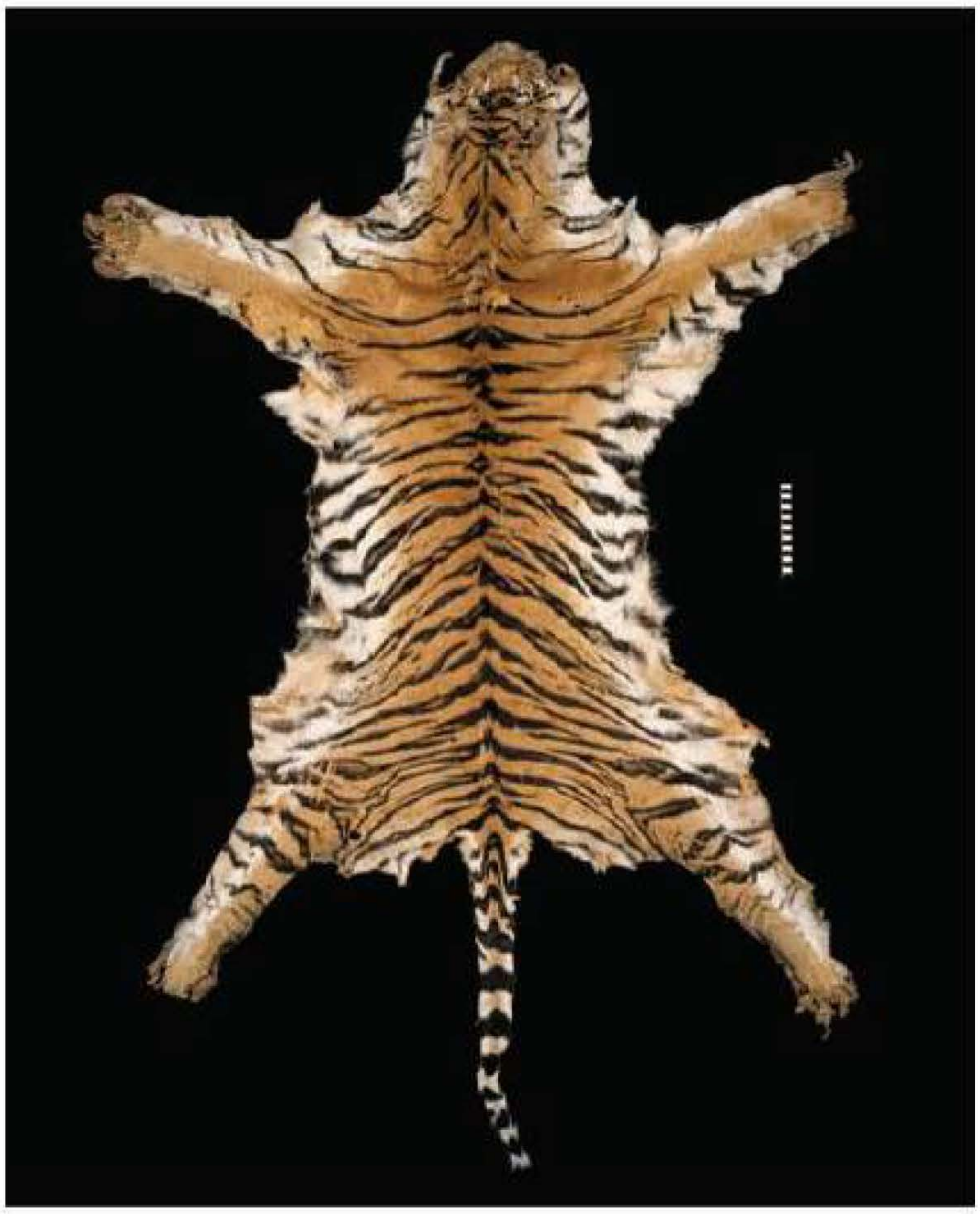
■ **Figure 10.4** Clearance of rainforest to make way for oil exploration. Such clearance has a massive environmental impact on a region

■ **Figure 10.5** The grey squirrel was introduced from North America into the UK: it competes with the red squirrel and has led to reduction in red squirrel (which is now rare)

■ **Figure 10.6** Plastic garbage in the sea



■ **Figure 10.7** Human population increase over 400 years



■ **Figure 10.8** Bengal tiger (*Panthera tigris tigris*) skin

The human effects on the environment can be summarized by the mnemonic 'A HIPPO'. Each image on these two pages represents a different way in which the environment is being disturbed by human activity (i.e. one letter in the mnemonic). What does each letter stand for?

Hint

The photos are in the correct order.

Write down your answers following this guide:

A = _ _ _ _ _ _ _ _ _ _ _

H = _ _ _ _ _ _ _ _ _ _

I = _ _ _ _ _ _ _ _ _ _ _ _ _ _ _

P = _ _ _ _ _ _ _ _ _

P = _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _

O = _ _ _ _ - _ _ _ _ _ _ _

◆ Assessment opportunities

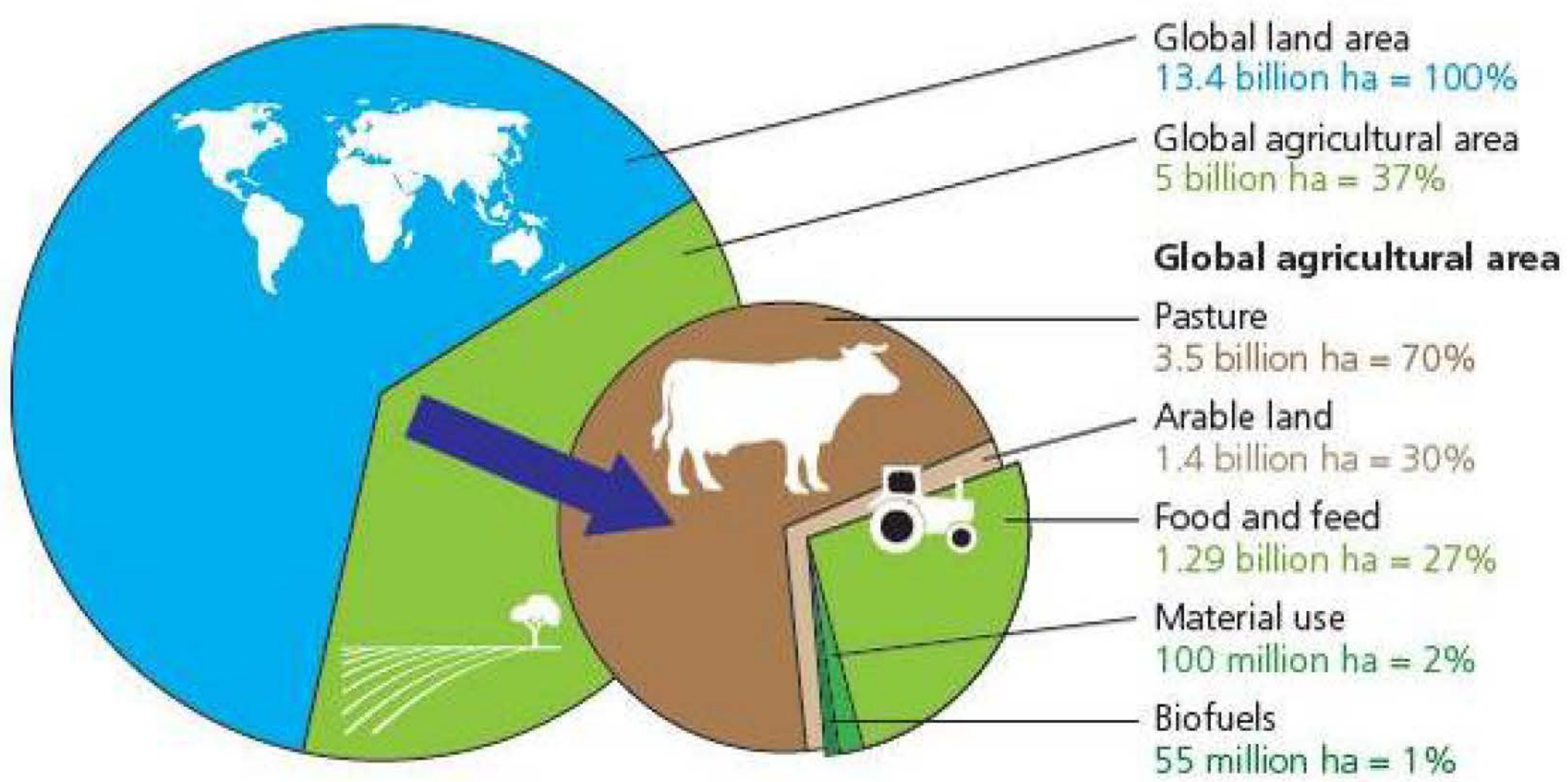
- In this activity you have practised skills that are assessed using Criterion A: Apply scientific knowledge to solve probems.

Humans have had a massive impact on the natural world over the last few hundred years in particular. Population growth (one of the two 'P's in 'A HIPPO') has fuelled demand for more resources, which has led to habitat loss ('H') as a result of deforestation, mining, land clearance for new housing and infrastructure (e.g. roads), and so on. The increase in the world population from around 3 billion people in the 1950s to over 7 billion people in 2015 has led to increasing demand for food: conversion of land to agriculture (A) has led to further habitat loss. Nearly 40 per cent of the Earth's land surface is used for agriculture (Figure 10.9), with an area approximately the size of South America used for crop production, and even more land (3.2 to 3.6 billion hectares) being used to raise livestock (such as cattle).

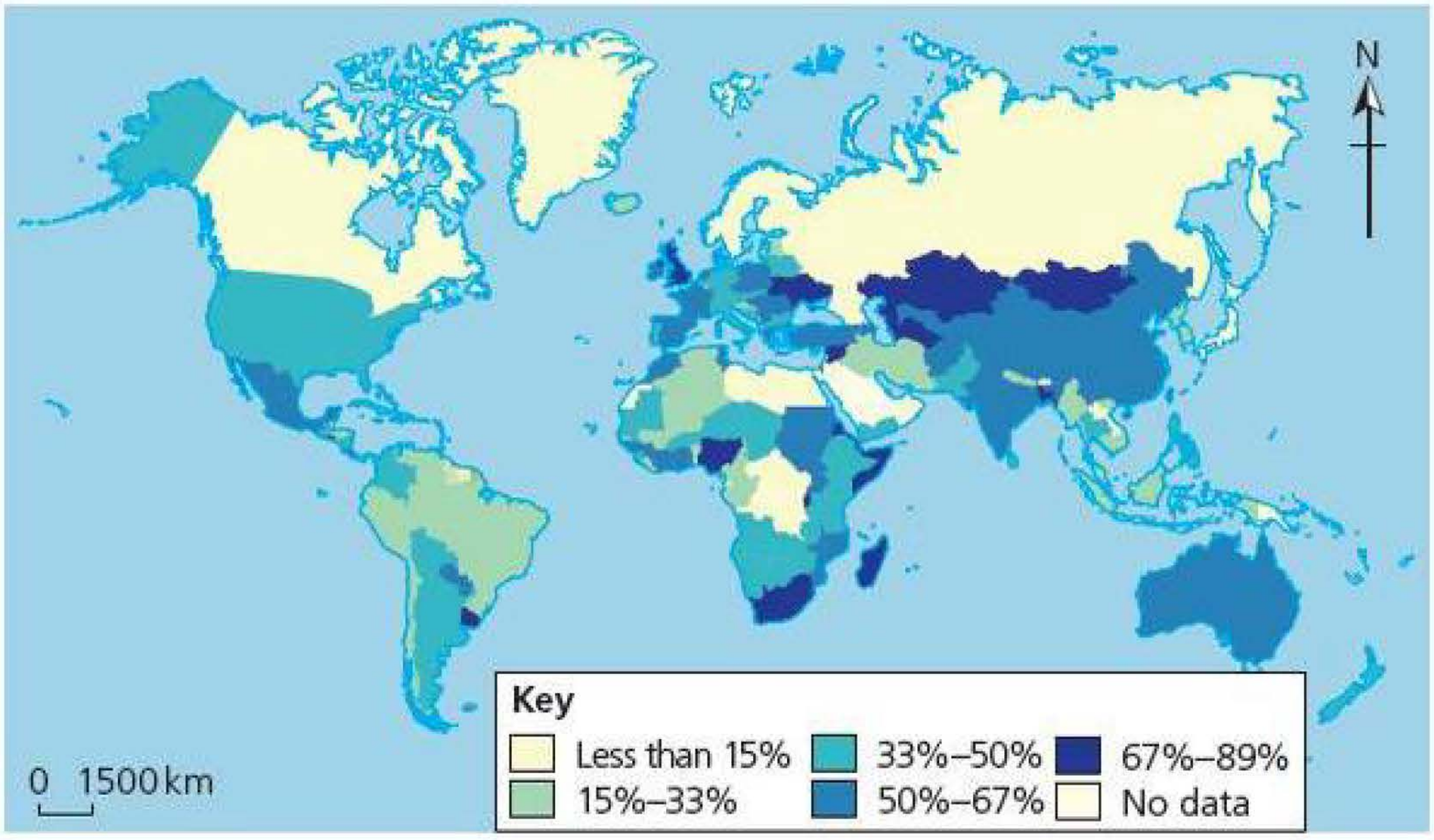
Some parts of the planet are more intensively farmed than others (Figure 10.10).

THINK–PAIR–SHARE

These threats are leading to species becoming endangered. Discuss with your neighbour how each threat is harming biodiversity (biodiversity is the variety of different types of life found on Earth). Now share your ideas with the whole class.



■ **Figure 10.9** Nearly 40% of the Earth's surface is used for agriculture. This pie chart shows how agricultural land is used for different purposes



■ **Figure 10.10** Agricultural land as a percentage of total land area

■ **Figure 10.11** Museum collection showing diversity of Oahu's land snails, many now extinct, Bishop Museum, Hawaii

As humans began to move around the planet they carried with them species that were then deposited in ecosystems where they had not existed before. These '**alien' species** in many instances became '**invasive**' (the 'I' in 'A HIPPO') when then they adversely affected **endemic** (native) **species** by competing with them, leading to a reduction in the population of endemic species.

- The grey squirrel was introduced into the UK from North America. This grey squirrel competes with the native red squirrel and has led to such a reduction in red squirrel numbers that the animal is now rare.
- Introduced red-clawed signal crayfish (*Pacifastacus leniusculus*), a large, aggressive American species, has wiped out almost 95 per cent of the native UK white-clawed species (*Austropotamobius pallipes*) since its introduction in the late 1970s.
- Invasive species can lead to the extinction of the native species: for example, in Hawaii many species of endemic snail (Figure 10.11) have been wiped out by the introduction of rats to the islands, habitat loss, and also following the deliberate introduction in 1955 of the carnivorous snail *Euglandia* to control the alien African snail (*Euglandia* ate not only the African snail but also the endemic snail species). Read about a program to conserve the Hawaiian snail fauna here: **http://dlnr.hawaii.gov/ecosystems/nicp/sep/**

Pollution (the other 'P') includes chemicals, litter, nets, plastic bags and oil spills. Pollution damages habitats and kills animals and plants, leading to the loss of life and reduction in species' population numbers.

Overhunting ('O') has led to a significant reduction in population size of many species. Animals are hunted for food, medicines, souvenirs, fashion (e.g. fur coats), and to supply the exotic pet trade. Overhunting of North Atlantic cod in the 1960s and 1970s led to a collapse in fish numbers.

SUMMARY REFLECTION

- **What have you learnt about the impact human disturbance has had on natural systems?**
- **Outline six ways in which humans have adversely affected the natural world.**

How is pollution harming the environment?

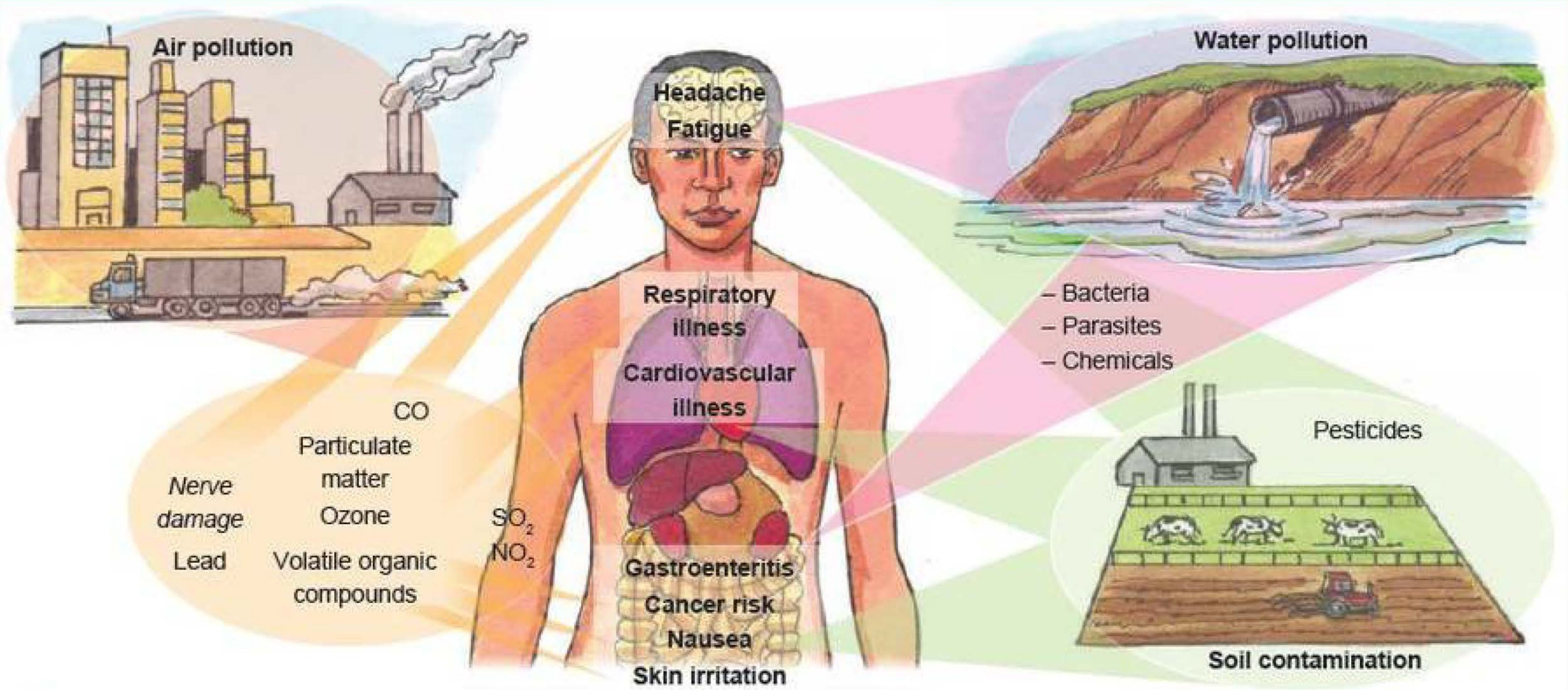
WHAT IS POLLUTION?

Pollution is contamination of the Earth and atmosphere to such an extent that normal environmental processes are adversely affected. Pollutants, that is to say the factors that cause pollution, are disagreeable, toxic and harmful.

There are many types of pollution (see Table 10.3). The effects of pollution on humans are widespread, including death, decreased levels of health (Figure 10.12), poor air quality, and reduced water resources and soil fertility.

Table 10.3 The main sources of pollution

Source	Type of pollution	Cause	Effects
Agriculture	Fertilizers, manure, silage	Spreading fertilizers on fields; runoff of manure and silage	Eutrophication
	Pesticides	Spraying crops	Pesticides build up in food chains and affect the health of animals
	Salinization	Irrigation	Accumulation of salts in soils kills plants
Manufacturing industry	Solid waste	Disposal of by-products and waste	Contaminated land, e.g. Lower Lea Valley, London (Olympic Games site, 2012)
	Toxic spills and leaks	Industrial dumping and accidents	Bhopal, India
Domestic waste	Solid domestic waste	Waste in landfill sites	Contamination of groundwater; release of methane
	Sewage	Waste from toilets; disposable nappies	Eutrophication; reduced oxygen in water; disease
Transport	Runoff from roads	Oil leakages; road drainage	Contamination of groundwater, streams and soils
Energy	Sulfur dioxide	Burning coal	Acid precipitation
	Nitrogen oxides	Formed from atmospheric nitrogen in vehicles	Acid rain
	Nuclear waste	Radiation leaks	Fukushima-Daiichi, Japan 2011



■ **Figure 10.12** The effects of pollution on human health

ACTIVITY: The gases of pollution

ATL

- Creative-thinking skills: Apply existing information to generate new ideas

■ **Figure 10.13** A lump of coal

Fossil fuels were formed over millions of years from the remains of dead plants and animals: coal was formed from dead plant material; oil and gas were formed from dead marine organisms. Power stations use fossil fuels as a source of energy – when fossil fuels are burnt they release elements that have been trapped for millions of years back into the atmosphere.

THINK–PAIR–SHARE

What elements do fossil fuels contain? Think about what you know about the molecules that make up living organisms (Chapter 3, pages 56–57) – these elements will be locked up in the fossil fuels. Make a list. Now share with your neighbour.

What gases are produced when fossil fuels are burnt? Think about what gases the elements you have listed above would form when combined with oxygen. Make a list. Now share with your neighbour.

What effect will the gases released by burning fossil fuels have on the environment? Research the effect of each gas and make an 'Environmental awareness' booklet designed to raise awareness of the harmful effects of atmospheric pollution.

◆ Assessment opportunities

- In this activity you have practised skills that are assessed using Criterion A: Apply scientific information and understanding to solve problems.

EXTENSION

What other sources of pollution are there? Use these search words: **thermal pollution**, **sound pollution**, **plastic pollution**, **oil pollution** to find out more about pollutants and their effect on the environment.

Fossil fuels contain all the elements that were present in the living organisms from which the fuels were made, i.e. carbon, hydrogen and oxygen (from carbohydrates, lipids and proteins), and nitrogen (from proteins). Some proteins also contain sulfur. When the fossil fuels are burnt they form oxides of the different elements, which are released into the atmosphere:

- Carbon forms carbon dioxide (CO_2) and carbon monoxide (CO) (if the fossil fuel is incompletely burnt)
- Nitrogen forms nitrogen oxides (NO_x), such as nitric oxide (NO), nitrogen dioxide (NO_2) and nitrous oxide (N_2O). Their lifespans in the atmosphere range from one to seven days for nitric oxide and nitrogen dioxide, to 170 years for nitrous oxide.
- Sulfur forms sulfur dioxide.

Nitrous oxide and carbon dioxide are **greenhouse gases** (see page 261). Carbon monoxide combines with hemoglobin in the blood rather than oxygen, meaning that less oxygen reaches respiring tissues. CO is found in fumes produced when fossil fuels are burnt in vehicles, stoves, boilers, fireplaces, gas ranges or furnaces. CO can build up indoors and poison people and animals who breathe it – in high enough concentrations it can kill as it stops sufficient quantities of oxygen form reaching the brain.

Acid rain

Nitrogen oxides and sulfur dioxide dissolve in water in the atmosphere (in clouds), forming nitric acid and sulfuric acid (Figure 10.14). The water falls as rain or snow, affecting land (terrestrial) and water (aquatic) organisms. Figure 10.15 shows the effect of **acid rain** on trees.

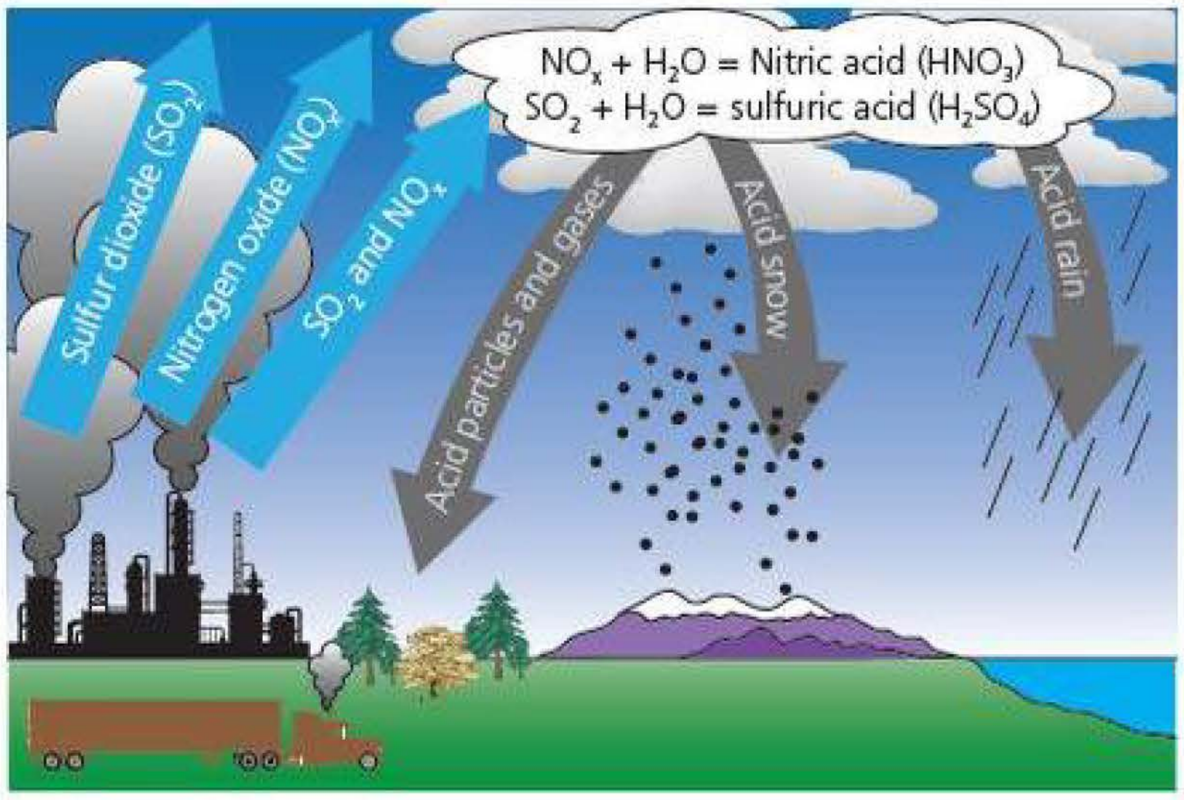


Figure 10.14 How acid rain is formed

Figure 10.15 The effect of acid rain on trees

Eutrophication

As well as atmospheric pollution, pollutants can come direct from the land. Overuse of **fertilizers** to improve crop **yields** has led to pollution of freshwater resources, such as lakes. Nitrate and phosphate fertilizers from surrounding farm land can be washed into a body of water causing the following sequence of events:

- Increased nitrogen and phosphorus in the water leads to increased **algal** growth (an 'algal bloom') – nitrogen is used by the algae to make **protein**, and phosphorus is needed to make cell membranes, **DNA** and other **organic molecules** of life.
- The algae block light from reaching lower levels in the lake – aquatic plants below the surface of the lake cannot **photosynthesize** and so die.
- Algae also die – there is a build-up of dead organic material on the bottom of the lake.
- Bacteria feed on the dead organic matter – they need oxygen to respire and so oxygen levels in the lake decrease (the water become 'anoxic').
- The lack of oxygen means that animals in the lake, such as fish, die.

This process is called **eutrophication** (which literally means 'good feeding' – because the algae have plenty of nutrients to help them grow).

Figure 10.16 A eutrophic river

Combating pollution

It is vital that pollution is controlled and managed. To be effective, pollution treatment should be applied at source: there is no point treating symptoms (e.g. treating acidified lakes with lime) if the cause is not tackled (for example **emission** of acid materials).

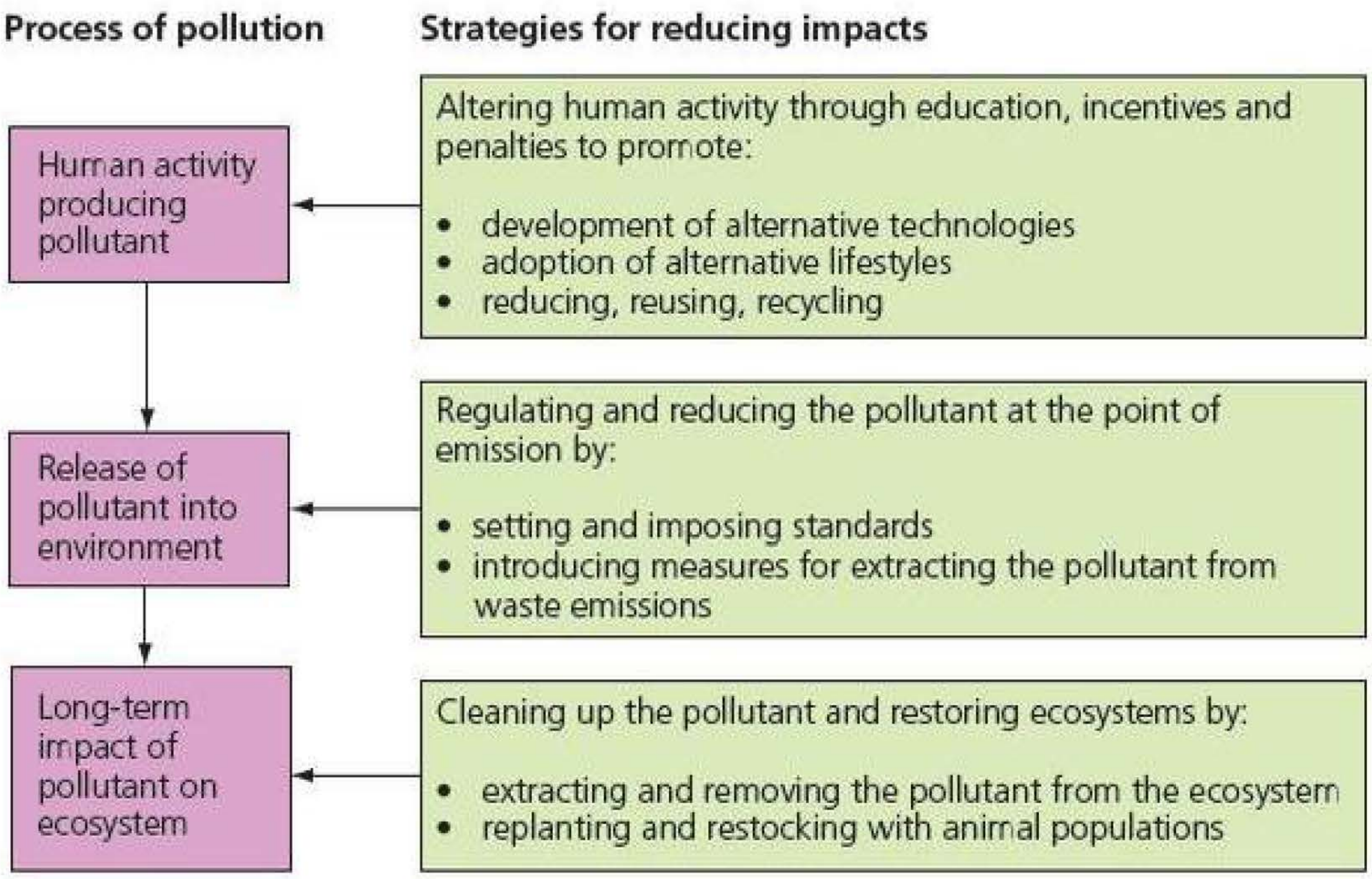


Figure 10.17 Different ways to manage pollution

SUMMARY REFLECTION

What have you learnt about pollution, and how pollution is harming the environment?

REVIEW

- What gases are released when fossil fuels are burnt?
- What effects do these gases have on the environment?
- What is acid rain and what effect does it have?
- What is eutrophication?
- How can pollution be managed?

What are the effects of climate change?

■ **Figure 10.18** Heavy smoke from industrial chimney polluting the environment

WHAT IS GLOBAL WARMING?

Burning fossil fuels releases pollutants into the atmosphere, some of which are greenhouse gases. The Sun produces many different wavelengths of light, from shortwave (ultraviolet, UV) through visible light to longwave (infrared, IR).

ACTIVITY: The greenhouse effect

■ ATL

- Transfer skills: Compare conceptual understanding across multiple subject groups

▼ Link to: Physics

In Physics you will have learnt about the properties of light waves. How can you apply this knowledge to the current activity?

Look at the following diagrams. Use the information above to **describe** what is happening at each stage. What is the **greenhouse effect**?

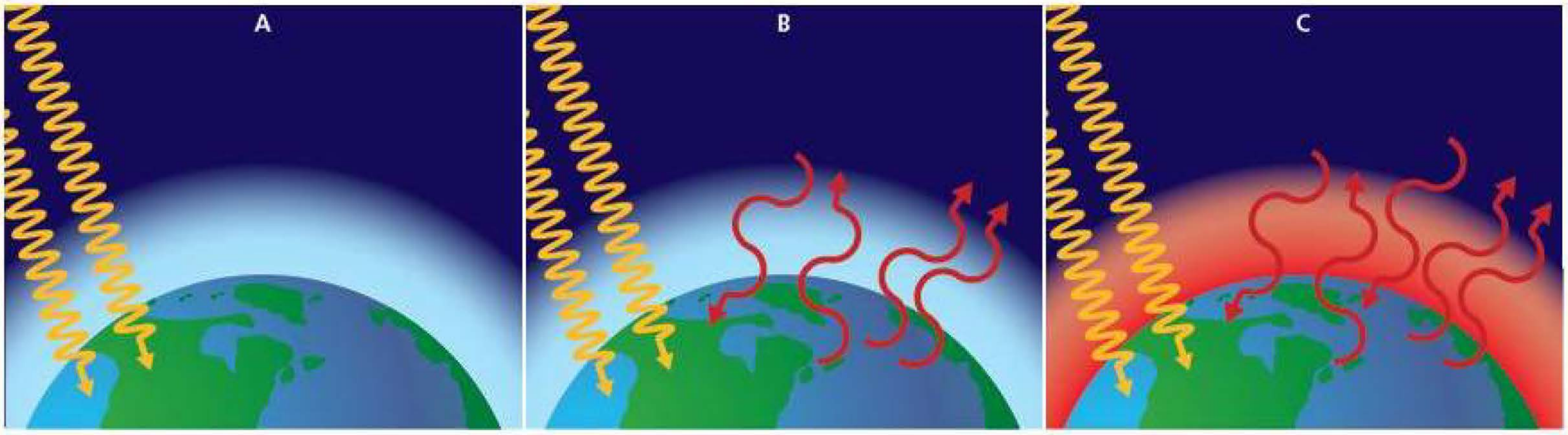
◆ Assessment opportunities

- In this activity you have practised skills that are assessed using Criterion A: Explain scientific knowledge.

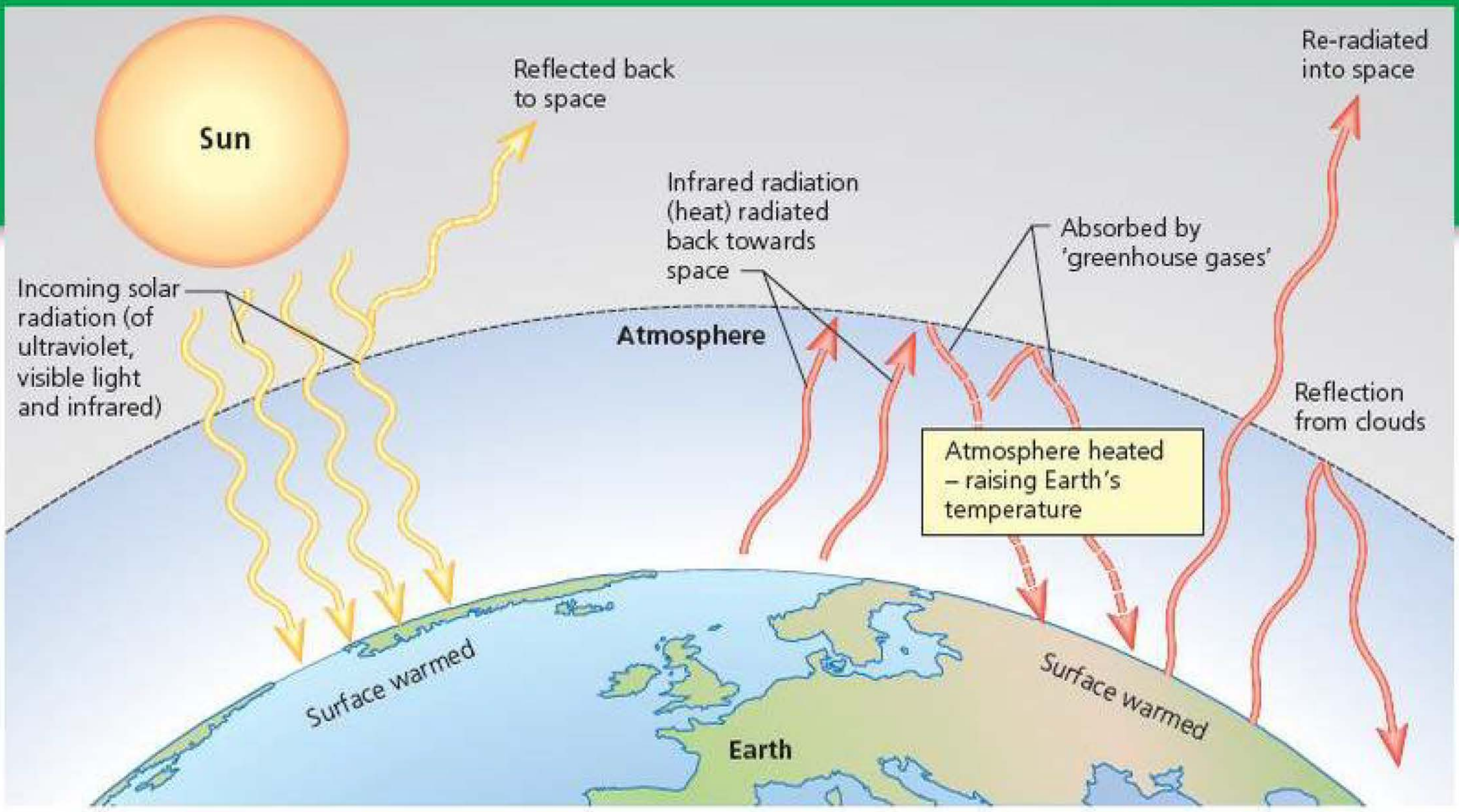
EXTENSION

Find out more about the greenhouse effect here: www.sumanasinc.com/webcontent/animations/content/greenhouse.html

Find out more about the greenhouse effect and global warming here: www.outdoors.org/conservation/mountainwatch/upload/greenhouse.swf



■ **Figure 10.19** The greenhouse effect



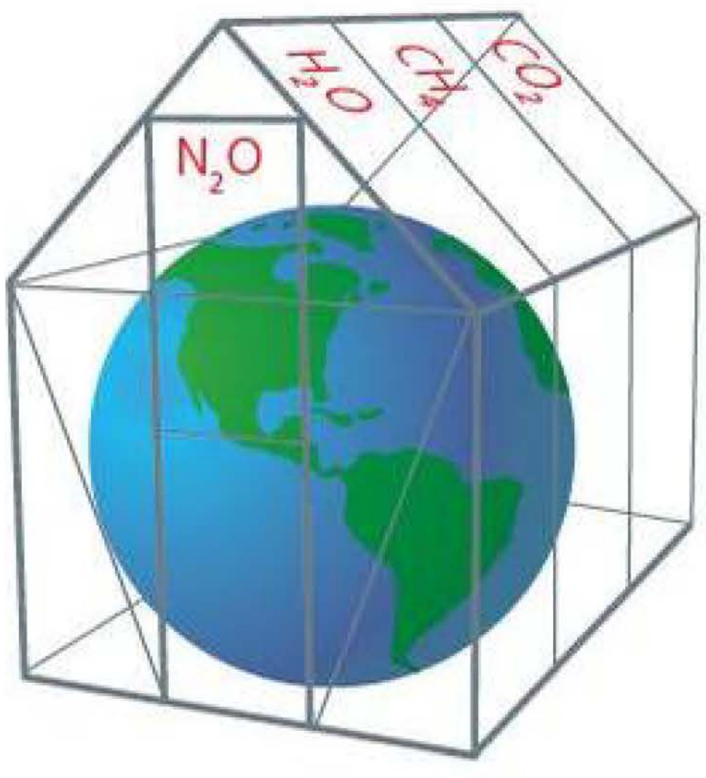
■ **Figure 10.20** The greenhouse effect

Greenhouse gases let through UV light but absorb IR light, resulting in a warming of the planet, known as the greenhouse effect (see Figure 10.20).

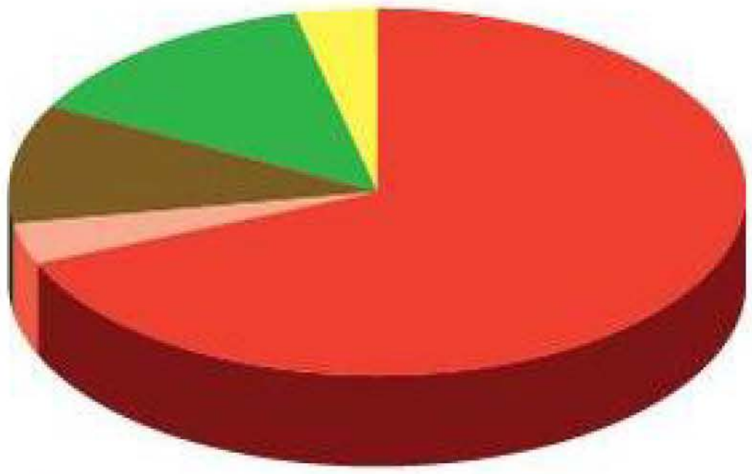
Greenhouse gases include:

- carbon dioxide
- methane
- nitrous oxide
- CFCs (chlorofluorocarbons)
- water vapour.

■ **Figure 10.22** The main greenhouse gas emissions released due to human activities



■ **Figure 10.21** Greenhouse gases trap IR light in the atmosphere, leading to a warmer Earth



■ **Figure 10.23** Sources of human-related greenhouse gases

The greenhouse effect is essential for life on Earth – without the greenhouse gases the average global surface temperature would be –18 °C, rather than the 15 °C that it is today. **Global warming** is an increase in average temperature of the Earth's atmosphere, caused by a build-up of greenhouses gases such as carbon dioxide and methane.

Sources of carbon dioxide include the burning of fossil fuels and forest fires. There are many different sources of methane including wetlands, bogs, stagnant water bodies, rice paddies, livestock (such as cows, which release methane produced by anaerobic bacteria in their gut), landfill sites, melting of permafrost, and manure and sewage.

ACTIVITY: Correlations between CO_2 and temperature

ATL

- Critical-thinking skills: Interpreting data

What evidence is there that links increases in greenhouse gases to climate change?

Look at the following graph – what evidence does it provide?

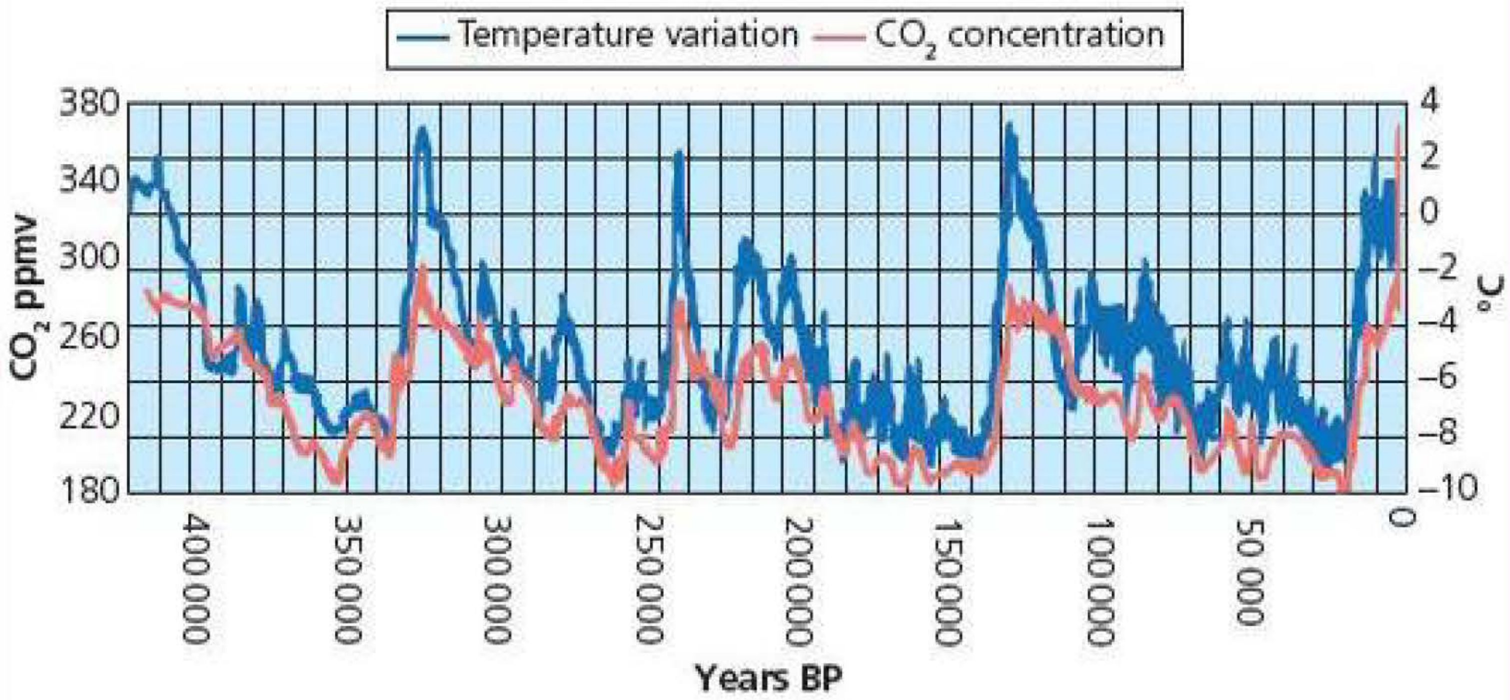


Figure 10.24 Carbon dioxide levels in geological time

Assessment opportunities

- In this activity you have practised skills that are assessed using Criterion A: Analyse and evaluate information to make scientifically supported judgements.

EXTENSION

Figure 10.25

What does Figure 10.25 suggest to you? How could you use it in a campaign to promote awareness of global warming?

Effects of global warming

The potential effects of climate change on the distribution of ecosystems, global agriculture and human societies are:

- ecosystems moving north/south with changing climate
- change in location of crop-growing areas (for example the area for growing grain in the USA may move north)
- changed weather patterns
- coastal flooding (due to seawater expanding as a result of increased temperature, and the melting of the Arctic icecap and Greenland ice sheet)
- effect on human health (spread of tropical diseases such as malaria)
- change in the distribution of many animals; some animals may no longer have a suitable habitat, whereas others may not be able to migrate to find suitable habitats
- competition from invasive species that spread due to climate change may lead to the extinction of endemic species (see also page 255).

There have been considerable changes in the levels of carbon dioxide in the geological past (Figure 10.24). Generally, higher levels of carbon dioxide correlate with higher temperatures, and lower levels of carbon dioxide correlate with lower temperatures.

The long-term records of changing levels of greenhouse gases and associated change in temperatures are based on evidence obtained from ice cores drilled in the Antarctic and Greenland ice sheets. The ice there has formed from the build-up of layers of frozen snow, deposited there over

REVIEW

- Name five greenhouse gases.
- What is the greenhouse effect?
- Is the greenhouse effect a 'good' or 'bad' thing?
- What is global warming?
- What is climate change?
- What evidence is there to show a correlation between increasing CO_2 levels and rising temperatures?
- What effect is climate change having on the planet?

thousands of years. Gases from the surrounding atmosphere were trapped in the frozen layers of snow. The amount of different gases in the bubbles of gas obtained from different layers of these cores were analysed from the Vostok ice in East Antarctic: this has resulted in a record of how the carbon dioxide and methane concentrations have varied over a period of 400 000 years of Earth's history.

Since the beginning of the Industrial Revolution in the developed countries of the world (the past 200 years or so), there has been a sharp and accelerating rise in the level of carbon dioxide. This is attributed to the burning of coal and oil. These 'fossil fuels' were mostly laid down in the Carboniferous Period. As a result, we are now adding to our atmosphere carbon that had been locked away for about 350 million years. There is a correlation between rising atmospheric concentrations of carbon dioxide and rising average global temperatures. Many climate scientists argue this development poses a major environmental threat to life as we know it.

Combating climate change

Release of greenhouse gases occurs locally but has a global impact. International cooperation to reduce emissions is essential. What actions are needed to prevent the worst consequences of continued global warming?

Effective actions that may combat threats from global warming include:

- conserve fossil-fuel stocks, using them only sparingly, and only when there are no apparent alternatives (such as oils from biofuel sources)
- develop nuclear power sources to supply electricity for industrial, commercial and domestic needs
- develop so-called renewable sources of power, exploiting environmental energy sources, such as wave energy and wind power
- develop biofuel sources of energy that exploit organic waste matter (which will naturally decay anyway) and biofuel crops that are renewable photosynthetic sources of energy
- reduce use of fuels for heating of homes (where necessary) to minimum levels by economical designs of (well-insulated) housing and reduce use of fuels in more efficient transport systems
- prevent the destruction of forests in general and of rainforest all around the tropical regions of the Earth in particular, since these are a major CO_2 stores.

SUMMARY REFLECTION

What have you learnt about global warming and the effects of climate change? What have you learnt about how climate change can be combatted?

To be effective, any such actions taken in response to environmental challenges need to:

- be agreed internationally as acceptable to all nations, and to be acted on by each and every one, simultaneously
- recognize that existing MEDCs have previously experienced their industrial development through **exploitation** of natural resources and LEDCs expect to be able to do likewise.

An international agreement to limit release of greenhouse gases by all industrial countries and emerging industrial countries was first agreed at the Earth Summit in Rio de Janeiro in 1992. An initiative, known as Agenda 21, was launched. Subsequently, at the Kyoto Conference in Japan a first attempt was made to meet the pledges made at Rio. Carbon dioxide emission targets for the industrial nations were set for the period 2009–2012. Now, discussions continue annually. However, 'polluting' nations (and there are many) have been allowed to **offset** emissions with devices such as **carbon sinks** – mechanisms by which atmospheric carbon dioxide is removed from the air either permanently or on a long-term basis. For example, carbon dioxide may be absorbed by additional forest trees, becoming the carbon of wood that is not harvested and burnt. However, many of the arrangements are so complex as to be difficult to enforce, or are not legally binding. Real progress is extremely slow.

How do human lifestyles determine the health of different ecosystems?

■ **Figure 10.26** Bulldozer making a logging road in rainforest, Sabah, Borneo

Tropical rainforests cover only 5.9 per cent of the Earth's land surface but may contain up to 50 per cent of all species. They are found in South America, Africa and Southeast Asia. The climate is warm and rainfall is high, with up to 2500 mm per year. The constant warm temperatures, high levels of sunshine and high rainfall lead to high levels of photosynthesis, leading to lots of new growth, different species (species richness) and diversity.

Tropical rainforests are rich in natural resources, such as timber, and so are vulnerable to exploitation, with an average of 1.5 hectares (equivalent to a football pitch) lost every 4 seconds. Because they have high biodiversity, many species are affected when they are disturbed. Deforestation and forest degradation are being caused principally by demands for timber, for land for cattle to provide beef and for **plantation** crops such as soya and **biofuels** (such as oil palm in Southeast Asia). Tropical rainforests are found on nutrient-poor soils that are thin and easily washed away once forest is cleared.

Ecological footprints (see page 266) are a good indicator of whether we are using the Earth's resources sustainably. If the land surface was divided equally among all the people who live on Earth, there would be 1.72 global hectares per person – this area of land should be sufficient to provide all the food, shelter, clothing material and other resources needed for survival, as well as removing all wastes. You are going to calculate your ecological footprint. What would happen if everyone on the planet lived as you do?

Human lifestyles directly determine the health of different ecosystems – the more resources we use, fossil fuels we burn, and pollution we produce, the greater the effect on the planet we inhabit. We only have one Earth – we should use the resources it provides wisely.

■ **Figure 10.27** Deforestation leads to habitat loss

ACTIVITY: Studying the effects disturbance on an ecosystem

■ ATL

■ Organization skills: Plan an assignment

In your local area there will be habitats where you can investigate the effect that human disturbance has had on natural ecosystems. These may be areas of forest that have been harvested for timber, grassland habitats that are regularly trampled by walkers, ecosystems where fire has damaged natural habitats, and so on. There are a variety of methods you can use to study disturbed ecosystems:

- Count the number of species present before and after disturbance (this will be your dependent variable). Perhaps you can focus on one group of animals or plants? Ensure you have an independent variable such as degree of canopy openness (how much sky you can see from the forest floor, expressed as a percentage, or light intensity).
- Measure average width of tree stems at breast height (DBH) – are there differences between undisturbed and disturbed sites?
- Measure light levels, temperature and wind speed.
- Measure the amount of soil erosion – in areas with high rainfall this can be simply calculated by measuring the depth of soil remaining under free-standing rocks and stones, where soil around these solid objects has been washed away.
- Measure soil pH (pH testing kits are available at most garden centres).

First you need to develop a hypothesis:

- **Explain** the research question to be tested by your investigation.
- **Formulate** and **explain** a testable hypothesis using correct scientific reasoning.
- **Explain** how to manipulate the variables, and **explain** how sufficient relevant data will be collected.
- **Design** a logical, complete and safe method in which you select appropriate materials and equipment.

Now you need to collect your data.

Having collected your data:

- **Organize**, transform and **present** your data numerically or visually as a graph.
- Accurately **interpret** your data and **explain** your results using correct scientific reasoning.
- **Evaluate** the validity of your hypothesis based on the outcome of the investigation.
- **Evaluate** the validity of your method based on the outcome of the investigation.
- **Explain** improvements or extensions to the method that would benefit the investigation.

◆ Assessment opportunities

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

ACTIVITY: Your ecological footprint

ATL

- Information literacy skills: Access information to be informed

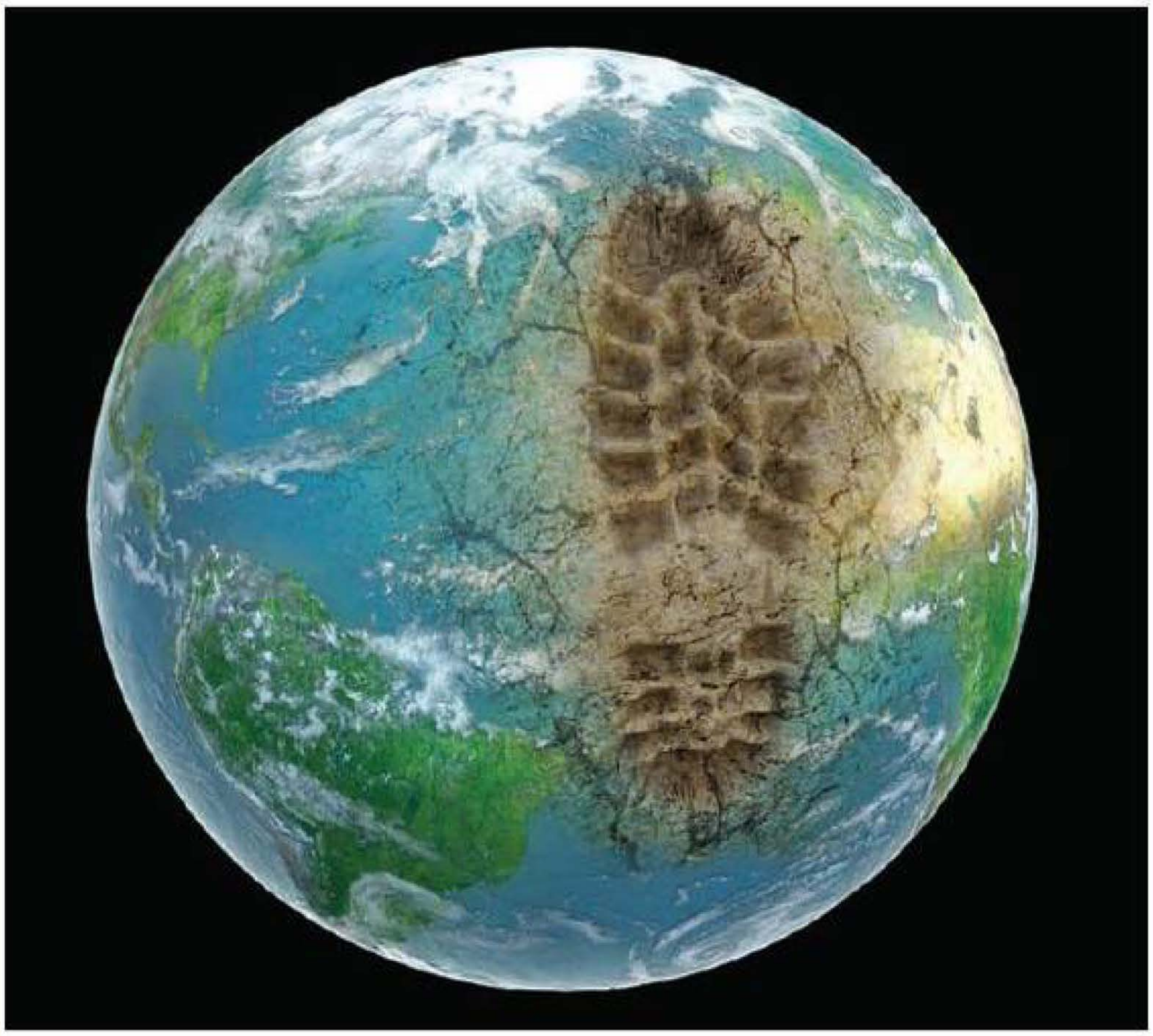


Figure 10.28 What is your ecological footprint?

An **ecological footprint** is the area of land and water required to sustainably provide all resources at the rate at which they are being consumed by a given population. How great this area is compared with the area available to the population then gives an indication of whether the population is living sustainably: an indication of unsustainability is given when the ecological footprint is greater than the area available to the population.

What is your own ecological footprint? Work it out using the following website: http://footprint.wwf.org.uk/

How many planets would we need if everyone lived the same lifestyle as you? What issues are taken into account when calculating ecological footprint? How can you reduce your ecological footprint? What steps can you take today to start this process?

Assessment opportunities

- In this activity you have practised skills that are assessed using Criterion A: Analyse and evaluate information to make scientifically supported judgements.

SUMMARY REFLECTION

What have you learnt about how humans **overexploit** natural resources? How do human lifestyles determine the health of different ecosystems?

REVIEW

- What impacts does deforestation have on biodiversity?
- Why are tropical rainforests especially prone to exploitation by humans?
- What is an ecological footprint and how is it measured?
- What does the size of an ecological footprint tell us about the overexploitation of natural resources?

How do conservation efforts support the health of different ecosystems?

Conservation means striving to 'keep what we have'. The aim of conservation is to protect Earth's biodiversity by maintaining habitats and ecosystems. By conserving habitats, species that inhabit them can also be protected from human disturbances, such as deforestation and pollution.

Conservation aims to slow down the rate of extinction caused by the unsustainable exploitation of natural resources. It also aims to maintain interactions between species (as we explored in Chapter 9). Conservation works to protect and preserve the Earth's ecosystems, so that future generations can live in a world that has the same biological richness that we enjoy today. Central to conservation is the concept of sustainability; that is to say using the resources of the Earth in a way that does not adversely affect future generations.

Non-governmental organizations (NGOs) include Greenpeace and the World Wide Fund for Nature (WWF). An example of an intergovernmental organization (IGO) is the United Nations Environment Programme (UNEP). Both governmental organizations and non-governmental organizations work together to preserve and restore ecosystems and biodiversity, and ensure that human activities are run on a more sustainable basis.

Figure 10.29 Protect the Earth

ACTIVITY: The role conservation organizations play

ATL

- Information literacy skills: Access information to be informed

Scientific research can show the impact that humans are having on the planet and indicate conservation measures that need to be taken. Governments are the organizations that have the ability to make real change. **Intergovernmental organizations (IGOs)** are established through international agreements. They bring governments together to work to protect the Earth's natural resources. Organizations not linked to government also have a role in raising awareness of environmental issues and campaigning for change – these **non-governmental organizations (NGOs)** are not run by, funded by or influenced by governments of any country.

- **Find out about one IGO and one NGO. What are the strengths and limitations of each type of conservation organization? What features do they have in common?**
- **What are international conventions? Find an example of an international convention and research how it has affected attitudes towards sustainability.**

Assessment opportunities

- In this activity you have practised skills that are assessed using Criterion A: Analyse and evaluate information to make scientifically supported judgements.

ACTIVITY: How do we conserve species?

ATL

- Creative-thinking skills: Apply existing knowledge to generate new ideas; Practice flexible thinking
- Critical-thinking skills: Evaluate arguments

Assessment opportunities

- In this activity you have practised skills that are assessed using Criterion A: Analyse and evaluate information to make scientifically supported judgements and Criterion D: Explain the ways in which science is applied and used to address a specific issue.

Imagine you know of a species that is on the verge of extinction. What measures could you take to protect it?

Look at the following photos that show a Sumatran tiger in two different situations. What do these photos tell you about different ways in which species can be conserved? What are the pros and cons of each approach?

Figure 10.30 Visitors photographing Sumatran tigers in a zoo enclosure. This rare subspecies of tiger lives on the Indonesian island of Sumatra. Photographed at the Downtown Aquarium, Denver, Colorado, USA

Figure 10.31 Wild Sumatran tiger in rainforest

International conventions have shaped attitudes towards sustainability. The UN Conference on the Human Environment (which took place in Stockholm, 1972) was the first time that the international community met to consider global environmental and development needs together. It led to the *Stockholm Declaration*, which played an essential role in setting targets and triggering action at both local and international levels. These initiatives ultimately led to the 1992 UN Earth Summit in Rio de Janeiro, organized by UNEP, which resulted in the Rio Declaration and Agenda 21:

- The Earth Summit was attended by 172 governments and set the agenda for the sustainable development of the Earth's resources.
- The Earth Summit led to agreement on two legally binding conventions: the UN Convention on Biological Diversity (UNCBD) and the UN Framework Convention on Climate Change (UNFCCC).
- Agenda 21 was an outcome of the Rio Earth Summit. It is a blueprint for action to achieve sustainable development worldwide, to be implemented at the local level.

NGOs are seen by UNEP as playing a vital role in implementing Agenda 21. The roles of NGOs in implementing Agenda 21 include:

- collecting information about conservation areas
- persuading politicians to implement sustainable development
- raising environmental awareness through publications, local activities, education, TV and radio
- working with other NGOs; sharing information and best practice; creating networks; sharing resources.

SUMMARY REFLECTION

What have you learnt about how humans are trying to protect nature and natural resources? How do conservation efforts support the health of different ecosystems?

***In situ* conservation** is the conservation of species in their natural habitat. This means that **endangered species**, for example, are conserved in their native habitat. Not only are the endangered animals protected, but also the habitat and ecosystem in which they live, leading to the preservation of many other species. *In situ* conservation works within the boundaries of conservation areas or nature reserves.

***Ex situ* conservation** is the preservation of species outside their natural habitats. This usually takes place in zoos, which carry out captive breeding and reintroduction programmes:

- A small population is obtained from the wild or from other zoos.
- Enclosures for animals are made as similar to the natural habitat as possible.
- Breeding can be assisted through artificial insemination.

Botanic gardens also have a role in plant *ex situ* conservation, where both living collections and seed banks are used to store genetic diversity.

Table 10.4 The strengths and limitations of zoos

Strengths	Limitations
They allow education through visits and so the public are more likely to support conservation campaigns	There are ethical arguments about keeping animals in captivity for profit
Genetic monitoring can take place	If the zoo is not properly managed, poor conditions can lead to psychological and physiological problems for animals
They allow captive breeding and reintroduction programmes	Zoo animals may be unable to adapt to life in the wild
The number of offspring surviving to adulthood is higher, so species numbers increase more rapidly	They often focus on high-profile/charismatic species and so can be less successful at saving 'non-cuddly' species
Studying species in zoos allows a better understanding of these animals, leading to improved management of the species outside zoos	Saving a species should require preserving the animal's habitat, which also benefits all other species
They can be used as an 'ark', preserving a species until its habitats are protected or restored	A species can be artificially preserved in a zoo while its natural habitat is destroyed (such as the giant panda)

REVIEW

- **What is meant by 'conservation'?**
- **What are the aims of conservation?**
- **What role do conservation organizations play?**
- **What are the differences between IGOs and NGOs?**
- **How have International Conventions shaped attitudes towards sustainability?**
- **What is meant by '*in situ* conservation'?**
- **What is meant by '*ex situ* conservation'?**
- **Evaluate the role that zoos and protected areas play in conservation.**

Table 10.4 summarizes the strengths and limitations of zoos. Table 10.5 compares the strengths and limitations of the two different approaches to conservation.

Table 10.5 Strengths and limitations of *in situ* (protected areas) and *ex situ* (e.g. zoos)

	Strengths	Limitations
Protected areas	Can conserve whole ecosystems Allow research and education Preserve many habitats and species Prevent hunting and other disturbance from humans Allow for *in situ* conservation	Can be expensive Difficult to manage Subject to outside forces that are difficult to control Difficult to establish in the first place due to political issues/vested interests
Zoos	Allow controlled breeding and maintenance of genetic diversity Allow research Allow for education Effective protection for individuals and species	Have historically preferred popular animals; not necessarily those most at risk Problem of reintroducing zoo animals to wild *Ex situ* conservation and so do not preserve native habitat of animals

Should governments create laws to change people's attitudes and behaviour?

■ **Figure 10.32** A rubbish tip indicates how consumerism-based societies have become, and the negative effects they are having on the environment

DOES THE POSSIBILITY OF ECONOMIC GROWTH JUSTIFY THE OVEREXPLOITATION OF NATURAL RESOURCES?

In this chapter we have learnt about how human population growth has put increasing pressure on the Earth's natural resources. Pollution, overhunting, the introduction of invasive species and habitat destruction are all putting species in danger and making our lifestyles unsustainable in the long term.

The economic growth enjoyed by many countries is often at the expense of the natural world. Economic growth relies on the continued exploitation of natural resources, in particular oil, which fuels energy demands in MEDCs. Burning oil and other fossil fuels is leading to climate change, and the continued quest for more and more resources in order to support the consumerist society of MEDCs leads to both pollution and habitat loss.

■ **Figure 10.33** Economic growth and the environment: pointing in different directions?

DEBATE: Does economic growth justify the overexploitation of natural resources?

ATL

- Collaboration skills: Listen actively to other perspectives and ideas; Negotiate effectively

■ **Figure 10.34** A landfill site in Russia

From what you have learnt in this chapter, you may be wondering why people do not work harder to reduce the negative impact we are having on the planet. If you have a comfortable lifestyle, how easy is it for you to change it, especially if you know the damaging effect it is having on the environment? People like to stay in their comfort zone and do not like change. Should governments, therefore, create laws to make people change their behaviour in order to reduce the negative effects their lifestyle is having?

EXTENSION

What does Figure 10.35 suggest to you?

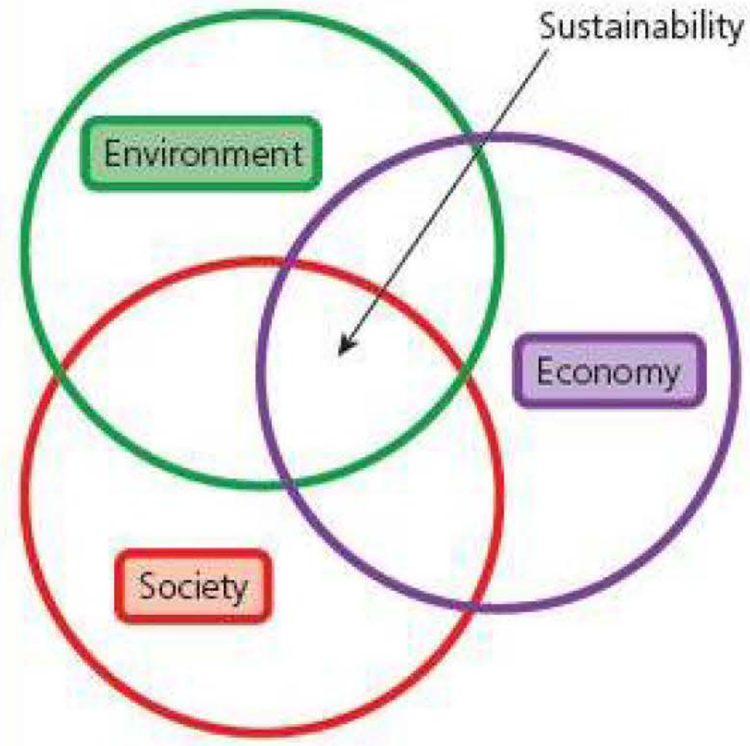


Figure 10.35 The concept of sustainability

SUMMARY REFLECTION

What have you learnt about whether economic growth justifies the overexploitation of natural resources? Should governments create laws that require people to alter their behaviour in order to mitigate the negative effects of human lifestyles?

Organize two class debates that address the following arguments:

- **Debate 1: To what extent should economic growth justify the overexploitation of natural resources?**
- **Debate 2: Should governments create laws that require people to alter their behaviour in order to mitigate the negative effects of human lifestyles?**

Divide into two teams – one group will argue the 'pro' perspective and the other the 'con' point of view.

Following the debate reflect on the views of the opposing side. Did they have a valid point of view? Has your own position changed as a result of the debate, and if so why?

Assessment opportunities

- In this activity you have practised skills that are assessed using Criterion A: Analyse and evaluate information to make scientifically supported judgements.

DISCUSS

- **Discuss with your neighbour the issues raised in this section. Do you agree or differ in your points of view?**
- **What have you learnt in this chapter about how the choices people make affect the environment?**
- **How has the human population changed over the past 12 000 years and how has this affected the environment?**
- **What human threats do natural systems face?**
- **What is pollution and how is it affecting the Earth?**
- **What is global warming and what are the effects of climate change?**
- **Does economic growth justify the overexploitation of natural resources?**
- **How can we conserve nature and natural resources, and ensure a more sustainable future?**
- **What have you learnt about yourself as a balanced learner? What have you learnt about recognizing our interdependence with others and with the world in which we live?**

Take action: Working towards a more sustainable future

Figure 10.36 Save the Earth

Figure 10.37 The 3Rs help to make a sustainable future

! In your class, work out the ecological footprint of your school or college. How could you reduce the footprint? Perhaps you could consider the following:

- Increase use of renewable energy, such as solar power, geothermal heat pumps, and wind power.
- Increase insulation in buildings if you live in the northern hemisphere.
- Use energy-saving bulbs.
- Use smart technology that switches off utilities when they are not in use.
- Reduce food waste.
- Recycle.
- Convert waste vegetable oil from cooking into biodiesel for use in school vehicles.
- Develop a culture that reuses resources and reduces consumption (see Figure 10.37).
- Turn off electrical equipment such as computers when not in use.
- Use rainwater ('greywater') for showers and toilets.

! Produce a report to give to the Head of your school or college. Indicate the current ecological footprint and your plans to reduce it. Now campaign for your changes to be implemented. Perhaps you could set up a 'Green team' to help keep the pressure up and ensure a sustainable future for your college?

Assessment opportunities

- This activity can be assessed using Criterion D: Explain the ways in which science is applied and used to address a specific issue.

EXTENSION: Solar roadways

Check out the future here:

www.youtube.com/watch?v=qlTA3rnpgzU

www.solarroadways.com/intro.shtml

SOME SUMMATIVE PROBLEMS TO TRY

Use these problems to apply and extend your learning in this chapter. These problems are designed so that you can evaluate your learning at different levels of achievement in Criterion A: Knowledge and understanding.

THIS PROBLEM CAN BE USED TO EVALUATE YOUR LEARNING IN CRITERION A TO LEVEL 1–2

1 **a** **State** what is meant by the term 'pollution'.

b **State** four gases produced by burning fossil fuels.

c **State** one gas responsible for acid rain.

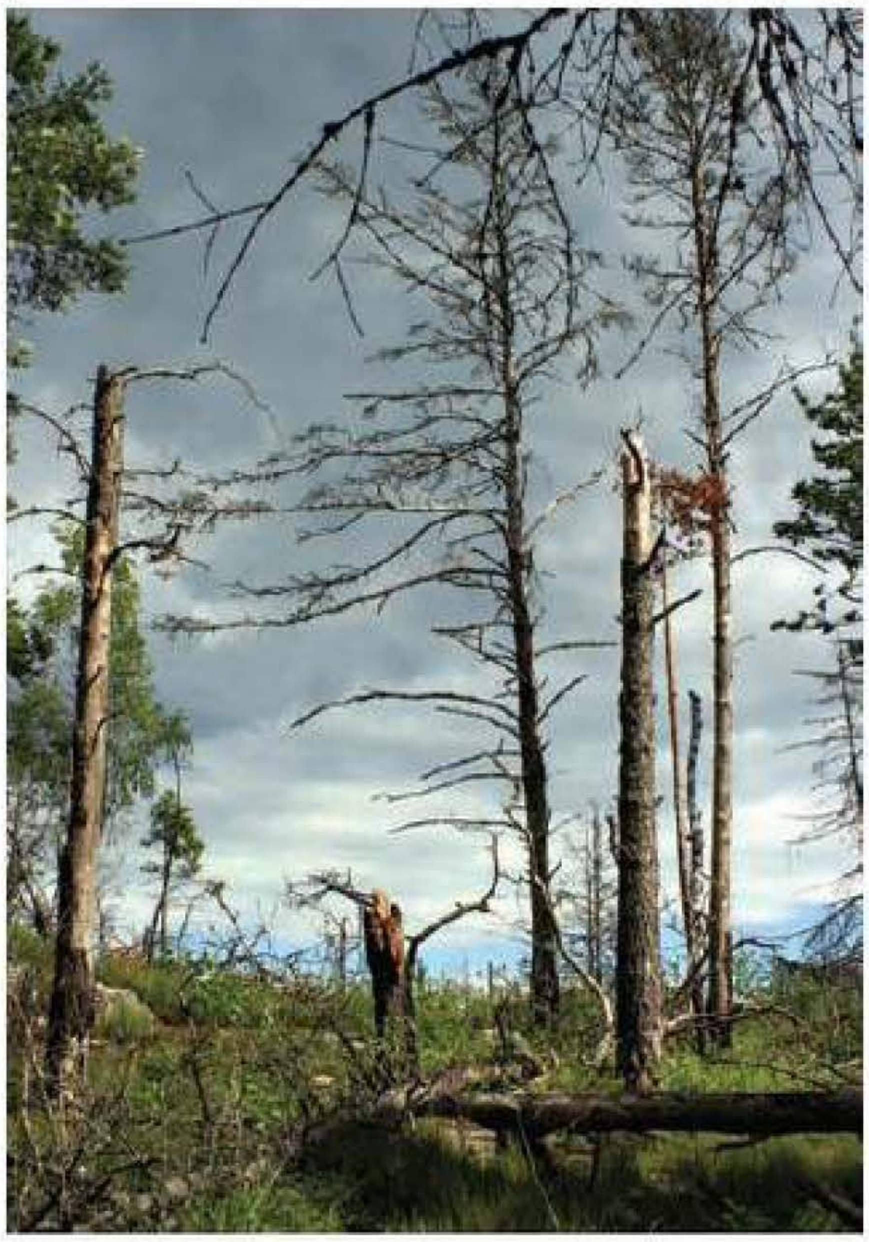
Figure 10.38 shows environments affected by pollution.

d **i** **State** which of the photos show the effects of acid rain.

ii **Suggest** how the effects of acid rain could be reduced.

e **i** **State** which of the photos show the effects of eutrophication.

ii **Suggest** how the effects of eutrophication could be reduced.

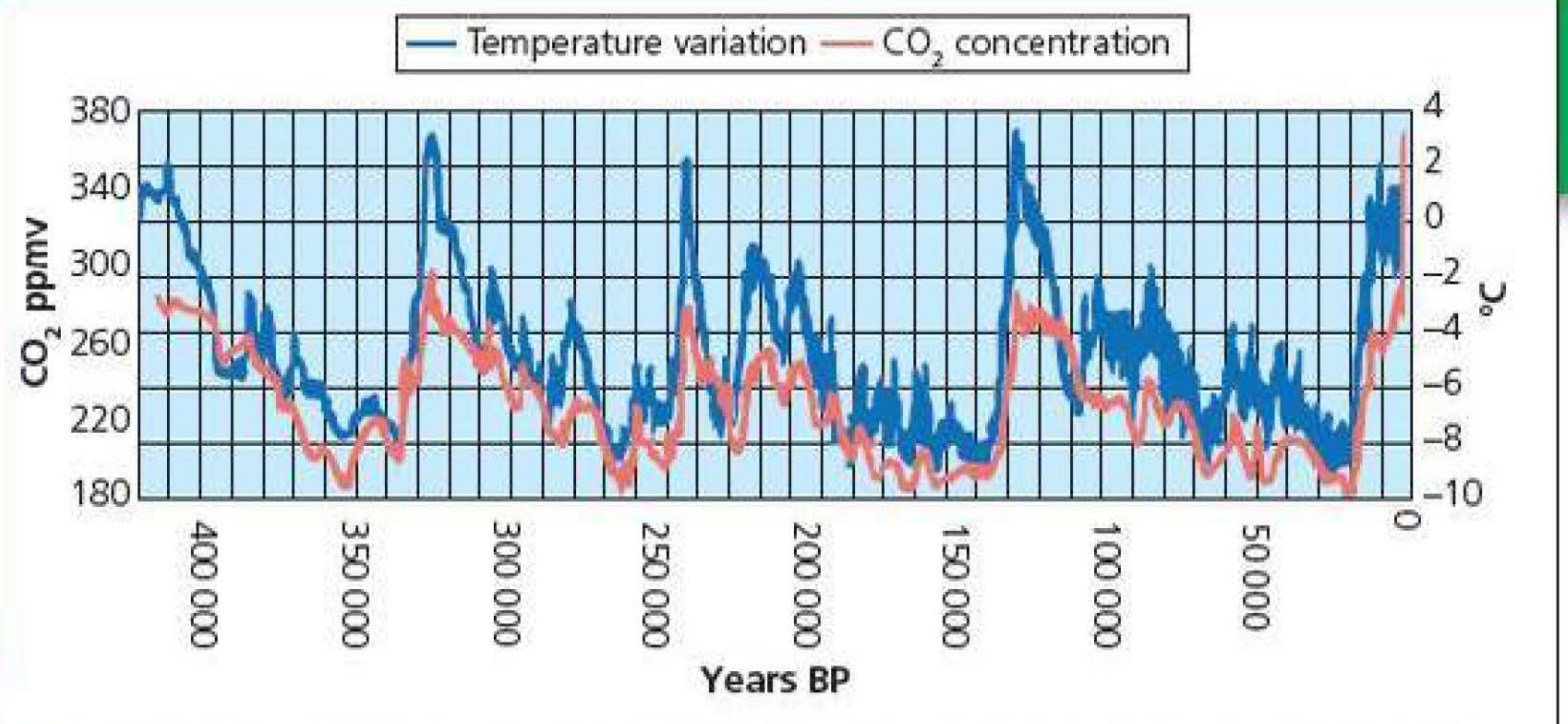


A

B

C

■ **Figure 10.38** The effects of pollution on the environment



■ **Figure 10.40** Changes in carbon dioxide concentration and temperature through time

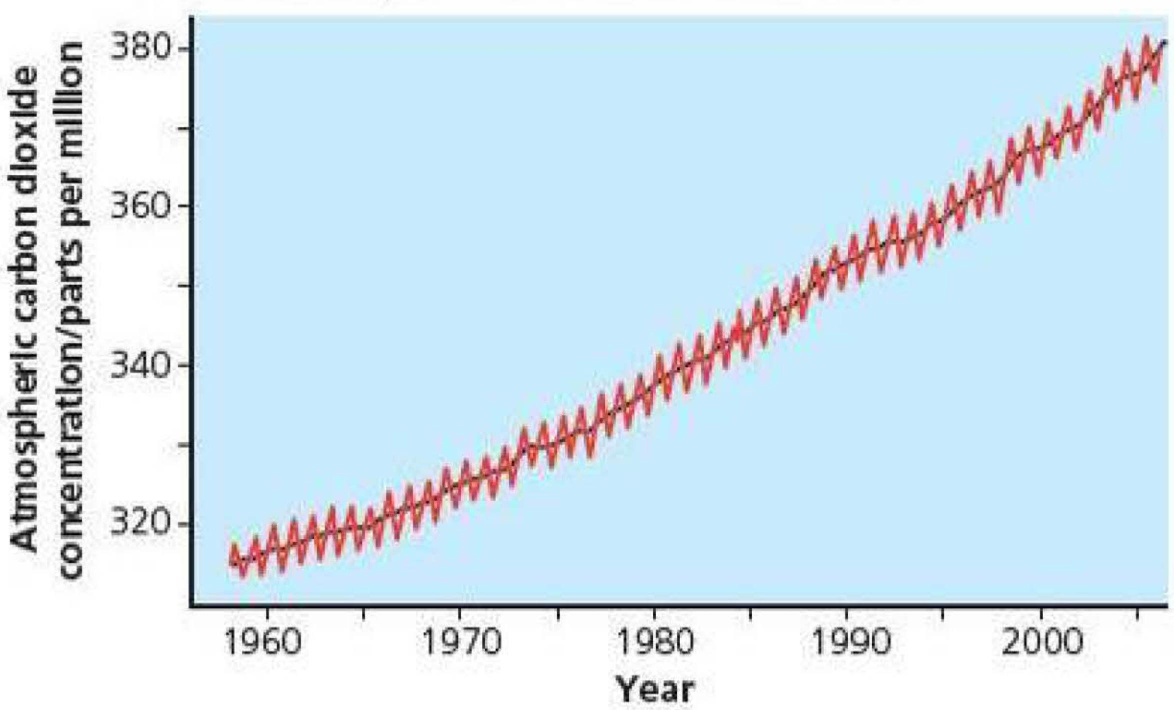
THIS PROBLEM CAN BE USED TO EVALUATE YOUR LEARNING IN CRITERION A TO LEVEL 3–4

2 **a** The levels of atmospheric carbon dioxide have been increasing during the past years (Table 10.6). **Outline** the reason for this increase.

■ **Table 10.6** Changing levels of atmospheric carbon dioxide

	CO_2 / ppm
pre-Industrial Revolution level	280 ± 10)
by mid-1970s	330
by 1990	360
by 2007	380
by 2013	400
by 2050 (if current rate is maintained)	**500**

b **Outline** the effects of increased carbon dioxide levels in the atmosphere on the Earth's climate.



■ **Figure 10.39** Changes in atmospheric carbon dioxide levels between 1960 and 2000

c Figure 10.39 shows data collected at the Mauna Loa Observatory, Hawaii. This is an atmospheric research station that has been continuously monitoring atmospheric change since 1957. The atmospheric carbon dioxide concentration shows increases and decreases, with lower concentrations in the summer months and higher in the winter months. **Apply** your scientific knowledge to **suggest** why these fluctuations occur.

d Figure 10.40 shows fluctuations in carbon dioxide concentration and temperature over the geological past up to the present day.

i **Outline** how these data could have been collected.

ii **Outline** whether these data are evidence for global warming caused by changes in greenhouse gas concentrations.

3 Carbon dioxide is a greenhouse gas.

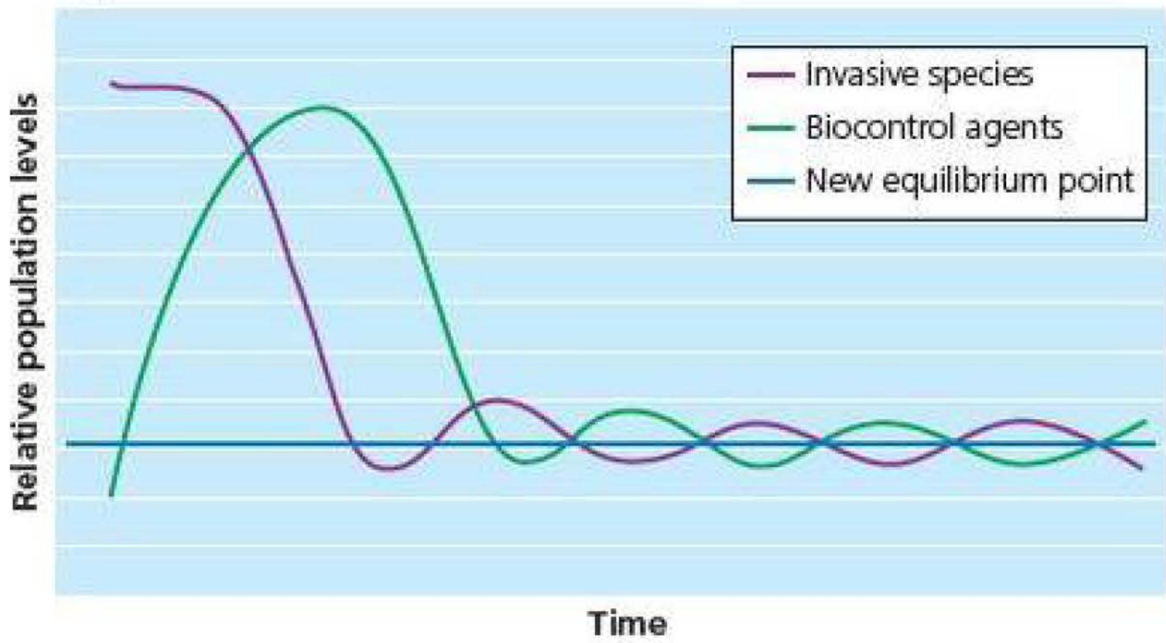
a **State** the name of one other greenhouse gas.

b **Outline** reasons why the greenhouse gas you have named in part **a** is increasing.

THESE PROBLEMS CAN BE USED TO EVALUATE YOUR LEARNING IN CRITERION A TO LEVEL 5–6

4 **Describe** how human activities are harming the environment.

5 Biocontrol agents can be introduced to control invasive species.



■ **Figure 10.41** Graph showing the effect of a biocontrol agent on an invasive species

a **Describe** what is meant by the term 'invasive species'.

b Use information in Figure 10.41 to **suggest** what is meant by the term 'biocontrol agent'.

c **Describe** the results shown in Figure 10.41 and **suggest** reasons for the patterns recorded.

d i **Suggest** what is meant by 'new equilibrium point'.

ii **Suggest** why the new equilibrium is important for maintaining the biocontrol agent population.

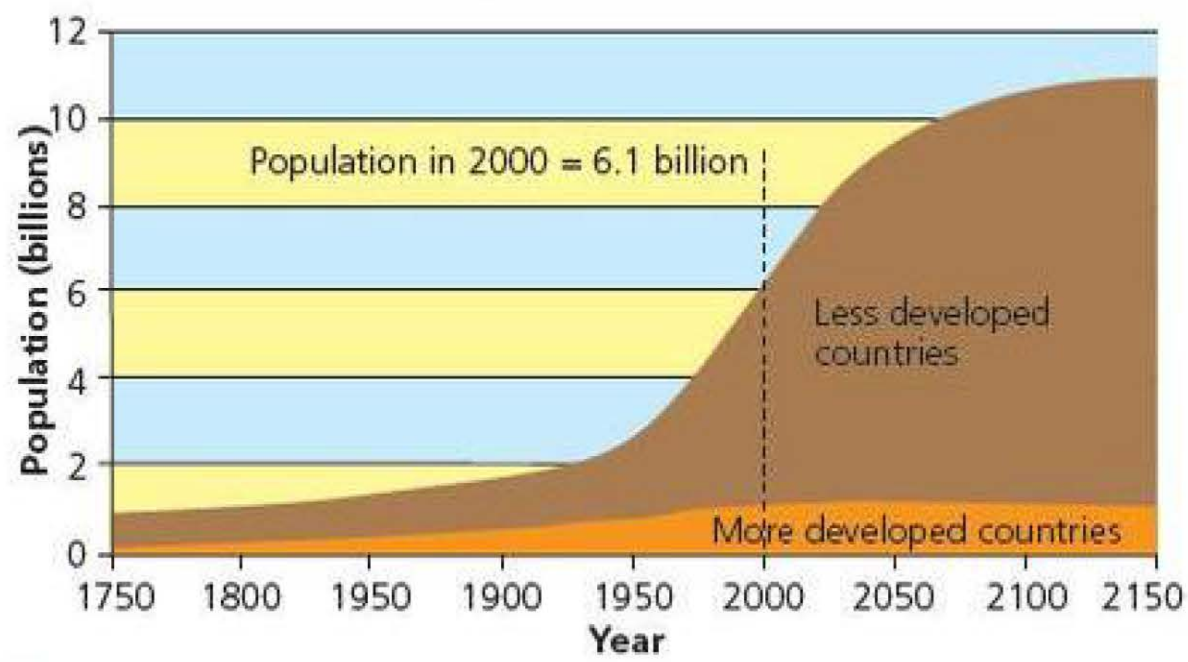
e **Suggest** why biocontrol agents must be carefully chosen.

THESE PROBLEMS CAN BE USED TO EVALUATE YOUR LEARNING IN CRITERION A TO LEVEL 7–8

6 Tropical rainforests are one of the most biodiverse ecosystems on Earth. They are under threat from human activities.

■ **Figure 10.42** Deforestation in the Amazon rainforest

a **Explain** why deforestation in tropical forests leads to loss of biodiversity.

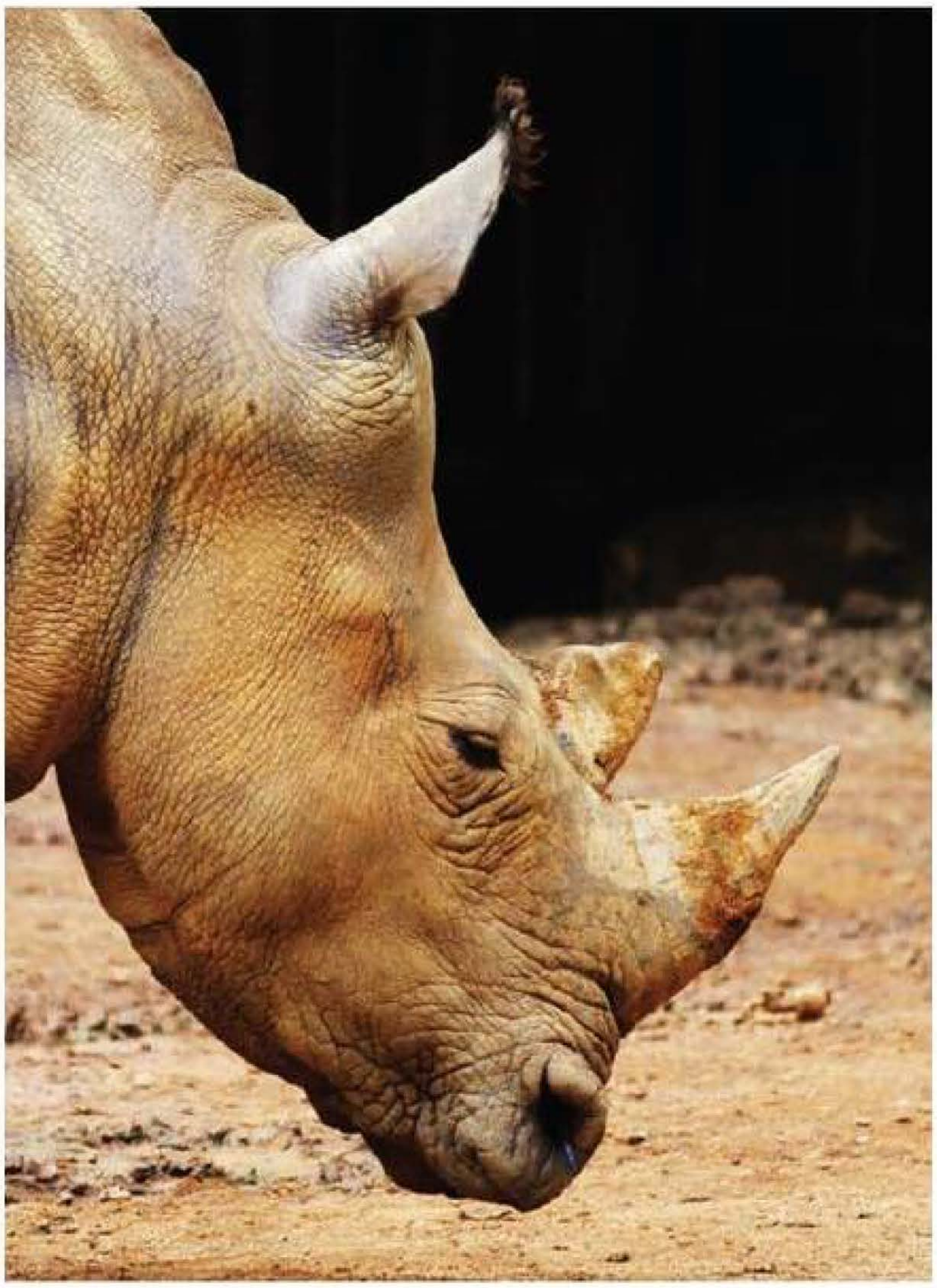


■ **Figure 10.43** Population growth in LEDCs and MEDCs

Tropical rainforests are mainly found in developing countries.

b Use information from Figure 10.43 to **suggest** reasons for loss of tropical rainforests due to human activities.

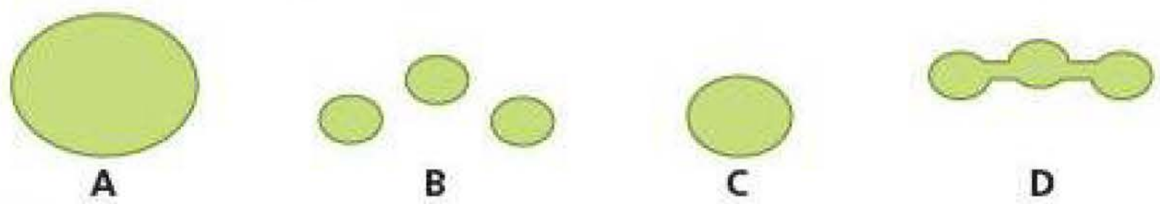
7 The Sumatran rhino is a large herbivorous animal found on the islands of Sumatra and Borneo. There may be less than 100 left in the wild.



■ **Figure 10.44** A Sumatran rhino

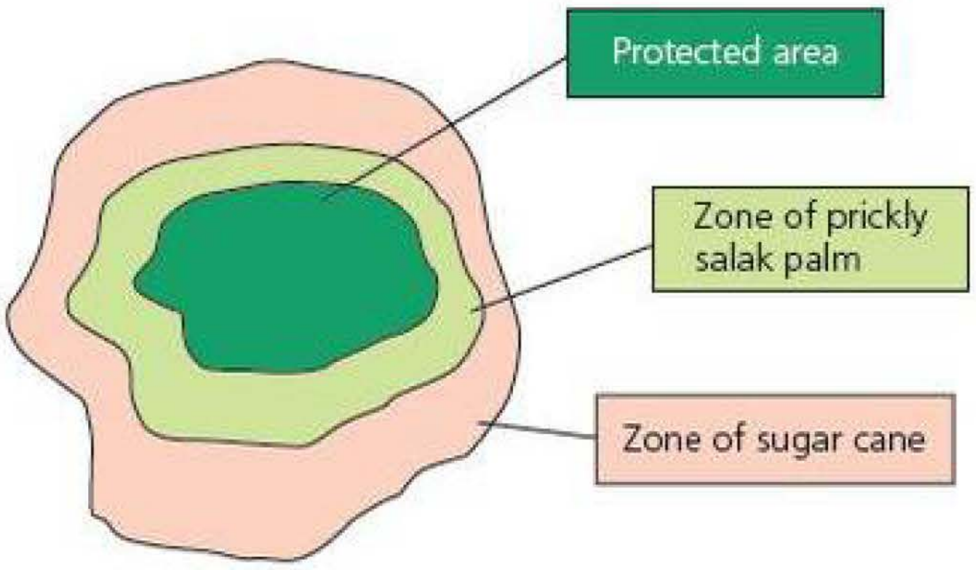
Sumatran rhinos can be protected in conservation areas.

a Which of the following conservation areas would be best for protecting the Sumatran rhino? You can select more than one design. **Explain** your selection(s).



■ **Figure 10.45** A selection of reserve designs

An area of forest in Borneo containing Sumatran rhinos and other endangered species is surrounded by a buffer zone.



■ **Figure 10.46** A buffer zone around a protected forest in Borneo

b i **Suggest** how the buffer zone helps protect endangered wildlife.

ii **Suggest** benefits to the local human population of

1 maintaining buffer zones.

2 maintaining biodiversity in the protected area.

c **Explain** alternative methods, other than protected areas, of conserving Sumatran rhinos. **Evaluate** the different methods of conserving the Sumatran rhino.

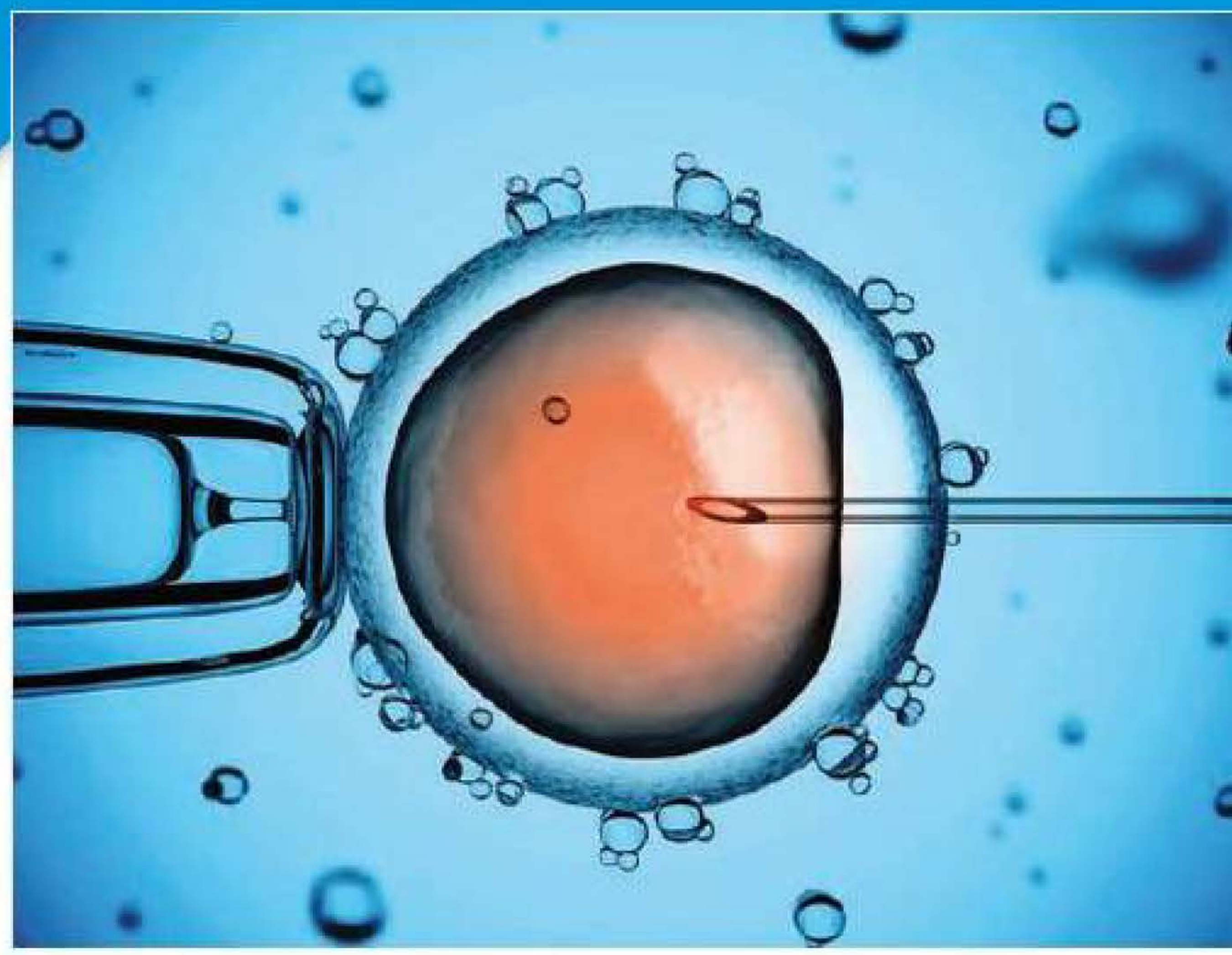
Reflection

In this chapter we have learnt about how the choices people make can affect the environment. We have seen how human population has changed over the past 12 000 years and the impact this has had on the environment. We have explored the human threats that natural systems face, and what we can do to alleviate these dangers. We have discussed whether economic growth can ever justify the overexploitation of natural resources, and how we can conserve nature and natural resources to ensure a more sustainable future. We have learnt about ourselves as a balanced learner, recognizing our interdependence with others and with the world in which we live.

<table>
<tr><th colspan="6">Use this table to reflect on your own learning in this chapter</th></tr>
<tr><td>Questions we asked</td><td>Answers we found</td><td colspan="4">Any further questions now?</td></tr>
<tr><td>Factual: How has human population growth changed over the last 12 000 years? In what ways do humans influence or change different habitats? What is pollution? What is global warming? In what ways do humans overexploit natural resources? In what ways do humans try to protect nature and natural resources?</td><td></td><td colspan="4"></td></tr>
<tr><td>Conceptual: Why has population growth changed? What impact has human disturbance had on natural systems? How is pollution harming the environment? What are the effects of climate change? How do human lifestyles determine the health of different ecosystems? How do conservation efforts support the health of different ecosystems?</td><td></td><td colspan="4"></td></tr>
<tr><td>Debatable: To what extent does the possibility of economic growth justify the overexploitation of natural resources? Should governments create laws that require people to alter their behaviour in order to mitigate the negative effects of human lifestyles?</td><td></td><td colspan="4"></td></tr>
<tr><td rowspan="2">Approaches to learning you used in this chapter:</td><td rowspan="2">Description – what new skills did you learn?</td><td colspan="4">How well did you master the skills?</td></tr>
<tr><td>Novice</td><td>Learner</td><td>Practitioner</td><td>Expert</td></tr>
<tr><td>Creative-thinking skills</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Critical-thinking skills</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Transfer skills</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Information literacy skills</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Collaboration skills</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Organization skills</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Learner profile attribute(s)</td><td colspan="5">Reflect on the importance of being balanced for your learning in this chapter.</td></tr>
<tr><td>Balanced</td><td colspan="5"></td></tr>
</table>

11 How does biotechnology create new options in industry and health?

The **development** and use of biotechnology to **change** and **transform** genes helps create new options, choices and opportunities in industry and health: whether these **developments are fair** for all remains to be seen.



■ **Figure 11.1** A human egg on the tip of a pipette – a needle is inserted into the nucleus to extract genetic material

CONSIDER AND ANSWER THESE QUESTIONS:

Factual: What is a clone? What is selective breeding? What techniques are used to modify genes? In what ways are humans able to manipulate genes to create new cells, tissues and organs?

Conceptual: How can cloning benefit farming and agriculture? How does the modification of genetic information influence human lifestyles? How do people's personal beliefs and values influence the development and application of biotechnological techniques? What are the possible consequences of developing and applying more biotechnology?

Debatable: To what extent should people be allowed to clone organisms? To what extent should genetically modified organisms be used in farming and food production? Should governments fund continued biotechnological research on stems cells and genetic modification? Who should have the power to modify and control genetic material? To what extent should income level determine a person's access to medical treatments that involve applying the products of biotechnology?

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

IN THIS CHAPTER, WE WILL …

- **Find out:**
  - how cloning and genetic modification occur;
  - about the impacts of biotechnology.
- **Explore** opportunities provided by biotechnology in industry and health, and whether these developments are fair for all.
- **Take action** by writing an article for a newspaper, magazine or website about the issues surrounding biotechnology.

KEY WORDS

ethical	modification	transfer
manipulate	technology	transformation

■ **Figure 11.2** Cell biologist holding a flask containing stem cells, cultivated in red growth medium, to investigate disease

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

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

We will reflect on this learner profile attribute …

- Communicators – expressing yourself confidently and creatively; collaborating effectively, listening carefully to the perspectives of others.

Assessment opportunities in this chapter:

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

SEE–THINK–WONDER

In this task, you are going to find out about the issues surrounding biotechnology. You will use this information to stage a class debate arguing the pros and cons of the new technology.

Individually, see what you can find out about biotechnology: **stem cells**, **cloning**, **genetic modification**, **GM, biotechnology**, **genome mapping**, **bioprinting**.

Now develop arguments surrounding this new technology. There are two key areas of debate:

- **The scientific debate: what techniques are possible within biotechnology, given our current knowledge of biology? What should science be researching? Is there anything it shouldn't be researching?**
- **The ethical/moral debate: people may object to the new technology because of religious beliefs, ethical arguments or because they believe that changing the DNA of humans or other organisms is contrary to nature. Others may have concerns about where such research may take us.**

In pairs, develop arguments (supported by evidence) for and against biotechnological development. Decide in your pair who will be 'pro' and who will be 'con'. Note – these positions do not need to reflect your own personal opinion. Spend one lesson gathering your arguments for a debate.

Now the whole class divides into teams – those 'for' in one team and those 'against' in the other. Exchange ideas and information within your team. How will you present your argument (e.g. PowerPoint, Prezi, speeches …?) Now hold the debate.

As a whole group **discuss**: Will these developments be fair for all?

Biotechnology involves the use of biological knowledge and understanding, and is where biological processes, organisms, **cells** or parts of cells are utilized to develop new technologies. New tools and products developed by biotechnology are useful in research, agriculture, industry and health.

The **technology** and issues involved in biotechnology can be controversial. Some people see the methods used by biotechnology as 'meddling with nature', whereas others believe that the ends justify the means.

How can cloning benefit farming and agriculture? To what extent should people be allowed to clone organisms?

The **DNA** in the **nucleus** of cells can be **manipulated** in a variety of ways. The two main techniques are:

- **Cloning** – where the DNA of one organism is copied exactly into another organism (there is no change to the DNA). **Genes** are copied *within* the same **species**.
- **Genetic engineering** or **genetic modification (GM)** (discussed on pages 283–288) – DNA is modified so that a unique set of genes is produced. Genes can be swapped *across* species (this is because DNA is found in all living things and is, therefore, a universal molecule). **Selective breeding** has, for thousands of years, been modifying the gene pools of species by selecting favourable **characteristics**, providing us with improved crops and livestock, leading to disease resistance or improved milk yield, for example. Genetic engineering provides a faster way to modify species by directly transplanting genes for a desired characteristic into an organism.

ACTIVITY: Create a clone

ATL

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

Figure 11.4 Baby twins – natural cloning

WHAT IS A CLONE?

Cloning made the headlines when Dolly the sheep came into the world. She was the first cloned mammal, and people began to speculate – if we can clone a sheep, then why not clone a human? What ethical and moral issues would this raise?

Figure 11.3 Professor Ian Wilmut and Dolly. In 1996, British scientist Professor Ian Wilmut created 'Dolly', the world's first sheep cloned from an adult sheep cell. The cell nucleus was removed from an egg cell taken from a Scottish Blackface ewe. Next, an adult cell from the udder of a 6-year-old Finn Dorset ewe was cultured and injected into the enucleated egg cell. A spark of electricity then fused the udder cell with the egg cytoplasm and stimulated the egg to grow into an embryo in the womb of a surrogate sheep

- Imagine you are a doctor in a hospital department dealing with infertility treatment.
- A couple come to you who want their own children, but cannot conceive. They want children that are genetically related to them.
- The country in which you work has no law against cloning humans. Your team decide to develop a technique for human cloning.
- On an A4 sheet **draw** the stages that your team would have to go through to clone patient 'X' (one of the couple who have come to you). Think carefully about how you would do this. Use your knowledge of DNA, the cell and what happens during meiosis and fertilization to help you.
- What ethical issues are raised here? Think back to the issues you explored in the activity on page 279.

What natural examples of cloning occur during human reproduction? How are these clones (otherwise known as identical twins) produced? Could scientists reproduce these events in the lab, or are there other techniques that could be used?

◆ Assessment opportunities

- In this activity you have practised skills that are assessed using Criterion A: Apply scientific knowledge to solve problems.

■ **Figure 11.5** Embryo splitting

■ **Figure 11.6** Gardener inserting hardwood cuttings of the Orange Ball Tree (*Buddleja globosa*) in a prepared trench. All cuttings are from the same parent tree

There is a variety of different types of cloning:

- **Embryo cloning/embryo splitting**: Splitting cells apart from a developing embryo, before they become specialized, to produce several identical embryos.
- **Nuclear transfer**: Transferring a body cell into an egg and then stimulating cell division to produce an embryo (Figure 11.3 and below).
- **Cuttings**: Taking a small piece of stem or leaf and growing it in the right conditions to produce a new plant.
- **Tissue cloning**: Getting a few cells from a desirable plant to make a big mass of identical cells, each of which can produce a tiny identical plant.

Clones can also be produced naturally, by asexual reproduction. This is reproduction that involves only one parent. There is no joining of gametes and the offspring are genetically identical to the parent.

The first vertebrate clone was a frog – the nucleus of a body cell was taken from an adult frog and placed in an egg cell – the size of frogspawn made this possible. The first cloned mammal was developed in 1996. Dolly the sheep became

■ **Figure 11.7** Tissue culture can produce large quantities of healthy plants in sterile laboratory conditions

SUMMARY REFLECTION

- **What have your learnt about how cloning takes place?**
- **What have you learnt about how cloning can benefit farming and agriculture?**
- **What do you think about these issues – to what extent should people be allowed to clone organisms?**

the most famous clone when she was born at the Roslin Institute in Edinburgh. A cell from the donor animal was taken from a mammary gland and put in the egg of another sheep – the fertilized egg was put into the surrogate mother and Dolly was born (Figure 11.8). The production of a healthy clone proved that a cell taken from a specific part of the body could recreate a whole individual.

What are the benefits of cloning?

- Providing new babies for infertile couples.
- Producing new **organs** for **transplant** that won't be rejected.
- Helping ensure the survival of endangered species, and bringing back extinct animals.
- Producing useful proteins in milk to treat diseases.
- Producing medically useful animals.
- Producing prize agricultural animals.
- Pet cloning.

REVIEW

- **What different techniques are there to clone organisms? List and outline three.**
- **What is nuclear transfer and how can this be used to clone organisms?**
- **What are the benefits of cloning? What are potential problems?**

What are the issues concerned with cloning?

- Many embryos were miscarried before Dolly was produced.
- A large number of embryos are destroyed in this technology, although in the future this wastage level may not be so high.
- Religious or ethical beliefs state that it is wrong to interfere with nature.
- Many believe that it is wrong to destroy or tamper with embryos.
- The method reduces genetic **variation**.

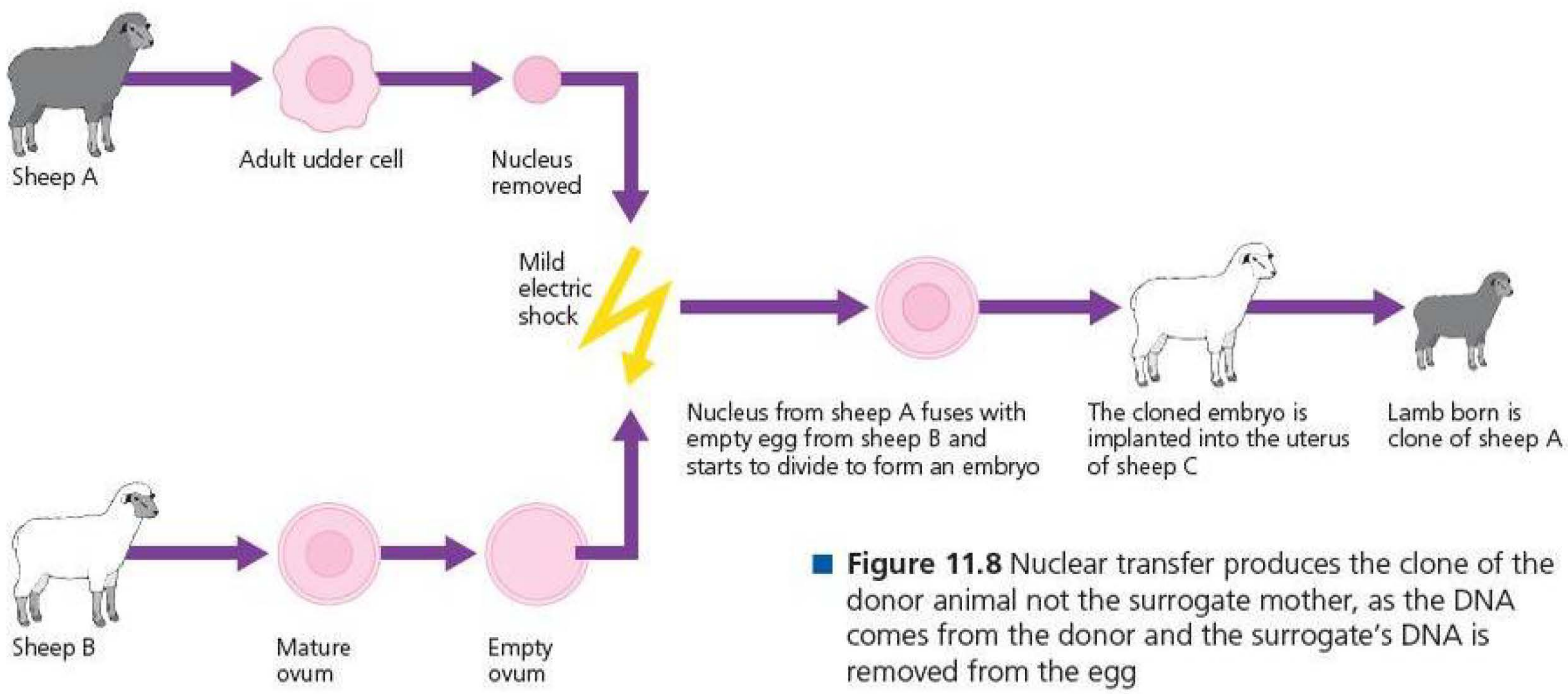
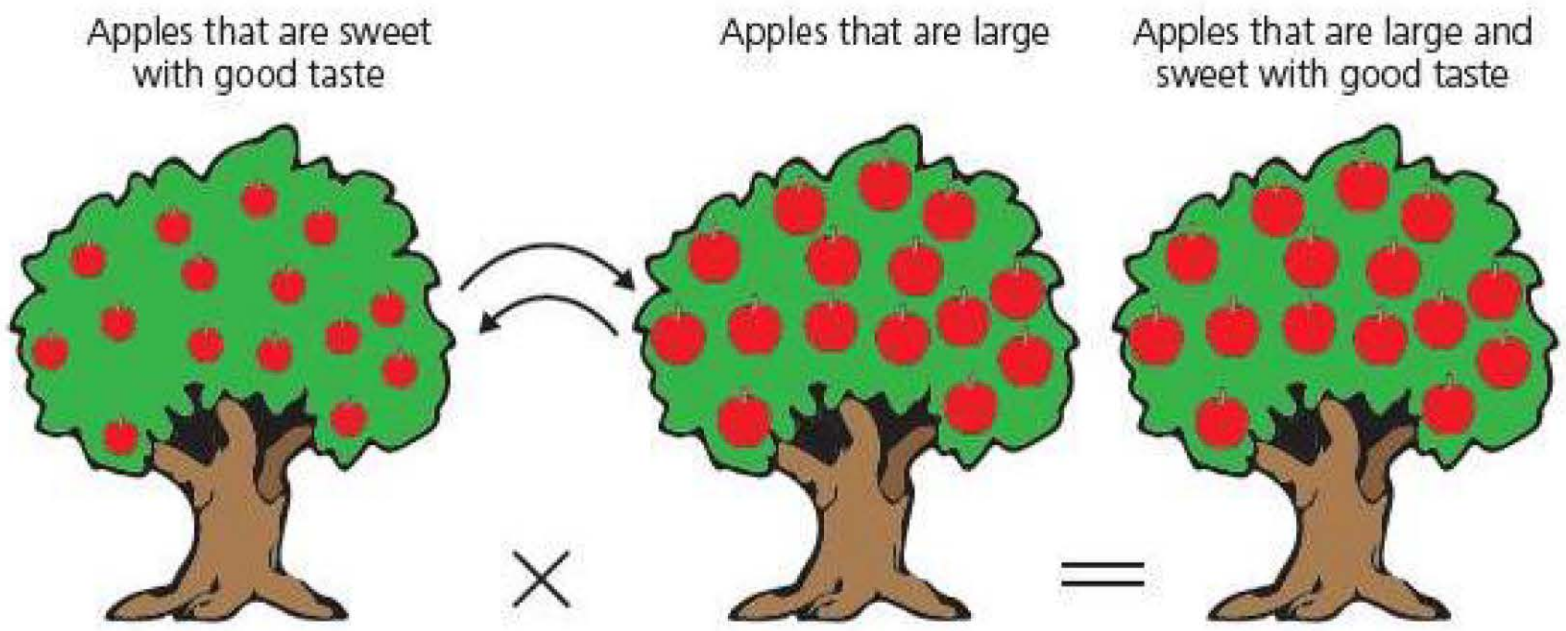


Figure 11.8 Nuclear transfer produces the clone of the donor animal not the surrogate mother, as the DNA comes from the donor and the surrogate's DNA is removed from the egg

WHAT IS SELECTIVE BREEDING?

Selective breeding provided Darwin with evidence to support his theory of **evolution** by **natural selection** (pages 173–185). Humans have created hundreds (if not thousands) of varieties of different species, generally used for food, by selecting desirable characteristics in organisms and then **cross-breeding** with similar individuals.



Pollen is removed from one tree and transferred to another: this ensures that the desired characteristics of one are combined with those of another. Humans have, therefore, selected which trees will reproduce, i.e. artificial selection has taken place.

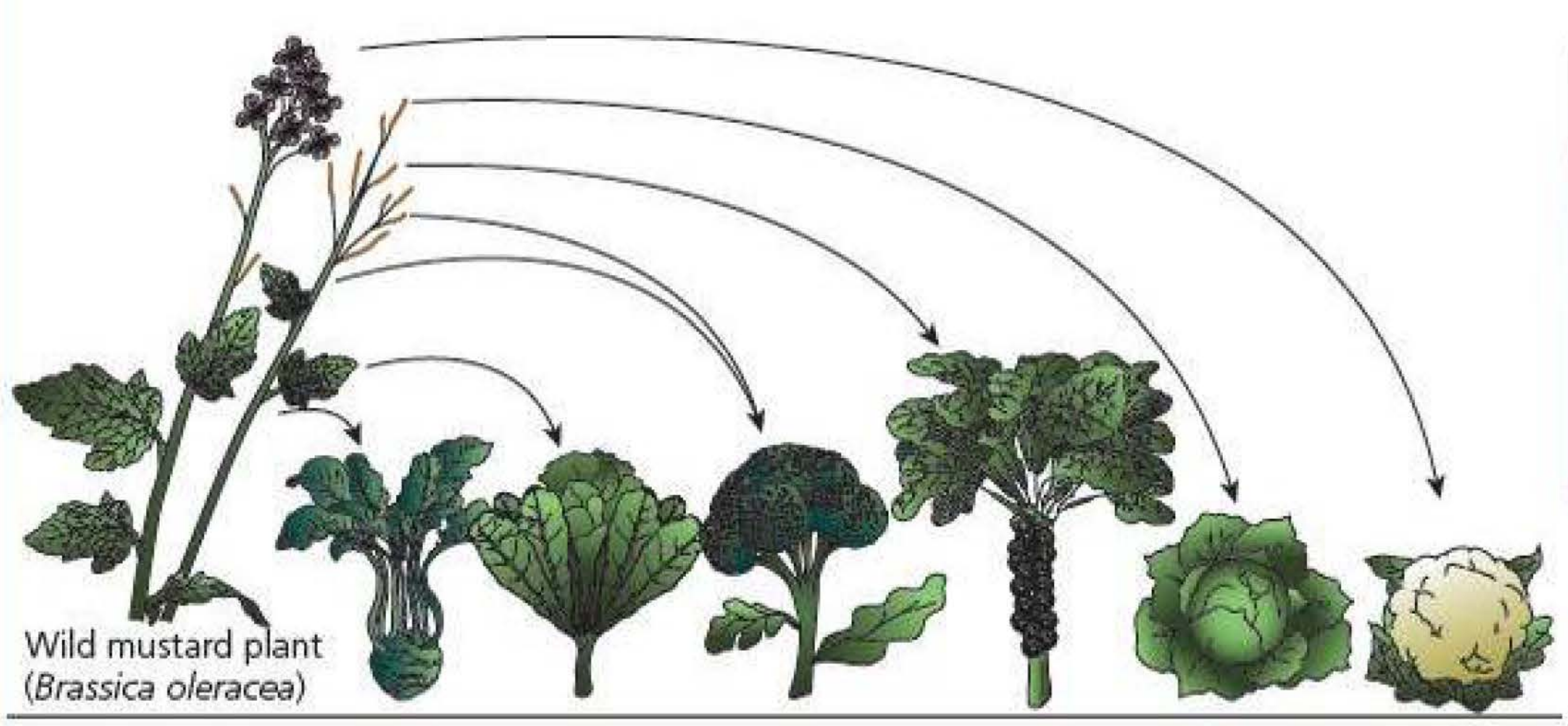
■ **Figure 11.9** Selective breeding has produced apple varieties from a wild species

ACTIVITY: Selecting different vegetables

■ ATL

■ Critical-thinking skills: Draw reasonable conclusions and generalizations

Look at the following diagram:



- **What does this diagram tell you about the origin of everyday sources of food?**
- **What other food that we eat daily is the result of similar selective breeding?**
- **Can this be seen as a form of 'genetic modification'?**

◆ Assessment opportunities

◆ In this activity you have practised skills that are assessed using Criterion A: Apply scientific knowledge to solve problems.

■ **Figure 11.10** Selective breeding of wild mustard to create different types of vegetable

ACTIVITY: Selecting for different breeds of dogs

ATL

- Critical-thinking skills: Draw reasonable conclusions and generalizations

Now think about different breeds of dog, and their wolf **ancestor**.

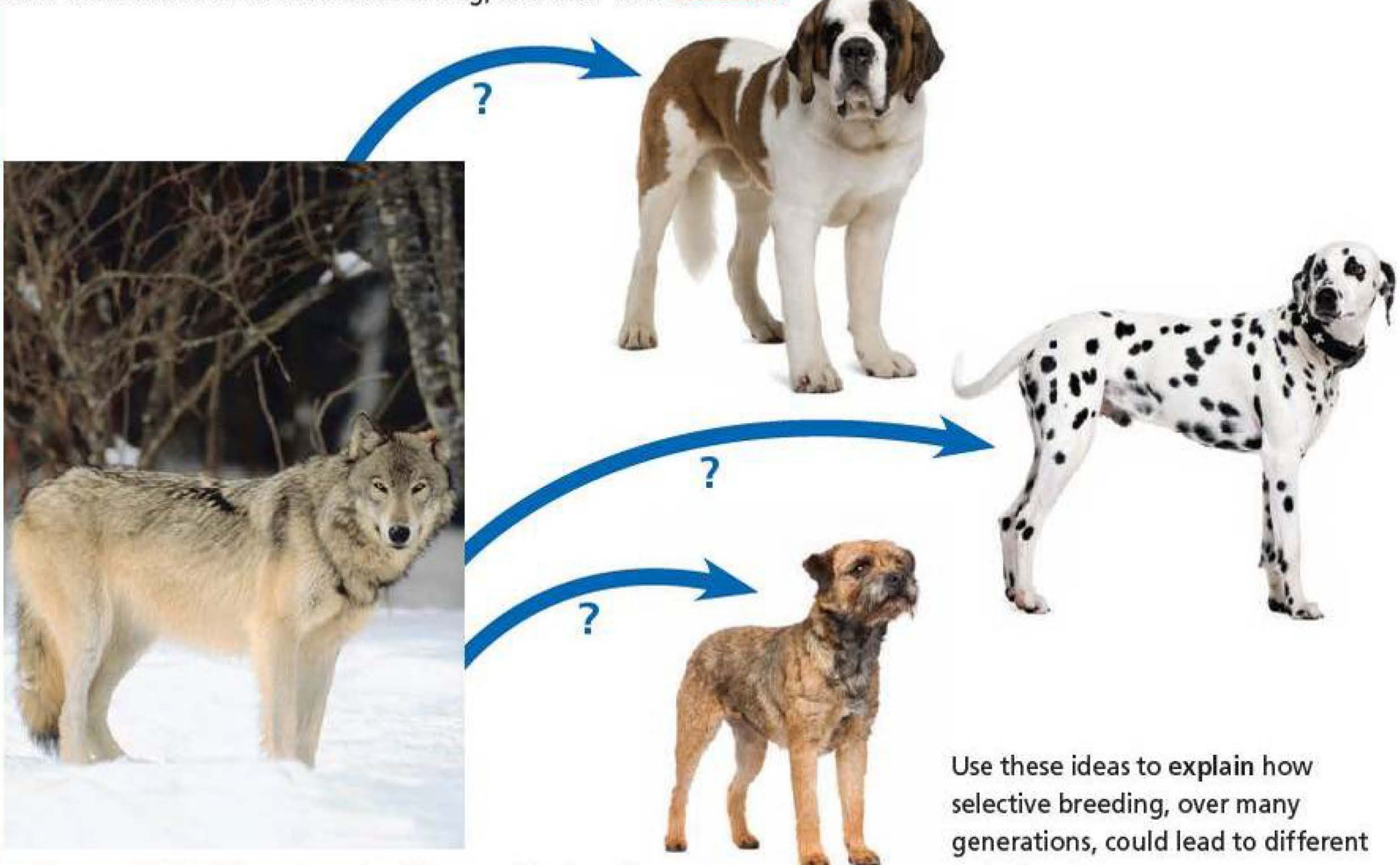


Figure 11.11 Different breeds of dog and their wolf ancestor

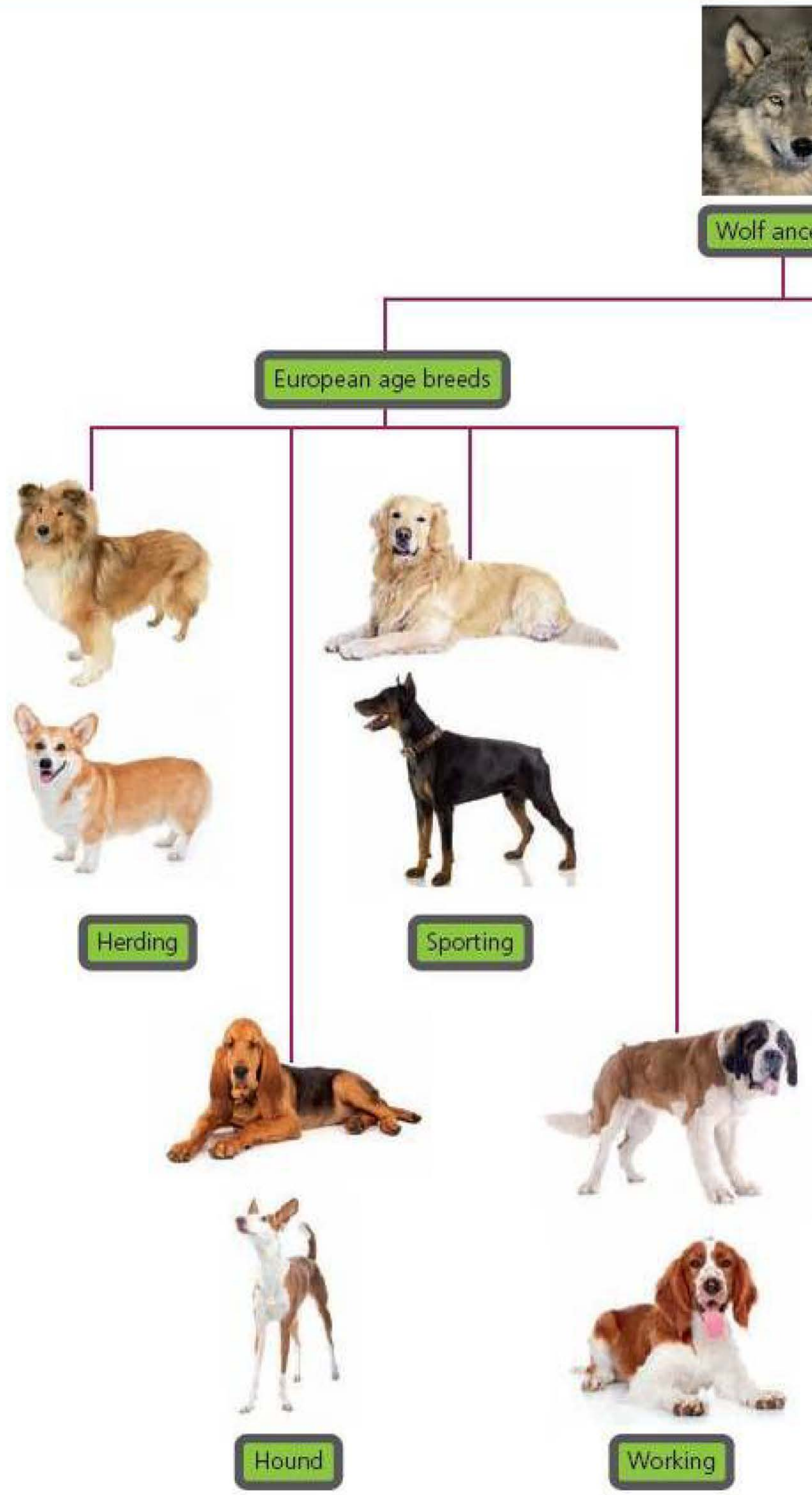
Selective breeding works in the following way:

- **Choose and animal or plant with a desired feature, for example large size.**
- **Mate this individual with another that has similar desirable characteristics.**
- **Identify the offspring that have inherited the desired gene.**
- **Continue to breed using selected offspring – do not allow others to mate.**
- **This increases the number of animals or plants with the desired feature.**
- **Continue over many generations.**

Use these ideas to **explain** how selective breeding, over many generations, could lead to different varieties of dog.

Pick a breed of dog, such as the St Bernard, and **outline** which features you would select to breed this dog (the St Bernard has been bred to rescue people in the snow-covered Alps – what characteristics would this dog need?).

Selective breeding can be seen as the original 'genetic modification' – something that today can be achieved much more rapidly (selective breeding takes many generations) as we will explore in the next section.



■ **Figure 11.12** Breeds of dog are the result of selective breeding from a wolf ancestor

◆ Assessment opportunities

- ◆ In this activity you have practised skills that are assessed using Criterion A: Apply scientific knowledge to solve problems.

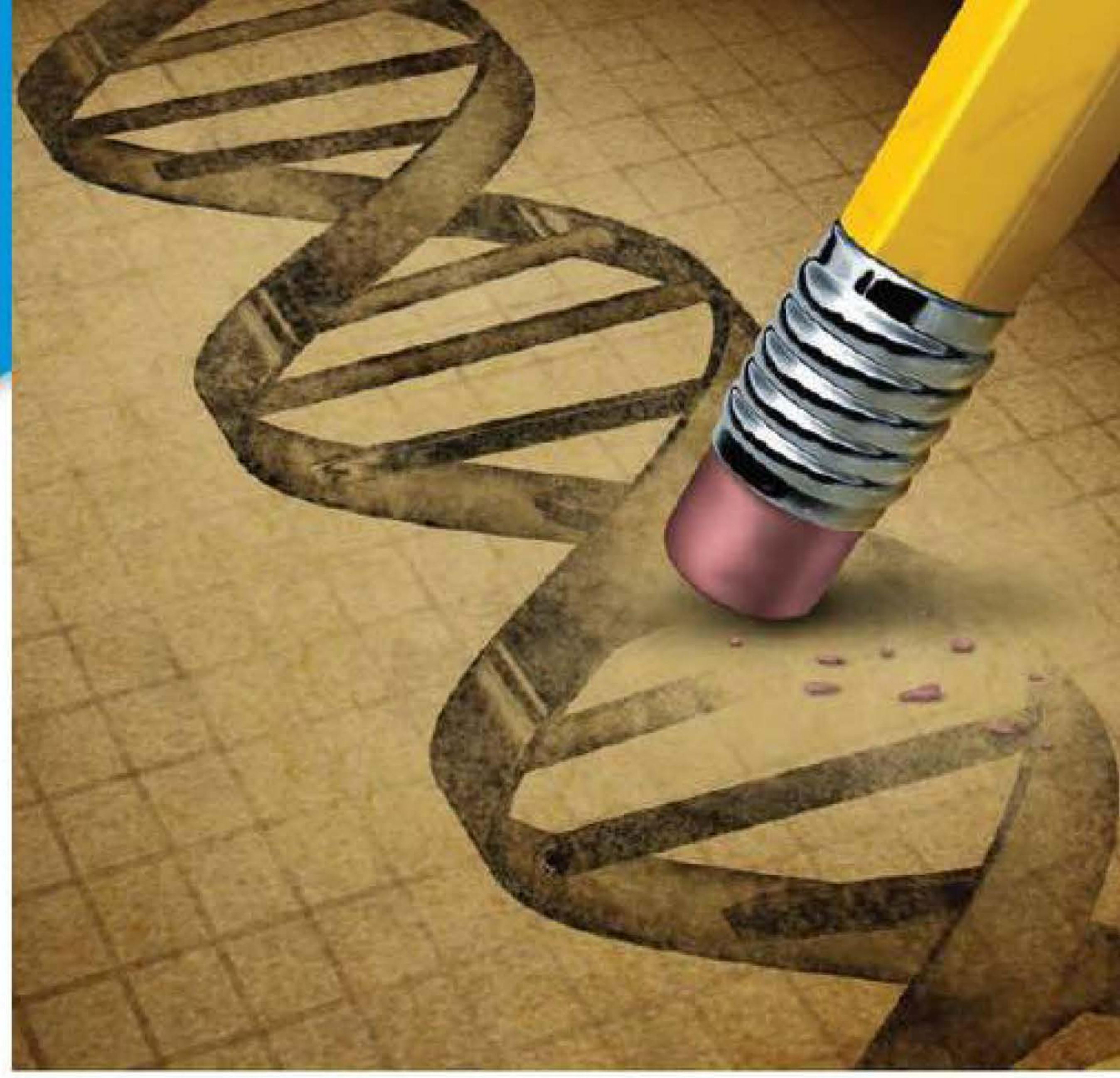
SUMMARY REFLECTION

- What have you learnt about selective breeding? How does it differ from natural selection?
- How have different breeds of dog been selected from ancestor wolf populations?

REVIEW

- Why is selective breeding carried out?
- When breeding cattle, what features might be selected? Which offspring would be used for further breeding?
- How is selective breeding of value to farmers?

How does the modification of genetic information influence human lifestyles?



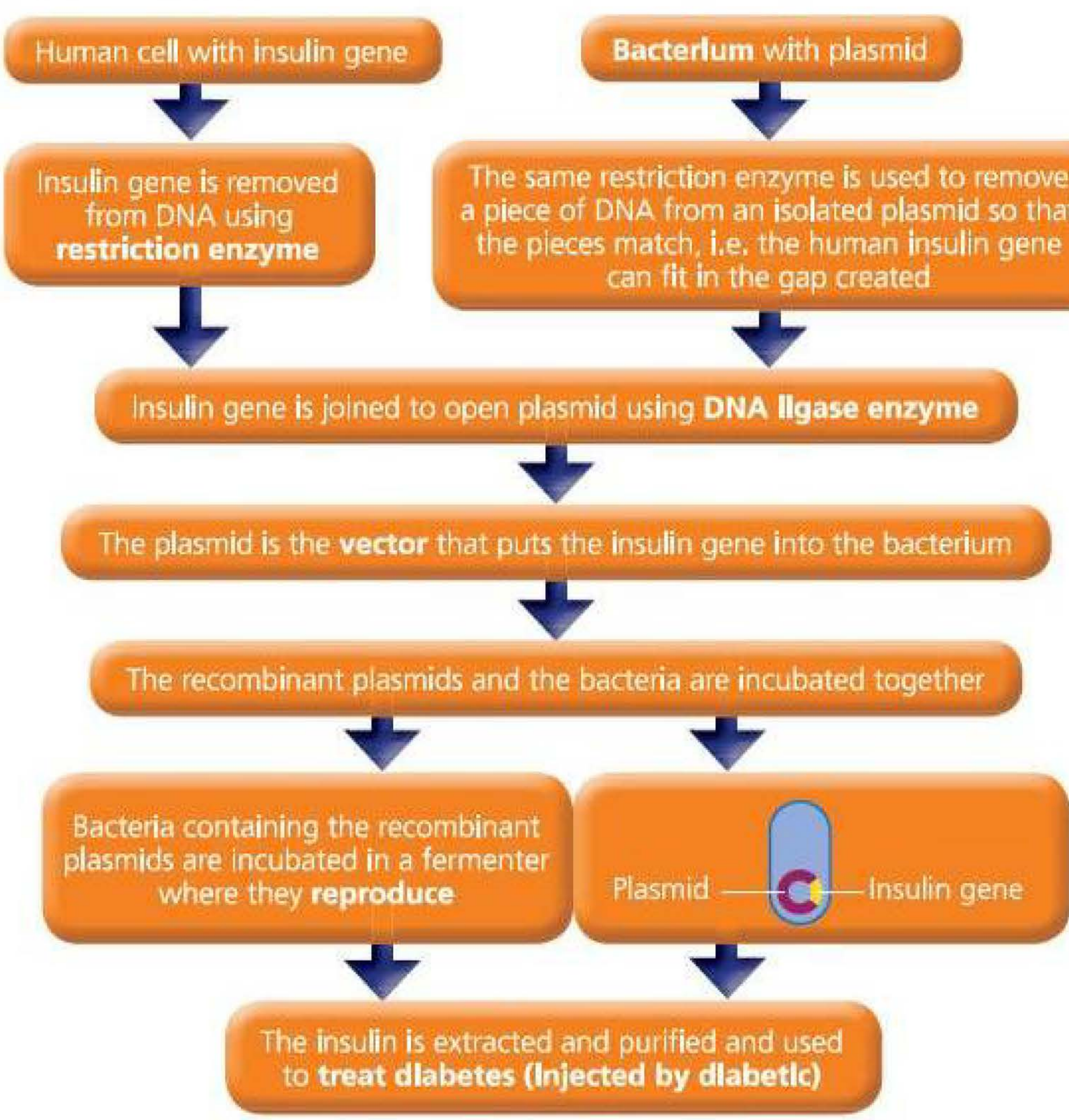
■ **Figure 11.13** Modifying genes

WHAT TECHNIQUES ARE USED TO MODIFY GENES?

Genetic modification involves the transfer of a gene from one organism into another.

- Genes are removed and inserted using special **enzymes**.
- Genes are transferred from one organism to another using a **vector**.
- We have seen in Chapter 1 that **bacteria** contain small circles of DNA called **plasmids**. Plasmids can be used as vectors as they can easily be removed from bacteria.

Here is how it works:



■ **Figure 11.14** Genetic modification in bacteria

ACTIVITY: Using GM technology to produce insulin

ATL

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

Diabetes is a condition in which the body cannot control blood sugar. Usually after a meal, **insulin** (a hormone) is released from the **pancreas** and travels to the liver and muscles where it instructs cells to convert glucose to the storage molecule **glycogen**. People with diabetes cannot produce any or enough insulin and so their blood sugar remains high – they must inject insulin to ensure their glucose level returns to a safe level.

Traditionally, insulin was removed from livestock following slaughter. This was not ideal, as animal insulin is not exactly the same as human insulin, and also a lot of animals were needed to produce only small quantities of the hormone. Biotechnology allows human insulin to be produced in large quantities by bacteria.

How does this work? Use the information outlined here to prepare a guide to producing human insulin using genetically engineered bacteria.

- **Your guide should include the picture (Figure 11.15) and glossary provided and a bullet-pointed method for how to carry out the engineering.**
- **Your method should use all the words from the glossary.**
- **Use the following diagram to help you. You will need to add labels and explain what is happening.**

restriction enzyme These enzymes are found in bacteria and are used to destroy viruses. They cut DNA at particular sequences leaving 'sticky ends'.

DNA ligase An enzyme which can connect pieces of DNA together. They can be used to 'stick' a gene into a vector such as a plasmid.

plasmid An independently replicating circle of DNA containing a few genes. They are found in bacteria and can be used to carry genes into a suitable host bacterium.

vector Something which can carry DNA from one organism to another. Examples are viruses (Figure 11.16) and plasmids.

host bacterium A bacterium which can be modified by adding genes using a vector. It is then allowed to multiply to produce lots of copies.

sticky ends When a staggered cut is made in DNA by a restriction enzyme, the exposed unpaired bases can pair with **complementary bases** on another strand of DNA which has been cut with the same restriction enzyme. These exposed bases are called sticky ends.

Assessment opportunities

- In this activity you have practised skills that are assessed using Criterion A: Apply scientific knowledge to solve problems.

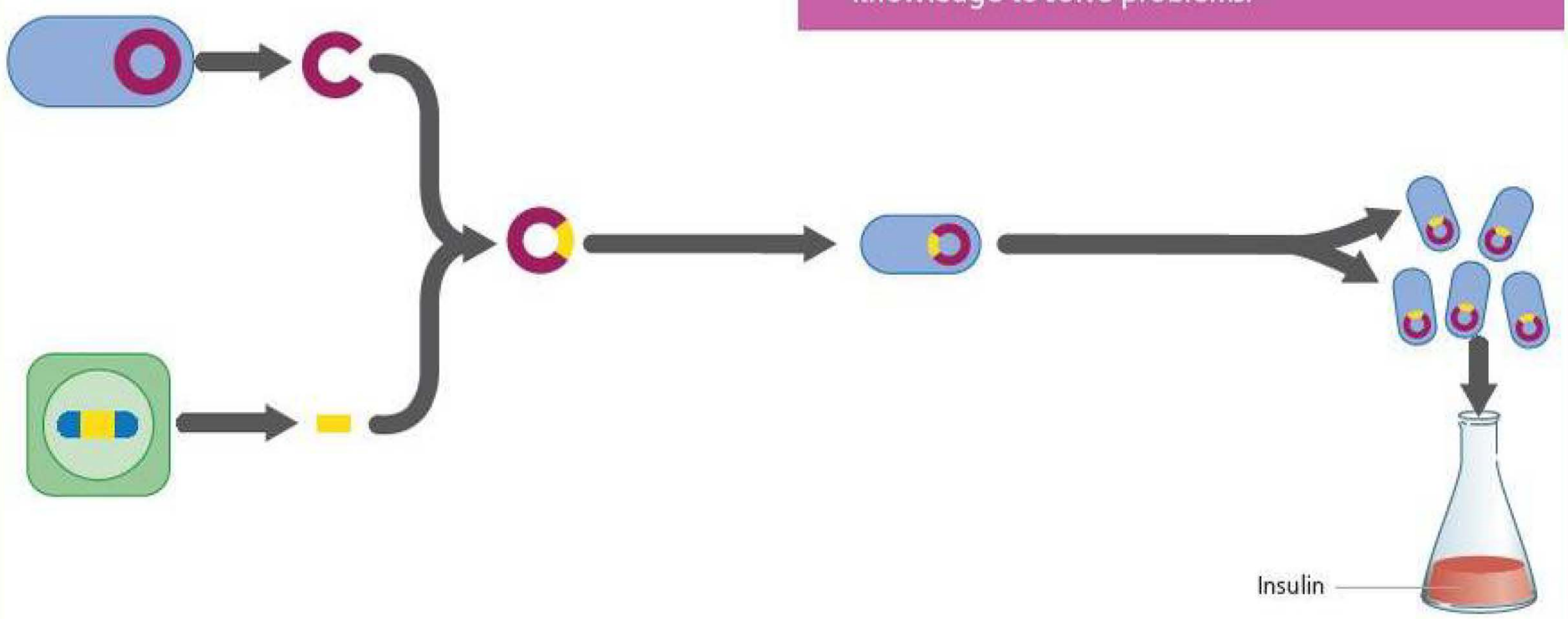
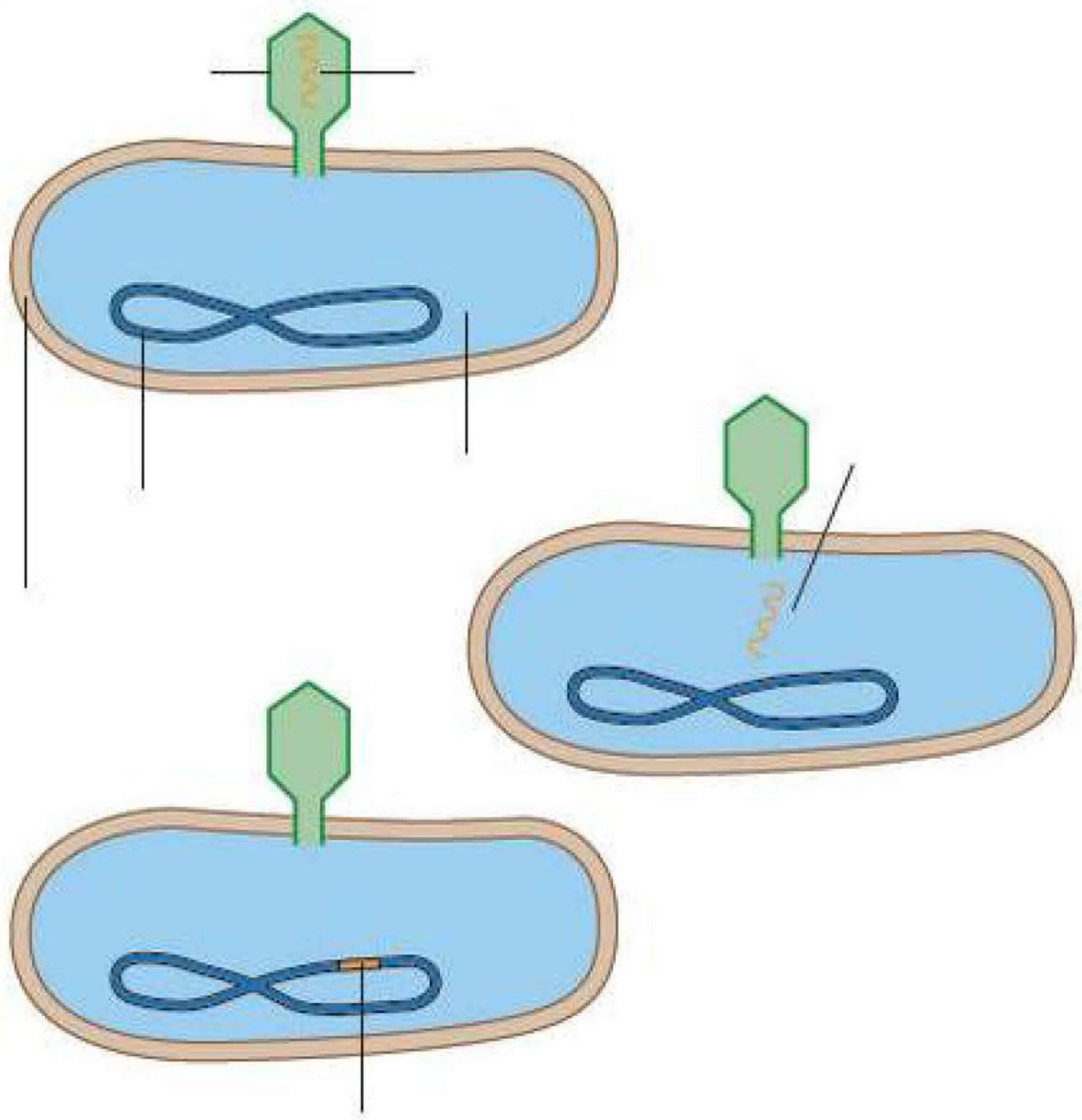


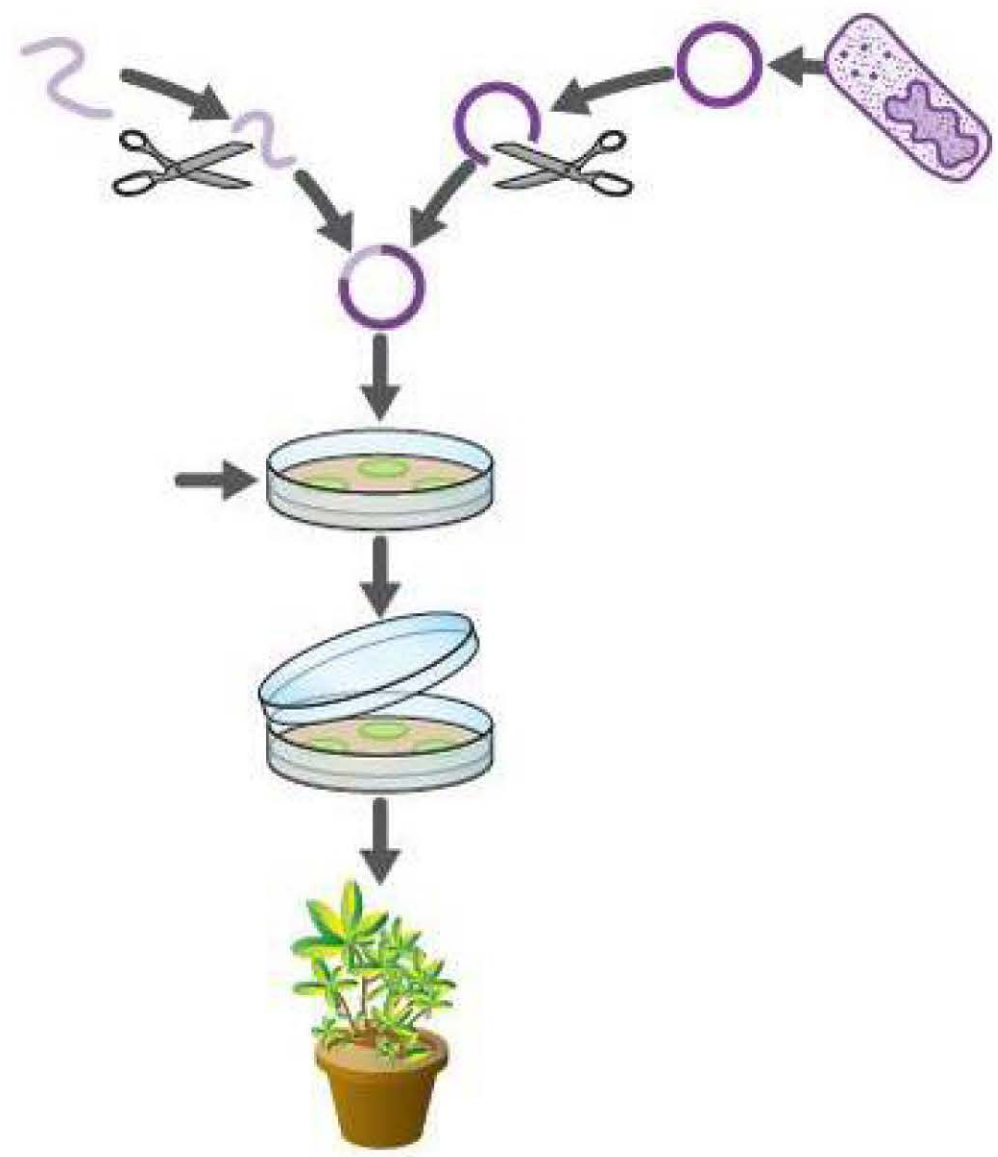
Figure 11.15 GM production of insulin

EXTENSION

Other methods for transferring genes from one organism to another are shown in the following two diagrams. Can you work out what is going on? Add labels and annotations to these diagrams.



■ **Figure 11.16** Viruses can act as vectors. They can carry the DNA of one organism and insert it into the DNA of another



■ **Figure 11.17** Plasmids are used to insert a gene into cell tissue culture

SUMMARY REFLECTION

- **What have you learnt about the techniques used to modify genes?**
- **How does the modification of genetic information influence human lifestyles?**

DISCUSS

- **What is meant by 'genetic modification'? In what ways is it different from cloning?**
- **What is meant by the term 'vector'? Give an example of a vector.**
- **Explain to your neighbour how genetically modified bacteria can be used to produce large quantities of insulin.**
- **Discuss in a small group how genetic engineering could be used to treat genetic diseases such as cystic fibrosis and Huntington's disease.**

You could use these search terms: **genetic disease**, **Huntington's**, **cystic fibrosis**, **gene therapy**.

Who should have the power to modify and control genetic material?

TO WHAT EXTENT SHOULD GENETICALLY MODIFIED ORGANISMS BE USED IN FARMING AND FOOD PRODUCTION?

We may take a healthy diet for granted, but in parts of the world this is not the case. Water shortages and droughts, outbreaks of crop **pests** and poor food storage, can mean that, in parts of the world, a balanced diet is hard to come by.

Genetic modification provides the opportunity not only to make crops grow better in harsh climates (e.g. make them disease, pest or drought **resistant**) but also the ability to insert genes that add extra nutrients to plants. In many less economically developed countries (LEDCs), where rice is the main food, iron and vitamin A deficiencies lead to high death rates, and illness in mothers and children. Genetic modification of rice to increase the availability of these nutrients can help to reduce the scale of these deficiency-related diseases.

Researchers have succeeded in genetically modifying rice to enhance its vitamin A and iron content. These new varieties will be made freely available to local rice farmers for planting.

Read about genetically modified food and its benefits here:

http://learn.genetics.utah.edu/content/science/gmfoods/

www.eufic.org/article/en/food-technology/gmos/artid/iron-vitamin-a-gm-rice/

Figure 11.18 Transgenic rice research: researcher working with transgenic rice (*Oryza sativa*) plant seedlings. Genetic modification is the process of introducing a gene from one organism – called a transgene – into that of a different living organism so that the organism will exhibit a new property and transmit that property to its offspring

Figure 11.19 Transgenic rice in field test

Read about how **transgenic** animals can be produced and how they can be used to benefit humanity: **http://learn.genetics.utah.edu/content/science/pharming/**

Genetic modification is not without controversy, however, and there has been a history of anti-GM protests from (mainly) environmental groups. But are their concerns valid? Shouldn't the potential to feed an ever-increasing world population by using available technologies overcome any possible objections? What do you think?

ACTIVITY: The GM debate

ATL

- Information literacy skills: Access information to be informed
- Critical-thinking skills: Revise understanding based on new information

Research an animal or plant that has been genetically modified. What are the benefits of the transgenic species? Have any problems been identified? What scientific research has been done to examine any possible impacts of the GM species in the wild?

Now research the GM debate and come to your own conclusions: **GM debate**, **GMO, Monsanto**, **Mark Lynas**, **'Frankenfoods'**, **transgenic**. Do the benefits outweigh any possible objections? Are arguments against GM based on scientific research?

You can use your research in the activity on page 297.

Assessment opportunities

- In this activity you have practised skills that are assessed using Criterion A: Analyse and evaluate information to make scientifically supported judgements and Criterion D: Explain the ways in which science is applied and used to address a specific issue.

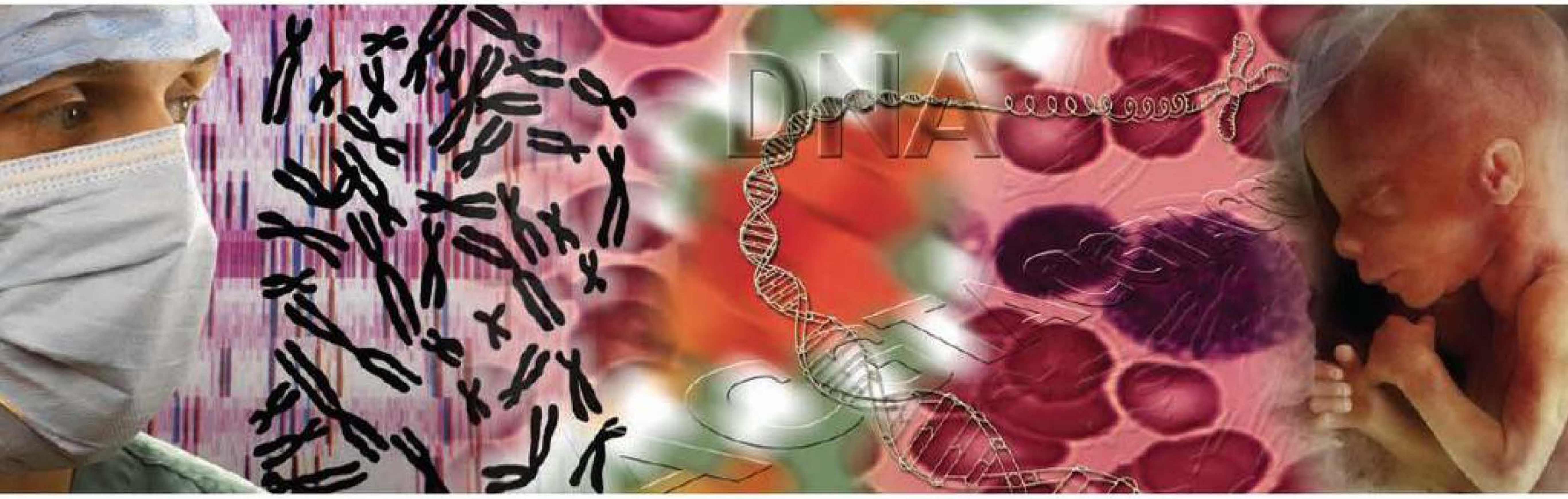
SUMMARY REFLECTION

What have you learnt in this section about how GM technology can be used in the food and agricultural industries? What have you learnt about the debate surrounding GM technology? Do you think that the controversy is warranted?

DISCUSS

Discuss with your neighbour about a transgenic crop or animal that you have researched. How do the case studies compare?

What are the possible consequences of developing biotechnology? What role do personal beliefs play?



■ **Figure 11.20** Manipulating DNA for human ends – what are the ethical issues?

HOW CAN HUMANS MANIPULATE GENES TO CREATE NEW TISSUES?

Stem cells are used in the body to replace worn out or faulty cells. Stem-cell technology has been used for more than 20 years in bone-marrow transplants, where the patient's bone-marrow stem cells are replaced with those from a healthy, matching donor. If the transplant is successful, the stem cells will migrate into the patient's bone marrow and begin producing new, healthy blood cells to replace the faulty cells. Stem cells offer even more potential, however, if they can be used to produce a variety of cell and **tissue** types.

As we have seen in Chapter 1, stem cells can be directed by the body to differentiate (change) into over 200 specific cell types. Stem-cell research is, in particular, seen as holding the key to many medical issues, from spinal-cord injury, stroke, burns, heart disease, to diabetes and arthritis.

Research using stem cells is controversial, with research using some types of stem cells more questionable than others. Some people, however, see these technologies as 'meddling with nature'. They raise moral and ethical issues that question the new technologies. Embryonic stem cells currently hold the best potential for research as they can differentiate into all cell types – eggs remaining from infertility treatment, for example, can be cultured in the laboratory and stem cells removed – this process will destroy the embryo. People who object to this technology argue that, under natural conditions, the embryos would go on to form a baby, whereas proponents argue that unused harvested embryos would anyway be destroyed and that, ultimately, the ends justify the means.

Now let us investigate how this new technology is being developed in novel and exciting ways.

ACTIVITY: The ethics of stem cell research

ATL

- Information literacy skills: Access information to be informed
- Critical-thinking skills: Consider ideas from multiple perspectives

Early in his first term, President Barack Obama ended a ban on federal funding of stem cell research. Obama's decision is a sharp reversal of the policies enacted by President George W. Bush.

There are clear benefits of stem-cell research, but many ethical issues are also raised.

Find out about the ethical issues surrounding stem-cell research: embryonic stem cells, 14-days+embryo, Human Fertilisation and Embryology Act in 1990, human cloning. What are people's concerns about stem-cell research? Could future developments in stem cells alleviate present concerns?

Write a summary statement of what you have found out on one side of A4. Do you think that the benefits of stem cell research outweigh any concerns people may have?

Assessment opportunities

- In this activity you have practised skills that are assessed using Criterion A: Analyse and evaluate information to make scientifically supported judgements and Criterion D: Explain the ways in which science is applied and used to address a specific issue.

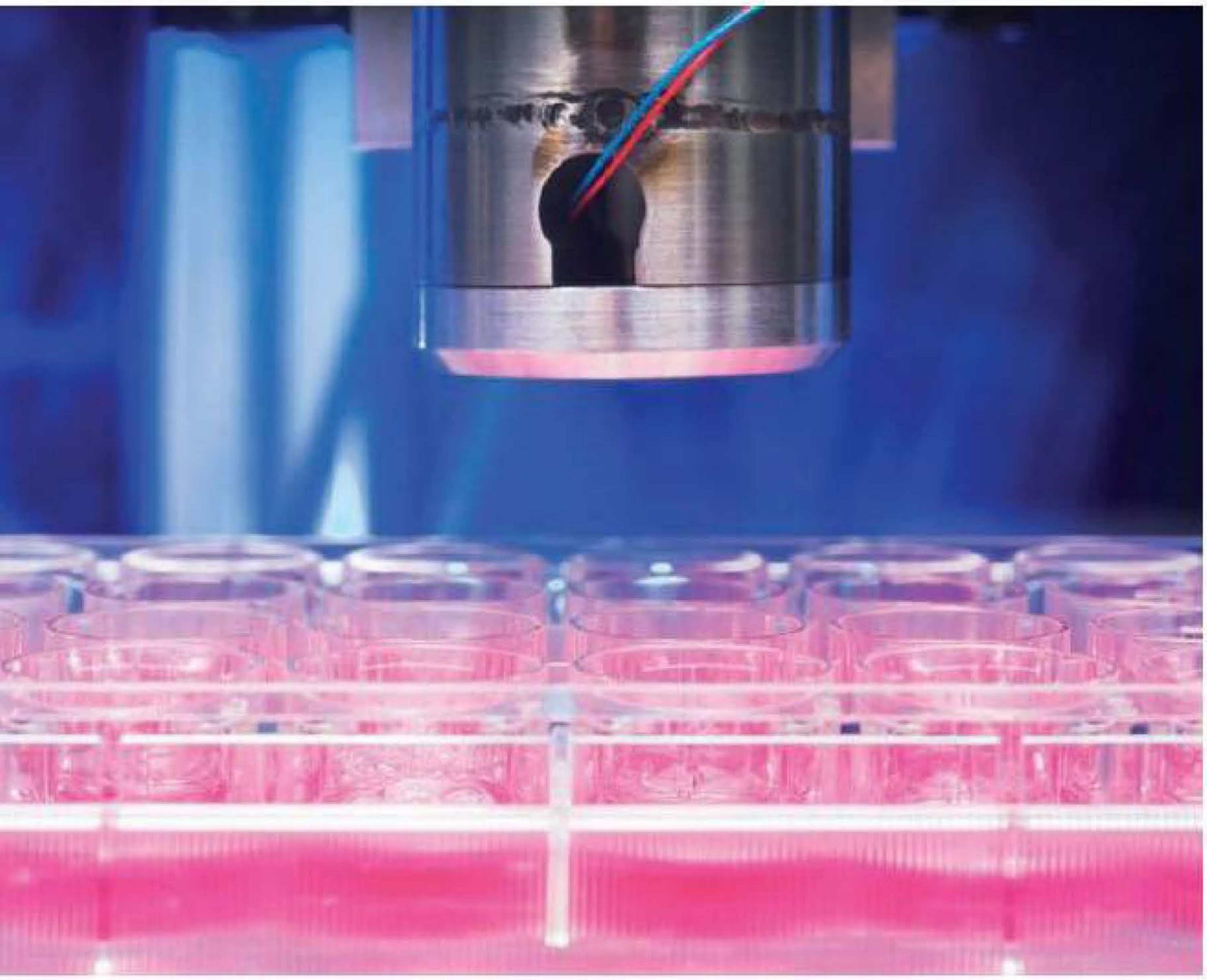
You can use your research in the activity on page 297.

BIOPRINTING

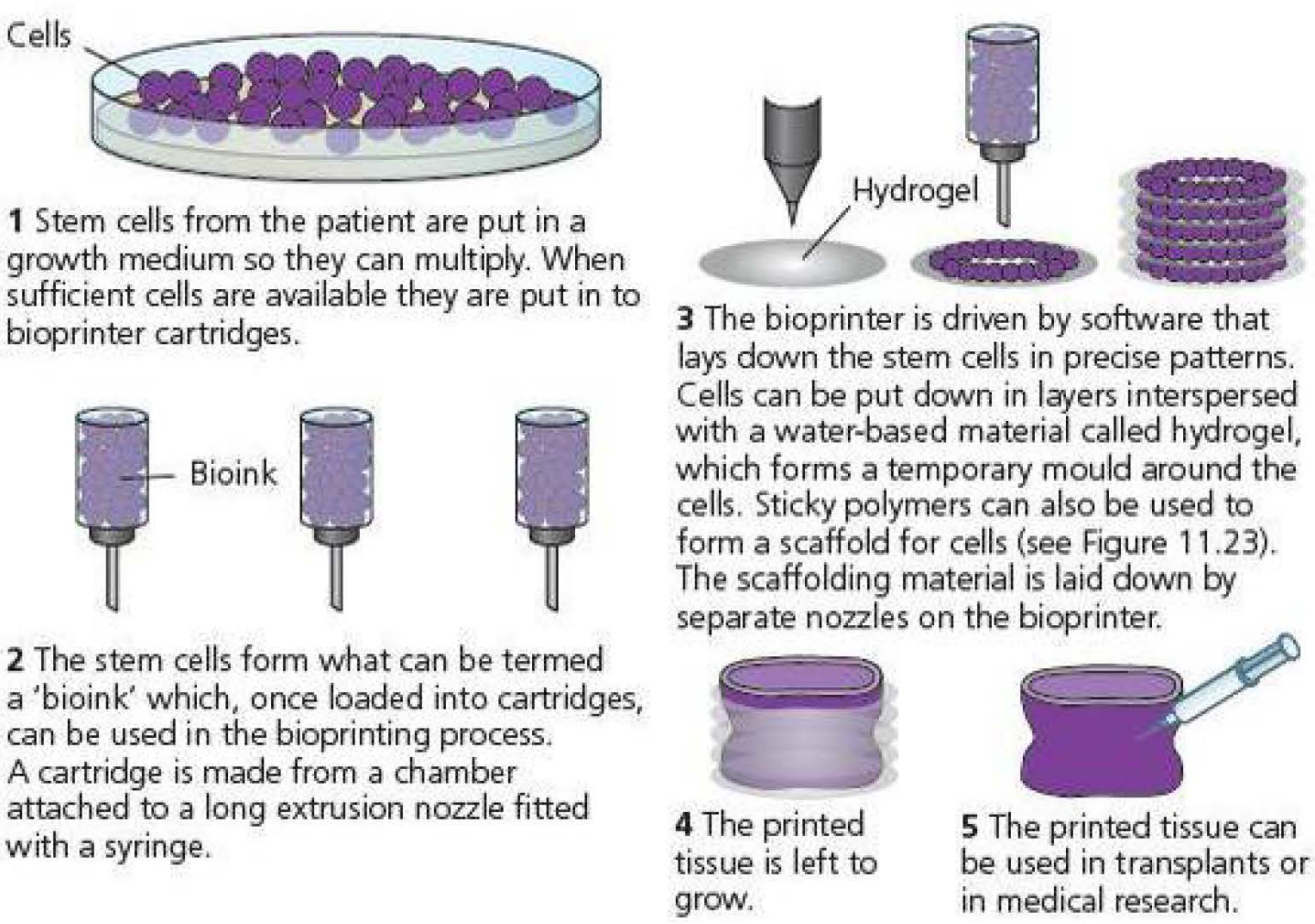
3D-tissue and organ printing is a new and novel way of utilizing stem cells. This biotechnology could revolutionize surgery and the replacement of faulty organs that are currently replaced by transplant.

3D-bioprinting is being applied to address the need for tissues and organs suitable for transplantation. Bioprinters use inkjet needles to deliver cells, a sticky polymer (that forms a support structure) and pressurized air. A small electric field is applied that converts the mixture into superfine threads with cells trapped inside.

Bioprinting is far more complex than non-biological printing – it involves the selection of the correct cells, materials to project these onto, the use of factors that help stem cells grow and differentiate in the correct way, and technical challenges related to the sensitivities of living cells and the construction of tissues. Several different technologies need to be combined together to make this work: engineering, biomaterials science, cell biology, physics and medicine. 3D-bioprinting has already been used to make and transplant several tissues, including skin, bone and heart tissue.



■ **Figure 11.21** Skin-cell printer. Printer nozzle (top centre) deposits skin cells onto wells containing alginate growth substrate. Bioprinters such as this could one day be used to 'print' artificial tissues and organs for use in surgery



■ **Figure 11.22** Bioprinting

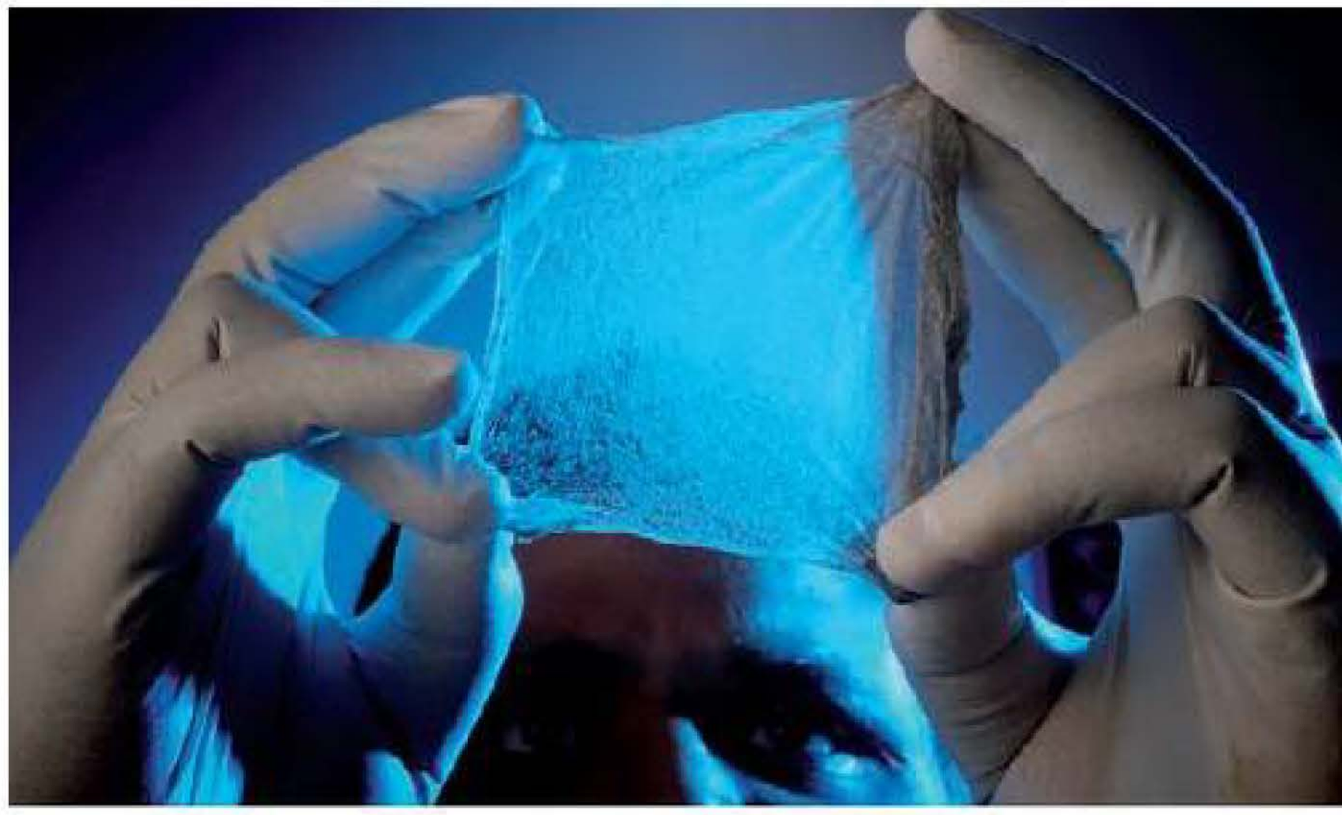
SUMMARY REFLECTION

- **What have you learnt about how humans are manipulating genes to create new cells, tissues and organs?**
- **What are possible consequences of developing and applying more biotechnology?**
- **How do people's personal beliefs and values influence the development and application of biotechnological techniques?**

DISCUSS

Discuss in a small group the ethics of stem-cell research. Do you agree or disagree? If your views differ, why is this?

Lab-grown tissues and organs can be made by creating artificial scaffolds in the shape of the desired organ and then adding living cells to the scaffold. The technique has been used grow artificial bladders first implanted in patients in 1999. Bioprinters would allow both an artificial scaffold and living cells to be assembled at the same. Bioprinting lays down layer after layer of live cells to form human tissue. The major problem in creating tissue has been making the vascular system (that is the blood supply, via **arteries**, **capillaries** and **veins**) needed to provide cells with oxygen and nutrients.



■ **Figure 11.24** Researcher holding a sample of bio-artificial tissue created by 'printing' a mixture of living cells and sticky polymer into a tissue scaffold. The technique uses a small electrical field that causes the droplets to disperse as a superfine thread with cells captured inside

■ **Figure 11.23** Bio-artificial tissue scaffold. This tissue has been created by 'printing' a sticky polymer mixture through fine inkjet nozzles. The technique uses three inkjet needles located inside one another to separately deliver cells, a viscous polymer and pressurised air. This technique arranges cells more precisely than other bioprinter technologies. Bioprinters could one day build artificial tissues and organs for replacement organ surgery

ACTIVITY: Poster on bioprinting

ATL

- Information literacy skills: Access information to be informed

Produce a poster or information leaflet about bioprinting. Use your knowledge of stem cells to **explain** how tissues and organs can be created: **3D tissue printers**, **bioprinter**, **tissue scaffold**, **organ and tissue transplant**.

How does it work, and what potential does it have for medical research and treatment?

Make the poster visually interesting.

Assessment opportunities

- In this activity you have practised skills that are assessed using Criterion A: Describe and explain scientific knowledge and Criterion D: Explain the ways in which science is applied and used to address a specific issue.

Who should control genetic material? Should income determine a person's access to medical treatments?

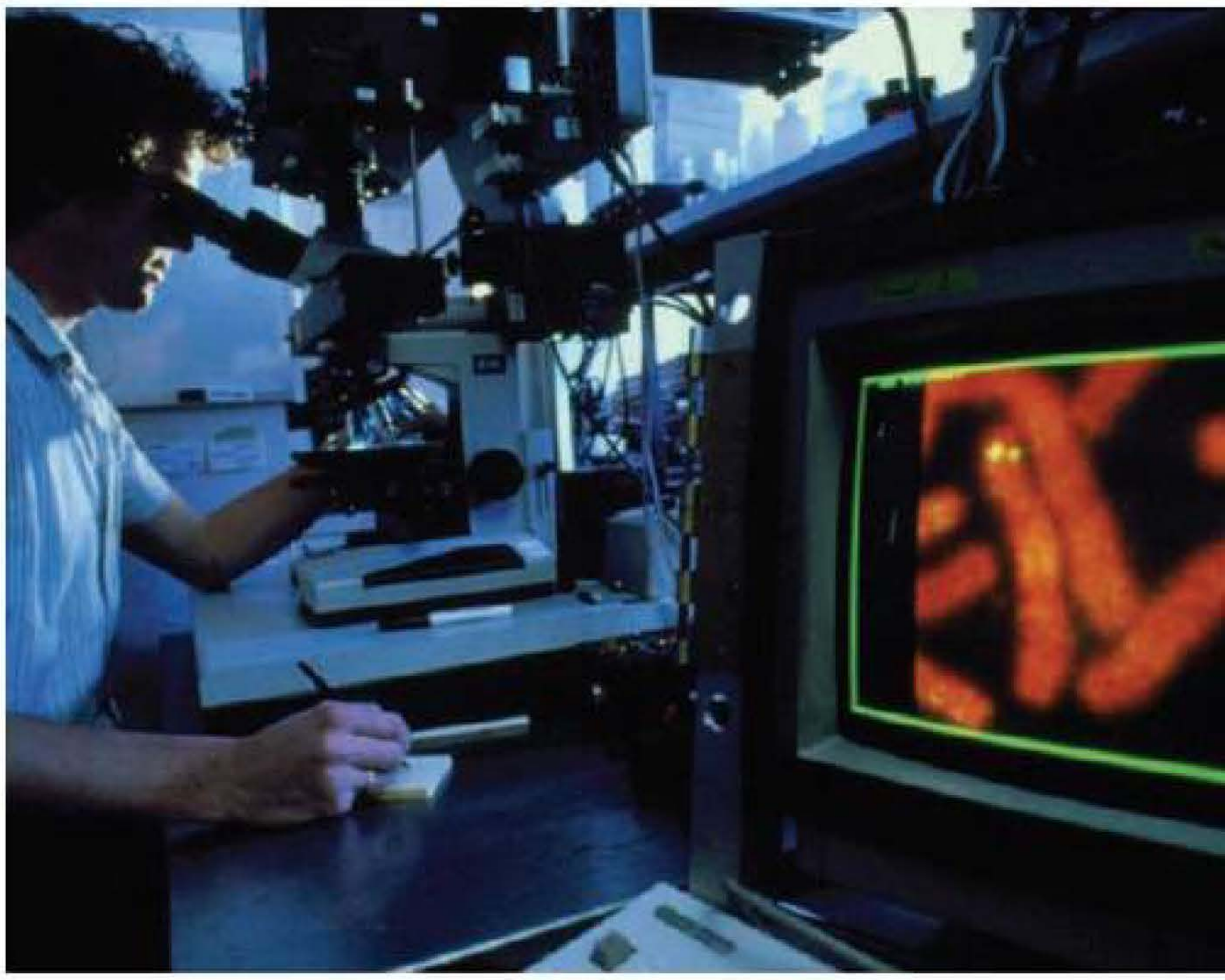
SHOULD GOVERNMENTS FUND BIOTECHNOLOGICAL RESEARCH ON STEM CELLS AND GENETIC MODIFICATION?

In 1990, work on the **Human Genome Project (HGP)** got underway. The project was an international scientific research project – its aim was to determine the sequence of the 3 billion base pairs which make up the DNA of humans (the human **genome**). The project was declared complete in 2003, with the human genome having been successfully been mapped.

Read ten facts about the HGP here: **www.sanger.ac.uk/about/press/2001/publication2001/facts.html**

You can read an interview with Professor J. Craig Venter, one of the first scientists to sequence the human genome (and who was lead scientist of the Harvard group who first created synthetic life – see Chapter 1, page 22), here: **www.wired.co.uk/magazine/archive/2013/11/features/j-craig-venter-interview**

But why sequence the entire human genome? Other than being of obvious scientific interest, what practical applications could this have?



■ **Figure 11.25** Research on the human genome. A light microscope is used to do fine mapping of long DNA fragments on human chromosomes: the chromosomes appear in red on the monitor screen, while the DNA fragments (called probes) appear yellow/green. Mapping chromosomes may be regarded as a physical survey of each chromosome to find the location of genes. The genome project was an ambitious plan to build a complete blueprint of human genetic information

THINK–PAIR–SHARE

Discuss this question with your neighbour – use your knowledge of DNA to hypothesize why sequencing the human genome was such an important breakthrough (and the reason why it received such extensive funding).

EXTENSION

Read about the Human Genome Project: **http://web.ornl.gov/sci/techresources/Human_Genome/index.shtml**

Information about HGP and ethical implications: **http://ghr.nlm.nih.gov/handbook/hgp**

ACTIVITY: Human genome: using new technology to treat genetic diseases

■ ATL

- Information literacy skills: Access information to be informed

genome mapping Methods used to find the exact location of a gene on a chromosome.

Genes code for proteins, and sometimes, as we have seen in Chapter 6, they can go wrong. **Mutations** can lead to faulty genes that lead to the wrong protein being made – this can result in genetic disease. Cystic fibrosis, for example, is the result of one faulty gene on chromosome 7.

The HGP opened up new ways in which genetic diseases could be identified and treated.

- **Researchers can make a genetic map of a patient with a genetic disease by collecting samples of blood or tissue. This can be compared to a genetic map of family members who do not have the disease.**
- **Scientists closely compare the DNA, looking for unique patterns in the DNA of the patient – any differences may be due to a mutation in the genetic code. The gene causing the disease can be identified.**
- **Once the gene has been identified, treatment can be targeted more accurately.**

Your task is to find out more about gene therapy and record your findings on a poster. How can knowledge from the HGP be applied to treat genetic diseases?

Access these sites, or others you can find, to gather information:

http://learn.genetics.utah.edu/content/genetherapy/

http://kidshealth.org/parent/system/medical/gene_therapy.html

Read further about how knowledge of the genome could lead to specific medical treatment here:

http://learn.genetics.utah.edu/content/pharma/snips/

◆ Assessment opportunities

- In this activity you have practised skills that are assessed using Criterion A: Describe and explain scientific knowledge.

Present your findings to your class.

■ **Figure 11.26** Computer analysis of DNA sequences of a human chromosome. This computer screen shows the variation of the four different organic bases, thymine (T), guanine (G), cytosine (C) and adenine (A). The gene being examined was selected because of its role in transplant rejection. This research is part of the human genome project, a worldwide study of the total collection of human genes

ACTIVITY: Class debate

ATL

- Communication skills: Negotiate ideas and knowledge with peers and teachers
- Information literacy skills: Access information to be informed
- Collaboration skills: Listen actively to other perspectives and ideas
- Critical-thinking skills: Revise understanding based on new information

At the beginning of this chapter you debated the issues surrounding biotechnology. Now that you have learnt more about the technology and its issues, it is time to return to your initial arguments. Look back at the material you prepared for the debate – what have you learnt during the course of your studies and has it affected your understanding and views of this new technology? Have your views changed?

Here are some questions for you to think about:

- **Should governments fund continued biotechnological research on stem cells and genetic modification? What are the pros and cons of such research? What ethical issues do they raise?**
- **Who should have the power to modify and control genetic material?**
  - **Currently, governments decide policy, but should it be left to the individual to decide? Is there a case for a global set of rules that apply to all, coordinated by the United Nations?**
- **To what extent should income level determine a person's access to medical treatments that involve applying the products of biotechnology?**
  - **Biotechnological research is expensive. Will breakthroughs in medical treatment be available to everyone, or will only people who can afford it ultimately receive the full benefit?**
  - **Will a 'haves' and 'have-nots' society emerge?**

You can use these search terms: **stem cells**, **cloning**, **genetic modification**, **GM**, **biotechnology**, **genome mapping**, **bioprinting**, **biotechnology**, **ethical issues**.

The debate could be framed around the question 'Should governments fund continued biotechnological research?', with one half of the class arguing for this proposal and the other half arguing against.

- **The class should be divided into two groups.**
- **Spend at least two lessons gathering information and framing your arguments.**

After the debate, assess how different it was from the earlier one you held. If it was very different, why do you think this was?

Assessment opportunities

- In this activity you have practised skills that are assessed using Criterion A: Analyse and evaluate information to make scientifically supported judgements and Criterion D: Explain the ways in which science is applied and used to address a specific issue.

SUMMARY REFLECTION

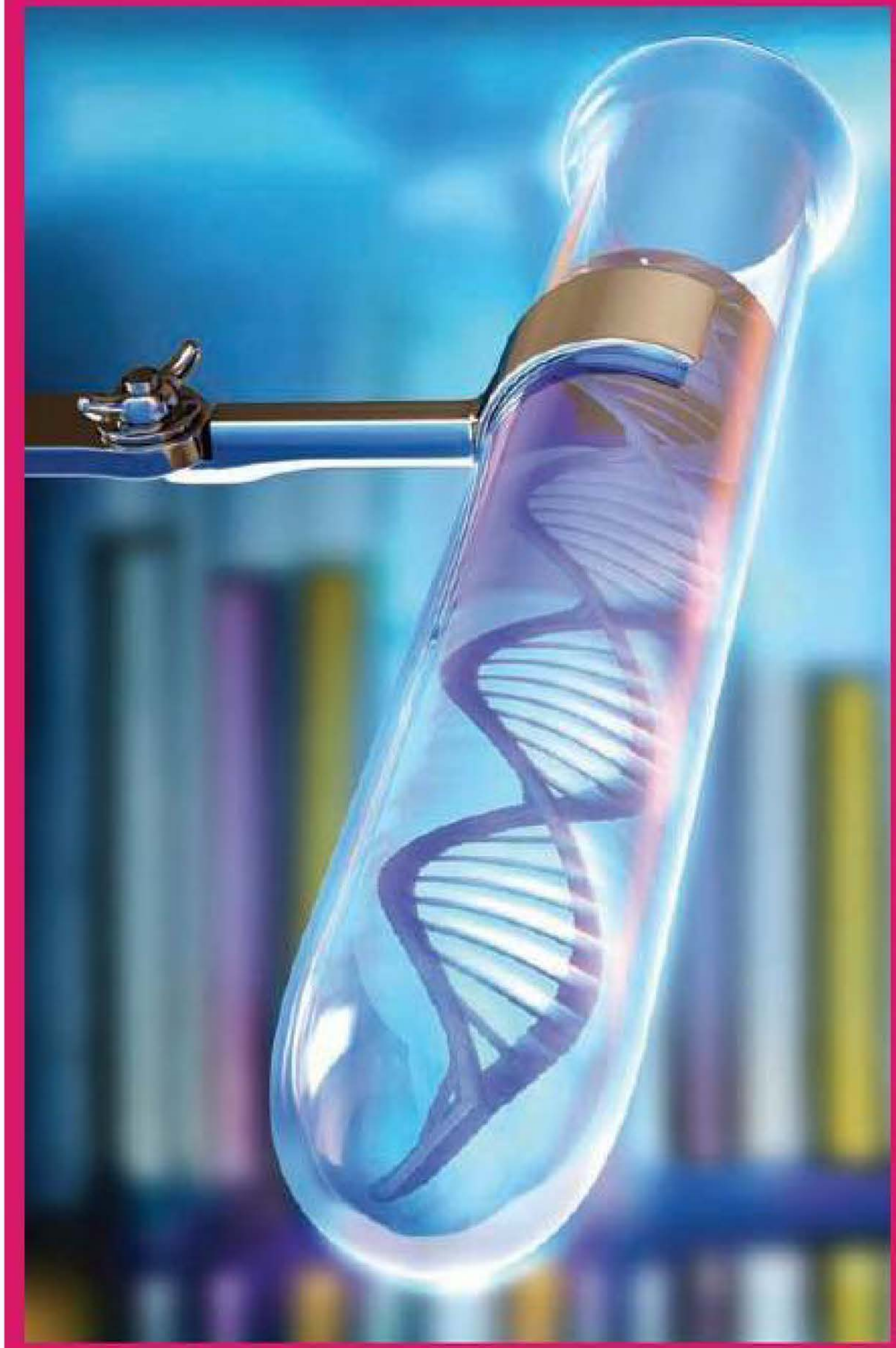
- **Have you changed your opinion about whether governments should fund continued biotechnological research on stem cells and genetic modification? If not, then why do you think this is?**
- **Who do you think should have the power to modify and control genetic material?**
- **To what extent do you think income level will determine a person's access to medical treatments that involve applying the products of biotechnology?**

DISCUSS

Discuss the outcomes of the debate with the rest of your class. What do you think you have learnt from the debate? Has it changed anyone's opinions about biotechnology? Do you think that these developments will be fair for all?

- **What have you learnt in this chapter about how biotechnology is used to change and transform genes?**
- **How does biotechnology create new options, choices, and opportunities in industry and health?**
- **Do you think that the opportunities created by biotechnology will be fair for all?**
- **What have you learnt about yourself as a communicator? What have you learnt about expressing yourself confidently and creatively? Have you been able to collaborate effectively, listening carefully to the perspectives of others?**

Take action: Opportunity to apply learning through action …



■ **Figure 11.27** Genetic research

Communicating your understanding of biotechnology

- In this chapter you have explored a variety of techniques that can modify or manipulate DNA. Choose one of these to write about – you should pick one that has been of particular interest to you.
- Write an article about the issue you have chosen and the medical treatments it has made possible (or the medical treatments that have not yet been developed). For example, you could write the article for:
  - a magazine
  - a newspaper
  - a website.
- Your article will give a balanced opinion of the biotechnology you have chosen, although you could give your own opinions at the end.
- Choose a paper or magazine you enjoy reading, and write your article in an appropriate style. Alternatively you may want to write an article for your school or college website. Use the information here and any other resources you can find as a basis for your article.
- You need to express your views of the biotechnology clearly and articulately, using accurate scientific language, with support from as much scientific evidence and as many examples as possible.
- Points to bear in mind:
  - Remember that people read news items for enjoyment as well as information – they are not reading a textbook!
  - Many people prefer reading articles about other people's lives.
  - Don't forget that editors are looking for articles that leave their readers better informed than when they began.

Assessment opportunities

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

SOME SUMMATIVE PROBLEMS TO TRY

Use these problems to apply and extend your learning in this chapter. These problems are designed so that you can evaluate your learning at different levels of achievement in Criterion A: Knowledge and understanding.

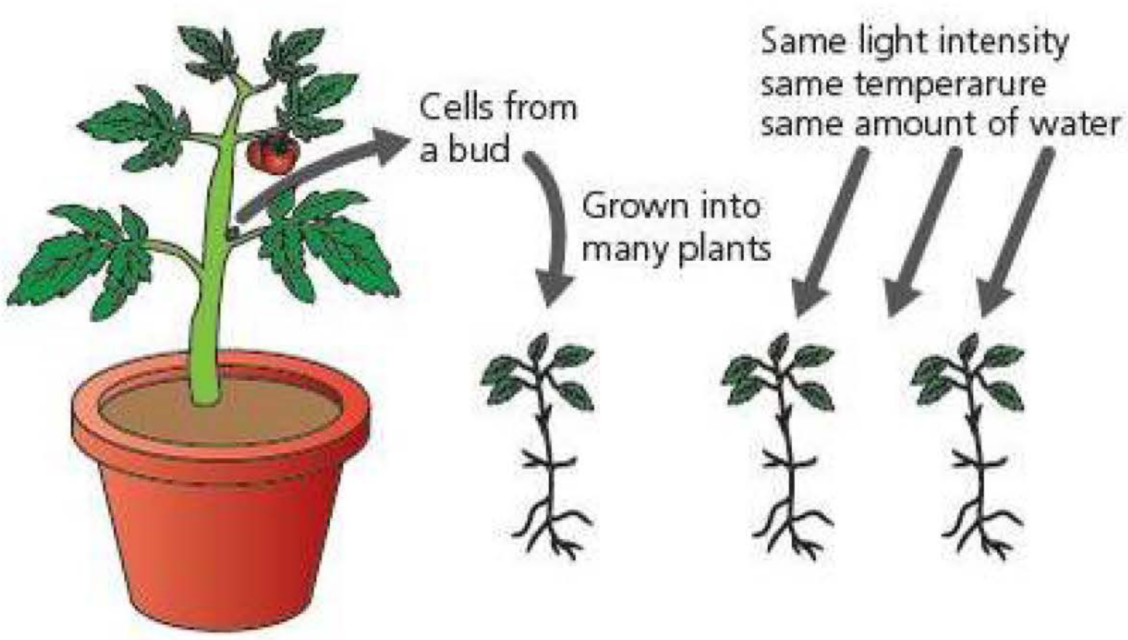
THIS PROBLEM CAN BE USED TO EVALUATE YOUR LEARNING IN CRITERION A TO LEVEL 1–2

1 a **State** what is meant by 'cloning'.

b Match up the following definitions:

A Embryo cloning	1 Reproduction that involves only one parent. There is no joining of gametes and the offspring are genetically identical to the parent
B Cuttings	2 Splitting cells apart from a developing embryo, before they become specialized, to produce several identical embryos
C Tissue cloning	3 Taking a small piece of stem or leaf and growing it in the right conditions to produce a new plant
D Asexual reproduction	4 Getting a few cells from a desirable plant to make a big mass of identical cells, each of which can produce a tiny identical plant

c The diagram below shows a method of producing a large number of plants which all look the same. Cells taken from the bud can be split into many groups. Each group of cells is then grown under the same conditions.



■ **Figure 11.28** Cloning a plant

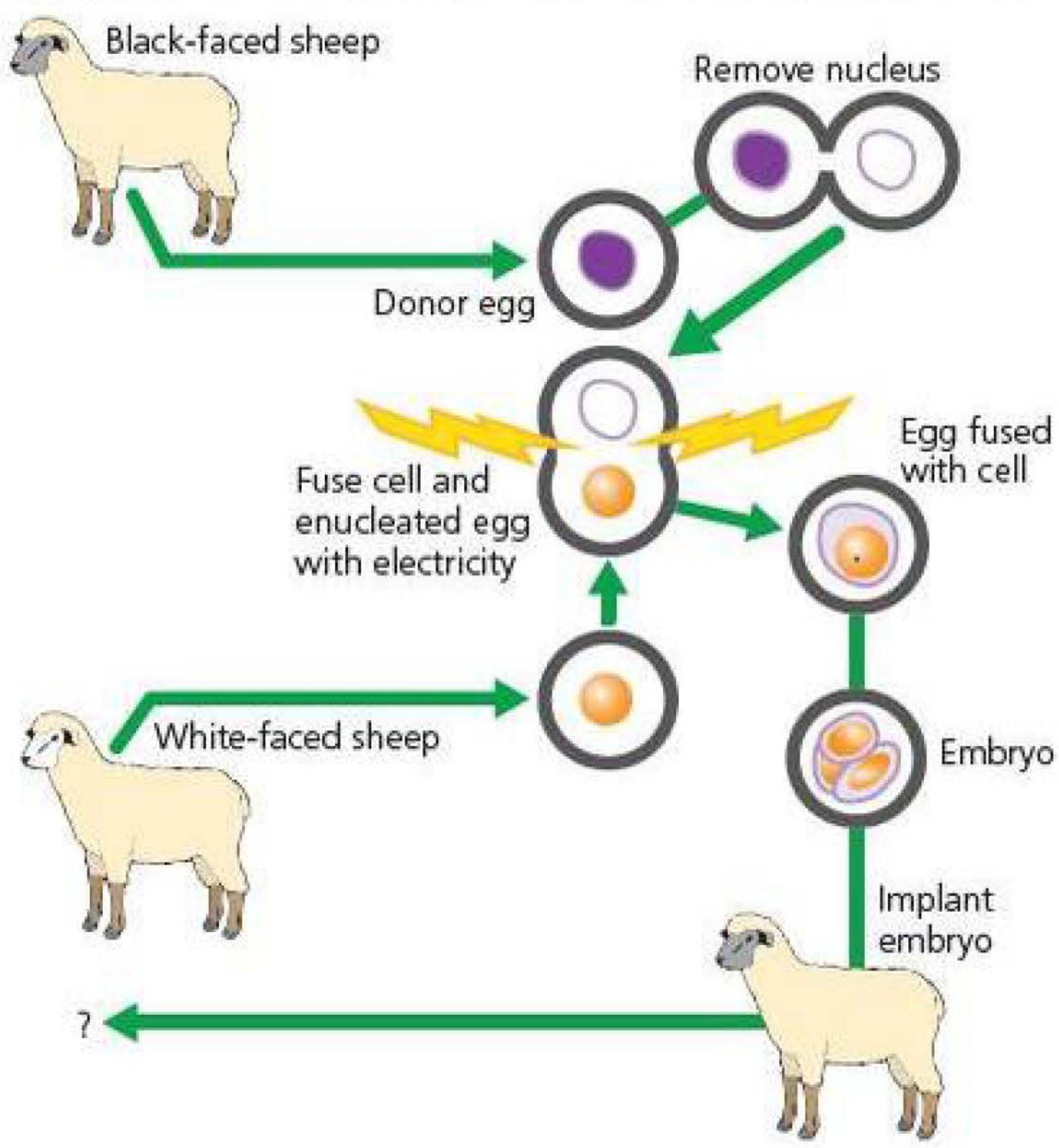
i **State** three advantages of cloning rather than using seeds.

ii **Suggest** three reasons why plants produced by this method will all look the same.

THESE PROBLEMS CAN BE USED TO EVALUATE YOUR LEARNING IN CRITERION A TO LEVEL 3–4

2 **Outline** the differences between cloning and genetic modification.

3 Figure 11.29 shows the process of cloning in sheep.

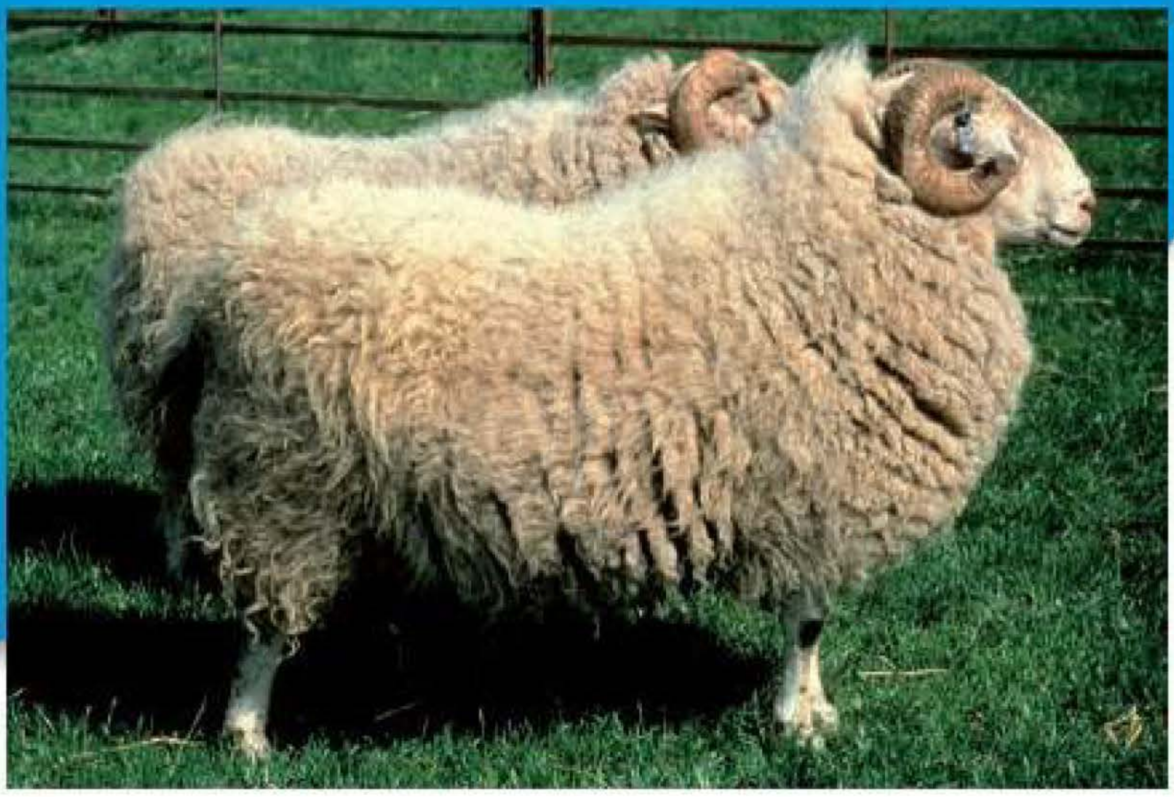


■ **Figure 11.29** Cloning in sheep

a Predict the colour of the black-faced sheep's offspring.

b **Suggest** two ways in which this method is different from the normal method of reproduction in sheep.

c **Outline** a different method of cloning animals to the one shown in Figure 11.29.



■ **Figure 11.30** Transgenic sheep

THESE PROBLEMS CAN BE USED TO EVALUATE YOUR LEARNING IN CRITERION A TO LEVEL 5–6

4 Figure 11.30 shows a sheep that has been genetically modified to contain a human gene for making a human protein in its milk.

The protein in its milk is alpha-1-antitrypsin (AAT). Hereditary deficiency of AAT in humans leads to the lung disease emphysema, and affects about 100 000 people in the western world.

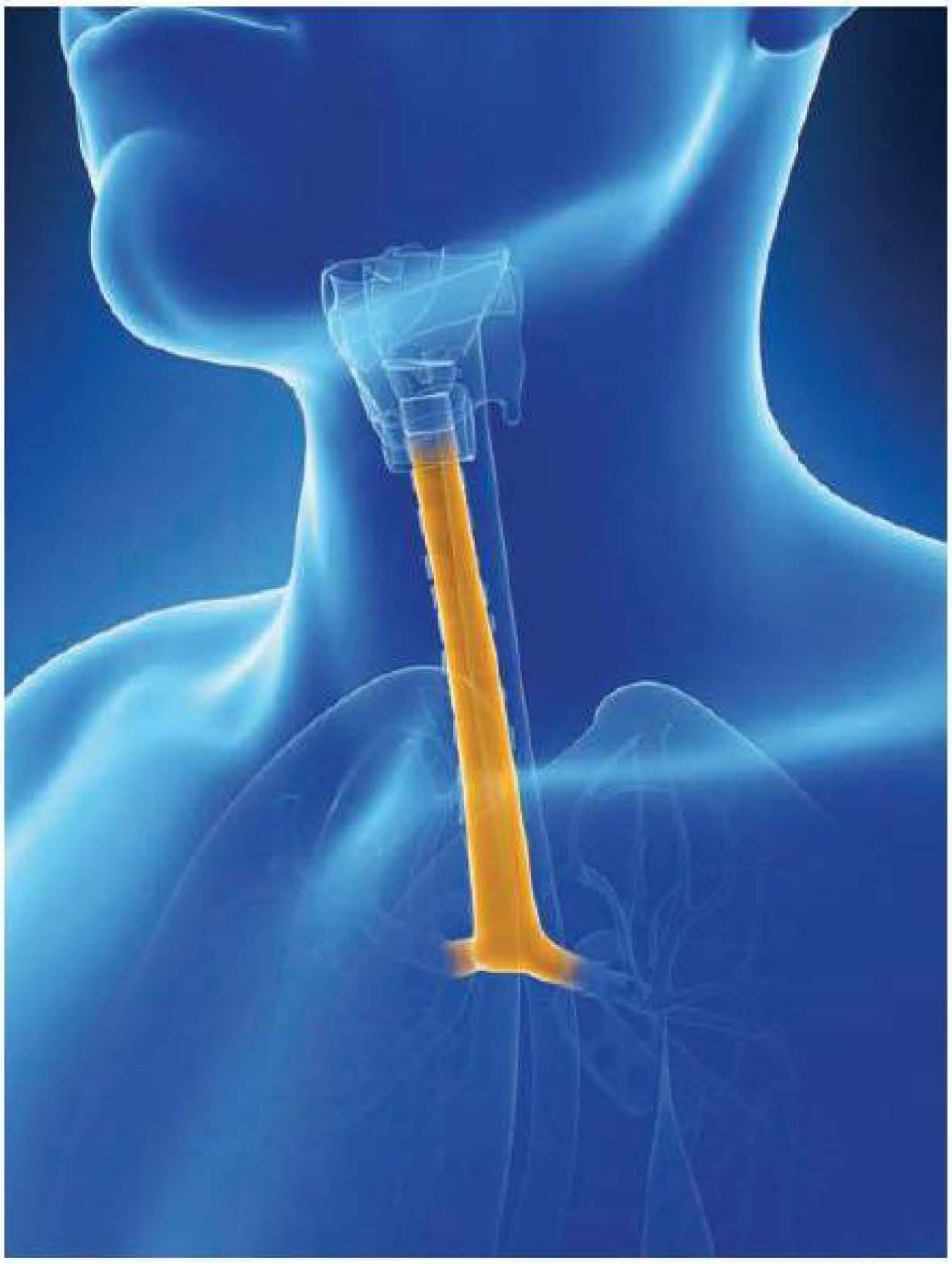
- a The process of genetic modification used to produce this sheep involves the use of two types of enzyme. One enzyme cuts DNA and the other enzyme joins DNA. The process also used a vector.
  - i Name the enzyme that cuts DNA.
  - ii Name the enzyme that joins DNA.
  - iii Name a vector.
- b What is meant by the term 'transgenic'?
- c **Suggest** how the AAT gene can be removed from a human cell and transferred to a sheep.
- d **Suggest** the benefits of producing AAT protein using transgenic sheep.

5 Animals kept on a farm to supply food or labour are known as livestock. Livestock have been developed by a process called selective breeding.

- a i **Describe** the process of selective breeding.
  - ii Give one example of a desired characteristic developed by selective breeding in a named livestock animal.
  - iii **Describe** why selective breeding is of benefit to farmers.
- b **Describe** how natural selection differs from selective breeding.

THIS PROBLEM CAN BE USED TO EVALUATE YOUR LEARNING IN CRITERION A TO LEVEL 7–8

6 A patient suffering from cancer of the trachea (windpipe) had part of their trachea removed. A replacement section of trachea was produced and attached to the remaining part.



■ **Figure 11.31** The location of the trachea

- a **Explain** how bioprinting could have been used to produce a replacement trachea.
- b **Explain** the advantages of using a bioprinted trachea rather than a donated one.
- c Bioprinters use stem cells. **Evaluate** the use of stem cells in medical research.

Reflection

In this chapter we have explored how biotechnology can be used to change and transform genes. We have seen how humans can manipulate genes to create new cells, tissues and organs. We have discussed how the modification of genetic information can influence human lifestyles, and the ways in which people's personal beliefs and values influence the development and application of biotechnological techniques. We have explored how biotechnology can create new options, choices, and opportunities in industry and health, and discussed whether these will be fair for all. We have learnt about our role as a communicator, expressing ourselves confidently and collaborating effectively, listening carefully to the perspectives of others.

<table>
<tr><th colspan="6">Use this table to reflect on your own learning in this chapter</th></tr>
<tr><td>Questions we asked</td><td>Answers we found</td><td colspan="4">Any further questions now?</td></tr>
<tr><td>Factual: What is a clone? What is selective breeding? What techniques are used to modify genes? In what ways are humans able to manipulate genes to create new cells, tissues and organs?</td><td></td><td colspan="4"></td></tr>
<tr><td>Conceptual: How can cloning benefit farming and agriculture? How does the modification of genetic information influence human lifestyles? How do people's personal beliefs and values influence the development and application of biotechnological techniques? What are the possible consequences of developing and applying more biotechnology?</td><td></td><td colspan="4"></td></tr>
<tr><td>Debatable: To what extent should people be allowed to clone organisms? To what extent should genetically modified organisms be used in farming and food production? Should governments fund continued biotechnological research on stems cells and genetic modification? Who should have the power to modify and control genetic material? To what extent should income level determine a person's access to medical treatments that involve applying the products of biotechnology?</td><td></td><td colspan="4"></td></tr>
<tr><td rowspan="2">Approaches to learning you used in this chapter</td><td rowspan="2">Description – what new skills did you learn?</td><td colspan="4">How well did you master the skills?</td></tr>
<tr><td>Novice</td><td>Learner</td><td>Practitioner</td><td>Expert</td></tr>
<tr><td>Information literacy skills</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Creative-thinking skills</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Critical-thinking skills</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Communication skills</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Collaboration skills</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Learner profile attribute(s)</td><td colspan="5">Reflect on the importance of being a good communicator for your learning in this chapter.</td></tr>
<tr><td>Communicator</td><td colspan="5"></td></tr>
</table>

Glossary

Note: Words in *italics* within the glossary definitions are glossary terms themselves.

3D-bioprinting The three-dimensional printing of biological *tissue* and organs through the layering of *stem cells*

abiotic non-living conditions or things

acid rain Any rainfall which is more acid than normal rainfall (pH 5.5–6.0). It is caused by emissions of sulfur dioxide and oxides of nitrogen

active site Region of an *enzyme* where the *substrate* binds

active transport Movement of substances from lower to higher *concentration* (i.e. against their concentration gradient). This needs energy from *respiration*

adaptation The process by which organisms adjust to changes in their *environment* in order to aid in their survival

adenine A base that pairs with *thymine* in *DNA* and with uracil in *RNA*

aerobic respiration Biochemical process that releases energy from a sugar in the presence of oxygen

algae *Protoctists* that contain *chlorophyll* but lack roots, leaves and transport tissue. Includes many single-celled forms and the seaweeds

alien species A non-native species living outside its normal range which has arrived there through human activity (either deliberate or accidental)

allele Different versions of the same *gene*

alveolus (pl. alveoli) Air sac in the lung where *gas exchange* takes place

amino acid Building block of proteins

anabolic reactions When complex molecules are built up from smaller ones

anaerobic respiration Respiration in the absence of oxygen, producing either lactic acid (humans) or ethanol (plants and yeast)

analogous features Similar in structure but of different evolutionary origin

anaphase Stage of cell division where *chromatids* separate and move to different ends of the cell

ancestor An early form of *species* from which others have evolved

ancestral Relating to/evolved from an *ancestor*

antibiotic Compounds produced by some micro-organisms which selectively inhibit or kill other *micro-organisms*; an antibiotic medicine prevents or stops the growth and spread of *bacteria*

antibody Proteins produced by the *immune system* that target and help to destroy specific pathogens

aquatic Relating to water

artery Blood vessel that carried blood away from the heart to tissues and organs of the body

artificial selection Selection in breeding, carried out deliberately by humans

asexual reproduction Reproduction not involving *gametes* or *fertilization*

atrium (pl. atria) The upper chambers of a heart, into which blood flows

autoimmune disease A disease that is caused when a body's *immune system* produces antibodies that attack the body's own cells

autotroph A 'self-feeder' – an organism that can make its own food (glucose) from simpler substances

bacteria (sing. bacterium) Microscopic organisms without a true *nucleus*

balanced A state of stability/the components of a system are in equilibrium

base The unit in *DNA* that contains the *genetic code*

behavioural Characteristics, such as how an animal lives with others in its group

bile Substance produced in the liver that neutralizes stomach acid and *emulsifies* fats in the *small intestine*

biodiversity The variety of different types of life found on Earth

biofuel A fuel produced from biological raw materials, such as plant crops or animal waste

biotechnology The industrial and commercial application of biology

biotic Things associated with or that come from living things

cancer The uncontrolled replication of cells

capillary Very thin blood vessel that supplies oxygen and nutrients direct to body tissues, and removes waste

carbohydrase Enzyme that breaks down *carbohydrates* into simple sugars

carbohydrates Molecules that provide a ready source of energy for the body. They come in simple forms such as glucose, and in complex forms, such as starches and *cellulose*

carbon capture Mechanisms by which atmospheric carbon dioxide is removed

carbon offset A reduction in carbon dioxide emissions, using *carbon capture* techniques, in order to compensate for emissions made elsewhere by e.g. burning fossil fuels

carbon sink Something that absorbs more carbon, usually in the form of carbon dioxide, than it emits, for example a tropical rainforest

carnivore an animal that eats only other animals

catabolic reactions Where complex molecules are broken down into simpler ones

catalyst A substance that alters the rate of a chemical reaction, but remains unchanged at the end

cell The basic building blocks of structure in an organism. Cells are the smallest unit of life and are made from other cells by division

cell membrane Partially permeable structure that controls the passage of substances in and out of a cell

cell wall A tough, flexible, fully permeable structure located outside the cell membrane of plants, fungi, bacteria and plant-like *Protoctista*. It supports the cell and prevents it from bursting when water enters

cellulose A *macromolecule* made of 2000–3000 glucose units joined together. It is the main molecule in plant *cell walls*

central nervous system *(CNS)* one of the two main systems of the nervous system; the CNS is made up of the brain and spinal cord and is responsible for processing information that comes from and goes to all parts of the body

centromere The part of a *chromosome* that joins the two *chromatids* together, and to which spindle fibres attach during cell division

characteristic A distinguishing feature of an organism

chemoreceptor Specialized sensory *neurons* that respond to chemical stimuli such as the presence of smell or taste molecules, or changes in the concentration of carbon dioxide

chemosynthesis The process of producing organic forms of chemical energy (*carbohydrates*) from non-organic forms of chemical energy

chitin A long *macromolecule* made from glucose and *amino acid*, used in the construction of the cell wall of fungi and the exoskeleton of arthropods

chlorophyll The main photosynthetic pigment of green plants

chloroplast Organelle that is the site of *photosynthesis* and contains *chlorophyll*

chromatid One of two copies of a *chromosome* after it has replicated

chromosome A long length of *DNA*, packaged with protein, containing many genes

classification The process of dividing organisms into groups with similar *characteristics*

climate change See *global warming*

clone A group of genetically identical individuals (or cells)

cloning Making a genetically identical copy of an organism

common ancestor The most recent species from which two or more different species have evolved

communicable disease A disease that is spread between individuals through air or body fluids; also known as an 'infectious disease'

community A group of populations of organisms living and interacting with each other in a habitat

comparative anatomy The study of similarities and differences in the anatomy of different species, used to study the *evolution* of species

complementary bases Two *bases* that have shapes that can fit together. *Adenine* pairs with *thymine*, and *cytosine* with *guanine* in DNA

concentration The quantity of a substance in a defined space or volume

concentration gradient The difference in *concentration* between one area and another

cross-breed To produce an animal or plant by deliberately mating individuals of different breeds or varieties

crossing-over Exchange of genetic material between chromosomes during *meiosis*

cycle A series of events that are regularly repeated in the same order

cytokinesis Division of cytoplasm after the nucleus has divided into two

cytoplasm Site of many chemical reactions controlled by *enzymes*. Contains organelles such as *mitochondria*

cytosine A base found in *DNA* and *RNA* that pairs with guanine

decomposers *Bacteria* and *fungi* that feed on dead plant and animal material

deforestation The removal of trees from an area of land

deletion The removal of a base from *DNA*

denature A structural change in a protein that results in the *substrate* being unable to fit the *active site*, stopping activity

deoxygenated With oxygen removed

destarch Remove starch from a plant by keeping it in the dark

detritivore Decomposer, such as a fly, that breaks down and uses dead organic matter as a source of food and energy

diabetes Inability to control blood-sugar level due to lack of *insulin*

diaphragm A sheet of tissues, largely muscle, separating the thorax from the abdomen in mammals

diet The types of food an organism usually eats

differentiate Make or become different in the process of *growth* or development

diffusion The movement of molecules from higher to lower *concentration*

digestion The process of breaking large *insoluble* molecules into small *soluble* ones

diploid Cells with nuclei that have two sets of *chromosomes*, one from each parent

distribution Location of a *species* around the world

diversity The amount of biological variety in an area. It can be measured in terms of *species*, *habitat* or genetic diversity

DNA Deoxyribonucleic acid – a molecule common to all life on Earth. It contains the code that determines the structure of living things

DNA ligase An enzyme which can connect pieces of *DNA* together

dominant An *allele* that always shows through, and that causes the *homozygous* form and the *heterozygous* form to look the same as each other

ecological footprint The area of land and water required to provide sustainably all resources at the rate at which they are being consumed by a given *population*

ecosystem A community of organisms that depend on each other and the *environment* they live in

egg Female sex cell

embryo The earliest stages in development of a new organism

embryonic Relating to an *embryo*

emission The production and release of something, e.g. a gas

emulsification Break fats into very tiny droplets

endangered species A *species* at risk of *extinction*

endemic species A *species* found in a particular area and nowhere else. See also *native species*

environment The external surroundings of an organism that act on it and affect its survival

environmental Relating to the *environment*

enzyme A biological *catalyst*

enzyme–substrate complex Structure formed when a substrate combines with an *enzyme* at its *active site*

ethical Relating to beliefs about whether something is right or wrong

eutrophication The addition of nitrates or phosphates to a body of water resulting in an increase in algal growth and reduced dissolved oxygen

evolution The cumulative and gradual change in the genetic characteristics of successive *generations* of a species; the cumulative gradual changes eventually give rise to species different from the *common ancestor*

evolve The process of having undergoing *evolution*

***ex situ* conservation** The preservation of species outside their natural habitats, usually in zoos which carry out captive breeding and reintroduction programmes

excretion Get rid of waste produced by chemical reactions in cells

exploitation Using something for maximum gain

extinction The irreversible loss of species

fatty acid One of the building blocks of fat, along with *glycerol*. Made from a long chain of carbon and hydrogen atoms

fauna Animals

fertilization The fusion of male and female *gametes* to form a *zygote*

fertilizer A chemical or natural substance added to soil to increase the *yield* of a crop

fibre Substance in food made from *cellulose cell walls*

flora Plants

food chain Linear sequence of what eats what in an *ecosystem*

food web Graphical representation of interconnected food chains in an *ecosystem* to show the complex connections of what eats what in each *trophic level*

fossil The remains or impression of an ancient *species* preserved in rock

fossil fuels The remains of dead plants and animals formed millions of years ago: coal was formed from dead plant material; oil and gas were formed from dead marine organisms

fungus (pl. fungi) *Heterotrophic*, non-motile, *multicellular* (usually) organisms with a *mycelium* of *hyphae* and *chitin cell walls*. They constitute a separate *kingdom*

gamete Sex cell (e.g. ovum, sperm)

gas exchange Process through which oxygen and carbon dioxide are transferred in opposite directions across a specialized surface

gene Sections of *DNA* found in the nucleus of all cells

gene pool All the different types of *gene* found within every individual of a species

generation A group of organisms born and living around the same time

genetic Relating to *genes* and *heredity*

genetic code The order of bases in *DNA* that determines the sequence of *amino acids* in a *protein*

genetic disease Disease caused by changes in the genetic code, rather than by *pathogens*

genetic engineering/genetic modification (GM) *DNA* is modified so that a unique set of genes is produced

genome The whole of the genetic information of an organism

genome mapping Methods used to find the exact location of a gene on a *chromosome*

genotype The 'genetic makeup' of a person; the genetic information in the cell

global warming An increase in the average temperature of the Earth's atmosphere

glucagon *Hormone* produced by the *pancreas* that converts *glycogen* into glucose

glycerol One of the building blocks of fat, along with *fatty acids*

glycogen Storage molecule of glucose in animals and *bacteria*

gradient Change in quantity of something (e.g. temperature, pressure, or concentration) from one area to another

gravitotropism Adaptive response in plants that causes them to move and grow in response to gravity

greenhouse effect A natural process in which *greenhouse gases* allow short-wave radiation to pass through the atmosphere but trap some outgoing long-wave radiation. It increases global temperatures by about 33 °C, allowing life on Earth to exist

greenhouse gas Gases, such as carbon dioxide and methane, which absorb infrared radiation; this can lead to global warming

growth Achieve a permanent change in size

guanine A base found in *DNA* and *RNA* that pairs with *cytosine*

habitat The place where a *species* lives

haploid Cells having one set of *chromosomes*

herbivore An animal that eats only plants

herbivory The process of searching for, finding and eating plants

heredity Passing *characteristics* genetically from one *generation* to the next

heterotroph An organism that feeds on other organisms to obtain its food

heterozygous Two different *alleles* for a particular characteristic in each cell

hierarchy A structure made from many different levels. In biology it relates to the different levels of classification from *kingdom* to *species*

homeostasis Maintaining a constant internal environment

homeostatic Relating to *homeostasis*

homologous features Similarity due to *common ancestry*

homozygous Two identical *alleles* for a particular characteristic in each cell

hormone A chemical messenger in living things

host An organism on or in which a parasite lives; the host provides nutrients and other benefits to the parasite at the expense of the host's well-being

Human Genome Project (HGP) An international scientific research project; its aim was to determine the sequence of the 3 billion base pairs which make up the *DNA* of humans

hyphae Each of the branching filaments that make up the *mycelium* of a *fungus*

immune system The body system that defends the body against infection, disease, and foreign substances

implication A possible future effect or result

***in situ* conservation** The conservation of species in their natural habitat

infertility Inability to have *offspring*

inheritable disease A disease that is determined by the genetic sequence of the individual with the disease, and that can be passed from parents to offspring; also known as a *genetic disease*

inheritance Passing on from parents to *offspring*

insertion The addition of a base to DNA

insoluble Unable to dissolve in water

insulin *Hormone* produced by the *pancreas* that converts glucose into *glycogen*, thereby removing it from the blood

intercostal muscles Muscles that run between the ribs, and are involved with *ventilating* the *lungs*

intergovernmental organizations (IGOs) Bodies established through international agreements to bring together governments to work on an international scale (e.g. the United Nations Environment Programme, UNEP)

interphase The period between nuclear divisions when the nucleus controls and directs the activity of the cell

interspecific competition Competition between individuals of different species

intraspecific competition Competition between individuals of the same species

introduced species A species moved from its native habitat to a new area through human activities

invasive species An *alien species* that has increased rapidly in number, having a negative effect on the environment and on native species

isolation The process by which two populations become separated; if the flow of genetic material between the two populations is stopped, new species may evolve

keystone species a species which has a unique and vital role in maintaining a balanced *ecosystem*

kinetic Relating to or resulting from motion

kingdom The highest classification into which living organisms are grouped. There are 5 kingdoms: animals, plants, *fungi*, *protoctists* and *bacteria*

leaf The photosynthetic organ in plants

life cycle A period involving one *generation* of an organism through means of *reproduction*

life expectancy The average length of time a person or group of people (or other organisms) may expect to live

limiting factor Components of an *ecosystem* that limit the numbers or distribution of a *population*

lipase *Enzyme* that breaks fats down into *fatty acids* and *glycerol*

lipid Substances such as fats and oils, used as a store of energy in living things

lock-and-key mechanism Relating to the specific nature of enzymes, where one substrate (the 'key') fits into one active site (the 'lock')

lung Organ adapted for *gas exchange* in land vertebrates

macromolecule A very large molecule, such as a *protein*, made of many smaller units (e.g. *amino acids*) joined together

manipulate Control or influence something

mechanoreceptor Specialized cell that responds to stimuli of touch, pressure or movement

meiosis Sexual cell division, resulting in *gametes*

metabolic reactions Chemical reactions in cells

metabolism Combined system of all the chemical reactions in cells

metaphase Stage of cell division where *chromosomes* line up in the middle of a cell

micro-organism A small living thing that can usually only be seen with the help of a microscope

microscopy Using a microscope to study very small organisms

microvillus (pl. microvilli) Fine folds in the cell membrane of a *villus*, further increasing its *surface area*

minerals Elements such as iron (used to make hemoglobin in blood) and calcium (used to make bone)

mitochondrion (pl. mitochondria) Organelle releasing energy in cells

mitosis Nuclear division where the cells produced have the same number of *chromosomes* as the parent cell

modification Altering or changing something

molecule A group of atoms joined together

monohybrid A genetic cross involving one *characteristic/gene*, such as eye colour

motor neuron Nerve cells that control muscle movement

movement Relocate from one place to another

multicellular An organism made from many cells

mutagen A substance causing a *mutation*

mutation A change in the amount or the chemical structure (i.e. base sequence) of *DNA* of a *chromosome*

mycelium A mass or network of *hyphae*

native species A species found in an area where it originated, i.e. occurs naturally within a particular *ecosystem*

natural selection The process whereby organisms that are better adapted to their surroundings are more likely to survive and produce more *offspring*

nervous system The body system made up of the brain, spinal cord and nerves, which controls all actions in the body by receiving information from and sending messages throughout the whole body

neuron Specialized cells that are able to perceive stimuli and send information about the stimulus throughout body via the nervous system; also called 'nerve cell'

niche Where, when and how a species lives. A complete description of a species' role within a *community*

non-governmental organizations (NGOs) Bodies not run by, funded by or influenced by governments of any country (e.g. Greenpeace; the World Wide Fund for Nature, WWF)

nucleotide The building block of *DNA* and *RNA*

nucleus Contains *genetic* material. Controls a cell's activities

nutrition Obtain nutrients by either feeding or making food

nutritional Relating to the *nutrition* of an organism

offspring An animal's young/children

omnivore An animal that eats both plants and other animals

organ Groups of *tissues* that work together to carry out a specific function, such as the skin, heart and lungs

organ system Groups of *organs* that work collectively to perform a function for the body, such as the digestive, reproductive, and circulatory systems

organelle Structures found within cells that carry out specific functions

organic molecule A molecule that is normally found in or produced by living matter

organization The state of being organized

osmosis The movement of water from higher to lower water *concentration* through a partially permeable membrane

overexploit Remove or reduce a *resource* in a way that is not *sustainable*

overhunting Hunting an animal in a way that is not *sustainable*

oxygenated Containing oxygen

palisade cells Oblong-shaped cells towards the surface of a *leaf*, containing many *chloroplasts* for *photosynthesis*

pancreas Organ in the body that produces enzymes for digestion and *insulin* to control blood-sugar level

parasite An organism or virus that lives in or on another organism (the *host*) and gets nutrients and other benefits at the expense of the host's well-being.

pathogen An organism, such as *bacteria*, fungi or *parasite*, or *virus* that causes disease in its *host*

peripheral nervous system One of the two main systems of the nervous system; nerves in the PNS connect the *central nervous system* at the spinal cord to organs, muscles, cells, blood vessels and glands

pest Animal or plant that has become a nuisance to humans

phenotype What you look like; the outward effect of the *genetic* code on the body

phenotypic traits Physical *characteristics* that determine the appearance of an organism

photoreceptor Specialized cell that responds to stimuli from light waves

photosynthesis The process by which green plants convert light energy from the Sun into useable chemical energy stored in organic matter. It requires carbon dioxide, water, *chlorophyll* and light

phototropism Adaptive response in plants that causes them to move and grow toward a light source

physical Relating to the body of an organism

physiological Adaptations which involve the function of the organism's body, such as temperature regulation

placenta A temporary organ that joins the mother and fetus, transferring oxygen and nutrients from the mother to the fetus and allowing the release of carbon dioxide and waste products from the fetus

plantation A crop usually of one species of e.g. tree

plasmid An independently replicating circle of *DNA* containing a few genes. They are found in bacteria and can be used to carry genes into a suitable host *bacterium*

pleural membrane Tissue lining lungs and thorax cavity ensuring that the lungs are air-tight

pollutant A substance that pollutes something, especially water or the atmosphere

pollution The addition of a substance or an agent to an environment by human activity, at a rate greater than that at which it can be made harmless by the environment, and which has an notable effect on the organisms within it

population A group of organisms of the same *species* living in the same area at the same time

predation The process of hunting, killing, and eating animals

predator Animal that hunts, kills and eats other animals

prey Animal that is hunted, killed and eaten by a *predator*

primary consumer A consumer on the second *trophic level* that eats producers

producer Plants, algae and other micro-organisms that use the energy from the Sun, plus carbon dioxide and water to make sugars (food)

product A substance produced as the result of a chemical reaction

prokaryotes (bacteria) A microscopic organism without a true nucleus. One of the five *kingdoms* of life

prophase Stage of cell division where *chromosomes* start to appear in the cell

protease *Enzyme* that breaks *proteins* down into *amino acids*

protein A long chain of *amino acids* joined together, forming a specific shape

Protoctista *Kingdom* containing all unicellular, microscopic organisms, as well as seaweeds. Some protoctists have the characteristics of animal cells, whereas others are like plant cells, i.e. containing a *cell wall* and *chloroplasts*

quarternary consumer A consumer on the fifth *trophic level* that eats *tertiary consumers*

random assortment Refers to the way *chromosomes* line up in the centre of the cell during *meiosis*. It results in each *sperm* and each *egg* having different combinations of *chromosomes* from the mother and father

reactant Substance that reacts with another in a chemical reaction

recessive An *allele* that affects an animal's appearance only if it is present in the *homozygous* state and is not hidden by a dominant allele

reflex An automatic reaction in response to certain types of stimuli

relay neuron Conveys impulses from the *sensory neuron* to the motor neuron within the *central nervous system (CNS)*

replication Making an identical copy of something

reproduction The process of producing offspring

reproductively isolated Occurs when two populations can no longer interbreed and exchange genes

resistant The ability of an organism to survive something

resource A substance in an organism's *environment* needed for *growth*, maintenance and *reproduction*

respiration Break down glucose to release energy

restriction enzyme Enzymes found in bacteria and used to destroy viruses. They cut *DNA* at particular sequences leaving *sticky ends*

ribosome *Organelle* where proteins are made. It is the smallest organelle in cells

RNA A nucleic acid containing the sugar ribose and the base uracil rather than *thymine*. Unlike *DNA*, it is single-stranded rather than double-stranded

saprotroph *Decomposers*, such as bacteria or fungi, that live on and chemically break down dead organic matter

saturated Refers to a *fatty acid* where all carbon atoms are fully bonded to other atoms

scavenger Animals such as hyenas that feed on dead animals as their source of food and energy

secondary consumer A consumer on the third *trophic level* that eats *primary consumers*

selection A process in which environmental/genetic factors determine which organisms survive and which do not

selective breeding See *artificial selection*

sensitivity Responding to changes in the environment enabling the survival of the organism

sensory neuron Specialized neurons that receive information from stimuli

sexual reproduction The production of *offspring* from two parents using *gametes* (egg and sperm)

small intestine The part of the intestine that runs between the stomach and the large intestine, where *digestion* and absorption of food takes place

soluble Can dissolve in water

sonoreceptor Specialized cell that responds to stimuli from sound waves

specialized Having a specific purpose/role

speciation The process by which new species form

species A group of organisms that can mate together and produce young that are able to breed and have their own *offspring*

sperm Male sex cell, produced by *meiosis*

spinal cord Tube-like bundle of nerves that connects the brain with the *peripheral nervous system* to send information to and from the brain and throughout the body

spongy mesophyll Layer of cells in a leaf where *gas exchange* takes place

stem cell A cell can that can repeatedly divide into more stem cells which are unspecialized (i.e. have yet to become specific types of cell), and the later ability to differentiate into mature cell types, such as muscle, blood and nerve cells

sticky ends When a cut is made in *DNA* by a restriction enzyme the exposed unpaired bases can pair with *complementary bases* on another strand of DNA which has been cut with the same restriction enzyme. These exposed bases are called sticky ends

stimulus (pl. stimuli) An event or substance that causes a reaction

stoma (pl. stomata) Hole/pore usually on the underside of leaves that allows gases to enter and leave the leaf, and transpiration to occur

substitution The change of one *base* to a different base (often caused by the *DNA* being copied incorrectly)

surface area The sum of all the areas that cover the surface of an object

surface area : volume ratio The relationship between *surface area* and volume

sustainability Living within the means of nature

sustainable Using a *resource* so that it is not exhausted or permanently damaged

sustainable development Meeting the needs of the present without compromising the ability of future generations to meet their own needs

symbiosis Arrangements and relationships between organisms living in the same area, including parasitism, mutualism and commensalism

technology The application of scientific knowledge for practical purposes

telophase Stage that completes nuclear division in cells

terrestrial Relating to land

tertiary consumer A consumer on the fourth *trophic level* that eats secondary consumers

thermoreceptor Specialized cell that responds to stimuli from changing temperatures

thigmotropism Adaptive response in plants that causes them to move and grow in response to touch or contact

thorax The part of the body above the *diaphragm* and below the neck, containing the lungs and heart

thymine A base found in *DNA* that pairs with *adenine*

tissue Groups of cells of similar type that work together to perform a particular function in the body, such as muscle and bone tissue

transfer Move from one place to another

transformation A change in form

transgenic An organism containing the *DNA* of another species

transplant Take a living tissue or an organ and put it into another organism

trophic level Level in a *food web* that is made up of organisms that get their energy in a similar way

unicellular An organism consisting of only one cell

unsaturated Refers to a *fatty acid* in which not all carbon atoms are fully bonded to other atoms, i.e. some carbons contain double bonds

vaccine A substance given to possible host organisms, such as humans or other large animals, that contains elements of a *pathogen* in order to stimulate the recipient's *immune system* to produce *antibodies* to protect the person/animal from a possible future infection

vacuole Large fluid-filled sac in plant cells

variation Differences between individuals of a *species*. May be caused by environmental or genetic factors

vector Something which can carry *DNA* from one organism to another. Examples are *viruses* and *plasmids*

vein Blood vessel that carried blood toward the heart from tissues and organs of the body

ventilation The act of drawing in oxygen and removing carbon dioxide from the body

ventricle (pl. ventricles) The lower chambers of the heart, from which blood is pumped along *arteries* into the body

vessel A hollow tube along which substances can flow

villus (pl. villi) Folds in the wall of the *small intestine*, increasing *surface area* for the absorption of food

virus A non-cellular *pathogen* made up of a protein coat and genetic material that invades living cells and uses their cellular machinery to *replicate*. Does not independently carry out any of life's functions

vitamins Chemicals that ensure cells function properly, e.g. vitamins C and D

xerophyte Plants that can live in dry conditions (from 'xero' which means dry, and 'phyte' which means plant)

yield The amount of an agricultural *resource* produced e.g. plant crop

zygote Cell produced by the fusion of *gametes*

Acknowledgements

The authors would like to extend their grateful thanks to Antoine Giust, who thoroughly reviewed the full manuscript and gave invaluable advice that helped to materially improve the text. Thanks also to the team at Hodder Education who have brought together the text and illusrations just as the authors would have wished.

The Publishers would like to thank the following for their advice and support in the development of this project: Robert Harrison, Head of Middle Years Programme Development, IBO; the *MYP by Concept* series editor, Paul Morris; Antoine Giusti, Munich International School and Rita Bateson, Curriculum and Assessment Manager for Mathematics and Sciences, Middle Years Programme, IBO, for reviewing the manuscript.

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Andrew Davis teaches IB Diploma Biology and Environmental Systems and Societies (ESS), and is the author of Diploma Science titles and the digital component, the Teaching and Learning Resources, of our bestselling textbook, *Biology for the IB Diploma*, Second edition.

Patricia Deo is an MYP Coordinator, as well as teacher of MYP Sciences, IB Diploma Biology and DP Environmental Systems and Societies. She is an experienced MYP educator who has taught at international schools in the Middle East and Europe. She is also the co-author of *MYP by Concept 1–3 Sciences*, with Paul Morris.

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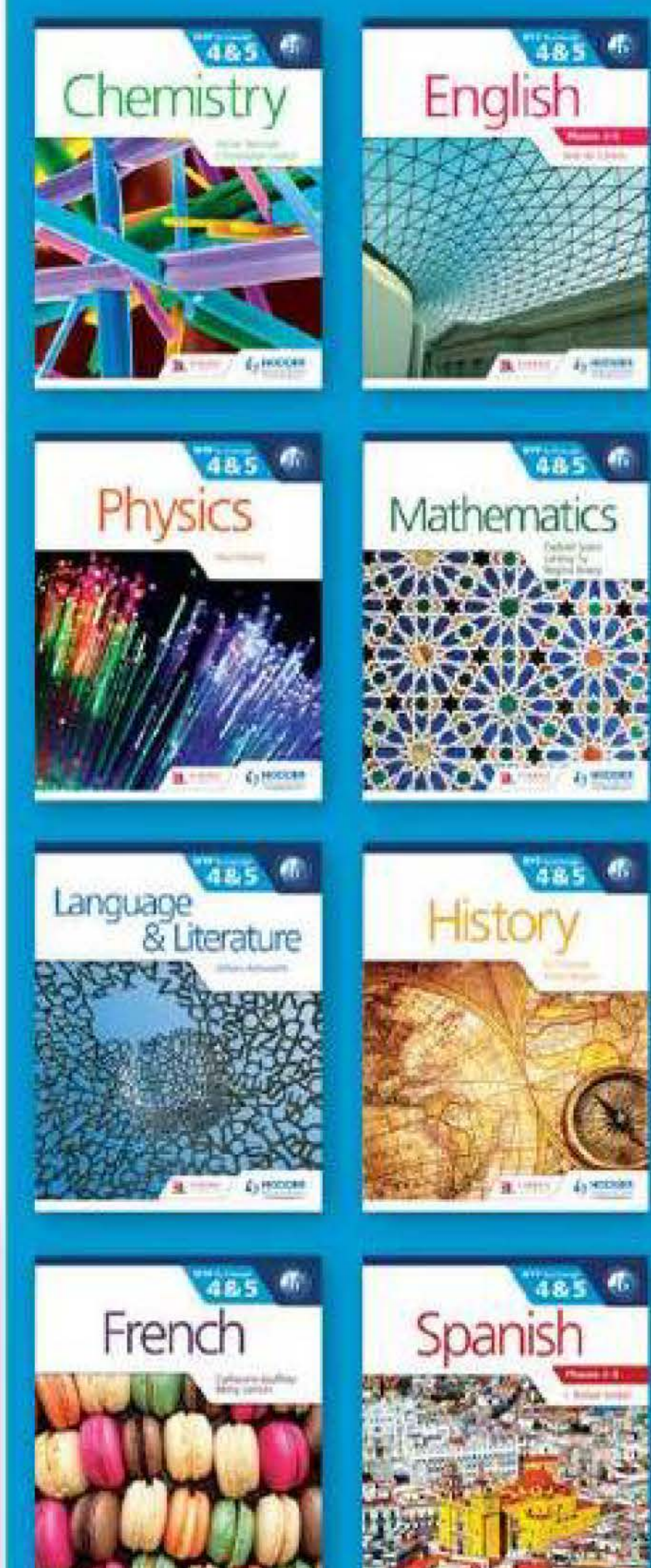

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ISBN 978-1-4718-4170-5