# Year 12

# Biology

# BIOLOGY

Year 12

GOVERNMENT OF SĀMOA

MINISTRY OF EDUCATION, SPORTS AND CULTURE

Acknowledgements

The Ministry of Education, Sports and Culture would like to thank the following people for their vision, patience and hard work in putting together this valuable book:

| | |
|---|---|
| Cara Scott | Consultant |
| Anna Egan-Reid | Additional illustrations |
| Masa Fa'asau | Robert Louis Stevenson's Secondary School |
| Tamasoali'i Saivaise | CMAD |
| Desmond Mene Lee-Hang | ICSPI Secretariat (UNESCO Office for the Pacific) |

The MESC would like to thank Desmond Mene Lee-Hang (International Council for the Study of the Pacific Islands secretariat) for advice on Sāmoan herbal medicine.

Some of the material in this book is taken from the following texts and is used with the permission of New House Publishers Ltd, Auckland, New Zealand and the listed authors/illustrators:

*Biology Pathfinder Year 12*
Author: David Relph
Series Editor: George Hook
Illustrations: Tony Mander
Photograph acknowledgements:
page 4 R. Morris, Dept Conservation
page 8 Ministry of Forestry
pages 27, 35, 61 Neil Andrews, SEM Technician, Plant and Microbial Sciences Dept, University of Canterbury
page 35 Dr Paul Broady, Plant and Microbial Sciences Dept, University of Canterbury
page 36 Duncan Shaw-Brown, Photographic Services, University of Canterbury
pages 9, 65, 79, 83, 93 Royal NZ Forest and Bird Society
page 37 Manfred Ingerfeld, TEM Technician, Plant and Microbial Sciences Dept, University of Canterbury
pages 34, 36, 59, 86 D. Stringer, SEM Technician, Engineering Dept, University of Auckland
page 86 Associate Professor Brian Butterfield, University of Canterbury

*Science Pathfinder Year 11*
Series Editor and author: George Hook
Illustrations: Tony Mander
Photograph acknowledgements:
pages 4, 5, 6 Neil Andrews, Canterbury University
pages 4, 5, 6 Dr Ian Hallett, Hort Research
pages 7, 10, 11, 23 Dave Relph

*The Living World, Level Six Science*
Authors: David Relph, Murray Black, Jan Jamieson

*Emergency Clinic: A learning context for the human body*
Author: Monique Curran
Illustrations: Warren Mahy



Designed, edited and typeset by Egan-Reid Ltd, Auckland, as part of the Sāmoa Secondary Education Curriculum and Resources Project for:

Government of Sāmoa Ministry of Education, Sports and Culture, 2004.

Funded by the New Zealand Agency for International Development, Nga Hoe Tuputupu-mai-tawhiti.

Printed through Egan-Reid Ltd.

Managing Contractor: Auckland UniServices Limited.

ISBN 982-517-063-8

# Table Of Contents

# Unit 1

# Variety Of Life

This unit is divided into sections that cover living things and micro-organisms.

## Living Things

In this section you learn to:

- **describe** the life processes carried out by living things
- **classify** living things into kingdoms
- **describe** features of the main groups of plants and animals
- **use** dichotomous keys to identify organisms.

### Biology and life

**Biology** *is the scientific study of life.* It is the study of all living things – from fragile butterflies which battle to survive on high alpine peaks to 40 metre strands of wave-tossed giant kelp on rocky coast lines; from majestic lions of the African savanna to tiny micro-organisms that live on their skin.

Biology is the study of humans and of the 1.5 million different kinds or **species** of living things that are known (and of the many millions of species yet to be discovered).

Humans are interested in biology because we too are part of the living world. We are curious animals who want to know how life functions, and how we can coexist with and use the living world around us.

If biology is the study of life, then first we must be clear what **life** is. When compared with matter that is non-living, objects that are alive are characterised by a number of special features.

Living things are made up of small units called cells. Living things use energy to carry out movement, growth and reproduction. Living things also respire, sense their surroundings, obtain nutrition and excrete wastes.

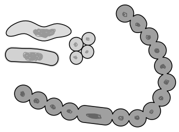
Use the letters MRS C GREN to remember the features of living things. **M**ove, **R**espire, **S**ense, **C**ells, **G**row, **R**eproduce, **E**xcrete, **N**utrition.

# Kingdoms

Organisms which are **unicellular** or **multicellular** (but lack complex organs) are called 'simple' organisms. Organisms in the Kingdoms Monera, Protista and Fungi are simple organisms.

**Kingdom Monera**
- 10 000+ species
- most common organisms
- unicellular
- no nuclei or chloroplasts
- bacteria, blue-green algae

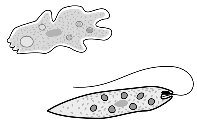
*bacteria*



*blue-green algae*

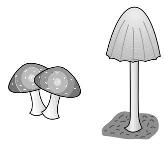
**Kingdom Protista**
- 55 000+ species
- simplest organisms with nuclei
- unicellular and multicellular
- mitochondria and chloroplasts
- protozoa, algae, slime moulds

*Amoeba*



*Euglena*

**Kingdom Fungi**
- 100 000+ species
- multicellular and immobile
- nuclei present in cells
- external digestion of food
- moulds, toadstools, yeasts



**Kingdom Plantae**
- 300 000+ species
- complex, multicellular
- live on land or in fresh water
- make food by photosynthesis

**Kingdom Animalia**
- 1 000 000+ species
- complex, multicellular
- must consume food

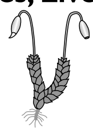
*Figure 1.1 Kingdoms*

## Kingdom Plantae – plants

The plants in Kingdom Plantae can be divided into groups which have similar features.

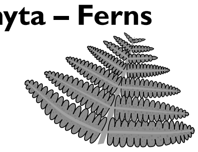
Small, flat or tufted green plants, found in damp places →

**Phylum Bryophyta – Mosses, Liverworts**
- 16 000+ species
- no true leaves
- no conducting tissue
- spores in capsules



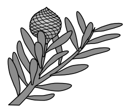
Plants with stems and fronds, often in damp places →

**Phylum Pterophyta – Ferns**
- 12 000+ species
- true leaves
- conducting tissue
- spores in capsules



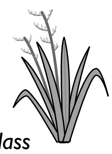
Tall plants with sharp leaves and cones, in many habitats →

**Phylum Coniferophyta – Conifers**
- 550+ species
- true leaves
- conducting tissue
- seeds in cones

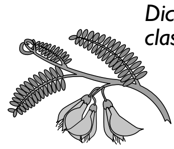


Tall plants with broad leaves and flowers, in many habitats ↓

**Phylum Anthophyta – Flowering Plants**
- 250 000+ species
- true leaves
- conducting tissue
- seeds in fruits



*Monocot class*



*Dicot class*

*Figure 1.2 Classification of plants*

## Kingdom Animalia – animals

The animals in Kingdom Animalia can be divided into groups which have similar features. These groups can then be divided into small groups of even more similar animals.

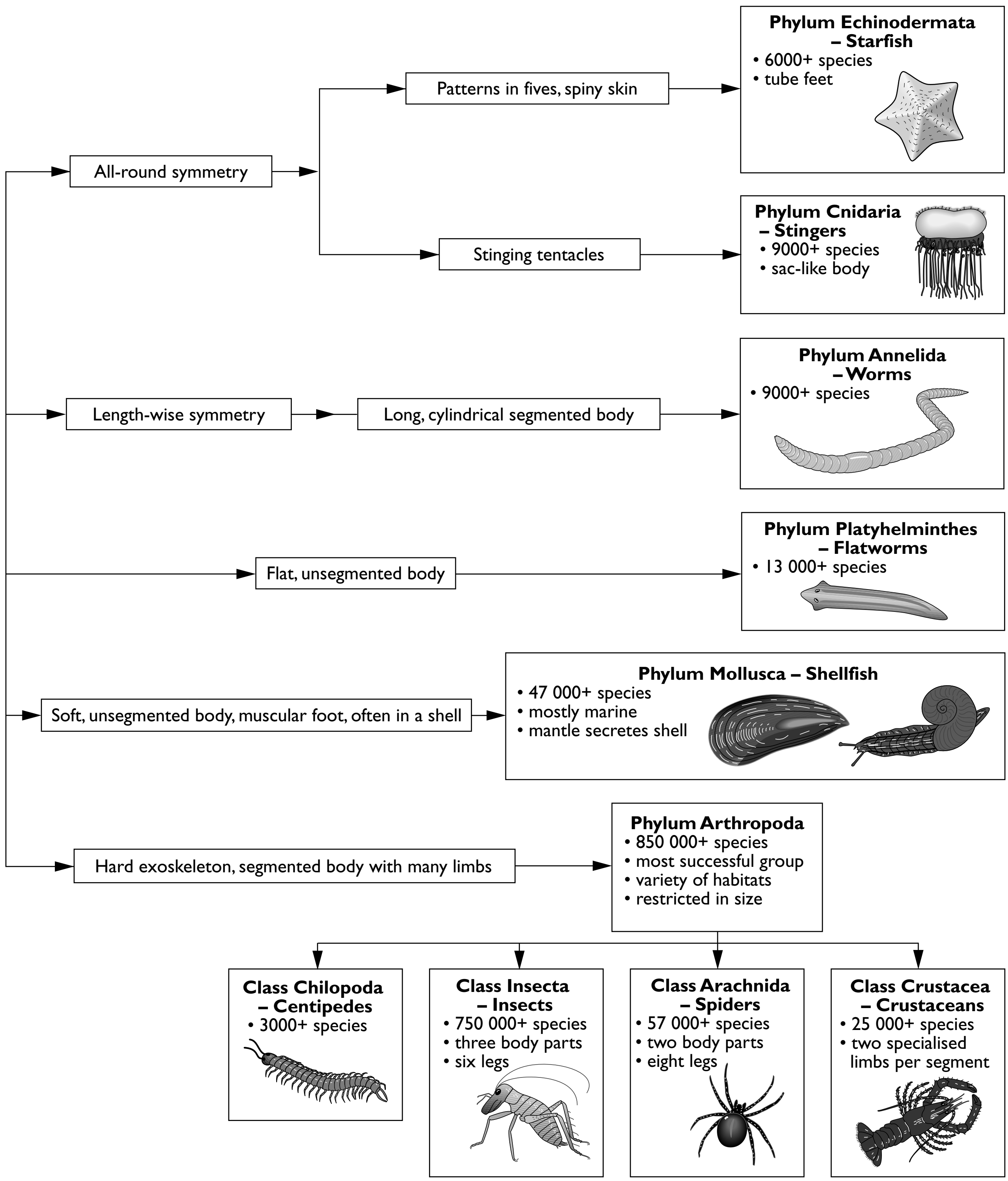



*Figure 1.3 Classification of invertebrates*

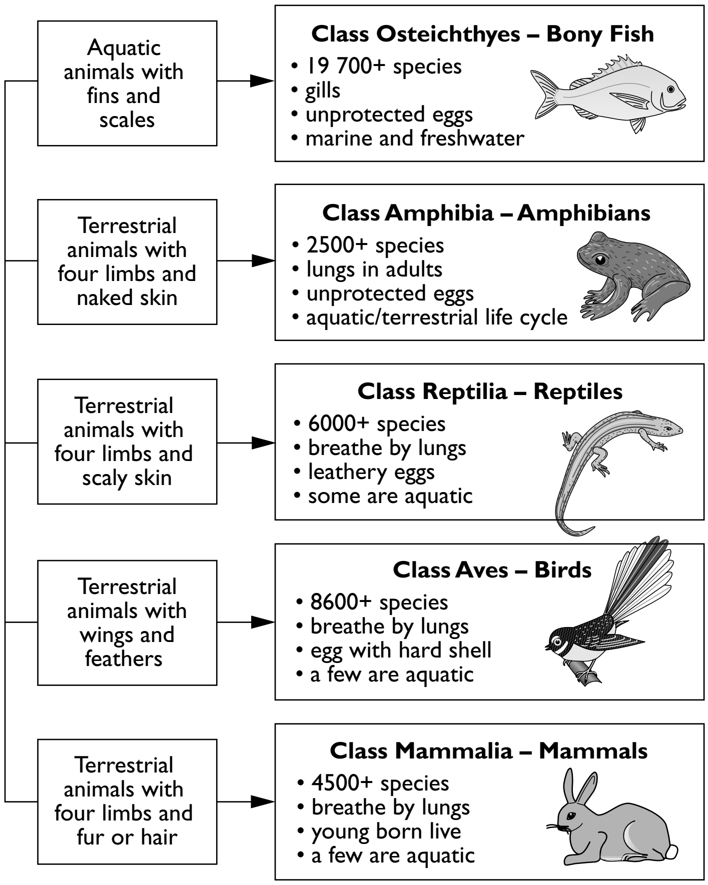



*Figure 1.4 Classification of backbone animals which belong to the phylum* ***Chordata***

## Micro-Organisms

In this section you should learn to:

- ❑ **describe** the structure of viruses, bacteria and fungi
- ❑ **culture** bacteria or fungi
- ❑ **investigate** the growth, respiration or reproduction of bacteria or fungi
- ❑ **explain** how bacteria and fungi carry out the life processes: feeding, growth and asexual reproduction
- ❑ **explain** why viruses are always pathogenic
- ❑ **discuss** how bacteria and fungi are used for economic, environmental or medicinal purposes.

### Micro-organisms

There are three main groups of micro-organisms which are important to people. These are bacteria, fungi and viruses. Micro-organisms are very small organisms which you can usually only see with a microscope. The cell of a bacterium is smaller than 0.01 millimetres which is smaller than the cells in your body.

Even though micro-organisms are difficult to see, their activity can be helpful or harmful to people, plants and animals. Harmful micro-organisms spoil food, damage crops and cause diseases. Helpful micro-organisms break down wastes and dead material to recycle the materials. They digest food in the gut of animals including humans and they can make food.

# Yeast

Studying biology means finding out about living things. Most of us know something about the plants and animals that surround us and therefore we want to investigate further how they live and work. Our observations usually start with what we see with our own eyes – the animals we see near villages, or keep at home or in the biology laboratory; the plants in our garden, in plantations or the school grounds. In this unit however we will study living things that are everywhere around us but which we can't usually see because they are so small.

For centuries people have been growing wheat, and pictures drawn 4000 years ago show the ancient Egyptians used yeast to make bread. The recipe for bread making requires yeast. People made beer and wine for many centuries before they realised that yeast was involved. It was not until 1676 that Anton van Leeuwenhoek, using one of his first microscopes, found that yeast was a living cell and that different types of yeast cells could also be used for brewing beer and making wine.

The famous French scientist Louis Pasteur discovered in 1859 that when you mix yeast, a single celled **micro-organism**, with sugar in dough you make carbon dioxide gas and alcohol. It is the two products of this reaction that give bread its light spongy texture and distinctive flavour. Pasteur called this special chemical reaction **fermentation** (*fa'amafu*). Because of the very large number of loaves of bread made each day throughout the world there has to be a way to produce enough yeast for all the bakeries. Each yeast cell is so tiny that it takes up to 25 billion healthy cells to make up 1 gram – imagine how many cells must be included in the tonnes of yeast that is used at the Vailima Breweries each week!

## Yeast production

From a tiny speck the size of a pin head, 25 tonnes of yeast is grown in just 3 days. The photos below show the process:

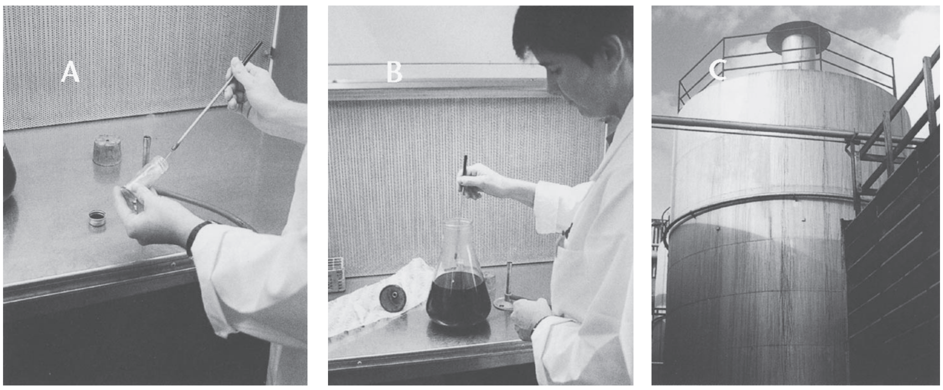



*Figure 1.5 The process of growing yeast:* **a** *A lab technician transferring yeast cells with a sterilised nichrome wire from a pure culture imported from Australia;* **b** *A very small amount of the pure culture is added to the sterilised molasses sugar solution in a glass flask where it grows rapidly, doubling the number of yeast cells ever four hours;* **c** *The flask of yeast is then poured into a large stainless steel vessel where it continues to grow. At the same time large volumes of sterilised air are pumped into the vessel to stir the brew and to provide the oxygen to help the yeast grow rapidly.*

Three days after starting, each flask that was set up has now produced 25 tonnes of yeast! The yeast cells are separated from the mixture they were growing in, washed and then stored in refrigerated tanks before being delivered to the bakeries or dried to be sold in packets or small jars at the supermarket.

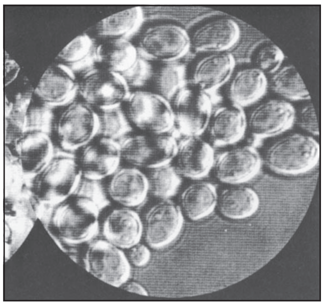


*Figure 1.6 Yeast cells as seen under a microscope*

## *Knowing your yeast*

**Population numbers**

1 Describe how yeast cells increase their numbers. How quickly can they double their number?

2 Other organisms called bacteria can double their number in only 20 minutes. Suppose you started with 10 bacteria cells: draw up a chart recording how many cells there will be after each 20 minutes up to 4 hours (240 minutes).

3 Now draw a graph of these results (time across the bottom, numbers of bacteria up the side). Label your graph.

4 Describe what is happening to the number of bacteria cells and explain what might happen to yeast cells living in the same molasses.

**Questions**

1 Write down definitions of the words in bold type.

2 How could you demonstrate that dry yeast in a packet on a supermarket shelf is alive?

3 From the process shown in the photos on page 9 list examples of how they show physics, chemistry, biology and technology in action.

## *Revising microscope skills to look at yeast*

Can you remember how to set up and use a light microscope? If you are not sure go to page 64. In this practical session you will revise your skills by studying yeast cells.

**Gear**
Microscope, slide, coverslip, yeast.

**What to do**
Read through the following checklist carefully. When you can answer yes to each item move on to the next.

**Slide preparation**

1 Did you clean the microscope slide and coverslip you collected and carry them by the edges to avoid fingerprints?

2 Have you placed one drop of the liquid containing the yeast cells onto the centre of a microscope slide?

3 Did you place the coverslip at an angle to the slide but just touching the edge of the liquid?

4 Did you use a needle to carefully lower the coverslip over the drop?

*When all your answers are YES you are ready to set up the microscope.*

**Setting up the microscope**

1 Have you checked which side of the mirror you are using? (Use the curved side if there is no condenser under the stage.)

(cont.)

2 Have you turned the mirror to make the light reflect into the microscope?

3 Did you turn the condenser lens as far up as possible and fully open the diaphragm?

4 Have you adjusted the mirror to give you the most even and the brightest light while looking through the eyepiece?

5 Have you placed your slide on the stage of the microscope and clipped it in place?

6 Are the yeast cells right in the centre of the microscope stage and lined up with the objective lens?

*When all your answers are YES you are ready to look at your yeast cells.*

**Looking at yeast cells**

1 Is the smallest objective lens (low power) on the nosepiece clicked into place?

2 Did you watch carefully from the side as you turned the coarse focus control (the larger knob) to bring the objective lens to stop just above the slide?

3 Did the yeast cells come into focus as you slowly moved the objective lens and the stage apart by turning the coarse focus?

*If they did not, try again. If they are still not in focus, ask for help now.*

4 Have you adjusted the diaphragm and condenser lens to get the best view of your cells?
*You are now ready to increase the magnification.*

5 Did you watch from the side as you turned the nosepiece to the next most powerful objective lens (high power)?

6 Did you turn the fine focus control knob to move the stage and lens apart while you looked through the eyepiece?

7 Have your yeast cells come into focus clearly again?

*When all your answers are YES you are ready to draw your yeast cells.*

**Drawing yeast cells**

Using the high power lens draw a large, clear diagram of one yeast cell. This diagram should be at least half a page and should have a title as well as details about the magnification of your microscope.

If you have time your teacher may give you other activities such as counting, staining or measuring the yeast cells.

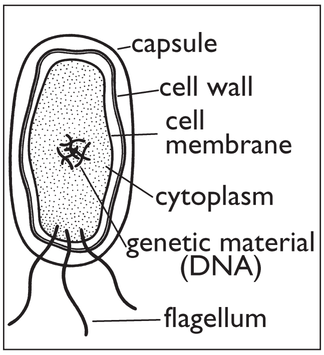



*Figure 1.7 Bacterial cell structure*

## The structure of bacteria

There are thousands of different types of bacteria. Some are single cells and others live as groups of cells joined together. Each type has its own special shape and structure. The common shapes are **coccus** (sphere), **bacillus** (cylinder) and **spirillum** (spiral).

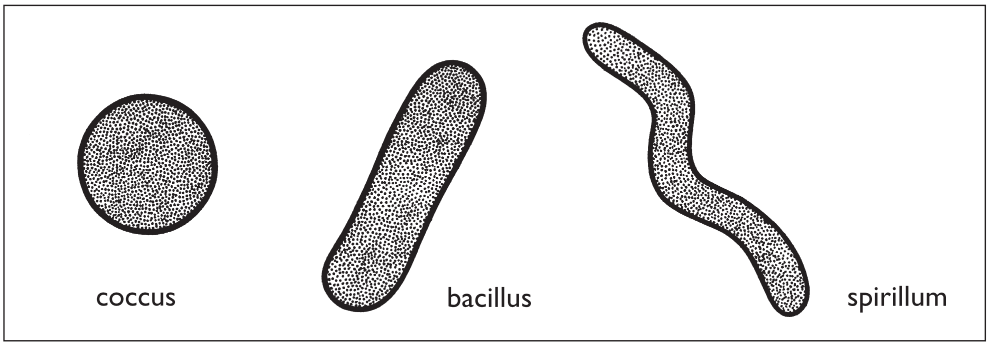



*Figure 1.8 Shapes of bacterial cells*

Bacterial cells are made up of cytoplasm and genetic material in the form of a long chromosome. The cytoplasm is surrounded by a strong cell wall. Bacteria have no cell nucleus and have none of the cell organelles found in plant and animal cells. Because there are no organelles, the chemical reactions needed for life occur in the cytoplasm of the cells.

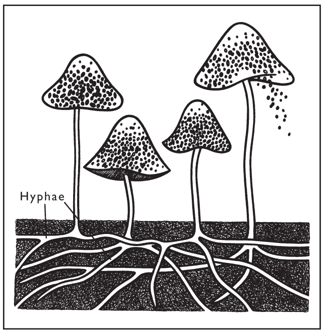



*Figure 1.9 Body and reproductive structures of a fungus*

## Structure of fungi

Some fungi are small organisms made up of one cell, for example yeasts. Others can be large organisms made up of many cells such as moulds, mushrooms and toadstools. The body, or **mycellium**, of a large fungus is made up of fine threads called **hyphae**.

Often we can only see the reproductive part of the fungus because the rest is growing through the material it is feeding on.

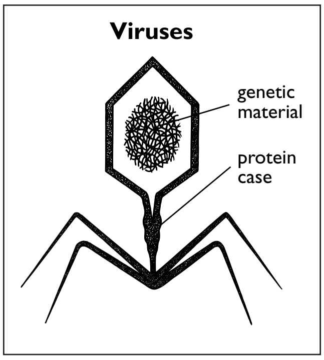



*Figure 1.10 A virus*

## Structure of viruses

Viruses are very simple organisms. They don't have organelles found in plants and animal cells and they even lack the cytoplasm found in the cells of bacteria and fungi. They only have a covering made from protein and some genetic material.

The lack of cytoplasm means that the virus is unable to carry out the normal life processes that other living things can. Some scientists say that viruses are non-living, but viruses do carry out one of the life processes and that is **reproduction**. When a virus reproduces it must use the parts of a living cell to help it produce copies of itself. This causes problems for people because as the virus reproduces it causes harm to the living cell. Often the cell dies as a result of the virus reproduction. The process of reproduction used by viruses must always use a living cell as a host cell. This means that viruses always cause disease in the living organism whose cells they use for reproduction. Some viruses only last three hours outside of a host cell before being unable to reproduce again.

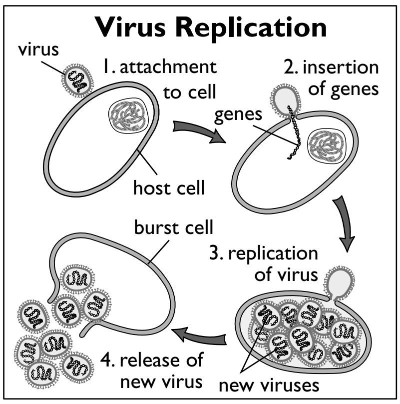



*Figure 1.11 Virus reproduction*

The first step in virus reproduction is when the virus attaches itself to a host cell. It then either enters the cell or puts its genetic material into the cell. The genetic material of the virus joins with the genetic material of the host cell. The virus genetic material takes over the functioning of the host cell, stops the cell's normal activities and causes the organelles of the host cell to produce many copies of the virus. The copies of the virus then leave the cell to repeat the process in many other cells.

## Growing bacteria and fungi

If bacteria grow in good conditions, for example on agar plates, they reproduce to form groups called *colonies*. After two or three days, the colonies are big enough to be seen through a microscope. A single colony can have more than a billion bacteria in it.

Look closely at the microscopic view of the bacterial colony and you will see the individual cocci bacteria.

Fungi can grow on a food source, such as, fruit or bread. Fungi and bacteria can be grown on agar plates. An agar plate is a dish with a lid which contains a layer of agar jelly. Agar plates are used to grow bacteria and fungi because they contain the conditions in which bacteria grow and reproduce quickly. Good conditions for growth include nutrients, water and warmth. Some bacteria and fungi are **aerobic** which means they also need oxygen for respiration. Some are **anaerobic** and do not need oxygen for respiration.

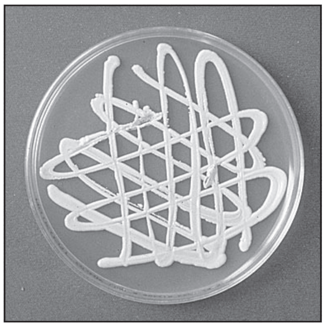


*Figure 1.12 Colony of micro-organisms*

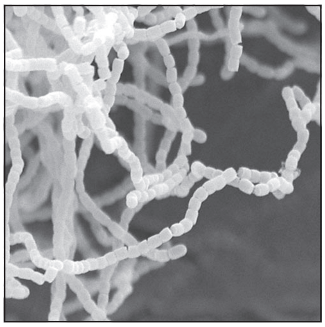


*Figure 1.13 Bacterial colony*

### Testing for micro-organisms

Agar plates can test where bacteria can be found. The plates have material such as paper or hair placed on the surface of the agar and then removed. This **inoculates** the plate, which means it transfers bacteria or fungi on to it. The plates are incubated in a warm place and any bacteria or fungi from the material that transferred on to the agar will grow into a large colony. A *control* plate is also used. The control is a plate that has had nothing added to it. It is used to check if the plates already had bacteria in them. If bacteria grow on the control it means that the original agar contained bacteria. We therefore cannot reliably say that the bacteria grew from what was being tested.

## Activity 1 Growing bacteria and fungi

**Aim**: To grow fungi and colonies of bacteria.

**Materials:**

Water

Nutrient agar, gelatin or animal bones

Dishes – petri dishes or jars with lids

Sticky tape

### What to do

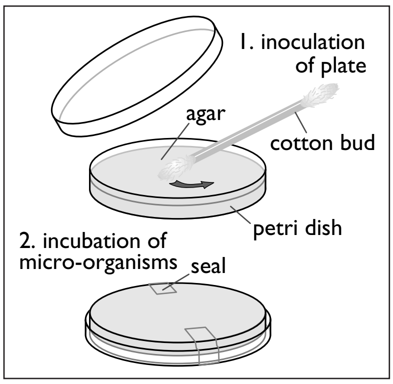
1 Dissolve agar or gelatin and a very small amount of nutrients in water, then boil to kill any bacteria. Cover and allow to cool slightly.

If agar or gelatin is not available, boil up some fresh animal bones in water for 2 to 3 hours to collect the gelatin.

2 Pour a 0.5 cm thick layer of agar or gelatin into several dishes. Cover and allow the layer to cool and become solid.

3 Leave the cover on one dish and label it ‘control’. Tape it shut and turn it upside down.

4 Use the rest of the plates to test if bacteria and fungi are growing on different surfaces or in different materials. Do NOT spit in the dish or put anything that may be carrying disease causing bacteria on to it. Be careful not to remove the lid completely as you place the materials on the dish. Instead partly open one side of the dish. If you remove the lid bacteria and fungi in the air could land on the plate and spoil your experiment.



**Example of possible tests include:**

- ❑ Place sticky tape on a surface such as a desk, table, or door handle then place it on the surface of the agar. Remove the tape after a minute. You can also use a cotton bud to rub across a surface and then across the agar or gelatin. Tape the dish shut and turn it upside down.
- ❑ Pour three to five drops of water, milk, or other liquid onto the agar surface. Swirl the dish to spread the sample across the surface and then pour off any extra liquid. Tape the dish shut and turn it upside down.
- ❑ Mix a small amount of soil with a small amount of boiled water. Then pour a small amount of the water into the dish. Swirl it to get the water over all the agar or gelatin surface and then pour off any extra water. Tape the dish shut and turn it upside down.
- ❑ Place an object such as a leaf, soap, fingertip, or a key onto the agar or gelatin. Do not damage the surface of the agar or gelatin. Remove it, then tape the dish shut and turn it upside down.
- ❑ Leave a dish open to the air for 20 minutes. Tape the dish shut and turn it upside down.

5 Leave the dishes in a warm place for 2 to 6 days. Check each day. Do NOT remove the lids in case some disease causing bacteria are growing on the agar or gelatin. Any small, round, shiny spots growing on the agar are colonies of bacteria. Fungi will look furry. Record your results using drawings.

6 When finished burn the plastic dishes and jars unopened. Leave the glass jars unopened and get rid of them through the rubbish system.

## Life processes of bacteria and fungi

### Feeding

Bacteria and fungi both feed by **extracellular digestion**. 'Extracellular' means that the digestion of food occurs outside the cell. There are three steps in extracellular digestion:

1 Fungi and bacteria live on their food source so the cell can secrete **enzymes** onto the food.

2 The enzymes digest the food outside the cell.

3 The cell absorbs the digested food chemicals and uses them for growth and respiration.

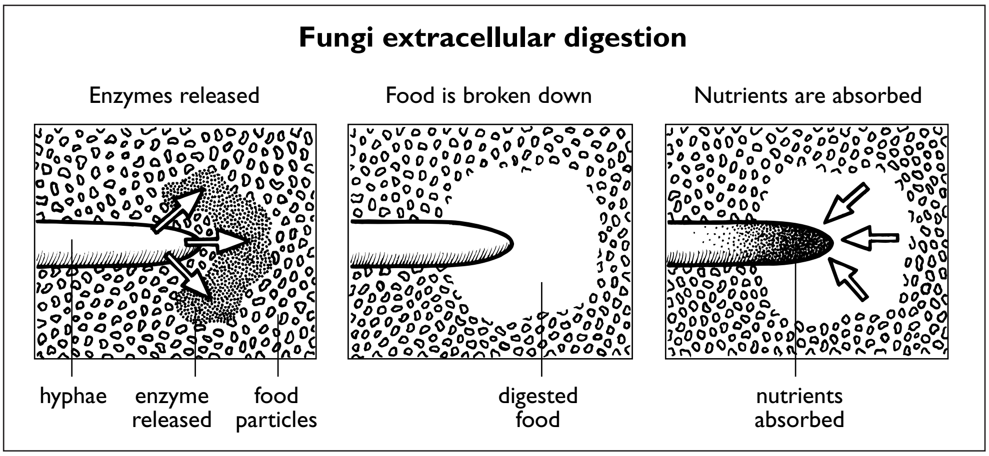



*Figure 1.14 Fungi extracellular digestion*

Different types of bacteria and fungi have different ways of life. Some are **saprophytes**. Saprophytes feed on dead plant and animal materials. Other bacteria and fungi are **parasites**. Parasites cause diseases by feeding on plants and animals while they are still living. Diseases bacteria cause include food poisoning, tetanus and syphilis. Ringworm, thrush and tinea are diseases caused by fungi. Organisms that cause disease are called **pathogens**.

## Growth and reproduction

### Bacteria

When bacteria grow, the cells increase in size. Nutrients are used to add more cytoplasm and to increase the cell wall. When the cell is large enough, it will reproduce asexually by dividing into two cells. This process is called **binary fission**.

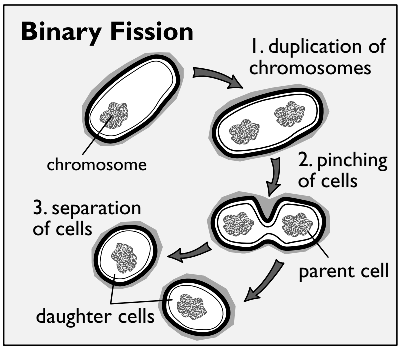



*Figure 1.15 Bacteria reproduction by binary fission*

During binary fission the genetic material is copied and each copy moves to the opposite ends of the cell. The cell wall then grows across the cell splitting the cytoplasm in half. Now reproduction is finished and two cells, with exactly the same genetic material, have been produced.

Bacteria can reproduce very often, once every 20 minutes in good conditions. This means that the number of bacteria can increase very, very quickly. This fast rate of reproduction usually stops when the bacteria run out of space, food, or they are surrounded by their own **toxic** waste. The rate of reproduction is slower when the temperature is too hot or too cold.

### Fungi

The mycelium of a fungus is made up of many cells in long threads called hyphae (see Figure 1.9, page 12). The hyphae grow longer when cells divide. This way the fungi can grow into new food sources.

Fungi reproduce *asexually* by producing **spores**. When a fungus is ready to reproduce, special structures called **sporangia** grow and produce millions of small, light spores. The spores are released and float in the air. If the spores land on a food source they germinate and grow new hyphae into the food source. The resulting fungi is genetically identical to the parent.

## Respiration

Oxygen is the gas in the air that we all breathe in to keep us alive. If we stop breathing or oxygen is not able to get around our bodies we can die within minutes! We and most other living things need oxygen to use as a raw material for **respiration** – the chemical process that goes on all the time in our bodies to change food into energy. The chemical equation for **aerobic respiration** (using oxygen) is as follows:

*Aerobic Respiration*

food (sugar) + oxygen ⟶ carbon dioxide + water + energy

$$C_6H_{12}O_6 + 6O_2 \longrightarrow 6CO_2 + 6H_2O + \text{energy}$$


*Figure 1.16 Drinks made by fermentation*

However, some micro-organisms do not need oxygen at all and can live in water, mud or even inside our intestines – all places where no air can get. These micro-organisms are often bacteria and fungi and because they live without air they are called **anaerobic**. The reason that they are able to stay alive in conditions which would kill us very quickly is that they use a different chemical reaction to produce their energy. The chemical equation for **anaerobic respiration** is:

*Anaerobic respiration (micro-organisms)*

food (sugar) ⟶ alcohol + carbon dioxide + energy

$$C_6H_{12}O_6 \longrightarrow 2C_2H_5OH + 2CO_2 + \text{energy}$$

If you have studied the two equations carefully you will have already realised that a very important product of anaerobic respiration is alcohol. Although anaerobic respiration is less efficient and does not produce so much energy, it is a process that humans have found to be very useful.

| Source of sugar | Drink produced |
|---|---|
| apples | cider |
| barley | whisky |
| ginger | ginger beer |
| grain | vodka |
| grapes | wine |
| hops | beer |
| molasses | rum |
| potato | aquavit |
| rice | sake |

*Figure 1.17 Example of fermented drinks*

## Fermented drinks

The alcohol that anaerobic respiration produces can be used in many kinds of drinks. It is possible to control the flavour and other characteristics of the alcoholic drink that is produced by choosing a particular kind of sugar from a certain type of plant, or by choosing a particular type of micro-organism (see Figure 1.17).

The name **fermentation** (*fa'amafu*) is given to all these changes which involve anaerobic respiration. Fermentation is obviously very important in the brewing industry which produces wine, beer and spirits but it is also an important stage in the production of tea leaves, silage and bread.

When the product is going to be a drink for sale it is important that the correct micro-organism starts the fermentation process and that no foreign bacteria or fungi get into the brew. For example wine will quickly change into vinegar if certain bacteria, called *Bacillus aceti*, get into the container where the grapes are fermenting. These bacteria change the alcohol into sour-tasting acetic acid. You may have recognised the smell of rotting fruit as 'alcoholic' but many different types of bacteria in such an uncontrolled environment means that much of the alcohol is changed to a variety of other unpleasant chemicals. However the quotation below shows that alcohol is found in the decaying fruit that some birds (like the New Zealand tui) like to feed on.

> *Just like the drunken humans, a tui in the same state draws attention to itself – especially when it hangs upside down from branches, chortling loudly! This type of uncoordinated behaviour has been put down to the fermented nectar that the birds had eaten. During hot summers it is common for sugary nectar in flowers such as pohutukawa to produce enough alcohol to affect nectar-eating birds such as tui, kaka and bellbirds.*

# Investigation into the growth, respiration or reproduction of bacteria or fungi

Investigations can involve research, practical work or design of your own investigations.

**Design type investigation**

## Activity 2 What conditions do bacteria prefer?

Your group is to design and carry out an experiment to do one of the following:

1 **Temperature conditions**

Study the effect of different temperature conditions on the growth of bacteria. This will involve putting petri dishes containing bacterial colonies in a wide range of temperature conditions (e.g. from in the freezer to over 70°C if possible).

2 **Nutrient preferences**

Study the effect of different nutrients on the growth of bacteria. A wide range of nutrients (foods) can be tested by boiling a standard amount of a food with agar and letting it cool and set in a petri dish.

Nutrients you could choose include liquid from small samples of vegetables, fruits, meat, Marmite, etc. Don't forget to try agar without nutrients.

**Hints**

You must plan your experiment carefully. Work out and record what gear you need, what things you must do and how to record your results.

For the nutrients experiment the petri dishes with different nutrients will need to be prepared first.

**Take Care**

There is a danger that you could culture harmful pathogens unless you follow the correct routines and always keep conditions sterile.

### *Subculturing*

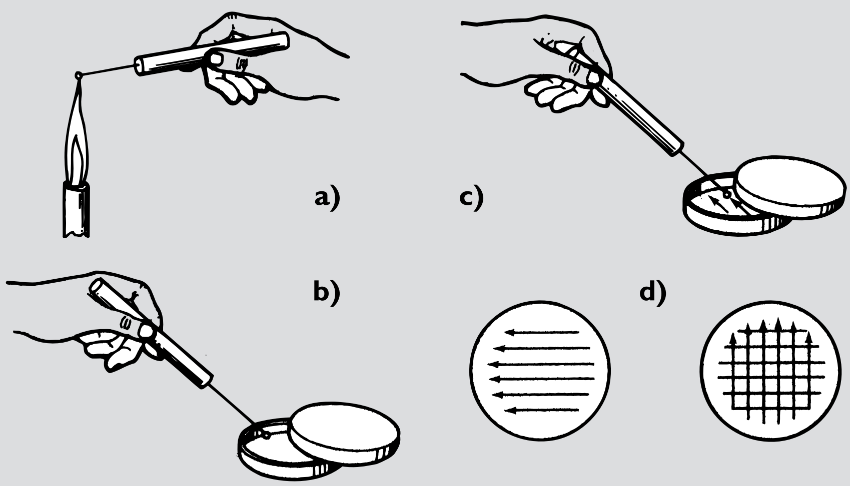
Whichever experiment you do you will need to know how to *subculture* bacteria. Subculturing is when you inoculate your prepared petri dishes with bacteria from your original colonies. It is done as shown in the diagrams.

**a** Sterilise the wire loop by passing it through a flame.

**b** When the loop is cool, touch a bacterial colony with it.

**c** Raise the lid of each petri dish just enough to gently sweep the loop across the surface of the agar. Streak it several times, first one way then at right angles.

**d** Colonies should now be spread over the agar and the petri dishes are ready to be used in your experiment.



**Materials:**

- 2 boiling tubes
- Stoppers
- Length of plastic tubing
- Olive oil
- Strong glucose solution
- Limewater
- Samples of at least three brands of yeast
- Made-up solution of dilute sulphuric acid (50 ml) and potassium dichromate (2 g)
- Balance
- Warming cupboard or incubator
- Watch

## Activity 3 Experiments on anaerobic respiration

Your group is to design experiments to answer one or more of the following questions. Using only the equipment listed you have to:

- ❑ Design the experiment (sketch the way you set up the apparatus and list what you will do).
- ❑ Carry the experiment out and note your results.

1 **Carbon dioxide**

How can we show that yeast feeding on glucose sugar is carrying out anaerobic respiration?

CLUE: A sure sign that respiration is going on is the release of carbon dioxide. If it is being released even though no oxygen is present then it is likely to be anaerobic respiration.

2 **Alcohol**

How can we show that alcohol is produced by fermenting yeast?

CLUE: A dilute solution of sulphuric acid and potassium dichromate is an indicator of alcohol. It will turn from orange to green when heated if alcohol has been formed. (Careful – because both acid and alcohol must be heated very gently and carefully.) Don't forget about controls!

3 **Quality control in yeast**

How can we test the rate of fermentation in different brands of yeast?

CLUE: Your teacher may be able to supply several brands of yeast. Some brands may work more quickly than others.

**Practical work**

**Materials:**

- 250 ml conical flask
- Molasses
- Water
- Cotton wool
- Dry yeast
- Incubator

## Activity 4 Growing yeast cells

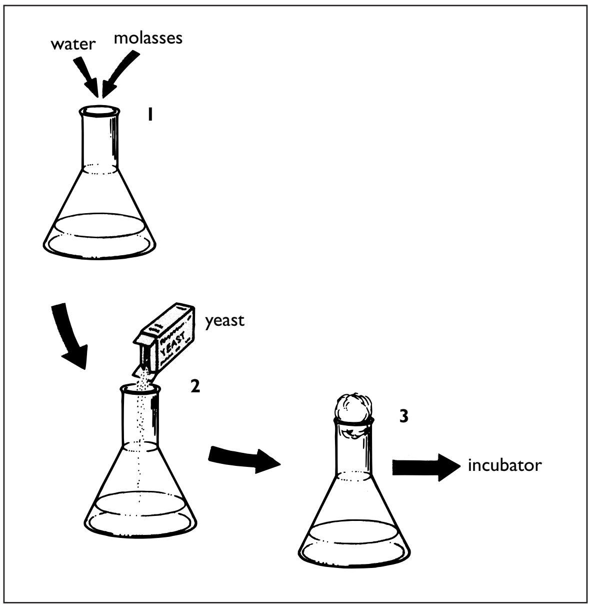
Here is how to grow yeast cells.

1 Mix 50 ml of molasses with 50 ml of water in a 250 ml conical flask.

2 Add a few grains of dry active yeast and plug the flask with cotton wool.

3 Label the flask with your name and the date then place the flask in an incubator at 30°C.

4 Observe the flask each day for 5 days and record what you see.



**Research**

## *Bully beef and dehyd spud*

Ask your grandparents and you may find that this was once a meal that was quite common. In order to stop the food from going bad it had to be *preserved*. In the case of the 'bully beef' this meant soaking the beef (meat from cattle) in salt water (brine), cooking it then putting this corned beef into an airtight tin. For the 'dehyd spud' it meant drying the potato out (dehydrating it) and turning it into flakes which were later mixed with water again before eating.

**Basic Facts**

1. Without heat or moisture bacteria will not grow.
2. It is possible to sterilise food (killing any bacteria) then seal the food from contact with any more bacteria. This is what is done with all tinned meat and pet food in tins.
3. Certain chemicals can be added to foods to stop bacteria in them from growing.

## Fruit juice


Fruit juices like these contain no preservatives. Before the juice was packaged it was sterilised by heating to 75°C. When full, the package was sealed so that no bacteria could get in. While unopened the juice can remain on a shelf for years. Once opened, bacteria in the air can get in and grow on the juice, so you must keep a container of juice that has been opened in a refrigerator until it is used up.

# Preserving methods and their problems

Until very recently most food has been preserved from bacterial attack in one of the following ways, each of which has some problems:

**Chemical preservatives**

Certain chemicals, such as sulphur dioxide ($SO_2$), can be added to food to kill any bacteria in them, thus making the food last longer. However, in recent years research has suggested that preservatives, and other chemicals added to foods to give them colour and flavour, are bad for the body and may have serious effects on children's behaviour. That is why many people do not want food with preservatives and demand labels on packaged food to show which have preservatives and which do not.

**Heating**

If living material is heated to above 50°C the chemicals inside the cells begin to break down. As living material begins to boil, steam inside the cells bursts them open and so the form and texture of the food substances change. The result of being cooked is a change to a soft, mushy texture which lacks a lot of the goodness of fresh food.

### Freezing

During normal freezing tiny crystals of ice break open the cells, changing the texture of the food. For example, when a crisp fruit or vegetable is frozen then thawed it becomes soft and mushy.

## High-tech preserving by freeze-drying

The problems with the commonly used preserving methods mean that many people are trying to find ways to preserve food without adding anything, but at the same time to keep the original structure and chemical composition of the food.

One process used widely to achieve this standard of preservation for both food and non-food materials is freeze-drying. Many freeze-dried foods are dry and hard and inside specially sealed packets – Maggi soups, noodles, instant coffee, herb powders and vegetables are a few common examples. They last for a very long time without bacteria getting a chance to grow on them and decompose them. Yet they have not been cooked, they are not frozen and they contain no preservatives.

They have been preserved because almost 98 per cent of the water inside the food material has been very quickly removed without doing any damage to the chemical structure of the food.

This is done by placing the food in a freezer at a temperature of -30°C and at the same time creating a vacuum around the food – the equivalent to being 100 kilometres out in space! Any water is sucked out of the food and immediately condenses on refrigerated coils to form ice. The frozen water can't get back into the food, which is removed from the drier before the ice can melt.

The flavour, colour and form of the freeze dried food is the same but because it contains no water, bacteria cannot live in or on it. If it is sealed in foil or plastic no air can get in and the food will now last for a very long time.

## Food preservation technology

The technology of food preservation involves finding ways to stop bacteria from growing in the food so that the food will last for a long time and still remain edible. Some methods of preserving are very old, and have been used successfully for centuries, while others are because of recent discoveries and inventions. They all rely on one or more of the Basic Facts listed on the previous page.

### Researching preserving

Food preserving is a major part of all of our lives. The following are some topics for research. Your group should choose one or more:

1. **Preservation methods**
   For each of the photographs on page 21 find out how the food has been preserved – write a statement using information from the Basic Facts box. Use the fruit juice example as a model.
2. **Fresh and preserved food**
   People in Sāmoa often use both fresh and preserved foods. Find out how these foods are kept safe for people to eat. What preservation methods are used? How is fresh food looked after? How do the methods used reduce the chance of bacteria and fungi growth?
3. **Milk preserving**
   Milk can be bought from the supermarket in several different forms each of which has been processed to help it to keep longer. Your task is to find out about each of the milks – powdered, long-life, condensed, pasteurised.

Research how it has been processed, then compare the advantages and disadvantages of each type of milk including facts and opinions about taste, shelf-life, the technology required, costs and the popularity.

4 **Shipboard food**
At the time of Captain Cook and earlier, sailors who were at sea for months had major problems with food and related health problems like scurvy. Find out about their food, how it was preserved and why there were health problems.


*Figure 1.18 Methods of preservation*

## Helpful bacteria and fungi

### Decomposition and recycling

The role that bacteria play in breaking down organic matter is huge. Sometimes this role is helpful to humans and sometimes it is not. The following examples show how useful bacteria can be, and also what can happen if things go wrong.

### Cleaning up our wastes

Anyone care for a ride around the oxidation ponds at a sewage works? Well as you can see in the photograph people actually do it! Of course it is not usually done for pleasure – it is part of the scientists' work in trying to stop the wrong sort of micro-organisms from growing in the water.

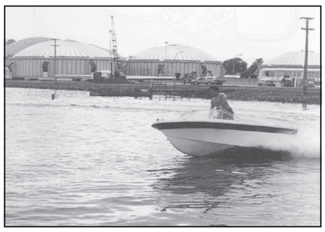


*Figure 1.19 Oxidation pond being stirred up by a boat in order to increase the oxygen in the water*

The scientists are actually trying to get more oxygen into the water. A shortage of oxygen means that anaerobic bacteria will thrive. They tend to produce unpleasant smelling chemicals as they respire. Too many anaerobic bacteria means that winds will blow smelly gases towards people living nearby.

If plenty of oxygen is present then aerobic bacteria will thrive. The right sort of bacteria will feed on the dirty waste from houses and factories and change it into clean treated water. Bacteria that live in the oxidation ponds and sludge lagoons shown in the diagram on the next page do just that – and more.

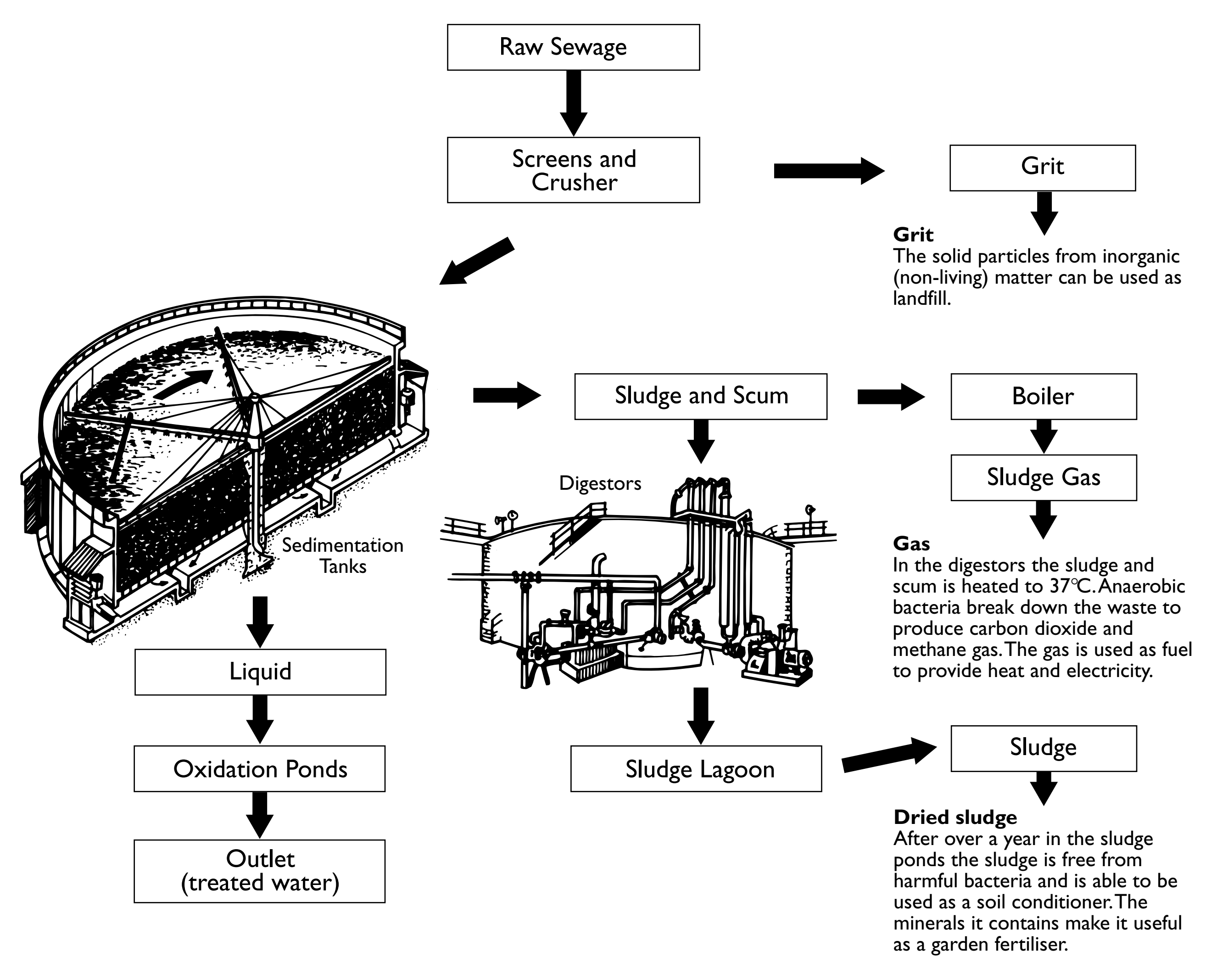



*Figure 1.20 Flow diagram of sewage treatment plant*

## The milky way

When a dairy company emptied fresh milk into the Waipa River in New Zealand they did not mean to kill all the fish. Yet that is exactly what happened, and the reason for the deaths in the river is **BOD – biological oxygen demand**.

*Figure 1.21 Plastic Media. The secondary sedimentation tanks are filled with these little objects. They provide a very large surface area on which bacteria can grow*

Most living things need oxygen to stay alive. Animals that live in water (fish) absorb oxygen that is dissolved in water through their skin or through special parts of their body called gills. The oxygen in the Waipa River that the aquatic animals use is quickly replaced and the water remains fresh. The large volume of milk (10 000 litres) became the food for a huge population of micro-organisms, particularly bacteria. As these bacteria fed and grew, they produced more and more bacteria. More and more oxygen was used by the bacteria until there was no oxygen at all left in the water. This is why the fish died.

The biological oxygen demand is the amount of oxygen being used up by the living things in an area of water. The greater the BOD the more risk there is of some sensitive plants or animals dying, just as the fish did in the Waipa.

### Recycling nutrients

As plants grow they take the substances that they need for their development (nutrients) from the soil through their roots. The soil would quickly run out of essential nutrients if the nutrients were not replaced. The nitrogen cycle is an example of how the main nutrient, nitrogen, is being replaced all the time. It relies on the action of decomposer micro-organisms and is explained in detail on page 25.

### Compost

While soil micro-organisms break down most dead organic matter in nature, humans like to help the process along with farming and gardening. The dark organic material in soil, produced by the rotting of vegetable or animal matter is called **humus**. We can speed up the process of rotting dead plant matter into rich humus by setting up conditions in which the decomposing micro-organisms operate best. A well organised compost bin can produce rich humus in six weeks or even less.

What are the best conditions for decomposers? Most important is the need for respiration to be aerobic because this is many times more efficient than anaerobic. So there must be plenty of air around the decomposing matter. That is why people who make compost 'air' it or dig up the matter they buried to decompose. Of course there must also be plenty of the soil-living decomposers around – including earthworms as well as micro-organisms. They all grow faster if it is not too cold and they need moist but not soggy conditions.

## Activity 5  Testing the conditions

What are the best conditions for decomposers?

Your group is to design an experiment to test one of the conditions that you think are important for leaves to be broken down. If you have time your teacher may ask you to do the experiment.

The following hints will help you:

**1** At least four of the main conditions needed are mentioned in the above paragraph on compost. Others are shown in Activity 6 – The perfect compost bin. Choose one, or you may also like to test other conditions that you feel might be important.

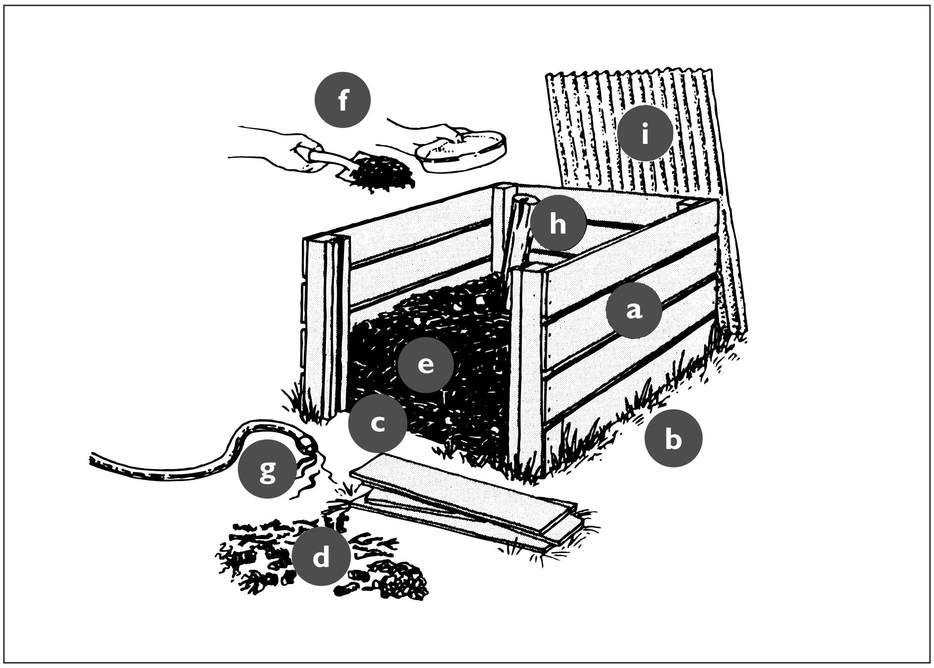
**2** Remember the importance of controls for comparisons.

**3** You will need to put the leaves in some type of container and control the conditions that they are in.

# Activity 6 The perfect compost bin

Nobody knows all the answers for perfect composting, but the diagram shows what a very successful compost maker might do.

**1** Explain how each of the points listed below may help to make good compost quickly.




**a** Bin made of timber with gaps between.
**b** Total area of bin no more than one square metre.
**c** Compost directly on the soil.
**d** Compost material well chopped up first.
**e** Layers of stems between layers of leafy matter.
**f** Handfuls of old compost and lime added.
**g** Watered as heap built up.
**h** Large stake through the middle – pulled out when complete to let air in.
**i** Lid put over the top.
**j** After several weeks the heap is turned and rebuilt.

**2** After a few days the compost in the bin shown had become too hot to put your hand into the middle. There was a little smell at first but it did not last long. After two months it had all broken down. Even the seeds of weeds that had been thrown on were dead.

**a** Explain why it got hot.
**b** Why did it smell at first?
**c** Explain how the seeds had been destroyed.

## Nitrogen collectors

Some of the most important bacteria live in soil. There are large numbers of them. There are probably as many as 10 000 000 in just one handful of soil. Without soil bacteria most plants would not grow successfully. The vital role of bacteria in breaking down dead plants and animals is shown in Figure 1.22 below.

The nitrogen that decomposing bacteria release from dead matter is essential for plants to grow. Bacteria feed on dead plants and animals and break down the complex proteins into simple nitrate ions that plants can absorb through their roots. Different bacteria are involved in different stages of the breakdown of organic matter. This is what is going on when compost is being made. The faster the decay the hotter the compost!

Certain plants called legumes (peas, beans, lupins, clover) are particularly useful because their roots have nodules that contain bacteria called *nitrogen fixers*. These bacteria are able to absorb nitrogen directly from the air and make it available to plants. This makes such plants especially valuable.

Scientists are now trying to improve the ability of plants to obtain nitrogen by finding ways of adding nitrogen-fixing bacteria such as *Rhizobium* to the roots of plants. It is now possible to inoculate some seeds with *Rhizobium* bacteria. Scientists are also trying to manipulate the genes of some bacteria to make them more efficient nitrogen fixers.

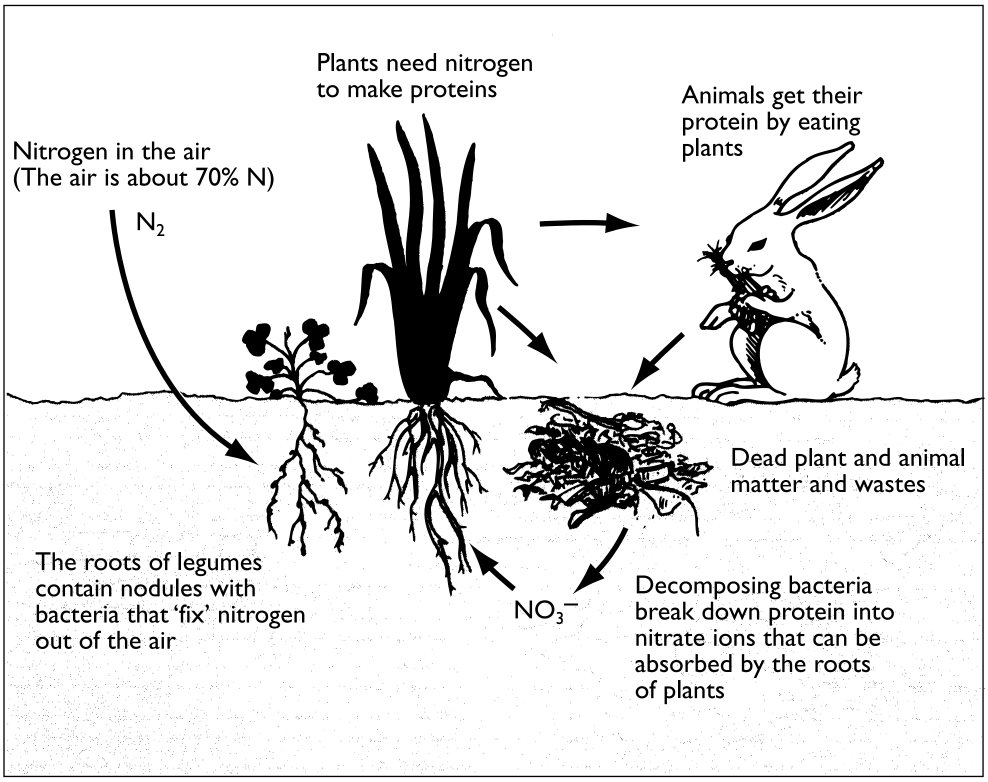



*Figure 1.22 The nitrogen cycle*

## Cellulose digesting bacteria

Cattle are an example of herbivores (animals that feed on plants) that have cellulose-digesting bacteria in their digestive systems. Cellulose is the tough cell wall of plant cells. Without these bacteria, the cattle cannot digest the cellulose.

## Biotechnology

Humans have found many ways of using micro-organisms to produce foodstuffs, better crops, medical drugs and consumer products. This use of micro-organisms for human ends is called **biotechnology**.

Yoghurt bacteria convert lactose sugar in milk into lactic acid. The lactic acid solidifies the milk into yoghurt. Other bacteria are used to curdle milk for cheese making. Pharmaceutical companies use **genetically engineered** bacteria to produce chemicals for medical drugs. Special bacteria produce insulin which is used by diabetics to control their blood sugar levels.

Yeasts are an important group of fungi that convert sugar into carbon dioxide and alcohol by **fermentation** (a form of anaerobic respiration). These micro-organisms are used to make bread rise and to ferment beer and wine (see page 9). Other fungi produce chemicals called antibiotics that are used to fight bacterial infections.

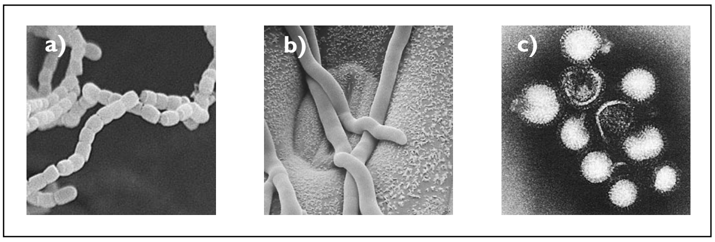
Some viruses are used to control pest organisms, e.g. calicivirus (RCD) has been introduced into New Zealand to control rabbit populations. This use of micro-organisms to control pests is called **biological control**.

## Revision

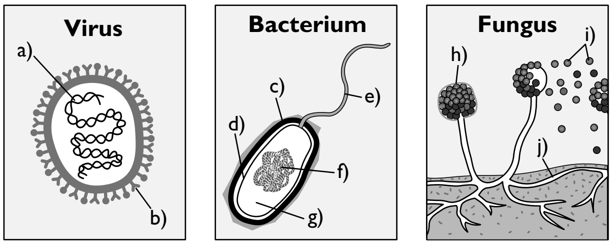
**1** Match up terms with definitions.

| Terms | Definitions |
|---|---|
| micro-organism | **a** micro-organisms made up of fine threads |
| bacteria | **b** the control centre of a cell containing chromosomes |
| cell nucleus | **c** a tough-walled resistant reproductive cell for dispersal |
| cytoplasm | **d** chemicals which break down large food molecules |
| cell membrane | **e** the production of multiple copies of a virus |
| pathogen | **f** the bulk of the cell where reactions of life occur |
| digestive enzymes | **g** an organism which feeds on dead organisms |
| binary fission | **h** fine threads of a fungus which invade the host |
| spore | **i** the part of the cell that encloses and controls entry and exit of chemicals |
| viruses | **j** micro-organisms which do not have a cell nucleus |
| replication | **k** 'non-living objects' which use cells to make new copies |
| fungi | **m** a disease-causing organism |
| saprophyte | **n** the process of splitting into two organisms through cell division |
| hyphae | **o** a very small organism visible under the microscope |

**2** Identify the following micro-organisms.




**3** Copy and label the three micro-organisms shown below. Choose from the terms in the box.




• cell wall • chromosome • genes • spores • cell membrane • cytoplasm • protein coat • hyphae • flagellum • spore case

**k** Which of the three objects are considered to be alive?

**l** What activity do all three objects carry out?

**m** Why are these objects called micro-organisms?

**4** Decide whether the following statements are true or false. Rewrite the false ones to make them correct.

**a** You always need a microscope to see a micro-organism.

**b** Unicellular organisms consist of one cell only, but multicellular organisms are made of many cells.

**c** Bacteria, fungi and viruses are all living organisms.

**d** Bacteria can be both helpful and harmful to humans.

**e** The genes of a bacteria are found on a single chromosome floating in the cell cytoplasm.

**f** Organisms which live on dead bodies are called pathogens.

**g** Bacteria and fungi carry out digestion of food outside of their bodies.

**h** Spores are usually a form of sexual reproduction.

**i** Viruses take over living cells and make the cells produce new viruses.

**j** Both bacteria and fungi play important roles as decomposers.

**5** Copy and complete the following paragraphs using the words in the box below.

**a** Most bacteria are ________ as they are unable to make their own food. Bacteria digest their food by releasing digestive ________ . Those which live on and feed off larger organisms are called ________. Many bacteria cause disease and are ________ .

**b** Fungi are ________ like plants, but are unable to make their own ________. Fungi which feed on dead matter are ________, others are parasites. Fungi ________ their food externally.

**c** Viruses do not feed; they can only ________ using living ________ which they invade. All viruses are ________ as they damage hosts.

• cells • consumers • digest • enzymes • food • immobile • parasites • pathogens • reproduce • saprophytes • pathogens

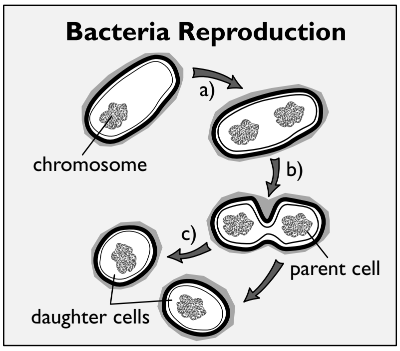
**6** Describe events **a**) to **c**) in the diagram.

**d** What is this form of reproduction called?

**e** Is it sexual or asexual?

**f** What is the advantage?

**g** What is the limitation?




**7** Describe events **a**) to **d**) in the diagram.

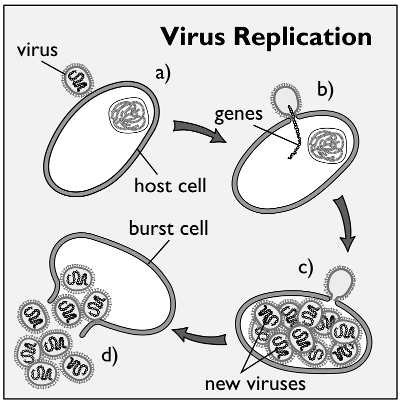
**e** What is this form of reproduction called?

**f** Can viruses reproduce independently?

**g** How do viruses use their host cells?

**h** How do new forms of viruses arise?

**i** Why are viruses always pathogens?



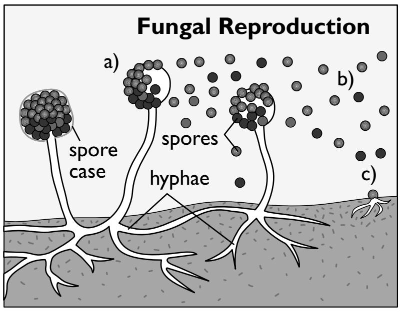

**8** Describe events **a**) to **c**) in the diagram.

**d** What is special about spores?

**e** How are spores spread?

**f** What happens to the spores?

**g** Is reproduction sexual or asexual?



**9** Write a short paragraph on each of the following topics:

**a** Fungi – Neither Plants nor Animals.

**b** Viruses – Living or Non-Living?

**c** Bacteria Lifestyles – Parasites, Pathogens or Saprophytes.

**10** Describe the differences between the terms:

**a** unicellular and multicellular

**b** internal and external digestion

**c** inoculation and incubation.

**11** Read the passage below, then answer the questions that follow.

## Bird flu virus threat

Scientists are concerned that the bird flu virus, which first appeared in Hong Kong in 1997, could turn into an epidemic which would rapidly spread across the world. Hundreds of millions of people could be infected within months.

Flu viruses cause the illness influenza. Most flu virus strains produce a relatively harmless infection, but some strains have devastating effects on young and old people as well as those in poor health. In 1918 the Spanish influenza virus killed somewhere between 20 and 40 million people. In 1957 the Asian flu killed over a million people.

The bird flu virus is unusual because it appears to have crossed the species barrier. Somehow the virus has been transferred from its original bird hosts to human beings.

Initially about a quarter of the 17 people identified as having the virus died. This indicated it was a very virulent strain. So far there has been no evidence of person-to-person transmission of the virus, which would be serious if it began to occur. All patients appear to have caught the virus directly from birds or bird products. Hong Kong slaughtered over a million chickens in an attempt to rid itself of the deadly virus.

Scientists have isolated the virus and are attempting to modify it to produce a vaccine. The vaccine would contain a weakened form of the virus, which would provide resistance to infection.

**a** What is meant by the term 'epidemic'?

**b** Why are flu viruses usually able to spread so rapidly around the globe?

**c** What are the typical symptoms of the flu?

**d** Why is the 'bird flu' virus unusual?

**e** How could the virus have been transferred from birds to humans?

**f** What would the virus do once it had entered a human cell?

**g** Why is the 'bird flu' virus considered to be a virulent strain?

**h** What was the 'good news' about the 'bird flu' virus?

**i** How does a vaccine help give people immunity to a virus?

# Harmful Micro-Organisms

In this section you should learn to:

- ❑ **describe** examples of harmful micro-organisms
- ❑ **describe** common diseases caused by viruses, bacteria and fungi
- ❑ **investigate** a pathogenic disease that occurs in Sāmoa.

Micro-organisms cause harm by damaging crops, timber, food and fabrics and causing diseases. Viruses cause diseases such as colds and flu. They also cause serious illnesses such as polio, hepatitis B and AIDS. Food poisoning is another common problem caused by bacteria.

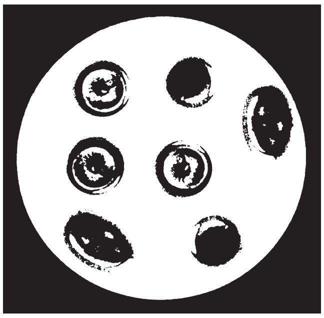


*Figure 1.23 Colonies of* Salmonella *bacteria (x6)*

## *Meet the enemy*

One of the most common causes of food poisoning is the bacterium *Salmonella*. The disease that it causes is called '*salmonellosis*' which usually gives rise to violent vomiting, diarrhoea, abdominal pain and flu-like symptoms 12 to 36 hours after eating the contaminated food. The bacteria can get onto food from dirty cutlery or dishes, unclean work areas, unwashed hands or rats and flies. One of the problems with *Salmonella* bacteria is that they may infect animals that we eat for food, including poultry and their eggs, cattle, pigs and sheep. In some cases infected hens will lay eggs in which the yolk and white inside the shell are contaminated with the bacteria.

Healthy food gives our body a balanced diet and builds up immunity to disease. However even more important than the type of food we eat is to make sure that we do not get poisoned by eating food that contains harmful bacteria.

**But is it safe to eat?**

Healthy food is safe to eat when it has been stored, handled and served carefully and does not have harmful bacteria living in it. Food which has bacteria living in it is said to be *contaminated*. It is very important *not* to eat contaminated food because it can result in poisoning which can make you very ill. You can't always tell by looking at food whether it has bacteria in it so you have to treat all food carefully. Fortunately there are many things we can do to help protect us from food poisoning. Each precaution mentioned in the boxes on the next page is based on one or more of the following scientific facts:

**a** Keeping the bacteria that are all around us away from the food that we are going to eat will stop them from causing food poisoning.

Bacteria can be passed from one thing to another by touch so it is important to make sure that anything that touches food is very clean. Being hygienic means making sure that your hands, all equipment such as knives and spoons and any bench tops on which the food is placed have no harmful bacteria living on them.

**b** Eating food while it is fresh means bacteria do not have a chance to grow on it and contaminate the food.

Bacteria will grow rapidly when the conditions are suitable. They can double their numbers every 20 minutes thus contaminating food in a very short time.

**c** Stopping any bacteria that might get onto the food from growing will prevent them from doing any harm.

Bacteria cannot grow in cold or dry places, although they will stay alive. To actually kill bacteria and sterilise the food you have to boil it or add special chemicals called preservatives.

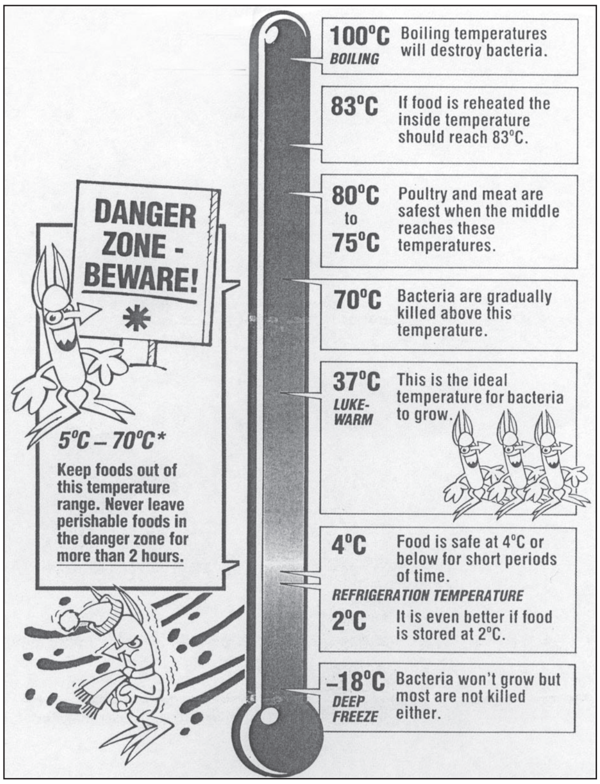



*Figure 1.24 Temperatures at which it is safe to keep food*

## Activity 7 Hygiene awareness

**1 Hygiene awareness survey**

Each group should prepare a survey as follows:

**a** Within your group, each person should choose one of the five sets of instructions on page 32.

**b** Prepare a questionnaire to find out how carefully people treat food. Do this by changing each instruction in the box into a question.

**c** Each member of the group should give the questionnaire to at least three people (try parents, neighbours, people you know who work with food).

**d** Make a group summary of the answers you give to all the questionnaires.

**e** From your results identify the most common things people do when working with food that you consider unhealthy.

**f** Prepare a group report to the class. Be as creative as possible in your presentation.

**2 Healthy food poster**

Your teacher will give you one of the set of instructions for keeping food healthy. Your task is to present it as a poster with additional information about the scientific reason for each instruction and appropriate illustrations.

**3 Bacteria and food poisoning**

Read the following information about what happened with listeria poisoning in New Zealand. Discuss the consequences for the people involved.

### Manslaughter charge follows listeria poisoning

Two directors of a shellfish processing factory will be charged with manslaughter following the death of newborn twins from the bacterial infection listeriosis.

The twins' mother had eaten shellfish processed in the South Island factory while she was pregnant. Police claimed that the infection, which caused the twins to die within half an hour of their birth, could be traced to the factory. Sophisticated testing of the shellfish from the factory showed the presence of listeria bacteria which do not usually cause serious infection in adults but which can cause death of the foetus or a miscarriage.

Health officials often warn pregnant women not to eat foods in which listeria is common, such as soft cheeses and pâté, and to reheat thoroughly cooked and chilled meats and ready-to-eat poultry.

The factory has been closed since the positive listeria tests were reported.

## Instructions for keeping food safe

**1 Buying food**

- ❑ Choose meat, fish and poultry from a fridge or freezer.
- ❑ Check the 'use-by' date and make sure that you will be able to finish the food before then.
- ❑ Buy cold food last and get it home quickly. Carry cold and frozen food in a carry icebox or wrapped in newspaper.
- ❑ Do not buy unpacked food that you have seen someone else touch.
- ❑ Make sure raw and cooked foods are packed in separate bags.

**2 Storing food**

- ❑ Put food away as soon as you arrive home.
- ❑ Store raw and cooked food separately.
- ❑ Place raw meats on the lowest shelf of the fridge so their juices will not drip onto other food.
- ❑ Make sure the refrigerator is cold enough – it should be below 4°C.
- ❑ Put leftover food into the refrigerator as soon as possible.
- ❑ Keep the refrigerator as clean as possible.

**3 Preparing food**

- ❑ Wash your hands before you start.
- ❑ Keep a hand towel in the kitchen so you don't wipe your hands on teatowels.
- ❑ People who are sick should stay out of the kitchen.
- ❑ Use clean knives, clean bench tops, clean cutting boards and clean utensils.
- ❑ Use different cutting boards for raw and cooked foods.
- ❑ Keep pets out of the kitchen.

**4 Cooking food**

- ❑ Thaw food completely before you cook it – in the fridge or microwave is best.
- ❑ Follow cooking times in reliable recipes.
- ❑ Cook food thoroughly – do not serve pink (half-cooked) poultry meat.
- ❑ Stir and rotate food in microwaves for even cooking.
- ❑ Cover food in microwaves so steam helps to cook.
- ❑ Leave microwave-cooked food to 'stand' after taking it out so it finishes cooking.
- ❑ Serve hot foods hot and cold food cold.

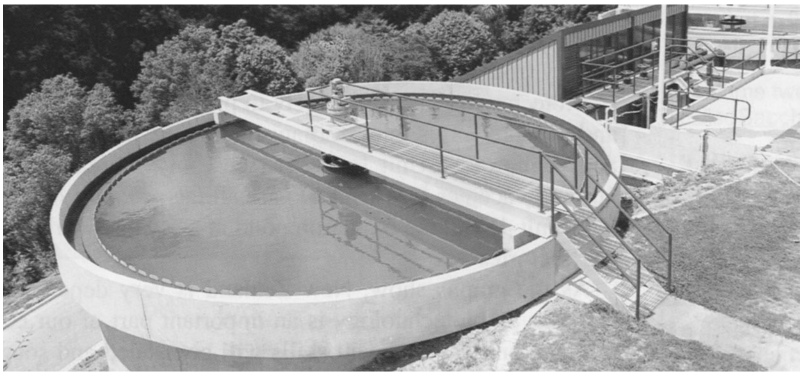
**5 Parties and picnics**

- ❑ Keep the number of cooks to a minimum.
- ❑ Keep food in the fridge until it is served – ask neighbours to let you use their fridge or store drinks in the laundry tub with ice to give you more room.
- ❑ When you reheat food make sure it is piping hot right through to the middle.
- ❑ Do not reheat foods more than once.
- ❑ Take food to picnics in carry iceboxes.
- ❑ Use canned food because this needs no preparation.

# Activity 8 Water safe to drink

Often water must be treated before it is safe to drink. The diagram below shows what happens in a typical water treatment station.

| RAW WATER from spring or dam | 1 DOSING | 2 SETTLING | 3 FILTERING | 4 CHEMICAL ADDITION | TREATED WATER to town or city |
|---|---|---|---|---|---|
| **ANALYSIS**<br>Coliform bacteria: 15 per 100 ml<br>Total organisms: 50 per 100 ml<br>pH: 7<br>Turbidity: 5 NTUs<br>Dissolved solids: 80ppm<br>Aluminium: 0ppm<br>Iron: 0.2ppm<br>Chlorine: 0ppm<br>Fluoride: 0ppm | Aluminium suplhate (alum) is added to gather together the organic matter in the water forming a sludge | The alum sludge settles allowing it to be removed from the water | The water flows through layers of sand to remove any floating particles | Fluoride ($F^+$) for dental health<br>Chlorine (Cl) keeps the water bacteria-free<br>Lime helps preserve the water pipes | **ANALYSIS**<br>Coliform bacteria: 0 per 100 ml<br>Total organisms: 2 per 100 ml<br>pH: 7.7<br>Turbidity: 0.3 NTUs<br>Dissolved solids: 90ppm<br>Aluminium: 0.04ppm<br>Iron: 0.05ppm<br>Chlorine: 0.2ppm<br>Fluorine: 1.0ppm |



Water Care Services

*Figure 1.25 Treatment of drinking water at a water filter station.*

Compare the analysis of the raw and treated water.

1 Describe the differences between raw and treated water.

2 Explain what has been done to cause the differences in the raw and treated water.

3 Find out how fresh water is supplied if there is a cyclone or flood.

4 Carry out research on your local water supply. What happens to make sure people have water that is safe to drink?

## Diseases

People have always suffered from diseases, but it is only in the last 130 years that we really know what makes us sick and why people die from some illnesses. Almost all diseases of plants, animals and human beings are caused by micro-organisms. The micro-organisms that cause disease are called **pathogens**. Until the 19th Century more people died inside hospitals from disease than were cured or treated by the doctors! Only as recently as the 1860s did the nurses and doctors working in hospitals realise that they were the ones who were spreading micro-organisms from their infected patients to the healthy ones. They then realised that it was important to keep hospitals as extra clean as possible, to sterilise surgical instruments, to use disposable gloves and gowns, to change patients' bandages often, and so on.

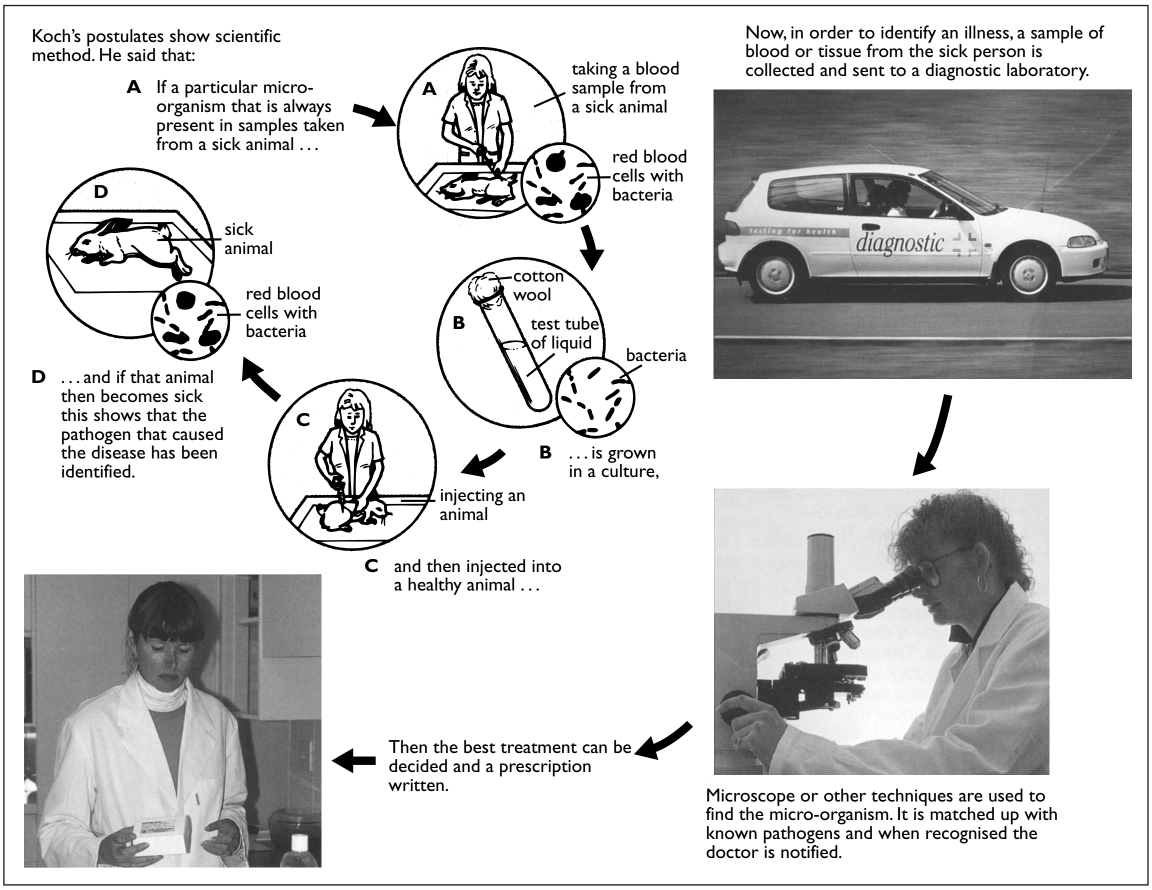



*Figure 1.26 Koch's postulates and modern diagnosis*

Today most of us know that the germs which make us sick are the tiny living things we have been calling micro-organisms. One of the first doctors to show that this was true was Robert Koch. His method was to first find the micro-organism by using a microscope to look at the blood of a sick animal, then to grow the micro-organism and inject it back into another animal to see if it became sick too. This is still the standard way to prove an organism causes a disease and is known as **Koch's postulates**.

When we get sick we usually assume that a doctor or specialist will be able to tell us what is wrong and how to get better. If the doctor is still unsure after having made a first hypothesis he or she may then need to follow Koch's postulates to find out for sure what the disease organism is. Figure 1.26 above shows this.

## Activity 9 Scientific methods in diagnosing illness

We use the methods of science all the time in everyday life. We use them when working out what is wrong when we feel ill. Read the following:

> When Sione woke up his head was throbbing and his throat felt raw. He coughed once and let out a groan as he rolled over. He was expecting his mother's usual warning about being late for school but this morning her voice softened when she heard Sione's croaky voice.
>
> 'It's the doctor for you this morning,' she said a few minutes later as she checked his temperature on the special clinical thermometer. Sione was glad to sip the glass of lemon-honey drink his mother had brought in but all he really wanted to do was to lie down again and sleep!

The things that you can see when you get sick are called symptoms.

> The doctor listened carefully as Sione told her how he felt. She told Sione she had a fair idea what was wrong with him but she just needed to check it out. The stethoscope was cold as she moved it to various places on his back. She waited while Sione coughed then asked him to take one more deep breath.
>
> 'It's a bit rattly in there,' she commented. If Sione hadn't been so fascinated with the little torch shining down his throat he would have heard the doctor asking him to open a little wider.
>
> 'That's better,' she said, adding to herself, 'Just as I thought.'
>
> Before Sione could ask what was wrong a thermometer was popped into his mouth and the doctor was gently pressing around his neck to feel for any swelling.

The doctor was really carrying out a scientific experiment with Sione. After listening to his symptoms she made up a hypothesis about what might be causing his illness. She then checked each of the things about her idea, from what she knew from her study at medical school, to see if they matched her hypothesis.

### Listing symptoms

**1** Make a list of all the symptoms Sione had and add at least two more that are not mentioned.

### Forming a hypothesis

**2** List each of the things the doctor checked on Sione and suggest what you think she was looking for.

> The doctor sat down and began writing on a little pad.
>
> 'This medicine will get you well again,' she explained, handing Sione the prescription for the chemist. 'You have bronchitis. There are a lot of bacteria living on the cells at the bottom of your throat and these have spread to the part of the lung called the bronchus, causing the bad cough. The poisons made by all those bacteria have spread around your body giving you the headache and the fever. Your body is trying to fight off the bacteria – that is why your glands are swollen – but if you take a 5 ml teaspoonful of this medicine three times a day until it is finished it should kill all the bacteria. If he is not better by then make sure you bring him back,' she added to Sione's mother as they left.

When the doctor had studied all the evidence she came to a conclusion about the cause of Sione's illness and was then able to give him the best treatment. She had obtained some data, formed a hypothesis, tested the hypothesis and came to a conclusion about what was the matter so she could decide how to treat it.

# Activity 10 Asking the right questions

Science involves obtaining accurate data, forming hypotheses and obtaining more data to confirm or reject the hypotheses. Medical diagnosis is an example of scientific method at work. Two important skills of the scientist are:

**a** knowing the right question to ask and

**b** recognising the useful answers. These skills are also important to the doctor.

In the activity below you will take turns at being the doctor and the patient and from the interview must try to find the right treatment. *Good luck!*

## 1 A pain in the chest

How good are you at obtaining and interpreting data? This game is designed to test your diagnostic skills. The patient's first statement is: 'Please Doctor, can you do something about this severe pain in my chest?' The doctor must diagnose the cause of the pain using as few questions as possible.

RULES

**a** The object of the game is to see who within the group can correctly diagnose the cause of the pain.

**b** Group members take it in turn to be the doctor, while the others are patients.

**c** Each patient chooses one of the six chest problems in the chart of symptoms opposite.

**d** The doctor questions each patient in turn about their symptoms (one group member recording the number of questions needed to get the right answer).

**e** The patient must answer each question truthfully using information from the chart. A little playacting is okay but extra symptoms cannot be added.

## 2 Other clues

The skilled doctor will have other information available to help with the diagnosis. Each of the following may be very useful: the patient's past medical record, the time of year, the type of health problems common in the district, the age of the patient.

For each of these clues discuss in your group why such information may be useful.

## 3 Confirming the diagnosis

Make a list of the technical tools that a doctor has that may be useful in confirming the diagnosis.

| Cause of Chest problems | Location | When pain occurs | Type of pain |
|---|---|---|---|
| Cracked rib | At a specific spot on one side of chest. | When breathing deeply, coughing or moving chest. Began after being hit by a hockey ball. | Very sharp at one precise spot – especially if chest is pushed. Bruise at site of pain. |
| Torn intercostal (between ribs) muscle | At a specific spot on one side of chest. | When breathing deeply or coughing. Began after trying to bowl a cricket ball extra fast. | Quite sharp. No bruising. |
| Shingles (virus infection) | In a narrow band along lower ribs at one side. Row of small red blisters. | All the time. Not affected by exercise. More painful when touched. | Acute pain and itching. |
| Pneumonia (bacterial infection of one lobe of lung) | Throughout one side of chest. | When breathing deeply or coughing. | Stabbing pain. Chills, high fever and coughing. |
| Angina (heart not receiving sufficient blood) | Middle of chest and up towards left shoulder and down arm. | Appears suddenly when exercising, and gets better after the exercise stops. | Deep heavy pain with nausea and feeling of pressure on chest. |
| Heartburn (acid liquid from stomach rising into oesophagus) | Middle of chest and up towards throat. | Appears after meals and when lying down. Coffee and alcohol make it worse. | Burning sensation. |

## Examples Of Pathogens

Our bodies are open to attack from many different pathogenic micro-organisms. They each have their own way of entering the body. They each attack it in different ways and cause different symptoms. There are far too many for us to examine them all, but we can get a good idea of what they are like and how they function and spread by looking more closely at a couple of examples – the common cold and meningitis.

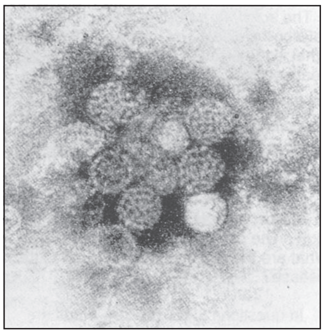


*Figure 1.27 Virus*

### The common cold – a familiar enemy

This is the one infection that we all suffer from and know well. Each person can expect to suffer two to three colds per year. When this is added up for the whole population the common cold can be blamed for many hours of lost work and much medical expense. Even though scientists have developed new treatments for many diseases, nobody has found a way to cure the common cold.

Acute coryza is the medical term for 'Cold in the head; an acute catarrhal inflammation of the nasal mucous membrane'. It is caused by any one of a group of 120 different types of virus. The thing the viruses have in common is that they all infect the cells that form the lining of the nose and throat in the area called the upper respiratory tract. The very sensitive cells in this part of our body react to the infection by swelling and by increasing the amount of mucus that they produce.

The common cold viral infection generally works like this:

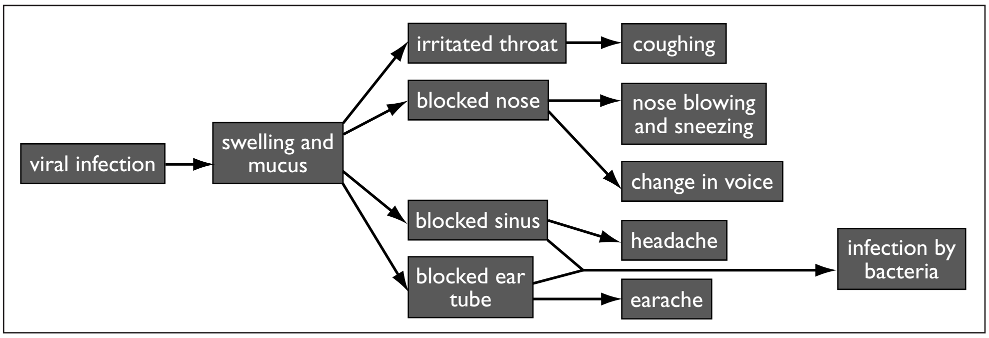



*Figure 1.28 Viral infection*

Cold symptoms can disappear within 2 or 3 days but unfortunately the irritated membranes of the nose and throat usually allow the entry of various bacteria which cause further symptoms and can lead to complications.

The fact that so many different viruses could be involved is the main reason why it has not been possible to develop a vaccine to prevent the common cold. So we have to put up with a few days of discomfort until our own immune system has managed to cope with the infection. This usually results in immunity to that virus for a few months.

## Activity 11 Testing the remedies

**1 Consumer report**

During the winter there are hundreds of advertisements for remedies for colds and flu. How effective are they? You are to do a consumer report on the claims of the various remedies.

**a** Bring to school as many different empty packets for remedies for cold and flu symptoms that you can. If you can't find any at home you could make a note of what is on the chemist's shelves.

**b** Draw up a chart, similar to the one below, with headings across the page.

**c** For each remedy, tick each column for the symptoms it claims to help.

**d** In the last column put comments from anyone who has used the remedy about how effective they found it.

**2 Designing a trial**

You will not be able to test all the cold remedies, but you can design a scientific way of testing some of them. Take one group, say sore throat remedies, or blocked nose remedies. Write down an outline of the way that a scientific test for their effectiveness could be done. Make sure that you mention the following: *design of the trial, numbers involved, controls, measuring results*.

| Remedy | Sore throat | Tickle or cough | Block throat | Headache | Fever | Cost | Effectiveness |
|---|---|---|---|---|---|---|---|
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |

## Meningitis – a killer at large

This is a serious disease. It attacks mostly small children – and perhaps 5 to 10 percent of these will die.

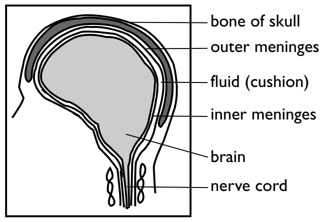



*Figure 1.29 The meninges*

### What is meningitis?

Meningitis is the name given to an inflammation of the 'meninges' or membranes that surround the brain and spinal cord. The meninges become infected by one of several types of bacteria or virus that reach them through the blood or lymph. The inflammation (swelling and other effects) happens when our immune system tries to deal with the invaders and their poisonous wastes. The fluid around the membranes becomes cloudy and contains many white blood cells as well as the pathogen.

### What causes meningitis?

Several kinds of micro-organisms can cause the symptoms of meningitis.

*Amoebic Meningitis* – This is very serious but fortunately very rare. It is caused by a tiny one-celled animal which lives in the water of hot springs. It enters the body through the mouth and nose openings. That is why people are often warned not to put their head under water when they swim in hot springs.

*Viral Meningitis* – This is more common and several types of virus may cause symptoms of meningitis. Viral meningitis tends to be not quite as severe as other forms and those infected usually survive.

*Bacterial Meningitis* – This is, at present, the most important type of meningitis. The most common culprit is a bacterium called *Haemophilus influenzae* Type b (often referred to as Hib). Recent epidemics have involved another bacterium called *Neisseria meningitidis*.

Pathogenic bacteria like these live as single cells and reproduce very quickly as each one divides into two. This means that a very large population of cells can grow in a very short time. As the cells grow they use the cells around them as food and at the same time make waste chemicals (toxins) that are poisonous to living cells.

### What are the symptoms of meningitis?

Meningitis is serious and if the symptoms shown here appear, you should get medical help fast.

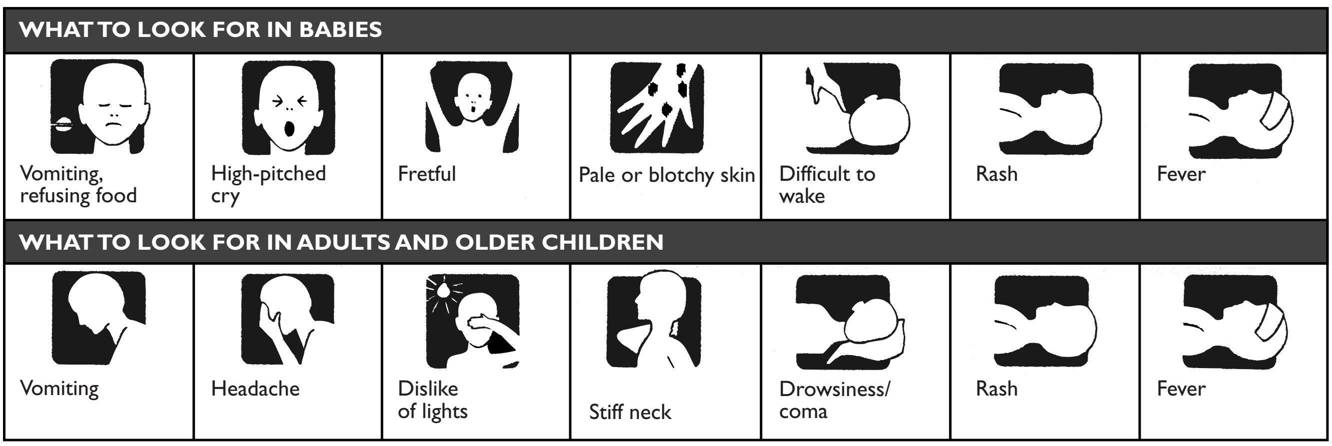



*Figure 1.30 Symptoms of meningitis*

## The life history of a meningitis epidemic

> The doctor quickly became concerned as he began his examination of the small child that had been brought into the clinic by his very worried mother. The child obviously had a fever and although limp was holding his head as if his neck was stiff. 'He seemed quite all right earlier this morning' the mother said. 'Then he began to vomit and he has been crying a lot and is so hot.' The doctor noticed some small purplish spots on the child's skin and immediately called his nurse. 'Please prepare an injection of cefotaxime then ring for an ambulance? I suspect this child has meningitis. He must be sent to the hospital urgently.'

This happened frequently in Auckland, New Zealand during the winter of 1986, and has also happened in the early 1990s. The child was showing symptoms of severe meningitis. His chances of survival were not good without rapid treatment.

### How it spreads

The meningococcal bacterium is present in a small number of people who are not affected by it but who are carriers. It is spread in the tiny droplets coughed or sneezed or even breathed into the air by carriers. Other people breathe it in and it enters the blood stream through the moist surfaces of the nose and throat.

Nobody knows exactly why an epidemic starts and some people suffer more from it than others but we know the following:

1. There seem to be some carriers at all times even when there is no epidemic present – perhaps as high as 5 percent of people. So the source of infection is always around.
2. It is more likely to spread among people in poor living conditions. If there is overcrowding in a house, there are many smokers and if the general health of the people is poor.
3. It spreads most when the climatic conditions are right. (In Auckland this seems to be winter and spring. However, it is not like that in other countries).
4. Some factor starts it off – it tends to develop when other infectious diseases of the respiratory system (flu, etc.) are common and many people are coughing and sneezing and have weakened membranes of the nose and throat.

### Treatment of meningitis

Usually the infection is so sudden and severe that the body's immune system has difficulty in dealing with it, and death is quite possible unless special hospital treatment is begun quickly. The patient should be kept in quiet, dark conditions. Patients are usually given a drip to supply fluids and antibacterial and anticonvulsant drugs. They are watched carefully for convulsions, low blood pressure and other problems. The disease is likely to be critical and speed of treatment is most important. If there are no complications the patient may be recovering within a week. Follow-up with hearing tests is important.

# Activity 12 Analysing an epidemic

**1 Diagnosing meningitis**

From the paragraph in the grey box on page 40, list the symptoms and signs that made the doctor suspect meningitis (there are at least five).

**2 Analysing the table**

*Table 1.1 Cases of meningitis (Group A) in Auckland 1985/6 (All figures are rate per 100 000)*

| Ethnic Group | All Ages | Under 5 Yrs Old | Under 15 Yrs Old | District | | |
|---|---|---|---|---|---|---|
| | | | | North | Central | South |
| European | 2.3 | 13.8 | 9.0 | 4.1 | 18.1 | 7.8 |
| Maori | 28.1 | 141.4 | 66.8 | 16.4 | 81.6 | 83.2 |
| Pacific Islander | 34.9 | 233.5 | 105.9 | 16.8 | 101.7 | 179.9 |
| Overall | 8.3 | 68.8 | 30.4 | 6.1 | 41.9 | 45.3 |

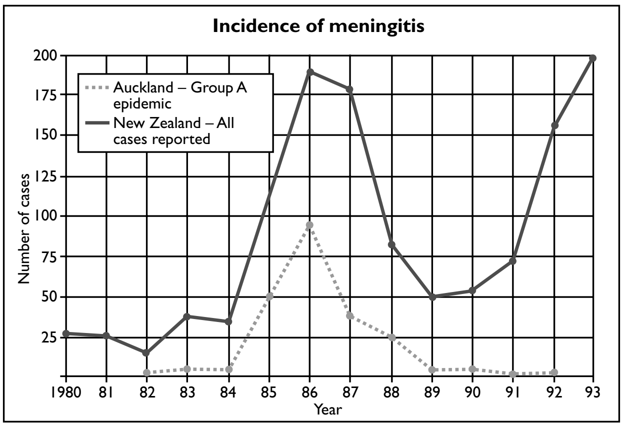
**a** From the table of meningitis cases identify the people and district which were most at risk.

**b** List reasons why this group may be most at risk.

**c** Explain why the figures are given as rate per 100 000 and not total numbers.

**3 Analysing the graph**

Study the graph below and describe the rate of meningitis in New Zealand apart from Auckland, for the 13 years shown.




**4 Publicity**

In your group prepare publicity material (a poster, outline of a TV ad, a notice to drop in letterboxes) warning people about the possibility of meningitis in the coming winter, and explaining what to do to avoid it.

## Return of the killer disease

In this age of extraordinary medical developments and high-technology research is it possible to completely eradicate a disease from our Earth so that nobody will ever get it again?

With the success of the World Health Organisation (WHO) in eliminating smallpox, and its progress with the control of poliomyelitis and other diseases it seemed a very realistic aim. But it may not be that easy, as the problems with TB (tuberculosis) show.

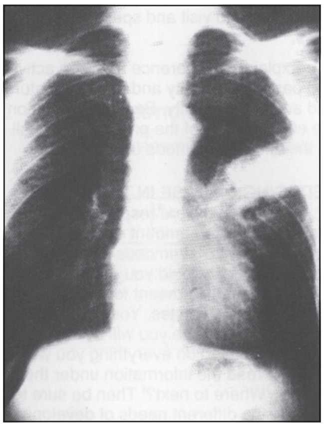


*Figure 1.31 Chest x-ray*

## TB

Tuberculosis (TB) is a disease in humans caused by the bacterium *Mycobacterium tuberculosis*. It attacks the membranes lining many of the organs of the body. Tuberculosis of the lungs is the most common form, destroying lung tissue and leaving 'cavities' that show up on x-rays as light patches. It is spread as droplets coughed up or spat out. It is particularly common in overcrowded areas. Treatment of TB is usually successful with the antibiotic streptomycin, although resistant strains are quite common. Until recently a vaccine known as BCG was made available to all children early in their third-form year. Because of this TB is now so rare that the vaccination programme has been stopped. BCG (Bacillus Calmette-Guerin), the most widely used vaccine in the world, contains live bacteria from cattle. These bacteria have been weakened in the laboratory until they are no longer able to cause disease. Once in the body BCG causes the production of antibodies to fight TB.

### The battle to eradicate tuberculosis

Look carefully at the graph of the number of cases of tuberculosis for New York City in the period 1920–1991. This is typical of campaigns to eliminate TB. It appeared to be on target until about 1980, but now the worldwide picture has changed and is quite a frightening one. One-third of the world's population is infected with the TB-causing bacteria. Not all of these people become sick with the disease, but TB does kill over 3 million people each year. Most important, this number is increasing.

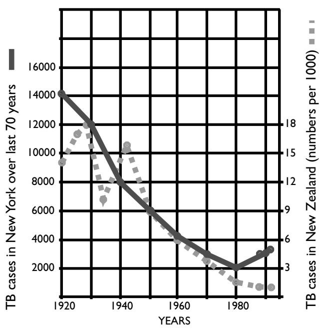



*Figure 1.32 TB cases in New Zealand compared to TB cases in New York*

Compare the figure for TB in New Zealand. TB rates here have levelled off also, and since 1989 they have actually been showing a slight rise. Some cases, but not all, have arrived from immigrants from poor parts of Asia.

Why has the battle against TB suddenly become less effective? The vaccination programme introduced in the 1950s was responsible for reducing the numbers of deaths to a very low level. However when a disease kills very few people, some people no longer bother about vaccinations because they think they are safe. This means that the number of unprotected people in the population increases and so the disease can begin to spread again.

Some people are now infected with a drug-resistant strain of TB. The strain of the disease is increasing because there is nothing to kill it or control its spread. A disease often becomes resistant when only one drug is used to treat it or the treatment is not finished by the patient. If this happens some of the bacteria will still be alive in the person's body even though he or she may feel well again. The bacteria that survive are the ones that have resisted the treatment and they then get passed on to other people. As more resistant bacteria appear in the population an epidemic can begin. This is what appears to be happening with TB.

Three things are very important in preventing the development of resistant strains of diseases:

1. As many people as possible taking part in vaccination programmes.
2. Training doctors to use the drugs in the best ways.
3. Making sure that if a doctor gives a patient medication the patient uses it in the correct way and does not stop taking it until it is finished.

## Activity 13 Disease research

Carry out research on the occurrence, effect and control of a pathogenic disease that occurs in Sāmoa.

## Methods Of Controlling And Curing Diseases

In this section you learn to:

- **investigate** the effectiveness of antiseptics, disinfectants or antibiotics
- **discuss** methods of controlling and curing diseases, e.g. antibiotics, vaccination, herbal
- **explain** the development of antibiotic resistance in pathogens and how it can be prevented
- **discuss** how the human body defends itself against pathogens
- **describe** the effect of HIV on the immune system.

As people have increased their knowledge of how diseases spread they have been able to develop effective methods to control them. The following seven points show how some diseases are spread:

1. Droplets in the air from a cough or sneeze, e.g. colds and flu.
2. Dust and particles in the air or on material, e.g. smallpox.
3. Touching the infected area on another person, e.g. impetigo (school sores), athlete's foot.
4. Animals (big and small) carrying the disease, e.g. ringworm (cats), malaria (mosquitoes), rabies (dogs).
5. Cuts and scratches from dirty objects, e.g. hepatitis (especially from used syringes), tetanus (often from rusty nails).
6. Eating food containing bacteria or fungi, e.g. salmonella (food poisoning).
7. Untreated sewage, e.g. typhoid (from human faeces).

## Activity 14 Medical history

Discuss how the procedures described in A, B, C and D in the box below have improved medical practice. Record your ideas.

### A. 17th Century

Hospitals were breeding grounds for the micro-organisms that cause disease (pathogens). New patients were often put into the dirty beds from which dead people had just been taken and rats and mice ran around everywhere.

### B. 1854

Florence Nightingale was sent to Turkey in the middle of the Crimean War. The conditions were terrible for both the soldiers and the doctors but Florence and her nurses cleaned toilets and scrubbed floors, sewed mattresses and washed the men and their clothes, setting an example of how cleanliness could help save lives.

### C. 1865

Joseph Lister prepared a report called 'The Antiseptic Principle in the Practice of Surgery', which explained the use of a chemical called carbolic acid as a *disinfectant*. This was sprayed on the patient's wound during the operation, reducing the surgical death rate from 50 percent to 10 percent. Hospitals became safer places to be in.

### D. 1929

Alexander Fleming was growing bacteria on plates of jelly. One night he accidentally left a dish uncovered. When he found it later there was a mould growing on the plate and his bacterial colonies had been killed. He took action at once to find the killer and discovered that the mould, called *Penicillium*, made a chemical called an antibiotic. Antibiotics made in laboratories are called penicillin.

## Our body's defence

With all the disease causing micro-organisms around, it is important for our bodies to have a range of defences against them.

### The first line of defence

In a military exercise guards are always placed at sites where they are in a position to attack any enemy who might get in. Our body's defences are like guards who stop an enemy getting into a fort. In our body's fight against disease the same sort of military strategy is used. The skin is a barrier (or wall) and all the entry points (ways in) are well guarded against micro-organisms. These main entry points for disease are the openings that lead to moist places where there are living cells, for example, the eyes and nose. Fluids such as tears, saliva and mucus protect the openings.

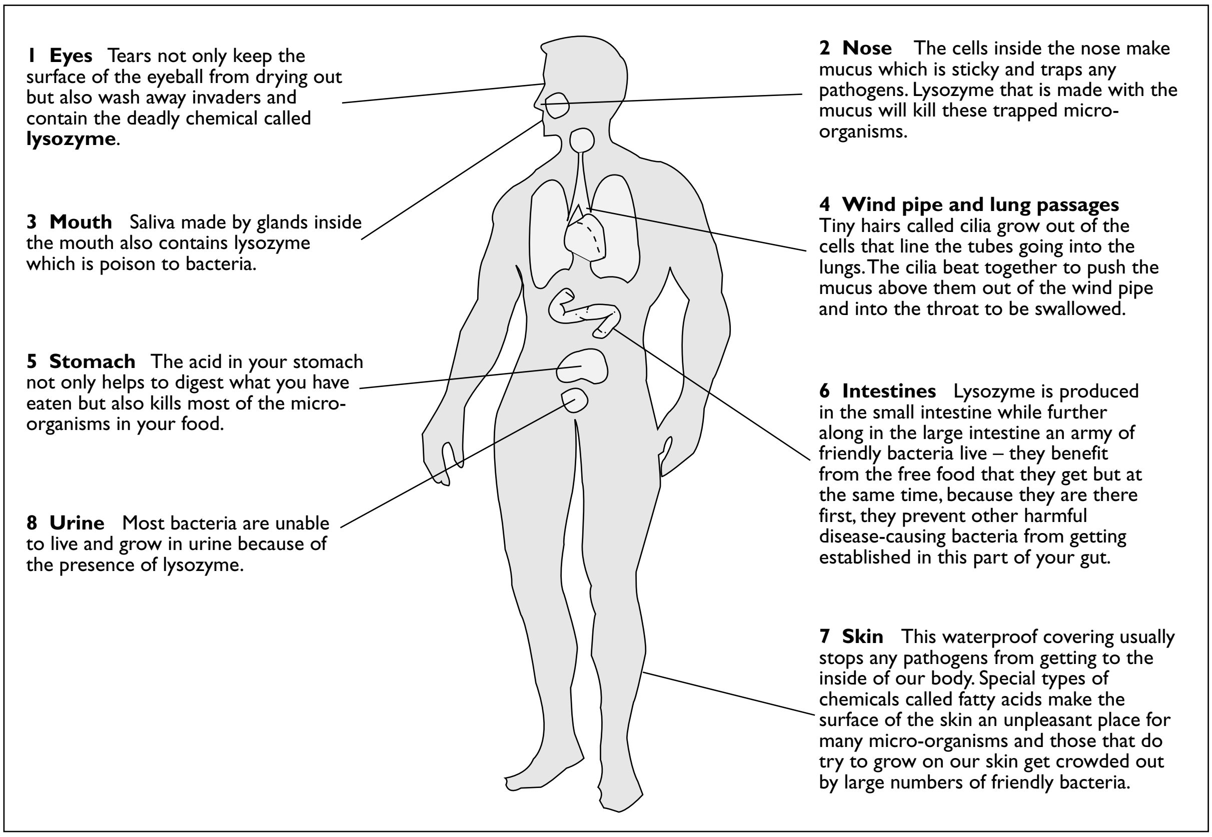



*Figure 1.33 The first line of defence*

## The second line of defence – our internal bodyguard

Any invading organisms that get through our body's first line of defence and reach the living cells inside the body are faced with our second line of defence. This is in our *blood system*, which reaches all the cells in the body.

The marrow inside the long bones of our arms and legs makes the blood cells. The white blood cells, called **leucocytes**, have the special job of stopping any micro-organisms that do get in from harming our body. There are many different types of these disease-fighting white cells and together they can deal with most invaders.

## White blood cells

All the body's white blood cells (leucocytes) begin their life in the same way. They first form in the bone marrow then develop in one of many ways to form the various disease-fighting cells of the blood and the lymph which make up the amazingly complex internal defence systems of the body. Figure 1.34 is a very simplified summary of the main types of leucocyte.

Foreign objects such as pathogens that get into our body have chemicals called **antigens** on their surface. These are quickly identified and trigger off an attack on the invaders.

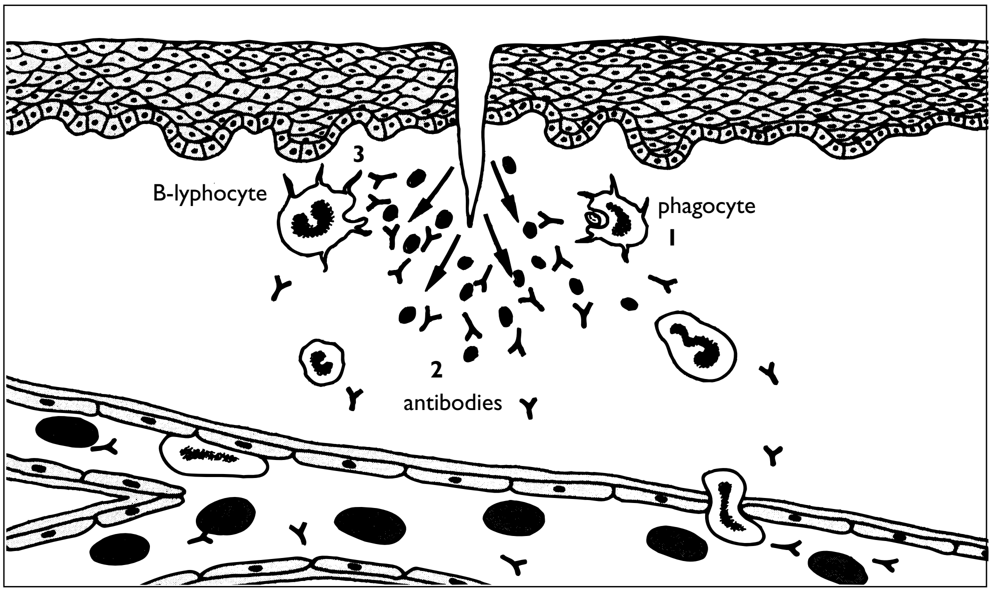



*Figure 1.34 Disease-fighting cells*

## Immune deficiency

Although our immune system does an amazing job against its enemies there are times when the immune system does not work properly. One situation where this happens is leukemia (the disease which produces too many white blood cells). Another is a virus called HIV, which attacks the body's T-cells and eventually stops them from working. Without these special T-cells to 'switch on' and 'control' the production of antibodies the body soon begins to lose the battle against disease-causing micro-organisms that get into it.

# Activity 14 Our internal defence system

**1** In your notebook draw up a chart with three columns like the one below and complete the empty spaces using the information from this unit:

| Type of defence | Where in our body the work is done | How it protects our body |
|---|---|---|
| Lysozyme | | |
| Mucus | | |
| B-cells | | |
| Cilia | | |
| Acid | | |
| T-cells | | |
| Friendly bacteria | | |
| Fatty acids | | |
| Phagocytes | | |

**2** For each number on Figure 1.33 on page 44 and using Figure 1.35 below name the type of defence that is operating.

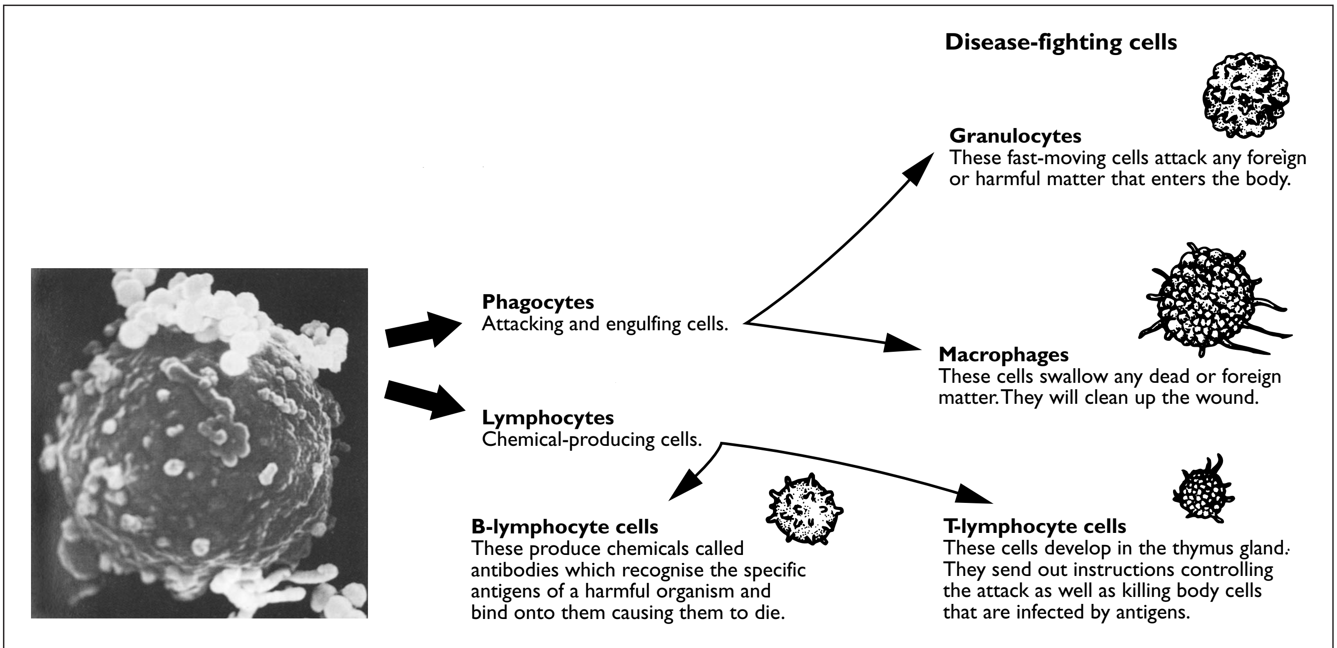



*Figure 1.35 The body's defences at work*

## Use Of Plants As Medicines

Most of the time people are well, which means that they are in balance with the natural, social and supernatural elements that make up their world. Stresses and disturbances in the balance between a person and their environment causes them to feel unwell. When this happens, people search for the cause of the stress or disturbance. They either seek help from medical doctors and expensive modern medicines or most likely (especially when the hospital is far away), most seek the help of the local healer or *taulasea.*

The *taulasea* can use a range of treatments including internal or external medicine, massage or *fofo*, manipulation or therapeutic counselling. These treatments can be used singly (*lē soa-gia*) or in combination with each other (*soa-gia le fofo*). Each *taulasea* has memorised numerous formulae for the making and use of medicines from local materials. The materials are mostly from plants but other materials are also used. Other materials include: salt water, freshwater, raw fish (*fuga* species), breast milk, leaf ash, smoke, burning or crushed charcoal, warm air and spittle (which is mixed with leaves when the *taulasea* chews them to soften them up).

Different types of plants, including trees, shrubs, creepers, grasses, ferns and lichens are used. The parts of a plant that can be used to make medicines include roots, leaves, trunk, rhizomes, shoots, sap, young leaves, mature leaves, immature fruit, mature fruit, seeds and flowers. Often the plant parts are used to make an 'infusion'. This is a liquid produced by soaking the plant parts in hot water. The chemicals in the plant are released into the water.

The following are examples of plants used as medicines:

### *A'atasi* or Polynesian cress (*Rorippa sarmentosa*)

*a member of the mustard family*

This plant is one of the most commonly used to treat infants. The whole plant or just the leaves are crushed and used to make an infusion given to infants to treat aliments and inflammation. Juice from crushed leaves or heated leaves can be applied to boils and infected wounds. This juice can be dripped into the eyes to treat eye injury.

### *Lega* (*ano*) or turmeric (*Curcuma longa L.*)

*a member of the ginger family*

A mixture of *lega* powder and coconut oil is used to treat stomatitis (*gutu papala*), blisters on the lips (*'atiloto*), skin sores (*papala, po'u*) and inflammation (*mūmū* or *mageso*). An infusion made from scrapings of the rhizome can be used to treat stomachache (*manava tigā*), ulcers (*puta papala*), diarrhoea (*manava tatā*) and urinary tract problems (*tulitā*).

### *'Ava* or *kava* (*Piper methysticum*)

*a member of the pepper family*

An infusion of pounded root is used to treat stomachache, backache (*tua tigā*) and pain in other areas of the body as well as venereal disease (*ma'i afī*) and urinary tract problems.

## *‘Ava‘avaaitu tu* (*Macropiper puberulum*)

*a member of the pepper family*

An infusion of the leaves is often used to treat ghost sickness (*ma‘i aitu*) and is also used in massage of illnesses such as swellings (*fula*) and inflammation that are believed to be caused by ghosts (*sāūa* ailments).

## *‘Ava‘avaaitu sosolo* (*Piper graeffei*)

*also from the pepper family*

An infusion made from scraped bark (*valusaga o le pa‘u la‘au*) is used as a potion for mouth infections (*gutu papala*) and coughs (*tale*). The juice from crushed leaves is also used to treat ghost sickness, inflammation and infected wounds thought to have supernatural causes.

## *Fiu or ginger* (*Zingiber officinale*)

*a member of the ginger family*

An infusion of crushed or scraped rhizome is taken as a potion for treating stomachache, stomatitis and respiratory difficulties (*ma‘i sela*).

## *Fu‘afu‘a* (*Kleinhovia hospita*)

*a member of the cacao family*

Sap scraped from the inner bark is used to stop the bleeding from cuts (*lavea*) and wounds (*manu‘a*). The sap (*apulupulu*) can also be used to treat eye injuries and irritations (*mata pa‘ia*).

## *Lau magamaga* (*Phymatosorus scolopendria*)

*a member of the common-fern family*

This creeping fern is one of the most widely used medicinal plants. An infusion of scraped rhizomes or crushed leaves is taken as a potion (*vai a le taulasea*) for treating inflammation, childhood ailments, stomachache and urinary tract problems. An infusion of crushed leaves is taken as a potion or is applied to the skin to treat infected, hard to cure wounds.

## *Lau papata* (*Macaranga harveyana*)

*a member of the spurge family*

A potion made from an infusion of scraped bark is used as a purgative for treating internal ailments such as digestive tract disorders (*fe‘efe‘e*), intestinal worms (*‘anufe*), and urinary tract problems.

## *Matalafi* (*Psychotria insularum*)

***a member of the coffee family***

This is one of the most frequently used medicinal plants and is believed to be the one most effective in treating supernaturally caused ailments. It is used as a potion, made from an infusion of crushed leaves or scraped bark, to treat inflammation, infected wounds, swellings and various body aches (*tino gagase*).

## *Moso'oi* (*Cananga odorata*)

***a member of the soursop family***

An infusion of scraped bark is used to treat constipation (*manava mamau*), stomachache, mouth infection, coughs, postpartum sickness (*failele gau*) and an internal pain called *to'ala*. A boiled infusion of the leaves and flowers are used in a steam bath to improve wellbeing.

## *Vao vai* (*Peperomia pellucida*)

***a member of the pepper family***

The crushed plant is applied to boils (*ma'i sua*).

**Further information can be found in the following books**:


- Macpherson, C. and L. (1990) *Sāmoan Medical Beliefs and Practice* Auckland University Press: Auckland.
- Whistler, W. A. (1996) *Sāmoan Herbal Medicine* Isle Botanica: Honolulu.


Or simply ask your local *Taulasea*.

## Antiseptics, disinfectants and antibiotics

These three types of chemicals help us control the growth and reproduction of micro-organisms. *Antiseptics* are chemicals that are used to kill micro-organisms on human tissue and *disinfectants* are used to kill micro-organisms on surfaces and fabrics. *Antibiotics* are chemicals that fungi produce to stop the growth of bacteria. People have learnt to produce antibiotics and use them to make medicines.

## Vaccination

Our bodies have a number of ways of defending us against infection by pathogens but some pathogens are very nasty and can get past the defences. Vaccinations have been developed to help our immune system fight diseases.

The chart below is a way of showing how our immune system operates to fight an infection over a period of time. You can see that there is a time delay of up to 10 days between the first infection and the destruction of the disease-causing micro-organisms by the leucocytes.

**FIRST INFECTION**

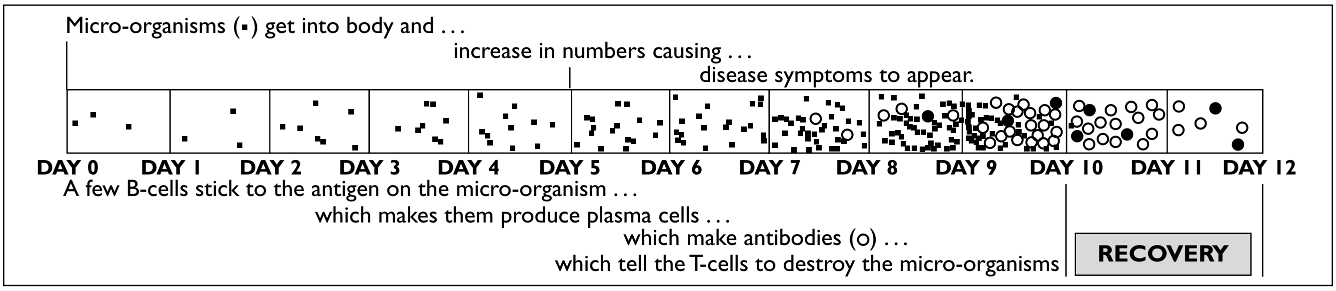



*Figure 1.36 First infection*

Once the micro-organism gets into your body the race is on. If the micro-organism can increase in numbers faster than the cells and chemicals of the immune system then symptoms of the disease appear in your body. It takes some time for our immune system to overcome the micro-organism, so there is a period of time when we are sick, but we recover when the immune system wins! This does mean though, that there may be a risk of disease harming the body and even causing death with the first infection. However, the next time the micro-organism gets into your body the immune system is ready and waiting, as the second chart shows.

**SECOND INFECTION**

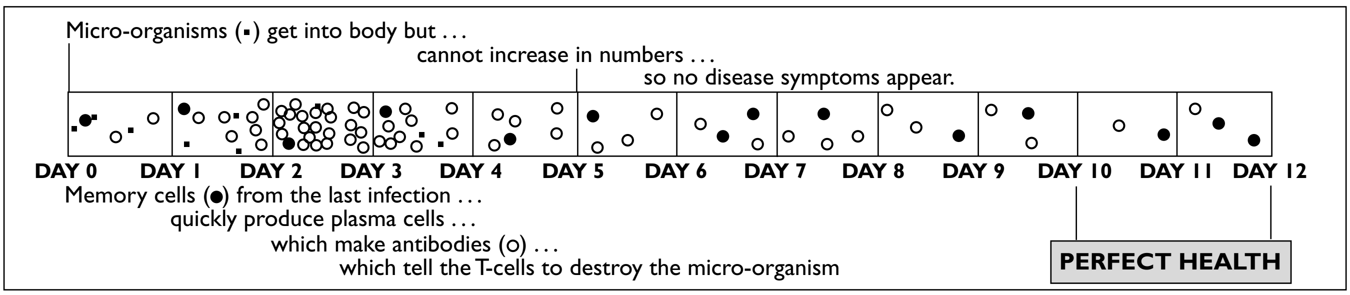



*Figure 1.37 Second infection*

Because the immune system works more quickly after the first infection, sometimes pathogens will get into your body yet you will never know that you had the disease. Before you were born you received antibodies from your mother through the **placenta**, and as a small baby you received more antibodies through your mother's milk. After a few months the immune system is on its own.

### Vaccinations

One way to give your immune system a boost is to add antibodies with an injection. Your body does no work to make these injected antibodies so this is called **passive immunity**. Unfortunately the antibodies do not last very long and your body is soon at risk of getting sick again. What you need is a way to get your body to make antibodies before a pathogen gets into your body, so it is prepared to fight the disease.

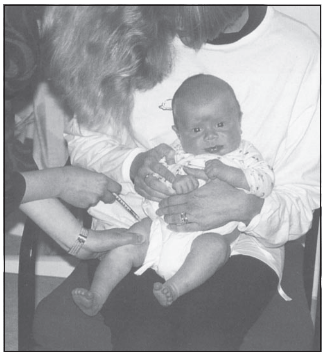


*Figure 1.38 Small child having his two month vaccination*

The other type of vaccination is an injection that tricks your body into thinking that you have a disease so antibodies and memory cells will be made. These memory cells can then swing into action as soon as any of the real pathogens get in. This reduces the possibility of any harm coming to your body from the disease. It is called active artificial immunity.

### Where to next?

Medicine has developed ways to stop the huge epidemics of the past. But what of the future? Here are a few facts to think about.

1 **Limits on success**

There are still many diseases for which there are no vaccines – typhoid, dengue, hepatitis A and AIDS are some. AIDS is proving to be particularly difficult.

It is very difficult to develop vaccines against some of the more complex disease organisms such as worms and protozoa like the malaria pathogen. Some of these organisms can cover themselves in a layer that the human body's immune system doesn't recognise but they often change their antigens during different stages in their life. Some can also grow and reproduce in animals other than humans.

2 **Disease elimination**

As vaccines are cheap, easy to produce and safe and effective to use it has now become possible to completely eliminate certain types of disease. So the World Health Organisation (WHO) has completely eliminated the disease smallpox from the world. No case of this very serious disease has been reported anywhere since 1981. Another goal of WHO is the elimination of the disease poliomyelitis. This will not only save lives but will also save a lot of money at present being spent on vaccination.

3 **Are we winning in the fight against disease?**

More than 70% of the world's children in developing countries receive some immunisation before they are one year old. However the death rate is still very high – the World Health Organisation says that more than 8000 children die every day because they are not immunised against diseases for which there are vaccines.

*Table 1.2 Immunisation programme*

| Injection | When given | Disease immunisation is acting against |
|---|---|---|
| BCG | New born | Tuberculosis |
| HB 1 | New born | Hepatitis |
| HB 2 | 4 to 6 weeks | Hepatitis |
| DPT 1 | 6 weeks | Diphtheria, Polio and tetanus |
| Polio 1 | 1 to 6 weeks | Polio |
| DPT 2 | 10 weeks | Diphtheria, Polio and tetanus |
| Polio 2 | 10 weeks | Polio |
| HB 3 | 14 weeks | Hepatitis |
| DPT 3 | 14 weeks | Diphtheria, Polio and tetanus |
| Polio 3 | 14 weeks | Polio |
| Measles and rubella | 1 year | Measles and rubella |
| DPT | When begin school | Diphtheria, Polio and tetanus |

## Activity 15 Understanding immunity

**1** Make a list of the diseases included in Table 1.2, Immunisation programme.

**2** Find out which of these you have been vaccinated against.

**3** Explain the difference between active and passive immunity and between natural and artificial immunity. Be sure to mention the effectiveness of the protection as well as the different methods used.

**Reducing disease in the future**

**4** If your group were responsible for spending a limited amount of money on a worldwide vaccination development programme how would you spend it? Prepare a case to present to the class in no more than five minutes. Your plan must list priorities because you will not have enough money to do everything you would like. First read the information under the heading 'Where to next?' Then be sure to consider the different needs of developed and developing countries, the need for research as well as making sure every child is vaccinated.

## Activity 16 Diseases

**1** Describe ways that diseases spread.

**2** Discuss ways that people in Sāmoa use to control and cure diseases.

## Antibiotic resistance

- Unfortunately, some bacteria develop **resistance** to a particular antibiotic. Bacteria belonging to one species are not all the same. They can change their genes by **mutation**. Some bacteria acquire resistance to a particular antibiotic and are not killed by it. They multiply, passing their resistant genes on to their offspring.
- As the antibiotic kills off bacteria, the bacteria population gradually changes to a resistant strain. Scientists have to develop new antibiotics to fight these resistant strains.

  We can help to prevent the development of antibiotic resistant bacteria if we carefully follow the instructions for any antibiotics we are taking. For example, it is important to take all the antibiotics and not just some of them and not to give up using them when we feel better.

## Activity 17 Antiseptics and disinfectants

Set up the following investigation to test the effectiveness of different types of disinfectant or antiseptic.

**1** Firstly obtain identical sterile petri dishes with nutrient agar.

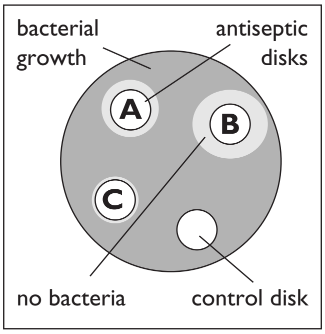
**2** Next make up a standard solution of each antiseptic (e.g. 5 ml per 100 ml of water).

**3** Cut identical small disks of filter paper and label them. Dip each in a different antiseptic. Dip one disk in water as a control.

**4** Obtain bacteria from the same source by wiping a cotton swab over an existing colony. Lightly wipe the swab over the agar in a petri dish. Drop the antiseptic disks onto the agar.

**5** Seal the dish. Place in a warm place for three days.

**6** Clear areas in the agar indicate bacteria are absent. Observe the size of the clear area around each disk and decide which antiseptic is the most effective.




The investigation could be changed to investigate the effect of *concentration* on the effectiveness of the disinfectant or antiseptic. Design and carry out an investigation to test the effect of concentration on the effectiveness of a disinfectant or antiseptic.

# Revision

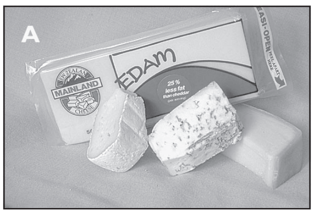
**1** Match up terms with definitions.

| | |
|---|---|
| fermentation | **a** the growth of harmful micro-organisms in or on your body |
| pathogen | **b** a chemical which recognises and helps destroy a pathogen |
| infection | **c** a marker chemical on a pathogen |
| toxin | **d** the ability to prevent an infection occurring |
| phagocyte | **e** a white blood cell which produces antibodies |
| antigen | **f** a disease-causing micro-organism |
| lymphocyte | **g** the conversion of sugar into alcohol and carbon dioxide by yeast |
| antibody | **h** when bacteria are no longer affected by an antibiotic |
| antiseptic | **i** the chemical produced by a pathogen which may poison cells |
| immunity | **j** the chemical produced by fungi which is used to kill bacteria |
| vaccination | **k** a white blood cell which engulfs pathogens |
| antibiotic | **l** the chemical applied to a wound to prevent infection |
| antibiotic resistance | **m** injection with dead or weakened microbes to give immunity |

**2** Copy and complete the following table by listing harmful and helpful effects of micro-organisms.

| Micro-organism | Harmful Effect | Helpful Effect |
|---|---|---|
| viruses | ❑<br>❑ | ❑<br>❑ |
| bacteria | ❑<br>❑ | ❑<br>❑ |
| fungi | ❑<br>❑ | ❑<br>❑ |

**3** Identify the micro-organism involved.






4 Decide whether the following statements are true or false. Rewrite the false ones to make them correct.

a Decomposers are micro-organisms which are able to release nutrients from dead matter.

b Herbivores need the help of fungi which live in their gut to break down the tough cell walls of plants.

c Biotechnology can use micro-organisms to help humans.

d Antibiotics are used to fight both bacterial and viral infections.

e Viruses are all pathogens, but they can be useful when they are used for the biological control of pests.

f All diseases are caused by pathogens.

g A pathogen can cause harm by destroying living tissue or by poisoning cells with the toxins it produces.

h A pathogen produces antigens which are absorbed by lymphocytes which then produce antibodies to attack that pathogen.

i Immunity occurs through antibodies.

5 Explain the difference between:

a an antigen and an antibody

b disinfectant and antiseptic

c immunity and vaccination.

6 Copy and complete the following paragraphs using the words in the box below.

a White blood ______ are involved in fighting ______. Phagocytes ______ any pathogens they encounter. Lymphocytes produce ______ which attack and help destroy particular types of pathogens. The antibodies recognise ______ on the surface of the pathogen.

b After your first infection by a particular ______, you gain natural ______ to further attacks due to the presence of ______ in your blood. You can gain ______ immunity to a particular pathogen by being ______ with dead or weakened strains of the pathogen. This increases the level of the appropriate antibody in the ______.

c Antibiotics are produced by ______ and are taken internally by humans to destroy ______. Some bacteria have developed ______ to particular antibiotics. A few of the bacteria are genetically different and are not killed by the antibiotic. They increase in number and eventually produce a resistant strain.

• antibody • antigens • artificial • bacteria • blood • cells • engulf • fungi • immunity • pathogens • resistance • vaccinated • pathogen • antibodies

7 In an investigation into the effectiveness of three disinfectants (A, B and C), students inoculated a sterile agar plate with bacteria from an established colony by wiping the surfaces with a cotton bud.

They dipped a small labelled disk into the first disinfectant and placed it on the agar. They repeated this step for the other two disinfectants. The plate was sealed and incubated for three days. Figure 1.39 shows the results.

a What is a disinfectant used for?

b What are the students actually testing?

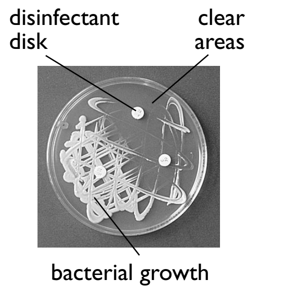
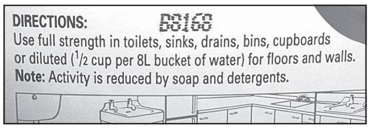



*Figure 1.39 Agar plate with bacteria*

- **c** What does the word 'sterile' mean? Why was it important the plate was sterile to begin with?
- **d** Why did they use bacteria from an established colony?
- **e** What is the difference between inoculation and incubation?
- **f** Why is it important that the filter paper disks were the same size?
- **g** What do the filter paper disks do when dipped in disinfectant?
- **h** What do the pale areas in the photo indicate? What do the clear areas around some of the disks indicate?
- **i** Which disinfectant appears to be most effective at killing bacteria? How do you know this?
- **j** The teacher commented that their test was not a completely fair test. Suggest why it was not a fair test and how the students could change their method to make it fairer. (Hint – read label.)




- **k** The teacher also said that they should have included a control disk to check that filter paper does not inhibit the growth of bacteria. What should they do to the control disk to check this?
- **l** Suggest a limitation of this particular test of the effectiveness of disinfectants in killing bacteria in general.

**8** Read the passage below, then answer the questions.

## HIV and AIDS

The disease AIDS (acquired immune deficiency syndrome) is caused by a viral pathogen. The virus is called HIV (human immunodeficiency virus).

The virus first appeared in Africa in the 1980s and it is believed to have originated in a monkey species.

The virus is transmitted from person to person in body fluids (e.g. blood and semen). It can be transferred through sexual activity, blood transfusions and by sharing needles. It is not caught by touching or coughing.

Once the virus enters the body, it invades lymphocytes which fight disease.

The virus remains dormant in the lymphocytes for up to ten years. When it becomes active the virus takes over the lymphocyte cells and makes them produce many more copies of the virus, which escape to invade other lymphocytes.

The body's immune system now ceases to function and the person is vulnerable to many opportunistic infections. These include diseases such as thrush, diarrhoea, tuberculosis, pneumonia and some cancers. When these symptoms occur, the person then has AIDS. Often there are times of recovery followed by relapse. Eventually the person's health deteriorates and an infection proves fatal.

Researchers are developing drugs which may prevent the onset of AIDS. They are also investigating vaccines, but as the HIV virus mutates rapidly this is a difficult task.

- **a** What do the acronyms HIV and AIDS stand for?
- **b** What type of pathogen causes AIDS?
- **c** This pathogen has crossed the 'species barrier'. What does this mean?
- **d** Suggest three ways in which the spread of the disease could be reduced.

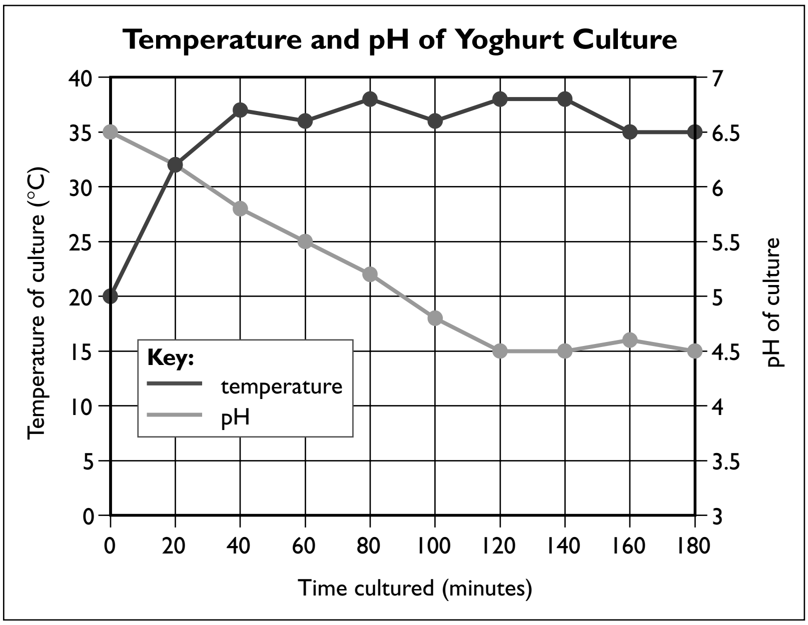
**e** What does it mean when a person is tested and found to be HIV positive?

**f** Why is there usually a long delay between infection with HIV and the development of AIDS?

**g** What are 'opportunistic infections'? (If you do not know the word 'opportunistic' look it up.)

**h** Why is it difficult to develop an effective vaccine?

**9** To culture yoghurt, milk was heated until it nearly boiled. Yoghurt-making bacteria were added when the milk had cooled to 20°C. The liquid was placed in a water bath set to 35°C. The temperature and pH of the mixture was monitored over three hours. The results are plotted on the double axis graph below.




**a** What ingredients do you need to make yoghurt?

**b** Why was the milk heated till it nearly boiled?

**c** What was the milk inoculated with?

**d** Why was the culture put in a water bath?

**e** Describe the trend shown by the temperature graph line.

**f** Was the water bath thermostat accurately calibrated?

**g** Why was the water bath thermostat set to 35°C?

**h** Why do you think there were temperature fluctuations in the culture?

**i** The student used a pH meter to find the pH of the culture. What does pH indicate?

**j** After 100 minutes, what was the temperature and pH of the culture?

**k** Describe the trend shown by the pH graph line.

**l** Describe in words what happens to the acidity of the culture during the experiment.

**m** What would have caused this change in pH?

**n** After 120 minutes the culture was no longer runny; why was this?

# Unit 2 Cell Biology

This unit is divided into sections that cover cell structure, respiration, osmosis and diffusion, and enzymes.

## Cell Structure

In this section you learn to:

- **use** a light microscope to view prepared slides or wet mounts, e.g. onion cells, human skin cells
- **draw** cells and tissues as seen under the microscope
- **explain** the relationship between cells, tissues and organs
- **describe** the differences between plant and animal cells
- **explain** the structure and function of cell components and organelles, e.g. cell membrane, cell wall, nucleus, cytoplasm, vacuole, chloroplast, ribosome, endoplasmic reticulum, mitochondria, Golgi bodies.

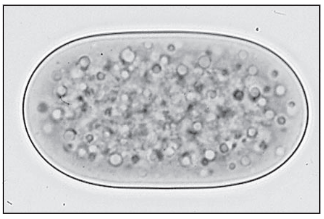


*Figure 2.1 Single cell organism*

All organisms are made up of **cells**. Cells are very small, so small that you can only see them using a microscope. All cells carry out the life processes that separate living things from non-living things, e.g. nutrition and gas exchange. Cells are called the 'basic unit of life' because some very small living things such as bacteria, single cell organisms and some algae, are made up of one cell that can live independently from other cells.

Although some cells can live independently, most cells live as part of a multicellular organism. A human is a multicellular organism. Your body is made up of many cells working together to keep you alive. Plants are also made up of many cells working together.

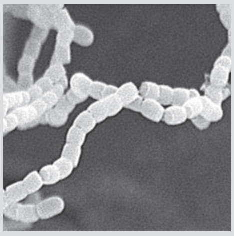
### *How big are cells?*

- You need to be familiar with these units:

  1 m = 1000 mm (millimetre)
  1 mm = 1000 µm (micrometre)
  1 µm = 1000 nm (nanometre)

- An amoeba is one of the largest unicellular organisms. At about 200 micrometres (µm) diameter it is just at the limit of human vision.

- Most plant and animal cells are between 10 and 100 µm in diameter, which means that you need a microscope to see them.
- Apart from the nucleus and chloroplasts, most of the fine structure of cells is too small to be seen with a light microscope. An electron microscope, which can show structures from 100 µm down to 0.1 nm in size, is capable of showing these smaller organelles.
- Some relevant sizes are:
  - the largest cells are bird eggs, e.g. chicken egg at 60–70 mm
  - the longest cells are nerve cells up to 600 mm
  - most cells are in the range 10–100 µm
  - most bacteria are in the range 1–7 µm
  - mitochondria are about 1.5 µm long
  - large molecules are 4–10 nm
  - small molecules are 0.4–0.8 nm



- Bacteria have a cell wall but no nucleus.

## Cell organelles

The cells from all organisms contain a range of different parts inside them. These parts are called **organelles**. Organelles are so small that we need an electron microscope to see them.

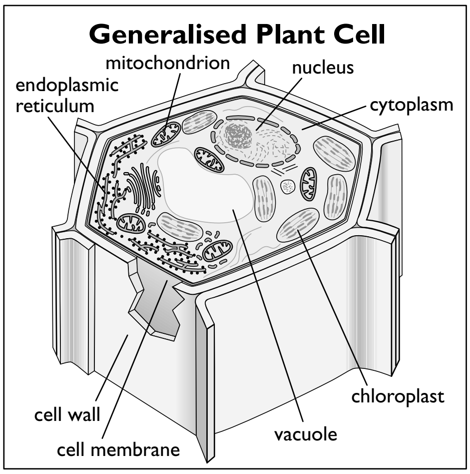



*Figure 2.2 Plant cell*

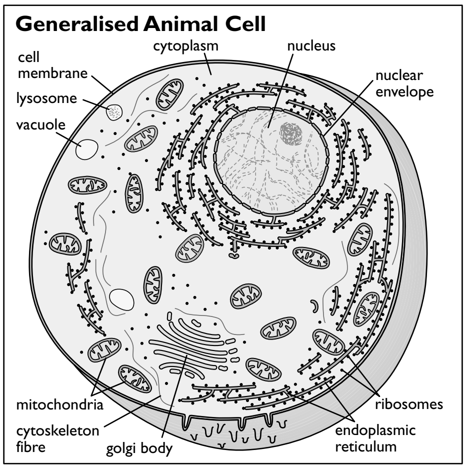



*Figure 2.3 Animal cell*

All cells are surrounded by a **cell** or **plasma membrane**. The cell membrane is like both a wall and a gate that separates the cell from where it lives and controls what materials enter and leave the cell. The different parts of the cell membrane are designed to transport materials in and out of the cell.

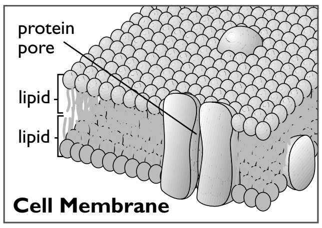



*Figure 2.4 Cell membrane*

The cell membrane is made up of two layers of lipid (fat) molecules. A small number of protein molecules can also be found in between the lipid molecules. The protein molecules form pores that control the movement of large molecules across the cell membrane.

Plant cells have a cell wall outside the cell membrane. The cell wall is made up of *cellulose* and it provides that cell with support. The strong cell wall gives plant cells a fixed shape.

The insides of plant and animal cells contain a jelly-like material called the **cytoplasm**. The cytoplasm is also made up of fibres that form a **cytoskeleton** throughout the cytoplasm. The cytoskeleton supports the cell, giving it shape and allowing some cells to move. The following cell organelles are found in the cytoplasm.

| Organelle | Description | Function |
|---|---|---|
| Nucleus | Area of the cell surrounded by a double layer of membrane containing small pores | Contains the genetic information that controls the functioning of the cell |
| Golgi bodies | A number of flat disc-shaped layers of membrane | Package chemicals that are then used outside the cell |
| Mitochondria | Sausage-shaped, with folds of membrane on the inside | Carries out respiration |
| Ribosome | Small, round | Make proteins |
| Endoplasmic reticulum | A system of membranes and connecting tubes. Sometimes covered in ribosomes | Provide a work surface for chemical reactions and passageways for moving materials |
| Chloroplast | Oval shaped containing layers of membranes and also chlorophyll | Carry out photosynthesis |
| Vacuole | Membrane sacs. Large in plant cells and small in animal cells | Store water, food or wastes |

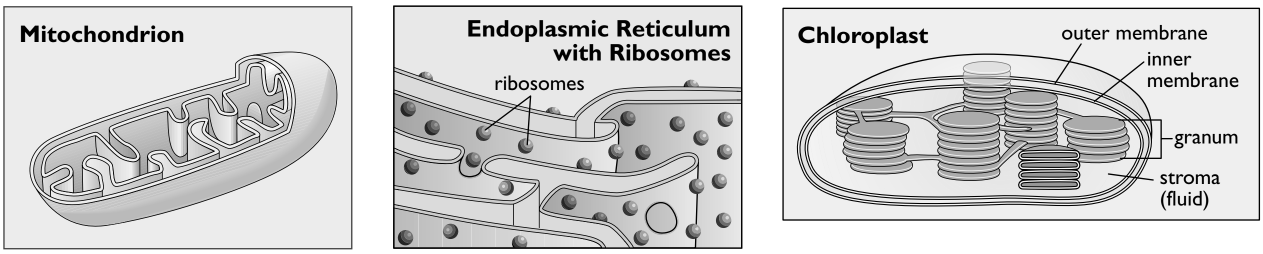



*Figure 2.5 Mitrochondria, Endoplasmic reticulum and chloroplast*

## Plant and animal cells

There are three main differences between plant cells and animal cells. Plant cells have:

- ❑ a cell wall that gives them a strong rigid shape
- ❑ chloroplasts that carry out photosynthesis
- ❑ large vacuoles that can take up most of the cell. A high level of water in the vacuole provides pressure on the cell wall which gives the plant support.

## Cell, tissues and organs

Cells in multicellular plants and animals are specialised so that they can carry out particular functions. Examples of specialised cells in animals are skin, nerve, bone and blood cells. Examples of the functions of plant cells include to provide support, to absorb water, to conduct liquids, to allow gases in and out, to make food, forming protective surfaces and reproduction. Specialised cells have special features that allow them to carry out their function.

The bodies of multicellular plants and animals have cells and groups of cells that work together to carry out a particular function. A group of the same type of cell is called a **tissue**. For example, muscle tissue in animals is made up of mostly muscle cells that work together to allow the animal to move. *Xylem* is an example of a plant tissue. The cells in xylem work together to move (transport) water from the roots to all parts of the plant.

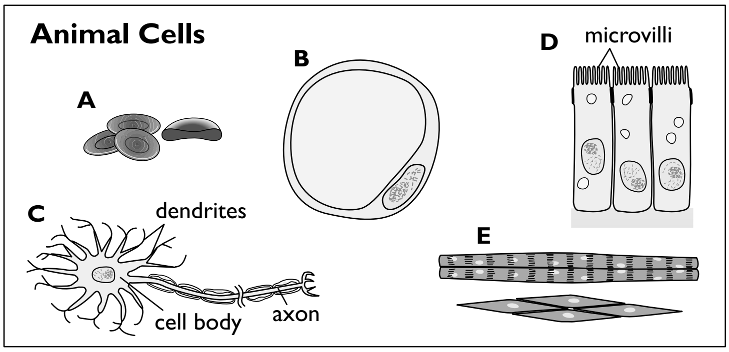
An **organ** is a collection of different types of cells which work together to carry out a particular function. For example a leaf is an organ. It is made up of layers of different sorts of cells that work together to carry out photosynthesis. The heart is an organ. The heart contains muscle cells, nerve cells and connective tissue that work together to pump blood around the body.

## Activity 1 Cell structure

**1** Matching terms with definitions.

| | |
|---|---|
| cells | **a** the organelle which is the site of protein synthesis |
| organelles | **b** the organelle which is the site of photosynthesis |
| cell membrane | **c** various structures within the cytoplasm |
| cytoplasm | **d** the basic building blocks of living things |
| cytoskeleton | **e** a whip-like extension of the cell membrane |
| Golgi body | **f** the semi-fluid substance filling the cell interior |
| mitochondrion | **g** flat disc-shaped sacs in the cytoplasm |
| endoplasmic reticulum | **h** a sac containing digestive enzymes |
| ribosome | **i** the structure which maintains the shape of a cell |
| lysosome | **j** a sac containing water or storage products |
| vacuole | **k** the double layer of lipids enclosing the cytoplasm |
| nucleus | **l** the cellulose layer that surrounds plant cells |
| cell wall | **m** the structure in a cell containing genetic information |
| chloroplast | **n** a system of membranes and connecting tubes |
| flagellum | **o** the organelle which is the site of cellular respiration |

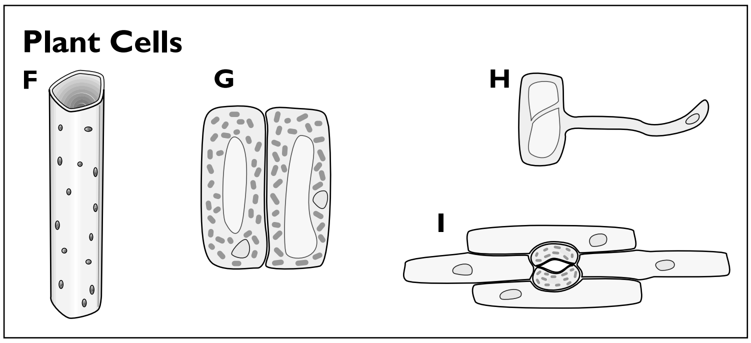
2 Matching cell types to roles.




Match the animal cell types in the picture above with these roles:

- **a** **nerve cells** – long, thin cells with connections to other cells
- **b** **absorption cells** – cells with numerous finger-like projections to increase the surface area available for absorption
- **c** **muscle cells** – long, thin cells with fibres that contract to change the length of the cells
- **d** **fat storage cells** – cells with vacuoles filled with fat
- **e** **blood cells** – disc-shaped cells able to pass through tubes.

Match the plant cell types below with these roles:




- **f** **water transport vessels** – long tubes with thickened cell walls, walls perforated with pores
- **g** **root hair cells** – have long extensions for absorbing water
- **h** **epidermal cells** – flat cells forming a layer, pores present
- **i** **palisade cells** – vertical cells stacked in parallel, they have many chloroplasts for carrying out photosynthesis.

3 True or false?

Decide whether these statements are true or false. Correct the false ones.

- **a** Most cells are less that one tenth of a millimetre in length.
- **b** Cell membranes are made up of two layers of protein molecules.
- **c** The folds in cell organelles provide a work surface on which complex chemical reactions take place.
- **d** Lysosomes contain the genetic information which controls cells.
- **e** The cell wall of plants is made of layers of cellulose fibres placed in different directions.
- **f** The rows of tiny beating hairs on the surface of some unicellular organisms are called flagella.
- **g** The DNA in bacterial cells is not found in a separate nucleus.
- **h** All cells have the same basic structure.

**4** Identifying the internal structure of cells.

This magnified view of a cell was taken by a transmission electron microscope. Compare it with other cell diagrams.

**a** From the list below label the parts above:

• cell wall • cell membrane • cytoplasm • vacuole • mitochondria
• chloroplasts • nucleus • nuclear envelope

**b** Is this a plant or an animal cell? Give two reasons.

**5** Describe the differences between plant and animal cells.

**6** Explain the relationship between cells, tissues and organs.

## Microscopes

We use different types of microscopes to investigate cells. For example:

- **Light microscopes** direct light through a thin, semi-transparent sample of cells and we observe them after magnification by two lenses. These instruments are able to **resolve** (clearly show in detail) objects bigger than 200 nm in size.
- **Electron microscopes** are expensive instruments which use a beam of electrons to create an image. As electrons have much shorter wavelengths than light waves, they can be used to reveal much smaller objects. The photo of the cell above was taken through an electron microscope.
- **Transmission electron microscope** (TEM), electrons pass through an extremely thin section of cells to produce an image which resolves objects bigger than 0.2 nm. The image is a flat two-dimensional slice.
- **Scanning electron microscope** (SEM), electrons are bounced off a sample to reveal the three-dimensional surface structure of cells or organelles. An SEM will only resolve cellular objects bigger than 10 nm in size.

## *Using a light microscope*

If you are to use a light microscope you need to follow a sequence of steps.

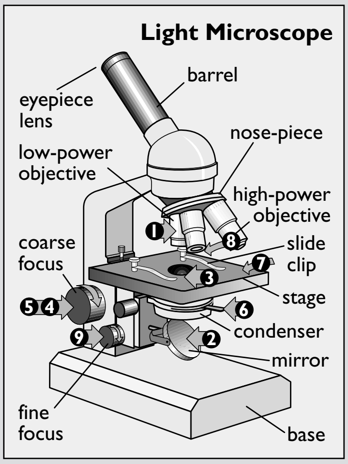
1 **Make sure** the low-power objective lens is in line with the barrel.

2 **Look** through the eyepiece lens and **adjust** the curved mirror so that light enters the microscope.

3 **Place** the slide on the stage with the sample centred on the viewing area.

4 Looking from the side, **wind** the coarse focus knob clockwise until the objective lens is just above the slide.

**Do not wind down when you are looking through the lens!**




5 **Look** through the eyepiece lens and slowly **turn** the coarse focus knob anticlockwise until the cells come into focus.

6 **Adjust** the condenser under the stage to give the best lighting.

7 Gently **move** the slide about with one hand, adjusting the focus with the other.

8 When you have the best view of cells **rotate** in the high-power objective lens.

9 **Bring** the image into sharp focus using the fine focus knob.

When you have finished, rotate the low power lens into line and remove the slide.

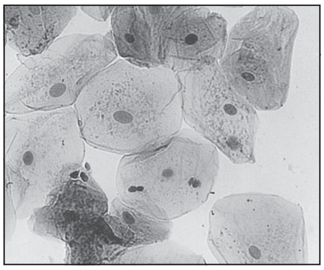


*Figure 2.6 Human epidermal cells (x400)*

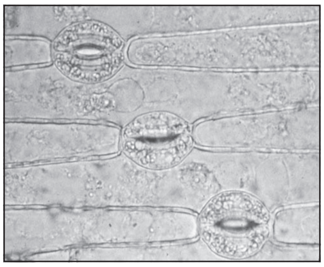


*Figure 2.7 Leaf epidermal cells (x100)*

## *Drawing cells*

To record your observations of cells under the microscope, follow these guidelines.

- ❑ Use unlined paper, a sharp pencil and a clean rubber.
- ❑ Select what to you need to draw and only draw the required detail.
- ❑ Sketch an outline of a group of cells. Make your drawing large.
- ❑ Use sharp lines and no shading.
- ❑ Make sure the lines join up so that structures are complete.
- ❑ Add labels and a suitable title.
- ❑ On your drawing write the magnification. The label on Figures 2.6 and 2.7 give examples of how to do it.

**Drawing cells**

The photos opposite are typical of the views of cells you will see using a light microscope. Draw a group of cells from each photo using the guidelines above.

## Activity 2 Investigating cells and tissues

**Aim:** To use a microscope to investigate cells and tissues.

1 Make wet mounts, leaf tears and stained sections of various plant tissues so that you can use a light microscope to investigate the structure of the cells and tissues present.

2 Label drawings of the cells and tissues.

3 View prepared slides and make drawings of the cells and tissues.

4 Mount animal skin cells and view with a light microscope.

# Respiration

In this section you learn to:

- ❑ **write** an equation to describe the process of respiration
- ❑ **explain** the importance of respiration and its relationship with photosynthesis
- ❑ **compare** aerobic and anaerobic respiration
- ❑ **investigate** fermentation in yeast
- ❑ **discuss** how anaerobic respiration results in muscle fatigue.

All cells need energy to carry out their activities. Plants get energy from the sun which they trap by the process of photosynthesis. Then they use this energy in a series of chemical reactions called **respiration**. When animals eat plants or other animals they gain food molecules that can be used in respiration to release the energy.

Respiration is carried out by a series of different enzymes that are attached to membranes. Cells only need small amounts of energy at a time so respiration removes the energy from glucose and stores it as chemical energy in a molecule called **adenosine triphosphate** or ATP. The ATP molecule can diffuse throughout the cell supplying small amounts of energy. An active cell needs the energy from millions of ATP molecules each second.

During respiration of a glucose molecule, the chemical energy is released by two separate processes called **glycolysis and respiration**.

Glycolysis occurs in the cytoplasm of the cell. It is a series of enzyme controlled reactions which break down glucose molecules into two pyruvic acid molecules. Two ATP molecules are formed in this process.

If oxygen is present in the cell, then *aerobic* respiration occurs next, but if oxygen is absent then *anaerobic* respiration occurs.

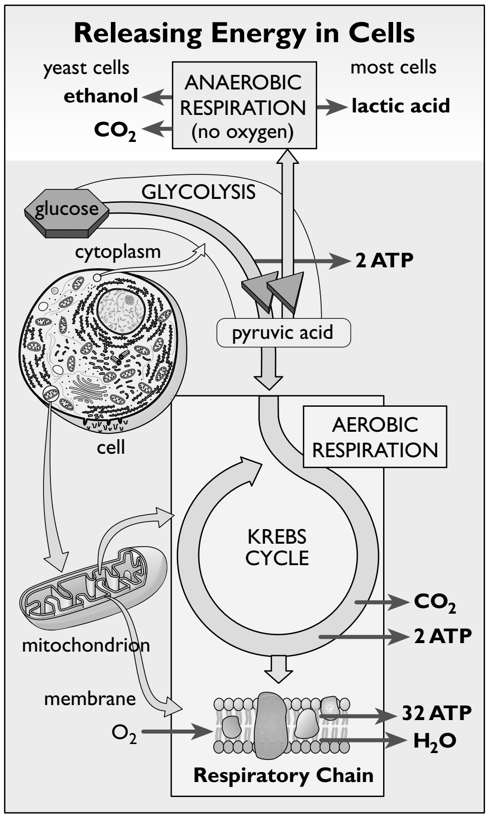



*Figure 2.8 Releasing energy in cells*

## Aerobic respiration

At the beginning of aerobic respiration, the two pyruvic acid molecules produced by glycolysis diffuse into the mitochondria. In the mitochondria they go through another series of enzyme controlled chemical reactions called the *Krebs cycle*. ATP and carbon dioxide are produced during the Krebs cycle. Another series of chemical reactions, called the *respiratory chain*, follow on from the Krebs cycle. Oxygen is used during the respiratory chain reactions and water and 32 ATP molecules are produced.

The following reaction is a summary of what happens to each glucose molecule.

| | | |
|---|---|---|
| Glucose + oxygen | ➔ | carbon dioxide + water + energy in 36 ATP molecules |
| $C_6H_{12}O_6 + 6O_2$ | ➔ | $6CO_2 + 6H_2O$ + energy in 36 ATP molecules |

When fats or protein molecules are used as the source of energy, they are first broken down into molecules which can be fed into the Krebs cycle.

## Anaerobic respiration

When there is no oxygen present only glycolysis can occur. In most plant and animal cells, the pyruvic acid changes into lactic acid. This is called *anaerobic respiration*. Lactic acid is a poison which builds up if anaerobic respiration is used. In animals a build up of lactic acid causes muscle fatigue which, if it continues, will cause the muscles to stop working. If oxygen becomes available again the lactic acid is then changed back into pyruvic acid and the pyruvic acid goes through aerobic respiration.

In yeast cells the pyruvic acid undergoes anaerobic respiration or fermentation into carbon dioxide and alcohol. You will remember this process is used in wine and bread making.

## Activity 3 Respiration

1 Write an equation to describe respiration.
2 Explain the importance of respiration.
3 Explain the relationship between photosynthesis and respiration.
4 Explain how anaerobic respiration results in muscle fatigue.
5 Compare aerobic respiration with anaerobic respiration.

## Activity 4 Fermentation

| **Materials:** |
|---|
| Yeast |
| Flasks |
| Balloons |
| Glucose |
| Water |

**Aim:** To investigate fermentation by yeast.

1 Make up a solution of 2 grams of glucose, 50 mls of water and 0.1 grams of yeast in a conical flask.
2 Make up a control solution of 2 grams of glucose and 50 mls of water in a conical flask.
3 Place balloons over the top of each of the flasks.
4 Leave for 24 hours in a warm place. Record the increase in size of the balloons.

## Activity 5 Temperature and fermentation

**Aim:** To investigate the effect of temperature on fermentation by yeast.

1 Use the reaction investigated in the previous activity as a starting point for your plan. In your plan identify the following and describe how they will be used to investigate the effect of temperature on fermentation by yeast:
- ❑ independent variable
- ❑ dependent variable
- ❑ controlled variables
- ❑ repeats.

2 Carry out your plan and collect the results.

3 Write out a report on your investigation.

## Activity 6 Respiration data

You can find the rate of respiration in cells by measuring the uptake of oxygen or the release of carbon dioxide gas.

In an experiment, a few yeast granules were sprinkled into a glucose solution and left for a period of time. A sample of the solution was placed in a volumeter which measures changes in gas volume. The yeast cells respire anaerobically in the water, so any change in gas volume is due only to the production of carbon dioxide.

**a** Why was glucose added?

**b** Which direction will the water drop move, left or right?

**c** What is the syringe for?

**d** Why is the volumeter in a water bath?

**e** A similar volumeter without yeast was set up in the water bath. Why?

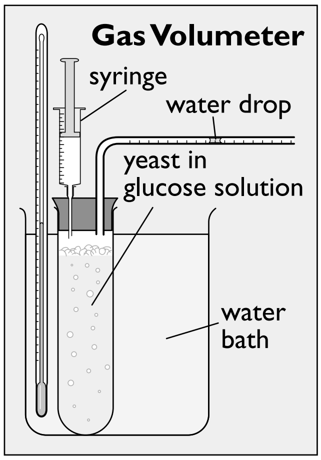



*Figure 2.9 Gas volumeter*

## Diffusion And Osmosis

In this section you learn to:

- ❑ **investigate** the processes of diffusion *or* osmosis
- ❑ **describe** the processes of diffusion *and* osmosis
- ❑ **explain** the importance of diffusion and osmosis in cell transport.

An important part of the functioning of cells is the movement of materials, including molecules and ions, in and out of a cell and also across the cell. Different processes transport different materials. Some of these processes require the cell to use energy and others do not.

Processes, such as diffusion and osmosis, do not require energy to transport materials so are called **passive transport**. **Active transport** uses some of the cells energy to carry materials from areas of low concentration into areas of high concentration.

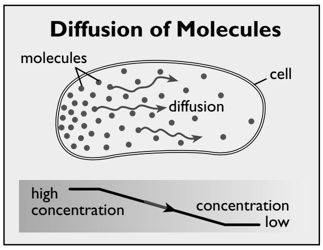



*Figure 2.10 Diffusion of molecules*

## Diffusion

Molecules and ions in a solution move all the time. The particles bump into each other and as they do, they spread throughout a liquid without stirring the liquid. The movement of individual particles is random, but the overall movement of particles occurs down the concentration gradient (from an area of high concentration of the liquid to an area of low concentration). This is called **diffusion**. Cells are so small that diffusion can carry a molecule across the cell in a fraction of a second.

How quickly diffusion occurs depends on a number of factors.

1 Molecule size: Small molecules move faster than larger molecules.
2 Temperature: Particles move faster at higher temperatures.
3 Concentration: Diffusion is faster down a steeper concentration gradient.

Molecules that enter or leave a cell must cross the cell membrane. The cell membrane is **selectively permeable**, which means that some materials can pass through it easily and others cannot diffuse across it. Water can pass in and out of a cell easily, but sucrose sugar cannot.

## Osmosis

**Osmosis** is the diffusion of water molecules across a selectively permeable membrane from the side with the lowest concentration of dissolved substances, called **solutes**, to the side with the highest concentration of dissolved substances.

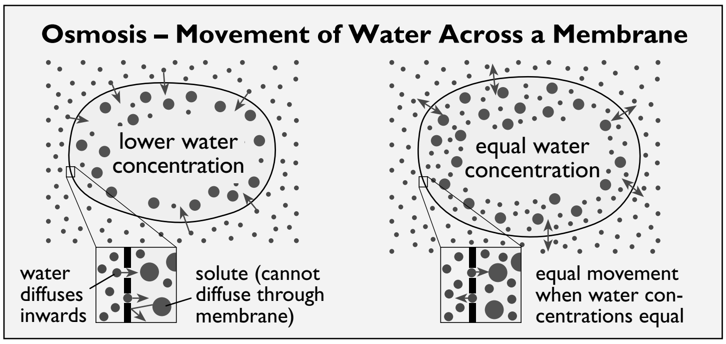



*Figure 2.11 Osmosis*

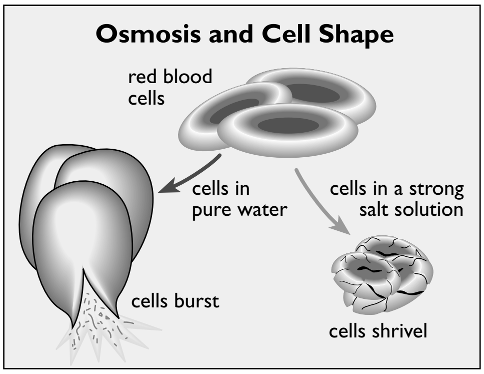



*Figure 2.12 Osmosis and cell shape*

Cells tend to have a higher concentration of dissolved materials than their surroundings. Therefore the process of osmosis takes water into the cell, creating pressure which helps to support the cell and keep it firm. If cells are placed in pure water, the water will quickly move into the cell. Plant cells will fill until cell contents are pushed up against the cell wall so much that no more water can enter. If animal cells, for example human red blood cells, are placed in water they will fill until the cell membrane cannot hold the pressure and the cell will burst.

If cells are placed in a solution with a high concentration of solutes, then the water will move out of the cell by osmosis. In plant cells, the removal of water causes the cytoplasm to move away from the cell wall. This is called **plasmolysis**.

Single celled animals that live in fresh water use an organelle called a **contractile vacuole** to collect and remove the water that enters the cell by osmosis. The contractile vacuole stops the cell becoming so full of water that it bursts.

# Activity 7 Transport

**1** Matching terms with definitions.

| | |
|---|---|
| diffusion | **a** lets molecules in solution pass through |
| osmosis | **b** the movement of water across a membrane |
| solutes | **c** molecules and ions dissolved in water |
| permeable | **d** the movement from high to low concentration |
| active transport | **e** the movement of molecules against a gradient |

**2** True or false?

Decide whether the following statements are true or false. Rewrite the false ones to make them correct.

**a** Particles always diffuse from higher to lower concentration areas.

**b** Active transport requires energy to move particles across a membrane down a concentration gradient.

**c** Some proteins carry certain molecules across cell membranes.

**3** Investigating the effect of temperature on diffusion rate.

An experiment was set up to test the hypothesis that if you increase the temperature it increases the diffusion rate. The time for a purple dye to diffuse set distances in water at different temperatures was recorded.

| Water Temp. | 2 cm | 4 cm | 6 cm | 8 cm | 10 cm |
|---|---|---|---|---|---|
| 10°C | 60 s | 114 s | 210 s | 300 s | 450 s |
| 20°C | 30 s | 66 s | 108 s | 282 s | 222 s |
| 30°C | 12 s | 30 s | 55 s | 80 s | 125 s |

**a** Plot the three sets of data on the same graph. Use a key.

**b** Do these results support the above hypothesis? Explain your answer.

**4** Investigating the importance of surface area for cells.

Raw materials enter a cell by diffusion through the cell membrane. The number of molecules which diffuse into a cell depends on its surface area. To function efficiently a cell needs a large surface area relative to its volume.

Imagine a cell is a cube with sides of 1 cm length; this ratio can be calculated using the following method:

- ❑ Surface Area = 6 x area of a single side
  = 6 x 1 x 1
  = 6 cm$^2$
- ❑ Volume = width x depth x height
  = 1 x 1 x 1
  = 1 cm$^3$
- ❑ Surface Area to Volume Ratio (SA:V) = 6:1

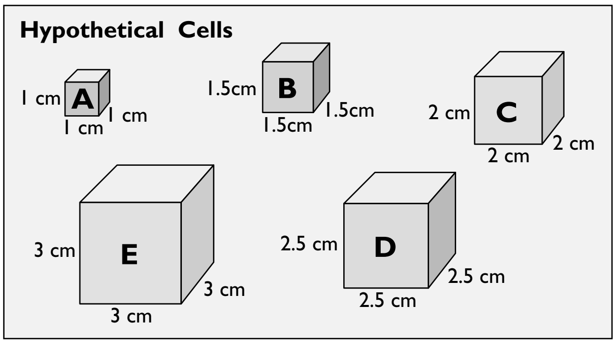



*Figure 2.13 Hypothetical cells*

a Complete the calculations in the table for each cell.

| Side | Length | Surface Area | Volume | SA:V Ratio |
|---|---|---|---|---|
| A | 1 cm | 6 x 1 x 1 = 6 $cm^2$ | 1 x 1 x 1 = 1 $cm^3$ | 6:1 |
| B | | | | |
| C | | | | |
| D | | | | |
| E | | | | |

b Plot both surface area and volume versus side length on a dual vertical axis graph. Use a key.

c As the cell sides increase in length, which increases faster – surface area or volume?

d Describe what happens to the surface area to volume ratio as the cell length increases.

e Which cell would be most efficiently supplied with raw materials by diffusion?

Cell shape may also be a factor in the SA:V ratio.

f Calculate the SA:V ratio for the cell shown opposite.

g Compare this cell with cell B above which has the same volume. Which cell will be better supplied by diffusion? Is shape important?

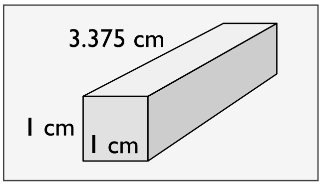



*Figure 2.14 Cell*

5 Interpreting experimental data.

The following experiment was set up to measure the effect of increasing sugar solution concentration on the rate of water uptake in potato cells by osmosis.

Five small potato cubes were weighed and put into vials which contained sucrose solutions as specified in the table.

After 24 hours the cubes were re-weighed and then the new weights were recorded.

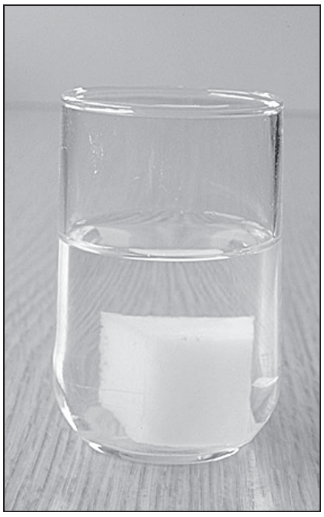


*Figure 2.15 Potato cube in solution*

$$\%\ \text{Weight Change} = \frac{(\text{final weight} - \text{original weight}) \times 100}{\text{original weight}}$$

a Calculate the percentage weight change for each potato cube using this formula:

| Cube | Sucrose Solution | Weight at start (g) | Weight after 24 hours (g) | % Weight Change |
|---|---|---|---|---|
| A | 0.0 molar | 1.2 | 1.5 | +25% |
| B | 0.1 molar | 1.4 | 1.6 | |
| C | 0.3 molar | 1.5 | 1.5 | |
| D | 0.5 molar | 1.4 | 1.1 | |
| E | 0.7 molar | 1.6 | 0.9 | |

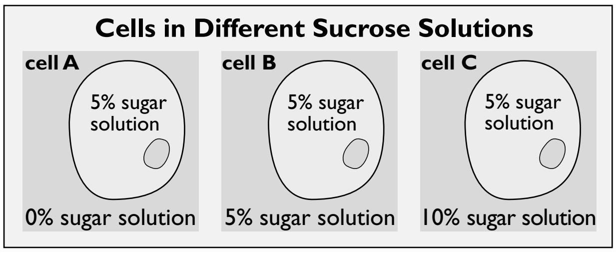
**b** Plot a graph of percentage weight change (vertical axis) versus solute (sugar) concentration (horizontal axis).

**c** Explain what this graph shows about the effect of increasing solute concentration on water movement in and out of the potato cells.

**d** Estimate the original solute concentration inside the cells.

**6** Predicting experimental results.

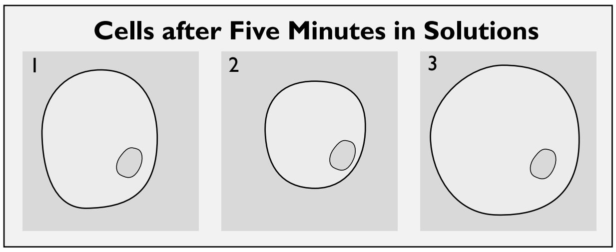
The diagram shows three cells in different sucrose solutions.




**a** For each cell indicate the overall direction water would move through the membrane (in/ out/ no net movement).

**b** For each cell indicate the overall direction in which sucrose molecules would move (in/ out/ no movement).

**c** Which of the following cell drawings would best show the appearance of each cell after five minutes?




## Activity 8 Diffusion

**Aim:** To investigate diffusion of ammonia.

**Materials:**

Ammonia solution

Timer

### What to do

Place a container of ammonia solution at the front of the room. Time how long it takes for people in each row of desks to smell the ammonia.

## Activity 9 Osmosis cup

**Aim:** To investigate osmosis in cells.

**Materials:**

Small cups cut out of a potato – 2 cm x 2 cm x 2 cm potato

Strong salt or sugar solution

Water

Beakers

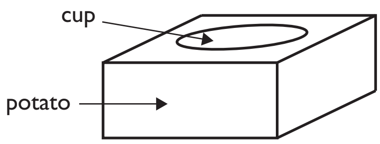
Cover for beakers, e.g. clingwrap, tin foil

### What to do

1 Set up three beakers with water to a depth of 0.5–1.0 cm.

2 Place a potato cup into each beaker.

3 Half fill one potato cup with water, one with strong salt or sugar solution and leave one empty.




4 Cover each beaker and leave for 24 hours.

5 Observe the level of the solutions in the potato cups.

6 Use what you have learned about osmosis to explain your results.

**Materials:**

Plant material such as beet root cells, rhubarb or red cabbage cells

Strong salt or sugar solution

Microscope

Microscope slides and coverslips

## Activity 10 Plasmolysis

**Aim:** To investigate plasmolysis in a plant cell.

1 Prepare one slide of tissue mounted in water and another of the tissue mounted in strong salt or sugar solution.

2 Use a microscope to compare the tissue on the two slides.

3 Draw diagrams of the cells in water and strong solution.

4 Explain your results in terms of osmosis.

# Enzymes

In this section you learn to:

- ❑ **describe** the structure and function of enzymes
- ❑ **investigate** the effect of temperature on enzymes
- ❑ **discuss** the effect of temperature on the structure and function of enzymes.

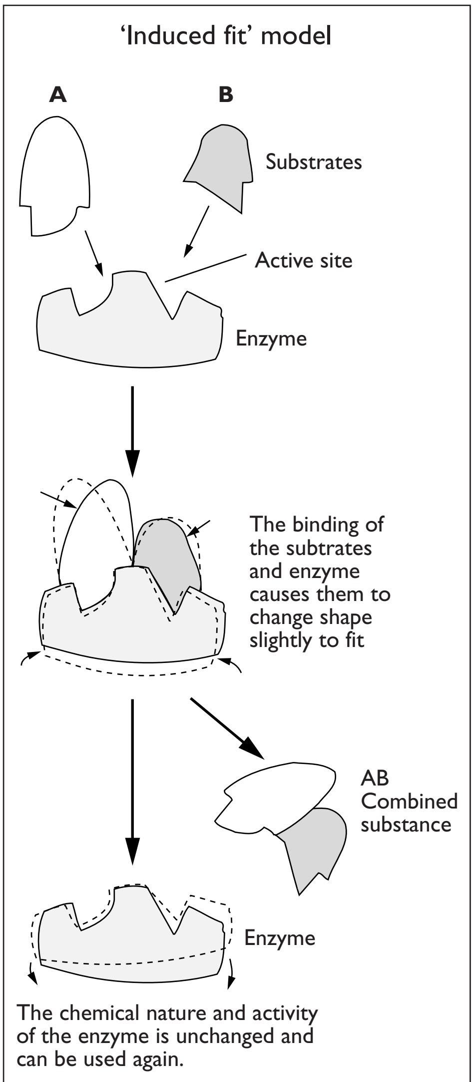



*Figure 2.16 'Induced fit' model*

**Enzymes** are called *biological catalysts* because they control the speed of all chemical reactions within our bodies. Each active cell can have thousands of different chemical reactions occurring every second. Nearly all of these reactions have to have an enzyme to help them occur. Each different chemical reaction that occurs in cells needs a different enzyme. Therefore there are thousands of different enzymes.

Some enzymes are common. For example, every living cell has a set of enzymes that control **respiration** – the reactions that release energy from food molecules. Specialised cells often have special enzymes that do a special task. For example, the plant cells in a yellow flower petal have the enzymes to make the yellow pigment (colour).

Enzymes that work inside a cell are called **intracellular** enzymes. **Extracellular** enzymes are outside the cell where they do special tasks such as digestion.

## How enzymes work

Most reactions have an **energy barrier** which must be overcome before the reaction can occur. Enzymes lower the amount of energy needed for the reaction to occur by changing the molecules involved in the reaction.

An enzyme is a special protein made up of one or more amino acid chains folded into a special shape with a pocket called an **active site**. The reactants involved in the reaction catalysed by the enzyme can fit into the active site. These reactants are called the **substrate** of the enzyme. Each of the molecules involved in chemical reactions in the cell has a specific shape, therefore each enzyme will only work with one reaction because only the substrate molecules involved in that reaction will fit into the active site. When the substrate is joined onto the active site of the enzyme, the reaction occurs quickly.

There are currently two models of enzyme activity. They are called the **lock and key** model and the **induced fit** model. The induced fit model is becoming more popular.

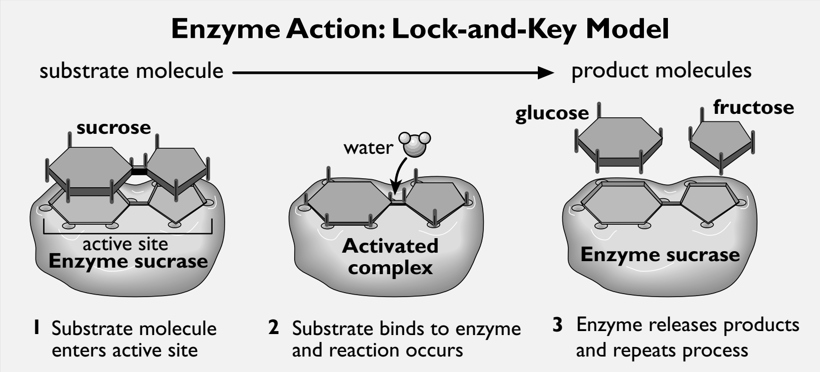
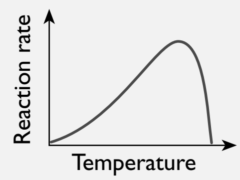



*Figure 2.17 Enzyme action*




rising temperature speeds up reaction but eventually unfolds the enzymes

*Figure 2.18 Factors affecting reaction rate*

Temperature affects the amino acid chains in enzymes. Each enzyme has a temperature at which it works best or at the optimum rate. At temperatures below the optimum, the reaction occurs slowly. At temperatures above the optimum, the temperature causes changes in the shape of the enzyme. This means that the active site is no longer the correct shape to catalyse the reaction and the rate of the reaction will slow down. At high temperatures the enzyme shape changes so much that it is said to be **denatured**, that is, it is not able to catalyse the reaction.

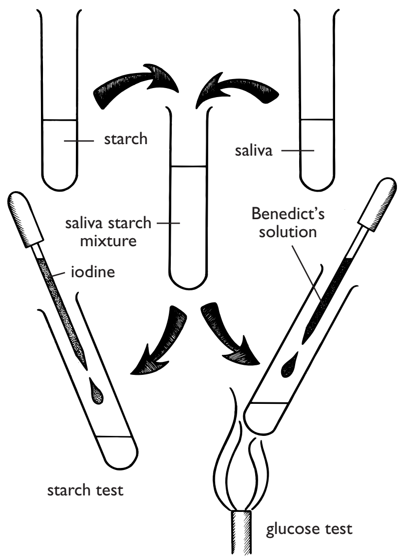
## Activity 11 Enzyme reactions

**Materials:**

- Starch solution
- Iodine
- Saliva

**Aim:** To investigate the action of an enzyme.

1. Make up a 4% starch solution by dissolving starch in boiling water. Allow the solution to cool.
2. Take a small sample of the starch solution and test it for glucose by adding two to three drops of Benedict's solution and heating it. A blue colour indicates no glucose is present.
3. Dribble some of your saliva into a small beaker and dilute it with an equal volume of water. Test a small sample of this saliva to make sure no glucose is present.
4. Mix the remaining saliva with an equal volume of the starch solution. Keep the mixture at body temperature (37°C).
5. Take samples of this mixture every two minutes and test for both starch and for glucose.
6. Write a report on this investigation.



## Activity 12 Temperature and enzyme activity

**Aim**: To plan, carry out and report on the effect of temperature on enzyme activity.

**1** Use the reaction you investigated in the previous activity as a starting point for your plan. In your plan identify the following and describe how you will use them to investigate the effect of temperature on the rate of an enzyme controlled reaction:

- ❑ independent variable
- ❑ dependent variable
- ❑ controlled variables
- ❑ repeats.

**2** Carry out your plan and collect the results.

**3** Write out a report on your investigation.

## Activity 13 Enzymes

**1** Matching terms with definitions.

| | |
|---|---|
| enzyme | **a** the amount of energy needed to start a reaction |
| catalyst | **b** a biological catalyst |
| intracellular | **c** the process of releasing energy from food using oxygen |
| extracellular | **d** the chemical that an enzyme acts upon |
| energy barrier | **e** splitting glucose into two pyruvic acids |
| active site | **f** occurs within the cell |
| substrate molecule | **g** carries small amounts of energy about cell |
| ATP | **h** occurs in the absence of oxygen |
| glycolysis | **i** results in alcohol and carbon dioxide gas |
| aerobic respiration | **j** reduces the energy barrier of a reaction |
| anaerobic respiration | **k** occurs outside the cell |
| fermentation | **l** the part of enzyme which substrate fits into |

**2** True or false?

Decide whether the following statements are true or false. Rewrite the false ones to make them correct.

**a** Each enzyme can catalyse a wide range of reactions.
**b** Without enzymes most cell reactions would not occur.
**c** Enzyme-controlled reactions slow down at temperatures above 45°C.
**d** Mitochondria contain enzymes that control the process of respiration.
**e** In exercise, a muscle can build up lactic acid due to insufficient oxygen.
**f** The alcohol produced in wine-making comes from aerobic respiration.

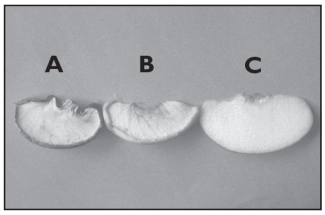


*Figure 2.19 Apple slices*

**3** Interpreting a chemical reaction.

In the photo, apple slice A was left in the air for 24 hours; slice B was boiled then left in the air for 24 hours; and slice C is freshly cut.

**a** Describe slices A, B and C.

**b** A student suggested that what happened to slice A was due to the action of an enzyme in the fruit. Do you agree? Why?

**c** Does the appearance of slices B and C support the hypothesis that enzymes are involved in slice A?

**4** Interpreting an experiment.

You can study the activity of an enzyme by using peroxidase. The peroxidase enzyme is present in most cells and it reacts with hydrogen peroxidase and rapidly breaks it down to release oxygen gas. If you place living cells in a weak hydrogen peroxide solution, bubbles of oxygen gas (froth) indicate the activity of peroxidase.

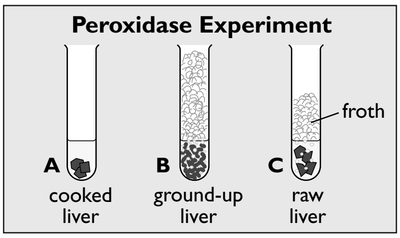
Three test tubes, each with a weak hydrogen peroxide solution, were set up as shown and left for two minutes.

**a** What do tubes B and C indicate about peroxidase?

**b** Explain the difference between B and C results.

**c** What does A show?

**d** A further tube was set up using crushed raw potato. The result was similar to C. What does this indicate about peroxidase?




Suppose you are asked to design an experiment to test the effect of increasing temperature on peroxidase from an animal liver.

**e** What temperature range (lowest to highest temperatures) would it be appropriate to test?

**f** How would you set up the experiment so you could measure the effect of increasing temperature.

The data shows the results of an experiment into the effect of temperature on enzyme action.

| Temp. | Froth Height |
|---|---|
| 20°C | 12 mm |
| 25°C | 26 mm |
| 30°C | 54 mm |
| 35°C | 73 mm |
| 40°C | 82 mm |
| 45°C | 2 mm |

**g** Plot the data on a graph.

**h** What does the graph show up to 40°C? Why does this occur?

**i** What does the graph show above 40°C? Why does this occur?

# Unit 3

# Genetics

**Genetics** is the study of **inheritance**, that is, the way in which characteristics, or distinguishing features or qualities pass from one generation to the next. This unit is divided into sections that cover cell division and inheritance.

## Cell Division

In this section you learn to:

- **explain** the relationship between chromosomes, DNA, genes and alleles
- **describe** the behaviour of chromosomes in mitosis and meiosis
- **explain** the importance of meiosis in reducing the chromosome number
- **discuss** the role of meiosis and fertilisation in mixing genetic material.

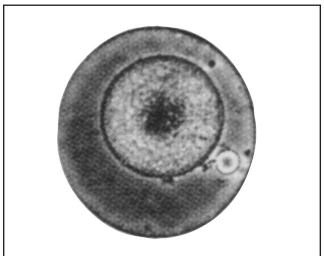


*Figure 3.1 Zygote*

### Zygotes and chromosomes

- Life begins as a single-celled **zygote** formed when a sperm fertilises an egg. The zygotes of humans, chimps and horses all look the same yet they develop into different organisms. Why?
- The zygote **nucleus** contains many **chromosomes**, and each chromosome is made of several thousand **genes**.

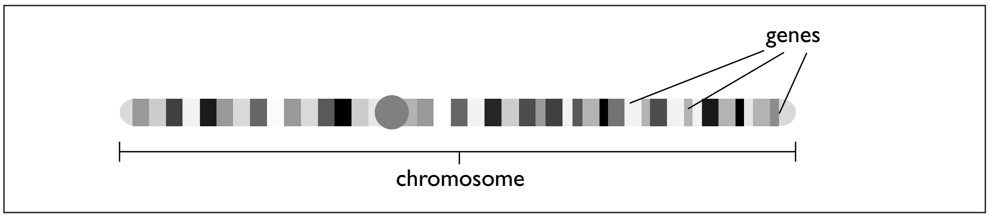



*Figure 3.2 Chromosomes*

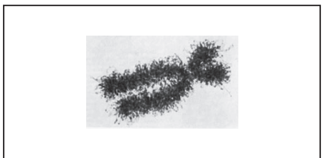


*Figure 3.3 Coiled up chromosome with a duplicate*

- All the genes in an organism's zygote are called the organism's **genome**. The genome specifies (decides in detail) what species the organism will be and its particular characteristics.
- Chromosomes are very long, thin thread-like structures which can coil up tightly into short, fat shapes. Chromosomes in this state are visible under the microscope as cells divide.
- All members of a **species** have the same number of chromosomes at the zygote stage. The number of chromosomes is always an even number, e.g. human zygotes normally have 46, chimp zygotes 48 and horse zygotes 64.

- ❑ The chromosomes in a zygote have different sizes and shapes, but they can be arranged into matching pairs. Human zygotes have 23 matching pairs. These matching pairs are called **homologous chromosomes**. One chromosome of each pair will have come from an egg and the other from a sperm. Human egg and sperm have 23 each.
- ❑ Usually you inherit two genes for each characteristic – one gene from each parent. If one of those genes is at a site on a particular chromosome, then the other gene will be found at the same site on the other homologous chromosome.

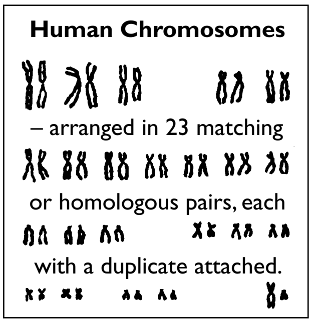



*Figure 3.4 Human chromosomes*

## Chromosomes and genes

- ❑ Chromosomes are complex structures made of molecules of deoxyribonucleic acid or **DNA** for short. How does DNA carry genetic information?
- ❑ Each chromosome is made up of two long DNA molecules. Each DNA molecule has millions of chemicals called **bases** attached at regular intervals along its length. There are only four types of bases, which are called C, G, A and T for short.
- ❑ The two DNA molecules join together to form a ladder-like structure with millions of rungs. Each rung of the ladder is formed by a pair of bases – a base on one strand is attracted to a base on the other. But C bases can only fit with G bases, and A bases can only fit with T bases.
- ❑ The scientists Watson and Crick discovered that the ladder structure is twisted into a helix (a spiral shape). As there are two DNA molecules involved they called this structure the **double helix**.

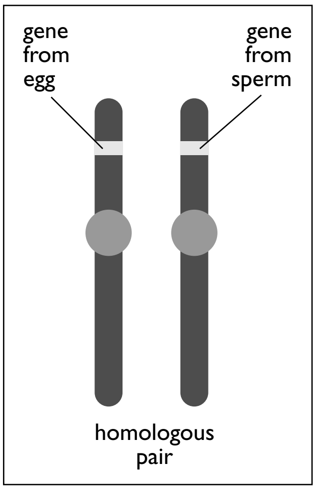



*Figure 3.5 Homologous pair*

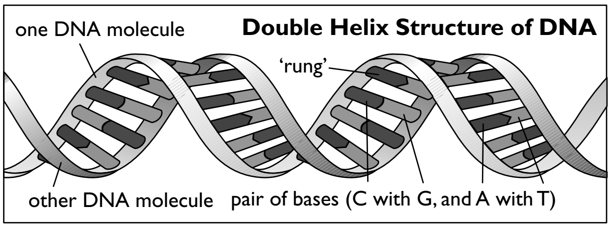



*Figure 3.6 DNA*

- ❑ Along each DNA molecule is a sequence of over a million bases, e.g. ATTCCGATGGACTCGGAATCTCTT. . . Watson and Crick proposed that a gene was actually a length of DNA several thousand bases long.
- ❑ Next, they proposed that the information carried by a gene is encoded in the sequence of bases along a section of one of the DNA molecules. Just as Morse code uses so many dots and dashes to represent a letter of the alphabet (three dots represents 's' and a dash and three dots represents 'b') so the **genetic code** uses an 'alphabet' of just four bases which are arranged in triplets (groups of three), e.g. ATT-CCG-ATG-GAC-TCG-GAA-TCT-CTT-. . .

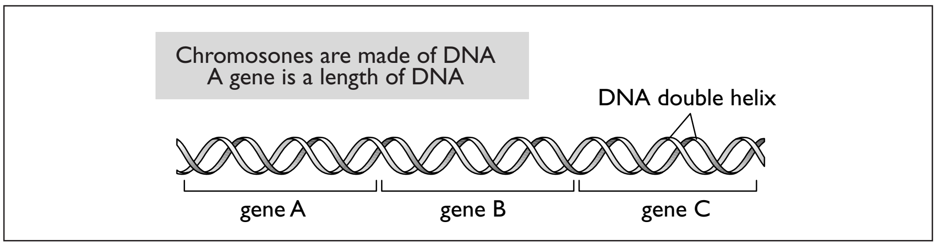



*Figure 3.7 DNA double helix*

- ❑ The unique sequence of bases that make up a particular gene decides what the structure of a unique **protein** will be. That protein then becomes part of deciding the appearance of a particular characteristic. Each of the 80 000 plus genes in your genome determines a different protein, which in turn determines the appearance of a particular characteristic (e.g. your hair or eye colour).

A gene codes for a protein which determines a trait, e.g. blue eyes.

## Mitosis

- ❑ A new organism grows from a single-celled zygote to an adult organism by **mitosis**. Mitosis is when a cell divides to make all new cells except sex cells. One cell divides into two, they each divide to give four, each of which divides to give eight and so on. Eventually, the adult organism consists of billions of body cells, each with an identical set of chromosomes (e.g. human body cells all have 46 sets of chromosomes).

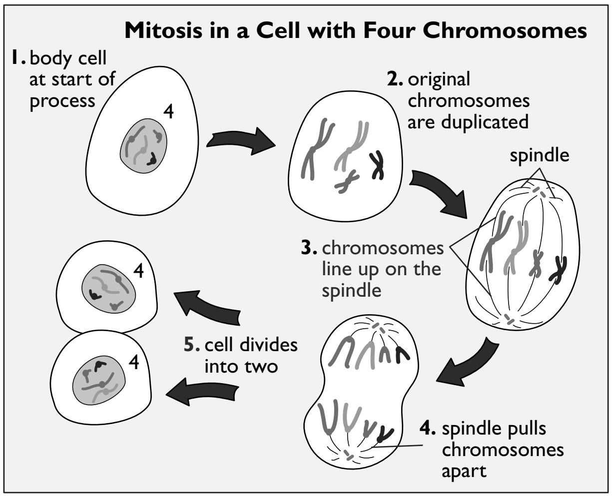



*Figure 3.8 Mitosis*

- ❑ Early in mitosis, when chromosomes shorten, each chromosome appears with an identical copy or duplicate attached. As mitosis proceeds duplicated chromosomes are separated, resulting in each new cell having an identical set.
- ❑ Mitosis takes place where new body cells are being formed.

## Passing on chromosomes

Genes pass from one generation to another on the chromosomes inside the **gametes** (egg and sperm). Gametes are formed by the process of **meiosis**, which occurs in a woman's ovaries and a man's testicles. Gametes have half the number of chromosomes that body cells have and each gamete has a different collection of chromosomes.

## How does meiosis achieve this?

Meiosis consists of two cell divisions which result in four gametes. During meiosis the original cell divides twice but the chromosomes are duplicated only once, so gametes end up with half the normal number of chromosomes. The chromosomes are duplicated early on. Duplication of chromosomes involves DNA self-replication.

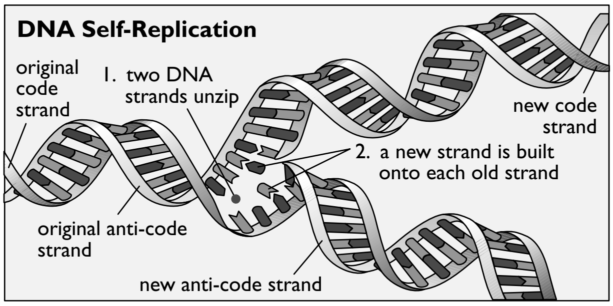



*Figure 3.9 DNA self-replication*

- In the first division (first stage) homologous chromosomes separate. First they are brought together and lengths of chromosomes are swapped. The chromosomes then pull apart so that the two new cells get one chromosome from each homologous pair. As members of pairs randomly separate each new cell has a different collection of chromosomes.
- In the second division (second stage) the duplicated chromosomes separate so there are gametes with only half the number of chromosomes as body cells. Because each gamete gets only one chromosome from each homologous pair, a gamete will have only one gene for each characteristic. But a zygote will have two at fertilisation.

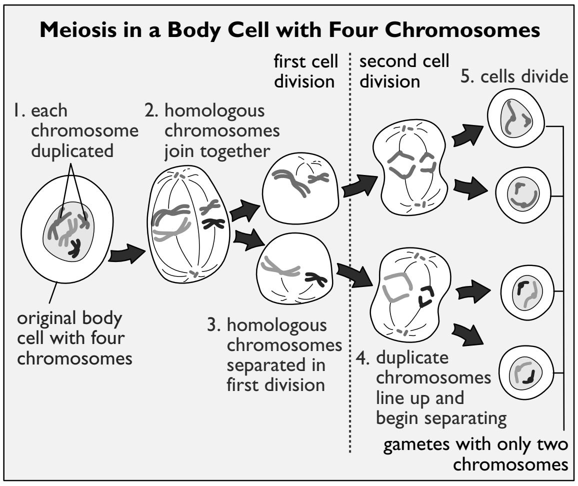



*Figure 3.10 Meiosis in a body cell with four chromosomes*

Remember: **mitosis** is a cell division which produces all new cells except sex cells and **meiosis** is cell division which produces sex cells.

The following table compares the processes of mitosis and meiosis.

| | Mitosis | Meiosis |
|---|---|---|
| Number of cells produced | 2 | 4 |
| Number of chromosomes | Daughter cells have the same number of chromosomes as the first cell | Daughter cells have the half the number of chromosomes as the first cell |
| Number of division | One | Two |
| Occurs in | Some body cells of adult animals (e.g. skin) but not others (e.g. nerves) | Only occurs in the reproductive organs, ovary and testis |
| Purpose | Growth, repair and replacement of cells | To produce gametes |

Meiosis produces gametes with only half the normal number of chromosomes. Gametes must have half the number of chromosomes so that when fertilisation occurs, and the genetic material from an egg and a sperm come together in the zygote, the zygote will have the correct number of chromosomes.

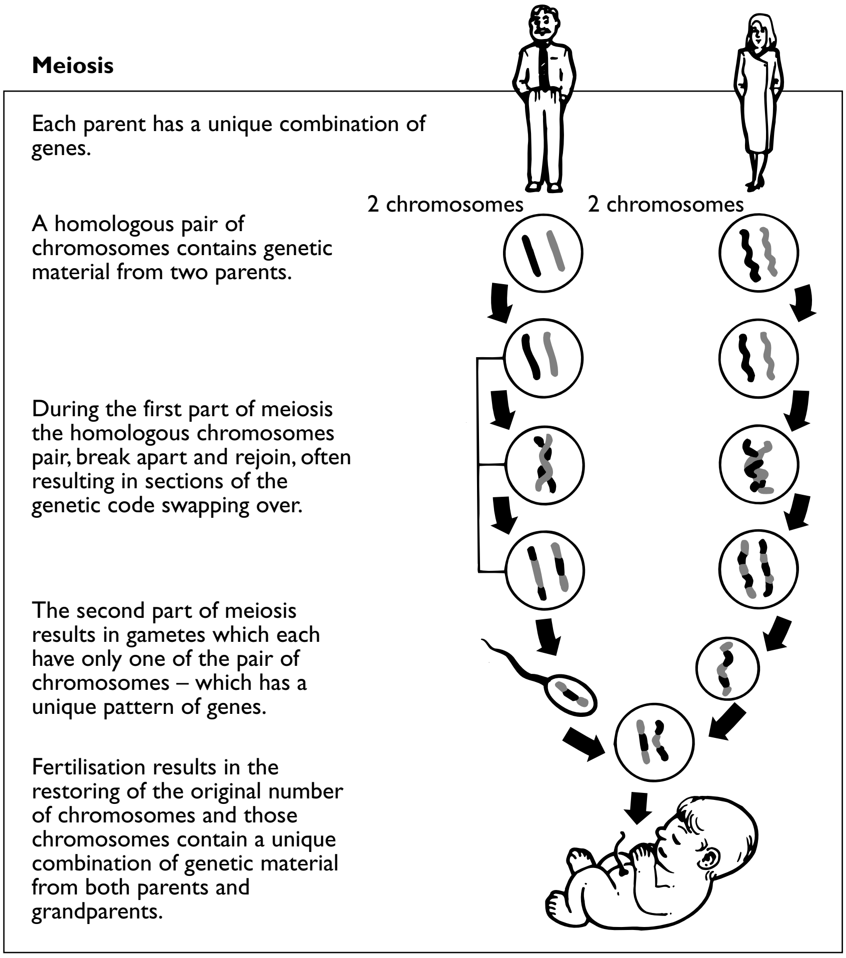



*Figure 3.11 Human life cycle*

## Activity 1

**1** Match up definitions with terms.

| | |
|---|---|
| zygote | **a** the shape which two DNA molecules form together |
| nucleus | **b** special sex cells with half the normal number of chromosomes |
| chromosomes | **c** the total collection of genes possessed by an organism |
| gene | **d** the molecules which chromosomes are made out of |
| genome | **e** genes are expressed through these molecules |
| characteristic | **f** a group of similar organisms able to interbreed successfully |
| species | **g** the long, thread-like structures which carry the genes |
| DNA | **h** the ability of DNA to make duplicate copies |
| homologous chromosomes | **i** cell division which produces four gametes each with half the normal number of chromosomes |
| bases | **j** a pair of chromosomes, one of which came from each parent |
| double helix | **k** the first cell of an organism after a sperm fertilises an egg |
| genetic code | **l** cell division which gives two cells with identical chromosomes |
| proteins | **m** the feature of an organism which is determined by genes |
| mitosis | **n** these form the units of the genetic code |
| self-replication | **o** the structure within a cell which contains the chromosomes |
| gametes | **p** the code which is used to specify information carried by genes |
| meiosis | **q** an inherited object which determines the appearance of a characteristic |

**2** For each of these points explain the difference between the terms.

**a** gene and genome
**b** identical and homologous chromosomes
**c** body cells and gametes
**d** mitosis and meiosis.

**3** Copy and complete the table then answer the questions below.

| | Number of Chromosomes in . . . | | | |
|---|---|---|---|---|
| **Species** | **Egg** | **Sperm** | **Zygote** | **Body Cell** |
| humans | 23 | 23 | 46 | 46 |
| chimps | 24 | 24 | 48 | |
| horses | | 32 | 64 | |
| dogs | | | 78 | 78 |
| cats | | 19 | | |

a What process makes sure that gametes have half the number of chromosomes compared to body cells?

b What process makes sure that a zygote has twice as many chromosomes as gametes?

c What process makes sure that body cells have the same number of chromosomes as the zygote?

4 Decide whether the following statements are true or false. Rewrite the false ones to make them correct.

a In sexual reproduction a zygote is the first stage of a new organism.

b Your genome is the complete collection of genes that were in your zygote.

c All species have the same number of chromosomes.

d All members of a species have the same number of chromosomes in each of their body cells.

e Normally you have two genes for each characteristic, one inherited from each parent.

f Chromosomes are made of DNA and a gene is a length of DNA.

g The genetic code uses an 'alphabet' of four bases which are arranged into three-letter 'words' called triplets.

h Genes are expressed (that is, produce an effect) through proteins which determine the appearance of a characteristic.

i Chromosomes are duplicated by the process of DNA self-replication.

j Mitosis produces four gametes with half the normal number of chromosomes.

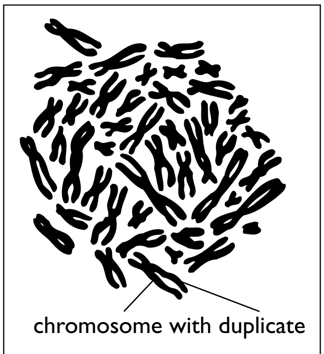



*Figure 3.12 Chromosome with duplicate*

5 The diagram opposite shows the chromosomes in a body cell early on in mitosis cell division. Note that each chromosome has a duplicate attached.

a What type of organism is this body cell likely to come from? How do you know?

b Why have the chromosomes been duplicated?

c How many duplicated chromosomes are there in total?

d What produced the duplicated chromosomes?

e After cell division, how many chromosomes will each new cell have?

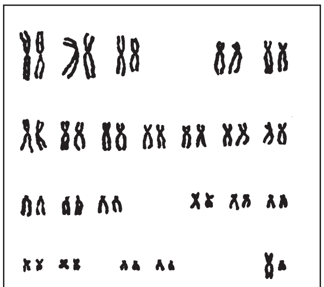


*Figure 3.13 Matching chromosomes*

6 The chromosomes in Figure 3.13 were cut out and arranged into matching pairs as shown in this diagram.

a How many pairs are there?

b What features are used to match up the chromosomes?

c What are these pairs of chromosomes called?

d Where did each member of a pair originally come from?

e Which pair is strange? Why?

7 Label structures **a)** to **e)**, then answer the questions below.
  **f** What type of cell division is shown?
  **g** How do you know?
  **h** What has happened to the chromosomes by stage B?
  **i** What is happening to the chromosomes at stages C and D?
  **j** What two statements can you make about the chromosomes in the two cells shown at stage E? (number and nature)

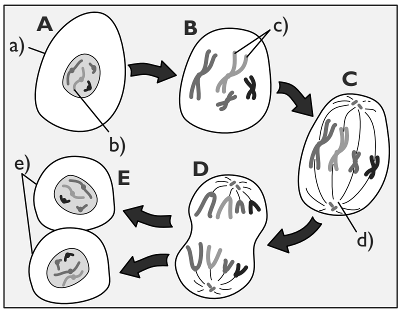



*Figure 3.14 Chromosomes*

8 Label structures **a)** to **e)**, then answer the questions below.
  **f** What type of cell division is shown?
  **g** How do you know?
  **h** Where would this process be taking place in male and female animals?
  **i** What has happened to the chromosomes by stage A?
  **j** What is happening to homologous chromosomes in stage B?
  **k** What type of chromosome pairs have separated by stage C?
  **l** What type of chromosome pairs are separating at stage D?
  **m** What two statements can you make about the chromosomes in the four cells shown at stage E compared to the chromosomes in the original cell? (number and nature)
  **n** If this process was occurring in a male what would the four cells produced be called?

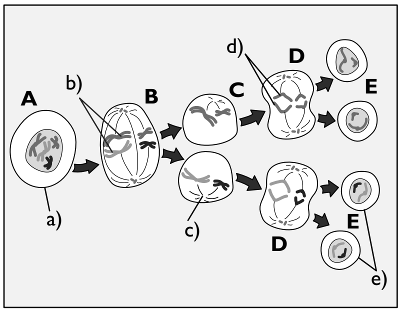



*Figure 3.15 Cell division*

9 Read the passage below, then answer the questions.

## The human genome project

The Human Genome Project aimed to identify all of the 30 000 genes that humans possess and to determine the sequence of the three billion base pairs that make up human DNA.

A genome is all the DNA in an organism at the zygote stage. This DNA contains coded information for all the genes, but much of the DNA is redundant (having more than it needs) and does not code for anything. So sequencing all of the DNA takes much longer than finding the location of the genes.

The DNA is found in the 23 pairs of chromosomes that all human body cells have. Teams of geneticists sequence the DNA of different chromosomes or sections of chromosomes.

DNA is made up of four bases (C, G, A and T) that are repeated millions of times in the genome. The order of Cs, Gs, As and Ts is important. It decides if an organism is human or another species.

Because each person's genome is unique (except for identical twins) and samples from different people will be used, the reference genome will not be an exact match for any one person's genome. Geneticists estimate that we differ in about 0.1% of our three billion base pairs.

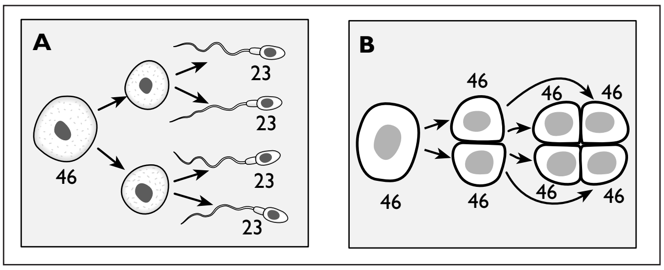
Genes are lengths of DNA several thousand bases long and they code for all the proteins in the body. These proteins determine the structure, appearance and functioning of our bodies.

Scientists isolate a protein and, from the way it is composed they identify the sequence of bases of the gene. The task of the scientist is called 'sequencing'. The scientists identify which chromosome carries that sequence and where along that chromosome the sequence is. Because each chromosome is millions of bases long, this is a difficult task.

The first stage of the Human Genome Project, which was to determine the sequence of the 3 billion base pairs that make up human DNA, was completed in June 2000.

- **a** What are the two aims of the project?
- **b** If we have about 30 000 genes and 23 distinct chromosomes, on average how many genes does a chromosome carry?
- **c** If there are 3 000 000 000 base pairs in the genome – on average how many base pairs long will a chromosome be?
- **d** What units are used in the genetic code?
- **e** Why will the reference genome not be any one particular person's?
- **f** What percentage of the reference genome will be common for everyone?
- **g** How do geneticists map where the gene for a particular protein is located?
- **h** When was the sequencing of the base pairs completed?

**10** Study the diagrams below showing the processes of meiosis and mitosis, then answer the questions underneath.




- **a** Why are these diagrams likely to be of human cells?
- **b** Give two reasons why diagram A shows meiosis, and two reasons why diagram B shows mitosis.
- **c** What are the functions of mitosis and meiosis?

# Inheritance

In this section you will learn to:

- ❑ **investigate** examples of continuous variation and discrete variation
- ❑ **compare** continuous variation and discrete variation
- ❑ **solve** monohybrid inheritance patterns involving complete dominance and sex determination, e.g. punnett squares, family trees, resource material
- ❑ **explain** the role of the X and Y chromosomes in determining the sex of the individual
- ❑ **discuss** examples of inheritance patterns in terms of: characteristics, traits, genes, alleles, dominant alleles, recessive alleles, genotype, phenotype, homozygous, heterozygous.

## Variation

The range of variation among living things is so enormous that at first you might think there is no pattern to it. One role of science is to measure things and try and find patterns that help us to understand the world around us. Measuring variation and recognising patterns has led to some important scientific discoveries.

### Samples

When you measure variation patterns your first job is to make sure that your sample is large enough. The size of your sample to be measured must be large so that if you add more numbers to it there is very little difference to the pattern that has appeared. Once this meant that plotting data was a huge task. Now the use of computers makes the handling of large numbers much easier.

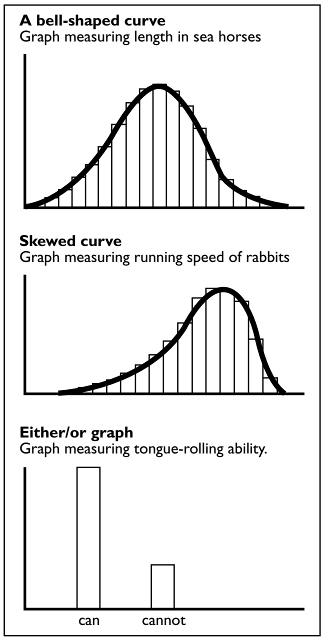



*Figure 3.16 Bell curves*

### Bell-shaped or 'normal' curves

Scientists found that when data on variations is plotted it so often forms a curve the shape of a bell that this pattern became known as a 'normal' curve. This shows that the greater the variation from the average the less often it occurs (Figure 3.16).

Sometimes the curve of variation may be skewed which shows that most individuals' variations are nearer to one end of the range of variations. See Figure 3.16.

### Either/or variations

You probably know from earlier studies that not all variations follow a wide range. Some features are quite clear-cut. They are either one or the other of two possibilities. In humans some of the best known examples of either/or variations are tongue-rolling ability and earlobe shape (fixed or free).

It was the recognising of either/or patterns like these that led to the first breakthrough in understanding how inheritance works. It has also led to our being able to predict inheritance patterns. For example, you can predict that in any class of 30 students three people are left-handed. Does this fit in your class? You may find your sample size is too small. However, in the whole population the ratio has been found to be 1 in 10. So how many left-handers would you expect in a school of 800 students?

## Activity 1 Interpreting variation

From the information on this page and your own knowledge try the following:

**1** Divide the following human variations into *either/or* and *gradual* variations: eye colour, skin colour, cleft chin, freckles, length of index finger, sex.

**2** Think of reasons why a population of rabbits shows a skewed curve, when their speed of running was measured.

**3** Draw frequency graphs that you would expect for the following (put range of variation on the horizontal axis and numbers on the vertical axis):

**a** body length in ulava'i or freshwater shrimps

**b** flower colour in poppies (orange through to yellow)

**c** coconut tree height in a plantation grown naturally

**d** coconut tree height in a population grown from genetically selected ones for tallness.

## Activity 2 Patterns of variation

This activity is to measure variation in a large sample.

When you study patterns of variation you need plenty of data to make sure that any patterns that you find are not too influenced by chance. With computers as a tool to cope with large volumes of data, teams of people can investigate very large samples quite easily.

**1 Choose the investigation topic**

Discuss with your teacher the example of variation the class wishes to measure. You need a type of continuous variation for which you can obtain large numbers of samples quite easily (e.g. leaf size in one species of shrub in the school grounds or the height or weight of students in the school).

**2 Work out the measurement details**

Decide exactly what you are going to measure. The whole class must use the same units and must use the same size groups so everybody's results can be compared.

**3 Set up research teams**

Divide the class into six research teams.

**4 Gather the data**

Each team must have four separate sets of data – numbered 1 to 4.

**A** *Data collectors* – should measure the samples.

**B** *Data recorders* – should fill in a separate record table for each collector and add up the totals.

**C** *Data processors* – should calculate means for individual collections and for the team.

**5 Draw graphs**

Draw graphs of the data from each person in your team.

**6 Analyse the data**

❑ Compare the results of one collector in your team with the other collectors in your team and with the collectors in other teams. How does the overall mean for one collector compare with the team and class mean?

- ❑ Use the graphs that show the measurements for increasing numbers of collectors. What happens to the results when the number of collectors increases?
- ❑ When the graph stops changing greatly, even after more collectors are added, you have reached the minimum size for an accurate sample. What number of sample collectors is needed?

7 **Present the results**

Make a display of your results for the class or Science Department noticeboard. Make sure students from other classes who look at the display will understand exactly what you did and what you found out.

**Regular ratios**

When scientists analysed clear-cut variations they began to understand how inheritance works. They saw that inheritance follows definite rules. Often when they counted large samples they saw quite clear ratios. For example if green and blue budgies are mated, about three out of four of the offspring will be green with only about one in four blue. We can also predict that the ratio of tongue rollers to non-tongue rollers in a class will be 3:1. Do pairs of either/or ratios always follow a regular pattern?

## Activity 3 Either/or ratios

1 **Class ratios**

In your class check if:

**a** The ratios of tongue rollers to non-tongue rollers will be approximately 3:1.

**b** The first of the following is more common than the second:

free ear lobes / fixed ear lobes

straight thumb / hitchhiker's thumb

straight hairline / widow's peak.

## Activity 4 Our ancestors exploit variation

1 How would a dog have been useful to prehistoric hunters?

2 How would the planting of crops have affected the lifestyle of people?

3 How would the early farmers have been able to improve the quality of their sheep and cattle?

4 Name a plant that was brought from America and is now an important crop in Sāmoa.

5 Choose a modern domesticated (tame) animal. Use three columns and list:

**a** the original characteristics that caused it to be domesticated

**b** the characteristics that would have been culled out

**c** the characteristics that would have been selected for.

6 Wild strawberries are tiny, rather tasteless fruit with lots of seeds. Draw diagrams of wild and farmed strawberries and label them to show the difference selection has made. Underneath the diagram write down any difficulties the cultivated strawberry may have.

7 Modern wheat has been selected for many years. List features that would make it difficult to survive in the wild.

**8** The following are data on hair colour that a student collected from other students. Complete the table by calculating the percentages, then plot those percentages on a pie graph. (Remember: 10% = 36°)

| Hair Colour | Number | % of Class |
|---|---|---|
| brown hair | 13 | |
| black hair | 7 | |
| blonde hair | 3 | |
| auburn hair | 2 | |

**a** What type of variation is shown by this trait?

**9** Read the passage below, then answer the questions.

## The cloning of Jill the calf

- ❑ On 16 April 1998 the New Zealand scientist Dr. David Wells from the Agresearch centre at Ruakura announced the first successful cloning of a calf in the Southern Hemisphere. Born in March 1998, Jill the calf is the offspring of a single 'parent'.
- ❑ The team used methods pioneered by Scottish scientists who cloned the first mammal in 1997.
- ❑ Jill's 'parent' was not an adult cow but a 34-day old embryo. A body cell was removed from this embryo and the nucleus extracted. The nucleus contained all the chromosomes of the 'parent'. An unfertilised egg was taken from an adult cow and the nucleus of the egg removed and discarded. This egg no longer contained any chromosomes.
- ❑ The nucleus from the body cell of the embryo was then inserted into the 'empty' egg. This egg now had all of the 'parent' embryo's chromosomes.
- ❑ The egg was subjected to an electrical current which started cell division. After multiple divisions, the egg developed into a new organism made of millions of cells. Each cell had a set of chromosomes identical to those the 'parent' embryo possessed.
- ❑ Growth and development continued as normal. Cells specialised and developed into tissues. Eventually Jill the calf was born.
- ❑ If scientists can apply the technique to many body cells from a single embryo, then they could rapidly clone herds of identical cows.

**a** What does the term 'cloning' mean?
**b** Why is cloning a method of asexual reproduction?
**c** Is cloning a natural or artificial method?
**d** What was in the nucleus extracted from a body cell of the embryo?
**e** Why was the nucleus of the unfertilised egg discarded?
**f** What process made sure that all Jill's cells contained an identical set of chromosomes?
**g** How could a scientist produce a cloned herd?
**h** What might the potential benefits be of a cloned herd of animals?
**i** Why do many people object to the idea of cloning humans?

**10** Below are the left foot lengths of 40 students. Copy and complete the table by adding up the tally for each length interval. Put the data on a bar graph, then answer the questions below.

| Length (cm) | Tally | Number |
|---|---|---|
| 12.0–14.9 | ✓ | |
| 15.0–17.9 | ✓✓✓ | |
| 18.0–20.9 | ✓✓✓✓✓✓✓ | |
| 21.0–23.9 | ✓✓✓✓✓✓✓✓✓✓✓ | |
| 24.0–26.9 | ✓✓✓✓✓✓✓✓✓ | |
| 27.0–29.9 | ✓✓✓✓✓ | |
| 30.0–32.9 | ✓✓✓✓ | |
| 33.0–35.9 | ✓ | |

**a** Is this an example of either-or, multiple or continuous variation?

**b** What sort of shape does your graph have?

**c** What is the mode (most frequent measurement) of the data?

**d** Do you think differences in foot length are because of acquired or inherited variation? (Give a reason for your answer.)

**11** Plotting variation.

These are the heights of 18-year-old students.

| Height Range | Number |
|---|---|
| 148–151 cm | 1 |
| 152–155 cm | 4 |
| 156–159 cm | 4 |
| 160–163 cm | 8 |
| 164–167 cm | 11 |
| 168–171 cm | 18 |
| 172–175 cm | 12 |
| 176–179 cm | 7 |
| 180–183 cm | 2 |
| 184+ cm | 1 |

**a** Draw a bar graph of the data. Describe the distribution of heights.

**b** What type of curve is the graph like?

**c** Is height a continuous or discrete variable?

**d** Since the start of the 20th Century, the average height of adults has steadily increased. Do you think this is due to inheritance or upbringing? Give your reasons.

**12** Interpreting variation.

About 75% of humans are right-handed, another 15% are predominantly right-handed and 10% are predominantly left-handed. Right-handed parents usually have right-handed children. For left-handed parents, half of the children tend to be right-handed and the other half left-handed.

**a** Is handedness continuous or discrete variation?

**b** What evidence suggests that handedness is inherited?

The current view is that it is because of a single gene. The dominant gene R+ strongly tends to cause right-handedness, but the recessive form of the gene R– causes no bias in handedness.

**c** Why would a person with just one R+ gene be right-handed?

**d** What genotype do left-handed people have?

**e** Why can offspring of left-handed parents be either left- or right-handed?

**f** Why are large numbers studied?

*Figure 3.17 Sweetpea*

## The study of genetics

At least 8000 years ago humans were already improving crops by selecting good examples from existing crops. However, the plants selected were often the result of variation in environmental conditions and their features were not inherited. In the 18th Century many plant breeders developed a method called **hybridisation**. If they artificially crossed varieties of self-pollinating plants and then selected the offspring for a number of generations they could produce stable forms that had improved features from both parents.

The breeders noticed that they produced a generation by cross-fertilisation that was fairly uniform but later generations were variable. They could not explain why.

### Gregor Mendel (1822–1884)

The real breakthrough in our understanding of inheritance first came when a monk named Gregor Mendel tested his ideas about the natural laws of inheritance in experiments which he carried out in a very careful, patient and scientific way.

Mendel was a teaching monk who worked in the monastery garden. He chose garden peas for his experiments. This was a good choice because garden peas are normally self-pollinated plants and Mendel could artificially cross two varieties. He could then follow the inheritance of their characteristics in future generations without worrying that stray pollen from other plants might complicate results.

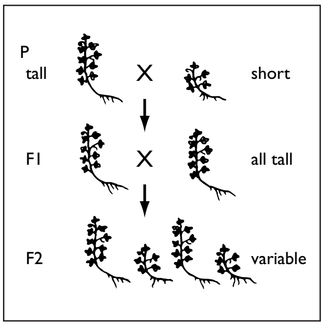



*Figure 3.18 Inheritance*

Mendel also was lucky he chose the garden pea because at that time existing varieties showed seven pairs of contrasting characteristics (such as tall or dwarf plant height and smooth or wrinkled seeds) which were inherited in a way that was straightforward and easy to observe. But it wasn't because Mendel was lucky that he discovered the key to inheritance. You can see his careful, logical and scientific approach in the following list of ideas that he used in planning his experiments.

## Mendel's ideas

- ❑ Find distinctive either/or traits like tall and short in peas.
- ❑ Look at one characteristic at a time to start with.
- ❑ Use plants to work out the rules because pollination can be controlled.
- ❑ Use large numbers of identical matings to minimise chance effects.
- ❑ Analyse the results mathematically and look for ratios.
- ❑ Use the ratios to predict the outcome of further crosses to check the theory.

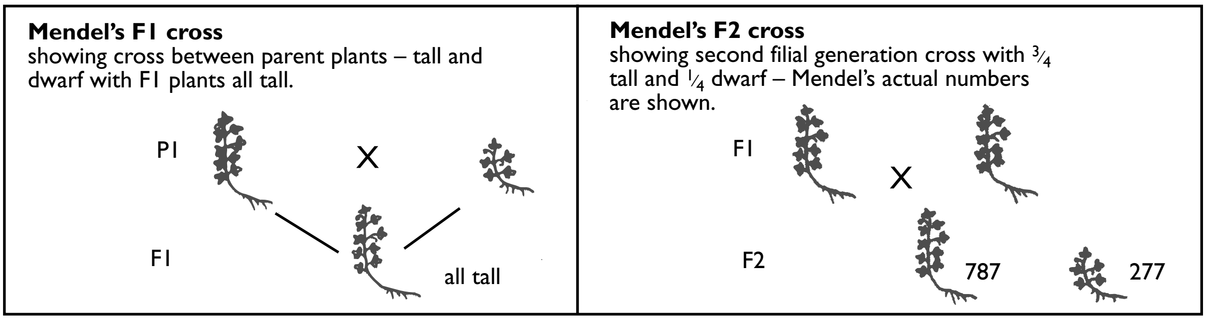



*Figure 3.19 Mendel's F1 cross*

## Mendel's F1 cross

One of Mendel's experiments was a study of height in peas. This is called a **monohybrid** cross because there is only one set of contrasting traits (i.e. height – tall or short). His first parent or **P1** plants were pure-breeding tall and short peas. He took pollen from large numbers of the tall peas and used it to cross-pollinate the dwarf ones. The dwarf ones had had their stamens removed so could not self pollinate.

When he grew the seeds, he found that the plants were all tall. These offspring were the **first filial** or **F1** generation (filial refers to son or daughter). He concluded that tall was **dominant** over dwarf and gave the tall traits the symbol capital letter T and the dwarf small t. In about 1910 scientists began referring to traits – either **dominant** or **recessive** – as **genes**, and contrasting genes controlling the same trait set were termed **alleles**.

## Mendel's F2 cross

Mendel allowed the peas in the F1 generation to self-pollinate and collected their seed. When this **second filial** or **F2** generation matured, he found that three-quarters of them were tall and one-quarter were short, a ratio of 3:1. There were slightly more than 1000 plants in this sample. Imagine Mendel's patience in growing and analysing this many plants! This result showed that the dwarf allele was not lost. It also showed there were no 'in between' types. He concluded that each pea had two factors or alleles for height, one inherited from each parent. These two alleles formed a gene pair. The **gametes**, the reproductive or sex cells, each carried one of these alleles.

The **genotype** (structure of the alleles) of the F1 tall plants were different from the alleles of the P1 (parent) tall plants and pure-breeding dwarf plants were said to be **homozygous** (*homos*, same) because each has two identical height alleles, TT and tt. The F1 plants resulting from the first cross got one tall allele, T, from the pollen of the tall plant and one dwarf allele, t, from the ovule of the dwarf plant. Their genotype Tt was **heterozygous** (*heteros*, different).

Mendel carried out similar breeding experiments in which he used the other six contrasting gene pairs in peas and in each case he got a similar pattern of results. He later extended his work to find out how more than one set of traits were inherited at one time. All this research allowed him to formulate some rules which we now call Mendel's Laws. These allowed the outcome of crosses to be predicted when inheritance of a trait is uncomplicated.

Mendel published his results in a little-known journal in 1865 and at the time their importance was not recognised. It was not until the early twentieth century, after Mendel's death, that other people rediscovered his work. Inheritance is seldom as simple as in Mendel's examples, and genes are often affected by other genes and by other factors. However his work gave plant and animal breeders important information to work from. It was a great scientific discovery.

*Table 3.1 Results from Mendel's breeding experiments*

| Parent traits | F2 (second generation) nos. | Ratios |
|---|---|---|
| tall x short stems | 787 long : 277 short | 2.84:1 |
| yellow x green seeds | 6022 yellow : 2001 green | 3:01:1 |
| round x wrinkled seeds | 5474 round : 1850 wrinkled | 2.96:1 |
| green x yellow pods | 428 green : 152 yellow | 2.82:1 |
| axial x terminal flowers | 651 axial : 207 terminal | 3.14:1 |
| inflated x constricted pods | 882 inflated : 299 constricted | 2.95:1 |
| red x white flowers | 705 red : 224 white | 3.15:1 |

## Activity 5 Interpreting Mendelism

**1** The rules about inheritance are not difficult, but you need to understand all the technical terms. Write down definitions of each of the terms in bold type. (Use the glossary in this book or a dictionary if you are stuck.)

**2** Mendel made his breakthrough discoveries because he used good scientific methods. Explain how:

- **a** he was patient
- **b** he used scientific methods
- **c** he analysed his results carefully by using his mathematical skills
- **d** he reduced the possibility of chance results
- **e** he had some luck.

**3** How can you check to see if he invented his results?

**4** Write a sentence to explain why it was important that the environmental conditions did not vary much in the monastery gardens where Mendel grew his plants.

**5** From the table of Mendel's results work out the average ratio for the seven experiments. None of these ratios is exactly 3:1. Explain why these results are good evidence that a prediction of 3:1 is pretty accurate.

**6** In your group, design and carry out an experiment of tossing a coin to get heads or tails, to test that the effects of chance reduce as the sample size increases.

Mendel's experiments showed that traits may be in pairs, that one trait is more powerful than the other, and that traits are inherited by chance from each parent. We can show that the laws of chance operate in the pea traits that Mendel measured without having to do all the work that he did.

*Table 3.2 Dominant and recessive alleles*

| Dominant trait and allele | Recessive trait and allele |
|---|---|
| Round seed, R | Wrinkled seed, r |
| Inflated pods, I | Constricted pods, I |
| Yellow seeds, Y | Green seeds, y |
| Coloured seed coat, C | White seed coat, c |
| Axial flowers, A | Terminal flowers, a |
| Green pods, G | Yellow pods, g |
| Tall plants, T | Dwarf plants, t |

Note that the symbol for each trait is a letter – the same letter for each trait but shown as a capital if the trait is *dominant* and a small letter if it is *recessive*.

## Activity 6 Card game: Inheritance in peas

Play these games in pairs. Play them on the grid of 25 squares that you create. The five squares across, and five squares down. Cards with pictures represent the pea traits.

Each group of two players chooses one of the contrasting pea traits that Mendel studied. These are shown in the table above.

### Game One

**Testing for dominance**

1 Each pair of players chooses a pair of contrasting traits.

2 One player makes 20 cards for the dominant allele while the other makes 30 for the recessive allele. Keep 10 of the recessive cards aside for the second board game, the test cross.

Each card is to be no bigger than the grid spaces that are created.

3 On each card choose a bright symbol for the dominant allele and a dull one for the recessive allele. Write the allele symbol in a large letter on each card, with dominant symbols in capitals and recessive symbols in small letters.

4 Your cards now represent Mendel's parent (P1) generation and each card is a sex cell or gamete.

5 Each of you shuffles your cards and deal one card onto each square.

6 Place any dominant cards on top.

7 Copy the tally sheet on the following page and enter the appearance or phenotype of these F1 offspring.

8 Now take half of the offspring each and shuffle them. You are now acting as if you are the self-pollinating P2 (second generation) parents.

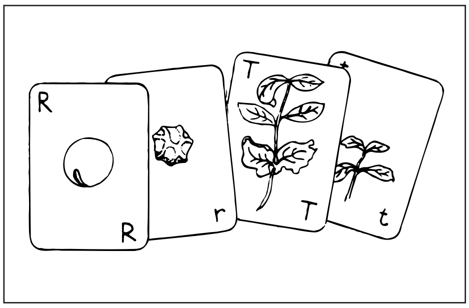



*Figure 3.20 Games cards*

**Tally Sheet**

| Dwarf | Tall |
|---|---|
| F1 | |
| F2 | |
| F2 | |
| F2 | |
| F2 | |
| F2 | |
| Total for 100 | |
| Ration | |

*Figure 3.21 This is an example of the score sheet that you will need to record your results. Copy it, but do not write on it.*

9 Shuffle and deal your cards, or sex cells, as before. Add up your F2 phenotypes.

10 Repeat this procedure five times so that your results represent 100 crosses. Alternate the alleles you start off with.

11 Add up the totals for the phenotypes of the F1 and F2 generations and express them both as percentages and as the nearest simple ratio.

12 SUMMARY: Discuss the outcome of the game as a class and find out if each group got similar results. Write down what this suggests to you about Mendel's interpretation of his results.

## Game Two

### Testing for hidden alleles

Phenotypes were all Mendel could see. He could tell that individual F2 plants with the dominant trait had at least one dominant allele. But he could not tell if there were two dominant alleles or if one was a hidden recessive allele. However if his theory about alleles was correct there was a way of checking.

He could do a test cross or a back cross. This is what Game Two does.

1 The player representing dominant must decide to be either homozygous or heterozygous. Choose 20 cards to represent sex cells from this individual (20 dominants for homozygous or 10 of each for heterozygous).

2 The other partner represents a homozygous recessive and needs 20 recessive cards. You may need the extra 10 cards.

3 Each shuffle your cards and deal one onto each square of the grid. Tally the phenotypes.

4 Repeat the game, this time using the other dominant phenotype (the one not chosen in No. 1). Cross it with the homozygous recessive as you did last time and tally your results on a tally sheet.

SUMMARY: Discuss the outcome of the second game in class. Did all pairs get the same results?

### Questions

1 What does the appearance of even one recessive offspring tell you about the genotype of the dominant parent for this trait?

2 Can a homozygous dominant parent ever have offspring that are recessive for this trait?

3 Why do we need to study large numbers in genetic studies?

4 If you plant seeds labelled F1 would you expect seeds collected from them to breed true? Explain your answer.

5 Why do you always use a homozygous recessive for a test cross?

## *Genetics rules*

1. A pair of genes contributes traits.
2. Genes for the same characteristic are called alleles.
3. Dominant alleles hide recessive ones.
4. Phenotype describes the way a characteristic appears.
5. Genotype lists the alleles present, three possible ways two alleles can combine in cells.
6. Sex cells or gametes have one allele for each characteristic.
7. In a test cross, dominant phenotypes cross with recessive. Recessive offspring show that the dominant has a masked recessive allele.
8. In heterozygous individuals one allele is dominant and one recessive.

NOTE: These are pretty much the rules that Mendel worked out to explain what happens. He did not know about genes and chromosomes so could not explain how it happened.

# Genetics problems

## Phenotype and genotype

- **Gametes** have one **gene** for each **characteristic**. At **fertilisation**, when a sperm fuses with an egg to give a **zygote**, the new **organism** has two genes for each trait – one inherited from each parent.
- The appearance of a characteristic is called the organism's **phenotype**, e.g. if the trait is tongue rolling, there are two phenotypes – rolling and non-rolling. (The word 'phenotype' is made from **type** of **phenomenon**.)
- The genes an organism possesses for a trait are called its **genotype**. (The word 'genotype' is made from **type** of **gene**.) Organisms usually have two genes in their genotype for each trait (see opposite).
- For some genes there are alternative forms which are called **alleles**. For tongue rolling, there is one allele which codes for the ability to roll one's tongue and another allele which codes for non-rolling.
- If the two genes in the genotype are the same allele, then the resulting phenotype is obvious, e.g. a person with two roller alleles can roll and a person with two non-rollers alleles can't. When the two genes are the same, the organism has a **homozygous** genotype and is said to be pure-breeding.
- If the two genes are different, then the organism has a **heterozygous** genotype. Usually only one of the alleles will be expressed in the phenotype. If a person has both a roller and a non-roller gene, it turns out that the individual can roll their tongue.

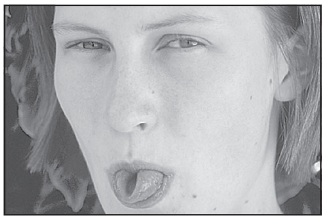


*Figure 3.22a Example of person with one or two roller genes*

*Figure 3.22b Example of person with two non-roller genes*

## Dominant and recessive genes

- The allele which is always expressed is called the **dominant gene**, and the one whose presence may be hidden is called the **recessive gene**.
- The dominant form of a gene is written as a capital letter and the recessive as the same letter in lower case. So, if the dominant tongue roller gene is written **R**, then the recessive non-roller gene would be written **r**.

- If a person has two roller genes (**RR**) then the individual has a **homozygous dominant** genotype. If the person has two non-roller genes (**rr**) then the individual has a **homozygous recessive** genotype.
- For a recessive gene to be expressed the organism must possess two of them (e.g. genotype **rr**), but a dominant gene will be expressed whether you have one or two of them (e.g. genotypes **RR** and **Rr**).

  A single dominant gene will do as will two recessives!

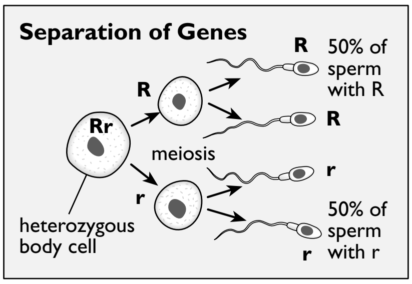



*Figure 3.23 Separation of genes*

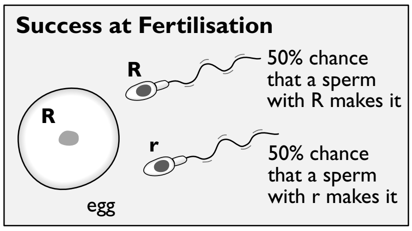


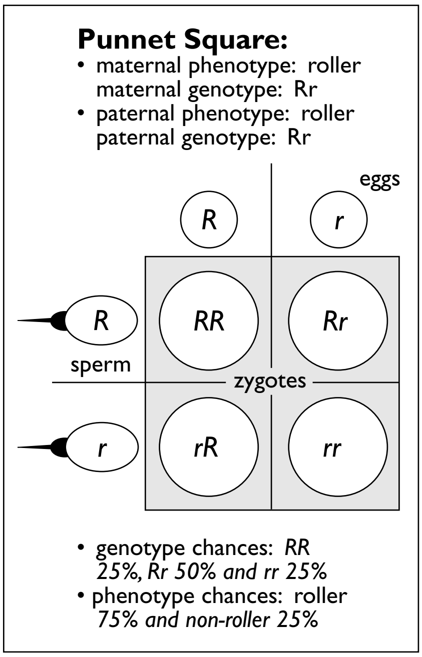

*Figure 3.24 Success at fertilisation*

### Chance in genetics

- In the ovaries and testicles many body cells undergo **meiosis** and produce huge numbers of gametes.
- When an organism produces gametes, the two genes it has for each trait are separated in such a way that each gamete gets only one gene. If the organism is homozygous (e.g. a female who is **RR**) then 100% of the gametes will have the same gene (all eggs will be **R**).
- But if the organism is heterozygous (e.g. a male who is **Rr**) then 50% of the gametes will land up with one allele (e.g. sperm with **R**) and 50% will have the other allele (sperm with **r**).
- In our example, at fertilisation there will be a 50% chance that the successful sperm has the dominant allele **R** and a 50% chance that it has the recessive allele **r**.

## Activity 7 Punnet squares: predicting phenotypes

With a **punnet square** you can identify the possible genotypes of offspring. You can then work out what the expected phenotypes will be and how likely they are to occur.




Note that each of the boxes in the punnet square is equally likely to occur, so there is a 25% chance that each zygote will happen. Also, note that genotypes **Rr** and **rR** are the same. **rR** is written as **Rr**.

**Problem**: If two parents are both heterozygous for the tongue rolling gene, predict the chances they will have of getting the different kinds of offspring (children).

### Steps:

1. Write down the phenotype and genotype of each parent: both father and mother are rollers with an **Rr** genotype.
2. Identify the type of gametes that each parent will produce: both parents will produce gametes with **R** and gametes with **r**.

3 To the left of the square write the genotypes of sperm: **R** and **r**. Above the square write down the genotypes of eggs: **R** and **r**.

4 In each box record the genotype of the zygote formed if the sperm on the left meets the egg from above: e.g. **r** sperm and **R** egg gives **rR**.

5 Identify the distinct genotypes and what the chances will be of getting each: **RR** = 25%, **Rr (and rR)** = 25% + 25% = 50%, **rr** = 25% chance.

6 Finally decide what the expected ratio of the two phenotypes will be:
- ❑ rollers (**RR** and **Rr** genotypes) = 25% + 50% = 75% chance
- ❑ non-rollers (**rr** genotype only) = 25% chance

## Activity 8 Pedigree charts: identifying genotypes

A **pedigree chart** identifies the genotypes of parents and their offspring (children). A circle represents a female and a square represents a male. A mating is a horizontal line that joins male and female. Offspring are placed on branches under parents. Phenotypes are written outside and genotypes inside circles and squares.

**Problem**: The chart gives the natural hair shape of family members. There are two basic phenotypes, curly (which includes wavy) and straight hair. The gene for curly hair is dominant over the gene for straight hair.

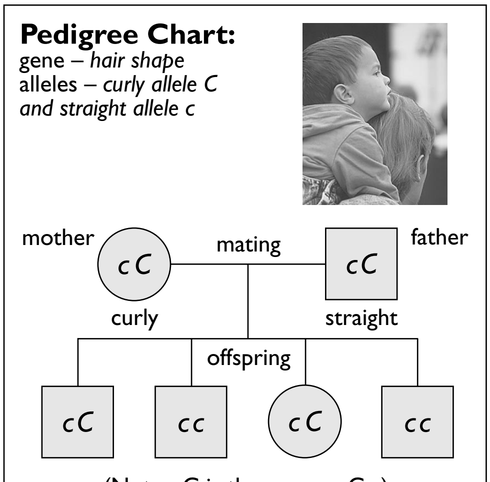
### Steps:

1 Decide on the symbols for the alleles: if the dominant gene for curly hair is written **C**, then the gene for straight hair will be **c**.

2 You need two recessive genes for the related phenotype: locate all straight-haired individuals and write in their **cc** genotypes.

3 Offspring which have straight hair must have inherited two **c** genes: check their parents have at least one **c** in their genotype, and if they do not, add a **c**.

4 Parents in which the recessive gene is expressed will pass on a **c** gene to each of their offspring: make sure each of these offspring has at least one **c** gene in their genotype.



(Note: cC is the same as Cc.)

5 You can now complete the genotypes of some individuals so that they will have their phenotype stated: e.g. if an individual has a **c** gene and curly hair then they must have genotype **cC**.

6 If for some individuals with the dominant trait you still do not know whether they are **CC** or **Cc**: just write in **C?**

# Activity 9 Problem solving

| Table 3.3 *Pea traits* | |
|---|---|
| **Dominant trait and allele** | **Recessive trait and allele** |
| Round seed, R | Wrinkled seed, r |
| Inflated pods, I | Constricted pods, I |
| Yellow seeds, Y | Green seeds, y |
| Green seed coat, C | White seed coat, c |
| Axial flowers, A | Terminal flowers, a |
| Green pods, G | Yellow pods, g |
| Tall plants, T | Dwarf plants, t |

**1** Describe each of the following genotypes as either homozygous dominant, homozygous recessive or heterozygous.

Aa, RR, ii, Yy

**2** What would the phenotypes of the following pea plants be?

cc, Gg, gg, RR

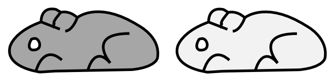
**3** List the gametes that each of the following genotypes could produce.

Aa, TT, Rr, ii

**4** Use punnet squares where necessary to work out the phenotype ratios produced by the following crosses.

Aa × Aa, Rr × RR, II × Ii

Aa X Aa, Rr X RR, II x Ii



Guinea Pigs

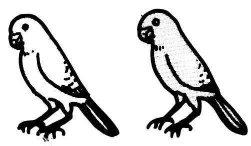
**5** In guinea pigs black coat colour B is dominant to brown coat colour b. What genotypes would the offspring be if you crossed a homozygous black male and a homozygous brown female?

**6** Use a punnet square to show the result of a cross between two guinea pigs with genotypes like the offspring in the previous cross.

**7** In a test cross of a black male guinea pig with a brown female, a brown baby is born. What does this tell you about the genotype of the black male? Draw a diagram which shows the cross.

**8** If two heterozygous black guinea pigs mate and produce 20 offspring, how many would you expect to be brown?

**9** In budgies, green colour G is dominant over blue g. Make up three genetics problems about breeding budgies and use them to test a member of your group.



Budgies

There are standard ways to setting out genetics problems which make them easier to follow. Mendel's experiment with tall and dwarf peas can be set out as follows:

## *Mendel's tall x dwarf pea cross*

T is the dominant allele (tall) and

t is the recessive allele (dwarf)

**First Cross**

| | | | | |
|---|---|---|---|---|
| P1 | T T (tall) | x | t t (dwarf) | |
| gametes | T | x | t | |
| F1 | T | | t (tall) | The F1 plants all have a tall phenotype. |

**Second Cross**

| | | | |
|---|---|---|---|
| P2 | T t | x | T t |
| gametes | T,t | x | T,t |

F2

| | *T* | *t* ← gamete |
|---|---|---|
| *T* | *TT* *tall* | *Tt* ← genotype<br>*tall* ← phenotype |
| *t* | *Tt* *tall* | *tt* *dwarf* |

A probability grid (or punnet square) can be drawn to show the result of this cross.

The ratio of the F2 phenotypes is 3 tall:1 dwarf.

## *Test cross*

You can set out a test cross for an F2 dominant phenotype like this:

If the dominant is heterozygous

| | | | |
|---|---|---|---|
| | T t | x | t t |
| | tall | | dwarf |
| gametes | T,t | x | t |

| | *T* | *t* |
|---|---|---|
| *T* | *TT* *tall* | *Tt* *tall* |
| *t* | *Tt* *tall* | *tt* *dwarf* |

The ratio of the phenotypes is 1 tall : 1 dwarf

If the dominant is homozygous

| | | | |
|---|---|---|---|
| | TT | x | t t |
| | tall | | dwarf |
| gametes | T | x | t |

| |
|---|
| *Tt* *tall* |

All the offspring are tall and are heterozygous

# Activity 10 Revision

**1** Match up definitions with terms.

| | |
|---|---|
| gamete | **a** the appearance of a characteristic |
| gene | **b** the first cell of a new organism in sexual reproduction |
| characteristic | **c** when the two genes an organism possesses are different |
| fertilisation | **d** alternative forms of a gene |
| zygote | **e** the fusion of a sperm with an egg resulting in a zygote |
| homozygous recessive | **f** when the organism has two dominant genes in its genotype |
| homozygous dominant | **g** cells involved in sexual reproduction (egg and sperm) |
| genotype | **h** the process of cell division which produces gametes |
| allele | **i** a gene which will always be expressed |
| homozygous | **j** an inherited object which affects the appearance of a characteristic |
| heterozygous | **k** a technique used to identify genotypes in a family |
| dominant gene | **l** a technique used to predict the phenotypes of offspring |
| recessive gene | **m** an individual living thing |
| phenotype | **n** the two genes an organism possesses are identical |
| organism | **o** when the organism has two recessive genes in its genotype |
| meiosis | **p** a gene which is only expressed if the organism has two |
| punnet square | **q** a feature whose appearance is determined by genes |
| pedigree chart | **r** the two genes an organism possesses for a characteristic |

**2** Explain the differences between the terms below.

**a** characteristic and gene

**b** phenotype and genotype

**c** homozygous and heterozygous genotypes

**d** dominant and recessive genes.

*Figure 3.25 Father and son*

**3** The photo shows a father and son. The gene for straight hair (c) is recessive to the gene which codes for curly or wavy hair (C).

**a** What are their phenotypes?

**b** What genotype will each have?

**c** Are the father and son homozygous or heterozygous?

**d** What can you say for sure about the mother's genotype?

**e** What can you say about the mother's phenotype? (explain)

**4** A daughter can roll her tongue but her mother cannot. The gene for tongue rolling (R) is dominant over the gene which codes for non-rolling (r).

**a** What are their phenotypes?

**b** What genotypes would each have?

**c** Which person is homozygous?

**d** What can you say for sure about the father's genotype and phenotype?

**5** Decide whether the following statements are true or false. Rewrite the false ones to make them correct.

**a** Gametes have two genes per characteristic and organisms have one.

**b** Meiosis produces gametes and fertilisation produces a zygote.

**c** Phenotype describes the appearance of an organism for a characteristic, whilst the term genotype describes the genes an organism has for that characteristic.

**d** Organisms usually have one gene in their genotype for a characteristic.

**e** In a heterozygous genotype the two genes are the same.

**f** A dominant gene can mask the presence of a recessive gene.

**g** For a recessive gene to be expressed an organism requires two of them.

**h** For a dominant gene to be expressed an organism needs to be heterozygous or homozygous dominant.

**i** Ovaries produce eggs and testicles produce sperm.

**j** With a heterozygous individual, 50% of gametes will have a recessive gene.

**6** In rabbits there is a gene which controls whether fur is brown or white. The allele coding for brown fur (B) is dominant over the allele coding for white fur (b).

**a** Would a pure-bred rabbit be heterozygous or homozygous?

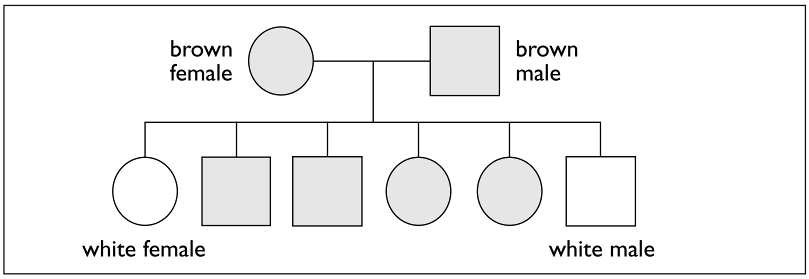
**b** What would the genotype of each of these rabbits be?

A pure breeding white female rabbit was crossed (mated) with a pure breeding brown male and they produced five brown baby rabbits.

**c** What would the genotypes of each of these rabbits be?

When these brown baby rabbits reached maturity, a male and female were mated and they produced the white and brown offspring shown in the pedigree chart below.

**d** Complete the chart to show the genotypes of all rabbits (BB, Bb, bb or B?).

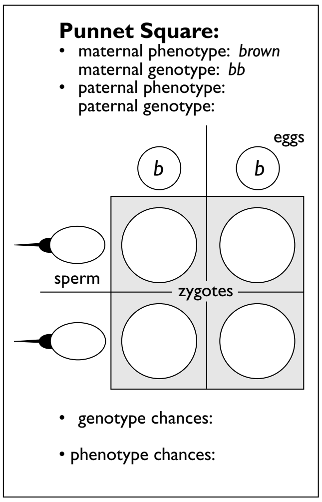



**7** In guinea pigs there is a gene which controls whether fur is black or brown. The allele coding for black fur (B) is dominant over the allele coding for brown fur (b).

A breeder wanted black guinea pigs for her pet shop chain, but she was unsure whether her black male guinea pigs were all pure breeding for coat colour. So she carried out *test crosses* to uncover any recessive brown genes in her males. This meant she crossed each of the black male guinea pigs with a brown female guinea pig and then checked the coat colour of their offspring.

**a** Complete a punnet square to predict the expected offspring if a black male was pure breeding for black coat colour.

**b** Complete another punnet square to predict the expected offspring if a black male had a recessive brown gene.



The table below shows the actual results from her test crosses.

| Male | Offspring in Litter |
|---|---|
| Angus | 5 black |
| Mac | 3 black, 3 brown |
| Pesky | 5 black |
| Rastus | 3 black, 2 brown |

**c** Which males are likely to be homozygous dominant? Why?
**d** Which males are heterozygous? How do you know?
**e** Which males definitely have a recessive allele for brown hair?
**f** Which males should the breeder not use for her breeding programme?
**g** In general why do breeders use test crosses, and what genotype does the test cross organism need to be?

**8** Read the passage below, then answer the questions.

## Left- or right-handed?

- Approximately 75% of the human population are strongly right-handed and approximately 90% are predominantly right-handed.
- Among the remaining 10%, there is a great deal of variability. Some people are strongly left-handed and others are ambidextrous (left-handed for some tasks and right-handed for others).
- The preference of individual humans could be because of inherited variation (i.e. genes) or because of an acquired variation (e.g. training and social pressures in childhood) or a combination of both.
- Left-handedness does run in families and since far fewer people show left-handedness then maybe left-handedness is because of a recessive gene.
- But if the reason was simply dominance and recessiveness, you would expect that all children of two left-handed parents would be left-handed, but it turns out that about 50% are right-handed and 50% left-handed.
- Identical twins have identical genotypes, so if genes decided their left- or right-handedness then we would expect that if you knew the handedness of one twin you should be able to correctly predict the handedness of the other. But this does not turn out to be true.
- Many geneticists currently accept that our genes determine right-handedness, but that left-handedness is more variable.
- The geneticist Marian Annett proposed that a single gene is involved which has two alleles.
- The dominant allele R+ has a strong tendency to cause right-handedness whether you inherit one or two.
- The recessive form of the gene R- does not cause left-handedness if you have two of them, rather it does not produce a bias towards either form of handedness. So people who have two recessive genes are free to develop either left- or right-handedness or they may become ambidextrous.

**a** How is the human species unique?

**b** What does 'ambidextrous' mean?

**c** What evidence supports the idea that genes influence handedness?

**d** What two pieces of evidence suggest that simple dominance and recessiveness does not determine our handedness?

**e** What two genotypes are right-handed people likely to have?

**f** If you have an R+ gene, what are you likely to be?

**g** If you have two R- genes, what are you likely to be?

**9** With the gene coding for hair shape there are two alleles. Dominant gene C codes for curly (including wavy) hair and c codes for straight hair.

There are two phenotypes (curly and straight) and three possible genotypes (CC, Cc and cc).

In this activity you will investigate what offspring you can expect with each combination of parents. It turns out that there are six distinct combinations of parental genotypes possible. These are listed down the left side of the table.

Complete the table by working out the chances of getting the different genotypes and phenotypes amongst the offspring. A few are obvious, but with others use a punnet square.

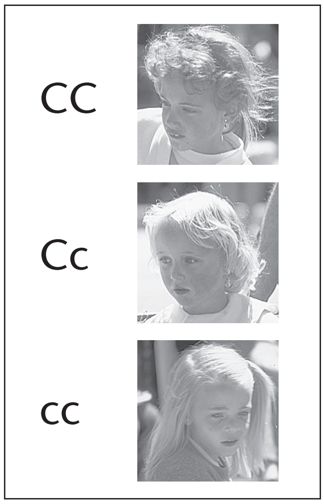



*Figure 3.26a–c Hair types*

| Parents | Offspring Genotypes | Offspring Phenotypes |
|---|---|---|
| CC x CC | CC = % Cc = % cc = % | curly = % straight = % |
| CC x cc | CC = % Cc = % cc = % | curly = % straight = % |
| CC x Cc | CC = % Cc = % cc = % | curly = % straight = % |
| Cc x Cc | CC = % Cc = % cc = % | curly = % straight = % |
| Cc x cc | CC = % Cc = % cc = % | curly = % straight = % |
| cc x cc | CC = % Cc = % cc = % | curly = % straight = % |

**a** Which combination involves two homozygous dominant parents?

**b** Which combination involves two homozygous recessive parents?

**c** Which combinations of parents will produce only one type of phenotype amongst their offspring?

**d** Which combination of parents will give some offspring which are different from both parents?

**e** Explain why it is possible for two curly-haired parents to produce a straight-haired child and why it is impossible for two straight-haired parents to produce any curly-haired children.

**10** Predicting phenotype ratios.

Complete punnett squares to predict the ratio of dimple- to non dimple-chinned offspring for each of the following couples. Dimpled chin is caused by a dominant allele D.

**a** Both parents are heterozygous.

**b** One parent has a non-dimpled chin, the other a heterozygous genotype.

**c** One parent has a non-dimpled chin, the other is homozygous for the dominant allele.

Two dimple-chinned parents have four children, two of whom have dimpled chins and two of whom do not.

**d** Show how the children with non-dimpled chins could have inherited the trait. What must the parents' genotypes be?

**e** The parents decide to have another child. What are the chances that it will have a non-dimpled chin?

**11** Interpreting results.

When a pure-breeding black-haired guinea pig was mated with a pure-breeding brown-haired one, all the offspring had black hair.

The difference is determined by a single gene.

**a** Which trait appears to be linked to a dominant allele?

**b** Would the offspring be homozygous or heterozygous?

One of the offspring was mated with a pure-breeding brown-haired pig. Half of the next generation had brown hair.

**c** What does this confirm about the genotype of offspring from the first mating?

Two offspring from the first mating were mated together.

**d** Predict the ratio of black- to brown-haired offspring in this cross (use a punnett square).

**12** Comprehension and interpretation.

Read the information below, then answer the questions.

## Breeding pure strains

- ❑ For pet breeders it is important that animals breed true for a trait. In the case of budgies, the colours blue and green are determined by one gene which has two alleles. G, the dominant allele, codes for a green coat, and g is the recessive allele coding for a blue coat.
- ❑ Tilimai wanted to breed blue budgies from several blue females, but both of her males were green. To find out the genotypes of the males she did **back crosses**. Each male was crossed with two blue females.
- ❑ For male A, the offspring from the two crosses were 4 and 5 chicks respectively. All chicks were green. For male B, the offspring of one cross were 4 green and 1 blue birds, and 2 green and 2 blue birds for the second cross. One of the blue chicks was male and other two female.
- ❑ With the information she got from these back crosses Tilimai was able to breed pure strains of blue budgies.

**a** Why did Tilimai not have to back cross the blue females to identify their genotypes? What was their genotype?

**b** Why was the breeder initially unsure of the genotypes of the green males? What genotypes could the green males have had?

**c** After she saw the offspring of the back crosses, Tilimai was sure that the genotype of male A was GG. Why?

**d** She was also certain that male B was Gg. Why?

**e** Which male bird would Tilimai use to ensure that the chicks were all blue? What would its genotype be?

f Why did she breed each of the green males with two females?

g What do you think would be the ratio of offspring from mating male bird B and a blue female?

13 Corn cobs.

Figure 3.27 is a photo of dark and light seeds on an F2 maize cob. These colours result from a pair of alleles for dark and light colour. Work out from the photo

a what the two P1 plants were like

b what the cobs from the F1 plant would have been like.

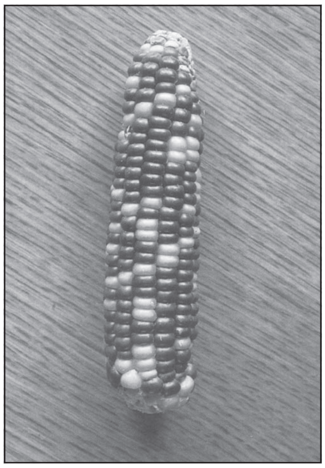


*Figure 3.27 Corn cobs*

# X and Y chromosomes

## Sex facts

1 The ratio of males to females is not exactly 50/50. Although the ratio of sperms produced is 50/50 there are other factors. For example, Y sperms are slightly more active and fertilise eggs more often. On the other hand male embryos seem slightly more fragile so that more male embryos spontaneously abort and male babies are more delicate at birth.

2 It is now possible to sort out X and Y sperms of cattle fairly accurately. At present the process is too slow to be economically worth while.

3 Very rarely a mistake occurs in meiosis and the inheritance of maleness and femaleness is not clear cut. Two examples are:

*Klinefelter's syndrome* About one male in 1000 may inherit more than one X chromosome (e.g. XXY or XXXY). These people may have undeveloped testes and a slight tendency to develop female-like breasts.

*Turner's syndrome* There is one X chromosome but no Y. The reproductive organs, although female, are not fully developed. This happens in one female in 3000.

4 It is just as well that humans produce large numbers of sperms. About 8% of sperms and even more eggs have defective chromosomes.

## What made me Male or Female?

The traits or features we inherit is determined by which parent we inherit a particular gene from and whether that gene is dominant or recessive. However, for one very important feature the method of inheritance is rather different. This is the inheritance of our sex.

Maleness or femaleness is of course a very big part of our genetic make-up and includes all sorts of things apart from sexual organs. Sex also affects the size and shape of our body, the distribution of hair and fat on our body, voice and the hormones we produce that can affect our emotions. All this is determined by the way we inherit just one of our 23 pairs of chromosomes. The *sex chromosomes* are called the X and Y chromosomes. Females have a pair of X chromosomes in each cell and males have one X chromosome and a smaller Y chromosome. The pattern of inheritance of X and Y chromosomes is shown in Figure 3.28.

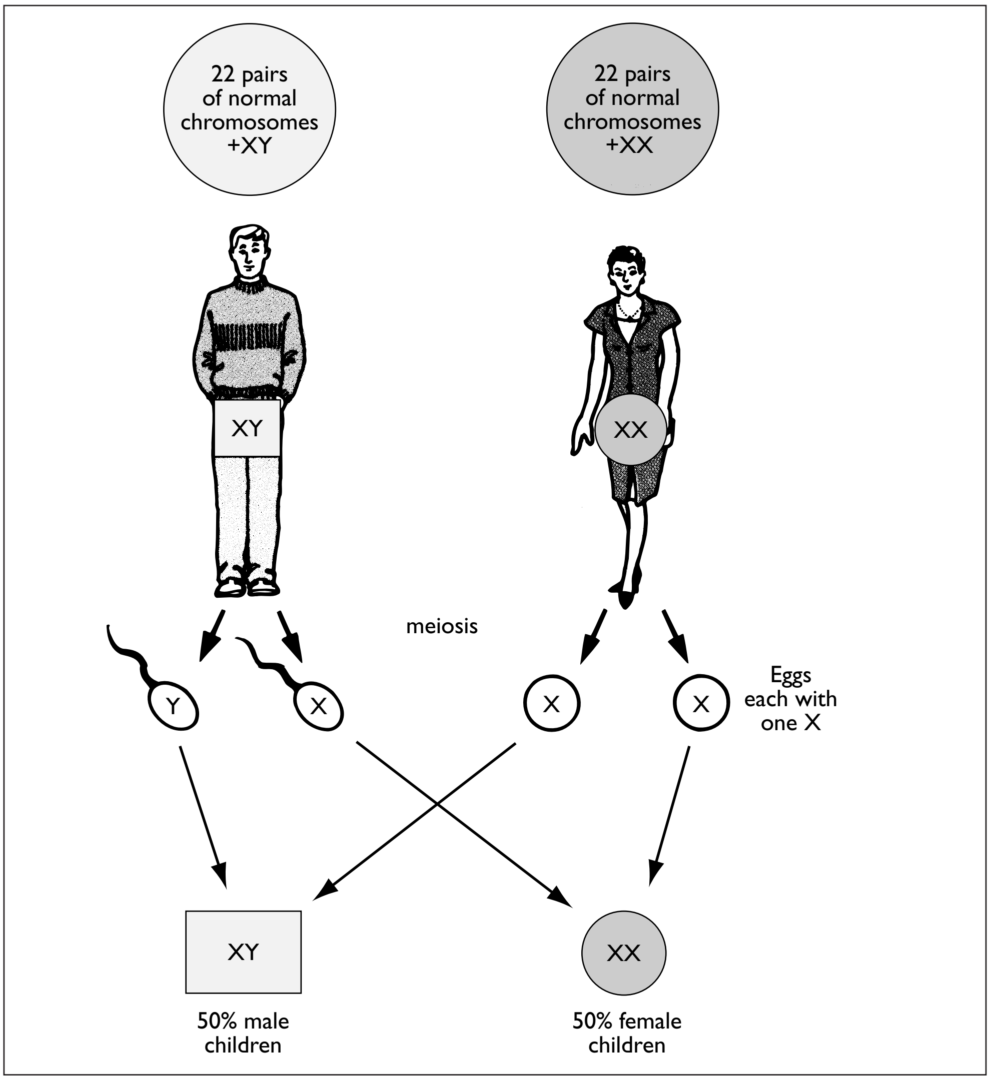



*Figure 3.28 How sex is determined*

As the diagram shows, sex is determined by chance – whether an X or Y sperm is first to reach and fertilise the egg. Half of the father's sperms carry an X chromosome and half a Y chromosome, so a population always has approximately 50 percent males and females. The Y chromosomes carry certain genes that cause the body to develop male characteristics.

## Activity 11 Number of boys and girls

Find out how many boys and girls there are in the families of your class. How close is each family to the 50% females to 50% males ratio? How close is it to 50% of each when all the families of class members are considered?

Why does the size of the sample make a difference?

Unit 4

# Plants

This unit is divided into sections that cover photosynthesis, plant structure, plant processes and co-ordination.

## Photosynthesis

In this section you learn to:

- **investigate** the process of photosynthesis
- **write** an equation to describe the process of photosynthesis
- **investigate** leaf pigments
- **explain** the importance of photosynthesis to plants and other living things.

### Photosynthesis and Life

- Photosynthesis is the process by which green plants make food. Without photosynthesis, no life would exist on Earth's surface. All living things need energy to live and because the source of energy is food molecules, the food-making process of **photosynthesis** is vital to life.
- Organisms that make food molecules using raw materials and energy from the environment are called **producers**. They include **terrestrial** (plants on land) plants and **aquatic** algae. Other organisms must obtain food molecules ready-made from producers. These organisms are either **consumers** (animals) or **decomposers** (fungi and bacteria).
- Producers are able to manufacture all the other molecules required for life (carbohydrates, lipids, proteins and nucleic acids) starting with glucose and simple ions (e.g. nitrates) from the soil or the sea.

### Summary of Photosynthesis

- **Photosynthesis** occurs in special centres of chemical activity called **chloroplasts** which are inside leaf cells. Photosynthesis traps light energy and changes carbon dioxide and water into glucose and oxygen.
- The conversion of raw materials into products can be summarised:

Carbon dioxide + water + light ➔ oxygen + glucose

$6CO_2 + 6H_2O + \text{light} \rightarrow 6O_2 + C_6H_{12}O_6$

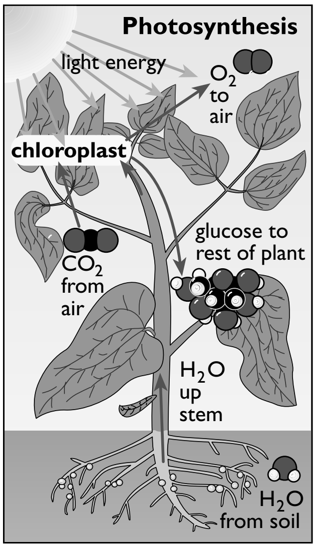



*Figure 4.1 Photosynthesis*

- Photosynthesis is much more than the raw materials coming together. Glucose molecules assemble step-by-step in the chloroplasts, and each step is controlled by a different enzyme – see Unit 9.
- A plant needs the molecule **chlorophyll** to trap light energy. Chlorophyll makes leaves green as it absorbs the red and blue colours of the **spectrum** that makes up sunlight.
- The sun provides a vast supply of energy, but less than 1% of the light which reaches Earth is used in photosynthesis. Photosynthesis is a massive process making 200 billion tonnes of glucose per year, most of which is turned into **cellulose**.
- The raw materials for photosynthesis are carbon dioxide, which plants get from the atmosphere or sea water, and water, which terrestrial plants get from the soil.

## Activity 1 Investigation of photosynthesis

**1** Checking controls.

As in all experiments, in your experiments with plants you need a *control* before you can make a valid conclusion. A control is the part of an experiment we use to compare the effect of changing conditions. Otherwise you cannot be sure whether the factor is needed or not.

**Problem:** Will the experiment below confirm whether light is needed for plants to make starch or not?

**a** Check that the experimental setup has all known factors for the process, as well as the one being tested: water ✓ warmth ✓ carbon dioxide ✓ **plus light ✓**

**b** Check the control has identical conditions except that the factor being tested is absent: water ✓ warmth ✓ carbon dioxide ✓ **no light ✓**

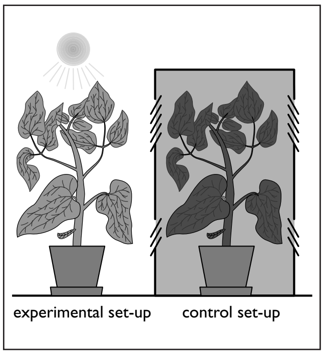



*Figure 4.2 Experimental and control set up*

Both plants were placed as shown for six hours. Leaves from each were tested for starch, but only the leaves from the plant in sunlight tested positive for starch. This confirms that light is needed.

**2** Research to find out how to test a leaf for starch.

**3** Design and carry out an investigation to prove that photosynthesis needs carbon dioxide or chlorophyll or the effect of light (e.g. colour, length of time in light, shading) on photosynthesis.

## Activity 2 Leaf pigments

**Aim: To extract and separate leaf pigments.**

Extraction of leaf pigments (e.g. chlorophyll)

**1** Chop some soft, green leaves into small pieces.

**2** Place a pinch of sand in a mortar. Add a very small amount of ethanol or acetone and the leaf pieces.

**3** Crush and grind the leaf pieces with the pestle. This will break the cells open and the leaf pigments will dissolve in the ethanol or acetone.

**4** Filter the liquid to remove the leaf material and the sand. What colour is the liquid? What is the main chemical in the ethanol or acetone?

## Separation of the leaf pigments

The leaf pigment extract needs to be as concentrated as possible for this investigation. You may have to allow some of the ethanol or acetone to evaporate.

1 Cut a strip of chromatography paper or filter paper so that it will fit into the length of a test tube.
2 About two cm from one end of the paper strip place a small dot of the extract. Let it dry and then add another drop. Repeat this until you have a small concentrated dot of extract.
3 Collect or prepare the solvent – 92% petroleum ether, 8% acetone.
4 Add one cm of solvent to the test tube and carefully fit the paper into the test tube so that the solvent just covers the end of the paper, as shown opposite.
5 Leave until the solvent has almost reached the top of the paper. Remove the paper from the test tube and allow to dry.
6 Mark the bands of coloured pigment. Identify the pigments.

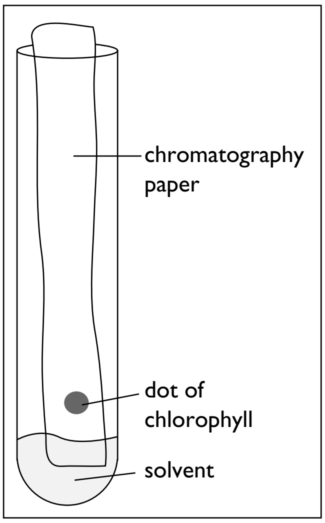



*Figure 4.3*
*Chromatography set up*

| Order on paper | Colour | Name |
|---|---|---|
| Closest to start | Green-yellow | Chlorophyll b |
| | Green-blue | Chlorophyll a |
| | Dull yellow | Xanthophyll |
| Furthest from start | Yellow-orange | Carotene |

7 Repeat steps 1 to 6 to investigate the pigments in other coloured leaves.

# Activity 3

| Time of Day | Sugar Concentration (% dry mass) |
|---|---|
| 4 a.m. | 0.45 |
| 8 a.m. | 0.60 |
| 12 p.m. | 1.75 |
| 4 p.m. | 2.00 |
| 8 p.m. | 1.40 |
| 12 a.m. | 0.50 |
| 4 a.m. | 0.47 |

**1** Interpreting a table.

The data was obtained when a scientist measured the sugar concentration in grass in a paddock every 4 hours.

**a** At what time of the day is the greatest concentration of sugar present?

**b** Explain why the sugar concentration is higher in the afternoon rather than in the morning.

**c** The oxygen level was also higher within the grass leaves during the day than at night. Explain why.

**d** When would the carbon dioxide concentration be highest within the grass leaves?

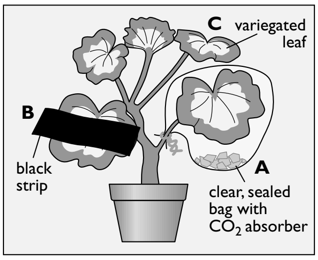



*Figure 4.4 Analysing controls*

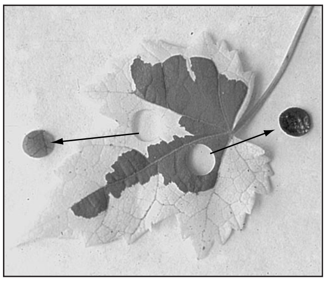


*Figure 4.5 Leaf C*

**2** Analysing controls.

There was an experiment to see if plants need chlorophyll, light and carbon dioxide to make starch.

**a** A plant with green and white leaves was left in the dark overnight.

**b** The plant was set up as shown and left in sunlight for four hours.

**c** Leaves A, B and C were removed and tested for starch.

- ❑ Sketch leaf B and indicate which part would test positive for starch.
- ❑ Which leaf was the experiment and which the control to test whether $CO_2$ (carbon dioxide) was needed?
- ❑ Which leaf was both the experiment and the control to test whether light was needed?
- ❑ For the chlorophyll experiment, leaf C had two discs removed (Figure 4.5). The right disk had starch present but not the left. What do these results indicate?

**2** True or false?

**a** Carnivores as well as herbivores depend on photosynthesis.

**b** Photosynthesis produces more oxygen than a plant requires.

**c** Photosynthesis increases as temperature rises above 40°C.

**d** Carbon dioxide is pumped into glasshouses to increase growth rates.

**e** The veins of leaves are for both strengthening and transportation.

**f** Most photosynthesis takes place in the spongy mesophyll cells of a leaf (the tissue between the upper and lower surface).

# Plant Structure

## Leaf structure

In this section you learn to:

- **investigate** the internal structure of leaves
- **discuss** the functions of leaf parts (what leaf parts do).

### Food-making factories!

- **Leaves** are very well **adapted** to act as the light-gathering, photosynthetic organs of plants. They are the food-making factories of land plants.
- Leaves have demands. The first is to expose as much of the leaf as possible to light energy and the second is to conserve water and at the same time take in the carbon dioxide the plant needs for photosynthesis.

### Overall leaf features

- A leaf is basically a thin, flat, green organ. A flat leaf needs a large **surface** area for collecting light energy. The leaves on a plant are often arranged in a pattern to make sure that all get as much light as possible. Because they are thin light can reach to all cells within the leaf.
- The **petiole** (stalk) holds the leaf blade up to the light. In some species, the petiole can orientate (twist) the blade during the day to intercept (face and catch) more sunlight. The network of **veins** which emerge from the petiole provide strength for the blade.
- A waxy **cuticle** covers the leaf surface. The cuticle is transparent to light, but limits water loss by evaporation. This is important because leaves would not be able to photosynthesise if they lost too much water.

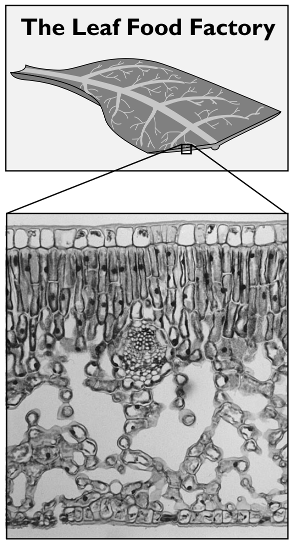



*Figure 4.6 Leaf food factory*

### Internal structure of leaves

- The internal (inside) structure is also highly *adapted* for photosynthesis. The photo (Figure 4.6) and diagram (Figure 4.7) show a section of a leaf as seen under a microscope. There are four **layers** of cells. Look at the photo and diagram as you read the description.

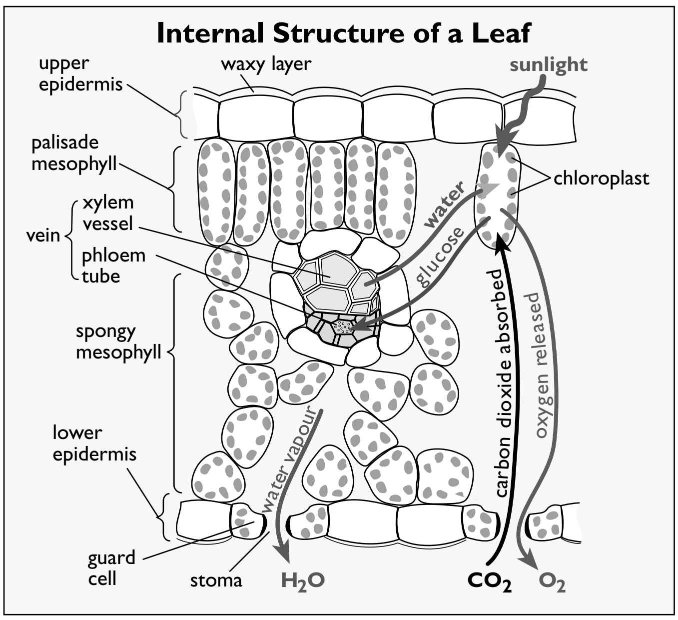



*Figure 4.7 Internal structure of a leaf*

- The **upper** and **lower epidermis** are single layers of cells that act as a protective skin for the leaf. The epidermal cells also secrete (or prepare) the cuticle wax that coats the leaf.
- The **palisade mesophyll** layer under the upper epidermis consists of closely spaced vertical cells which receive most of the sunlight. They contain many green **chloroplasts** – the sites (places) where photosynthesis takes place.
- The **spongy mesophyll layer** is between the palisade and lower epidermal layers. The loosely packed, irregularly shaped cells create large air spaces that allow air and water vapour to freely circulate throughout the leaf. These cells have fewer chloroplasts than the palisade cells.
- The network of veins form part of the internal transport system of the plant. Each vein or **vascular bundle** consists of long xylem vessels and shorter phloem tubes. Water comes up from the roots through the **xylem vessels** and diffuses out into the cells of the leaf. The glucose made in photosynthesis is transported to other parts of the plant by the **phloem tubes**.

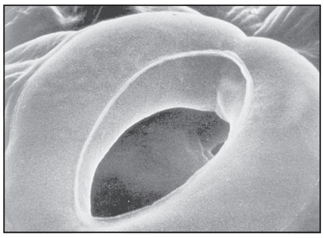


*Figure 4.8 SEM image of guard cells and stoma*

## Gas exchange and the stomata

- The **stomata** are microscopic pores in the epidermis that can open and close. Generally, they are found in the lower epidermis of leaves, which reduces (stops too much) **evaporation** of water from the leaves.
- During the day carbon dioxide gas **diffuses** (spreads) in, and water vapour and oxygen gas diffuse out of the leaf. Differences in concentrations inside and outside the leaf cause these movements.
- During the night, when there is only respiration in the leaf, oxygen gas diffuses in and carbon dioxide gas diffuses out.
- Each opening or **stoma** is surrounded by a pair of sausage-shaped **guard cells**. If guard cells absorb water they become **turgid** (swollen) and force the stoma open.
- During the daytime stomata open and allow $CO_2$ carbon dioxide in. Photosynthesis can be up to twenty times faster when the stomata are fully open.
- The stomata play an important part in controlling water loss by evaporation. If the leaf loses too much water the stomata close, but this slows down photosynthesis.

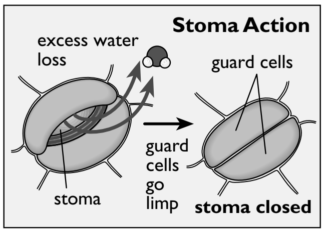



*Figure 4.9 Stoma action*

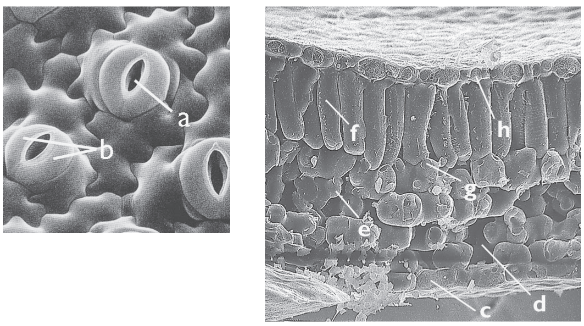
# Activity 4

**1** Matching terms with definitions.

| | |
|---|---|
| photosynthesis | **a** pair of cells surrounding a stoma |
| spectrum | **b** the stalk of a leaf |
| chloroplasts | **c** the waterproof layer outside of the epidermis |
| adaptation | **d** the internal transport system of plants |
| chlorophyll | **e** the microscopic pores on the surface of leaves |
| petiole | **f** the process by which all plants make food |
| epidermis | **g** the cells involved in transporting food (glucose) around plant |
| cuticle | **h** the different-coloured light which makes up sunlight |
| palisade mesophyll | **i** a feature of an organism assisting it to survive |
| spongy mesophyll | **j** the layer of closely packed vertical cells in leaf |
| vascular bundles | **k** a cell swollen with water |
| xylem vessels | **l** the molecule that traps energy from light |
| phloem tubes | **m** the layer of loosely packed cells inside the leaf |
| stomata | **n** the sites of photosynthesis in cells |
| guard cells | **o** the cells involved in transporting water |
| turgid | **p** the layer of cells forming the 'skin' of a leaf |

**2** Identifying leaf structures.

Match the labels with the lettered structures on the SEM (scanning electron microscope) images of external and internal leaf structures.




Labels:

• upper epidermis • lower epidermis • palisade mesophyll cell • spongy mesophyll cell • air space • chloroplast • stoma • guard cells

# Root Structure

In this section you learn to:

- ❑ **investigate** types of roots
- ❑ **describe** different root types
- ❑ **explain** how roots adapt to carry out their functions
- ❑ **investigate** the structure of a root
- ❑ **explain** the functions of different regions of the root.

Roots of plants support the plant by holding it firmly in the soil. The roots also absorb water and minerals from the soil. The roots of some plants, for example yams, also help store nutrients.

Plant roots are also used for asexual reproduction. For example some plants have underground stems called **rhizomes** which usually grow horizontally. New plants grow from points along the underground stem.

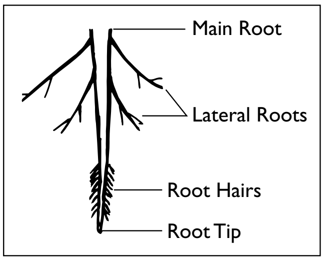



*Figure 4.10 Root structure*

Although all plants have roots with a similar structure they can have different types of roots depending upon their way of life. Some plants have a **tap root** system. For example mautofu has tap roots. A tap root system has one main root that can be large and go a long way down into the soil. These roots are strong and give the plant good support. Tap roots are also important to plants which live in very dry climates, such as much of Australia, as the roots can grow a long way down toward water.

Grass plants have a **fibrous root** system which means they contain many small roots. This type of root is made up of a large number of short roots that are about the same size. A fibrous root system helps to stop the plant from being pulled out when a herbivore eats the leaves.

The cells in a root are living cells. They receive nutrients that are produced in the stem and they get oxygen from the surrounding soil. **Pneumatophore roots** are special roots that grow up into the air from mangrove roots and have special adaptations for living in mud that lacks oxygen. The pneumatophore roots are designed to take oxygen from the air so that the root cells under the mud receive enough oxygen to stay alive.

**Adventitious root** describes any root that grows in an unusual way. Roots that grow from stems or leaves are called adventitious roots.

## Activity 5 Plant roots

### Part 1

**Aim:** Observe the structure of a growing root.

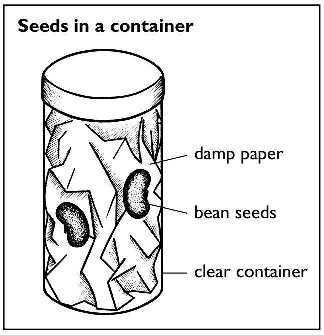



*Figure 4.11 Seeds in container*

1. Collect a clear plastic or glass container.
2. Fill the container with enough newspaper or other paper so that seeds can be held in place between the paper and the side of the container.
3. Add water so that the paper is damp and has a small layer of water in the bottom of the container.
4. Place different seeds between the sides of the container and the paper in a way that will allow you to observe and measure the growth of the roots produced by each seed.

5 Record observations and measurements over several days. Add water to the paper as needed.

**Part 2**

**Aim:** To describe the root systems of different plants.

1 Find examples of plants with fibrous and tap root systems. Carefully remove a lump of soil containing as much of the root system as possible.
2 Wash the root system carefully to remove the soil.
3 Observe and draw the root structure. Label the parts.

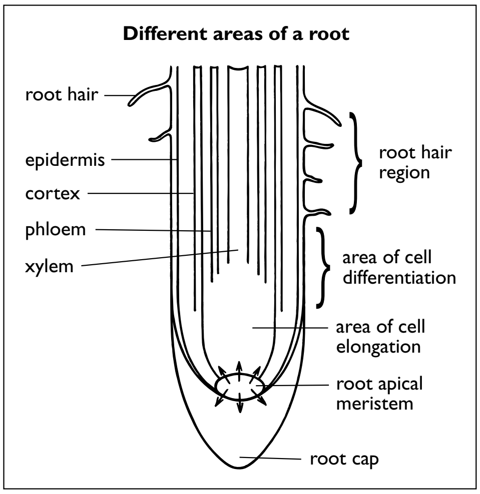



*Figure 4.12 Different areas of a root.*

## Structure of roots

The tip of each root has areas that carry out different functions (see Figure 4.12).

The **root cap** is an area of cells that protect the important root **meristem**. (The meristem is a group of cells that are in areas of active growth.) As the root grows longer, the root cap is pushed through the soil in front of the meristem. This reduces the chance of the meristem getting damaged during growth.

The **root apical meristem** is an area of cells that are able to divide. This allows the root to grow longer. Each time a cell in the meristem divides, *one of the cells* it produces becomes part of the root behind the meristem. The *other cell* produced stays as a meristem cell that will grow and divide again to produce another cell that will become part of the root behind the meristem.

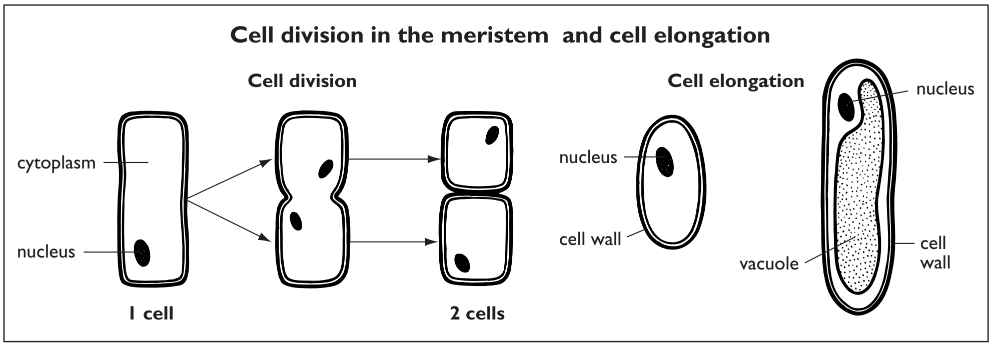



*Figure 4.13 Cell division in the meristem and cell elongation*

After the meristem area is an area where the cells produced by the meristem become longer. This process is called **cell elongation**. Cell elongation results in growth that pushes the root meristem and cap further or deeper into the soil.

When cells have elongated, they then change into the different cells that the root needs. This process is called **cell differentiation**. The type of specialised cell each cell will become depends upon where it is in the root.

Above the area of cell differentiation is the **root hair region**. The cell membrane of the epidermal cells in this area grow outwards to produce fine root hairs. These increase the surface area of membrane through which the root can absorb water and minerals from the soil. Plants need very large root surfaces so that they can absorb enough water and minerals to support the stem and leaves. Grass plants can have 130 times more root surface area than they have stem and leaf surface area.

## Activity 6 Root structure

**Aim:** To investigate the inside structure of a root.

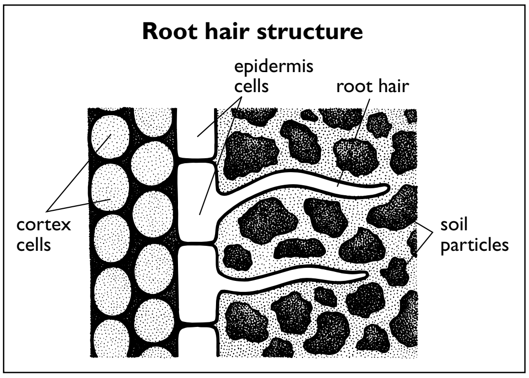



*Figure 4.14 Root hair structure*

1 Use a hand lens or dissecting microscope to look at the outside of the roots of a seed that has been grown on paper. Identify the areas of the root.

2 Look at prepared slides of root tissues or prepare your own slides by cutting and mounting sections from roots. To do this:
   - ❑ Hold the root in a material that is easy to cut, e.g. between two pieces of carrot.
   - ❑ Use a sharp blade, such as a scalpel, to cut very thin slices of root into a dish of water.
   - ❑ Choose the thinnest slice and mount it on a microscope slide, add a drop of water and cover with a coverslip. You can add stains to show up the cells in the root.

# Plant Processes

## Transpiration

In this section you learn to:

- ❑ **describe** the importance of transpiration
- ❑ **investigate** environmental factors that affect transpiration rates
- ❑ **explain** how environmental factors effect transpiration
- ❑ **discuss** adaptations of plants to reduce transpiration.

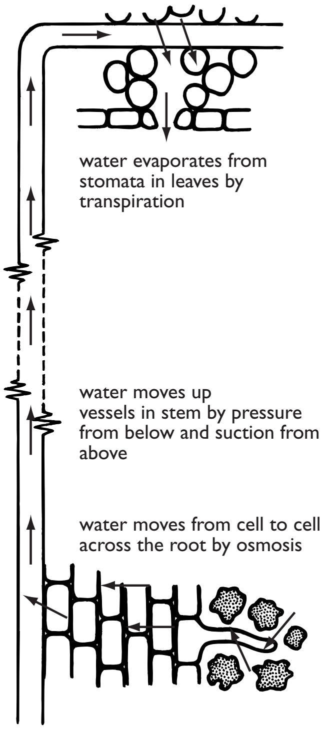



*Figure 4.15 Transpiration*

Transpiration (loss of water vapour from a plant) is important in the transport of materials through the plant. This method of transport is called transpiration pull.

**Transpiration pull**: Over 90% of the water passing up a plant is lost through **transpiration**. The heat of the sun causes this on-going loss of water vapour from leaves through the stomata.

Water vapour leaves through stomata it has **evaporated** from moist leaf cells. Evaporation increases the concentration of **solutes** (the substances which were dissolved in the water vapour) inside the cells, and draws water out of leaf xylem vessels into those cells by osmosis.

Water forms a continuous column inside the microscopic xylem vessels which run from root to leaf. The loss of water from the leaf end of a vessel creates a **tension** or pull on the entire column of water. So the column of water rises. Water is pulled upwards through a tiny tube because of the remarkably strong **forces of attraction** between water molecules.

Plants use no energy to lift all these litres of water. All the energy comes from the heat of the sun.

## Activity 7 Analysing experimental data

The rate of transpiration is affected by environmental conditions. Figure 1.16 on the opposite page shows a simple potometer, designed to measure the water loss of a leafy twig. The potometer was placed in different conditions for 30 minutes. In each case it was carefully weighed before and after.

1 Under each condition the apparatus weighed less after 30 minutes. Explain why the loss of water from the leaves causes the drop in weight, rather than evaporation of water from the flask.

The table gives the weight of the potometer in each case:

| Condition | Start | Finish | Change |
|---|---|---|---|
| still air/ shade/ dry air | 142 g | 138 g | g |
| still air/ sun/ dry air | 137 g | 129 g | g |
| wind/ shade/ dry air | 127 g | 120 g | g |
| wind/ sun/ dry air | 119 g | 105 g | g |
| still air/ shade/ humid | 103 g | 101 g | g |

2 Calculate the weight change in each condition.

3 Draw a bar graph to display the changes in weight.

4 What condition caused the greatest water loss?

5 Describe how each environmental factor (wind, radiant energy and humidity) affects the rate of transpiration, and explain why this might be so.

The effect of increasing the temperature on the rate of transpiration was investigated too. All other conditions were kept constant. The results are shown below:

| Temperature | 10°C | 15°C | 20°C | 25°C | 30°C |
|---|---|---|---|---|---|
| Water loss | 2 g | 5 g | 8 g | 15 g | 13 g |

6 Plot the results on a line graph and describe the trend.

7 Suggest a reason why the rate of transpiration eventually fell, even though the temperature increased.

When the investigations were complete, both sides of all leaves were smeared with vaseline. In this case, the potometer's weight did not change over 30 minutes.

8 Does this confirm that weight loss was due to transpiration?

## Effect of environment on transpiration

The rate of transpiration changes when the environment around a plant changes. This is because factors such as temperature and humidity, change the rate at which water evaporates from the surface of the leaf. Higher temperatures make the water evaporate quicker. More wind and lower humidity increase the transpiration rate because they increase the concentration gradient between the inside and outside of the leaf. The larger the difference in the concentration of water between the inside and the outside of the leaf, the quicker the rate of transpiration.

You can investigate the transpiration rate with a weight potometer. Potometers are instruments which measure the rate at which a plant takes in water. This is an indirect way of measuring the water loss by transpiration.

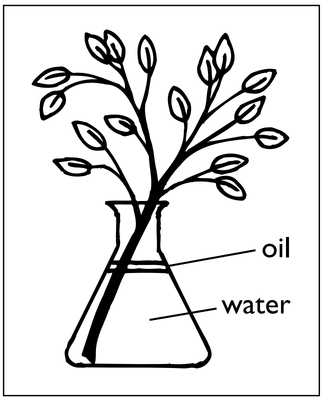



*Figure 4.16 Potometer*

### Weight potometer

You make a weight potometer by cutting a leafy branch and immediately placing it in a flask of water. You place oil on top of the water to stop evaporation of the water from the flask. You weigh the potometer very accurately, then place it in the conditions being tested for at least 30 minutes and then weigh it again. The potometer is easy to set up but must be weighed very accurately and it takes a long time to get results.

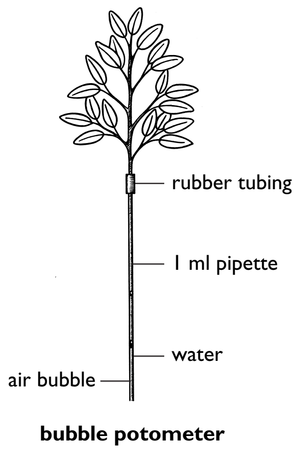



*Figure 4.17 Bubble potometer*

### Bubble potometer

This type of potometer can record very small water losses quickly and accurately but is more difficult to set up.

1. Cut a small leafy branch, under water if possible and leave the cut end in the water.
2. Put a short piece of rubber tubing and a 1 ml pipette in the water with the leafy branch.
3. Push the end of the branch into the rubber tubing and then the end of the pipette into the tubing. Hold the end of the pipette under the water and use petroleum jelly to make the joins watertight.
4. A bubble can be placed in the pipette by lifting the tip of the pipette out of the water for a short time.
5. Mark the position of the bubble on the pipette. The rate of transpiration can be measured by recording how far the bubble has moved in a given time, e.g. every five minutes for 20 minutes.

## Activity 8 Transpiration

**Aim**: To investigate the effect of an environmental factor on transpiration rate.

1. Set up a weight or bubble potometer and leave it to settle for 5 minutes.
2. Place the potometer in still, well lit conditions and take readings of the position of the bubble every two minutes for ten minutes. This will give you a set of results that you can use to compare other results against.
3. Change the conditions around the potometer and wait five minutes for the plant to adjust to the new conditions. You could test different temperatures, amounts of light, humidity or wind. The table below shows possible methods of changing the environmental factor.

| Environmental factor | Possible method |
|---|---|
| Temperature | Place a heat source near the potometer. Change the temperature by moving the heat source further away. |
| Light | Place the potometer beside a bright light. Fluorescent light is best because it gives off less heat. Change the conditions by moving the plant further away from the light. |
| Humidity | Use a clamp stand to hold the potometer. Place the potometer and the beaker of water inside a large plastic bag. The humidity can be raised by placing a beaker of hot water inside the plastic bag. The humidity can be lowered by using a chemical to absorb the water inside the plastic bag. |
| Wind | Use a fan or hair dryer to change the amount of air that moves around the potometer. |

### Adaptations to reduce transpiration

Plants need to open the stomata to take in carbon dioxide and as a result lose water (see Figure 4.19). The water is needed by the plant for support so it is important that the plant reduces water loss as much as possible. The drier the environment the more important it is for the plant to reduce water loss.

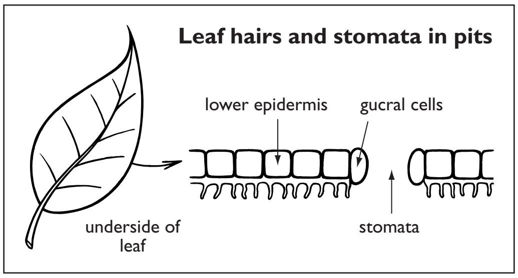



*Figure 4.18 Leaf hairs*

Plants have a number of different ways, called **adaptations**, to help them reduce transpiration. (Adaptation is any characteristic which helps the organism to adjust to the conditions under which it lives.) For example, different types of plants have different numbers of stomata on the surfaces of their leaves. Some only have stomata on the lower surface of their leaves. The rest of the cells on the surface of the leaf are covered in a waxy, waterproof cuticle to stop water loss.

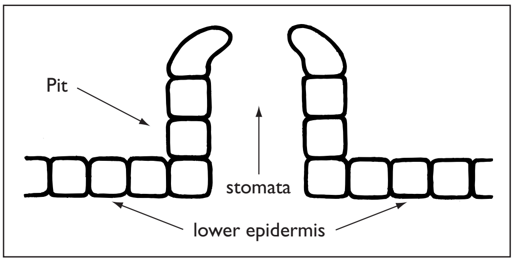



*Figure 4.19 Stomata in pits*

We have already seen that a flat leaf needs a large surface area for collecting light energy (**overall leaf features**).

The size and shape of the leaf is also important. Smaller leaves, needle leaves and rolled leaves are all adaptations to reduce water loss. Some leaves have hairs and some have their stomata in a pit in the leaf.

Hairs and pits help to reduce water loss because they hold a layer of still air against the leaf, therefore they keep the concentration of water inside and outside the leaf similar. When the concentration of water in the air outside the leaf is low, the leaf will lose more water.

## Activity 9 Plant adaptations

**Aim:** To investigate the adaptations that a plant has to reduce transpiration.

1. Use graph paper to investigate the surface area of a leaf. More water is lost from leaves with higher surface area.
2. Use a microscope to investigate the number of stomata on the upper and lower surfaces of a leaf. You can remove the epidermis from the leaf by using clear nail polish or acetone. Cover part of the leaf in clear nail polish and then tear the area of nail polish away from the rest of the leaf tissue. Place the nail polish piece, with leaf epidermis attached, onto a slide. You can also use this to see if the stomata are in pits of the leaf.
3. Use a dissecting microscope to view the surfaces of leaves to investigate the use of hairs to reduce transpiration.

# Asexual Reproduction

In this section you learn to:

- **describe** a range of types of asexual reproduction
- **explain** the advantages and disadvantages of asexual reproduction.

Asexual reproduction is a quick method that plants use to reproduce themselves when conditions are good. Asexual reproduction results in offspring that are genetically identical to the parent plant. It allows a plant to quickly form offspring to take advantage of the good conditions for growth.

The disadvantage of asexual reproduction can be that the offspring are all genetically identical to the parent plant. If conditions change, the offspring may not be able to adapt to the new conditions and they won't grow as well. It also means that the offspring have to grow close to the parent and therefore they are likely to be competing with it for resources. That is why most plants also carry out sexual reproduction so that they can produce genetically different plants that are dispersed away from the parent plant.

The table below describes the main natural methods of asexual reproduction in plants. The first five examples use modified stems for asexual reproduction.

| Method | Examples | Description of method |
|---|---|---|
| Runner | Vanilla (*vanila*)<br>Strawberry | New plant grows from areas called nodes in stems that grow along the ground |
| Rhizome | Ginger (*fiu*)<br>Bermuda grass | New plant grows from nodes in stems that grow under the ground |
| Corm | Taro (*talo*)<br>Gladiolus | New plant grows from a bud on a short, thick, upright underground stem |
| Tuber | Sweet potato (*umala*)<br>Yam (*ufi*) | New plant grows from buds on the swollen tips of underground stems |
| Bulb | Onion (*aniani*), lily | New bulb forms from a bud on a short underground stem |
| Suckers | Banana (*fa'i*) | New plants grow as suckers from the base of the stem |
| Vegetative reproduction | Mexican hat plant<br>African violet | New plant grows from tissue or an organ, for example, a leaf that drops or is separated from a plant |
| Cuttings | Hibiscus (*'aute*) | People take small branches from plants and grow them. |

## Activity 10 Asexual reproduction

**Aim:** To investigate examples of asexual reproduction.

1. Use the information on the table above to find and observe examples of plants carrying out asexual reproduction. Draw a diagram to show how the new or offspring plants form.
2. Take cuttings from different plants, grow the plants in your biology classroom. When they have developed roots, use them to plant around your school or village.

## Sexual Reproduction

In this section you learn to:

- **investigate** the structure of wind and insect pollinated flowers
- **discuss** the structure and function of wind and insect pollinated flowers
- **investigate** the structure of seeds and fruits
- **explain** the development of a seed and fruits
- **compare** different methods of seed dispersal.

# Insect- and wind-pollinated flowers

## Structure of flowers

1 **Flowers** contain the sex organs of plants. Most flowering plants are **hermaphrodites**, that is they have both male and female organs in the same flower. The male organs produce pollen and the female organs produce eggs.

2 Most flowers have these structures:

- **Sepals** and **petals:** Sepals are a leaf-like cover which protects young flower buds, while petals attract pollinators.
- **Stamens (male organs):** These consist of long **filaments** (stalk) which bear pollen-producing and fertile sacs called **anthers**. A flower usually has several stamens.
- **A pistil (female organ):** This consists of an **ovary** that bears a pollen landing-pad, called the **stigma**, on top of a long **style**. The ovary contains ovules, each with an egg.

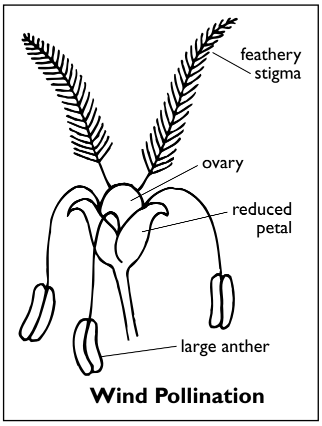



*Figure 4.20 Wind pollination*

## Adaptations for pollination

- **Wind** is a less sure way of transferring pollen so grasses produce large amounts of light, smooth pollen. Their anthers dangle in the wind to release pollen grains, which are caught by the feathery stigma.

# Activity 11 Flower structure

**Aim:** To investigate the structure of wind- and insect-pollinated flowers.

1 Collect two or three flowers that are insect-pollinated.

2 Collect two or three flowers that are wind-pollinated. You may have to look carefully to find them. Wind-pollinated flowers are green and are often very small compared to insect-pollinated flowers.

3 Draw the structure of one insect and one wind-pollinated flower.

4 Write notes around the drawing which explain the difference between the two flowers.

5 Use a hand lens or microscope to look at the detail of the part of both types of flower. Draw diagrams and write notes to compare their structures.

*Figure 4.21 Flowers that use different methods of pollination*

6 Identifying Pollination Adaptations.

The photos illustrate flowers that use different methods of pollination.

The birch tree catkins opposite are male flowers, which release large amounts of light pollen.

a Give three reasons why this plant is likely to be wind-pollinated.

The curved flax flowers opposite have nectar at the base. Tui are long-tongued birds of New Zealand which feed on nectar.

b Suggest two features of flax flowers that help ensure tui transfer pollen between flowers.

Lupin flowers are bee-pollinated. When a bee lands on the keel petal, the anthers spring out and brush the bee's abdomen with pollen.

**c** List two adaptations lupin flowers use to attract bees.

**d** Suggest a reason why lighter insects do not successfully pollinate lupin flowers.

## Seeds and fruits

Sexual reproduction of plants involves the development of seeds. Each seed contains a small embryo plant and the food it will require until it can grow big enough to carry out photosynthesis to make its own food.

Pollination is when the male and female gametes join to form an embryo inside the ovules (the sex cells) of the ovary. Each fertilised ovule develops into a seed with a tough outside seed coat called a **testa**. The rest of the ovule around the embryo develops into food storage areas.

The ovary of the flower and sometimes the surrounding parts develop into fruit. Some fruits are fleshy and others are dry. *Ifi* and *talie* are examples of dry fruits. *Tamato* and *esi* are examples of fleshy fruits. The function of all fruits is to protect the seed and to help disperse the seeds away from the parent plant.

| Type of fruit | How fruit is formed | Description of fruit | Examples |
|---|---|---|---|
| Simple | Formed by one or more ovaries from the same flower | **1** Fruit wall dry, splits when mature<br>**2** Fruit wall dry, does not split when mature<br>**3** Fruit wall fleshy | Bean<br>*Ifi*, sunflower<br>Banana |
| Aggregate | Formed by many ovaries from the same flower | Many mature ovaries joined to a large stem end called the receptacle | Strawberry |
| Multiple | Formed by many ovaries from different flowers | Many mature fruits grown together | Pineapple |

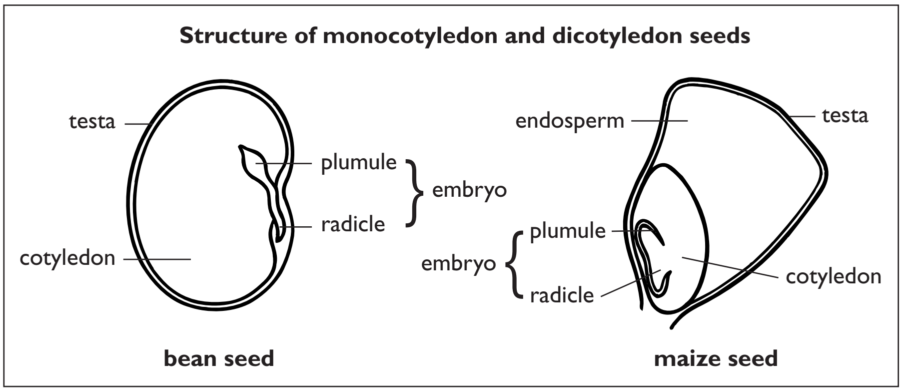



*Figure 4.22 Structure of monocotyledon and dicotyledon seeds*

## Seed dispersal

Dispersal means to be separated and moved apart in different directions, to be scattered. Seeds are dispersed in several ways. If the seeds of a plant land on the ground next to the adult parent they grow up and compete with it for light, nutrients and water. Plants produce fruits so that the seeds are able to be carried away from the parent. This reduces the chance of competition between the parent and the offspring.

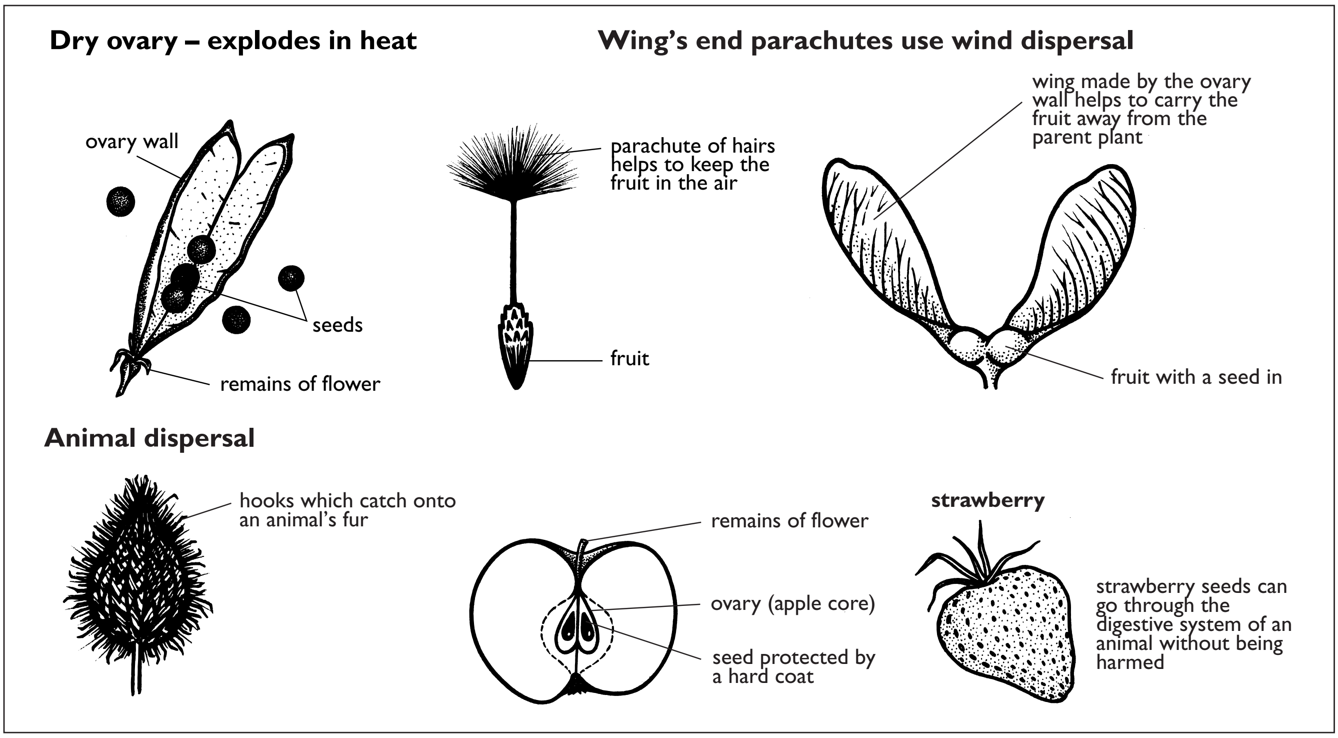



*Figure 4.23 Methods of seed dispersal*

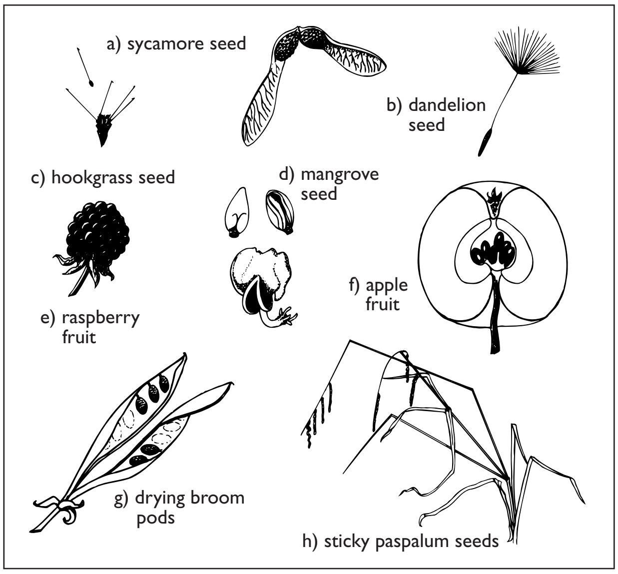
## Activity 12 Seeds and fruit

**Aim:** To investigate the structure of different seeds and fruits.

1. Collect five or six different types of seeds.
2. Draw the shapes of the seeds. Record the sizes and special features of the seeds.
3. Soak some bean seeds in water overnight. The next day, open the seeds by removing the testa. Look at the seeds under a dissecting microscope.
4. Split the seed apart to show the embryo. Look at it under a dissecting microscope. Draw the parts inside the seed.
5. Identifying Dispersal Adaptations.

   The diagram on the right shows eight fruits or seeds which have different methods of dispersal. Match each fruit or seed up to a method below:

   **a** dispersal by passing through an animal's gut
   **b** dispersal by external attachment to an animal
   **c** dispersal by floating in water
   **d** dispersal by wind
   **e** dispersal by ejection from a pod.



# Germination

In this section you learn to:

- ❑ **investigate** conditions needed for germination
- ❑ **explain** the process of germination including the conditions needed
- ❑ **investigate** plant growth
- ❑ **discuss** the role of meristematic tissue in plant growth.

Germination is when the embryo plant grows inside a seed to become a seedling. The structure of a seed is designed to protect the embryo plant from the time it is formed until the time it germinates. The embryo inside the seed is in a dormant state which means that the chemical reactions of life have slowed down, they have slowed so much that the embryo doesn't grow.

At the beginning of germination, water enters the seed through a small hole in the testa. The seed swells as more and more water enters. The seed swells so much that the testa splits. This allows oxygen from the surrounding air to enter the seed easily. The chemical reactions of life, particularly aerobic respiration, begin working very quickly. Starch is stored in the **cotyledon** which is the primary leaf of the embryo. Enzymes break this starch into soluble molecules that are transported to the now growing **radicle** and **plumule**. (The radicle is the root of the embryo and the plumule is the first apical bud or rudimentary shoot.) These molecules are used for growth and for respiration that supplies the energy needed for the growth. This is why germinating seeds need oxygen.

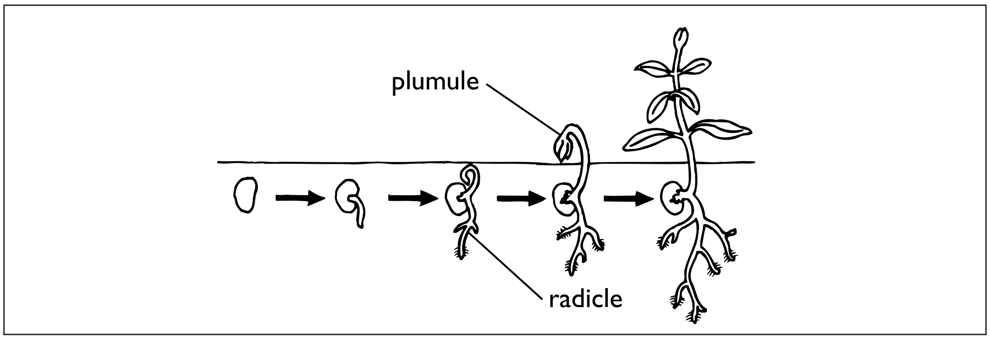



*Figure 4.24 Germination of a dicotyledon seed*

The temperature that is best for germination is different for different plants. Some plants in Sāmoa need warmer conditions to start germinating than seeds of plants in cooler parts of the world. The time of the year when germination begins is not as important in Sāmoa as it is in cooler places. This is because the climate in Sāmoa provides good plant growth conditions all year round.

Most seeds can germinate in the light or the dark but some seeds will only germinate in the dark and others will only germinate in the light.

## Activity 13 Germination

1. Explain the roles of the following in germination:
   water oxygen enzymes
2. Explain why temperature is less important to seed germination in Sāmoa than in places like New Zealand.
3. Mangrove seeds start to germinate and grow a root before they fall from the tree. Why is this necessary?

**4** Interpreting Experimental Results.

In an experiment on germination 120 fresh seeds were soaked in water for a day, then half were killed by being immersed in boiling water. The dead and living seeds were placed in separate, dark, closed petri dishes and left for 12 days.

Every second day 10 germinating seeds and 10 dead seeds were removed and heated to evaporate all water. Then each group of 10 seeds was weighed and the average weight of the seeds calculated. The results are plotted on the graph.

**a** Describe what happened to the weight of the dead seeds.

**b** Describe what happened to the weight of the germinating seeds.

**c** Explain the difference in the results.

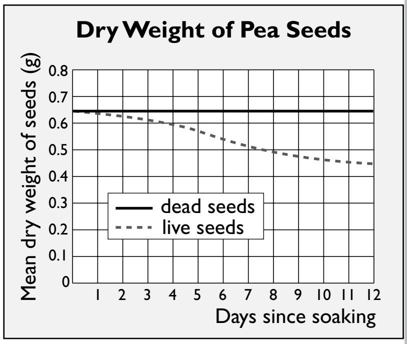



*Figure 4.25 Graph of 'Dry weight of pea seeds'*

**5** Designing Experiments.

Some students were discussing the conditions bean seeds need to germinate. The students all agreed that water was essential, but could not agree whether any of the following conditions were necessary or not:

• warm temperature • soil • darkness • oxygen

**a** Describe how you would set up an experiment to test whether each of the above four conditions was necessary for germination. The seeds have been well soaked and kept moist. Include a control in your design.

Some seeds will not germinate if they have not gone through a time of dormancy (inactivity), often over a cold period.

**b** Explain how a dormancy period could be an advantage.

**6** Carry out one of the investigations you designed for number 5 above.

## Plant growth

Plants grow bigger because cells divide, cells get larger and cells change into special tissues. Plants are different from animals because they can continue to grow taller and thicker throughout their lives. They can do this because they have areas of tissue, called meristems, which contain cells that keep dividing to form new cells. Plants have two different types of meristems. **Primary growth** occurs from the **apical meristems** which you find at the shoot and root tips. The cells in the apical meristem divide and some of the cells grow longer which makes the plant taller.

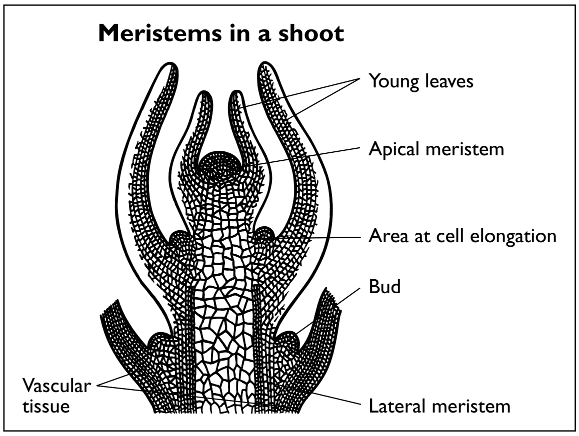



*Figure 4.26 Meristems in a shoot*

Secondary growth is in areas around the stem called **lateral meristems**. The lateral meristems form circles of **cambium** cells around the stem. (The cambium is a strip of cells which gives rise to daughter cells.) The cambium cells divide often. The new cells form **xylem** cells (wood cells) on the inside of the cambium and phloem on the outside. This process continues over the life of the plant and causes the stem to get wider and wider.

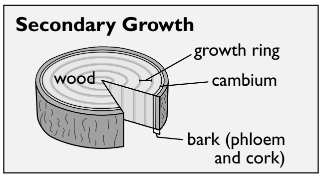



*Figure 4.27 Secondary growth*

The older xylem vessels towards the centre of the stem of trees develop thicker and stronger walls and become wood. The *dead* wood in the centre of the tree is strong and is called **heartwood**. The *living* phloem, cambium and xylem just under the bark of the tree are called the **sapwood**. Every year a tree develops new sapwood. At different times of the year the diameter of the xylem in sapwood is larger than others. These differences appear as growth rings that can be seen when the trunk of a tree is cut. We can tell how old a cut tree is by counting the number of growth rings, because one growth ring equals a year.

## Activity 14 Plant growth

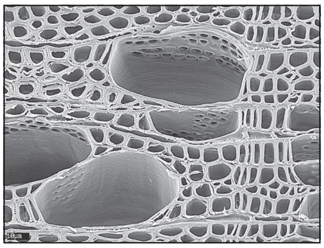


*Figure 4.28 Electron microscope view of wood*

1 Describe where the apical meristem is.

2 What is the apical meristem for and what does it do?

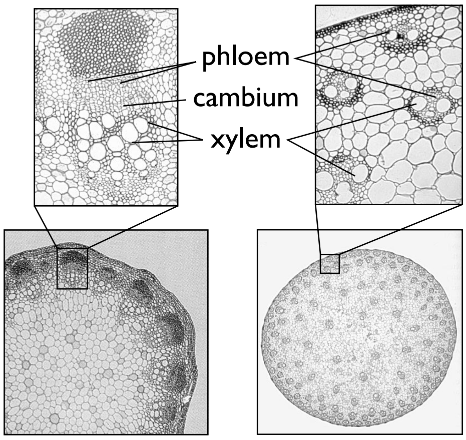
3 Explain the difference between primary and secondary growth.

4 Explain how the lateral meristem increases the width of a plant stem.

5 Explain the difference between heartwood and sapwood.

6 Interpreting Microscope Images:

The microscope images show the arrangement and types of tissue in the vascular bundles of a Dicot and a Monocot plant.




**a** How does the arrangement of vascular bundles in monocots differ from dicots?

**b** What tissue is absent in the monocot vascular bundle?

**c** What implications does this absence have for the size that monocot plants reach?

7 Investigate plant growth through research, experiments or designing and carrying out your own investigation. Investigations could relate to effect of environmental factors on growth, e.g. temperature, different light intensities or shading, mineral deficiencies, soil types, colour of light, wind, humidity.

## Co-ordination

In this section you learn to:

- ❑ **describe** role of hormones in plants
- ❑ **investigate** plant responses to stimuli
- ❑ **explain** plant responses to light, gravity and touch.

# Plant responses

Plants can't move around like animals, therefore it is important they sense and respond to their environment. Plants can respond to their environment by moving their individual parts such as petals and leaves but most of the time plants respond by changing their growth.

### Plant hormones

- **Hormones** control how plants respond to environmental stimuli. Hormones are chemical messengers which are made in the part of the plant that detects the stimulus, then transported to the parts where the responses occur. There are many different plant hormones. Often a hormone will have different effects when it reaches different parts of a plant.
- Hormones called **auxins** cause the tips of growing stems to grow towards directional light. Light-sensitive chemicals in the cells of shoot tips cause a hormone to migrate to the darker side of the plant. It stimulates the growing cells on that side to elongate (increase in length) more rapidly than the ones on the lighter side. This bends the stem towards the light source.
- **Gibberellins** set off the process of seed germination and makes cells expand in growing shoots. **Cytokinins** promote cell division. **Abscisic acid** makes sure seeds and deciduous plants stay dormant over winter. **Ethylene** makes sure fruit ripens and leaves fall off deciduous trees in autumn.

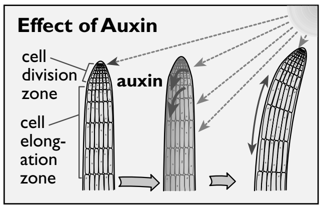


*Figure 4.29 Effect of Auxin*

### Plant sensitivity and responses

- Although we tend to think of plants as being insensitive (having no feelings) and immobile (cannot move), they respond to **environmental cues** and use them to orientate themselves. Often these responses mean that roots grow slowly or shoot tips in certain directions, but some leaves can open and close, some flowers can track the sun, and tendrils can twirl in circles.
- When a plant grows towards or away from an environmental stimulus it is called a **tropic response**. If the plant grows towards the stimulus it is called a **positive tropism**, and if it grows away it is called a **negative tropism**. Different parts of a plant may respond in different ways.
- **Phototropism** is when a plant grows towards or away from light coming from a certain direction. The shoots of the seedlings show a positive tropism towards light coming from the right.
- Other tropic responses include: **geotropism** to gravity; **hydrotropism** to water; **chemotropism** to chemicals; **thermotropism** to heat; and **thigmotropism** to touch (which the bean plant opposite has shown).


*Figure 4.30 Phototropism growth towards light*


*Figure 4.31 Thigmotropism – growth towards or away from touch*

# Activity 15 Responses

### Part one: Light

**Aim**: To investigate the effect of light from one side on the growth of bean seeds.

1. Germinate four groups of three to five bean seeds. Draw diagrams to describe the shape and size of the plants.
2. Place the groups around a bright light source. Draw diagrams to describe the shape and size of the plants over five or six days.
3. Write a conclusion for your results.
4. Write a discussion in which you explain the effect of light on plant growth.

## Part two: Gravity

**Aim:** To investigate the effect of gravity on the growth of bean seeds.

**1** Draw a circle on a piece of cardboard or paper. Mark the points that are quarter of the way around the circle.

**2** Stick a bean seed on the quarter marks around the circle. Make sure that the side of the seed with the embryo plant is facing out of the circle.

**3** Use clamp stands to hold the cardboard upright.

Diagram: Testing the effect of gravity on bean growth.

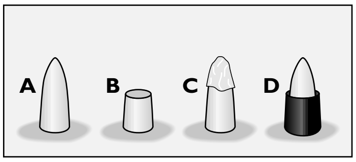
**4** Draw diagrams to describe the shape and size of each plant over five or six days.

**5** Write a conclusion for your results.

**6** Write a discussion in which you explain the effect of gravity on growth of the shoot and the root.

## Part three: Investigating trophic responses

**1** Interpreting Experimental Results.



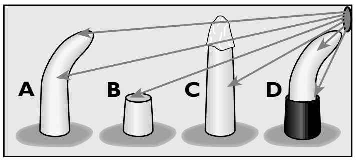

Some oat seeds were germinated in a container. When the shoots were about 1 cm above the soil, they were treated as follows:

**A** tip untouched

**B** tip removed

**C** foil cap on tip

**D** lower shoot in foil.




After three days in a black box which only let in light from one end, the seedlings had grown as shown opposite.

**a** Why was seedling **A** included in the experiment?

**b** What do the results for **B** and **A** indicate about the region of the shoot which is sensitive to the direction of light?

**c** How does the result from treatment **C** support the hypothesis that the tip is sensitive to the direction of light?

**d** What do the results for **D** and **A** indicate about the involvement of the lower shoot in sensing light direction?

**2** Identifying Tropic Responses.

Decide which tropism is involved in the following and whether it is a positive or negative response:

**a** Runner bean tendrils wind around an object they contact.

**b** Root tips grow towards soil with a high water content.

**c** Exposed root tips grow away from a light source.

**d** Root tips grow downwards in response to gravity.

**3** Designing an Experiment.

Your task is to test the hypothesis that when ripe fruit gives off ethylene gas the gas makes unripe fruit ripen faster. You need three unripe mangos, one unripe banana, one very ripe banana and three plastic bags.

**a** Describe how you would test the hypothesis.

**b** What results would you expect if the hypothesis was true?

**c** What implications do the results have for fruit exporters?

# Unit 5

# Animals

This unit is divided into sections that cover nutrition, circulation, gas exchange, excretion, movement, endocrine system, nervous system, reproduction and the effect of drugs and exercise.

## Nutrition

In this section you learn to:

- **explain** the importance of the essential nutrients, e.g. carbohydrates, lipids, protein, minerals (iron, calcium, iodine), vitamins (A, B, C, D), fibre, water
- **investigate** the effect of nutrient deficiencies, incorrect diet and eating disorders on humans
- **explain** the structure and function of the human digestive system
- **investigate** the presence of nutrients in food, e.g. proteins, lipids, starch, glucose
- **explain** how food tests are carried out.

Food molecules contain nutrients and are the source of energy for life. Yet unlike plants animals cannot manufacture their own food. So all animals must eat food to get these nutrients. Living things that eat food are called **consumers**.

The nutrients in food molecules provide the raw materials for growth and repair of damaged tissue. Different nutrients are used in different ways and often come from different sources:

1. **Carbohydrates:** Sugars are the main source of readily available energy for cells. Complex carbohydrates, such as glycogen, are used for energy storage in animals. As plant tissue is mostly carbohydrate, herbivores and omnivores need plenty in their diet. Taro, breadfruit, bananas and other starchy foods are rich in carbohydrates. Carnivores are more likely to use fat or protein in meat for energy. One gram of carbohydrate supplies 18 kJ of energy.
2. **Lipids:** Fats and oils are energy-enriched compounds. However, the energy is less readily available because lipids are stored in special fat cells. Lipids are also used to construct cell structures such as membranes. Herbivores get lipids from fruits and seeds, which are often rich in oils. Carnivores get lipids from fatty tissue found in meat. Margarine and butter are common sources of lipids for humans. One gram of lipid contains 40 kJ of energy.

3 **Proteins:** Proteins are made out of the amino acids which are essential because they build new tissue and make the enzymes which control **metabolism** (the chemical reactions carried out by cells). Carnivores get protein from meat, while herbivores get it from plant tissue such as seeds. Humans eat eggs, cheese and milk as other sources of protein. One gram of protein gives 17 kJ of energy.

4 **Minerals:** We need small amounts of these ions (e.g. calcium and iron) which are in grains, fruit, eggs, milk and meat. **Iron** is for the production of haemoglobin to transport oxygen in the blood. **Calcium** is for strong, healthy bones and teeth. **Iodine** makes the thyroid gland function properly.

5 **Vitamins:** Animals need these complex compounds to make certain enzymes work. Most are only manufactured by plants.

Vitamin A is for good eyes and good night vision. It is in orange and dark green vegetables.

Vitamin $B_1$ works with an enzyme involved in respiration. It is in pork, beans, peas, peanuts and whole grains.

Vitamin C is for healthy teeth and gums. It is in fruits and vegetables, cabbage, tomatoes and green peppers.

Vitamin D helps our body to absorb and use calcium and phosphorous to develop strong bones. It is in dairy products and egg yolk. Vitamin D is formed in the skin when it is exposed to sunlight.

6 **Fibre:** *Soluble* fibre absorbs water during digestion and helps the food to move through the intestines. *Insoluble* fibre is the main material egested (that comes out of the body) in faeces. Cellulose from plant cell walls is the major source of fibre for humans. Cereals, wholemeal bread, nuts, fresh fruit and vegetables are high in fibre.

7 **Water:** Most of our body is made up of water. Water is important because it is part of such chemical reactions as digestion and respiration. Water dissolves other materials such as oxygen and glucose and acts as a transport medium for many different materials. All foods have much water in them but water is needed in such high amounts that most animals have to drink extra water.

## Activity 1 Nutrients

**Aim:** To record information about nutrients.

1 Make a table that records the key points in the information about the function and sources of nutrients.

2 Work in groups of two or three. Practice explaining the importance of the different nutrients to each other.

3 Investigate and discuss the effect of nutrient deficiencies, incorrect diet and eating disorders on humans.

### Testing for nutrients

We can test for starch, glucose, protein and lipids. The following table shows a way to test food and the result if the food has the nutrient:

| Testing for starch | Testing for glucose |
|---|---|
| *Method*<br>Add a few drops of **iodine** to the food solution.<br>*Results*<br>The iodine turns black if starch is present. | *Method*<br>Add a few drops of Benedict's solution and heat in a water bath.<br>*Result*<br>Colour change. Green means a small amount of glucose.<br>Yellow means a higher concentration of glucose.<br>Red orange means lots of glucose.<br>Blue means no glucose. |
| **Testing for protein** | **Testing for lipids** |
| *Method*<br>To the solution being tested add an equal volume of 15% sodium hydroxide. Then add a few drops of 1% copper sulfate solution.<br>*Result*<br>A purple colour shows protein is present. | *Method 1*<br>To 1 ml of ethanol add liquid food or crushed up solid food. Shake then add 1 ml of water.<br>*Result 1*<br>If the liquid is cloudy white, fat or oil is present.<br>*Method 2*<br>Place a small amount of the food on brown paper or newsprint.<br>Squeeze.<br>*Result 2*<br>If lipid is present it will give the paper a shiny clear appearance. |

Note: You may need to grind up food samples in water before you test them.

## Activity 2 Testing foods for nutrients

**Aim**: To test for starch, glucose, protein and lipid in a variety of food samples.

**Materials:**

A range of different types of foods

Test tubes

Starch solution

Glucose solutions of different concentrations, e.g. 0.001%, 0.1%,1.0% concentrations

Protein, e.g. egg white

Lipid, e.g. butter

Iodine solution

Benedict's solution

15% sodium hydroxide solution

1% copper sulfate solution

Ethanol or paper

### Starch test

1 Set up a control test tube by testing starch solutions with iodine. Use this positive result to compare the food tested against.

2 Use iodine to test a range of foods for starch.

### Glucose test

1 Set up a set of control test tubes by testing the different concentrations of glucose solutions with Benedict's solution and heat it in a water bath. Use this positive result to compare the food tested against.

2 Use Benedict's solution to test a range of foods for glucose.

### Protein

1 Set up a control test tube by testing egg white with sodium hydroxide and copper sulfate. Use this positive result to compare the food tested against.

2 Use sodium hydroxide and copper sulfate to test a range of foods for protein.

**Lipids**

1 Set up a control test tube by testing butter with ethanol and water or paper. Use this positive result to compare the food tested against.
2 Use ethanol and water or paper to test a range of foods for lipids.
3 Draw diagrams to explain how to carry out a test for starch, glucose, protein and lipid.

## Human digestive system

The human digestive system is a series of organs linked together. The organs carry out the following four processes:

1 Ingestion – getting food into the digestive system.
2 Digestion – breaking down larger food molecules into smaller ones.
3 Absorption – diffusion of small food molecules into the blood.
4 Egestion – removal of undigested waste food.

The human digestive system includes the following organs for digesting food:

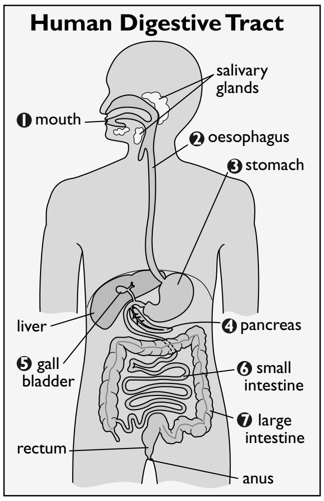


*Figure 5.1 Human digestive system*

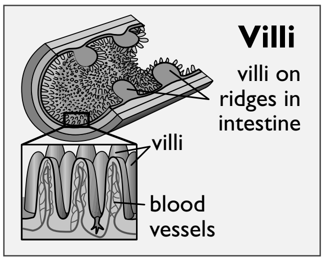


*Figure 5.2 Villi*

1 **Mouth:** Food is prepared for swallowing. The **teeth** cut and grind up the food. The **tongue** moves the food around the mouth. The **salivary glands** secrete water and enzymes. The saliva sometimes does part of the digestion and it lubricates the passage of food (makes it easier to swallow).
2 **Oesophagus:** This short tube has circular muscles that contract in waves called **peristalsis**. Swallowing is when the peristalsis pushes a moistened ball of food from our mouth to our stomach.
3 **Stomach:** This is a muscular-walled bag where food is mixed with gastric juice, which is made of water, **hydrochloric acid** and **pepsin** (an enzyme that digests protein under acid conditions). The soupy mixture in the stomach, called **chyme**, goes in small amounts through a round sphincter muscle into the **small intestine**.
4 **Pancreas:** This organ releases digestive juices, which break down all food types, into the small intestine.
5 **Gall Bladder:** Bile juice is also released into the small intestine. It provides the alkalines (solution in which hydroxide ions are present) which our different digestive enzymes need, and breaks fats up into tiny droplets.
6 **Small intestine:** This very long tube with a muscular wall helps mix food and digestive juices. It is lined with many tiny, finger-like projections called **villi**, which are rich in blood vessels. The villi increase the surface area for absorbing the small digested food molecules.
7 **Large Intestine:** Its main purpose is to reabsorb water from undigested food. This helps store water in the body and makes waste food solid. The **faeces** (waste matter, what the body cannot digest) are stored in the rectum, then **egested** (pushed out of the body) through the **anus**.

## Activity 3 Human digestive system

**Aim**: To develop understanding of the structure and function of the human digestive system.

1 Work in groups of two or three.

2 Write a story that describes the journey and all the changes that take place when a piece of food travels from the mouth, through the digestive system and out the anus.

3 Copy the diagram of the human digestive system and add notes around it to explain how each organ functions.

4 Matching terms with definitions.

| | |
|---|---|
| nutrition | **a** the waves of contraction of circular muscles |
| consumers | **b** a food-processing tube |
| ingestion | **c** obtaining and processing food |
| digestion | **d** the finger-like projections in the small intestine |
| absorption | **e** digested food entering body cells |
| egestion | **f** ions needed in minute amounts |
| metabolism | **g** the chemical which cuts up food molecules |
| vitamins | **h** a carbohydrate which is difficult to digest |
| minerals | **i** complex chemicals needed by animals |
| gut | **j** breaking down large food molecules |
| digestive enzyme | **k** all chemical reactions in a cell |
| peristalsis | **l** the elimination of undigested food |
| villi | **m** getting the food into the gut |
| cellulose | **n** living organisms which cannot make their own food |

5 True or false?

Decide whether the following statements are true or false. Rewrite the false ones to make them correct.

**a** The removal of waste food from the gut is called excretion.
**b** Food is a source of energy and of raw materials for new tissue.
**c** Lipids are a source of readily available energy in cells.
**d** Enzymes are a type of protein that control reactions by acting as catalysts.
**e** Enzymes in the small intestine of mammals need alkaline conditions.
**f** The sphincter is a circular muscle that closes off the stomach.

6 Finding energy usage.

The table shows the amount of energy we use in different activities.

**a** Display this data on a bar graph.

| Activity | Energy Used |
|---|---|
| sleeping | 4.2 kJ/min |
| sitting | 5.5 kJ/min |
| standing | 7.0 kJ/min |
| walking | 15.0 kJ/min |
| exercise | 30.0 kJ/min |
| light work | 15.0 kJ/min |
| heavy work | 40.0 kJ/min |

The second table shows the number of hours three people spent in one day in various activities.

| Activity | Student | Shop Worker | Forestry Worker |
|---|---|---|---|
| sleeping | 9 hr | 9 hr | 9 hr |
| sitting | 10 hr | 5 hr | 4 hr |
| standing | 2 hr | 2 hr | 2 hr |
| walking | 2 hr | 2 hr | 1 hr |
| exercise | 1 hr | 0 hr | 0 hr |
| light work | 0 hr | 6 hr | 2 hr |
| heavy work | 0 hr | 0 hr | 6 hr |

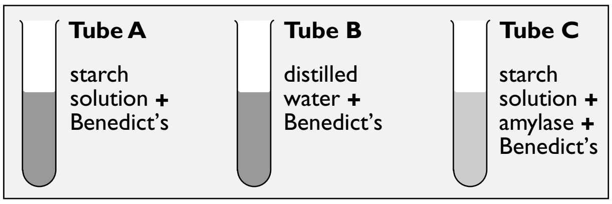
**b** Calculate the daily energy usage that each of these three people use.

**c** List the hours you spend on each activity in a typical day. Work out how much energy you use.

**d** Why do females usually need less energy than males?

**7** Interpreting Experiments.

The test tubes shown below were set up to test whether the enzyme amylase converts starch to maltose (malt sugar, the natural sugar in flour and wheat). Each test tube was heated for two minutes. (Benedict's turns yellow or orange when heated if there is maltose.)

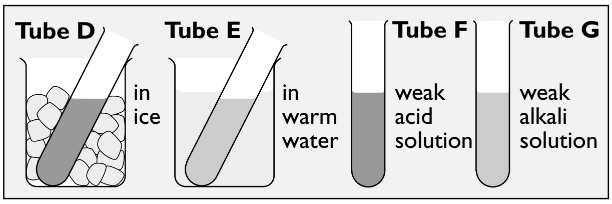



Tube C gave a positive test, but A and B were negative.

**a** Why were test tubes A and B included in the experiment?

**b** What does the result for test tube C indicate about the action of amylase on starch?

Test tubes containing starch and amylase were placed in the conditions shown below. After 10 minutes each had Benedict's added before being heated for two minutes.




Tubes D and F tested negative, but E and G were positive.

**c** What do the results for D and E indicate regarding the effect of temperature on starch digestion?

**d** What do the results for F and G indicate regarding the effect of pH (hydrogen ion concentration) on the action of amylase?

# Circulation

In this section you learn to:

- **state** the importance of an internal transport system in animals
- **explain** the structure and function of blood and blood vessels
- **describe** the basic structure of the human circulatory system
- **discuss** the roles of the circulatory and lymphatic systems for transport.

## The need for internal transport

Only in some very small animals (e.g. unicellular organisms) can **diffusion** by itself transport materials around the organism. In large, multi-cellular animals, diffusion is too slow and they require an **internal transport system.** Oxygen and digested food molecules have to be carried to cells. Carbon dioxide and other wastes have to be removed to prevent cells being poisoned. In addition, hormones, antibodies and water have to be transported around the body.

An internal transport system needs a way of transporting these materials. Animals such as humans, have **blood** to transport these materials around the body.

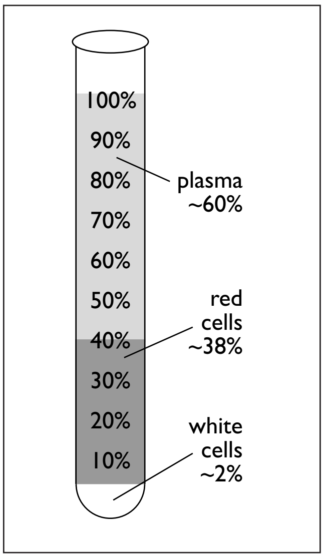



*Figure 5.3 Blood composition*

### Blood

Blood is tissue made up of different parts:

- *Plasma* is the liquid part of the blood. It is made up of mostly water and it contains proteins (e.g. enzymes, clotting factors) and a range of different dissolved substances (e.g. minerals, glucose, urea).
- *Red blood cells*. There are very many red blood cells in the blood. They have a flat shape and are full of haemoglobin. Their function is to carry to oxygen.
- *White blood cells* are important for fighting infections by bacteria, fungi and viruses.
- *Platelets* are small pieces of cells, packed with enzymes that help the blood to clot whenever a blood vessel is cut.

### Circulation system

The circulation system is made up of a series of tubes called blood vessels and a pump called the heart.

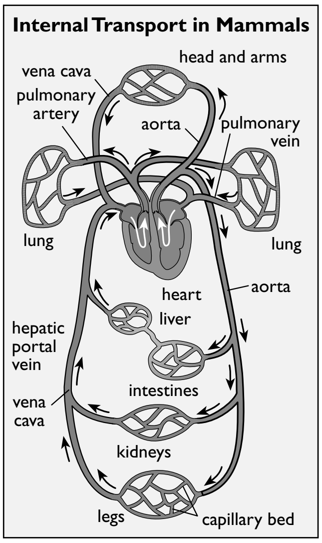



*Figure 5.4 Circulation system*

There are three different types of blood vessel: arteries, capillaries and veins. Together these blood vessels form a continuous system of tubes that carry the blood to all parts of the body.

- *Arteries* carry blood away from the heart. They have thick elastic walls. As the blood is forced along the arteries by the pumping action of the heart, the walls expand and then return to normal.
- *Capillaries* are very small blood vessels that are only a few cells thick. Oxygen, nutrients and other materials diffuse through the walls of the capillaries and into the surrounding cells. Carbon dioxide and wastes diffuse from cells into the capillaries.
- *Veins* carry blood back to the heart. They have thinner walls. Blood is helped back to the heart by the squeezing action of the body muscles. Veins have one-way cup-like valves that prevent blood flowing backwards.

The heart has two separate pumps that beat together. There is a separate circuit going to the lungs to oxygenate the blood and back to the heart and a second circuit from the heart, around the body and back to the heart.

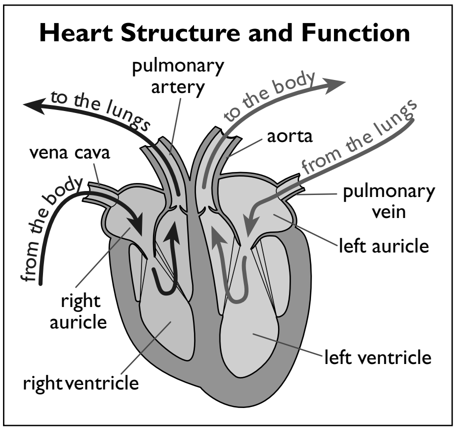



*Figure 5.5 The human heart*

The **right auricle** receives **deoxygenated blood** from the body. It contracts, pushing blood through a **valve** into the **right ventricle**, which contracts to pump blood to the lungs.

The **left auricle** receives **oxygenated blood** from the lungs. It contracts, pushing blood through a **valve** into the **left ventricle**, which contracts to pump blood out of the aorta and then around the body to the capillaries and back to the heart.

At rest, the heart **beats** at about 70 beats/min. **Nerve impulses** trigger it to beat much faster in response to exercise, excitement or fear. This supplies more blood so that the cells get more oxygen during exercise, excitement or fear.

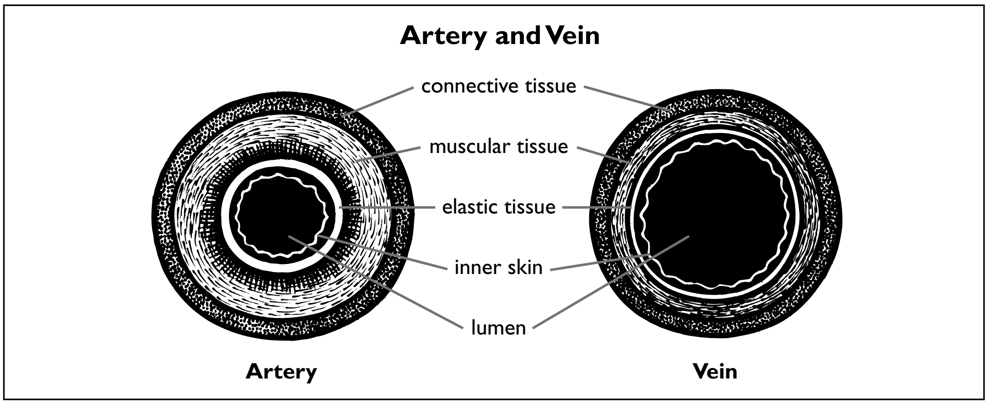



*Figure 5.6 Artery and vein*

## The lymphatic system

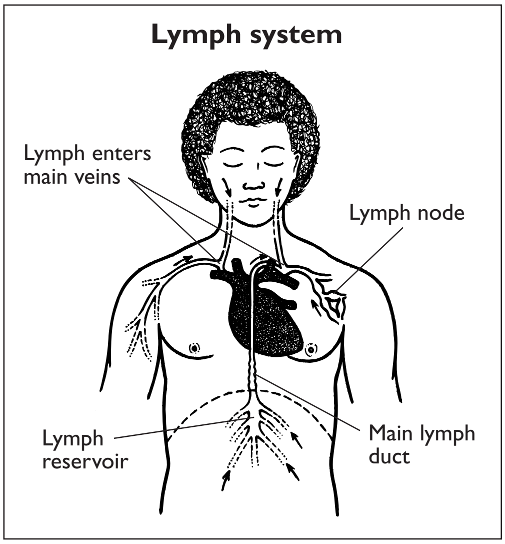



*Figure 5.7 The lymph system*

The lymph system is a system of tubes that begin beside the cells in the body. The tubes join together until they form one larger tube that returns the fluid they carry to the blood. The body needs the lymph system because pressure from the heart squeezes water in the blood plasma out of the capillaries and surrounds all the cells in the body. This helps with the transport of material to the cells but it means that the body has to gather the fluid, called **lymph**, and return it to the blood. This is the job of the lymph system. The lymphatic system is also important for the transport of fatty acids from the digestion of food. Fatty acids are absorbed by the small intestine and enter the lymphatic system. The fatty acids travel with the lymph and are added to the blood with the rest of the lymph.

The tubes of the lymph system go through areas called **lymph nodes**. The lymph nodes filter the lymph to remove harmful bacteria and viruses from the lymph. The special white blood cells in the lymph nodes carry out this function.

## Activity 4 Circulation

**Aim:** To record information on the human circulation system.

1 Explain why large animals need an internal transport system.

2 Describe the parts that make up the tissue called blood.

3 Make a table to describe the differences in the structure of arteries, capillaries and veins.

4 Draw a diagram to describe the pathway of blood through the heart.

5 The circulation system is made up of three parts: the heart (a pump), blood and blood vessels. Explain how the three parts work together to provide cells with oxygen and to remove wastes.

6 Describe the structure of the lymphatic system.

7 Explain how the lymphatic system works along side the circulation system and the digestive system.

8 Drawing a triple-axis graph.

A triple-axis graph is a useful way to display the results of an experiment which measures the effects of changing conditions on two different processes in an organism. This helps us to make comparisons even if the units for the two processes are quite different.

**Problem:** Draw a triple-axis graph to show what happens to heart rate and blood pressure after the body ceases to exercise.

| Time (min.) | Heart Rate (beats/min.) | Blood Pressure (mm Hg) |
|---|---|---|
| 1st | 132 | 184 |
| 2nd | 130 | 178 |
| 3rd | 128 | 142 |
| 4th | 104 | 120 |
| 5th | 85 | 108 |
| 6th | 72 | 104 |

**a** Mark out an even scale for time along the horizontal axis. Label the axis and add the units.

**b** On the left vertical axis construct a suitable scale to cover the range of heart rate values. Space the divisions equally. The scale does not need to start at zero. Label the axis.

**c** On the right vertical axis construct a suitable scale to cover the range of blood pressure values. Label the axis.

**d** Plot the two sets of data and draw a smooth curve through each set of points.

**e** Add a key and a title for the graph.

9 Matching terms with definitions.

| | |
|---|---|
| heart | **a** the part that produces many white blood cells |
| arteries | **b** the chemical that carries oxygen in the blood |
| veins | **c** the vessels taking blood away from the heart |
| capillaries | **d** the muscular lower chambers of the heart |
| auricles | **e** a liquid portion of the blood |
| ventricles | **f** the network of tiny blood vessels |
| blood | **g** the ducts that move fluid back into the blood |
| plasma | **h** the muscular organ which pumps blood |
| erythrocytes | **i** biconcave red blood cells |
| haemoglobin | **j** the internal transport medium of vertebrates |
| leucocytes | **k** cell fragments involved in clotting blood |
| platelets | **l** the thin-walled, upper chambers of the heart |
| lymph system | **m** white blood cells involved in defence |
| lymph nodes | **n** blood vessels with valves that return blood |

**10** True or false?

Decide if the statements are true or false. Correct the false ones.

**a** Veins need valves as they carry blood under higher pressure.

**b** The pulmonary vein is the only vein carrying oxygenated blood.

**c** A human heart beats about 100 000 times a day.

**d** Plasma transports carbon dioxide to body cells.

**e** Blood clots form when platelets are activated.

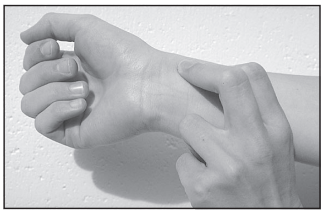


*Figure 5.8 Taking a pulse*

**11** Investigating fitness.

A pulse is the rhythmical beat of an artery, which is caused by your heart pumping. Pulse rate is a very good indicator of the work your body is doing and of your level of fitness. That is why doctors often test the pulse of their patient.

A pulse which is easy to find is in your wrist 2–3 cm back from the thumb joint. Find your resting rate by placing two fingers on the pulse of the opposite wrist, while sitting still. Feel your pulse beating. Count the beats for 30 seconds and multiply the number of beats by two. Get somebody with a stopwatch or a watch with a seconds hand to tell you when 30 seconds are up. Repeat this three times, then average the results to get your resting pulse rate.

**a** Why take the pulse several times and average the results?

Repeat the steps above under the following conditions when you are:
lying down standing walking hopping.

**b** Draw a bar graph to display your results and summarise the relationship between pulse rate and activity level.

A good measure of your fitness is the time your heart takes to return to its resting rate after hard exercise.

Run hard for 100 m, then while seated get someone else to record your pulse rate for 30 seconds every minute for 10 minutes. Multiply the result by two in each case.

**c** Plot this data on a line graph and write a sentence which summarises what the graph shows.

**d** Find out about **oxygen debt**. Explain why your pulse takes some time to return to normal after exercise.

**e** What does the length of time your pulse needs to return to its resting rate indicate about fitness?

**f** Using the above method, how would you identify the fittest person in your class?

**12** Comprehending information.

Read the passage below, then answer the questions.

## Circulatory disease

- Heart and circulatory problems cause about 45% of all deaths in many developed countries each year. Circulatory problems develop in a variety of ways. **Atherosclerosis** is when the arteries narrow because of the build-up of fatty deposits (plaque) on the inner walls of the arteries. This can lead to high blood pressure which is caused when the heart has to work harder to push blood around the body.

(cont.)

- If an artery is blocked by plaque or blood clots, the tissues it leads to start to lack raw materials. A **stroke** is the result of what happens in blood vessels which lead to areas of the brain. A **heart attack** is when there is a blockage of one of the coronary arteries which supplies blood to the heart muscles.
- **Damaged valves** or an **aneurism** (bubbling out of a weakened artery) can cause heart problems. Birth defects include a **'hole in the heart'** – usually a gap between the ventricles, which allow oxygenated and deoxygenated blood to mix. Surgery can usually fix this problem.
- Why are circulatory diseases the number one killer in most developed countries? Sometimes it can be because of a weakness a person has inherited from ancestors and that cannot be changed. However, statistical studies show that some lifestyle factors are related to an increased risk. Those things which cause circulatory disease but which we can change are diet (especially fatty food), smoking, weight, lack of exercise, continual stress and diabetes. It is also more common in males and older people generally.

**a** Why would ateriosclerosis (hardening of the arteries) cause high blood pressure?

**b** Why would the mixing of blood between ventricles as a result of a 'hole in the heart' be harmful?

**c** For each lifestyle factor, say how it would increase the risk of heart disease.

**d** Although more men are at risk of circulatory disease, this is changing and the disease is becoming more common in women. Suggest reasons why.

## Gas Exchange

In this section you learn to:

- **explain** the difference between respiration, gas exchange and breathing
- **describe** the breathing process in humans
- **explain** the structure and function of the human respiratory system.

All animals carry out **respiration** to release energy from food. Respiration is a series of chemical reactions that take place in all living cells. Respiration needs oxygen gas to take in and releases carbon dioxide. Therefore to survive, all animals must exchange these two gases with the environment. They must absorb $O_2$ (oxygen) from the air, soil or water and release $CO_2$ (carbon dioxide) in return. This is called **gas exchange**. Movements of our chest, called **breathing,** are used to get air into and out of the lungs so that gas exchange can occur.

### Breathing

Breathing is in two phases: you take air in or **inhale** and you breathe out or **exhale**.

The lungs are enclosed in an airtight rib cage so that during inhalation, the lungs can pull in the air by changes in the shape of the chest area. The muscles between the ribs contract and pull the ribs upwards and outwards. At the same time the diaphragm contracts and is pulled down and flattened. These two actions increase the volume of the chest and this pulls air into the lungs.

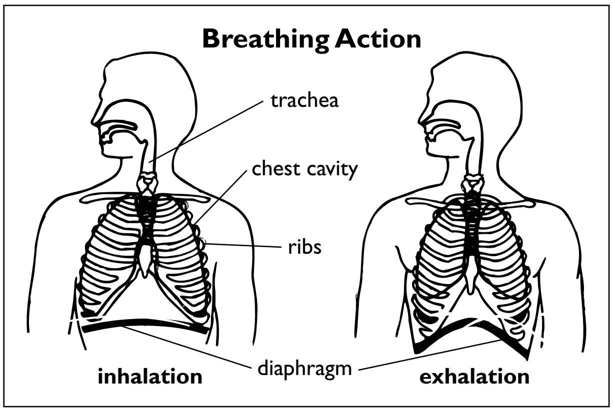



*Figure 5.9 Breathing action*

During exhalation the rib muscles and the diaphragm relax. This causes the volume inside the chest to become less and this forces the air out of the lungs.

## Structure and function of the respiratory system

Humans are very active animals. This means that we need a respiratory (breathing) system which can supply the large amounts of oxygen we need for respiration.

Air enters the body through the nose or mouth and moves down into the chest through a large tube called the **trachea** (or windpipe). The walls of the trachea contain rings of cartilage that hold it open so that it doesn't close and stop the air flowing in and out. The cells in the nose and trachea produce mucous and have tiny hairs called cilia. These are used to clean the air. The mucous traps dirt, such as dust and pollen, that comes in with the air. The cilia beat back and forward to push the mucous and trapped dirt out of the trachea.

The trachea divides into two smaller tubes called the **bronchi**. The bronchi divide again and again into thinner and thinner tubes called **bronchioles**. Each bronchiole ends in a small sac called an **alveoli**. The alveoli are surrounded by blood capillaries.

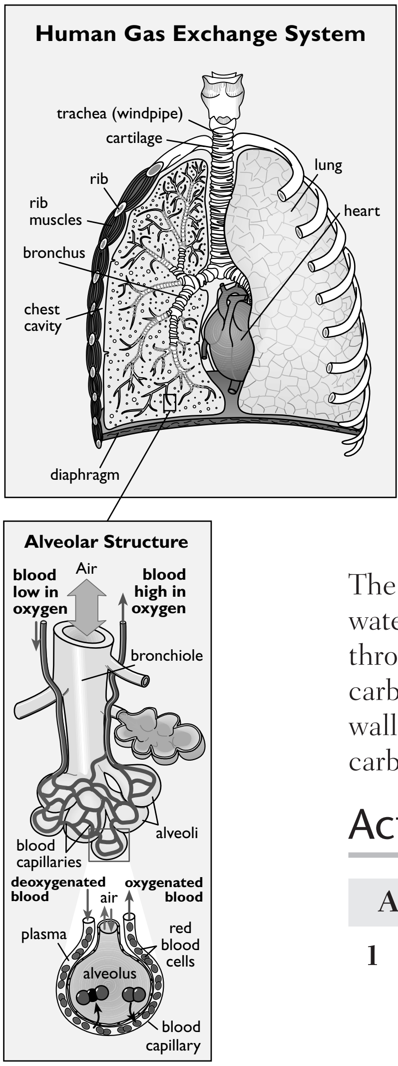



*Figure 5.10a Human respiratory system and Figure 5.10b Aveoli*

The oxygen in the air that has travelled into the alveoli dissolves in a thin layer of water on the inside membrane of the alveoli. It can then pass through the membrane, through the wall of the capillary and then into a red blood cell. At the same time, carbon dioxide from the blood travels from the blood plasma through the capillary wall, through the alveoli wall and into the air inside the alveoli. This exchange of carbon dioxide and oxygen is called **gas exchange.**

## Activity 5 Gas exchange

**Aim:** To record information on the human gas exchange system.

**1** Copy and complete the following table to compare breathing, gas exchange and respiration.

| | Breathing | Gas exchange | Respiration |
|---|---|---|---|
| What it is | | | |
| Where it occurs | | | |
| Purpose | | | |

**2** Describe, using diagrams and text, the process of breathing.

3 Describe, using diagrams and text, the structure of the human respiratory system.

4 Explain how the parts of the respiratory system work together to supply oxygen to the body and remove carbon dioxide.

5 Matching terms with definitions.

| | |
|---|---|
| respiration | **a** the hard external skeleton of animals such as insects |
| gas exchange | **b** fine tubes running from the skin to all organs |
| permeable | **c** the chest action that causes air to leave the lungs |
| medium | **d** very fine blood vessels which pass individual cells |
| organ | **e** membrane which allows gases to pass through it |
| gills | **f** the liquid part of the blood |
| exoskeleton | **g** the chest action that causes air to enter the lungs |
| tracheal system | **h** the gas exchange organs used in water |
| lungs | **i** the breakdown of food in cells to release energy |
| alveoli | **j** the substance inside or surrounding an organism |
| capillaries | **k** the structure of an organism made of many cell types |
| haemoglobin | **l** the muscular layer separating chest from abdomen |
| plasma | **m** the internal gas exchange organs used on land |
| breathing | **n** the microscopic air sacs found in the lungs |
| diaphragm | **o** the bulk movement of air in and out of the body |
| inhalation | **p** the exchange of oxygen and carbon dioxide gases |
| exhalation | **q** the electrical signal sent along a nerve cell |
| nerve impulse | **r** the molecule in red blood cells which attracts oxygen |

6 True or false?

Decide whether the statements are true or false. Correct the false ones.

**a** Respiration is the process of breathing air in and out of the lungs.

**b** Gas exchange organs need to be kept moist and have a large surface area.

**c** External gills on tadpoles provide a large surface area for diffusion of gases.

**d** The lungs of birds are less efficient than those of mammals.

**e** The internal gas exchange systems of land animals prevent drying out.

**f** The breathing rate of humans is determined by oxygen levels in the blood.

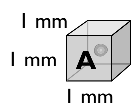
**g** The insect tracheal system takes air right to their tissues.

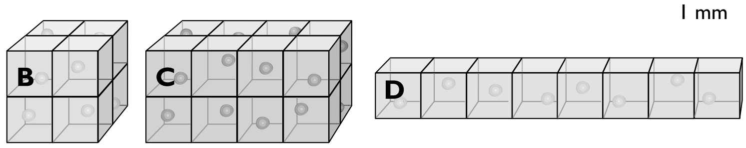
**h** Pressure changes in the chest cavity cause air to rush in and out of lungs.

**i** The spherical shape of alveoli maximises their surface area.

7 Analysing surface area to volume (SA:V) ratios.

The oxygen demand of an organism is related to its volume. Its oxygen supply is related to the area of its gas exchange surface. The higher its surface area to volume ratio, the more efficient gas exchange is.



Imagine cube A is a unicellular organism that uses its surface for gas exchange. Its surface area is 6 $mm^2$ (six 1 $mm^2$ sides) and its volume is 1 $mm^3$.

**a** What is its surface area to volume ratio?

Multicellular 'organisms' B, C and D are each made of eight cells. Each cell has the same dimensions as the one above.

**b** Calculate the surface areas of 'organisms' B, C and D.

**c** Find the volume of each organism.

**d** What is the ratio of surface area to volume for B, C and D?

**e** Which of the three 'organisms' has the most efficient gas exchange surface?

**f** An earthworm is a relatively large animal that relies on its skin for gas exchange. Does it have an efficient shape for gas exchange? Give a reason.

**g** A similar principle applies to heat loss – organisms with a ratio of high surface area to volume lose heat more rapidly. Which 'organism' would be able to conserve heat best?

**8** Analysing gas usage.

The table shows the percentage gas composition of air inhaled and exhaled by a student after exercise.

| Gas | Inhaled Air | Exhaled Air |
|---|---|---|
| $N_2$ | 79.0% | 79.0% |
| $O_2$ | 20.7% | 14.6% |
| $CO_2$ | 0.04% | 6.2% |
| $H_2O$ | varies | saturated |

**a** Why is the percentage of nitrogen gas unchanged?

**b** Why is the percentage of oxygen gas in exhaled air less than in inhaled air?

**c** Why is there a greater percentage of carbon dioxide gas in exhaled air than in inhaled air?

**d** Where does the exhaled water vapour come from?

The breathing rate and breath volume of the student were measured. You can find breath volume by blowing gently through a tube and displacing the water inside a large upside-down container. The following are the student's results before and after exercise:

| Activity | Breaths/ Min. | Average Breath Vol. (ml) |
|---|---|---|
| resting | 16 | 180 |
| after exercise | 26 | 375 |

**e** From this data calculate the total volume of air breathed during a resting minute.

**f** If air is 20.7% oxygen, how many millilitres of oxygen did the student breathe in during a resting minute?

**g** If during rest blood absorbs one sixth of the oxygen inhaled, how much oxygen would blood have absorbed during a resting minute?

**h** Calculate the total volume of air breathed in during the minute after exercise.

**i** If air is 20.7% oxygen, how many litres of oxygen did the student breathe in during the minute after exercise?

**j** If one sixth of the oxygen inhaled during exercise is absorbed by the blood, how much oxygen would the student absorb in the minute after exercise?

**k** How much extra oxygen did the student absorb in the minute after exercise compared with the normal rate?

**l** Why was this additional oxygen required after exercise? (See the topic on anaerobic respiration on page 66.)

**9** Analysing experimental results.

Water temperature affects the breathing rate of fish, because the amount of oxygen dissolved in water varies with the temperature.

The table shows the average breathing rate of a goldfish at different temperatures. (The breathing is measured by counting the number of times the goldfish's gill covers open.)

The fish was originally in a small bowl with water at 20°C. The temperature was varied by adding ice or warm water.

| Temp. (°C) | Breaths/Min. |
|---|---|
| 10 | 6 |
| 15 | 9 |
| 20 | 13 |
| 25 | 22 |
| 30 | 31 |

**a** The number of breaths are the average figures over three consecutive minutes. Why were averages used?

**b** Which is the baseline data?

**c** Plot the data on a line graph.

**d** What does the graph tell us about the effect of temperature on the breathing rate of a fish?

**e** What does the data suggest about whether oxygen gas is soluble in water as temperature increases?

**10** Interpreting biological diagrams.

The diagram opposite shows how a fish uses its gills to transfer oxygen from the surrounding water to its blood.

Match up these descriptions of the events involved with numbers on the diagrams.

**a** Water enters through the mouth of the fish.

**b** Water flows between the folds on the gill arches.

**c** Deoxygenated blood flows into the gills from the body.

**d** Blood in the capillaries moves in the opposite direction to the water flow.

**e** Dissolved oxygen moves from the water, through the gill membranes, into the blood capillaries.

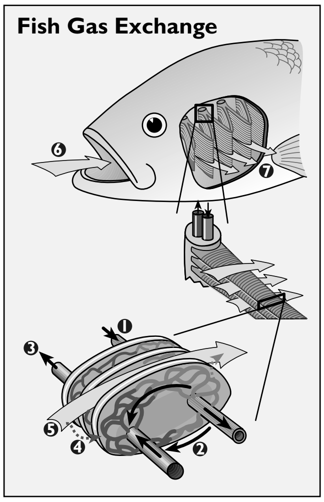



*Figure 5.11 Fish gas exchange*

f Oxygen-rich blood flows out of the gills, off to the rest of the body.

g Water passes out under the gill cover.

11 Measure your breathing rate when resting.

12 Plan, carry out and report on an investigation into the effect of an activity on breathing rate. The investigation could involve comparing people of different ages, males and females, or people with different levels of fitness.

13 Dissect the respiratory system of a pig or chicken.

# Excretion

In this section you learn to:

- ❑ **explain** the importance of excretory systems in animals
- ❑ **describe** excretory products and organs, e.g. carbon dioxide and lungs, urea and kidney, sweat and skin
- ❑ **explain** the structure and function of the human excretory system.

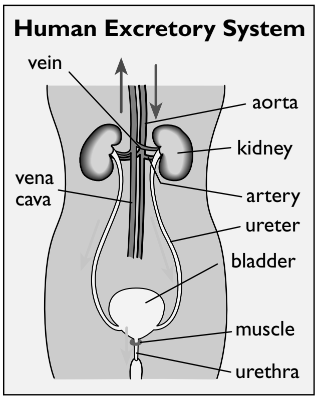



*Figure 5.12 Human excretory system*

Living cells carry out a large number of different chemical reactions. These chemical reactions are called **metabolism**. Some of the reactions produce waste products that must be removed from the body, for example $CO_2$ and urea. **Excretion** involves the removal of the wastes produced by metabolism in cells.

The major excretory organ of humans is the **kidney**, which filters unwanted substances out of the blood and at the same time keeps the substances which the body still needs. **Urea** is the main waste the kidneys remove. Urea is a poisonous waste product so it must be removed quickly. Water is used to dilute the urea so that it doesn't poison the body. This means that the kidneys of humans also help the body to keep the correct amount of water.

Humans have two kidneys that lie on the back wall of the abdomen. The kidneys are supplied with high pressure blood by the **renal arteries**. After it has been filtered, blood leaves the kidneys through the **renal veins**. Our kidneys filter about 180 l of blood a day.

Tubes in the kidneys called **nephrons** carry out the filtration of the blood. Each human kidney has more than one million microscopic nephrons. When the kidneys filter the blood they push all the small chemicals in the blood out of the blood and into the nephrons inside the kidney. These small chemicals include urea, glucose, minerals, vitamins and water. Because the body still needs some chemicals such as glucose, some minerals and vitamins, the body reabsorbs them from the nephrons and diffuses them back into the blood. Some water is always lost with the urea. This loss must be replaced by drinking.

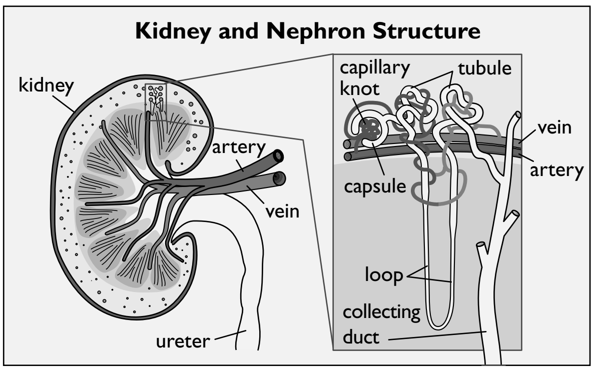



*Figure 5.13 Kidney and nephron structure*

The urea and other wastes form a water solution called **urine**. Urine passes down the **ureter** tubes to the bladder, where it is stored. The **bladder** is a muscular bag that holds up to 400 ml of urine. When full, the expanded walls of the bladder stimulate nerve receptors to send an impulse to the brain to initiate opening of the sphincter muscle at the base of the bladder. This allows urine to flow out of the **urethra**, through the penis in males, or an opening in front of the vagina in females.

### Other excretory organs

The **lungs** and **skin** also act as excretory organs. Carbon dioxide is excreted from the lungs during gas exchange. The skin is important in the excretion of salts. The excretion of salts is part of the way in which the skin helps to keep the human body cool at a temperature of 37°C. When the body sweats it loses water and salts and the evaporation of the water away from the skin removes heat.

## Activity 6 Excretion

**Aim:** To record information about the human excretion system.

1. Describe, using diagrams and text, the structure of the human excretory system.
2. Explain how the parts of the excretory system work together to remove wastes from the body.
3. Describe the roles of the lungs and skin in excretion.
4. Carry out a dissection of the excretory system of a pig or chicken.

## Movement

In this section you learn to:

- **describe** the importance of movement for survival in animals
- **explain** how voluntary muscles cause movement
- **explain** the importance of the skeleton for movement in vertebrates.

Even the smallest of animals have some system to **support** their bodies, and almost all animals need some way to **move** – to find or catch food, to locate mates, and to escape enemies.

Vertebrate animals such as humans, have a skeleton on the inside of their bodies. This is called an **endoskeleton**. The endoskeleton is made up of **bones**. Bones are living tissue made from bone cells, nerves and blood vessels. The bone cells are surrounded by a matrix of tough collagen fibres and calcium phosphate crystals. It is the matrix that gives bones their hard rigid properties.

Bones are held together by **ligaments** (bundles of white tissue that join two or more bones or hold organs in place. Where two bones join is called a **joint**. Joints can be fixed so that there is no movement or they can be a flexible joint. The flexible joints in your arms let you move your arm at the shoulder, elbow, wrist, hand and fingers. Slippery cartilage is at the ends of bones and lets bones slide over each other when they move.

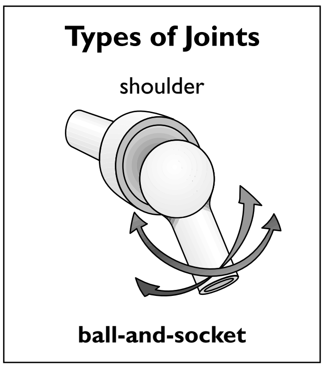



*Figure 5.14 Shoulder joint*

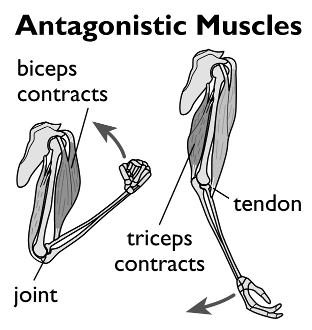



*Figure 5.15 Muscle pairs*

## Muscles and movement

Animals, move by **contraction** of muscles. Muscles are made of cells that contain protein fibres that can move over each other to shorten (contract) or lengthen (relax). The cells in muscles are in groups that form long fibres. Each muscle is made up of several fibres. The ends of the muscle fibres form tough **tendons.** The tendons join onto bones on the other side of a joint. This means that when they contract, the bone on the other side of the joint moves.

Muscles work in pairs to move parts of an arm or leg. One muscle contracts to move a bone while the other muscle relaxes and lengthens. The second muscle can then contract to pull the bone back again while the first muscle relaxes. The diagram in Figure 5.15 shows one muscle, the biceps, pulling the forearm towards the shoulder. Another muscle, the triceps, will pull the forearm in the opposite direction.

Movement is caused by the muscles of the skeleton. These muscles are called **skeletal muscles**. These muscles are under our *conscious or voluntary control*. (A voluntary muscle is any muscle which our will controls. When you want to do something, e.g. take a step forward, you are using voluntary muscles. Some parts that voluntary muscles control are the arm, thigh, neck.) This is different from the muscles in our heart, which are under involuntary control. Our body automatically causes the involuntary muscles to contract and relax and we don't have to think about it to make it happen.

## Activity 7 Movement

**Aim:** To record information about skeleto-muscular systems.

1. Investigate a range of different chicken and pig bones. Record information and observations about the similarities and differences between bones.
2. Why is it important that humans and other animals move themselves?
3. Explain how the skeleton is important for movement in animals.
4. With diagrams and words explain how a pair of muscles causes movement of an arm or a leg.
5. Matching terms with definitions.

| | |
|---|---|
| hydrostatic | **a** the chemical forming the insect exoskeleton |
| exoskeleton | **b** support provided by surrounding medium |
| chitin | **c** a tough, flexible substance made of collagen |
| endoskeleton | **d** tending to float or rise in fluid |
| bone matrix | **e** the part that attaches muscles to bones |
| cartilage | **f** a type of muscle that beats regularly |
| ligaments | **g** an internal skeleton made of bone |
| joints | **h** a part that connects adjacent bones together |
| filaments | **i** the microscopic contracting units in muscles |
| tendons | **j** a curved surface which can create lift |
| antagonistic | **k** the hard skeleton enclosing an organism |
| cardiac | **l** the part where bones meet, and which often allows movement |
| buoyancy | **m** gas-filled buoyancy organ |
| swim bladder | **n** muscles which work in opposition |
| aerofoil | **o** consists of collagen and calcium crystals |

6 True or false?

Decide if the statements are true or false. Correct the false ones.

a An earthworm moves by contracting layers of muscle against the fluid inside its body.

b A disadvantage of an exoskeleton is that it must be moulted before an arthropod can grow any larger.

c A tortoise has an exoskeleton only.

d Muscle fatigue occurs when insufficient oxygen reaches muscles.

e The muscle contractions that push food along the gut are consciously controlled.

f No matter how strong your biceps muscles become, they will not be able straighten your arm.

g The shape and structure of a bird's wings give a clear indication of its main mode of flight.

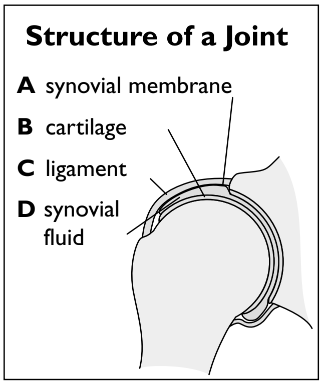



*Figure 5.16 Structure of joint*

7 Relating function to structure.

Study the joint shown opposite, then answer the questions.

a What are the functions of components A to D of the joint?

b What type of joint is it?

c Where do you find a hinge joint?

d What can hinge joints do and what can't they do?

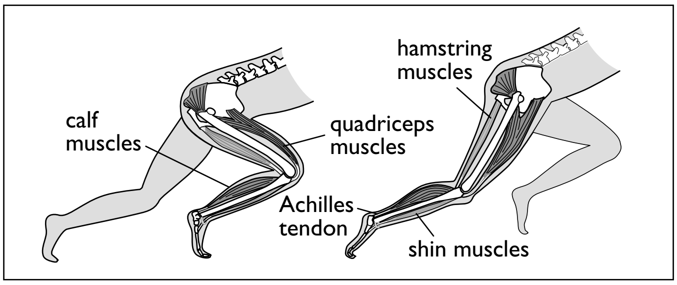
e Where in your body will you find a ball-and-socket joint?

f What can ball-and-socket joints do and what can't they do?

g Where in your body is a joint that allows both rotation (turning on an axis) and a nodding movement.

8 Relating muscles to movement.

Study the diagram which shows the four main groups of muscles in action as an athlete accelerates in a race, then answer the questions below.




a What happens to the leg when the quadriceps contract?

b What happens to the leg when the hamstrings contract?

c What happens to the foot when the shin muscles contract?

d What happens to the foot when the calf muscles contract?

e Are the muscles under voluntary or involuntary control?

f Name two pairs of antagonistic muscles in the diagram.

g What happens if a pair of antagonistic muscles contract at the same time?

h Why do athletes find that contracting a pair of antagonistic muscles together good exercise?

i What would happen to a foot if the Achilles tendon snapped?

# Endocrine System

In this section you learn to:

- ❑ **explain** the role of hormones in animals
- ❑ **name** endocrine glands and their secretions
- ❑ **explain** what hormones do, e.g. adrenaline, insulin, oestrogen, thyroxin.

The co-ordination of internal processes (acting in combination), the sensing of **stimuli** (external information) and the responses to it, are co-ordinated by the **nervous** and **endocrine system** in animals.

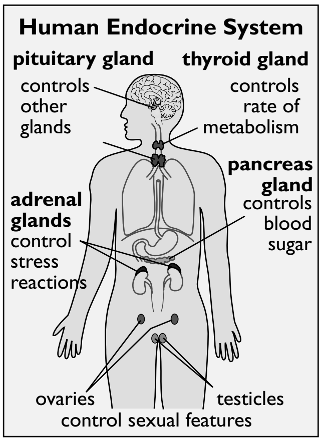



*Figure 5.17 Human endocrine system*

In vertebrate animals, the endocrine system helps to maintain the body so that it works normally. The **endocrine system** is many different glands that release **hormones** into the blood. A hormone is a chemical messenger between cells. Each hormone has a different function and is produced by one cell but causes a change in a cell or organ in a different part of the body. For example, the pituitary organ that sits underneath the brain controls the hormones that control the human reproductive system. Hormones reach glands and organs to control growth, reproduction and the daily processes of living.

The following table shows information about four of the hormones that the human endocrine system produces.

| Hormone | Where from | Acts on | Function |
|---|---|---|---|
| Adrenaline | Adrenal gland | A range of different cells | To prepare the body for 'flight or fight'. Causes increased pulse and respiratory rate. Limits blood flow to the skin and digestive system |
| Insulin | Pancreas | Liver cells | Cause the liver to remove glucose from the blood after a meal. This helps to keep the amount of glucose in the blood steady |
| Oestrogen | Ovaries | Uterus cells | Stimulates growth of the lining of the uterus |
| Thyroxin | Thyroid | A range of different cells | Controls the metabolic rate and growth rate |

## Activity 8 Endocrine

**Aim**: To record information on the endocrine system.

1. What is the role of hormones in animals?
2. Copy the diagram of the endocrine system and the hormones each secretes.
3. Discuss the function of different hormones.

# The Nervous System

In this section you learn to:

- **describe** the importance of human senses
- **explain** the central nervous system in humans
- **explain** the structure of nerve cells and what they do, e.g. sensory and motor
- **discuss** the significance of reflex actions
- **investigate** how an invertebrate responds to external stimuli, e.g. food, temperature, light, touch, humidity or gravity.

## Sense organs

Humans and other animals need to detect changes in their environment. Some changes can be immediate as when a predator or prey arrives. Other changes can be over time as when a weather pattern changes over a month. If an animal can sense changes in the environment it can respond to the change. For example, an insect that senses a predator may scuttle under a stone or burrow in the ground to avoid being eaten.

Animals have many **sense organs**. Each organ is sensitive to a different stimuli. For example, eyes are sensitive to light and ears are sensitive to sound. Each sense organ contains **receptors**. A **receptor** is a nerve cell that can change a particular type of stimulus into a nerve impulse. The nerve impulse travels to the brain where it is interpreted. The brain may send a nerve impulse down a motor nerve to instruct the muscles to respond to the stimuli. For example, if light is too bright the brain will instruct the iris in the eye to close.

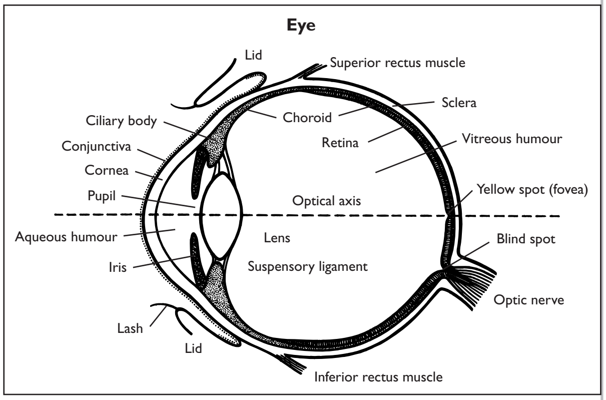



*Diagram 5.18 The eye*

The skin contains a range of receptors able to detect different stimuli. For example:

- **Mechanical receptors** detect touch, pressure or pain. Different numbers of these receptors are in different areas of the body. For example, we have many of them in our fingertips and lips.
- **Thermal receptors** in the skin detect external temperature changes.
- **Chemical receptors** are sensitive to chemicals in the environment, in the air or dissolved in food. In most mammals, these receptors are concentrated on the tongue and in the nose. Receptors in the human tongue are sensitive to four tastes – sweet, sour, salty and bitter.

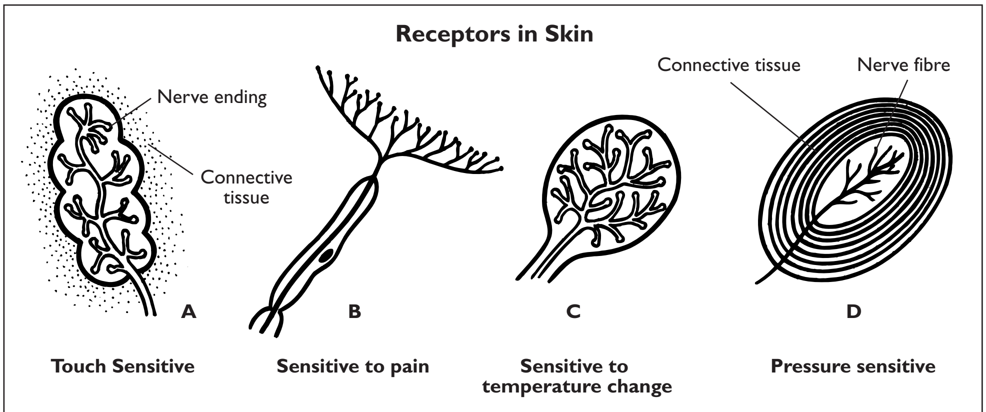



*Diagram 5.19 Receptors in the skin*

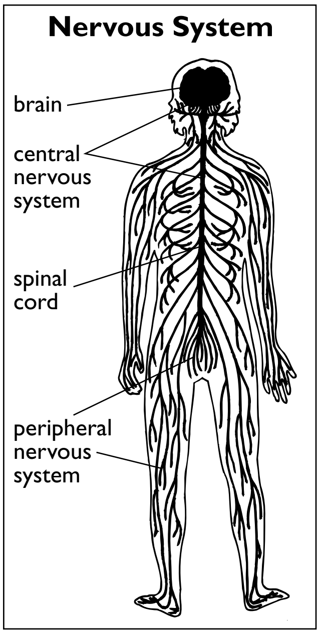



*Figure 5.20 Nervous system*

Smell is a more complex sense. Receptors in the nose are able to detect a huge number of different odours based on a **lock-and-key model**. The molecules of the odour fit into specially shaped molecules on the surface of receptor cells, which then trigger a nerve impulse.

The highly **complex eyes** of humans can detect dim light, movement, shape and colour, as well as focus over a wide range of distances. *Binocular vision*, with both eyes facing forward, allows humans to judge distances very well. Animals that are preyed on often have eyes on the sides of their heads, e.g. rabbits and mice, so they can see nearly all around.

In humans, hearing is important, particularly for speaking, but other animals (e.g. bats) depend more on hearing (e.g. for echolocation) and are sensitive to a different range of **sound frequencies**. Bats, which live in dark places and don't have strong eyesight make high-frequency sounds and have strong hearing. By listening to the echo of these sounds they can find food and avoid flying into obstacles. The human ear is designed to convert different frequency sounds into distinct electrical messages, which are sent to the brain for interpreting.

## Activity 9 Invertebrate responses

**Aim**: To investigate the responses of an invertebrate animal to an external stimuli.

Plan, carry out and report on an investigation into the responses of an invertebrate animal to an external stimuli, e.g. snail. The external stimuli can be one of: food, temperature, light, touch, humidity or gravity. Begin your investigation with a question. For example, 'How does the snail respond when touched by different objects?' Remember to repeat the test using lots of different individual organisms.

## The nervous system

Vertebrates have a **central nervous system** which consists of a large **brain** connected to the **spinal cord** found inside the backbone. The **nerves** in the rest of the body form the **peripheral nervous system.**

The central nervous system receives information from all over the body. The central nervous system co-ordinates the body's responses to the information it receives. For example, if you see a ball somebody throws towards you, your central nervous system will decide to either ignore it, catch it or get out of the way. The central nervous system then communicates, through nerves and hormones, with other parts of the body to carry out the chosen response.

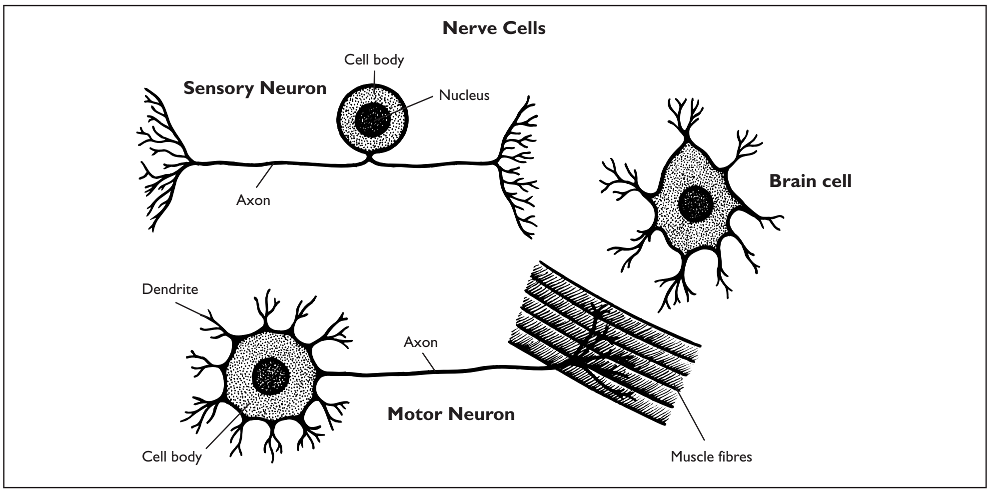



*Figure 5.21 Nerve cells*

The structure of a nerve depends on its function in the nervous system. Motor nerves are very long and thin. They begin in the spinal cord and end in the skeletal muscles. Impulses in the motor nerves cause the muscles to contract. The nerve cells in the brain are round and have lots of branches that connect them to other brain cells.

## Reflex action

When a stimulus (e.g. a thorn prick against a finger) triggers the **receptor cells** in a **sensory organ** (e.g. skin), information is sent along a **sensory nerve** as electro-chemical impulses to the central nervous system. Here the information is processed and the finger may make an automatic response called a **reflex action**. Impulses along **motor nerves** to muscles stimulate action (e.g. remove finger from the thorn). The information will also be relayed to the brain and the brain will make a **conscious response** (e.g. avoid thorns in future).

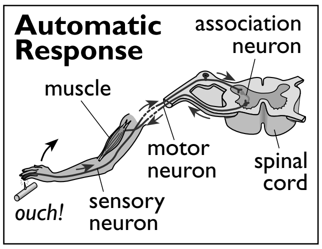



*Figure 5.22 Reflex action*

A reflex action gives a quicker response to a stimulus than the normal response that goes from receptor to brain and back to the muscle. The reflex action is quicker because the distance the nerve impulses travel are shorter – from the receptor to the spinal cord and to the muscles. Coughing, swallowing, response of the iris of the eye to changes in light and the withdrawal reflexes in the hand and foot are all examples of reflex action.

## Activity 10 The nervous system

**Aim:** To record information about the human nervous system.

**1** Why is it important for humans and other animals to sense their environment?

**2** Carry out research to find out how one of the main sense organs works.

**3** Describe the nervous system in humans.

**4** Explain why the central nervous system is important for helping an animal to survive.

**5** Explain what the central nervous system does.

**6** Draw diagrams to describe the structure of different types of nerves.

**7** Explain how the different types of nerve cells work in humans.

**8** What is a 'reflex action'?

**9** Why are reflex actions important to survival of the organism?

**10** Find the term from the text:

- **a** maintaining a steady internal state
- **b** the gland which produces insulin
- **c** a polymer made of glucose units
- **d** balancing the internal water volume
- **e** how body temperature varies with the environment
- **f** how body temperature is kept constant
- **g** the large, complex homeostatic organ with many different functions
- **h** glands and their associated hormones
- **i** a chemical messenger between cells
- **j** an organ which secretes hormones
- **k** the hormone involved in maintaining blood sugar levels
- **l** cells able to generate a nerve impulse

**m** a cluster of neurones

**n** a bundle of neurones reaching an organ

**o** something detected by a receptor cell

**p** a cell able to detect a stimulus

**q** the coiled-up tube able to detect sounds

**r** structures which help you stay upright

**11** True or false?

Decide whether the following statements are true or false. Correct the false ones.

**a** Blood sugar levels are affected by insulin, which is secreted by the adrenal gland.

**b** Marine fish release large amounts of dilute urine.

**c** The evaporation of sweat off the surface of your skin cools your body.

**d** Bird behaviour patterns tend to be learned rather than instinctive.

**e** The thyroid gland secretes a hormone that affects the rate of metabolism.

**f** The owl has binocular vision, so it is likely to be a predator.

**g** The eye position of the cow enables it to judge distances well.

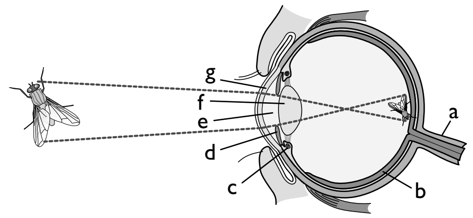
**h** The role of the ear bones is to both amplify and transmit sound waves.

**12** Relating function to structure.

The diagram shows the main structures of the human eye and the way an image forms on the retina.

Match up the letters in the diagram (right) with the terms below:

**Structure of the Human Eye**




- ❑ **Cornea:** curved, transparent protective surface
- ❑ **Iris:** ring of muscle which controls the size of the pupil
- ❑ **Pupil:** opening which allows light through
- ❑ **Lens:** transparent, flexible, disk-shaped structure
- ❑ **Ciliary muscles:** attached to the lens
- ❑ **Retina:** made of light-sensitive receptors
- ❑ **Optic nerve:** transmits visual information to the brain

**a** What are the two functions of the cornea?

**b** Why do iris muscles alter their tension in dim light?

**c** If the surface of the lens does not have the correct curve, how would this affect sight?

**d** How would contracting the ciliary muscles affect the shape of the lens?

**e** There is a blind spot on the retina. Where might this be?

**f** The image on the retina is upside down. Explain why.

**g** What must the brain first do to the visual image it receives from the retina?

**h** What happens to the eye when we focus on close then distant objects?

# Reproduction

In this section you learn to:

- ❑ **explain** the structure and function of the human male and female reproductive systems
- ❑ **describe** gametogenesis, fertilisation and embryonic development
- ❑ **explain** how materials are exchanged between the mother and the embryo.

## Animals use different methods of reproduction

- ❑ Some corals and fish produce and release thousands of eggs at the same time. They release them into the water for the male to fertilise. When young have hatched they have to survive by themselves.
- ❑ Birds produce fertilised eggs with a hard covering (shell) around them. When the young hatch, the adult birds look after and feed the young in a nest.
- ❑ Turtles produce eggs with a tough flexible outer shell. They lay their eggs and then leave the young to hatch and look after themselves.

Each of the methods animals use has advantages and disadvantages for both the parents and the offspring. Predators eat a large number of the offspring of animals that produce large amounts of eggs so that only a small number of the young survive to become adults. For example, sea birds called skuas eat young penguins and turtles or eat the eggs of turtles. When this happens, the animal is in 'population balance'. This means that the adults that die are replaced by about the same number of individuals.

Humans usually produce one offspring at a time and then look after that offspring for many years to make sure that it lives to reproductive age. Humans also improve the success of reproduction by:

- ❑ transferring sperm from the male to the female
- ❑ growth and development of the offspring inside the mother
- ❑ feeding the offspring with milk.

The use of this reproductive strategy and the way we are able to change our environment to suit us, means that we are not in 'population balance' and the numbers of people on Earth is still increasing.

## Human reproduction

### Gametes

The first step in reproduction is the making of sex cells called gametes. Human gametes are also called ovum and sperm. In animals male gametes are called **sperm** and form in the **testes**. In females the gametes are called **ova** (or eggs) and form in the **ovaries**. The female produces on ovum every month. The ovum develops inside the ovary and then bursts out the side of the ovary into the *oviduct*. It travels down the oviduct towards the **uterus** (also called *womb*). If there are no sperm in the female reproductive system the ovum dies and is passed out the vagina.

The male produces millions of sperm in a tiny tube inside the testis. The sperm live for a few days and if they are not released they are reabsorbed.

## Conception

A baby is conceived when the parents have sexual intercourse. When the male becomes sexually aroused his penis becomes hard and erect and can be placed into the female's vagina which becomes moist and slippery. When the male ejaculates (discharges seminal fluid) millions of sperm pass from his penis into the female's vagina. The sperm swim up through the uterus and into the oviduct. Fusion of the egg and sperm (when the egg and sperm come together) takes place (**fertilisation**). The fertilised egg (**zygote**) starts to divide and moves down the oviduct to the uterus. By the time it reaches the uterus it is a ball of cells called an **embryo**. The embryo embeds itself into the wall of the uterus.

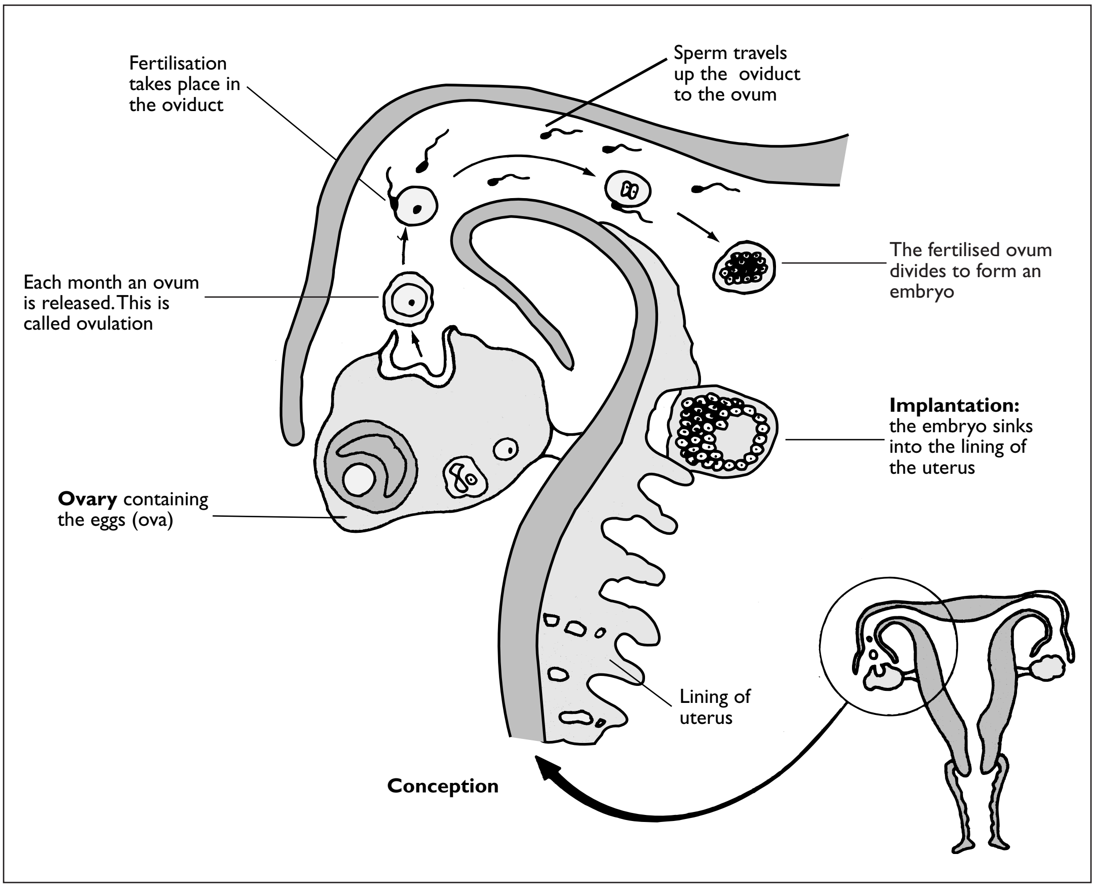



*Figure 5.23 Conception*

## Menstruation

A female does not menstruate (misses her period) if she is pregnant. Normally the inside wall of the uterus builds up each month with a thick lining ready to receive a fertilised egg. However, if there is not fertilisation then the uterus sheds the lining. Blood and dead cells flow down the vagina. This is called menstruation. Usually a woman uses a tampon or pad to collect the blood.

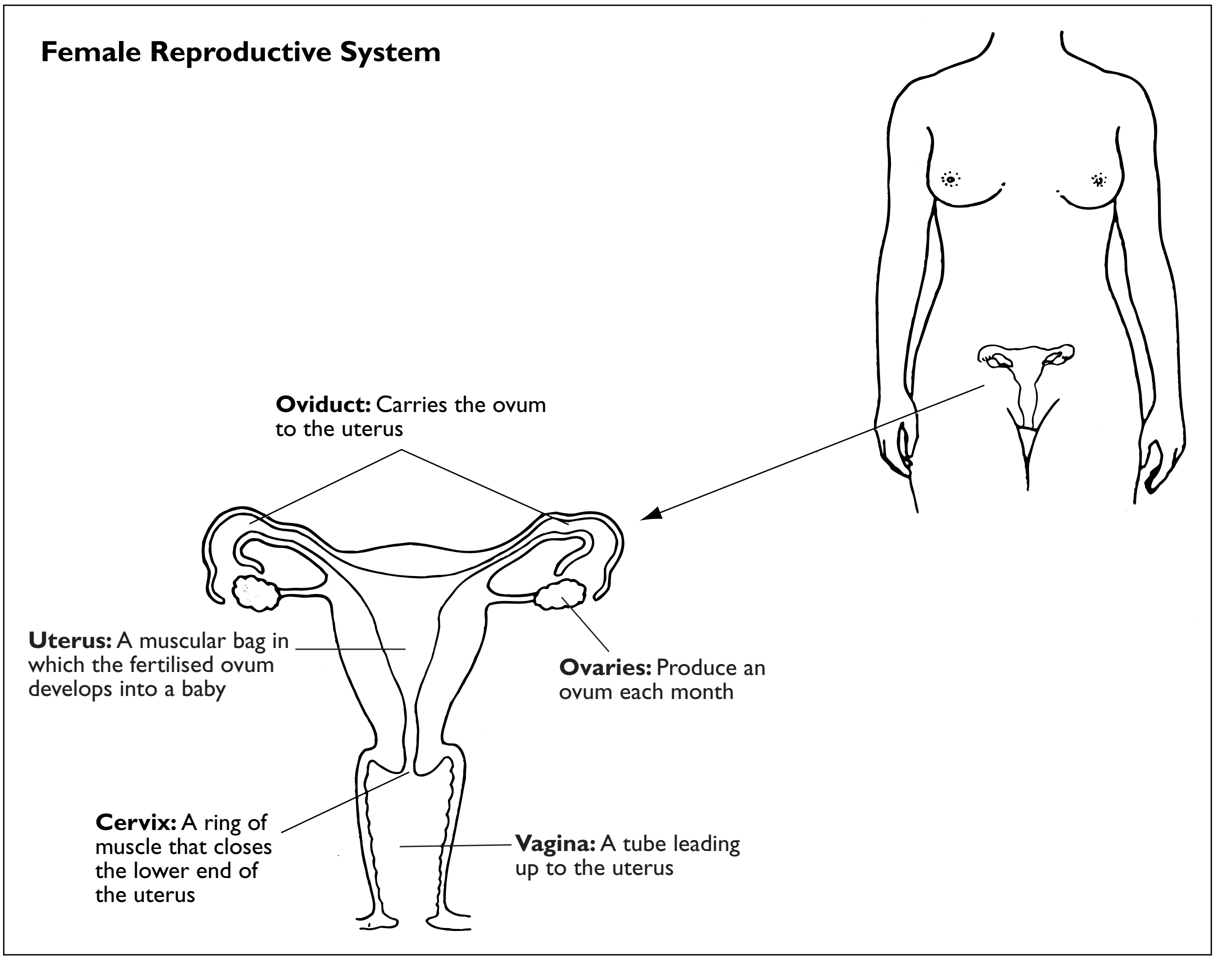



*Figure 5.24 Female reproduction system*

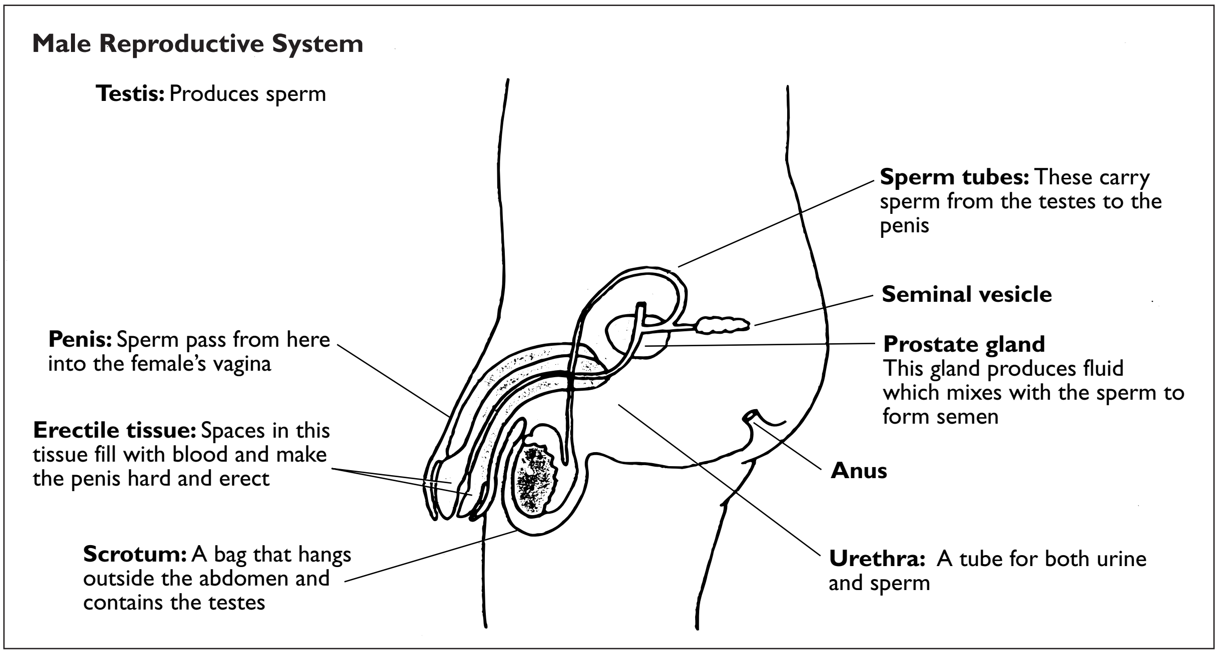


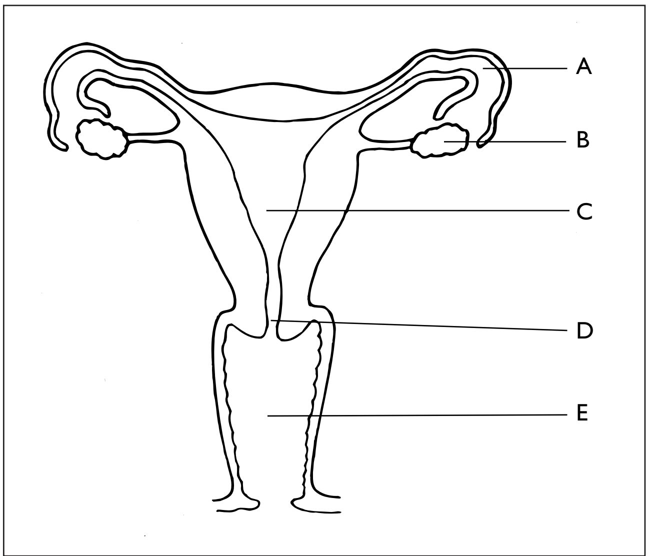

*Figure 5.25 Male reproduction system*

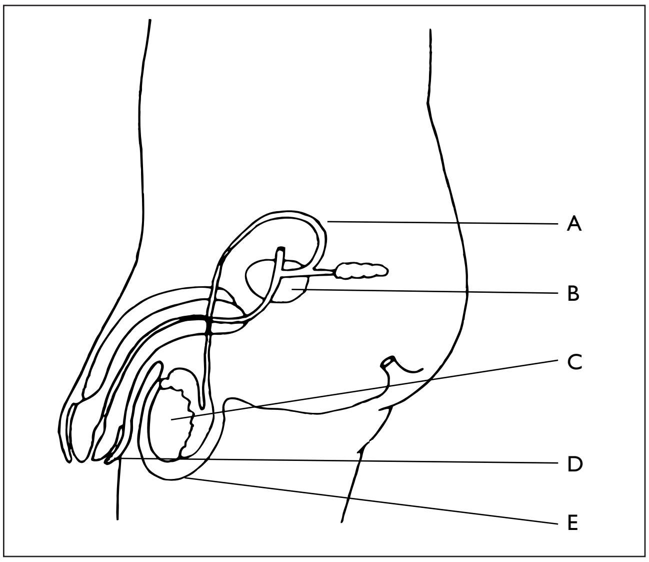
## Activity 11

**1** Copy or trace the diagrams and label the parts **A** to **E**.

**2** Match the following descriptions to the correct part of the diagram.

| | | |
|---|---|---|
| Place where sperm are made. | Gland which secretes fluid to mix with sperm. | Carry sperm to the penis. |
| A baby passes through these parts during birth. | The lining of this part is shed once a month. | Place where the smear tests are taken from. |
| Contains tissue that may fill with blood causing it to become erect. | Place where fertilisation occurs. | A bag which hangs outside abdomen so sperm are stored at a lower temperature. |
| | Ovulation occurs in this place. | |

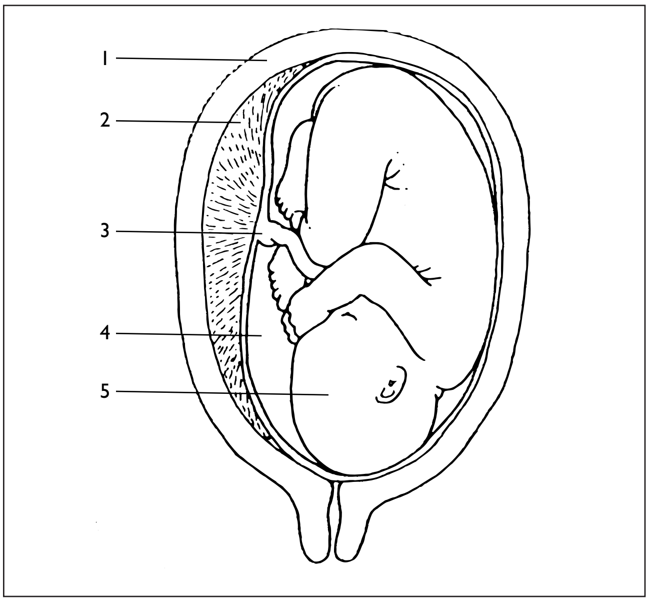



**3** **a** Trace the diagram and label the parts **1** to **5**.

**b** Describe the steps a woman would take to confirm she was pregnant.

**c** How could she discover whether the baby was a boy or girl?



**Ultrasound**

Ultrasound checks if a baby is developing correctly. A small probe is placed over the skin of the area that is being investigated and a beam of high-frequency sound is fired in short pulses through the body. These sound waves are then reflected back to the probe and converted into an electrical signal which the computer turns into a picture. Ultrasound is commonly used to produce pictures of unborn babies. It can also be used to detect abnormalities in parts of the body such as the organs in the abdomen.

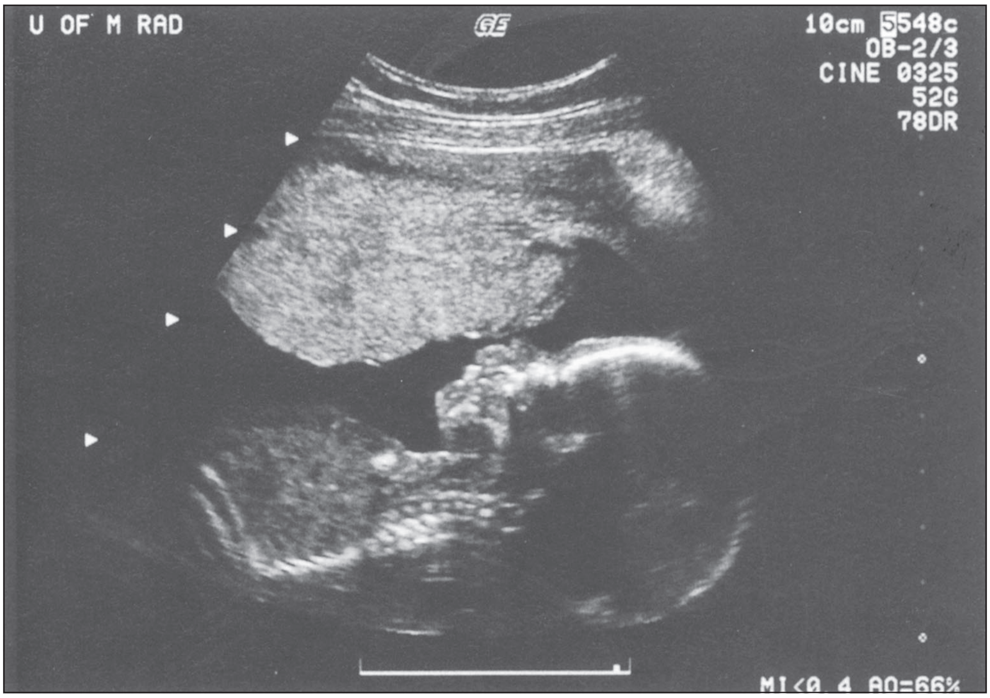



*Figure 5.26 Ultrasound scans*

## Development of the baby

After fertilisation, the zygote divides and forms a small ball of cells. The ball of cells goes into the soft uterus wall and grows to form an **embryo**.

The cells in the embryo continue to grow, divide and specialize as the embryo develops. The cells in different parts of the embryo specialise to become different types of cells. For example, some cells in the head area will become brain cells, others will become bone cells and others will become part of hair follicles. The baby will continue to develop and grow while inside the uterus. The time a baby spends in the uterus is called the **gestation period**. The gestation period for most human babies is nine months

When the ball of cells first goes into the uterus wall some of the cells form the **placenta**. The placenta is an area where the blood of the mother and the blood of the embryo come close together so that the embryo can receive oxygen and food from the mother and the mother can take wastes such as carbon dioxide away.

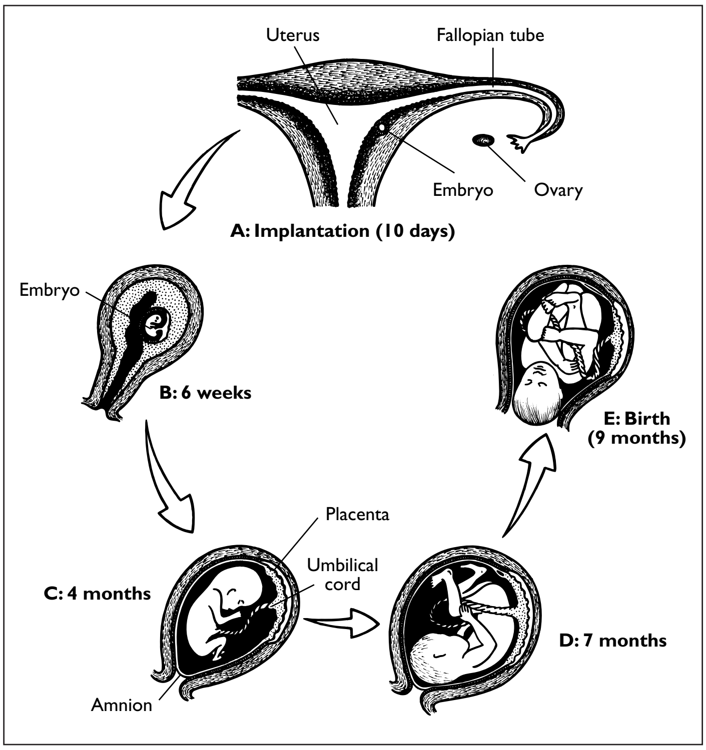



*Figure 5.27 Development of the baby*

# Activity 12 Human reproduction and development

**Aim:** To record information on the human reproductive system.

**1** Draw and label the parts of the human reproductive system.

**2** Explain the functions of the labelled parts.

**3** Describe the processes of ovum and sperm formation and fertilisation.

**4** Draw diagrams to show how the baby develops in the uterus.

**5** Explain how the placenta works to keep the baby alive when it is in the uterus.

**6** Explain the role of the placenta.

## *Constructing life cycle diagrams*

Life cycle diagrams are used to show the different stages and the crucial events during the lifetime of members of a species.

1. Identify the stages involved: zygote, embryo, foetus, juveniles, sexually mature male, sexually mature female, sperm, eggs.
2. Arrange the stages in order around a circle and connect up the stages using arrows.
3. Indicate where crucial events occur: meiosis, gamete release, fertilisation, development, hatching or birth, growth, puberty.
4. If the species undergoes a metamorphosis, indicate where the event occurs and label the different forms involved.
5. Indicate the sections of the life cycle involved in sexual and asexual reproduction.

# Activity 13

**1** Matching terms with definitions.

| | |
|---|---|
| asexual reproduction | **a** when eggs are fertilised inside the female |
| sexual reproduction | **b** the change of body form during life cycle |
| binary fission | **c** when eggs are fertilised in the environment |
| fruiting body | **d** the tube which transports eggs to the uterus |
| parthenogenesis | **e** the spore-producing organ of a fungus |
| external fertilisation | **f** the foetal organ which absorbs nutrients |
| internal fertilisation | **g** the organ which produces milk |
| metamorphosis | **h** reproduction involving two parents |
| copulation | **i** the period of development in the uterus |
| ovulation | **j** the period of gaining sexual maturity |
| oviduct | **k** releasing of eggs from an ovary |
| ejaculation | **l** the later stage of development of embryo |
| uterus | **m** asexual reproduction by splitting in two |
| placenta | **n** the organ inside which embryos develop |
| foetus | **o** new offspring from unfertilised eggs |
| gestation | **p** the release of millions of sperm from penis |
| mammary gland | **q** the act of mating which transfers sperm |
| puberty | **r** reproduction by a single parent organism |

**2** True or false?

Decide if these statements are true or false. Correct the false ones.

**a** Sexual reproduction is important as it results in varying offspring.
**b** Organisms produced by parthenogenesis are identical to siblings.
**c** Mussel eggs are externally fertilised, so mussels produce few eggs.
**d** External fertilisation needs water for gametes to meet.
**e** Gestation is the length of a menstrual cycle.
**f** The mother's blood passes through the foetus.
**g** Puberty is initiated by male and female hormones.

# The Effect Of Drugs And Exercise

In this section you learn to:

- ❑ **investigate** effects of drugs on society
- ❑ **describe** the effects of alcohol, drugs, and smoking on the body
- ❑ **investigate** effect of exercise on the breathing or pulse rate
- ❑ **describe** the effects of exercise on the body.

## Alcohol

Alcohol is a poisonous chemical. Large amounts taken quickly can kill a person. Once alcohol is in our system, our liver has to work hard over several hours to metabolise it (break it into simpler compounds) to remove the poisonous bit and make it safe. While this is happening, the alcohol travels in the blood and causes effects on the organs. The most noticeable effect of alcohol is the effect it has on the person's brain and nervous system. Alcohol depresses or slows down the functioning of the brain. It reduces the person's ability to think, control themselves, remember things and make precise movements. It reduces emotions such as tension, worry, boredom, and shyness, making mixing with other people easier. Unfortunately it increases the person's confidence by decreasing their judgement and sense of responsibility. This can often lead to antisocial behaviour, violence, abusiveness and dangerous driving.

**The effects of alcohol**

**Immediate effects**

BRAIN
Action is slowed down causing changes in judgement, self-control and ability to think.

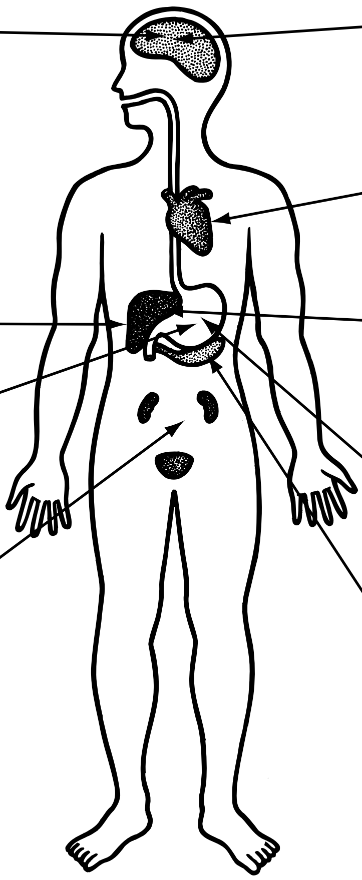
BLOODSTREAM
Causes red blood cells to clump together, slowing circulation and reducing oxygen carrying ability.

LIVER
Begins to break down the alcohol in the blood at a rate of about 7gm (1 drink) per hour.

STOMACH
Drinking too much, too fast may cause vomiting. Alcohol absorbed directly into blood stream.

KIDNEY AND BLADDER
Irritates the kidney, causing an increased loss of fluids and dehydration.

HANGOVER
The pain and distress that may appear some hours after heavy drinking. It is simply the side effects of alcohol on the body. Because alcohol has a pain relieving or anaesthetic effect a hangover appears after the alcohol has gone.



**Long term effects**

BRAIN
Brain cells are killed and cannot be replaced. Eventually causes loss of memory, judgement, learning ability.

BLOOD AND HEART
May inflame heart muscle and cause increased amounts of fats to form.

LIVER
Cells inflamed and gradually destroyed – eventually leading to cirrhosis or liver destruction. Bile secretion may be reduced and hepatitis may develop.

STOMACH
Lining may be irritated, resulting in ulcers. Absorption of some vitamins may be reduced.

PANCREAS
Cells are irritated, blocking flow of digestive enzymes. This may lead to upset digestion, damage to pancreas cells and susceptibility to diabetes.

*Figure 5.28 The effects of alcohol on the body*

Alcohol also effects the body. Some of the effects of alcohol are short term, but other long term effects can occur as a result of frequent drinking.

## Activity 14 Alcohol

**Aim:** To investigate the use of alcohol.

**1** Develop a table recording information on the long-term and short-term effects of alcohol on the body.

**2** A number of different activities could be carried out to investigate the effect of alcohol on the people in Sāmoa. For example:

- ❑ Find out about the types and amounts of alcohol sold in Sāmoa. What laws are there about making and using alcohol?
- ❑ Have a discussion about 'is alcohol a problem or not?'.
- ❑ Research and discuss the importance of alcohol in:
  - **i** health (e.g. the human body)
  - **ii** finances (e.g. household income/budget)
  - **iii** family unit (e.g. divorces, domestic violence, etc)
  - **iv** accidents (e.g. car accidents, etc).

## Drugs

The term drugs refers to any chemical that people use, legal or illegal, that causes an effect in their body. Even medicines that the doctor prescribes for a patient can be harmful if not used correctly or if a person other than the patient uses them.

## Activity 15 Drugs

**Aim:** Investigate the effect of drugs on the people in Sāmoa.

A number of different activities could be carried out to investigate the effect of drugs on the people in Sāmoa. For example:

- ❑ Have a class debate about the importance of staying drug free.
- ❑ Survey peoples attitudes on the use of drugs such as pain relief (e.g. panadol, paracetamol), viagra and marijuana.
- ❑ Research the statistics on drug use in Sāmoa.
- ❑ Discuss, with a pharmacist, the common prescriptions and over the counter drugs used in Sāmoa. What problems do these drugs cause?

## Effects of smoking

The smoke from a cigarette has a number of effects on the body. One cigarette causes your blood vessels to become narrower. This increases your pulse rate as much as 15 beats per minute because the heart has to work harder to push the blood around the body. The blood capillaries in the skin close down, which causes the temperature in the fingers and toes to become lower. The cells lining the lungs and air passages have tiny hairs called **cilia** that remove the dust and bacteria from the air. The chemicals in cigarettes stop the cilia from working for up to 15 minutes. This means that dust and bacteria can get into the lungs.

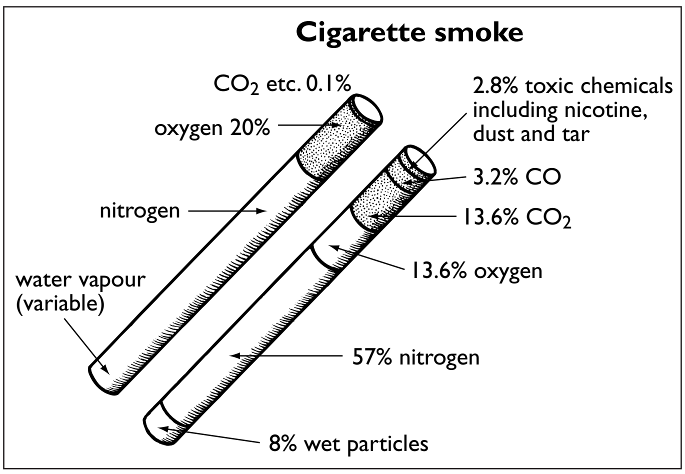



*Figure 5.29 Cigarette smoke*

The **carbon dioxide** is a waste that burning produces. Its presence reduces the amount of oxygen our blood can carry.

**Carbon monoxide** is a poisonous waste product from burning. It joins onto the haemoglobin in red blood cells and stops them from carrying oxygen. This is the main reason why smoking affects the performance of athletes.

**Nicotine** is a drug that affects the heart, blood pressure, blood vessels and brain.

**Dust** irritates the tubes in the lungs, causing mucous to form.

**Tar** is a sticky chemical that covers the lung surface and reduces gas exchange. It and the other chemicals in cigarette smoke cause cancer.

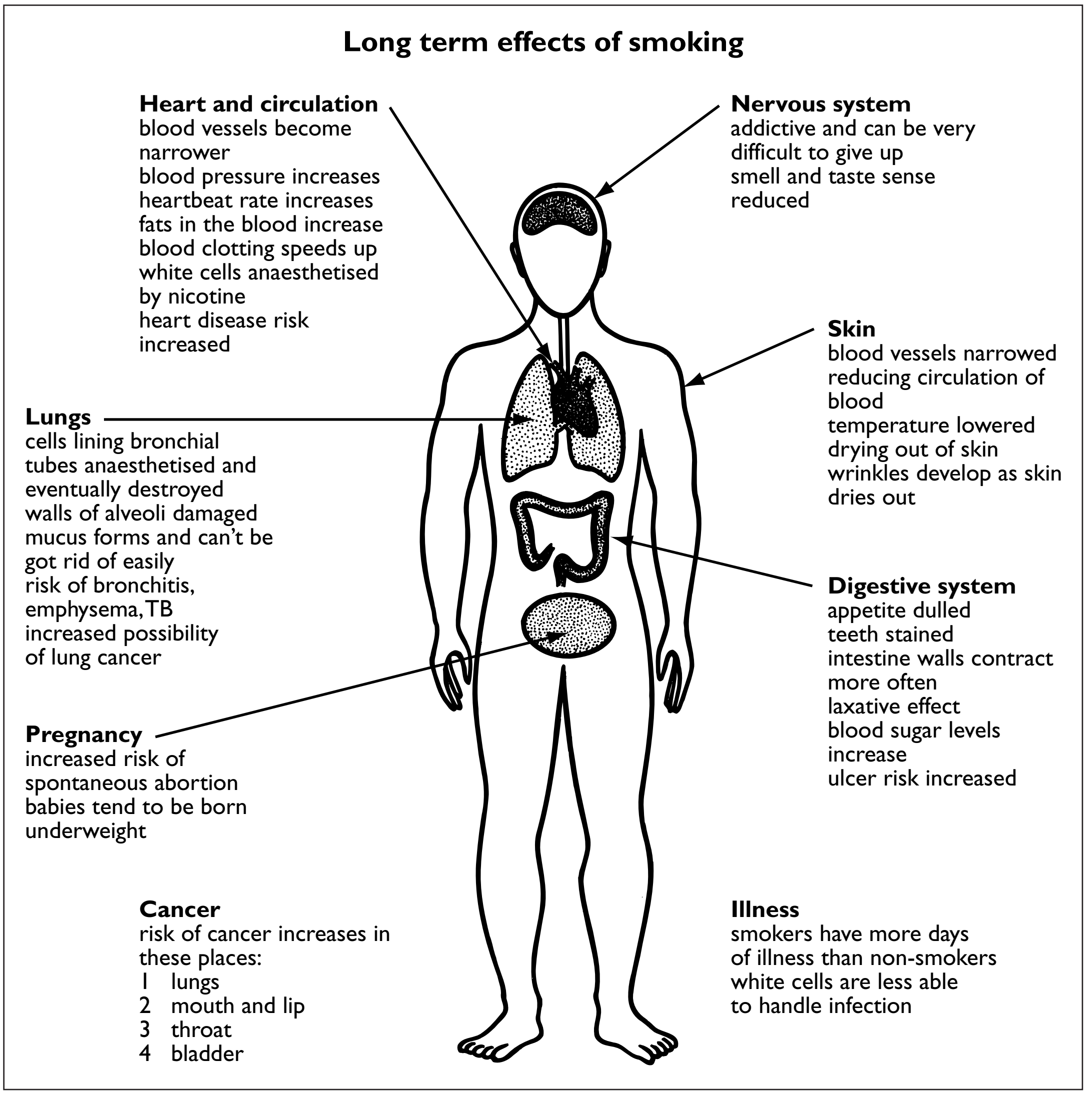



*Figure 5.30 Long-term effects of smoking on the body*

## Activity 16 Smoking

**Aim:** To investigate the effect of smoking on people in Sāmoa.

1 Develop a table which records information on the long-term and short-term effects of smoking on the body.

2 A number of different activities could be carried out to investigate the effect of smoking on people in Sāmoa. For example:

- ❑ Have a class debate about the problems associated with smoking.

- ❑ Survey people's opinions to find out which age groups in Sāmoa are smoking and how many cigarettes they smoke a day. Find out the types of cigarettes teenagers use, the number they smoke per day and where they get the cigarettes.
- ❑ Research the statistics on smoking-related problems in Sāmoa.
- ❑ Discuss, with a health professional, the effect on society if a number of people smoke heavily.

## Effects of exercise

Regular exercise increases the fitness of our circulation and respiratory systems so that the person can carry out the activity they require in everyday life easily and without getting puffed. Exercise also improves the body's strength, stamina, suppleness and resistance to disease.

A change in the pulse rate with exercise is an indicator of fitness. Although the heart rate varies from person to person, it averages about 72 beats per minute in an adult at rest. It is lower in very fit people and higher in children and elderly people. The pulse rate rises when we exercise. If we are more unfit the pulse rate will rise higher and will take longer to return to normal.

The **heart** of a fit person beats more powerfully. This pushes more blood around the body with each beat, so the heart doesn't have to beat as often. More food and oxygen can be supplied and the wastes removed more efficiently. As a result, the other parts of the body, muscles, skin, digestive system, all work more efficiently. Regular exercise greatly slows down the forming of fatty cholesterol deposits that can block up the blood vessels and cause heart disease.

The **muscles** of a fit person are harder, stronger and can work for longer. Exercise results in an increase in the number and size of the capillaries in the muscles. This means that the muscle cells get better supplies of food and oxygen when they need them.

The **lungs** of a fit person can absorb a greater amount of oxygen during each breath. This is partly because more capillaries have developed in the lungs and partly because the muscles that work the chest are more efficient.

The body needs more energy during exercise. Therefore more food is needed or fat stored in the body can be used, so weight becomes less. Posture (the position of the body and the limbs as a whole) also improves because the muscles are stronger and hold the body more firmly. If the circulation is improved because of exercise we pick up fewer infections and our body can fight them better. Exercise and fitness that results, also makes people feel better.

## Activity 17 Effects of exercise

**Aim:** To investigate the effects of exercise on the body.

1. Develop a table recording information on the long-term and short-term effects of exercise on the body.
2. Plan, carry out and report on an investigation into the effect of exercise on breathing and pulse rate.
3. Carry out research to find out about the long-term effects of exercise on the body.
4. Develop a series of survey questions to find out about people's attitudes to exercise.

# Unit 6

# Environment

This unit is divided into sections that cover adaptation, inter-relationships and conservation.

## Adaptation

In this section you learn the adaptations of organisms in relation to habitat and environment and:

- **investigate** how an organism's adaptations help it survive in a particular habitat or environment, e.g. structural, behavioural, functional, (e.g. body temperature, heart rate), life history
- **explain** how the activities of humans affect the relationship between an organism and its environment.

### Habitat and environment

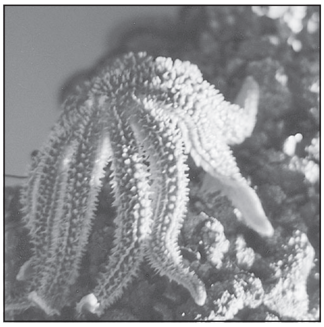


*Figure 6.1 Predatory starfish*

*Figure 6.2 Mussels*

Many living things don't just live anywhere. If you want to find slaters you look in damp, shady places because you won't find them in exposed sites. If you want to find mangroves you look in swamps. Organisms are found in particular places called **habitats**. Each habitat is the home of several species of plants and animals. The species in a particular habitat have adaptations that suit the environment in that habitat. Therefore they won't be found in other habitats where the environmental conditions are very different. For example marine organisms can't live in a freshwater environment.

The **environment** of a species includes all the conditions or factors experienced in its habitat. Different *environmental factors* are important for different organisms. Light is an important environmental factor of a seedling which grows in a forest but it is not so important for an earthworm which lives in the soil beneath the seedling. In fact worms don't have eyes because they don't need them.

There are **biotic** and **abiotic** environmental factors.

*Biotic* factors are caused by the other species that are living in the habitat for example, food supply, predation, parasites, grazing, competition and the actions of humans.

*Abiotic* environmental factors are physical or climatic conditions for example, light, salinity (saltiness of sea water), exposure due to tides, day-length, rainfall, humidity, temperature, dissolved oxygen, carbon dioxide, pH levels, wave action and wind.

## Adaptations

To survive day-to-day each organism must carry out the life processes which include movement, respiration, sensitivity, circulation of materials, growth, excretion and nutrition. Each species of organisms has special inherited features called adaptations which helps it to survive and reproduce in its habitat.

| Type of adaptation | Description | Examples |
|---|---|---|
| Structural or morphological | Physical features | ❑ Spiders have a silk gland and spinnerets that are used to make their webs<br>❑ Flies have bulging eyes which allow all-round vision<br>❑ Breadfruit trees have leaves with a large surface area to trap sunlight |
| Physiological or functional | Processes that the organism can carry out | ❑ Snakes ability to produce poison<br>❑ Human gut cells make enzymes to digest food<br>❑ Ability of some plants to produce nectar |
| Behavioural and responses | Ways in which members of a species act, either individually or as a group | ❑ Spider spinning a web – each spider species spins its web in a particular way<br>❑ Fish swimming in a group for protection against larger predators<br>❑ Plants grow towards the light |

*Figure 6.3 Adaptations – wings as structural adaptations, gums' leaves produce toxins, spinning a web is a behavioural adaptation*

## Biological drawings

Structural adaptations are often shown in biological drawings.

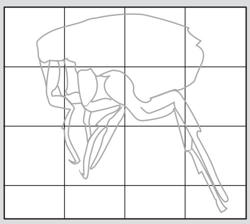
### *Biological drawings*

One way to obtain information about adaptive features is by careful observation and accurate drawing.

You don't need to be an artist to make effective biological drawings; just follow these basic steps.

The photo shows a flea.

**Steps:**



1 Use a sharp pencil to make clear line drawings on unlined paper.

2 Measure and record dimensions.

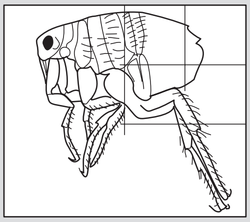
3 Rule up a grid and mark measurements using a suitable scale.

(cont.)

4 Lightly draw an outline of the shape of the organism.

5 Observe sections of the organism and fill in one square at a time.

6 Make separate sketches of special features such as mouth parts, sense organs, limbs, etc. Include notes with arrows to explain details.



7 Tidy up your drawing, erase the grid, and label the parts neatly.

## Activity 1 Adaptations

**1** Matching terms with definitions.

| | |
|---|---|
| organism | **a** an aspect of surroundings which affects an organism |
| habitat | **b** physical or climatic factors |
| species | **c** structures which help a species survive in a habitat |
| environmental | **d** an individual living thing, e.g. a plant or an animal |
| behavioural | **e** the process which helps a species survive in a habitat |
| biotic factors | **f** places where members of a species are found |
| abiotic factors | **g** the actions of organisms which aid survival |
| adaptation | **h** factors which are due to other species |
| structural | **i** a group of organisms which are able to breed |
| physiological | **j** a feature which enables a species to fit its habitat |

**2** True or false?

Decide whether the statements are true or false. Rewrite the false ones to make them correct.

**a** The ecological niche of a species is the place where its members live.
**b** The environmental factors that are important depend on the habitat.
**c** Trampling of plants by animals is a biotic environmental factor.
**g** The release of pheromones is a physiological adaptation.
**h** The flexibility of human hands is a behavioural adaptation.
**i** Some plants change their growth form as they mature, which means they are better adapted to new environmental conditions.

**3** Classifying adaptations.

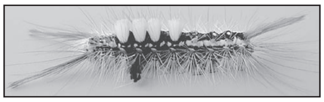


*Figure 6.4 White spotted tussock moth caterpillar*

The white-spotted tussock moth arrived in Auckland, New Zealand in 1996 from another country. It is an invader that could severely damage foliage. The species had not been well studied, so before they eradicated it, Ministry of Forestry ecologists had to identify its habitat and adaptations. They discovered that:

**i** The tussock moth has specialised life cycle stages.
**ii** The caterpillar eats plant material rapidly.
**iii** The adult female lays about 300 eggs.
**iv** There are up to three life cycles per year.
**v** Optimum breeding temperature is about 20°C.
**vi** The female adult releases pheromones.
**vii** The caterpillar gut digests leaves in alkaline conditions.

**a** Decide whether each of the above adaptations is structural, physiological, behavioural or related to life cycle.

**b** Suggest how each adaptation helps survival.

To eliminate the moths, firstly scientists used pheromone traps to determine the moth's distribution (to find in which area the moth was plentiful). Then there was aerial spraying from planes and helicopters with an organic chemical called Btk. Btk is made up of a bacterium that lives naturally in the soil (*Bacillus thuringiensis*, variety *kurstaki*). The insecticide releases a toxin under alkaline conditions.

**c** Which adaptations had ecologists found most useful in deciding how to attack the moth invasion?

**4** Explaining adaptive features.

Giraffes live on the African savanna (grassland with scattered trees). This habitat has a rainy season, but it is hot and dry for most of the year. The dry grassland is dotted with acacia trees, which are tough and very thorny. There are many other browsing animals, and also predators such as lions. Water can only be obtained from widely spaced water holes. Suggest how each feature listed below helps giraffes survive in this habitat:

**a** intestine with microbes for digesting cellulose in leaves

**b** tough tongue

**c** eyes on the side

**d** patterning on fur

**e** very long legs

**f** hard hooves

**g** good sight

**h** tough skin

**i** long neck

**j** fast runner

**k** live in a herd.

**5** Explaining adaptive features.

The sundew is a tiny plant found in swampy places. Environmental factors include:

- poorly drained soil
- acidic soil short of nutrients
- a cold and damp climate
- small insects breeding in bogs.

Few plants can thrive in such an inhospitable habitat. The sundew does as it has specialised adaptations. Explain how each of the following features could assist sundews to survive in this habitat:

**a** the plants are very small and low growing

**b** the plants naturally have a very slow growth rate

**c** the leaves are covered by hairs with drops of sweet, sticky liquid

**d** the leaf hairs bend over any insect that lands on the leaf

**e** the sticky liquid contains digestive enzymes.

*Figure 6.5 Sundew plant*

**6** Drawing an animal.

Complete a biological drawing of this snail to show the external features. Label the shell, the foot, the tentacles, and the eye at the tip of each tentacle.

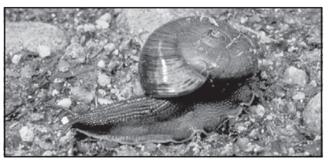


*Figure 6.6 Snail*

*Figure 6.7 Drawing a plant*

**7** Drawing a Plant.

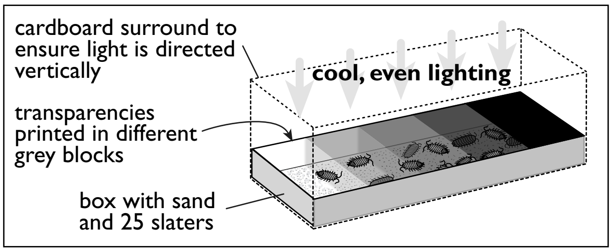
Complete a drawing of this plant to identify structural adaptations.

Remember:

- ❑ be accurate
- ❑ use a grid
- ❑ draw to scale
- ❑ be neat and clear
- ❑ label the parts.

**8** Investigating behavioural adaptations.

Behavioural adaptations are often more difficult to study than structural ones. A group of students investigating why slaters always seem to be found under objects designed a preference chamber, which was used to offer slaters a range of conditions for an environmental factor.




In three experiments, they tested the preferences of slaters for light, temperature and soil dampness. In each experiment 25 slaters were put into the chamber and left for one hour to move to the preferred conditions.

| **Light** | **full light** | **partial light** | **light shade** | **heavy shade** | **complete shadow** |
|---|---|---|---|---|---|
| No. of slaters | 0 | 0 | 0 | 4 | 21 |

| **Temp (°C)** | **5** | **10** | **15** | **20** | **25** | **30** |
|---|---|---|---|---|---|---|
| No. of slaters | 0 | 1 | 7 | 14 | 3 | 0 |

| **Moisture in soil** | **very dry** | **slightly damp** | **quite damp** | **very damp** | **completely saturated** |
|---|---|---|---|---|---|
| No. of slaters | 0 | 3 | 15 | 7 | 0 |

**a** Draw a series of three bar graphs to display the preference data.

**b** Summarise the habitat preference of slaters.

**c** Make a drawing to show how the students could modify the chamber to test for humidity preference.

**d** The students also placed the slaters in a chamber with uniform conditions throughout. What would have been the purpose of this?

## Activity 2 Investigation of adaptations

**Aim:** To investigate the adaptations of a single species.

**1** Use observations and written resources to find out about the structural, physiological and behavioural adaptations of a living thing.

2 Place a drawing or picture of the living thing in the centre of a page.
3 Around the drawing record information about as many of its adaptations as possible.

## Endangered species

Biological communities usually contain a wide variety of species. Unfortunately, when humans modify natural communities one of the most common consequences is the loss of species.

Sāmoa has a very poor record when it comes the fate of indigenous (native) species. Not only have we destroyed or put under threat of extinction our native bird species, including our *manumea*, but also many native fish, insects and plant species such as the *asi manogi* (sandalwood).

Native birds such as *manumea*, *manutagi*, *segavao*, *fuia* and *iao* are becoming endangered. Three factors are causing the loss of these birds:

1 Humans have released competing species. For example, the exotic birds that people brought to Sāmoa to control the tick on cattle. These birds end up competing against local native birds and have dominated the native birds' natural habitats. This is an example of biological control gone wrong.
2 Humans have released predatory mammals such as cats, dogs and rats. These mammals prey on the native species.
3 Humans have destroyed the natural habitat of the native species through clearfelling for plantations or residential purposes.

The Department of Lands, Survey and Environment and South Pacific Regional Environmental Programme (SPREP) have become famous for their efforts to save the turtles, bats and other native species whose numbers fell drastically in the late 20th Century. One problem with endangered species is that often we know very little about the lives of the endangered species and the numbers of individuals are so small that the species conservation people cannot afford to make mistakes.

## Maintaining biodiversity

**Biodiversity** is the range of species present in a community. Biologists who believe it is important to retain as high a biodiversity as possible give the following reasons:

- ❑ Genetic variation is important for the future. Loss of species now, will limit the range of species in the future.
- ❑ Species that we have not yet studied could be the source of future discoveries of scientific and economic importance. For example, the bark of a pine found only in one part of America has become an important part of some medicines for heart disease.
- ❑ All living species have a right to exist.
- ❑ If we have varied ecosystems the world becomes a more attractive and interesting place.

## Activity 3 Biodiversity

1 As preparation for a short talk prepare notes on the arguments for and against retaining indigenous biodiversity. Say who will benefit and why.
2 Give your talk to a small group.

## Community Inter-Relationships

In this section you learn to:

- **investigate** the inter-relationships that exist between organisms in a local community
- **explain** how inter-relationships help maintain a community and its organisms, e.g. predation, commensalism, mutualism, parasitism
- **explain**, with examples, the different roles of different trophic groups in food chains and webs.

A **biological community** consists of all the plants and animals that live within a natural boundary. The size of the community may range from as small as the living things in a puddle to all the organisms that make up an entire forest. The inter-relationships between the organisms in a community are sometimes **co-operative**, but more often the relationships are **competitive** or **exploitative**.

These relationships can be **intra-specific** which means between members of the same species for example, parents caring for their offspring. The relationship can be an **inter-specific** relationship which means between members of different species, for example, when two different types of tree are growing beside each other. They compete for light and space.

### Co-operative relationships

Co-operative relationships are when members of the *same species* work together to ensure mutual survival. For example, hunting animals, like lions, that hunt together in groups. Some animals share the rearing of young or have different roles within the group. In the fo fish the male carries the eggs and young in its mouth. Male wolves look after the pups when the mothers stop feeding them (six months after birth).

### Inter-specific competition

Inter-specific competition is when individuals from *two different species* both use the same resource, e.g. food, a nesting site or a rock on the beach. Plant species compete with each other for light, water, nutrients and space to grow. Fast growing plants have an advantage when competing for light as they are quickly able to grow over top of the other plants and get the most sunlight.

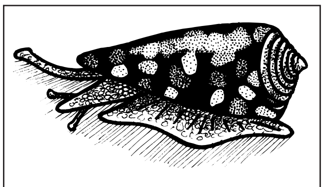


*Figure 6.8 Mata poto*

### Exploitation

Exploitation occurs when one organism *feeds upon another*. **Browsing** animals feed on the tissue of woody plants and **grazers** feed on the tissue of soft plants. **Predator** species exploit prey species by feeding on them. **Scavengers** are organisms that feed on dead material and material left over from a predators kill. A cone shell or mata poto is a predator. It captures moving prey such as sea worms and small fish by spearing them with its spear-shaped tongue.

### Commensalism

Some species *live in association with another species*. They benefit by obtaining food, shelter, or some other advantage. The other species is unaffected by the relationship. For example, epiphytic ferns grow on high branches of trees to gain more light but the tree is not affected. The messmate fish lives in the intestine of the sea cucumber. It comes out to get food and will return to the sea cucumber if in danger.

### Mutualism

In this relationship both of the species benefit. Micro-organisms in our intestines benefit by receiving food and shelter. In return we benefit from the digestive action they have on our food. Lichens are small organisms that are made up of two species that are living together in a mutualistic relationship. The fungi and the algae that make up lichen are no longer able to live independently. Another example is the algae that live in a mutual relationship inside the mantle of the giant clam or *faisua*.

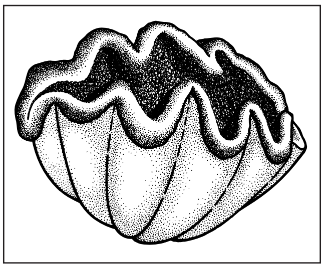


*Figure 6.9* Faisua *or Giant clam*

Clown fish or *tu'u* shelter among the tentacles of sea anemones. The fish give off a mucous substance to protect themselves from the anemones stinging cells. The sea anemone gets scraps of food from the clown fish and the clown fish get protection from the sea anemone.

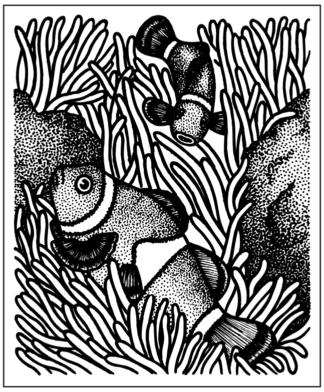


*Diagram 6.10 Clown fish and sea anemone*

### Parasitism

In a parasitism relationship one species lives on or in a host organism obtaining food and shelter. A well adapted parasite does not kill its host but may irritate the host or harm it by taking some of the host's food. Fleas are an example of a parasite.

### Saprophytes

These are organisms that feed on wastes and dead material and decompose it. Bacteria and fungi are examples of saprophytes. Maggots are also saprophytes.

## Activity 4 Inter-relationships

**1** Produce a table that summarises the above information on relationships and gives examples. For example:

| Relationship | Description | Example |
|---|---|---|
| | | |
| | | |
| | | |

**2** Matching terms with definitions.

| | |
|---|---|
| community | **a** feeding on the tissue of soft plants |
| exploitation | **b** a relationship which two species benefit from |
| intra-specific | **c** all plants and animals living in a defined area |
| inter-specific | **d** interactions between members of same species |
| browsing | **e** feeding on the tissue of woody plants |
| grazing | **f** a relationship when one species lives on another to obtain food |
| predation | **g** when bacteria and fungi feed on dead matter |
| scavenger | **h** a species which provides food or shelter |
| commensal | **i** interactions between different species |
| host species | **j** a relationship when species live with another without harming each other |
| mutualism | **k** hunting another animal species for food |
| parasitism | **l** species that feed on predator's left-over food |
| saprophytism | **m** the utilisation of another species for food |

**3** True or false?

Decide whether the following statements are true or false. Rewrite the false ones correctly.

**a** All the different species of plants and animals in a rock pool make up a biological community.
**b** Competition between harrier hawks for territory is classed as intra-specific.
**c** Commensalism always involves two species which cannot live apart.
**d** A well-adapted parasite does not usually kill its host.

**4** Classifying relationships.

Identify these feeding relationships.
**a** Frogs feeding on small insects.
**b** Moulds growing on bread and absorbing nutrients from it.
**c** Bees feeding on nectar from flowers.
**d** Small reef fish living amongst the branches of coral.
**e** Ants feeding on a dead cricket.
**f** Weeds growing with lettuces in a neglected vegetable garden.
**g** Fleas living in the fur of a cat.
**h** The alga and fungus which make up a lichen.
**i** Chitons grazing on green slime on rocks at high tide.
**j** Manumea feeding on seeds.
**k** Tiny wasps laying eggs on the pupae of German wasps.

**5** Graphing and analysing hypothetical data.

In 1984 rabbits arrived in an isolated valley in New Zealand which had plenty of food and was predator-free. A pair of hawks arrived in the area in 1988. The table shows the numbers of rabbits and hawks over 15 years.

| Year | Rabbits | Hawks |
|---|---|---|
| 1984 | 2 | – |
| 1985 | 13 | – |
| 1986 | 58 | – |
| 1987 | 195 | – |
| 1988 | 358 | 2 |
| 1989 | 420 | 6 |
| 1990 | 360 | 8 |
| 1991 | 232 | 12 |
| 1992 | 95 | 10 |
| 1993 | 138 | 6 |
| 1994 | 260 | 5 |
| 1995 | 87 | 7 |
| 1996 | 162 | 4 |
| 1997 | 98 | 7 |
| 1998 | 142 | 5 |

**a** Draw a line graph to show the rabbit population numbers over the full period.
**b** Describe the rabbit population growth before the arrival of predators. What is this type of curve called?
**c** On the same graph, but using a different scale on the right vertical axis, plot the hawk numbers.
**d** Describe the impact of the hawks on the rabbit population between 1989 and 1992.
**e** What is the shape of the rabbit graph after 1992?
**f** Explain the relationship between rabbit and hawk population numbers after 1992.

**6** Analysing life-history strategies.

Complete the table below for mussels and swans.

| Aspects of Reproduction | Mussel | Swan |
|---|---|---|
| number of young | | |
| size of young | | |
| rate of maturing | | |
| amount of parental care | | |
| formation of pair bonds | | |
| reproductive seasons | | |

**a** Do the species display pure short- or long-term strategies?
**b** List the advantages and disadvantages of short-term and long-term strategies.

7 Interpreting competition.

The photo shows two species of barnacle living at the high tide level on rocks. The large species is *Elminius* and the smaller *Chamaesipho*.

**a** What resources could the barnacles compete for?

**b** Describe the intra-specific competition shown.

**c** Describe the inter-specific competition shown.

**d** Would the intra- or inter-specific competition be strongest? Why?

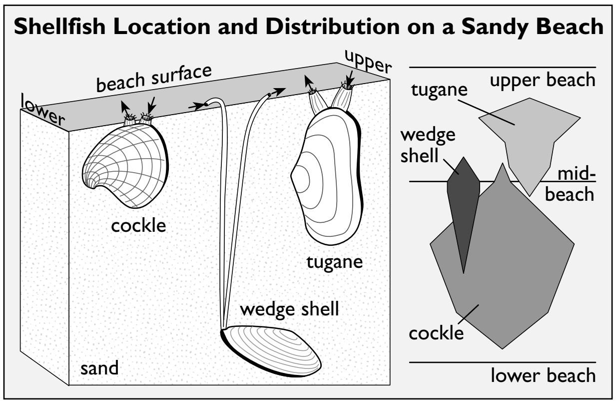
**e** The smaller barnacle *Chamaesipho* is more common. What could this suggest about its lifestyle?

**f** The habitat of barnacles appears to be restricted to the surface of hard rocks. Why might this be so?

*Figure 6.11 Two species of barnacle*

8 Studying niche differences.

The three species of burrowing shellfish shown below seem to share similar ecological niches. They are all filter-feeders that live in the fine sand of sheltered, sandy beaches.




Their distribution between the high and low tidal zones is plotted on the kite diagram. The width of the kite is proportional to the numbers present at that site.

**a** Describe what each kite diagram shows about the distribution of the species involved.

**b** The cockles and wedge shells coexist in the same beach area. Suggest how competition for space between the two species might be minimised.

**c** The smooth-shell bivalve sand-burrowing molluscs also feed in the same way (using their siphons to filter a stream of micro-organisms out of the water). What habitat factor might explain their distribution?

## Activity 5 Investigation of a local community

**Aim**: To investigate a local community and identify interrelationships between organisms.

1 Draw a map of an area which shows the location of a range of plants and animals.

2 Make a list of possible examples of inter-relationships between the organisms found in the area.

## Food chains and webs

All of the species in a biological community are linked through feeding relationships. These feeding relationships are shown in **food chains** and **food webs**. Food chains show a single set of feeding relationships.

All food chains and webs begin with a producer. A producer is a green plant that can carry out photosynthesis. The arrows in the food chain go from food to feeder.

producer photosynthetic plant → herbivore browses or grazes plants → Primary carnivore eats herbivore → Secondary carnivore eats primary carnivore

For example:

Seaweed ➔ cat's eye ➔ whelk ➔ seagull

Plankton ➔ coral ➔ parrot fish

Food webs show a number of interconnected food chains.

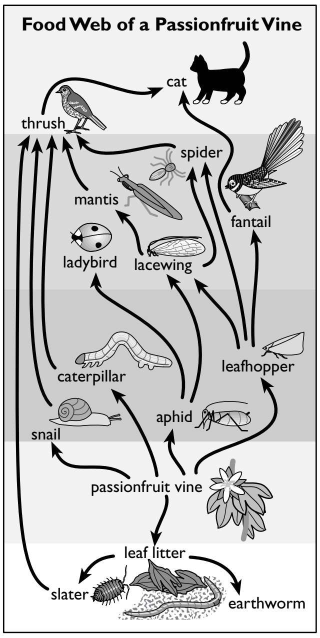



*Figure 6.12 Food web of a passionfruit vine*

## Activity 6 Food chains and webs

**Aim: Identifying feeding levels.**

Use these codes to identify the feeding levels of organisms:

P = producer, H = herbivore, C1 = primary carnivore, C2 = secondary carnivore, C3 = tertiary carnivore D = decomposer

**1** Identify the feeding levels of the organisms listed in the food chains above.

**2** Identify the feeding levels of the organisms listed in the food web above and the following food web.

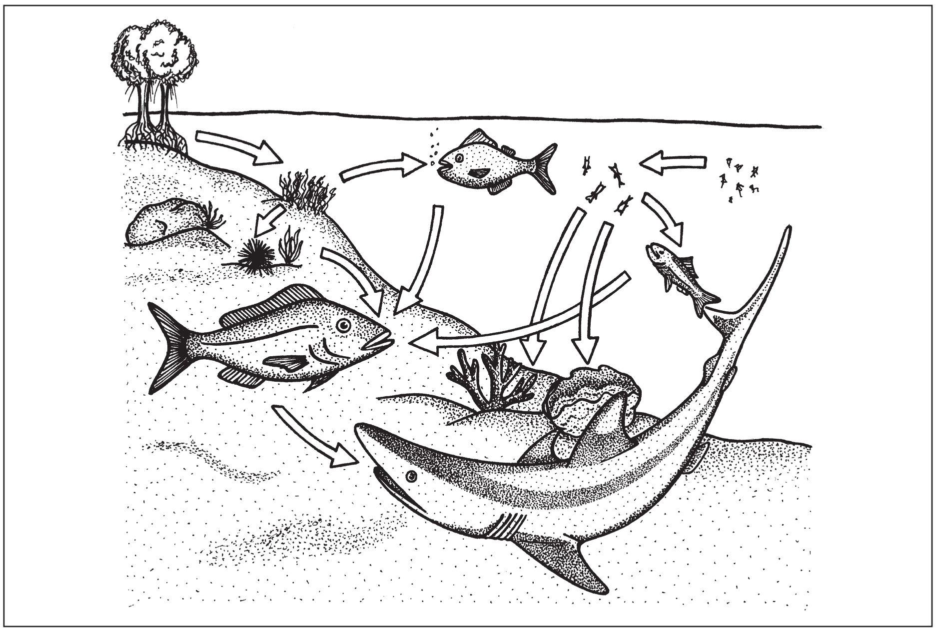


*Figure 6.13 Food web diagram*

**3** Identify possible feeding levels for the following organisms:
*lulu, veʻa, lupe, miti tai, segasega mauʻu, peʻa vao, pili, ūū, amu, faisua, alamea, feʻe.*

**4** Draw up food chains and food webs for other local organisms.

# Conservation

In this section you learn to:

- **investigate** a local environmental issue
- **discuss** causes and effects, and suggest possible solutions for environmental issues
- **explain** why it is important to recycle nutrients using the carbon and nitrogen cycles
- **compare** both the long-term and short-term effects of using biological controls on the environment, as opposed to the use of chemical controls such as pesticides.

## Recycling of chemicals

There are a number of chemicals necessary for growth and maintenance of all organisms in a community. Carbon, oxygen, hydrogen, and nitrogen are chemicals organisms need in large amounts. Many other elements, such as phosphorus and sulfur are needed in small amounts. These chemicals are continually being cycled from an environmental store, through the community, and then back to the store again. An environmental store is a place in the ecosystem such as the atmosphere or soil where the chemical can be found outside of the living things.

### Carbon cycle

The most important element is *carbon* whose atoms form the backbone of all complex molecules in organisms. The carbon cycle shows the movement and storage of carbon in an ecosystem.

Carbon is the key raw material in photosynthesis. Plants get carbon from carbon dioxide in the atmosphere and use it to produce carbohydrates. The plant then uses the carbohydrates and minerals from the soil to make all the chemicals that the plant needs to live. For example, cellulose, fats and proteins.

The carbon passes through the trophic levels of the community as plant and animal tissue is eaten. When herbivores eat the plants, they gain the carbon the plant has used. The herbivore uses the carbon chemicals in the food to make the chemicals needed for its body. When the herbivore is eaten, the carbon passes onto the next organism. The carbon in wastes and dead material passes to the decomposers.

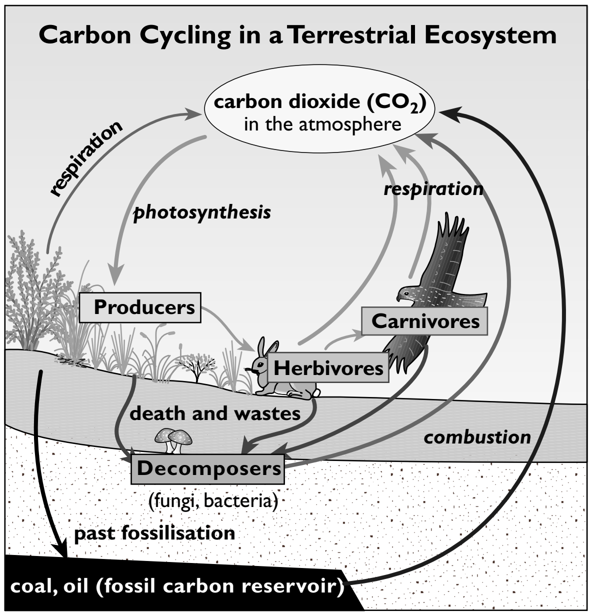



*Figure 6.14 Carbon cycle*

Carbon is released back to the environmental store in the atmosphere through respiration by plants, animals and decomposers.

Some carbon has been locked up in natural gas, coal and oil reservoirs, which were formed millions of years ago when dead organisms became buried in swamps or under sediment on the sea floor.

Currently, the level of carbon dioxide in the atmospheric store is rising faster then the plants of the Earth can use it. This is due to the huge increase in the amount of fossil fuels being used by people, e.g. petrol. The increase in carbon dioxide in the atmosphere is causing international concern as it is a 'greenhouse gas' and is contributing to global warming.

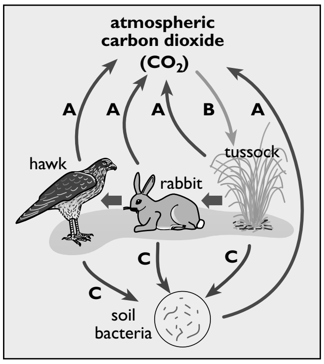



*Figure 6.15 Interpreting cycle diagrams*

### Nitrogen cycle

Nitrogen is an essential element required by plants to make amino acids which are the chemicals that are joined together to make proteins. See also page 25.

Adding fertilisers, containing nitrogen compounds, to the soil can increase the availability of nitrogen for plants.

## Activity 7 Nutrient cycles

1. Explain why nutrient cycles are important in the ecosystem.
2. Copy the diagrams of the carbon and nitrogen cycles into your books.
3. Interpreting cycle diagrams
   a. Identify the trophic levels of the four organisms shown below.
   b. Name the processes indicated by arrows A and B.
   c. Which trophic level carries out both processes A and B?
   d. Arrow C involves two processes. What are they?
   e. Which trophic levels are essential for ecosystems to function? Why?

## Environmental issues

### Introduced species

A threat to the stability of biological communities that humans cause is the introduction of new species. This creates new relationships and may cause major changes to communities.

Humans have introduced many exotic (non-native) plant and animal species. Some were brought to Sāmoa on purpose, but many arrived accidentally and unnoticed, e.g. insects coming on ships. Many exotic species are useful to humans for example, farmed animals.

Some species did little harm to other species, but others have caused major problems, for example, the mile-a-minute plant. Some exotic species directly harm organisms useful to humans for example, taro leaf blight and rhinoceros beetle. Others damage native species through exploitation or competition for example, the African snail and cats. Cats are a major predator of native organisms.

Introduced species are usually not such a problem in the country they come from because in that country there are some species that compete with it and others that exploit it. Therefore, in its own country it fits into the natural inter-relationship in the community. Usually these inter-relationships don't exist in the new country.

Introduced species often have to be controlled using biological control. Biological controls have advantages and disadvantages which mean that sometimes people use chemical controls instead.

## Activity 8 Introduced species and biological control

1. List examples of species that have been introduced into Sāmoa.
2. Mark, on your list, which introduced species have become environmental problems.
3. Explain why introduced species are usually not a major problem in the country they come from.
4. Research an example of biological control used in Sāmoa. Find out the following:
   - ❑ What are the advantages of using a biological control?
   - ❑ What are the disadvantages of using a biological control?
   - ❑ Compare the effects of the use of the biological control with the use of chemical controls, such as pesticides.

## Deforestation

A **rainforest** is a dense forest found in tropical and temperate areas with high humidity and heavy rainfall throughout the year. Few issues have raised such worldwide concern as the rapid and continuing removal of tropical rainforest, which is one of the world's major ecosystems. This became an issue in the 1920s, and so far, in spite of worldwide alarm, we seem to be powerless to stop it. Rainforest destruction means loss of habitat for plants and animals and disrupts the lives of local people and people in neighbouring countries. The problem has become so large that it is affecting local and global weather patterns.

*Figure 6.16 Tropical rainforest*

Tropical rainforests cover less than 6% of the Earth's surface, yet they are home to more than half of the **species** on our planet. Rainforests are the oldest and most diverse, productive and complex **ecosystems** on Earth.

The complex layer structure of rainforest provides a host of **micro-habitats**, and the heavy rainfall and high temperatures allow rapid growth all year long. The key to their value is **biodiversity**. Some ecologists calculate over 30 million species of plants and animals live in these forests. Many are still unknown. Newly discovered species are proving to be a vast store of potentially valuable medical drugs, foods and biological control agents. Apart from the scientific potential of the forest, we need to consider the basic right of rainforest species, including the **indigenous** human forest-dwellers, to survive in their **habitat.**

Why are the rainforests being destroyed at such an alarming rate?

1. **Population pressure:** Most of rainforests are in countries, such as Brazil, Indonesia and the Congo. These countries have rapid population growth and many poor people. People clear the forests to grow food. Unfortunately once the forest is cleared, the soils rapidly lose their fertility and do not support good crops for long.
2. **Cattle ranchers:** Large-scale ranchers move in and sow grass and graze cattle on the cleared land. The cattle are used to supply an overseas beef market. Forest clearance by commercial plantation owners is also a factor.
3. **Timber milling:** Large timber companies lease forest and mill it for the valuable hardwood timber. The South-east Asian rainforests found in Indonesia and Malaysia are the main world hardwood suppliers. In most cases, timber companies have short-term leases and have no interest in **sustainable milling**.

*Figure 6.17 Deforestation*

**Facts and figures**

- Humans have already destroyed over 50% of the world's rainforests.
- Less than 9 million square kilometres still remains (6% of the total land area).
- Each year 150 000 $km^2$ of rainforest is destroyed – 100 000 $km^2$ is cleared and 50 000 $km^2$ logged – an area about the size of two football fields goes every second!
- Less than 10% of the forests are being managed sustainably.
- It has been calculated that at the present rate of destruction about 135 species of rainforest plants and animals are becoming extinct each day!
- The economic value of one hectare of forest is $13 650 per year if sustainably harvested, but only $262 if used as cattle pasture.

## Climate change

Tropical rainforests are an important part of the **global weather system**. The water **evaporated** from rainforests is the main source of moisture in tropical air.

Reduced forests means reduced rainfall. The **rainfall distribution** changes and this leads to droughts in new areas, flooding in other areas and soil erosion. This has happened around the southern edge of the Sahara.

The vast rainforests act as **carbon sinks** absorbing the carbon dioxide, one of the '**greenhouse**' **gases** that are linked to **global warming**. Large-scale forest destruction also affects how the Earth's surface reflects the rays of the sun. Scientists now suspect that this factor may be affecting wind patterns and ocean currents, and may be linked to climate changes in other parts of the world.

## Saving the remaining forests

A number of groups of people are very concerned about the destruction of the rainforest and some have become activists that protest to governments of countries where rainforest destruction is occurring.

### *Passionate quotes made about rainforests*

'Rainforests are the finest celebration of nature ever known on the planet.'

NORMAN MYERS

Those who destroy the rainforest are acting 'with the savage unthinking ferocity of drunken apes in an art gallery. Whereas pictures can be repainted, tropical rainforests can't be recreated'.

GERALD DURRELL

'The destruction of two trees is the price of one hamburger.'

ANONYMOUS

The problem of rainforest destruction is so widely recognised that the United Nations has spent over $16 billion on a **Tropical Forestry Action Plan** to halt the destruction. In spite of this, the UN has had little impact – in fact recent reports suggest increasing rates of destruction. At the 1992 Earth Summit meeting, developing nations with rainforests were unwilling to co-operate in what they saw as an effort by wealthy countries to restrict resource development in poorer regions.

Indonesia, for example, argued that debt reduction by selling timber and clearing land for increasing population is more important to them than long-term environmental programmes. To make the problem worse, there is much corruption and often the logging companies are associated with the political rulers. Often sustainability agreements are not enforced. Tensions can be so high that in Brazil a prominent conservationist was killed by ranchers.

The original forest-dwelling tribes have little voice. They have to adapt or die. In Brazil, there were once over six million forest-dwellers. Now there are fewer than 200 000!

## Activity 9 Local environmental issues

**Aim:** To investigate a local environmental issue.

1. Your teacher will instruct you to work as a class or individual on this topic.
2. Select a topic from the list below or select an environmental issue that is relevant to your village or island:
   - ❑ deforestation
   - ❑ overuse of chemical pesticides and fertilisers
   - ❑ reclaiming of mangrove areas
   - ❑ dumping rubbish in riversides
   - ❑ using *Derris* plant root or Clorox or dynamite to catch fish
   - ❑ over-fishing
   - ❑ catching undersized fish
   - ❑ industrial pollution
   - ❑ marine oil spills
   - ❑ lack of proper sanitation threatens aquifers and the water table
   - ❑ effects of introduced species on local wildlife.
3. Find out about the topic so that you can complete the following:
   - ❑ Describe how or why the topic is an environmental issue.
   - ❑ What is the cause of the issue?
   - ❑ How are local people affected by the issue?
   - ❑ What are people trying to do about the issue?
   - ❑ Suggest possible solutions to the issue.
   - ❑ Give your opinion as to which is the best solution. Give biological, economic or social reasons to support your opinion.
4. Use a range of resources to find out about the issue:
   - ❑ guest speakers
   - ❑ field work investigations
   - ❑ printed resources
   - ❑ interviews with local people.

## Glossary

| Word/phrase | Meaning |
|---|---|
| **adenosine triphosphate (ATP)** | an enzyme that links water intake and respiration in plants by transfer of energy. |
| **aerobic** | needing oxygen for respiration. |
| **aerobic respiration** | a type of internal respiration in which glucose and oxygen get broken down into carbon dioxide, water and ATP molecules. |
| **allele** | different forms of a gene. |
| **anaerobic** | not needing oxygen for respiration. |
| **anaerobic respiration** | a type of internal respiration found, for example in yeast, in which no oxygen is used and pyruvic acid is broken down into lactic acid. |
| **antibiotic** | able to destroy pathogenic bacteria or a medicine to destroy pathogenic bacteria. The first antibiotic development was penicillin that was extracted from a mould. |
| **antigens** | any substance which stimulates the production of antibodies, e.g. bacteria, foreign red blood cells. |
| **antiseptic** | a substance applied to living tissue (e.g. externally on a wound) to kill micro-organisms on human tissue. |
| **asexual** | type of reproduction that does not depend on sexual process. |
| **back cross** | to get offspring by mating a first generation cross to one of the original parental types. |
| **bacterium** (plural **bacteria**) | a type of micro-organism. |
| **binary fission** | the way single cells (e.g. bacteria) reproduce, by splitting in two. |
| **biological oxygen demand (BOD)** | the amount of oxygen required for aerobic purification, the amount of oxygen being used by living things in an area of water. |
| **cellulose** | forms the wall of cells in all plants. |
| **chloroplast** | special centres of chemical activity inside a leaf cell. |
| **coliform bacteria** | organisms that enter natural streams by deposit of animal and human waste. |
| **concentration** | the amount of a substance in a given volume. |
| **consumers** | living things which cannot make their own food. |
| **control** | part of an experiment used to compare the changing of conditions. Most experiments need a control to ensure the conclusion is justified. |
| **cytoplasm** | the material basis of a cell apart from that of the nucleus. |
| **cytoskeleton** | the fibres that form the cytoskeleton, support the cell, give it shape and allow cells to move. |

## Glossary

| Word/phrase | Meaning |
|---|---|
| **decomposers** | living things that live on the breaking down of dead plant or animal matter. |
| **diffusion** | general transport of matter when molecules and ions mix in liquids. |
| **disinfectant** | a powerful chemical which kills micro-organisms. |
| **dispersal** | to separate and move apart in different directions, become scattered. |
| **dominant** | an allele which is always expressed when it is present. |
| **enzyme** | protein used to speed up cell reactions. |
| **express/expressivity** | the extent to which a gene shows an effect. |
| **extracellular digestion** | the digestion of material by enzymes secreted from a cell and acting outside a cell. |
| **fermentation** | conversion of sugars into alcohol using yeast. |
| **flagellum** (plural **flagella**) | structure which helps bacteria to move. |
| **foetus** | a young mammal within the uterus of the mother from the formation development of the organs until birth. |
| **fungus** (plural **fungi**) | a type of micro-organism. |
| **gametes** | sex cells. |
| **gas exchange** | the phase in respiration in which a living organism takes in oxygen from its surroundings and gives up or exchanges the oxygen for carbon dioxide. |
| **gene** | a unit of the genetic code which controls a characteristic. |
| **Golgi bodies** | flat, disc-shaped layers of membrane, scattered particles, that are packages chemicals use outside the cell. |
| **glycolysis** | enzyme-controlled reactions which break glucose molecules into pyruvic acid molecules. |
| **homologous pair** | pairs of similar genes or chromosomes. |
| **homozygous** | a genotype when both alleles are the same. |
| **lymph** | a colourless fluid that circulates the body of mammals. |
| **T-lymphocyte cell** | a cell that develops in the thymus gland. |
| **tissue** | a group of cells forming a continuous fabric. |
| **xylem** | a plant tissue. |
| **zygote** | fertilised egg cell. |

# Key Vocabulary

| Vocabulary | Collocations | Derivations |
|---|---|---|
| adaptations | structural adaptations | to adapt |
| | physiological adaptations | |
| | behavioural adaptations | |
| anti- | antibiotics | |
| | antibodies | |
| | antigens | |
| a cell | a host cell | |
| | the cell wall | |
| | the cell membrane | |
| | cell differentiation | |
| | unicellular | cellular |
| | multicellular | |
| | extracellular digestion | |
| concentration | the greatest concentration | |
| | the sugar concentration | |
| | the carbon dioxide concentration | |
| control | the biological control | |
| | chemical controls | |
| decomposers | decomposer micro-organisms | decomposer |
| to be determined | inherited features are determined by genes | |
| | sex is determined by chance | |
| diagnosing | diagnosing meningitis | diagnosis |
| | diagnosing illness | |
| effectiveness | the effectiveness of antiseptics and disinfectants | |
| | the effectiveness of antibiotics | |
| fibre | fibre in your diet | |
| | muscles fibres | fibres |
| to form a hypothesis | | |
| immunity | immunity to disease | |
| | passive immunity | |
| | active artificial immunity | |
| | immune deficiency | immune |
| | to be immunised against diseases | to be immunised |
| | | immunisation |
| nutrients | recycling nutrients | |
| | essential nutrients | |
| | nutrient deficiencies | nutrient |
| | nutrient preferences | |
| preserving | food preserving | |
| | food preservation technology | preservation |
| | preservation methods | |
| | preserved food | preserved |
| recycling | recycling of chemicals | |
| relationship | an intra-specific relationship | |
| | an inter-specific relationship | |
| | co-operative relationships | |
| | the relationship between an organism and . . . | |
| | feeding relationships | |
| | a parasitism relationship | |
| | a mutualistic relationship | |
| | interrelationships between organisms | an interrelationship |
| | community interrelationships | |

# Key Vocabulary

| Vocabulary | Collocations | Derivations |
|---|---|---|
| resistance | bacteria acquire resistance to an antibiotic<br>antibiotic resistance<br>a drug-resistant strain of TB | <br><br>resistant |
| a system | a system of membranes and connecting tubes<br>the digestive system<br>the immune system<br>the respiratory system<br>the circulatory and lymphatic systems<br>the excretory system<br>the skeleto-muscular system<br>the endocrine system<br>the nervous system<br>the internal defence systems of the body<br>the global weather system | |
| transpiration | transpiration rates<br>transpiration pull<br>the effect of environment on transpiration | |
| variation | variation patterns<br>inherited variation<br>acquired variation<br>continuous variation<br>discrete variation<br>either/or variations<br>independent variable<br>dependent variable<br>controlled variable | <br><br><br><br><br><br>a variable<br><br>variability |

# Useful structures

- long *filaments* bearing pollen-producing sacs called anthers.
- the *symptoms and signs* that made the doctor suspect meningitis.
- an i*nflammation* of the 'meninges' or membranes that surround the brain and spinal cord.
- a *threat* to the stability of biological communities that is caused by humans.

**Naming**

- Organisms which are unicellular or multicellular but lack complex organs are referred to as 'simpler' organisms. Organisms in the Kingdoms Monera, Protista and Fungi are simple organisms.
- Organisms that make food molecules using raw materials and energy from the environment are called producers.

**Defining**

- An organ is a collection of different types of cells working together to carry out a particular function.
- The leaf is an organ which is made up of layers of different sorts of cells that work together to carry out photosynthesis.

**Examples**

- Examples of specialised cells in animals are skin, nerve, bone and blood cells. Examples of the functions of plant cells include providing support, absorbing water, conducting liquids, allowing gases in and out, making food, forming protective surfaces and reproduction.

**Comparing and contrasting**

- When compared with matter that is non-living, objects that are alive are characterised by a number of special features.
- Some bacteria are single cells and others live as groups of cells joined together.
- Some fungi are small organisms made up of one cell. Others can be large organisms made up of many cells.
- Animals, unlike plants, cannot manufacture their own food.

**Making general statements about a class of things**

- All organisms are made up of cells.
- All cells carry out the life processes.

**Restricting the generalisation**

- Organisms usually have one gene in their genotype for a trait.
- Almost all diseases of plants, animals and human beings are caused by micro-organisms.
- Although some cells can live independently, most cells live as part of a multicellular organism.

**Describing physical structure**

- Bacterial cells are made up of cytoplasm and genetic material in the form of a long chromosome.
- The body, or mycellium, of a large fungus is made up of fine threads called hyphae.
- The cell membrane is made up of two layers of lipid molecules. A small number of protein molecules can also be found in between the lipid molecules.
- Plant cells have a cell wall outside the cell membrane. The cell wall is made up of cellulose and it provides that cell with support.
- Bacteria have no cell nucleus and no cell organelles.
- The cytoplasm is surrounded by a strong cell wall.

**Expressing changes in quantity**

- TB rates here have levelled off.
- They have been showing a slight rise.
- Reducing the numbers of deaths to a very low level.

**Expressing movement of substances**

- against a gradient
- across a membrane
- down a concentration gradient
- from higher to lower concentration areas

**Expressing measurement**

- bigger than 10 nm in size
- the cell of a bacterium is smaller than 0.01 millimetres
- in the range of 10 to 100 µm in diameter
- structures from 100 µm down to 0.1 nm in size
- up to 600 mm
- to a depth of 0.5–1.0 cm

# Topic specific vocabulary

**Related to Chapter 1: Living things and micro-organisms**
the phylum
kingdoms
pathogens, a pathogenic disease, pathogenic micro-organisms, pathogenic bacteria
fermentation
coccus
bacillus
spirillum
the organelles
the cytoplasm
aerobic respiration, anaerobic respiration
enzymes
saprophytes
binary fission
the mycelium of a fungus
hyphae
spores
to subculture bacteria, subculturing
nodules
nitrogen fixers
cellulose digesting bacteria
biotechnology
genetically engineered bacteria
inoculation
incubation
contaminated food
opportunistic infections
Koch's postulates
symptoms
inflammation
amoebic meningitis
toxins
carriers
membranes of the nose and throat
an epidemic
tuberculosis (TB)
medication
leucocytes
the bone marrow
leukaemia
HIV
lysozyme
mucous
phagocytes
vaccination
hepatitis A
poliomyelitis
AIDS

**Related to Chapter 2: Cell structure, respiration, osmosis and diffusion, and enzymes**
nucleus
vacuole
chloroplast
ribosome
endoplasmic reticulum
mitochondria
Golgi bodies
a cytoskeleton
endoplasmic reticulum
membrane sacs
connective tissue
to resolve objects
the Krebs cycle
glycolysis
pyruvic acid
lactic acid
solutes
plasmolysis
diffusion
biological catalysts
amino acid chains
to be denatured
to catalyse a reaction
peroxidase

# Topic specific vocabulary

**Related to Chapter 3: Cell division and inheritance**
mitosis
meiosis
a zygote
the genetic code
gametes
the genome
homologous chromosomes
deoxyribonucleic acid or DNA
the double helix
the Human Genome Project
monohybrid
hybridisation
Mendel's F1 Cross, Mendel's F2 Cross
a punnet square
phenotype
genotype
alleles
pure-breeding
pure strains
heterozygous
homozygous
a dominant gene
a recessive gene
dominance
recessiveness
a pedigree chart
trait
X and Y chromosomes

**Related to Chapter 4: Photosynthesis, plant structure, plant processes and co-ordination**
leaf pigments
consumers
the cuticle
the epidermis, the epidermal cells
the palisade mesophyll layer
the spongy mesophyll layer
vascular bundle
the phloem tubes
a stoma, stomata
guard cells
xylem cells
rhizomes
a tap root system
a fibrous root system
pneumatophore roots
an adventitious root system
the root cap
the meristem
meristematic tissue
a weight potometer
a bubble potometer
asexual reproduction
seed dispersal
hermaphrodites
sepals
stamens
the petiole
the pistil
an ovule
a testa
germination
the cotyledon
the radicle
the plumule
the cambium cells
the apical meristem
the lateral meristem
heartwood and sapwood
the vascular bundles
tropism

**Related to Chapter 5: Nutrition, circulation, gas exchange, excretion, movement, endocrine system, nervous system, reproduction and the effect of drugs and exercise**
lipids, fatty acids
amino acids
eating disorders
ingestion
absorption
egestion
oesophagus
peristalsis
pancreas
gall bladder
small intestine
large intestine
plasma
platelets
arteries
capillaries
the right/right auricle
the lymph nodes
a pulse
inhalation
exhalation
the diaphragm
the trachea
the bronchi
bronchioles
an alveoli
kidneys
nephrons
urea
the ureter
the bladder
vertebrate animals
an endoskeleton
ligaments
tendons
adrenaline
insulin
oestrogen
thyroxin
stimuli
receptors
a reflex action
gametogenesis
embryonic development
the uterus
the testis
the placenta
conception
fertilisation
menstruation

**Related to Chapter 6: Adaptation, inter-relationships and conservation**
biotic environmental factors
abiotic environmental factors
biodiversity
predation
commensalism
inter-specific competition
exploitation
ecological niches
exotic plant and animal species
deforestation
carbon sinks