8 Body systems

Why learn this?

The human body is an amazing machine. In the few minutes it takes this professional swimmer to swim a lap, processes take place inside her body that allow her to propel her body through the water with maximum speed and power. In this chapter you will learn about the systems that keep you alive and some of the things you can do to keep these working at peak capacity.

In this chapter students will:

8.1 outline how body systems work together to keep organisms alive
8.2 learn about the energy and nutrient content of food
8.3 describe the structure and function of the digestive system
8.4 distinguish between mechanical and chemical digestion and learn about the role of enzymes in digestion
8.5 learn about dietary diseases and some of the strategies that have been proposed to reduce their incidence, and investigate the work of dietitians
8.6 investigate the structure and function of the respiratory system
8.7 describe the components of the circulatory system and outline their function
8.8 learn about the heart and blood pressure
8.9 describe the structure and function of the excretory system
8.10 describe the function of the skeletal system and explain how muscles and bones work together to enable movement.

A competitive swimmer pushing her body to the limit

Know your body

As the swimmer shown on the previous page begins her lap, her breathing rate increases and she breathes more deeply to take in more air into her lungs. Her heart rate increases so that the oxygen in the air can be delivered to all cells of her body more rapidly. The diameter of some of her blood vessels increases to ensure that blood flow to the muscles that most need oxygen is maximised. In her muscles, glucose provides the energy. The glucose is burnt up so rapidly that a by-product called lactic acid forms, causing pain, but she pushes on regardless. All the systems that make up her body are working together to get her to the finish line.

1. Machines need a source of energy to keep running. What is the source of energy for the human body?
2. List some body systems you already know about.
3. Body systems are made up of organs. List two organs of the respiratory system and two organs of the urinary system.
4. Professional athletes do a lot of training. What changes to the athlete's body might result from this training? Which body systems are affected by the training?
5. List some diseases that affect the:
   (a) respiratory system
   (b) circulatory system.
6. What size and shape are your body parts? Think about the following items and how they might relate to the sizes of organs you may sketch in *Investigation 8.1*: an olive, your fist, your two fists touching together, a large grapefruit.
7. Have you ever heard the phrases, 'heart-shaped box' or 'kidney-shaped dish or swimming pool'? Some organs are often shown as stylised shapes. Discuss with a partner or your group what is wrong with the following images used to depict organs.

Is the heart located here? What size and shape is your heart?

This is a kidney dish but are the kidneys similar to this?

INVESTIGATION 8.1

Know your organs

AIM **To draw a diagram showing the locations and shapes of some of the organs of the human body**

You will need:
sheets of butcher paper
marker pens
sticky tape or masking tape

- Tape the pieces of butcher's paper together.
- One group member lies on the butcher's paper with their arms slightly away from their body while another group member traces the outline of their body.

Be careful when drawing around someone as you want to get a realistic outline — unlike the outline in this photo. The outline should be closer to the person's body shape.

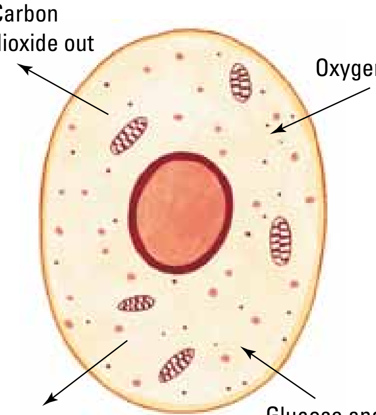
- Once the body outline is ready, work as a group to add the following organs to the diagram: heart, liver, intestines, stomach, lungs, bladder, uterus, kidneys, brain, ovaries, testes, oesophagus. Decide on the location, shape and size of each organ then draw them in.

DISCUSSION

1. **Compare your diagram with reference material. Which organs did you draw in the wrong positions? Did you estimate the sizes and shapes of the organs accurately?**
2. **Which system do each of the organs listed above belong to?**
3. **Would you normally find ovaries, a uterus and testes in the same body? Explain your answer.**

All systems go!

In chapter 2, page 55, you learned that there are unicellular and multicellular organisms. Unicellular organisms are made up of one cell only. That one cell must do all the jobs needed to keep the organism alive. Unicellular organisms are very small so the substances they need, such as oxygen and glucose, can simply **diffuse** into the cell from its surroundings. Waste products can diffuse out of the cell and into the surroundings.



Oxygen and other useful substances diffuse into cells and waste products diffuse out of cells.

Multicellular organisms are made up of many cells. Some multicellular organisms such as flatworms and sea lettuce are very thin and many of their cells are in direct contact with their surroundings. Flatworms have some body systems, but they do not have a respiratory system. They use their whole body surface to take in oxygen from the water in which they live. Similarly, sea lettuce lacks many of the systems found in land plants. Most of the substances it needs to survive diffuse from the water into the cells of the sea lettuce and waste products diffuse out of the cells into the water.

For larger animals with many layers of cells, things are not so simple. Many of their cells are deep inside their bodies and not in direct contact with their surroundings. How do oxygen and nutrients get to these cells? How do these cells get rid of their waste products and where does the waste go?

Most multicellular organisms are very complex and contain a number of systems that keep them alive.

- The respiratory system takes in oxygen and gets rid of carbon dioxide.
- The digestive system breaks down food into particles that are small enough to pass through the walls of the intestines and into the bloodstream.
- The circulatory system carries these nutrients, as well as oxygen, to all cells in the body. It also carries waste away from cells and takes it to organs that can excrete (get rid of) this waste.

A flatworm (above) and sea lettuce (right) are examples of multicellular organisms that are very thin and so do not require many systems to keep them alive.

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eLesson

Leonardo's sketches and anatomy

Watch a video from *The story of science* about anatomy.

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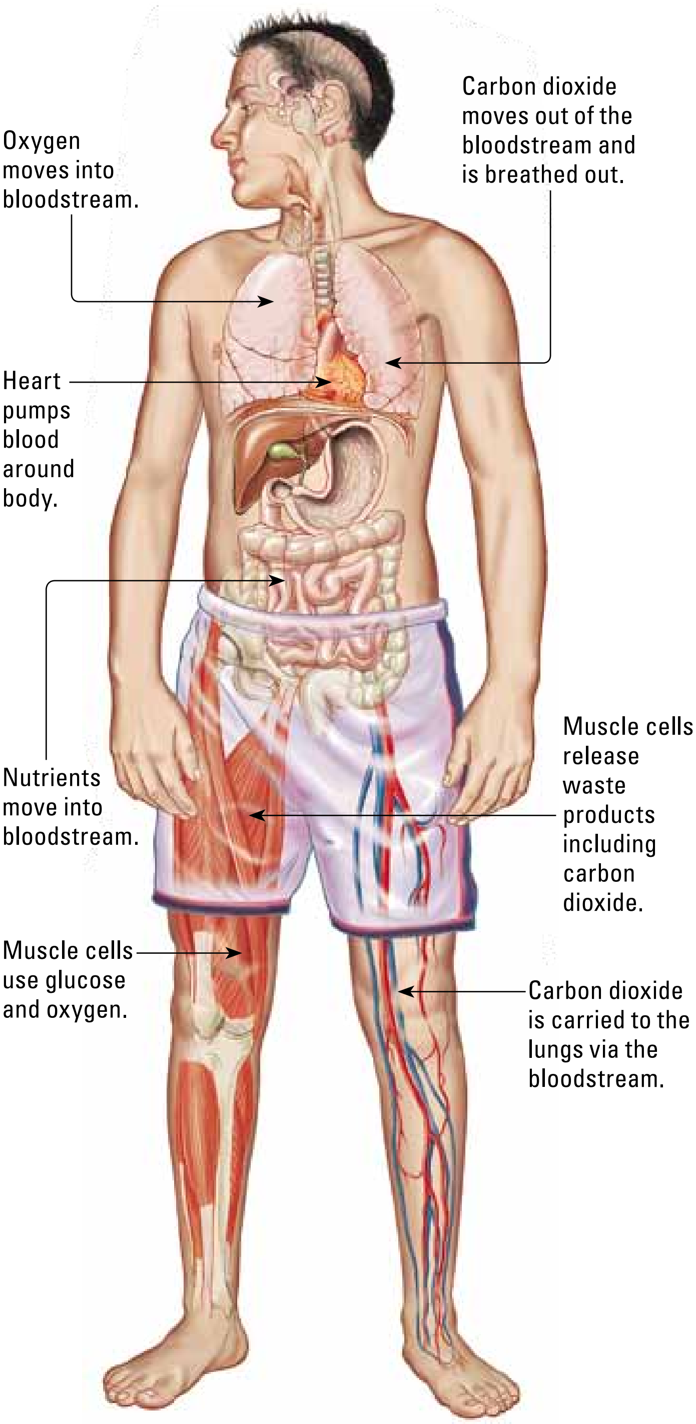
- The nervous system carries and processes messages along nerves from one part of the body to another.
- The skeletal system enables the body to move. Some bones also protect important organs.

Systems consist of organs. Some of the organs of the digestive system are the stomach, oesophagus, pancreas, intestines and liver. Organs of the circulatory system include the heart and blood vessels. Organs are made up of different types of tissue. The heart contains cardiac muscle tissue, blood, connective tissue and adipose tissue (fat). Tissues, in turn, are made of cells. Adipose tissue is made up of cells that store fat. Cardiac muscle tissue consists of cardiac muscle cells.

Working together

Body systems work together to keep organisms alive. The respiratory system brings oxygen into the lungs, but it is the circulatory system that delivers the oxygen to all cells. Without these two systems working together, cells would not obtain the oxygen they need for respiration. Similarly, while the digestive system breaks down food, once the nutrients in food have been converted to particles that are small enough to enter the bloodstream, these also must be transported to cells via the circulatory system. To move our limbs, muscles need to receive signals from the nervous system. Hormones produced by the endocrine system play an important role in regulating the action of the kidneys, which are part of the excretory system. The body systems must act as members of a team; each has a specific task but they must work collaboratively to keep the body functioning.



All body systems work together.

Some organs in our body systems

System	Organs
Reproductive	Ovaries, testes
Musculoskeletal	Muscles, skeleton
Nervous	Brain, nerves
Excretory	Kidney, ureter
Respiratory	Trachea, lungs
Circulatory	Heart, arteries
Digestive	Stomach, liver

INVESTIGATION 8.2

The pluck

AIM To investigate the structures of some internal organs of a sheep

You will need:

sheep's pluck (heart and lungs) with part of the liver and trachea attached
newspaper and tray to place the pluck on
plastic disposable gloves
balloon pump or vacuum cleaner

- Carefully observe the sheep's heart, lungs, liver and trachea.
- Push a piece of rubber tubing into the trachea until it reaches one of the lungs. Using a balloon pump or a vacuum cleaner in reverse mode, blow some air into the trachea.

CAUTION For hygiene reasons, it is not recommended that you use your mouth to blow air into the tube inserted in the trachea.

- Cut off a small piece of lung, liver and heart. Place each in a beaker full of water. Which one floats? Why?
- You might have heard of people having a 'burst lung'. That seems to suggest that lungs are hollow, like balloons. Slice through one of the lungs to find out if it really is hollow.
- Cut through the heart and liver to find out if they are hollow.

DISCUSSION

1. Copy and complete the table below in your notebook.

Organ	Shape (sketch)	Approx. size	Colour	System to which this organ belongs
Liver				
Lung				
Heart				
Trachea				

2. Which major blood vessels can be seen?
3. What happens to the lungs when air is blown in?
4. Explain why there are rings of cartilage around the trachea.
5. Where does the air go when the lungs blow up?
6. Why does the heart need to be hollow?
7. Use reference books to find out the function of the liver.

ACTIVITIES

REMEMBER

1 **Outline** how unicellular organisms take in oxygen and nutrients.

2 Copy and complete the following statements.
(a) ____________ are made up of groups of cells that carry out a specialised job.
(b) ____________ are made up of different types of tissues.
(c) Organs work together to make up a ____________.
(d) The ____________ in an organism work together to keep it alive.

THINK AND REASON

3 **Classify** each of the following as a type of cell (C), tissue (T), organ (O) or system: eye, smooth muscle, cardiac muscle, heart, white blood cell, liver, skin, skin cells, brain, neuron (nerve cell), circulatory system, intestine.

4 The table below is jumbled up. Re-organise the information in the table.

5 **Identify** which body system has each of the following functions.
(a) Detecting stimuli
(b) Supporting and moving the body
(c) Taking in oxygen and getting rid of carbon dioxide
(d) Conducting messages from one part of the body to another

6 In 2010, a male patient was the first person to be given an intestine transplant in Australia (previously the procedure had been carried out only overseas). Before the transplant he was not able to eat and had to receive nutrients through a drip. **Explain** how the drip was keeping him alive.

INVESTIGATE

7 Do all animals have the same body systems as humans? Choose one animal from the following list and investigate whether it has all the body systems shown in the mind map on the previous page.

dog snake spider worm starfish jellyfish

eBook*plus* work sheet 8.1 Organ systems

System	Some organs in this system	Function
Digestive	Brain, spinal cord, nerves	Takes oxygen into the body and removes carbon dioxide from the body
Musculoskeletal	Lymph nodes (also involves white blood cells in blood)	Coordinates processes in the body by sending messages that travel through nerves
Respiratory	Lungs, trachea	Carries oxygen and nutrients to all cells in the body; carries waste away from cells
Endocrine	Ovaries, uterus, fallopian tubes (female) Penis, testes, vas deferens (male)	Protects the body from disease
Nervous	Glands (e.g. thyroid gland, adrenal gland)	Breaks down food into particles that are small enough to pass through the walls of the intestine into the bloodstream
Circulatory	Bones, ligaments	Is involved in reproduction (making babies)
Reproductive	Stomach, intestine, oesophagus, pancreas, liver	Coordinates processes in the body by releasing hormones into the bloodstream
Immune	Heart, blood vessels	Supports the body, protects organs such as the heart and brain and enables movement

Taking in nutrients

The human body, just like a car, needs to be provided with fuel to keep it working. That fuel is the food we eat. Our bodies break down the food and release the energy that is locked up inside it. This energy can then be used by our bodies to move, grow and carry out important processes that are vital to our health.

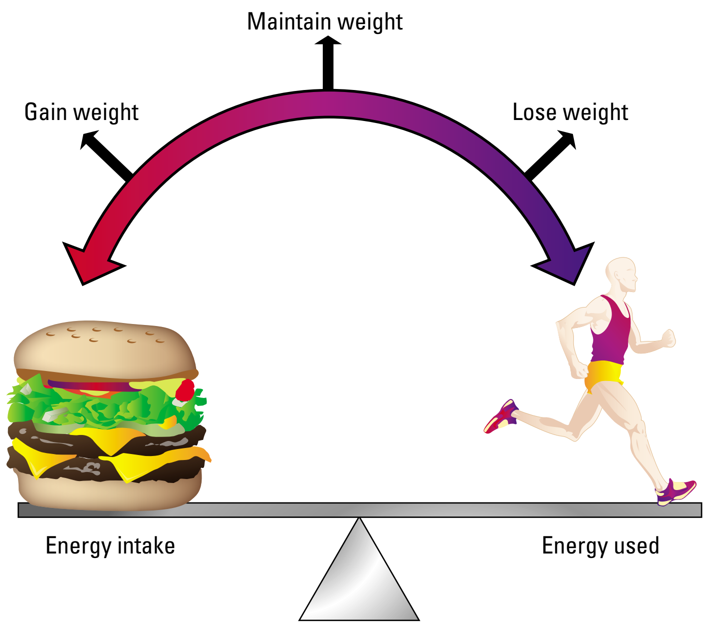
Food provides more than just energy though; it also provides important nutrients, vitamins and minerals that are essential to keep the body functioning. The digestive system breaks down the food we eat so that nutrients can enter the bloodstream and be delivered to cells.

Food contains energy

Food contains stored energy. The amount of energy stored in the food is measured in kilojoules (kJ) or Calories.

The amount of energy needed each day depends on how much physical activity a person does, as well as other factors including their size, age and gender. The table below shows the amount of energy used by a range of activities. For example, a person who sits at a desk for most of the day needs to eat less food than a person who spends a large part of the day walking. If we take in more energy than we need, our bodies store the excess energy as fat. If we take in less energy than we need, some of this fat can be broken down and used for energy.

Activity	Approximate energy use (kJ) per hour
Sleeping	250
Very light — sitting, reading, watching television, driving	450
Light — walking leisurely, washing, shopping, light sport such as golf	950
Moderate — fast walking, heavy gardening, moderate sport such as bicycling, tennis, dancing	1800
Heavy — vigorous work, sport such as swimming, running, basketball and football	3500



To maintain a healthy weight, it is important to balance your energy intake with the energy you use.

HOW ABOUT THAT!

It seems so simple doesn't it? Take in more energy than your body uses up and you will put on weight. Take in less energy than your body uses up and you will lose weight. Yet some people seem to be able to eat a high-energy diet with little effect on their weight.

One scientist set out to determine whether eating too much food has the same effect on all people. Fredrick Nyström of Linköping University in Sweden recruited 18 lean and healthy volunteers and asked them to double their energy intake and avoid exercising for one month. For health reasons, the volunteers were asked to stop the experiment if their weight increased by more than 15 per cent of their original weight. One volunteer reached this after just two weeks. Another volunteer found that his weight had increased by only 4.6 kg by the end of the experiment.

Nyström has suggested that perhaps some people release more of the extra energy they take in as heat rather than store it as fat. So, after overeating, these people may feel warmer or more fidgety as their bodies use up some of the extra energy.

Eating energy-dense food caused all of the volunteers to gain weight, but some gained weight a lot faster than others.

INVESTIGATION 8.3

Measuring the energy in food

AIM To compare the amounts of energy stored in a range of foods

You will need:

small metal basket (used to fry food)

samples of small biscuits, potato chips, uncooked pasta, crouton or small piece of toast

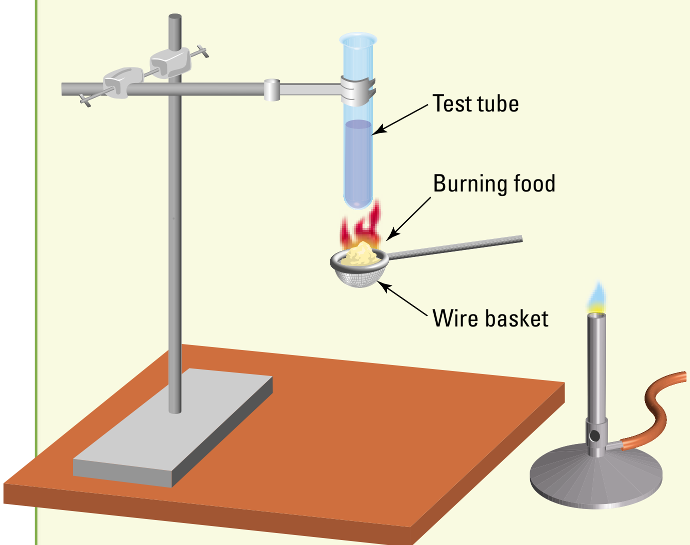
thermometer

retort stand, bosshead and clamp

large test tube

Bunsen burner

measuring cylinder



The apparatus used in this experiment

Before starting this experiment, read all the following steps and make a list of the risks (dangers) associated with this activity and how you plan to minimise these risks.

- Use the clamp to attach the test tube to the retort stand.
- Measure 30 mL of water and pour it into the test tube.
- Measure the temperature of the water.
- Weigh the biscuit.
- Place the small biscuit in the wire basket and set fire to it using the Bunsen burner. When the biscuit is alight, put the basket containing the biscuit underneath the test tube. The heat released from the burning biscuit will heat the water. Hold the basket under the test tube until the biscuit is completely burned. You can tell that the biscuit is completely burned if it is all black and will not re-ignite in the Bunsen burner flame.
- Measure the temperature of the water again.
- Calculate the amount of energy that was stored in the biscuit, using the following equation.

$$\text{Energy (in joules)} = 4.2 \times \text{volume of water (in mL)} \times \text{increase in temperature (in °C)}$$

- Calculate the amount of energy per gram of food by dividing the amount of energy by the mass of the food.
- Repeat the steps above using the other food samples.
- Copy and complete the table below.

Food	Biscuit	Chip	Pasta	Crouton/ toast
a. Mass of food (g)				
b. Volume of water (mL)				
c. Initial temperature of water (°C)				
d. Final temperature of water (°C)				
e. Increase in temperature (= $d - c$)				
f. Energy in food (J) (= $4.2 \times 30 \times e$)				
g. Energy in food (kJ) (= $f \div 1000$)				
h. Energy per gram of food (kJ/g) (= $g \div a$)				

DISCUSSION

1. **Copy and complete the aim of this experiment: 'To compare the amounts of ____________ stored in a range of foods'.**
2. **Copy and complete the conclusion: 'The food that contained the most energy per gram was ____________'.**
3. **Why was it necessary to calculate the amount of energy per gram of food?**
4. **Did all the heat from the burning food go into heating the water? Explain how this might have affected the validity of this experiment.**

What is in the food we eat?

The food we eat contains five main nutrient groups: carbohydrates, proteins, lipids, vitamins and minerals.

Nutrient groups

Nutrient group	Chemistry	Role	Foods with high levels of this nutrient	Energy per gram (kJ)
Carbohydrates	Simple carbohydrates are also called sugars (e.g. sucrose, glucose). Complex carbohydrates are made up of simple sugars linked together (e.g. starch consists of glucose units linked together).	Source of energy. *Note:* The energy from complex carbohydrates is released more slowly, so these tend to be a better source of energy.	Simple carbohydrates: soft drinks, lollies, fruit Complex carbohydrates: pasta, rice, cereal	16
Proteins	Amino acids linked together	Source of energy; used to make enzymes and body tissues (including muscle)	Meat, fish, dairy products, legumes	17
Lipids (fats and oils)	Fatty acids attached to glycerol	Source of energy; source of essential fatty acids	Nuts, butter, cooking oil, biscuits, chips	37
Vitamins	Varies	Needed for particular chemical processes in the body	Fat-soluble vitamins: foods containing fats and oils (including fatty fish such as salmon) Water-soluble vitamins: fruit, vegetables, grains	0
Minerals (e.g. calcium, magnesium, iron, zinc)	Varies	Needed for particular chemical processes in the body	Various (e.g. red meat is high in iron)	0

HOW ABOUT THAT!

In your great-grandparents' days, many children were given a daily dose of cod liver oil to maintain good health. It turns out that your great-grandparents may have been right about the benefits of fish oil. Fish oil is rich in omega-3 fatty acids. These fatty acids are being investigated as a possible treatment for conditions including rheumatoid arthritis, depression, attention deficit disorder and heart disease.

A number of scientific studies have shown that omega-3 fatty acids affect behaviour and mood. For example, Bernard Gesch did an experiment involving British prison inmates. He gave half the people who had volunteered for his study a daily supplement that contained omega-3 fatty acids and other vitamins and minerals. The other prisoners were given a placebo (a tablet that looked just like the supplement but did not contain fatty acids, vitamins or minerals). Over time, he found that the prisoners taking the supplement were involved in a lot fewer violent incidents. The prisoners taking the placebo showed no significant change in their behaviour.

Some sources of omega-3 fatty acids

ACTIVITIES

REMEMBER

1. **Recall** which unit energy is usually measured in.
2. If you take in more energy than your body needs, **explain** what happens to the extra energy.
3. **Explain** why it is important to use a placebo when testing the effect of a dietary supplement or medicine.
4. Match each term in the left-hand column with a definition from the right-hand column.

Term	Definition
a. Glucose	A A source of protein
b. Protein	B Simple sugars linked together
c. Lipids	C A component of lipids
d. Pasta	D Amino acids linked together
e. Glycerol	E Fats and oil
f. Complex carbohydrates	F Example of simple carbohydrate
g. Fish	G A source of carbohydrate

5 **Identify** what the items in the following pairs have in common.
(a) Carbohydrates and lipids
(b) Glucose and starch
(c) Fats and oils
(d) Iron and Zinc

6 In his experiment (see page 239), Bernard Gesch used a supplement that contained both fatty acids and other minerals and vitamins. **Outline** how he could test whether it was the fatty acids or the vitamins and minerals that caused the improvement in the behaviour of the prisoners.

SKILL BUILDER

7 Use the table on page 237 to answer the following questions.
(a) How much energy is used up in 1 hour of fast walking?
(b) **Calculate** the amount of energy used in 30 minutes of running.
(c) **Explain** why two people might both dance for 20 minutes but burn very different amounts of energy.

8 The tables below show the recommended daily energy intake for 12–15 year olds and the amount of energy contained in a range of foods sold at a snack bar.

Recommended daily energy intake, in kilojoules, for 12–15 year olds

Age (years)	Recommended daily intake (kJ)	
	Male	Female
12	9 800	8600
13	10 400	9000
14	11 200	9200
15	11 800	9300

Nutritional information for a snack bar menu

Food	Energy (kJ)
Pizza (2 slices)	2060
Hamburger	1900
Salad sandwich	940
Chocolate eclair	1320
Fresh fruit salad	290
Apple pie with ice-cream	2310
Medium cola	384
Strawberry thick shake	1230
Medium orange juice	530

(a) What is the recommended daily energy intake for someone of your age and gender?
(b) For lunch, Fred ate one hamburger and an apple pie with ice-cream. He also drank one medium orange juice.
(i) **Calculate** Fred's energy intake.
(ii) Fred is 13. **Calculate** the percentage of his recommended daily energy intake that his lunch contains.
(c) **Identify** the combination of main course and dessert that supplies the least energy.
(d) **Calculate** how many minutes of walking would be needed to use up the energy contained in two slices of pizza. (*Hint:* See the table on page 237.)

USE DATA

9 Use the nutritional panel below to answer these questions.
(a) The recommended daily intake of protein for a 13 year old is 40 g. **Calculate** the percentage of the recommended daily intake of protein supplied by one serving of this food.
(b) If one serving of this food provides 6 per cent of the recommended daily intake of fat, **calculate** the daily recommended intake of fat.
(c) Which food could this label belong to?

NUTRITIONAL INFORMATION Servings per package: 8 Serving size: 30 g	Average quantity per serving	Average quantity per 100 g
Energy	470 kJ	1570 kJ
Protein	1.4 g	4.6 g
Fat – total	2.8 g	9.3 g
– saturated	2.0 g	6.7 g
Carbohydrate	21.0 g	70.0 g
– sugars	8.7 g	28.9 g
Dietary fibre	1.7 g	5.5 g
Sodium	50 mg	180 mg

INVESTIGATE

10 Collect 10 nutrition panels from food packages. Use the information on the nutrition panels to rank the foods from highest to lowest for:
(a) energy
(b) fat
(c) carbohydrate
(d) protein.

11 Some foods are labelled with the Heart Foundation Tick. Find out what requirements the food must meet to be allowed to display the tick.

eBook*plus* work sheets
8.2 Nutrients
8.3 Food facts

The digestive system

Digesting the food

The role of the digestive system is to break down the food that we eat into particles that are small enough to pass through the walls of the intestines and into our blood. In this way, the nutrients in food can reach our body's cells. A number of organs make up the digestive system. Some organs break up the food mechanically by cutting, grinding or churning it. Other organs secrete chemicals that can break the chemicals in the food into smaller molecules.

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eLesson

From dinner plate to sewerage system
Watch the amazing journey of food through the human body.

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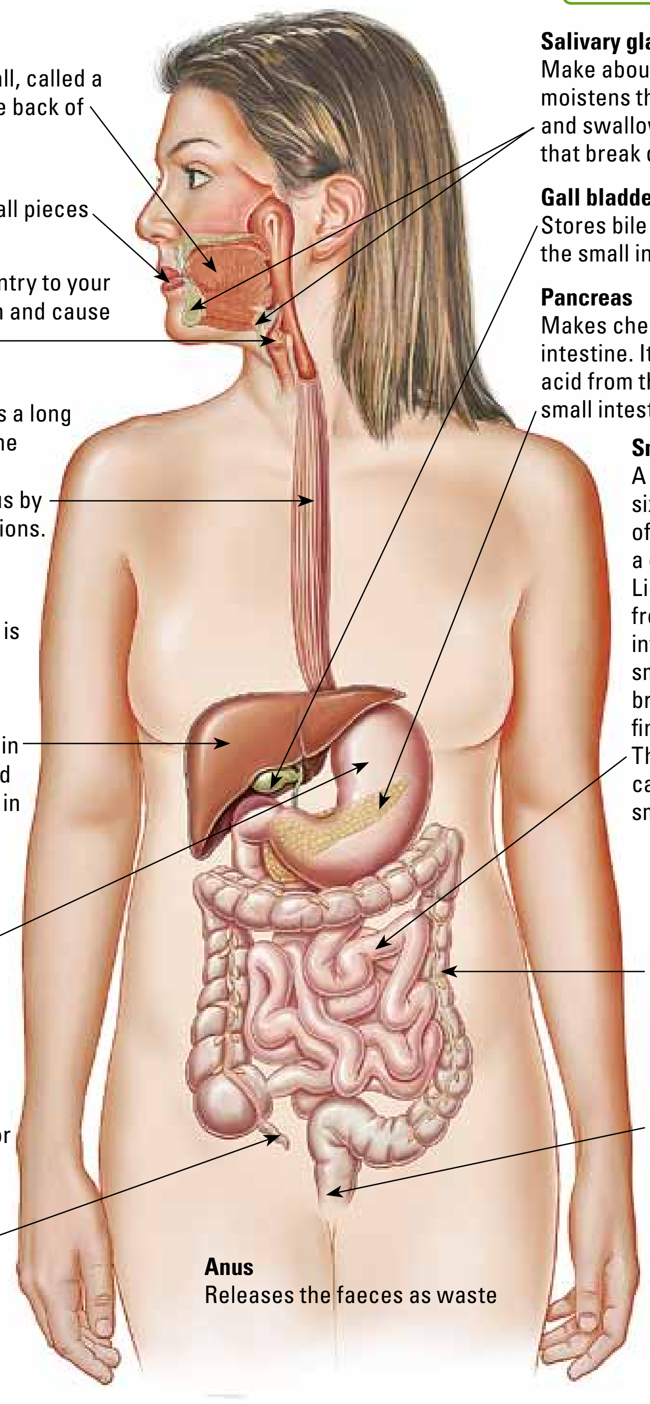


Tongue
Works the food into a little round ball, called a **bolus**. It then pushes the ball to the back of the mouth, where it is swallowed.

Teeth
Used to bite and chew food into small pieces

Epiglottis
A flap of tissue that closes off the entry to your lungs so that food does not go down and cause you to choke

Oesophagus
Directs the food to the stomach. It is a long muscular tube that moves food by the process of **peristalsis**. Peristalsis squeezes food down the oesophagus by repeated waves of muscle contractions.

Liver
Controls the number of glucose molecules in the blood. When there is too much, the liver stores it as glycogen and releases it when needed. It also makes **bile**, which breaks down fat into small droplets in the small intestine. The bile is stored by the gall bladder until it is needed in the small intestine. The liver also breaks down toxins in the blood.

Stomach
A large muscular organ that churns and mixes the food. The stomach lining releases chemicals that start to break down protein. It also releases hydrochloric acid, which kills unwanted bacteria. The stomach can hold between two and four litres of food and can store it for about four hours.

Appendix
A small projection at the beginning of the large intestine. In humans, it does not help with digestion.

Anus
Releases the faeces as waste

Salivary glands
Make about 1.5 L of **saliva** a day. Saliva moistens the food, making it easier to chew and swallow. Saliva also contains chemicals that break down the **starch** in food.

Gall bladder
Stores bile made in the liver until needed in the small intestine

Pancreas
Makes chemicals that are used in the small intestine. It also reduces the effect of the acid from the stomach on the walls of the small intestine.

Small intestine
A long, hollow, coiled tube about six metres long. It is the main organ of digestion. Food, which is now like a creamy soup, passes slowly into it. Liquid from the pancreas and bile from the gall bladder enter the small intestine to help with digestion. The small intestine is where the breakdown of starch and protein is finished and fat breakdown occurs. The food particles are then tiny and can pass through the wall of the small intestine into the bloodstream.

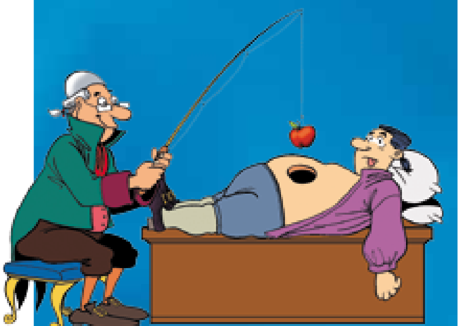
Large intestine
Undigested food and water pass into the large intestine from the small intestine. Bacteria in the large intestine help in making some vitamins and are the main source of gas. Water, vitamins and minerals pass into the bloodstream.

Rectum
Faeces is stored in this last part of the large intestine. Faeces contains the waste products of digestion. It consists of about 75 per cent water and 25 per cent solid matter — mainly dead bacteria and fibre.

HOW ABOUT THAT!

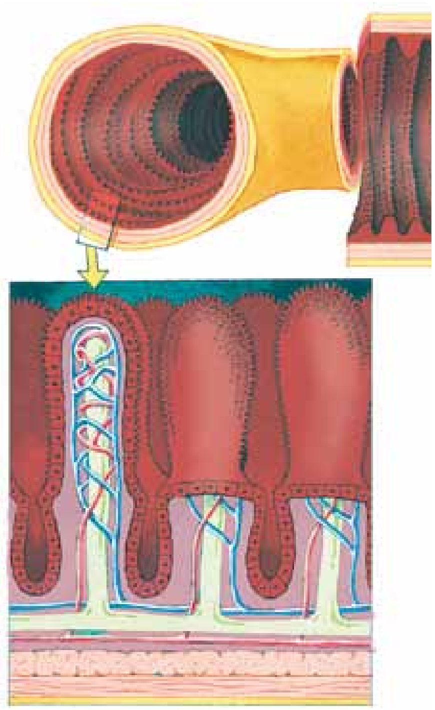
When Alexis St Martin was accidentally shot in the stomach at close range, he was not expected to recover from his injuries. He had a hole the size of a fist in his stomach. An army surgeon named Beaumont treated him. Alexis did recover but, as the wound healed itself, the edge of the hole in his stomach attached itself to the edge of the hole in his skin, so there was a small passage between the inside of his stomach and the outside of his body. The passage had to be sealed with bandages so the food and stomach juices could not leak out of his stomach.

Beaumont used this opportunity to study the process of digestion. Alexis became Beaumont's servant. As well as doing all the tasks normally expected of a servant, Alexis was also involved in a number of experiments on digestion. Beaumont collected some of the fluid that emerged from the hole in Alexis' stomach and did tests on it. He could also dangle various foods by a string into Alexis's stomach and pull them out after a period of time to find out what had happened to the food in the stomach.



Zooming in on the small intestine

Nutrients must pass through the walls of the small intestine and into the bloodstream. The walls of the small intestine are not smooth; they are lined with small finger-like projections called villi. This increases the surface area through which nutrients can diffuse across the walls of the small intestine. There are also many small blood vessels called capillaries associated with the villi. These transport the nutrients away from the intestines.



Small finger-like projections called villi line the walls of the small intestine.

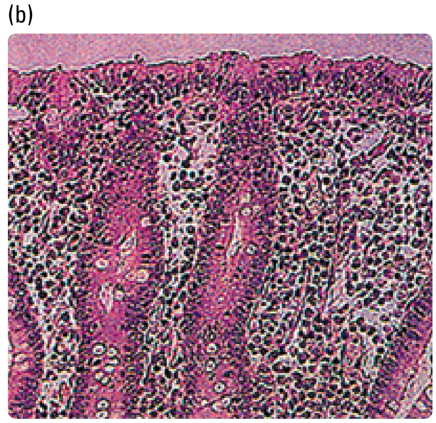
Coeliac disease

Coeliac disease is a condition where the villi of the small intestine are damaged. People with coeliac disease are intolerant to gluten, a substance found in wheat, oats, barley and rye and the numerous food additives made from these. If they eat foods containing gluten, the villi in their small intestines become damaged over time. This means that they can no longer absorb certain nutrients properly. An early symptom of coeliac disease is anaemia (low blood iron levels) as iron absorption is reduced by the damaged villi. Some coeliac sufferers may also experience stomach pains and bloating after eating foods containing gluten.

It is possible for coeliac disease to develop in childhood, but many people do not develop it until their thirties or later. Scientists are not sure why. Perhaps certain triggers are needed for the disease to develop. If coeliac disease is diagnosed in its early stages, it is reversible provided that the person completely avoids gluten for the rest of their life. This is challenging as gluten is found in so many foods including most types of bread, pasta, cakes and biscuits. Failure to avoid gluten can have dire consequences for people with coeliac disease. Apart from feeling unwell and being deficient in certain nutrients, coeliac sufferers who do not follow a gluten-free diet also have an increased risk of developing bowel cancer.

(a)

(b)



Biopsies of (a) normal and (b) coeliac intestine

Australian researchers are attempting to develop a vaccine as a new treatment for coeliac disease. In 2009, Dr Robert Anderson and his team at the Walter and Eliza Hall Institute of Medical Research in Melbourne began the world's first trials of a coeliac vaccine. If this treatment is successful, it could mean the end of gluten-free diets for people with the condition.

Dr Robert Anderson and his team at the Walter and Eliza Hall Institute of Medical Research in Melbourne began the world's first trials of a coeliac vaccine.

INVESTIGATION 8.4

Observing villi

AIM To investigate the structure of the walls of the small intestine

You will need:

prepared slides of walls of the small intestine
microscope
photos of villi seen in the weblinks in your eBookPLUS

- Observe the prepared slide under the microscope.
- Draw a diagram showing a small section of the walls of the intestine. Label a villus.
- Compare your diagram with the photos in your eBookPLUS.

DISCUSSION

1 Describe the appearance of the walls of the intestines.
2 Look carefully at one of the villi. Does it have a smooth shape?
3 Compare the two photos found by following the **Observing villi** weblinks in your eBookPLUS. Which of the photos shows the appearance of the villi under a light microscope? Which photo is an electron micrograph? Justify your answer. (*Hint:* See page 242.)

ACTIVITIES

REMEMBER

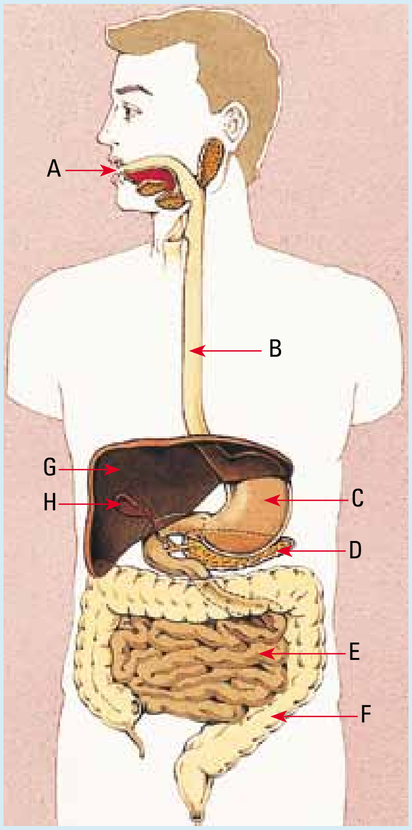
1 Match the following terms with their descriptions

Terms: oesophagus, gall bladder, liver, digestion, stomach, small intestine, epiglottis, rectum, peristalsis

Descriptions:
(a) The breakdown of food into particles that are small enough to pass through the walls of the intestines
(b) The tube that joins the mouth to the stomach
(c) Muscular contractions that move food along the digestive tract
(d) A flap of tissue that blocks the entry to the lungs when you swallow
(e) The organ that produces bile
(f) The organ where the digestion of protein begins
(g) The place where bile is stored
(h) Where fat is broken down
(i) Where faeces are stored until they can be released

2 Copy the table below and fill it in for each of the organs labelled in the diagram above right.

Organ	Function



THINK

3 Beaumont's experiments on Alexis St Martin raise some ethical issues.
(a) What does the term 'ethical' mean?
(b) Why would Beaumont's experiments be seen as unethical by some people?
(c) Do you think Beaumont would be allowed to carry out such experiments today? Give a reason for your answer.

4 **Explain** why a person who has coeliac disease is more likely to be anaemic (have low iron levels) or suffer from osteoporosis (a condition resulting from calcium deficiency).

RESEARCH

5 **Design** a three-course gluten-free meal. Make sure you check the list of ingredients for all foods included in your menu.

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6 Test your knowledge of the digestive system by completing the **Digestive jigsaw** interactivity in your eBookPLUS. **int-0216**

7 Find out more about the digestion of particular types of food by using the **Digestion animation** weblink in your eBookPLUS.

8 Practise naming the parts of the digestive system by using the **Digestive system drag-and-drop** weblink in your eBookPLUS.

work sheet 8.4 The digestive system

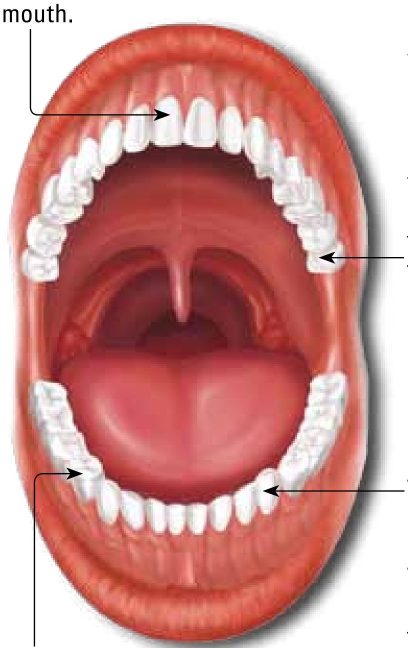
Physical or chemical digestion?

Digestion involves both physical and chemical processes. When food is broken down physically, it is cut, ground or churned to make the particles of food smaller. This increases the surface area of the food. Substances called enzymes can then work on the food more effectively to chemically break down the large molecules in the food so that they are small enough to pass into the bloodstream and be transported around the body.

Let's get physical!

Physical digestion mainly involves the teeth, although the churning action of the stomach is also an example of physical digestion. Humans have four different types of teeth. Each type has a different shape, position in the mouth and job in breaking down food.

Incisor
Incisors are spade shaped. They have a straight, sharp edge for cutting and biting food. You have eight incisors in total — four on each of the upper and lower jaws at the front of the mouth.



Molar
You have between eight and twelve **molars**, depending on your age. The last four molars are known as your wisdom teeth; they usually appear at the age of 17 or older. Molars grind food. They have between three and five **cusps**. The rough cusps help to break down the food.

Canine
There are four pointed canines — one on each side of the incisors. They are used for shearing and tearing through tough food.

Premolar
Premolars roll and crush food. There are eight premolars — two next to each **canine**. They have two pointed cusps to help break down food.

Chemical breakdown

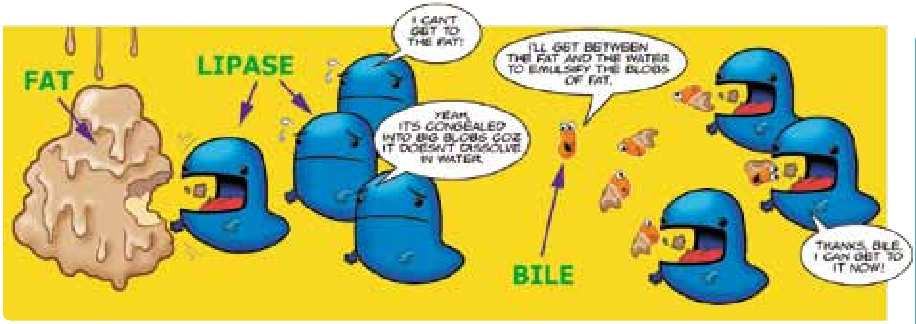
Once the food has been broken down into small pieces, chemicals called enzymes can get to work on the food particles. Enzymes speed up the chemical reactions in the body. There are many types of enzymes. Those involved in digestion break down the complex chemicals found in food into small molecules that can pass through the walls of the small intestine and into the bloodstream.

Some enzymes involved in digestion

Enzyme	Organ that secretes the enzyme	Role of enzyme
Amylase	Salivary glands in mouth	Break down starch into simple sugars such as glucose
Pepsin and trypsin	Stomach. These and other protease (protein-digesting) enzymes are produced in the stomach, pancreas and intestine.	Break down proteins into amino acids
Lipase	Pancreas	Break down fats and oils into fatty acids and glycerol; occurs mainly in the small intestine

Fat stuff

Breaking down lipids, such as fats and oils, is hard work! Because lipids are insoluble in water, they tend to clump together into large blobs. A substance called bile helps solve this problem. Bile is produced by your liver and stored in your gall bladder. As half of the bile molecule is attracted to water and the other half is attracted to lipids, it helps to **emulsify** or separate the lipids so the lipase enzymes can gain access to them and do their job. This is an *example of mechanical* digestion (bile) and chemical digestion (lipase) working together to get the job done!



Bile emulsifies fat so that lipases can break it down.

INVESTIGATION 8.5

Does temperature affect enzymes?

AIM To investigate how enzyme activity is affected by temperature

You will need:

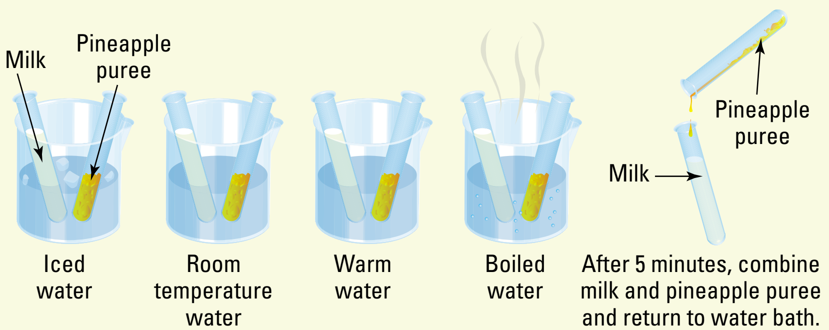
4 beakers — *8 test tubes*
milk — *4 thermometers*
fresh pineapple puree
(Fresh pineapple can be pureed using a food processor. If fresh pineapple is not available, use junket powder or a junket tablet dissolved in 10 mL water.)

- Add water to the beakers so that they are two-thirds full. Use cold tap water and ice for beaker 1, cold tap water for beaker 2, hot tap water for beaker 3 and boiling water (from a kettle) for beaker 4. These are the 'water baths'.
- Half-fill four test tubes with milk and put one test tube in each water bath.
- Pour one teaspoon of fresh pineapple puree (or 1 mL junket solution) into each of the other four test tubes. Put one of these test tubes in each water bath.
- Allow the test tubes to stand in the water baths for at least 5 minutes.
- For each water bath, pour the fresh pineapple puree into the milk and stir briefly. Quickly record the temperature of the milk and pineapple mixture and then allow it to stand undisturbed. The mixture will eventually set. Record the time taken to set. If the milk has not set after 15 minutes, record the time as 15+.
- Copy and complete the table of results below.

Temperature of milk and pineapple mixture (°C)	Time taken to set (min)

DISCUSSION

1. **Pineapple juice and junket contain an enzyme that causes a protein in milk (casein) to undergo a chemical reaction and change texture; that is why the milk sets. At what temperature did the enzyme work best? Explain your answer.**
2. **Did the enzyme work well at very high temperatures? Explain your answer.**
3. **Which variables were controlled in this experiment?**
4. **Do you think that the same results would be obtained if tinned pineapple puree was used instead of fresh pineapple? Explain your answer.**



ACTIVITIES

REMEMBER

1. **Distinguish** between physical and chemical digestion.
2. **Identify** the four types of teeth and their functions.
3. **Explain** why it is important to break food down into small pieces.
4. **Describe** the function of enzymes.
5. **Identify** the main digestive enzymes, where they are made and the type of substance they break down.
6. **Describe** how bile helps lipase enzymes get their work done.

THINK

7. When you eat a piece of bread, nothing much can be tasted at first. As you continue to chew, a sweet taste can be detected. **Explain** why.
8. It is sometimes necessary, for medical reasons, to remove the gall bladder. The gall bladder stores bile. **Justify** why a person who has had their gall bladder removed might need to follow a low-fat diet.
9. Amylase breaks starch down into glucose. Iodine solution turns blue-black when it is added to starch, but it is a light brown colour when starch is not present.
   (a) Jossie combined 10 mL of starch solution with 1 mL of amylase solution. She removed a small amount of the mixture and added iodine solution. The iodine solution turned blue-black. Half an hour later, Jossie removed another small amount of the mixture and tested it with iodine solution. This time the iodine remained light brown. **Explain** Jossie's observation.
   (b) Design an experiment to test the hypothesis that amylase is more active (converts starch to glucose faster) at 50 °C than at 20 °C.

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work sheet — 8.5 Mechanical and chemical digestion

Dietary deficiencies — one problem, many opinions

Australia has one of highest rates of obesity worldwide, yet many Australians suffer from a range of illnesses that are linked to dietary deficiencies. Healthy food is readily available to most Australians, but many of us make poor choices when it comes to our diet. What is the best approach to tackle this issue? Opinions are divided.

Tackling childhood obesity

The rate of obesity in children has risen dramatically over recent times. A recent survey showed that one in four children aged 5–17 years are overweight or obese. Health professionals are concerned about this because children who are overweight are at higher risk of a range of medical conditions including problems with joints, high blood pressure and type 2 diabetes. Many children who are obese go on to become overweight adults and may later develop health conditions associated with adult obesity.

The reasons for increasing rates of childhood obesity include:

- eating too much food that is high in kilojoules but lacking in vitamins, minerals and other important nutrients
- not getting enough physical activity. Many children now spend a great deal of their spare time on sedentary activities such as watching TV and playing computer games rather than running around. Children are increasingly driven everywhere and devices such as lifts, escalators and remote controls have reduced the energy we expend each day.

Opinions vary on the best way to deal with childhood obesity, particularly in very young children who have only limited choice in the food they eat, since their parents prepare their meals. Below are some strategies that have been proposed.

- Banning television advertising for unhealthy food during children's programs
- Applying a tax to foods that are high in fat or sugar
- Limiting the size of soft drinks in fast food outlets and restaurants
- Using a traffic light labelling system on foods (a green light for the healthiest foods, an amber light for foods that are not quite as healthy and a red light for foods that should be eaten only occasionally)
- Regulating the type of food that can be sold by school canteens (This is already in place in many NSW schools.)
- Increasing the number of hours spent doing physical activity in schools
- Allocating more time to teach children about nutrition and healthy meal preparation at school

Which of these approaches is likely to be most effective?

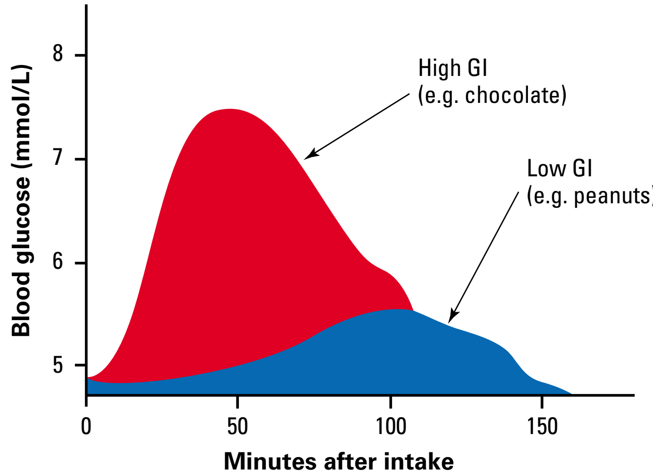
Type 2 diabetes — a disease linked to obesity

Diabetes mellitus is a group of diseases that affect the way your body uses blood sugar (glucose). There are different forms of diabetes. Type 1 diabetes usually starts in childhood and type 2 diabetes usually starts later in life.

Usually, glucose is able to enter your cells because of the action of insulin. Insulin is made in the pancreas. If you have diabetes, glucose cannot get into your cells. It stays in your blood. This happens either because your body does not make enough insulin, or because your cells do not allow glucose to enter. If the pancreas does not make enough insulin, it may be necessary to have insulin injections or use an insulin pump. Too much glucose in your blood can damage almost every major organ in your body. This can be fatal.

Type I diabetes is not linked to obesity. The exact cause of type I diabetes is unknown, but this type of diabetes is just as likely to affect a child in the healthy weight range as an overweight child. However, there is a link between type II diabetes and obesity. A combination of factors determine a person's chance of getting type II diabetes, including hereditary factors, but diet and other lifestyle factors are important. By eating a balanced diet, having a healthy weight and getting lots of exercise, you can reduce your chance of getting adult-onset diabetes, even if there is a high incidence of the disease in your family.

The treatment of type 1 diabetes usually involves insulin injections or the use of an insulin pump.



Foods with a high GI, such as chocolate, cause a sharp rise in blood sugar. Foods with a low GI, such as nuts, result in a more moderate but longer lasting rise in blood sugar.

High or low GI?

You might have noticed that some foods are labelled as 'low GI'. The GI or glycaemic index of a food is a measure of the time it takes for your blood sugar level to rise after you eat that food. Foods that are high in sugar, and starchy foods that are low in fibre, can be digested quickly by amylase. These foods have a high GI and they provide only a short burst of glucose. As your blood glucose level drops, you may start to feel hungry again. Foods with a low GI are digested more slowly. Blood glucose levels rise more slowly and over a longer period of time, so you feel full for longer. Choosing low GI foods might help maintain a healthy weight and perhaps also prevent certain diseases such as type 2 diabetes.

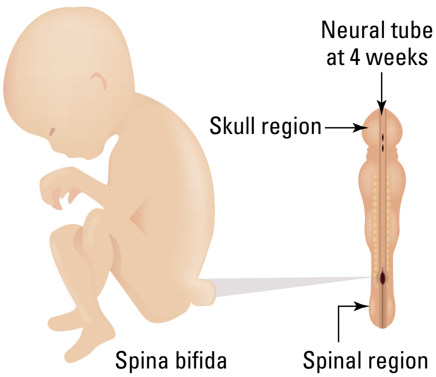
The table below indicates the glycaemic index of a range of foods. The graph above shows the blood glucose spike and drop that occur after eating high GI foods, and the more moderate, longer lasting rise in blood glucose level after eating low GI foods.

Glycaemic index	Extremely high	High	Moderately high	Moderately low	Low
Grains	Puffed rice Cornflakes White bread	Wholemeal bread Muesli Brown rice Porridge oats	Bran Rye bread White pasta Brown pasta	Tomato soup Lima beans	Barley
Fruit and vegetables	Parsnip Baked potato Carrot	Sweet corn Mashed potato Boiled potato Apricots Bananas	Sweet potato Peas Baked beans Grapes Orange juice	Pears Apples Oranges Apple juice	Red lentils Soybeans Peaches Plums
Sugar	Glucose Honey	Sucrose			
Snacks		Corn chips Chocolate Crackers Biscuits Low-fat ice-cream	Potato chips Sponge cake	Yoghurt High-fat ice-cream	Peanuts

Folate deficiency and neural tube defects

Have you noticed that many breakfast cereals, bread and other foods have folate added? Folate is an important vitamin, particularly for women of child-bearing age. Low levels of folate early in pregnancy can cause a type of birth defect called neural tube defects. Spina bifida is a disease that is the result of a neural tube defect; some of the vertebrae that protect the spinal cord are not formed properly. Symptoms vary greatly depending on the location and extent of the defect but can include paralysis.

Dr Fiona Stanley is an Australian scientist whose research was integral to establishing the link between folate deficiency and neural tube defects. She led a team of researchers that collected data on the health of mothers and their babies and looked for patterns in the data. Once the link between folate deficiency and neural tube defect had been established, opinions differed on the best way to tackle this. Some argued that, since pregnant women make up only a small percentage of the population, any strategies to address folate deficiency should focus only on pregnant women and women trying to fall pregnant. Doctors should advise these women to take a folate supplement. Others proposed that, since the highest risk period for neural tube defect is very early in pregnancy, many women would not see a doctor until it was too late for them to begin taking a folate supplement. Adding folate to staple foods such as bread and breakfast cereal would be a more effective way of preventing neural tube defect. In the end, this is the strategy that was adopted.



Neural tube defects occur when the neural tube does not close up properly early in pregnancy. Spina bifida is a neural tube defect affecting the lower area of the spine.

Vitamin D deficiency — it's a matter of balance

Vitamin D deficiency is becoming more common. This vitamin is found in some foods, but our bodies can also make vitamin D when our skin is exposed to the sun. Vitamin D is important for bone and muscle health, and low levels of vitamin D in early childhood causes the disease rickets. Addressing vitamin D deficiency is a sensitive issue. While exposure to sunlight increases vitamin D levels, it can also cause skin cancer. Too little sunlight is linked to vitamin D deficiency, but too much causes skin cancer. The ideal amount of exposure depends on skin colour (fair-skinned people need less sun exposure) and the intensity of sunlight.

Vitamin D deficiency is the cause of rickets, a disease where the bones of the legs do not form properly.

A melanoma, the most deadly form of skin cancer. Too much time spent in the sun can cause melanomas and other types of skin cancer to form on the skin.

There is some concern that, in an attempt to address vitamin D deficiency, we might see a rise in the incidence of skin cancer. Perhaps a safer alternative might be to add vitamin D to staple foods.

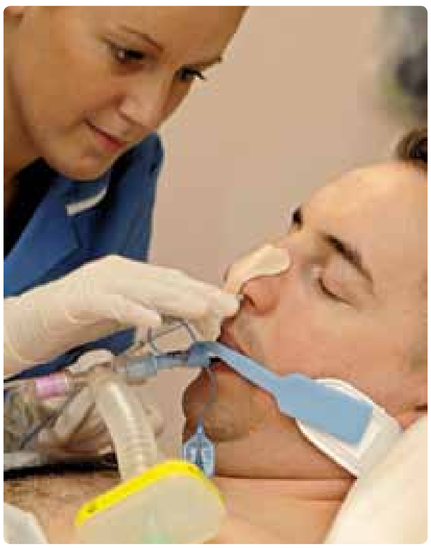
Science careers: dietitian

Joanne (not her real name) is a dietitian in a large city hospital. She is an expert on the science of food and its effect on the body. She works closely with doctors and other health practitioners and provides expert nutrition and dietary advice to patients. She has also been involved with a number of research projects.

A large part of the work of dietitians is to educate people about the type of diet they should be eating by explaining complex scientific information about nutrition in a way that patients can understand. Patients who have recently been diagnosed with diet-related diseases, such as diabetes, coeliac disease, heart disease and certain types of cancers, are referred to a dietitian to advise them on the types of foods they should eat. Certain medical conditions require that the patient follows a very strict and very specific diet. For example, patients with kidney problems may need to dramatically cut down the amount of salt they take in. This means that ordinary foods such as cheese and rice bubbles can create health problems for them.

Dietitians are also called upon when patients need to be fed through a drip or nasogastric tube (a tube that goes into the nose and down to the stomach). If a patient cannot eat due to a medical condition (such as tongue cancer), a dietitian will calculate how much and what type of food solution the patient needs.

Joanne, dietitian, giving dietary advice to a patient



A doctor inserting a nasogastric tube into a patient

A number of dietitians also do research. For example, Joanne has been involved in a study to assess the effect of patients' nutritional status on the time it takes for them to recover from an injury or illness. She worked out whether the patients were well nourished or malnourished and recorded the length of time the patients stayed in hospital. She showed that malnourished patients needed more time in hospital to recover from their injury or illness.

Not all dietitians work in hospitals. Some dietitians have their own practice (an office where patients come to see them), and other dietitians work with particular communities. Sports dietitians work with athletes and some dietitians work for the government or large companies that manufacture food.

The skills needed to be a dietitian vary with the type of work that they do, but all dietitians need a very good knowledge of food and its effect on the body. Good communication skills are also important as well as strong interpersonal skills (being able to work with people). All dietitians have university qualifications. Some universities require students to complete a science degree before specialising in nutrition.

ACTIVITIES

REMEMBER

1 **Outline** some of the health risks associated with childhood obesity.

2 **Outline** why it is important for people with diabetes to monitor and control their blood sugar levels.

3 **Explain** why a person who has type 1 diabetes needs to have regular injections of insulin.

4 **Distinguish** between type 1 and type 2 diabetes.

5 **Outline** why it is important for women who are pregnant to take in sufficient folate.

6 What is spina bifida?

7 What is the cause of skin cancer?

8 Which disease is associated with vitamin D deficiency?

THINK

9 **Suggest** why vitamin D deficiency is becoming more common in Australia.

10 Read through the list of strategies on page 246 that have been proposed to address childhood obesity. Choose three strategies and outline why some groups in society might oppose these strategies.

11 Have a class debate on the following topic: The Australian government should do more to tackle childhood obesity.

12 **Justify** why dietitians need good communication and interpersonal skills.

13 **Identify** other skills that might be important for dietitians.

14 **Explain** why athletes may need to see a dietitian.

SKILL BUILDER

15 Study the table on page 247 listing the glycaemic indexes of common foods.
(a) Are there any general trends?
(b) Deduce how the fat content of a food affects its GI. (*Hint:* Look at where the high-fat foods are in the table.)
(c) High-fat ice-cream has a lower GI than low-fat ice-cream. **Discuss** whether it is healthier.

INVESTIGATE

16 Osteoporosis, scurvy, atherosclerosis and rickets are all diseases with a dietary link. For each disease, find out what the symptoms are and how the disease is linked to the type of food eaten.

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17 Use the **Fiona Stanley** weblink in your eBookPLUS and other resources to find out more about Fiona Stanley's scientific work. Prepare a PowerPoint presentation summarising her achievements.

18 Use the **Dietitians Association** weblink in your eBookPLUS to find the name of the university closest to where you live that offers a course that can qualify you to work as a dietitian.

Breathe in, breathe out

Breathe in deeply . . . Now breathe out. You have just introduced some extra oxygen into your body and removed some unwanted carbon dioxide. You do this about 15–20 times per minute without thinking. The muscle movements required for **breathing** are automatic and controlled by the respiratory centre in the brain.

When you breathe in, you take in the mixture of gases called air. Oxygen and carbon dioxide are gases found in the air around you. Oxygen makes up about 21 per cent of the air, while carbon dioxide makes up only about 0.04 per cent. Your body uses some of the oxygen you take in. The table at right shows that the air that you breathe out contains less oxygen and more carbon dioxide than the air you breathe in. The percentages in the table are approximate and vary a little with weather conditions and height above sea level.

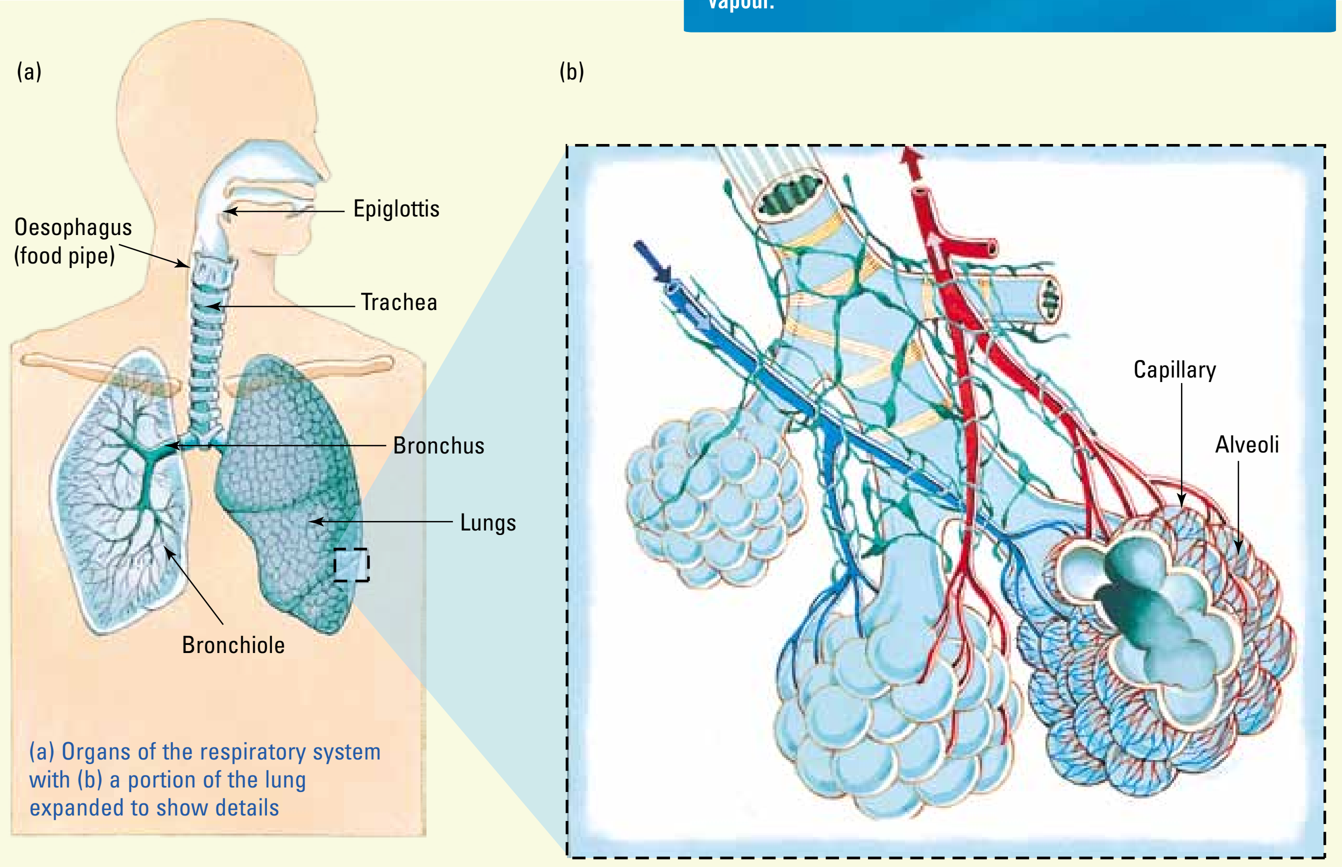
The air that you breathe enters your body through your nose and mouth. Unless your nose is clogged up by a cold, it is the most important airway. The hairs and sticky mucus in your nose trap dust and dirt and other harmful material such as disease-causing bacteria. Breathing in through your mouth gets the air in faster but without being filtered by the nose. When you play sport, your body uses oxygen more quickly and it is often necessary to breathe in through your mouth, bypassing the filter system in your nose.

What goes in and what comes out

Gas	Oxygen (%)	Carbon dioxide (%)	Water vapour (%)	Nitrogen (%)
Air breathed in	21	0.04	usually <1%	78
Air breathed out	16	4	2	78

HOW ABOUT THAT!

The water vapour that you breathe out carries heat away from your body and helps you to control your body temperature. You lose about 500 mL of water each day by breathing out water vapour.



(a) Organs of the respiratory system with (b) a portion of the lung expanded to show details

Going down?

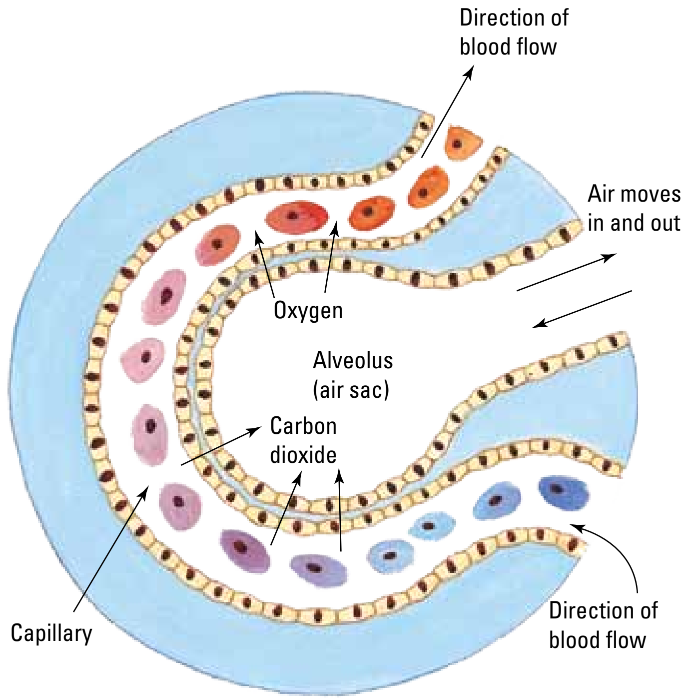
After entering your body, the air moves into a narrow tube called the **trachea**, which is more commonly known as the windpipe. At the top of this tube is a flap of tissue called the **epiglottis**. The job of this tissue is to stop food from going down into your lungs. If food does manage to pass it and 'go down the wrong way', a cough soon brings it back up again.

The trachea divides into two narrower tubes called the bronchi. Each of these tubes leads to a lung. Inside the lung, each tube divides into many smaller tubes called **bronchioles**. The bronchioles branch out, getting smaller and smaller until they end at thousands of tiny air sacs called alveoli.

What happens in an alveolus?

An alveolus is full of air. There are many small blood vessels called **capillaries** that run over the surface of the alveoli. The walls of the alveoli and the walls of the capillaries are very thin. Oxygen passes through these walls from the alveolus into the blood. Carbon dioxide goes in the opposite direction. This is an example of diffusion.

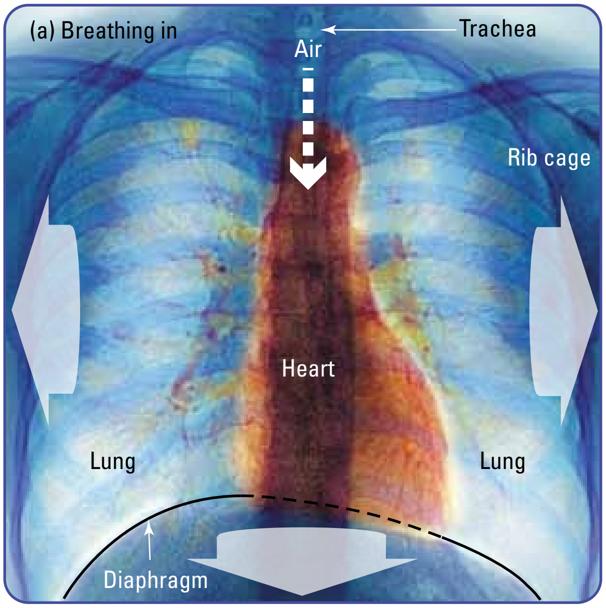
When a substance diffuses across a membrane, it moves in the direction that will even out the concentration on both sides of the membrane. In the lungs, the concentration of oxygen is higher inside the alveoli than in the blood so oxygen diffuses out of the alveoli and into the blood inside the capillaries.



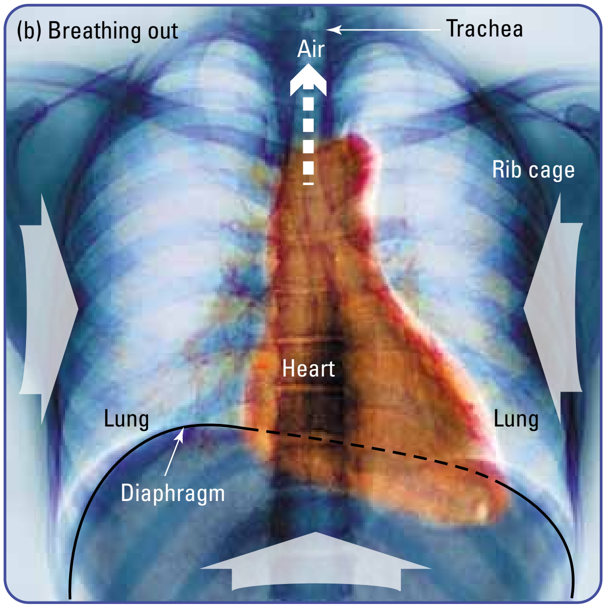
In an alveolus, oxygen diffuses into the blood and carbon dioxide diffuses out of the blood.

The concentration of carbon dioxide is greater in the capillaries than in the alveoli, so carbon dioxide moves out of the bloodstream and into the alveoli so that it can be breathed out.

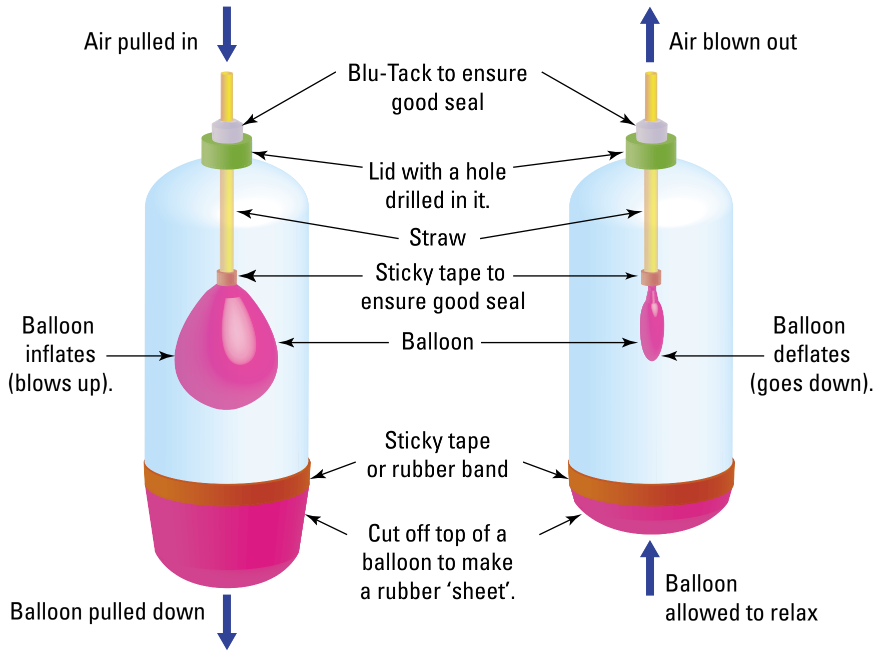
The movement of a muscle called the **diaphragm** helps the lungs do their job by pulling in and pushing out air. The diagram below shows how this happens.



(a) **Breathing in.**
The diaphragm tightens, allowing the lungs to expand, and the air is pulled into the lungs.



(b) **Breathing out.**
The diaphragm relaxes, making the lungs smaller, and the air is pushed out.



Lung capacity

Although adults can breathe out up to 5 litres of air with each breath, they usually breathe out only about half a litre. The largest volume of air that you can breathe in or out at one time is called your **vital capacity**.

A model lung. When the rubber sheet at the bottom is pulled down, the pressure inside the jar drops and air is sucked into the balloon. The balloon inflates (blows up).

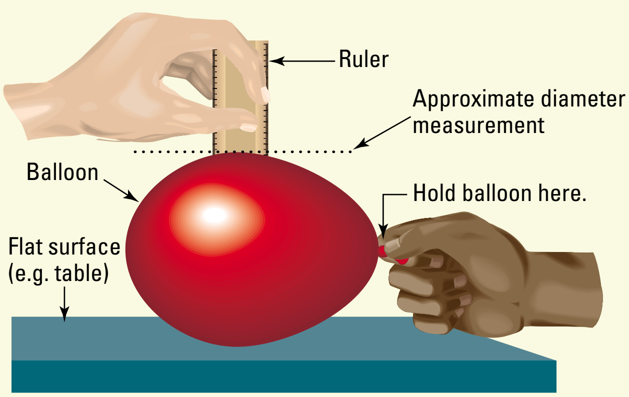
INVESTIGATION 8.6

Measuring your vital capacity

AIM To compare the vital lung capacities of a number of students

You will need:
balloon
ruler

- Blow up a balloon to about 20 cm in diameter two or three times to stretch it. Release the air each time.
- Take the biggest breath you can, then blow out all the air you can into the balloon. Tie up the end of the balloon to hold in your 'blown out' air.
- Use a ruler to measure the diameter of the balloon as shown below.



How to measure the diameter of the balloon

Determining vital capacity

Balloon diameter (cm)	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Approx. vital capacity (litres)	0.3	0.4	0.5	0.7	0.9	1.2	1.4	1.8	2.1	2.6	3.0	3.6	4.2	4.8

- Use the table at the bottom to determine your approximate vital capacity in litres.
- Release the air from the balloon and repeat your measurement of vital capacity three more times. Average your results to get your best estimate of the maximum 'blow-out' of your lungs.

DISCUSSION

1. **Why were you asked to stretch the balloon first?**
2. **Why did you measure your vital capacity four times?**
3. **(a) Draw up a table with the following headings.**

Name	Male or female?	Does this student play a wind instrument?	Lung capacity (L)

(b) Collect results from all the students in your class and complete the table.

(c) Calculate the average lung capacity for all the girls and all the boys. Do girls have a bigger or smaller lung capacity than boys in your class?

(d) Calculate the average lung capacity for all the students in your class who play a wind instrument. Compare that with the average value for the other students in the class. Does playing a wind instrument have an effect on lung capacity?

4. **Suggest another way of measuring the amount of air exhaled with each breath.**

HOW ABOUT THAT!

Whales, like all other mammals, have lungs. Unlike fish, they need to swim to the surface every so often to take in a huge breath of air. Large whales blow out then breathe in about 2000 litres of air through one or two nostrils on the top of their head. They need only about two seconds at the surface to do this. The air blown out contains a lot of water vapour and forms a cloud or spout that can shoot up to eight metres into the air.

ACTIVITIES

REMEMBER

1 List all of the parts that a molecule of oxygen must go through when travelling from the air into your bloodstream.

2 **Describe** the job done by each of the following parts of the respiratory system.
(a) Epiglottis
(b) Diaphragm
(c) Alveoli
(d) Lungs

THINK

3 The terms 'breathing' and 'respiration' are often confused with each other. **Differentiate** between these two terms.

4 When you breathe out onto a window on a cloudy day it fogs up.
(a) **Identify** the substance that makes the window fog up.
(b) Is the same substance breathed out on warm days? If so, why doesn't the window fog up?

5 Some people describe the structure of the lungs as an upside-down, hollowed-out tree. **Identify** which parts of the lungs the following parts of a tree might represent.
(a) Trunk
(b) Branches
(c) Twigs
(d) Leaves

6 Study the diagram of the model lung on page 252 and answer these questions.
(a) **Identify** the organs or body parts that the following parts of the model represent.
(i) Straw
(ii) Rubber sheet
(iii) Balloon inside bottle
(iv) Plastic bottle
(b) Copy and complete the following paragraph.

When you pull down on the rubber sheet, the space inside the bottle becomes ____________ . There is still the same number of air particles in that space so the air particles move further ____________ . This makes the air pressure inside the bottle ____________ and it causes air to be ____________ the straw. When the rubber sheet is let go, the ____________ inside the bottle returns to its original size and air is ____________ of the straw.

(c) **Explain** why alveoli and capillaries need to have very thin walls.

7 A year 8 student wrote in her exam paper: 'Humans breathe in oxygen and breathe out carbon dioxide'. Her teacher wrote: 'That's not entirely correct. If that were true, then mouth-to-mouth resuscitation could not keep a person alive'.
(a) Rewrite the statement made by the year 8 student so that it is correct.
(b) **Justify** the teacher's comment.
(c) If you breathed in air that had a lower oxygen concentration than your blood, **describe** what would happen in your alveoli.

INVESTIGATE

8 **Find** out what a spirometer is.

9 Research then write half a page to **explain** how high altitudes affect your breathing.

CREATE

10 **Construct** a model lung as shown in the diagram on page 252. You can use the following items:
- two clear 1-litre plastic bottles with tops
- four balloons
- two plastic drinking straws
- rubber bands or very sticky tape
- plasticine or Blu-Tack
- scissors.

eBook*plus*

11 Use the **Anatomy of breathing** weblink in your eBookPLUS to view an animation that outlines how the respiratory system works.

work sheet 8.6 Breathing — constructing a report

Blood highways

The respiratory system gets oxygen into our lungs. Once the oxygen is in the lungs, it needs some way of getting to all the cells of the body. That is the job of the **circulatory system**. The circulatory system consists of the heart, the blood vessels and blood.

Blood by the bucketful

An average-sized human has about five litres of blood; that's about a bucketful. It travels around the body in tubes called **blood vessels**. If these vessels were laid end to end, they would encircle the Earth two and a half times. These tubes enable materials in your body to be transported from one place to another.

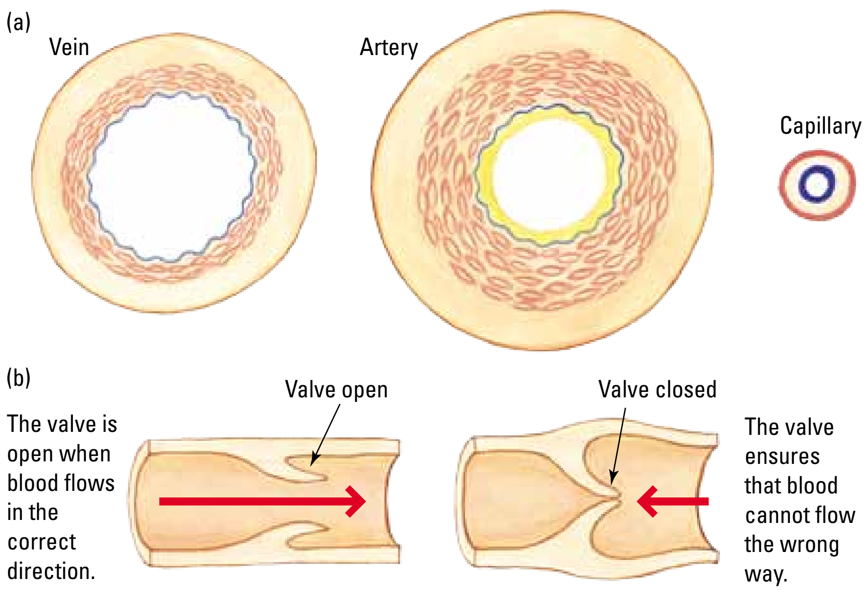
Some of these blood vessels are called **arteries**. They have thick, elastic, muscular walls and carry blood under high pressure away from your heart. Some other vessels are called veins. They have thinner walls, and valves that prevent the blood from flowing backwards. Veins carry blood to the heart.

The most numerous and smallest blood vessels are called capillaries. Your body contains about 1 000 000 km of capillaries, which penetrate almost every tissue. No cell is very far away from one. Capillaries are very important blood vessels because they carry materials such as oxygen and nutrients to the cells and remove wastes including carbon dioxide.

What's in blood?

The liquid part of blood is called **plasma**. It is a straw-coloured liquid and consists mostly of water. Many of the substances carried around in the blood are dissolved in the plasma. Nutrients such as glucose and some waste products, including carbon dioxide, are dissolved in the plasma.

A sample of blood that has been centrifuged (spun at high speed). The cells are in the bottom layer. They have separated from the plasma.



(a) Cross-sections of an artery, a vein and a capillary
(b) Veins have valves to ensure that blood flows in only one direction.

The reason that blood looks red is that it contains many red blood cells. In a drop of blood there are about 300 million red blood cells. They are red because they contain a chemical called **haemoglobin**.

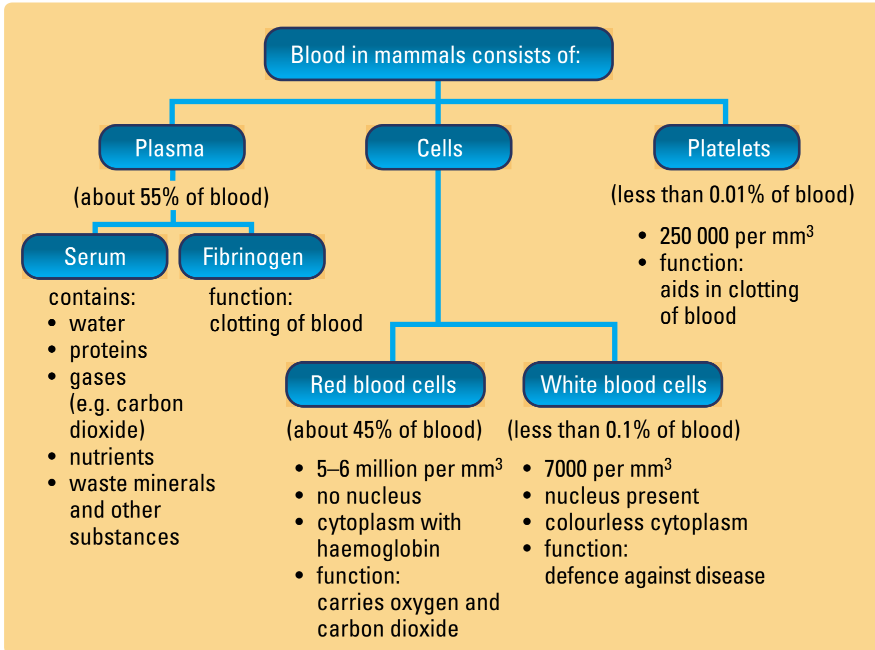
The job of red blood cells is to carry oxygen around the body. When red blood cells reach the lungs and oxygen diffuses into the blood, the oxygen reacts with the haemoglobin in red blood cells to form a chemical called

oxyhaemoglobin, which is bright red. So blood that contains a lot of oxygen is actually brighter red than blood that is low in oxygen. In fact, the colour of blood can provide an indication of its oxygen saturation level. In hospital, it is common for a small device that emits red light to be clipped to a patient's finger. The device is called a pulse oximeter. Most people undergoing surgery have a pulse oximeter attached. The device is used in other instances as well. The device emits two types of light. The proportion of each type of light that is absorbed as the light passes through the patient's finger depends on the level of oxygen in the blood, and hence its colour. A finger that contains highly oxygenated blood absorbs more of one type of light than a finger containing poorly oxygenated blood. The device provides a handy way of measuring a patient's oxygen saturation level without the need to draw blood to analyse it.

Red blood cells are very small so they can fit inside tiny capillaries. They form from cells in the bone marrow and, when mature, they lack a nucleus. This saves space. They also have a concave shape. This means that, for their size, they have a large surface area that allows them to carry lots of oxygen.

Red blood cells have a biconcave shape.

There are a lot fewer **white blood cells** in blood but they are larger than red blood cells and have a nucleus. White blood cells have an irregular shape and are not rigid so they can squeeze into small blood vessels. They are involved with fighting disease. Some white blood



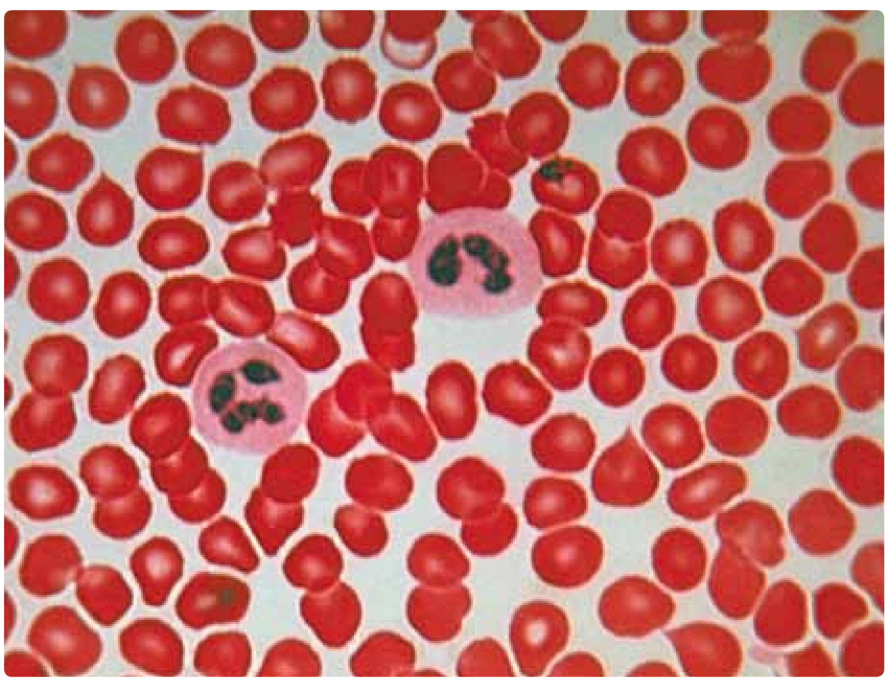
The components of blood

cells engulf (gobble up) germs while others produce substances called **antibodies**, which attack germs. When you are sick, the number of white blood cells in your blood increases.

Platelets are also found in blood. Platelets help blood to clot if a blood vessel is cut. This seals up the cut so that germs cannot get in.

HOW ABOUT THAT!

Insect blood looks a little like raw eggwhite, because it contains no pigment. The blood of crabs and crayfish, however, contains the pigment haemocyanin. This pigment has copper in it and is blue when combined with oxygen. This is different from haemoglobin in humans, which is red when combined with oxygen.



Human blood cells seen through a light microscope. The white blood cells are shown as pink, each with a nucleus.

INVESTIGATION 8.7

Viewing blood cells

AIM To draw a diagram of blood cells viewed under a microscope

You will need:

prepared slide of blood smear
microscope

- View the prepared slide under the microscope on high power.
- Find a white blood cell on the slide.

DISCUSSION

1. Sketch a few red blood cells and one white blood cell.
2. Estimate how many red blood cells would fit inside a white blood cell.
3. Estimate the number of red blood cells that can fit across the field of view.

Artificial blood — a reason to support scientific research

If you lose a lot of blood, you may need a blood **transfusion.** The blood from another person is injected into your veins to replace the blood you have lost. However, donated blood is always in short supply and the blood that is transfused must match your own blood type. If the person who donated the blood had an infection, there is also a risk of passing on that infection. What's the solution? Artificial blood.

No-one has quite succeeded as yet in making a perfect replacement for blood but a number of teams of scientists around the world are working on it. The ideal blood replacement would be a product that has a long shelf life, does not need to be refrigerated, does not need to match the patient's blood type and is guaranteed to be free of disease-causing germs.

A type of artificial blood called Hemopure has been approved to treat some cases of severe anaemia in South African hospitals. It is made from haemoglobin obtained either from blood that has passed its use-by date or from animal blood. The haemoglobin is wrapped in certain chemicals so that it behaves a lot like red blood cells do and can carry oxygen around the body.

Hemopure is not an ideal replacement for donated blood, and it has not been approved for human use in Australia. There are side effects to using this product but, in countries where there is a critically low supply of donated blood, the benefits of this blood substitute can outweigh the risks.

Other blood substitutes are also being tested. Some of these are completely synthetic and are not even red in colour. PFCs are blood substitutes that are white in colour. They carry out only some of the functions of blood, mainly transporting substances including oxygen around the body.

ACTIVITIES

REMEMBER

1. **Outline** what blood is and what it does.
2. Name and **describe** the types of blood vessels in which blood travels around your body.
3. **Compare** red blood cells, white blood cells and blood platelets.
4. **Explain** the advantage of red blood cells not having a nucleus.
5. **Explain** why haemoglobin is important.
6. Why isn't blood the same colour in all animals?

THINK AND ANALYSE

7. The higher the altitude, the less oxygen there is in the air. **Propose** a reason why people living at high altitudes usually have more red blood cells than people living at low altitudes.
8. The branching diagram on page 255 shows the composition of blood. **Construct** a divided bar graph that shows what proportion of blood consists of plasma, red blood cells, white blood cells and platelets.
9. Copy and complete the following: There are ____________ times more red blood cells than white blood cells in blood.

INVESTIGATE

10. Research one of the following circulation topics and **summarise** your findings to the class in a poster or PowerPoint presentation: blood transfusions, rhesus babies, varicose veins, leukaemia, haemophilia, thrombosis, embolisms, aneurisms.
11. Find out more about how blood circulates in insects and lobsters.

DISCUSS

12. With a partner, **construct** a PMI (see page 549) for a law that makes it compulsory for everyone over 16 to donate blood at least once a year.

Have a heart

Often linked with emotions, love and courage, the heart has a special meaning for most of us. In a clinical sense, however, it is merely a pump about the size of your clenched fist.

Two pumps in one

To be more precise, the human heart is actually *two* pumps. Veins bring blood back from all parts of the body to the heart. The veins join up into a large vein called the **vena cava**. This vein leads into the top right chamber of the heart. The blood is then pushed into the bottom right chamber. From here it is pumped out to your lungs where it picks up oxygen and becomes more reddish in colour. It also loses some of the carbon dioxide from it. The **oxygenated** blood then returns to the left-hand side of your heart to be pumped out again to your body tissues, where it delivers oxygen and nutrients. The **deoxygenated** blood then returns to the right-hand side of the heart for the cycle to be repeated.

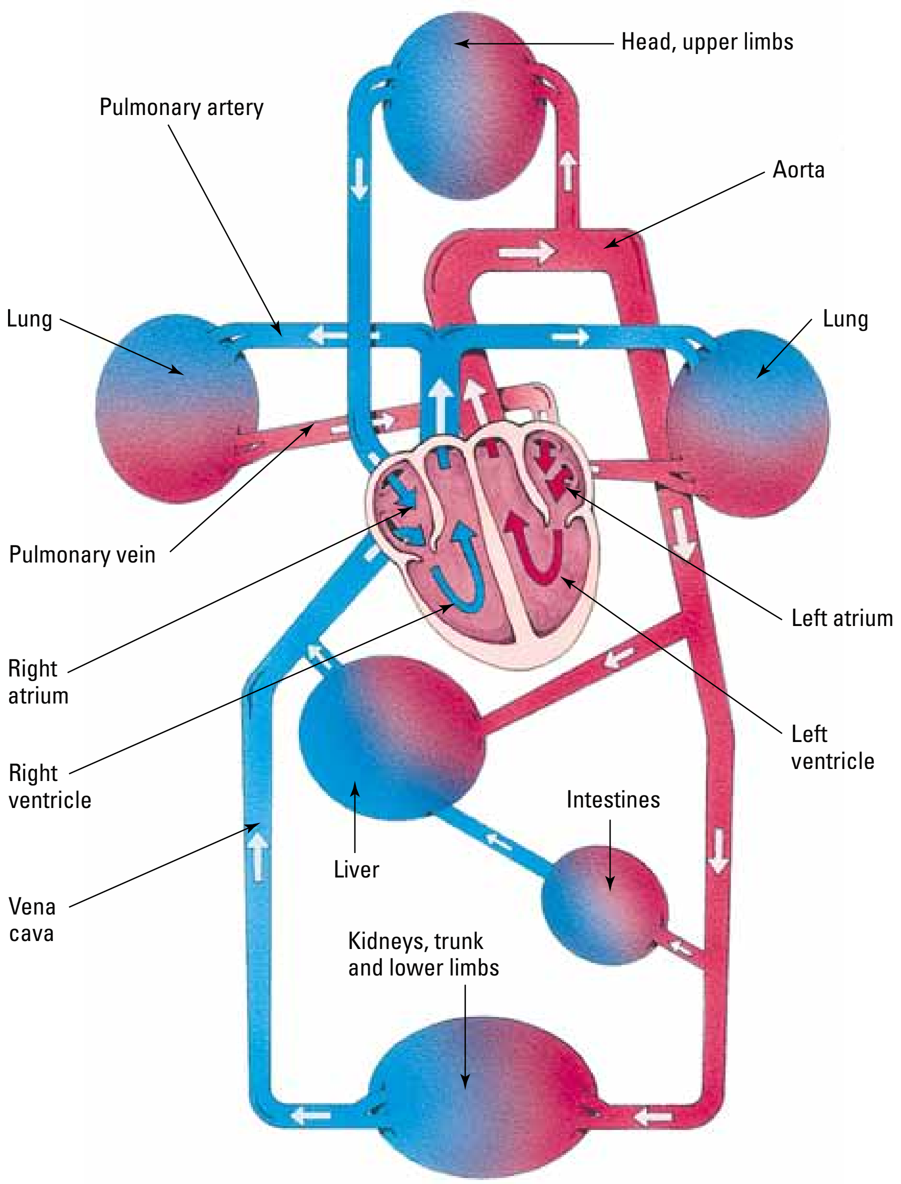
Four chambers

The human heart has four chambers. The upper two chambers are called the **left atrium** and **right atrium** (plural = atria), and the lower two chambers are the **left ventricle** and **right ventricle**. The two sides of the heart are different. The walls of the left side are thicker and more muscular because they need to have the power to force the blood from the heart to the rest of the body.

Flap-like structures attached to the heart walls, called **valves**, prevent the blood from flowing backwards and keep it going in one direction. If you listen to your heart beating you will hear a **'lub dub'** sound. The 'lub' sound is due to the valves between the ventricles and atria shutting. The 'dub' sound is due to the closing of the valves that separate the heart from the big blood vessels that lead to the lungs and the rest of the body.

HOW ABOUT THAT!

Not all animals have four-chambered hearts; in fact, some don't have hearts at all! A fish heart has two chambers, while amphibians and reptiles have three-chambered hearts. Can you suggest any advantages or disadvantages of these hearts over a four-chambered mammalian heart?



Connected highways — the routes for blood circulation

INVESTIGATION 8.8

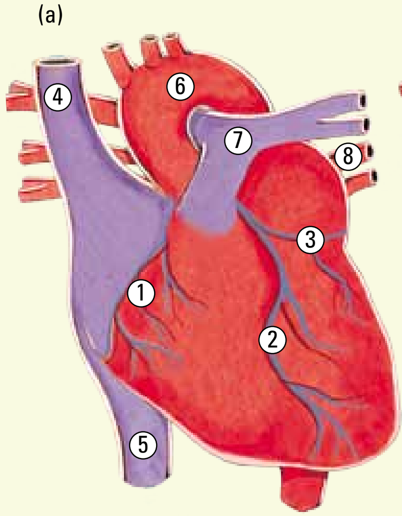
Dissect a heart

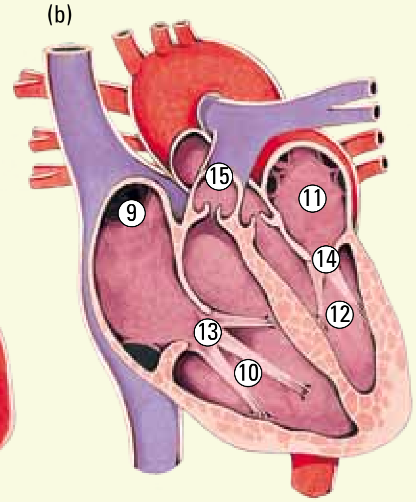
AIM To investigate the structure of a mammalian heart

You will need

sheep's heart preferably with the blood vessels still attached
dissecting instruments
dissecting board

- Place the heart on the dissection board as shown in diagram (a) at right. Use the diagram to identify the external parts of the heart.
- Try to locate where blood enters and leaves the heart:
  (a) to and from the lungs
  (b) to and from the rest of the body.
- Sketch and label the heart and use arrows to show the direction of blood flow.
- Cut the heart in two so that both halves show the two sides of the heart (similar to diagram (b) at right).
- In a diagram, record your observations of the thickness of the walls on the left side of the heart compared with the right side.
- Suggest reasons for the differences observed.
- Try to locate the valves in the heart.





1. Right coronary artery
2. Left anterior descending coronary artery
3. Circumflex coronary artery
4. Superior vena cava
5. Inferior vena cava
6. Aorta
7. Pulmonary artery
8. Pulmonary vein
9. Right atrium
10. Right ventricle
11. Left atrium
12. Left ventricle
13. Tricuspid valve
14. Mitral valve
15. Pulmonary valve

DISCUSSION

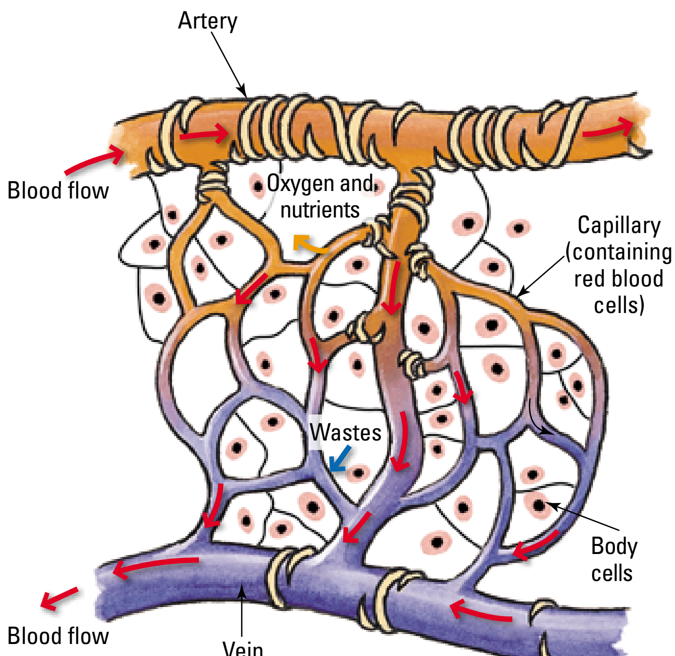
1. **Find out the role of the coronary arteries.**
2. **Find out what causes a heart attack.**
3. **Describe the valves and suggest their function.**
4. **Write a summary paragraph about the structure and function of the heart.**

Connected highways

Blood travels to all parts of the body in the capillaries. Oxygen and nutrients move out of the blood and pass through the walls of the capillaries. Waste products, including carbon dioxide, move out of cells and pass through the walls of the capillaries and into the bloodstream. Carbon dioxide is removed in the lungs. Other waste products are filtered out of the blood as it passes through the kidneys.

There are also many capillaries associated with the intestines. The digestive system breaks down food into particles that are small enough to diffuse through the walls of the intestines and into the blood. These nutrients are then delivered to all cells by the bloodstream.

Blood also passes through the liver. Your liver has numerous functions, including sorting, storing and changing digested food. It removes fats and oils from the blood and modifies them before they are sent to the body's fat deposits for storage. It also converts ammonia into urea. Ammonia is a toxic substance



In the capillaries, oxygen diffuses out of the blood and waste produced by cells diffuses into the bloodstream.

produced when protein is metabolised. Urea is less toxic than ammonia and can be filtered out of the blood by the kidneys. The liver also changes other dangerous or poisonous substances so that they are no longer harmful to the body. Your liver is something you cannot do without.

Your blood vessels make up a very busy highway system!

Blood pressure

The heart's pumping action and the narrow size of the blood vessels result in a build-up of considerable pressure in the arteries. The force with which blood flows through the arteries is called **blood pressure**. It is affected by different activities and moods. It also goes up and down as the heart beats, being highest when the heart contracts (**systolic pressure**) and lowest when the heart relaxes (**diastolic pressure**). A person's blood pressure is expressed as a fraction. This fraction is the systolic pressure over the diastolic pressure: for example, 120/70.

Keeping the pace

Each minute that you are sitting and reading this, about 5–7 litres of blood completes the entire circuit around your body and lungs. In a single day, your heart may have beaten about 100 000 times and pumped about 7000 litres of blood around your body.

A normal human heart beats about 60–100 times a minute, this rate increasing during exercise or stress. With each **heartbeat**, a wave of pressure travels along the main arteries. If you put your finger on your skin just above the artery in your wrist, you can feel this **pulse** wave as a slight throb. Your pulse rate immediately after exercise can be used as a guide to your physical fitness. The fitter you are, the less elevated your heart rate will be after vigorous exercise.

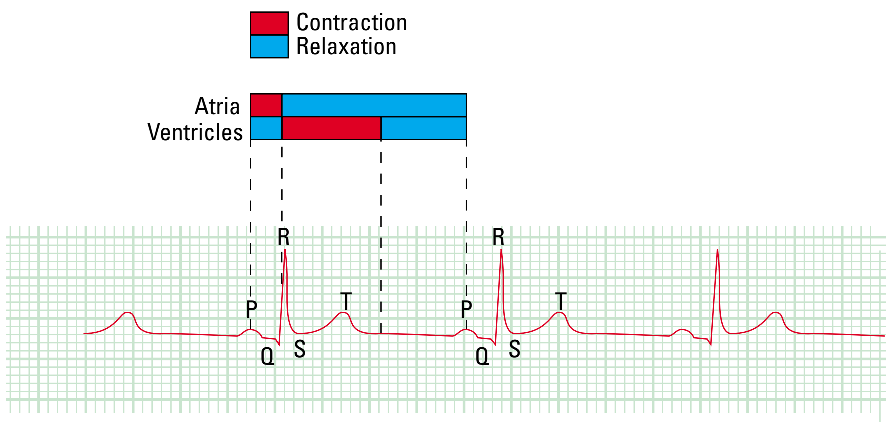
The regular rhythmic beating of the heart is maintained by electrical impulses from the heart's **pacemaker**, which is located in the wall of the right atrium. Some people with irregular heartbeats are fitted with artificial electronic pacemakers to regulate the heart's actions and correct abnormal patterns.

Try clenching your fist every second for five minutes. Getting a little tired? The heart is made up of special muscle called **cardiac muscle**, which never tires. Imagine having a 'cramp' or 'stitch' in your heart after running to catch the bus! Due to its unique electrical properties, heart muscle will continue to beat even if it has been removed from the body. Scientists have shown that even tiny pieces of this muscle cut from the heart will continue to beat when they are placed in a test tube of warm salty solution.

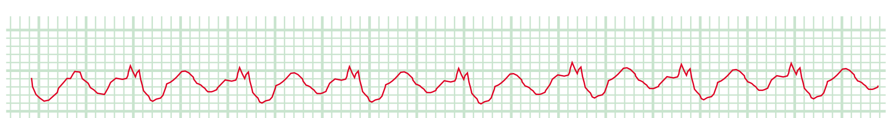
Getting the beat!

An **electrocardiogram (ECG)** shows the electrical activity of a person's heart. ECG patterns are valuable in diagnosing heart disease or abnormalities.

To produce the ECG, electrodes (flat pieces of metal that are connected to the ECG machine by wires) are stuck to the skin. The machine measures the tiny electrical impulses produced by the heart as it beats. It produces a trace similar to the one shown in the diagram below. An abnormal trace could indicate that the patient has arrhythmia. This is a condition where the heart beats irregularly. Another reason for an unusual trace could be a cardiac infarction. In this condition there is dead tissue in the heart. The electrical signal cannot travel through the dead tissue so the ECG looks abnormal. There are many other conditions that can cause an unusual ECG, and doctors will often follow up an abnormal ECG with further tests.



(a) Normal electrocardiogram



(b) Abnormal electrocardiogram

Electrocardiograms

INVESTIGATION 8.9

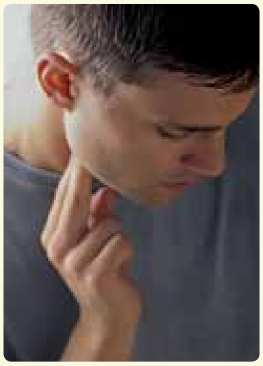
Check your heart

AIM **To investigate the short-term effects of exercise on heart rate and blood pressure**

You will need:
stopwatch
blood pressure monitor

- Find your pulse, either on the inside of your wrist or in your neck (see the illustrations). Make sure you use two fingers, not your thumb, to find your pulse.


(a)


(b)

Two places where your pulse should be easy to find: (a) radial location (wrist) and (b) carotid location (neck)

- Measure your heart rate in beats per minute (bpm) by counting the number of times your heart beats in 15 seconds and then multiplying this number by 4.
- Measure your blood pressure using the blood pressure monitor.
- Go for a walk in the playground or around the school oval. Measure your heart rate and blood pressure again.
- Run up and down a flight of stairs. Measure your heart rate and blood pressure again.
- Copy the table below in your notebook and enter your own results.

Test	Heart rate (bpm)	Blood pressure (mm Hg)
Before exercise		
After walking		
After running up stairs		

DISCUSSION

1. **What effect does exercise have on heart rate and blood pressure?**
2. **Design and carry out an experiment to test the following hypothesis: 'There is a link between a person's resting heart rate and the number of hours the person spends exercising each week'.**

ACTIVITIES

REMEMBER

1 Match each term with its description:

Term	Description
(a) Vein	A Blood vessel taking blood away from the heart
(b) Atria	B Organ where oxygen diffuses into the bloodstream and carbon dioxide is removed
(c) Liver	C Organ that pumps blood around the body
(d) Small intestine	D Organ with numerous functions, including converting toxic ammonia into urea, which is less toxic and can be filtered out of the blood by the kidneys
(e) Ventricles	E Organ where nutrients including glucose, amino acids and fatty acids move from the digestive system into the bloodstream
(f) Heart	F The top two chambers of the heart
(g) Artery	G The bottom two chambers of the heart
(h) Lung	H Blood vessel taking blood back to the heart

2 **Contrast** the following:
(a) the blood in the two sides of the heart
(b) the structures of the two sides of the heart
(c) systolic and diastolic pressure.

3 **Explain** why there are valves in the heart.

4 **Define** the terms 'systolic blood pressure' and 'diastolic blood pressure'.

5 (a) **Recall** how many times a normal human heart beats each minute.
(b) **Outline** what might cause the rate of heartbeats to increase.
(c) **Outline** how the rhythmic beating of the heart is maintained.

6 **Explain** what an electrocardiogram is and when is it useful.

7 **Describe** how an ECG is used to detect heart abnormalities.

8 **Describe** what is unusual about cardiac muscle.

9 **Explain** why you can't live without your liver.

THINK AND CREATE

10 (a) Copy the 'connected highways' diagram on page 257 into your notebook.
(b) Use a coloured pencil to show the path taken for a red blood cell to travel from the pulmonary vein to the pulmonary artery, if it goes via the intestines.

11 Mark the following sites (a, b, c, d) on your diagram. In which blood vessel(s) would you expect the highest:
(a) blood pressure
(b) blood glucose levels
(c) blood carbon dioxide level
(d) oxygen level?

12 List the following in the order that a red blood cell would reach them after leaving the aorta.
pulmonary artery, left ventricle, right atrium, intestine, lung, pulmonary vein, left atrium, liver, right ventricle

13 Convert your classroom or sports oval into a 'circulatory highway system'. Pretend to be a red blood cell and travel along the route it would take around the body.

14 (a) Read through the information on pages 257–258 to refresh your memory on the structure and function of your heart.
(b) **Construct** a flow chart to show the movement of blood through your body using the following labels.
left atrium, right atrium, right ventricle, left ventricle, pulmonary artery, pulmonary vein, lungs, aorta, vena cava, from body, to body

SKILL BUILDER

15 **Interpret** the cardiac cycle at right to answer the following questions.
(a) In which stage do the atria contract?
(b) In which stage do both the atria and ventricles relax?

16 Systole is the contraction of your heart muscle and diastole is the relaxation of your heart muscle. **Propose** what the following might mean.
(a) Atrial systole
(b) Ventricular systole
(c) Atrial diastole
(d) Ventricular diastole

17 **Interpret** the electrocardiograms on page 259 to answer the following questions.
(a) At 'P', are the muscle cells of the atria contracted or relaxed?
(b) After the 'QRS' wave, is the ventricle relaxed or contracted?
(c) How does the normal electrogram differ from the abnormal electrogram?
(d) Suggest what might be wrong with the heart activity shown on the abnormal electrogram.

18 **Compare** the information in the ECG on page 259 with the diagram below. Which sections of the normal ECG correspond to each of the stages of the cardiac cycle shown in the diagram?

INVESTIGATE

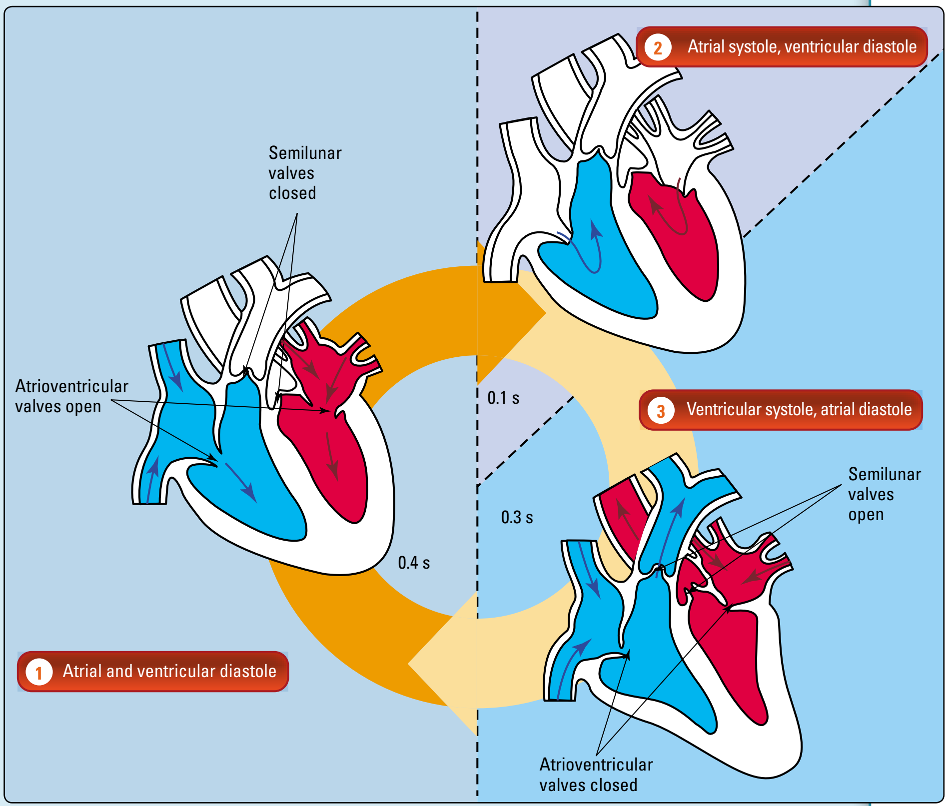
19 Hypertension or high blood pressure has been called 'the silent killer'. Find out about high blood pressure and answer the following questions.
(a) What do doctors consider to be high blood pressure?
(b) **Outline** how high blood pressure can lead to death.
(c) **Outline** what people with high blood pressure can do to bring their blood pressure back to normal.

eBook*plus*

20 Test your ability to label the parts of the heart by completing the **Beat it!** interactivity in your eBookPLUS. **int-0210**

21 Use the **Electrocardiogram game** weblink in your eBookPLUS to simulate performing ECGs on patients referred to you by medical doctors.

work sheets 8.7 Blood and blood highways



One complete cardiac cycle can take about 0.8 seconds in an adult human with a pulse of about 75 beats per minute.

Source: Fig. 42.6, p. 876 from BIOLOGY, 6th ed. by Neil A. Campbell and Jane B. Reece.

Getting rid of waste

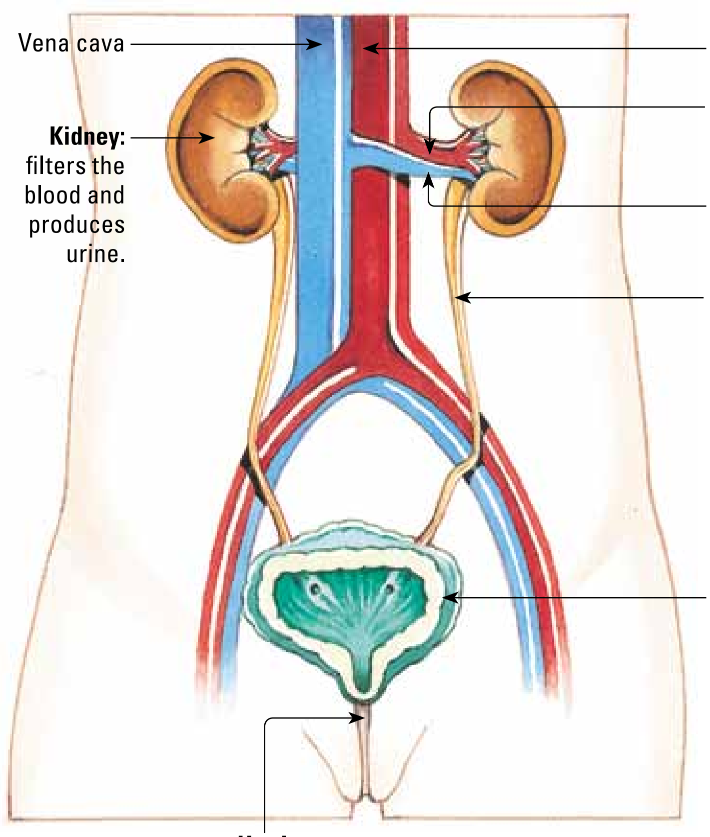
The human body takes in substances including food, water and oxygen. It also needs to get rid of unwanted substances that are produced by the body.

A number of organs are involved in getting rid of waste, including the lungs, the liver, the skin and the organs that make up the urinary system.

Many of the chemical reactions that occur inside cells produce toxic waste products. If our bodies could not get rid of these we would die. Excretion involves the removal of these harmful substances from the body. Carbon dioxide, produced in respiration, is excreted via the lungs; we breathe it out. Our skin excretes some salts and water in the form of sweat. Another harmful substance we need to excrete is urea. In the liver, excess amino acids are converted to urea. Urea is carried away from the liver in the bloodstream. The kidneys remove urea from the blood.

If you put your hands on your hips, your kidneys are close to where your thumbs are. You have two of these reddish-brown, bean-shaped organs. Without them you would survive only a few days.

Kidneys play an important role in filtering your blood. About a quarter of the blood that your heart pumps is sent to your kidneys. These small organs filter about 50 litres of blood each hour. As blood passes through the kidneys, the urea and some other harmful substances are removed. Other substances, like salts and water, which may be in excess, can also be removed. This keeps their concentration in the blood constant. If this did not occur, your cells would not work properly.



The urinary system

Urine is produced by your kidneys. This watery fluid contains unwanted substances. Tubes called **ureters** transport urine from your kidneys to your **bladder** to be stored temporarily. As it fills, your bladder expands like a balloon. It can hold about 400 mL of urine. **Urination** occurs when urine moves from your bladder through a tube called the **urethra** and out of your body.

Blood, water and urine

Both blood and urine are mostly made up of water. Water is very important because it assists in the transport of nutrients within and between the cells of the body. It also helps the kidneys do their job because it dilutes toxic substances and absorbs waste products so that they may be transported out of the body.

A comparison of what is found in the blood and the urine. How are they different?

	Quantity (%)	
Substance	**In blood**	**In urine**
Water	92	95
Proteins	7	0
Glucose	0.1	0
Chloride (salt)	0.37	0.6
Urea	0.03	2

Too much or too little

The concentration of substances in the blood is influenced by the amount of water in it. If you drink a lot of water, more will be absorbed from your large intestine and the kidneys will produce a greater volume of dilute urine. If you do not consume enough liquid, you will urinate less and produce more concentrated urine.

Kidney failure

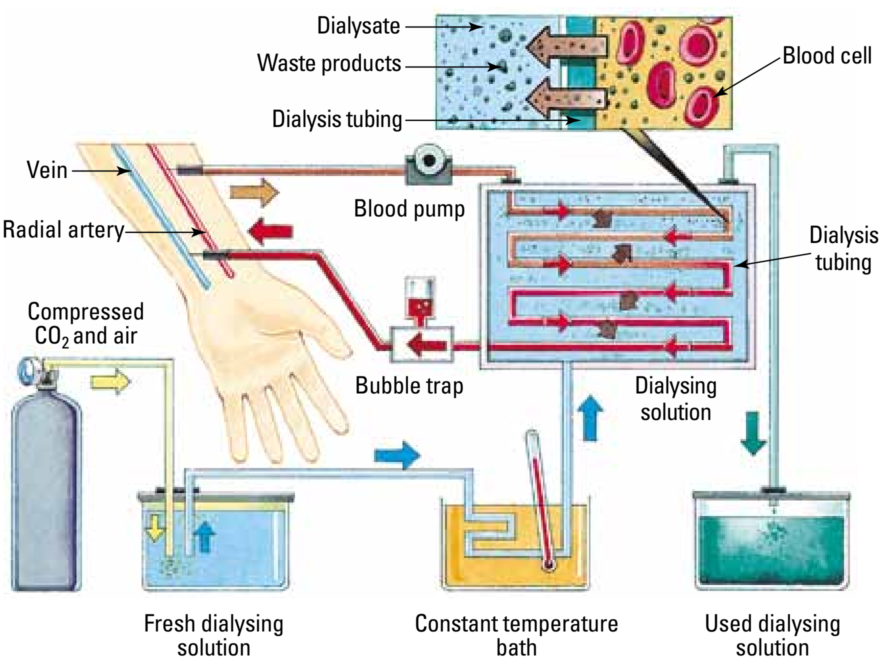
People with kidney disease may not be able to remove waste materials from their blood effectively. Kidney disease is more likely to affect people who have diabetes, high blood pressure or inflammation of the kidney. Kidney failure occurs when the kidneys become so inefficient that waste products start to build up in the blood. It is life threatening and often the only cure is a kidney transplant. People whose kidneys do not work properly may need to have haemodialysis treatment. Tubes are attached to the arm of the patient and their blood is pumped out of their body into a machine that does the job of the kidneys — it removes urea and other substances from the blood. The blood then goes back into the body.

Getting rid of alcohol

Drinking excessive amounts of alcohol is linked to many health risks. The part of the digestive system that is most affected by alcohol is the liver. The liver breaks down alcohol. Enzymes in the liver convert alcohol first to a substance called acetaldehyde, then to acetate, and finally into carbon dioxide and water. The carbon dioxide diffuses out of the bloodstream in the lungs and is breathed out. The water leaves the body as urine, sweat or vapour in the breath.

If you drink alcohol faster than the liver can break it down, the alcohol that is not eliminated is absorbed in the body and you become intoxicated. The liver works at a fixed rate and can detoxify about one standard drink each hour. So coffee, cold showers, fresh air and vomiting do not speed up the process of getting rid of alcohol from your body.

Alcohol also affects the amount of urine produced by the kidneys. It reduces the body's production of a hormone that keeps urine concentrated. The kidneys produce more urine than usual, instead of reabsorbing water into the body. As a result, you urinate more and can become dehydrated. In extreme cases, a heavy drinker can lose so much water that the body cannot function properly.



Haemodialysis

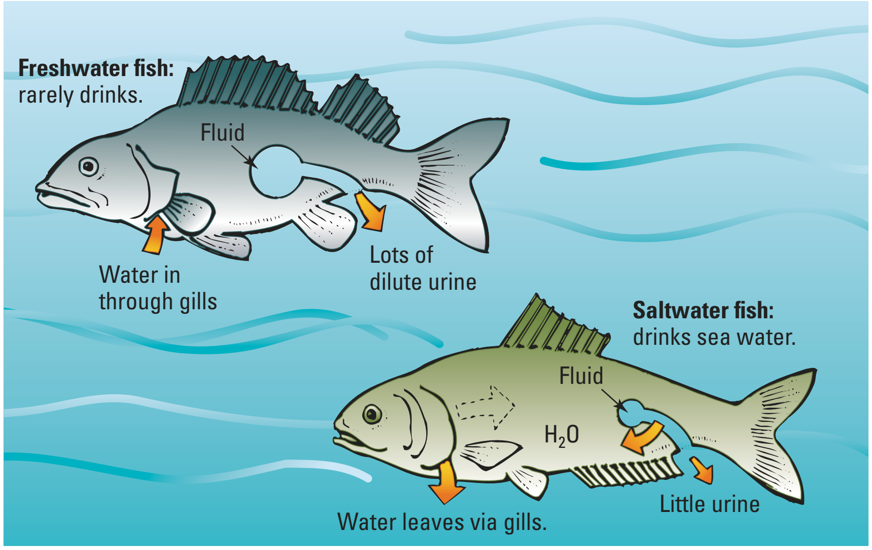
HOW ABOUT THAT!

The human kidneys remove excess salt from the blood to help keep levels constant. Different types of animals have other ways of removing excess salt from their bodies. Turtles, for example, have salt-secreting glands behind their eyes. Hence you may see a turtle 'shedding tears'. Penguins, on the other hand, may appear to have runny noses because that is where their salt-secreting glands are located.

What type of waste?

Has a bird dropping ever landed on your head or car window? If so, you have probably noticed that bird droppings are quite different from the type of waste produced by humans. We produce large amounts of urine. To produce this urine we need to take in a considerable amount of water. Consuming that much water and storing large volumes of urine in a bladder would weigh birds down. Birds produce their waste in the form of solid uric acid. It is even less toxic than urea, so the birds can store it in their bodies without the need to dilute it in water, and they pass it out of their bodies along with their faeces. Reptiles and insects also excrete their waste in the form of uric acid, mainly because they tend to live in dry regions where conserving water is important.

For fish and other aquatic animals, conserving water is not necessary. They save energy by releasing their waste in the form of ammonia. Ammonia is highly toxic but, for animals that live in water, this is not a great problem. They are able to release the ammonia directly into the water and thus dilute it to reduce its toxicity.



Which type of fish rarely drinks?

Birds excrete their waste in the form of uric acid.

ACTIVITIES

REMEMBER

1 **Define** the term 'excretion'.

2 Draw and label a diagram of the urinary system showing the following: renal arteries, renal veins, ureters, bladder, urethra.

3 What do blood and urine have in common?

4 **Outline** two effects of drinking large amounts of water.

5 **Describe** one way in which excess salt is removed from your body.

6 **Explain** how haemodialysis can assist people with kidney disease.

THINK

7 **Outline** what happens to alcohol in the liver.

8 Look carefully at the diagram of haemodialysis on page 263 and suggest reasons why the following are included in the process:
(a) blood pump
(b) bubble trap
(c) constant temperature bath.

9 **Identify** what you would expect to find in the used dialysing solution.

10 **Explain** why red blood cells don't pass through the dialysis tubing.

11 **Compare** dialysis with the way a real kidney works.

SKILL BUILDER

12 Use the table on page 262 and the other information on pages 262–263 to answer the following questions.
(a) **Construct** two divided bar graphs to show the quantity of water, proteins, glucose, salt and urea in blood and in urine.
(b) **Identify** which substance is in the greatest quantity in both blood and urine. Suggest a reason for this.
(c) **Identify** the substances found only in blood.
(d) **Identify** the substances found in urine in a greater quantity than in blood. Suggest a reason for this.
(e) **Explain** why the concentration of urea in the urine may vary throughout the day.

INVESTIGATE

13 Research and report on one of these conditions: urinary incontinence, kidney stones, dialysis, kidney transplants, cystitis.

14 Find out:
(a) the differences between the urethra in human males and females
(b) why pregnant women often need to urinate more frequently
(c) how the prostate gland in males may affect urination in later life
(d) which foods can change the colour or volume of urine
(e) which tests use urine in the medical diagnosis of diseases.

15 People who regularly drink large amounts of alcohol are at greater risk of developing liver problems. Find out about a medical condition called cirrhosis of the liver and why heavy drinkers are at greater risk of this disease.

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16 Use the **Alcohol** weblink in your eBookPlus to find out about the effects of alcohol on various parts of the body.

work sheet 8.8 Removing waste from the blood

Bodies on the move

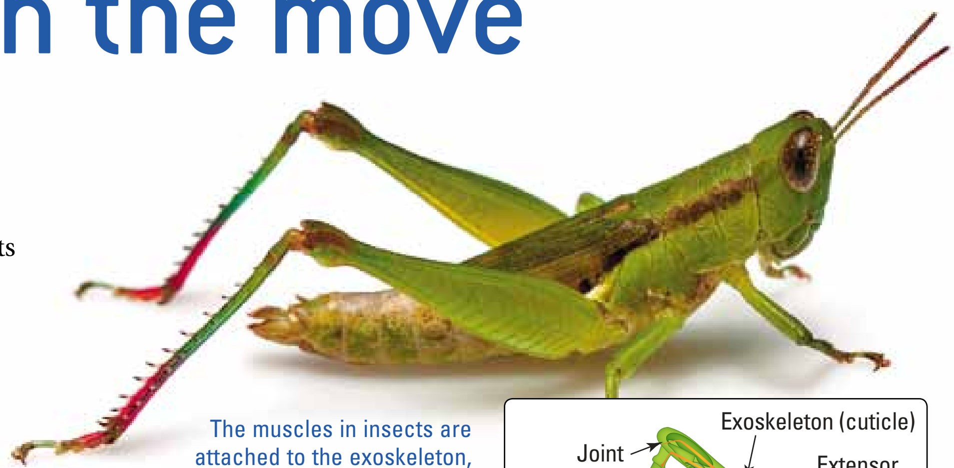
Muscles use the energy from food to enable us to move. They move the bones they are attached to, allowing us to walk, run, lift objects and perform fine movements such as those involved in writing. Together, muscles and bones form the musculoskeletal system, the system responsible for body movements.

Muscles

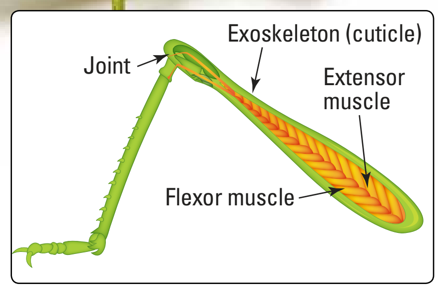
Muscles are tough and elastic fibres. You have muscles to make your heart pump, muscles to help you digest food and muscles to help you breathe. Many muscles, however, are joined to bones. Muscles pull on bones by **contracting**, or shortening. Muscles never push.

The movement of muscles is controlled by the brain, which sends signals through your nerves. Muscles such as those that make your heart pump and those that control your breathing are called **involuntary muscles**. They work without you having to think. The muscles that are connected to bones are called **voluntary muscles** because you have to choose to use them.

In animals without bones, such as worms and slugs, the muscles bring about movement by stretching and shortening certain parts of the body. It can be quite an effective way to move in water. Squid and jellyfish, for example, can propel themselves reasonably quickly in water even though their muscles are not attached to hard parts. They achieve this by pumping water into body cavities and releasing it suddenly to provide thrust. On land, this option is not available. To achieve high speeds on land, it is necessary for muscles to be anchored to something rigid. Insect muscles are attached to a layer of tough material on the outside of their bodies. This layer is called the **exoskeleton**. It is made of a substance called chitin. The diagram above shows how insects can move by contracting and relaxing their muscles.



The muscles in insects are attached to the exoskeleton, the outer covering of the body. This grasshopper can extend its leg by contracting the extensor muscle and relaxing the flexor muscle.

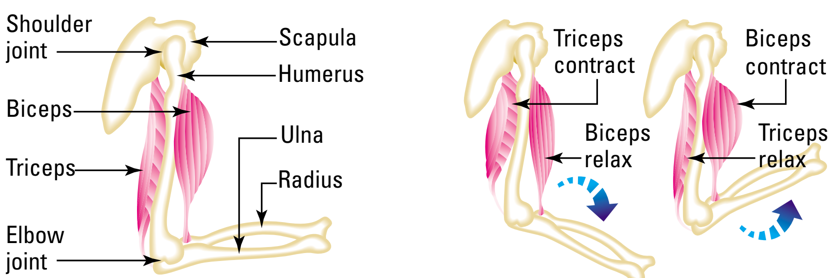


Bones

In humans and other vertebrates (animals with a backbone), the muscles are attached to bones inside the body by bundles of tough fibres called tendons. The muscles move the bones by contracting and relaxing.

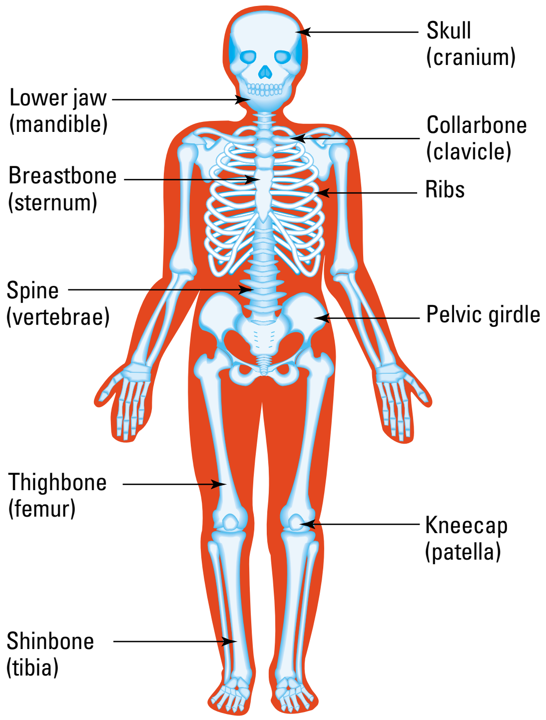
There are more than 200 bones in the skeleton of an adult human. Apart from providing a rigid structure for muscles to attach to, thus allowing you to move, the skeleton also has two other important functions. The skeleton provides support and forms a frame that gives your body its basic shape.

Without a skeleton, you would be a jelly-like blob.



When your biceps contract, your arm bends upwards. When your triceps contract, your arm straightens.

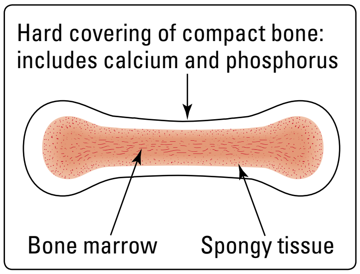
Certain bones of the skeleton also protect vital organs. For example, the brain is protected by the bones of the skull, and the heart is protected by the rib cage.



What's in a bone?

Long bones, such as the shaft of the femur (in your thigh), have an outer layer of hard, strong **compact bone** that covers an interior of spongy tissue containing the **bone marrow**. Some of the most important parts of your blood are made in the bone marrow. Some other bones in your body, such as the head of the femur, are made up of lighter **spongy bone**, which is more open in structure than compact bone.

Bones are alive. They contain living cells and need a blood supply to provide oxygen and other nutrients. If bones were not alive, how would you grow taller? How would a broken arm or leg mend?



The structure of a bone

Your bones cannot remain hard without an adequate supply of two important minerals: **calcium** and **phosphorus**. In fact, until you reach the age of about 20, the soft **cartilage** that made up your skeleton when you were born is being gradually replaced. Cartilage is very soft and rubbery, not as hard and solid as bone.

The hardening of your bones as you get older is called **ossification**. After ossification, the bone is made up of about 70 per cent non-living matter and 30 per cent living matter. As you get old, your bones may get dry and brittle. That is why older people break their bones more easily.

Not all cartilage changes into bone. The ends of your bones remain covered in cartilage. Your trachea (windpipe), nose and ears are made mostly of cartilage.

Investigation 8.10 shows what could happen to your bones without a supply of important minerals.

INVESTIGATION 8.10

Rubbery bones

AIM To investigate the effect of vinegar on bones

You will need:

2 chicken or turkey bones *2 jars* *vinegar*

- Clean the two chicken or turkey bones and leave them to dry overnight. Place one bone in a jar of vinegar and the other in a jar of water.
- Allow the bones to soak for at least three days. Then remove the bones and observe any changes.

Vinegar is an acid and dissolves minerals such as calcium and phosphorus compounds, removing them from the bone.

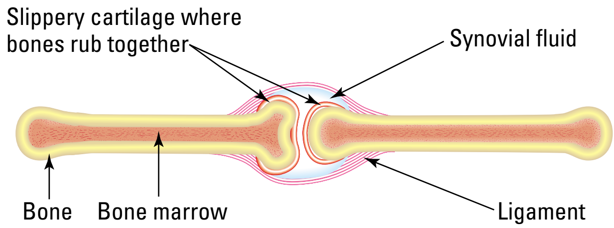
- Return the bone to the jar of vinegar for another week, then remove and observe any further changes in the bone. Try to tie the bone in a knot.

DISCUSSION

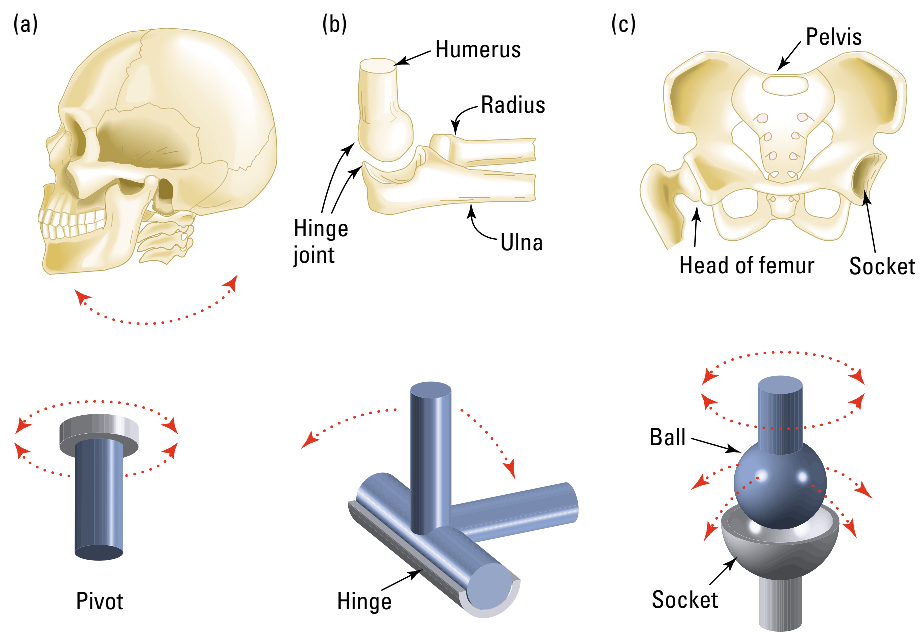
1. **What changes occurred in each of the two bones?**
2. **How did the bone change after more than a week in vinegar?**
3. **Why was the jar of water used in the first part of this experiment?**

Joints

A joint is where two bones meet. The elbow and knee are examples of joints. At a joint the bones are held together by bundles of strong fibres called **ligaments**. The ends of each bone are covered with cartilage. The cartilage is covered with a liquid called **synovial fluid**. Together, the cartilage and synovial fluid stop the bones from scraping against each other.



The region where bones meet is called a joint.



Different types of joints: (a) pivot joint, (b) hinge joint, (c) ball and socket joint, (d) immovable joint

Most joints allow your bones to move. The amount and direction of movement allowed depends on the type of joint.

The knee and elbow are **hinge joints**, like those in a door. They allow movement in only one direction.

The hip and shoulder joints are **ball and socket joints**. They allow movement in many directions.

The joint between your skull and spine is a **pivot joint**. It allows a twisting type of movement.

Some joints, such as those that join the plates of your skull, do not move. Such joints are called **immovable joints**. While not allowing movement, these joints provide a thin layer of soft tissue between bones. Their job is to absorb enough energy from a severe knock to prevent the bone from breaking.

Broken bones

When a bone breaks, the ends of the bone need to be put back into place (set), so that they can grow together. If a bone is shattered into several pieces, it is sometimes possible to use pins or wire to hold the pieces in place while the bone heals. A **greenstick fracture** occurs when the bone cracks but does not break. Greenstick fractures are common in children because the bones are more flexible.

Osteoporosis

Osteoporosis is a loss of bone mass that causes bones to become lighter, more fragile and easily broken. It occurs in middle-aged or elderly men and women. In Australia, about 60 per cent of women and about 30 per cent of men are affected in some way by osteoporosis. It is believed to be caused by a lack of calcium in the diet. Insufficient exercise is also an important factor in the development of osteoporosis.

In your teen years, you can help protect yourself from getting osteoporosis later by having a healthy diet. It should include dairy products such as milk, cheese and yoghurt and other foods high in calcium. Such a diet will help ensure that your bone mass is adequate as an adult.

INVESTIGATION 8.11

Chicken wing dissection

AIM To investigate the structure of a chicken wing

You will need:

chicken wing
scalpel
scissors
dissection tray or board
newspaper
disposable gloves

- Using the scissors and scalpel, gently pull away the skin from the chicken wing. Put the tip of the scalpel blade between the skin and the muscle to separate the skin from the muscle.
- When you have completely removed the skin from one joint, inspect it carefully. Follow each muscle near this joint from one end of the muscle to the other. Try pulling on the muscle. Can you get the bones to move by pulling on the muscle?
- Use scissors to cut through the joint. As you do so, look for tendons and shiny white cartilage.

DISCUSSION

1. **Sketch one of the joints in the chicken wing. Label the bones, the tendons and the muscles. Show clearly where the muscle inserts (attaches to the bones). Use arrows to show how the bones move when the muscle is shortened.**
2. **Feel the cartilage with a gloved hand. Does the cartilage feel rough or slippery? Why does it need to be slippery?**
3. **Is cartilage harder or softer than bone?**

ACTIVITIES

REMEMBER

1 Cover up the diagram of the human skeleton on page 266 and test your memory of the names of some of your important bones by completing the table below.

Scientific name	Common name
Vertebral column	
	Skull
Clavicle	
	Breastbone
Mandible	
	Thighbone
Patella	
	Shinbone

2 **Describe** the job done by each of the following parts of a joint.
(a) Ligament
(b) Cartilage
(c) Synovial fluid

3 Some joints are referred to as immovable joints. What is the use of having joints that don't move?

4 **Identify** an example of each of the following types of joint.
(a) Hinge
(b) Ball and socket
(c) Pivot
(d) Immovable

5 Ligaments and tendons are bundles of tough fibres. **Identify** the major difference between a ligament and a tendon.

6 **Describe** the action of the biceps and triceps muscles as you bend your elbow to raise your forearm.

7 **Recall** which organs the skull and rib cage protect.

THINK AND INVESTIGATE

8 Look carefully at each of the skeletons below. Three of them are incomplete. **Identify** which skeletons are incomplete and name the missing parts.

9 **Explain** why our skeleton isn't made of just one bone.

10 **Explain** why it is that, in a similar accident, an adult gets a broken bone while a child may suffer only a greenstick fracture.

11 Find out where the following bones are in the human skeleton.
(a) Humerus
(b) Fibula
(c) Coccyx
(d) Scapula

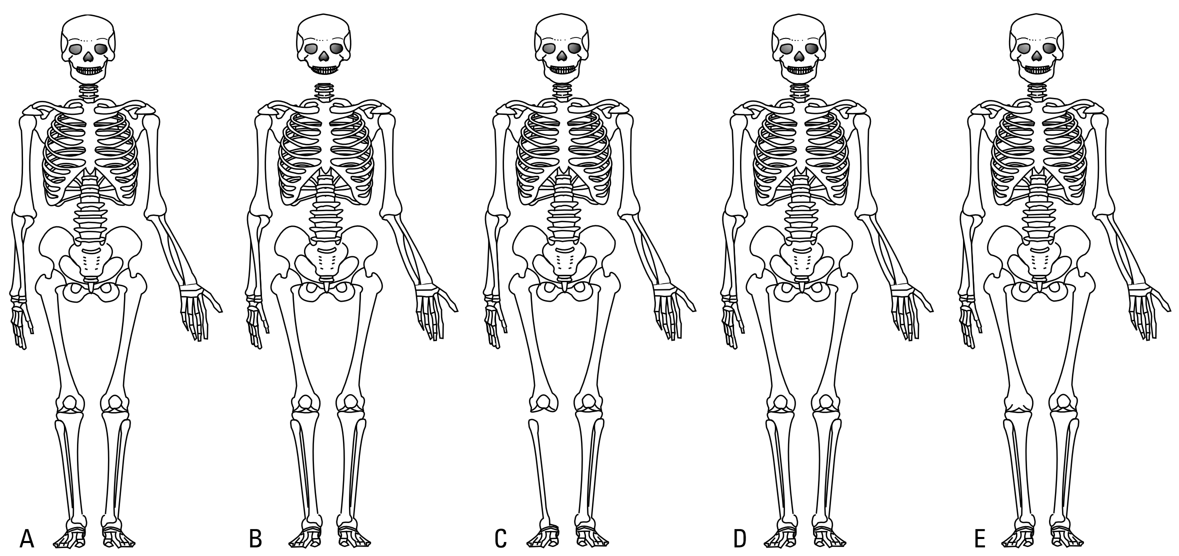
12 The muscles in your food pipe contract and relax to push food down into your stomach. Are these muscles voluntary or involuntary muscles? **Explain** your answer.

13 **Describe** what would happen if the cartilage in your knee joint wore out.

CREATE

14 **Construct** a skeleton mobile to hang from the ceiling.
(a) Trace the skeleton diagram on page 266 (or a larger one from another book), colour it and cut it into a number of sections.
(b) Paste each section onto cardboard and thread the sections together to make a skeletal mobile.

eBook*plus* work sheet 8.9 Bones, joints and muscles



assess on

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FOCUS activity

Work in groups of three or four students to design a body system board game. It could be based on a familiar board game such as snakes and ladders or trivial pursuit but it needs to include questions that relate to body systems.

Access more details about focus activities for this chapter in your eBookPLUS.

doc-10556

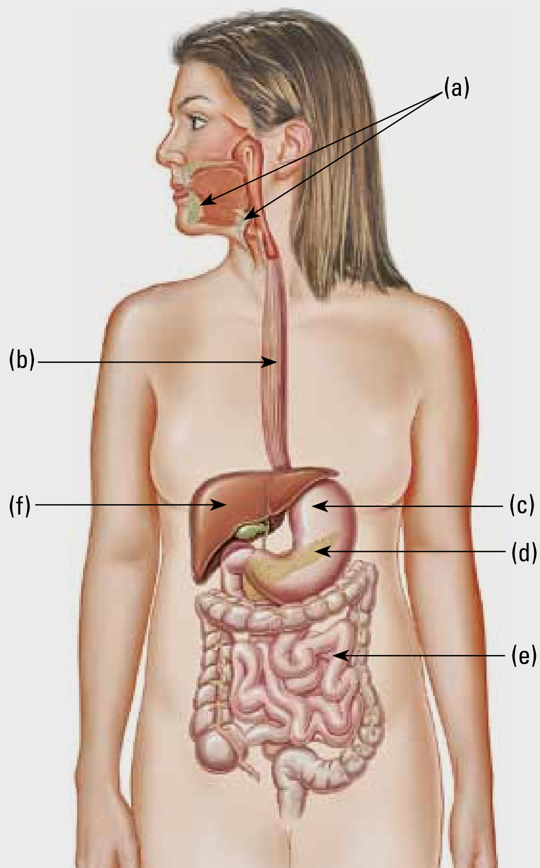
1 Copy and complete the following table.

Name of tissue	Two organs in this system	Name of system
Nerve tissue	___________, spine	
Cardiac muscle tissue	Heart, ___________	

2 Complete the table below to **summarise** what you know about some of the substances in food.

Nutrient	Why is it needed?	In which foods is it found?
Carbohydrates		
Fats and oils		
Proteins		
Vitamins		
Minerals		
Fibre		

3 **Identify** the names and roles of the organs marked in the following diagram of the human digestive system.



4 (a) What is the purpose of digestion?
(b) **Explain** the difference between mechanical and chemical digestion.

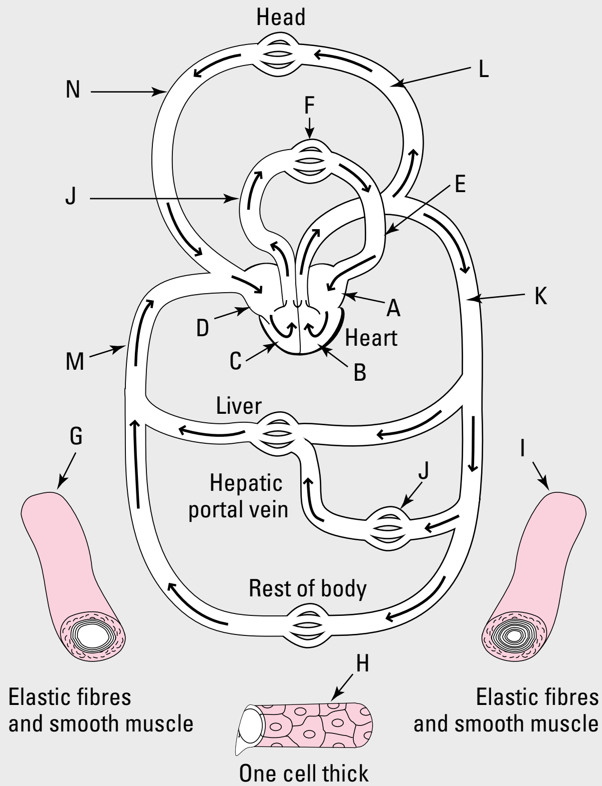
5 **Explain** why the small intestine is actually a long tube with many folds and lined with finger-like projections called villi.

6 Copy and complete the following table.

Dietary deficiency	Foods that are high in this vitamin	Symptoms of deficiency
Vitamin D deficiency		
Folate deficiency		

7 **Contrast** type I and type II diabetes.

8 (a) Name the lettered parts (A to N) of the human circulatory system and blood vessels in the diagram below.
(b) Trace or copy the diagram below. Then use a red pencil to colour in the blood vessels with oxygenated blood, and a blue pencil for those with deoxygenated blood.
(c) State whether the blood in the following blood vessels is deoxygenated or oxygenated:
(i) K
(ii) J
(iii) N
(iv) E
(v) L.
(d) Draw up a table that shows the differences in structure and function of the arteries, veins and capillaries.



The human circulatory system

9 The following diagram shows an alveolus. Match the letters in the diagram with the correct labels from the following list.

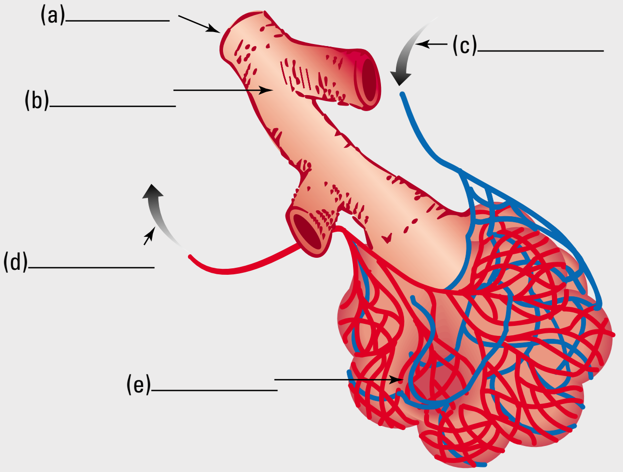
Alveolus

Bronchiole

Air flows into the lungs

Deoxygenated blood

Oxygenated blood



10 **Identify** all the body parts that oxygen would need to travel through to get from the air you inhale through your nose to the cells in your big toe.

11 **Outline** the function of each of the following organs of the urinary system: bladder, ureter, kidney, urethra, renal vein, renal artery.

12 Draw a diagram to show how a hinge joint works. Show the muscles in your diagram and use arrows to show how the muscles move the bones.

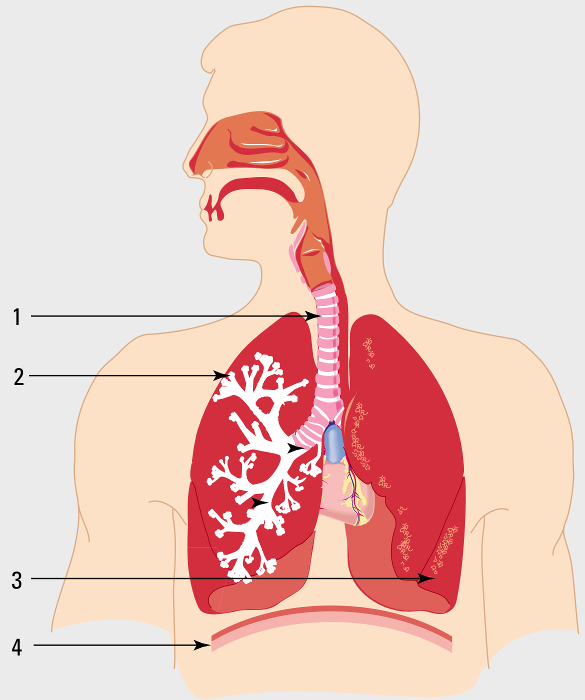
TEST YOURSELF

1 In which part(s) of the digestive system does mechanical digestion occur?
A Mouth only
B Mouth and stomach
C Mouth and small intestine
D Small intestine and large intestine (1 mark)

2 Which organ removes urea from the bloodstream?
A Bladder
B Liver
C Kidney
D Urethra (1 mark)

3 A diagram of the circulatory system is shown on the previous page. Which label is pointing to an artery that contains blood that has a much lower oxygen concentration than most arteries?
A E
B J
C N
D K (1 mark)

4 A diagram of the respiratory system is shown below.



The parts labelled 1 to 4 are
A trachea, alveolus, lung and diaphragm.
B bronchus, trachea, lung and diaphragm.
C larynx, lung sacs, diaphragm and rib.
D trachea, alveolus, intercostal muscles and pulmonary artery. (1 mark)

5 What is the main function of the circulatory system?
A To carry out respiration
B To get rid of waste
C To transport substances around the body
D To break down food into small particles (1 mark)

6 (a) **Describe** the role of teeth in the process of digestion. (1 mark)
(b) **Justify** why humans have different types of teeth. (1 mark)
(c) What are enzymes? **Describe** their role in digestion. (1 mark)

7 **Explain** why multicellular organisms such as humans need to have specialised organs such as a heart and lungs. (2 marks)

8 **Outline** three functions of the skeleton. (3 marks)

9 **Explain** why kidney failure is a life-threatening condition. (2 marks)

eBook*plus* work sheet
8.10 Body systems 1 puzzle
8.11 Body systems 1 summary
8.12 Body systems 2 puzzles
8.13 Body systems 2 summary

STUDY CHECKLIST

MULTICELLULAR ORGANISMS

- ☐ **explain** why multicellular organisms need specialised organs and systems **8.1**
- ☐ **outline** the relationship between cells, tissues, organs and systems **8.1**

DIGESTION AND NUTRITION

- ☐ **explain** why animals need to eat food **8.2**
- ☐ **describe** the roles of carbohydrate, protein, lipid, vitamins and minerals in the diet **8.2**
- ☐ label a diagram of the digestive system **8.3**
- ☐ **describe** the function of the main organs of the digestive system **8.3**
- ☐ **distinguish** between mechanical and chemical digestion **8.4**
- ☐ **describe** the role of teeth in digestion **8.4**
- ☐ **describe** the role of enzymes in digestion **8.4**

DIETARY DEFICIENCIES

- ☐ **outline** some of the reasons why health professionals are concerned about rising levels of childhood obesity and some strategies that have been proposed to address the issue **8.5**
- ☐ **describe** diseases linked to vitamin D and folate deficiency **8.5**
- ☐ **summarise** information about the work of dietitians **8.5**

CIRCULATORY AND RESPIRATORY SYSTEM

- ☐ **describe** the roles of the respiratory system and circulatory system in maintaining humans as functioning organisms **8.6–8.8**
- ☐ **explain** how air goes in and out of the lungs **8.6**
- ☐ **describe** what happens in an alveolus **8.6**
- ☐ **identify** and **describe** the components of blood **8.7**
- ☐ **describe** the structure of the heart **8.8**
- ☐ **explain** how the heart works to circulate blood through the body **8.8**
- ☐ **define** the terms 'blood pressure', 'pulse' and 'heart rate' **8.8**
- ☐ **outline** how blood circulation relates to the removal of waste products from the body **8.9**

EXCRETORY SYSTEM

- ☐ **explain** why excretion of waste is essential **8.9**
- ☐ label a diagram of the urinary system **8.9**
- ☐ **describe** the roles of the main organs of the excretory system **8.9**
- ☐ **define** the term 'haemodialysis' **8.9**

MUSCULOSKELETAL SYSTEM

- ☐ label the major bones of the human skeletal system **8.10**
- ☐ **outline** the role of the skeletal system **8.10**
- ☐ **explain** how muscles and bones work together to allow movement **8.10**
- ☐ **describe** the structure of bones **8.10**
- ☐ **identify** examples of hinge, pivot and immovable joints in the body **8.10**

SUMMARY

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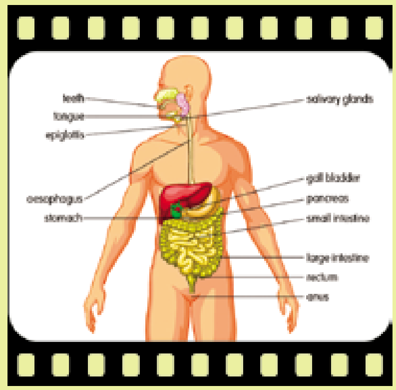
Digital documents

Individual pathways

Activity 8.1	Activity 8.2	Activity 8.3
Investigating body systems	Analysing body systems	Investigating body systems further
doc-10557	doc-10558	doc-10559

eLessons

From dinner plate to sewerage system
This video lesson explains the amazing journey of food through the human body, from dinner plate to sewerage system. Learn how our bodies release chemicals to break down food and absorb energy-giving nutrients, all without us even being aware of the process. A worksheet is attached to further your understanding.

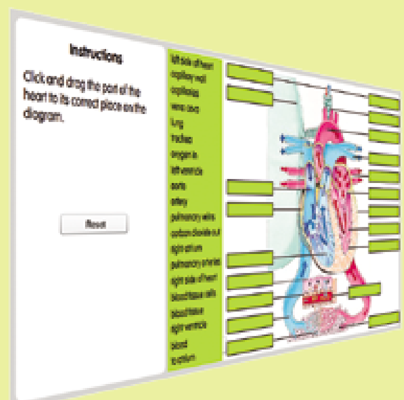


Searchlight ID: eles-0056

Leonardo's sketches and anatomy
Watch a video from *The story of science* about anatomy.
Searchlight ID: eles-1769

Interactivities

Beat it!
The heart is one of the most important organs in the human body. This interactivity tests your ability to label the parts of the heart. Instant feedback is provided.



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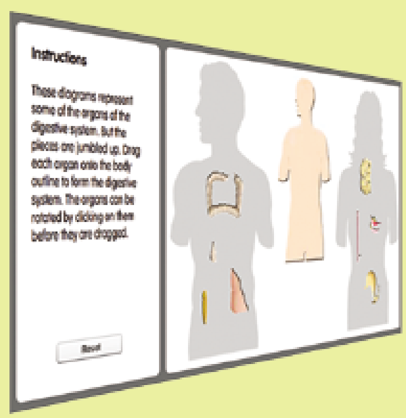
The digestive jigsaw
This interactivity looks at the jigsaw puzzle that is the digestive system. Test your knowledge by re-creating the human digestive system. Instant feedback is provided.



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