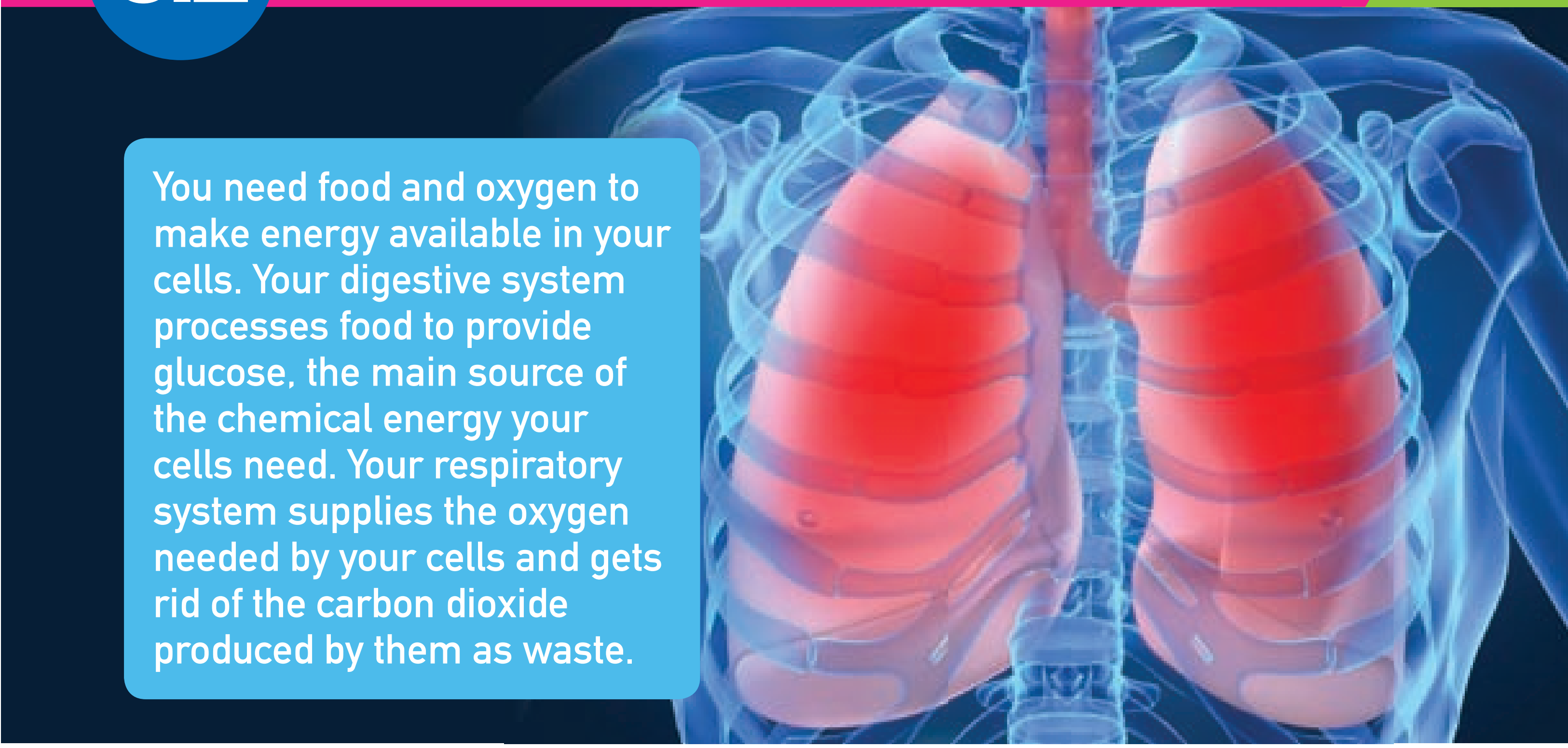
3.2 Breathing and respiration



You need food and oxygen to make energy available in your cells. Your digestive system processes food to provide glucose, the main source of the chemical energy your cells need. Your respiratory system supplies the oxygen needed by your cells and gets rid of the carbon dioxide produced by them as waste.

Respiration

Respiration refers to the series of chemical changes that take place in cells to release energy. For humans and many other animals, breathing is the process by which the body takes in and lets out air.

The system of organs and tissues that takes the air into the body and ultimately makes the oxygen available to the cells is the **respiratory system**.

Respiratory system

Your respiratory system takes in air and extracts oxygen from it. It allows oxygen to pass into your bloodstream to be distributed to the cells for respiration. Figure 3.2.1 shows the structure of your respiratory system.

Where the air goes

When you breathe in, some air may come in through your mouth but most of it comes in through your nose. Within the nasal cavity, the air is warmed and moistened. Large dust particles are filtered out as the air passes through the hairs inside your nostrils. Glands in the skin lining the nose produce sticky mucus. The mucus helps tiny hairs called cilia lining the nose to trap fine particles.

The mucus with the trapped particles then moves to the back of the nose and into the **pharynx**. It is then swallowed. You swallow about 600 mL of mucus every day without being aware of it.

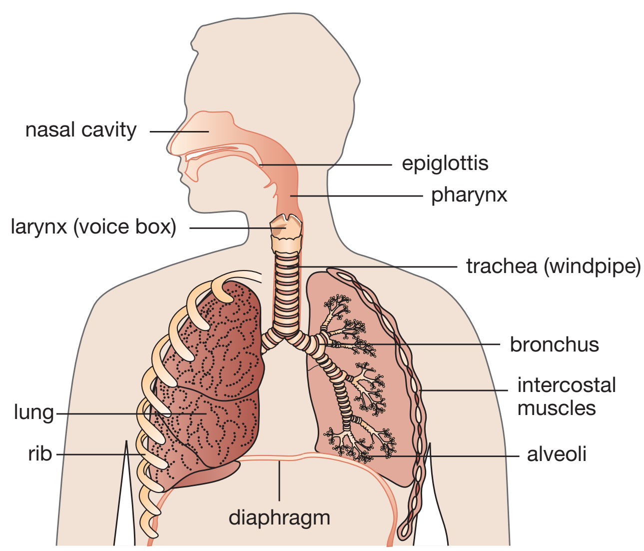


Figure 3.2.1 Structure of the human respiratory system

The warm, moist air then passes down the **trachea** (windpipe). The thin walls of the trachea are reinforced with rings of a firm elastic material called cartilage that keep your trachea from collapsing as you breathe in. You can feel these rings as ridges on the front of your throat. They are shown in Figure 3.2.2. The trachea divides into two **bronchi** (singular: bronchus), which divide and divide into ever smaller tubes (**bronchioles**), eventually ending in a cluster of sacs called **alveoli** in the lungs (singular: **alveolus**).

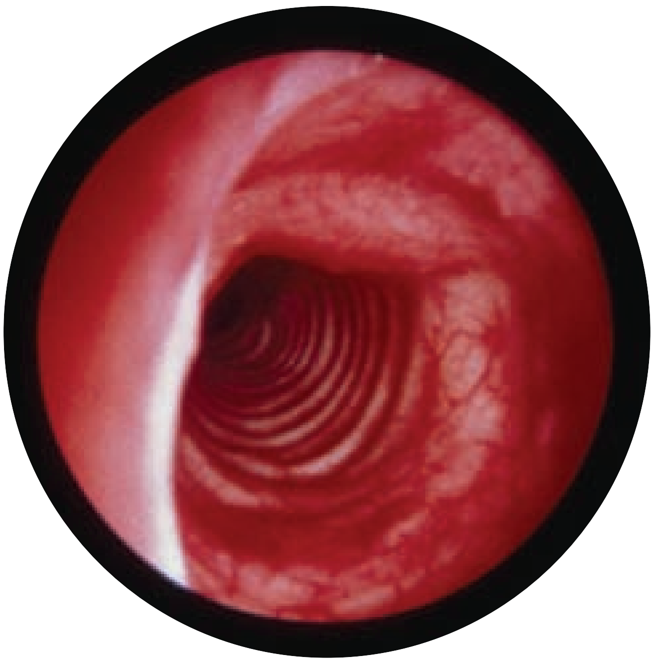


Figure 3.2.2 Ridges of stiff flexible cartilage can be seen clearly in this photograph of a trachea.

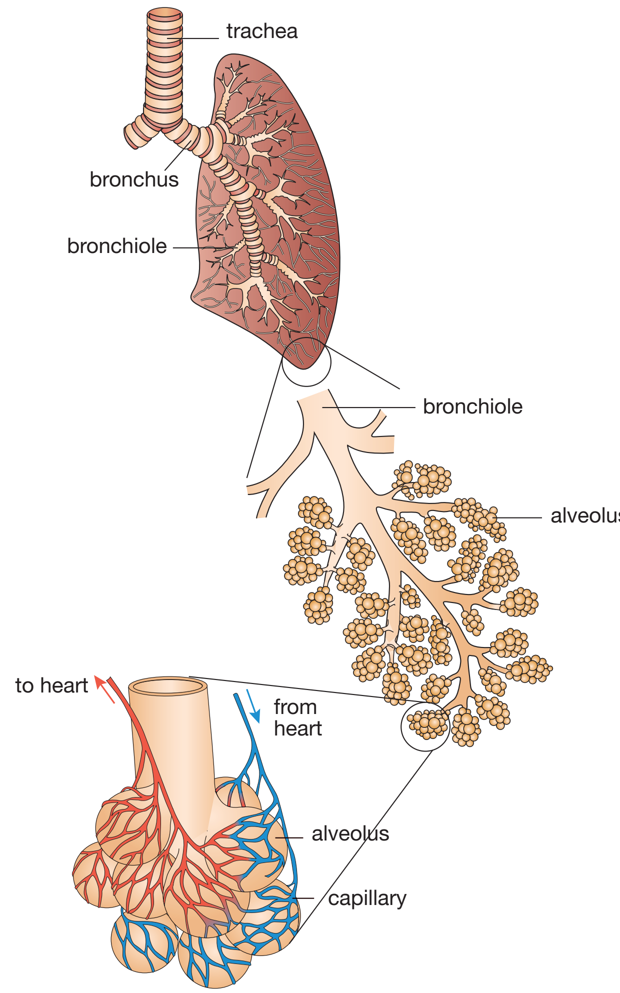


Figure 3.2.3 The air follows a path that starts with the trachea, a tube about the same diameter as a garden hose, and finishes in a microscopic sac called an alveolus.

Alveoli are microscopic and about 500 million of them make up your lungs. The alveoli provide a very large surface area, allowing gas to be easily exchanged between the lungs and bloodstream. Figure 3.2.3 shows the alveoli in a section of a lung. Figure 3.2.4 shows a magnified view of lung tissue.

SciFile

Breathing space

In each of an adult's lungs, there are about 300 million alveoli. If they could be spread out, they would cover an area about the same size as a tennis court (about 160 m^2). This is about 80 times the area of your skin.

3.5

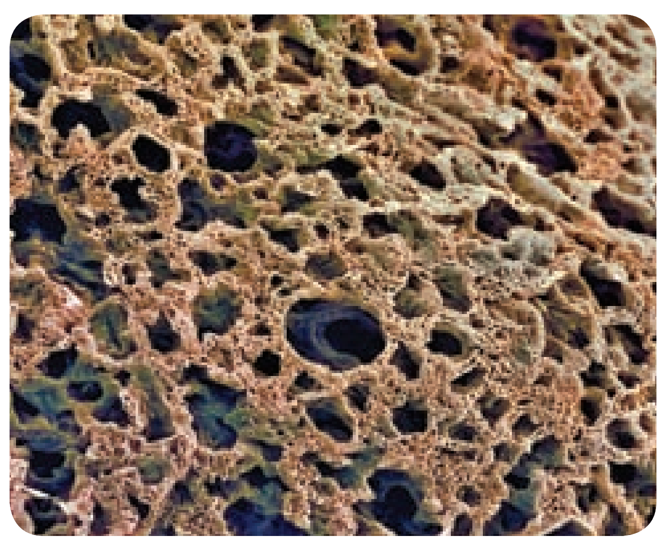


Figure 3.2.4 The alveoli within the lung are closely packed, making the lung like a sponge.

INQUIRY

science 4 fun

How big?

Yes

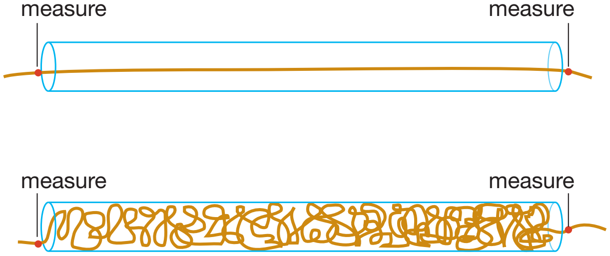
The lungs have a large surface area, but what does that mean?

Collect this …

- 20 cm length of plastic tubing (such as garden hose) at least 1 cm in diameter
- ball of string
- measuring tape

Do this …

1. Thread the string through the plastic tubing without twisting or folding it.
2. Measure the length of the string.
3. Twist and fold the string to find out how much string can be fitted inside the tubing.
4. When you cannot get any more string in, mark the end or cut off the string.
5. Unravel the string from the tubing and measure the length of the string you were able to fit inside.



Record this …

Describe the difference between the two lengths of string.

Explain which of the pieces of string has the largest surface area and how this relates to the working of the lungs.

Gas exchange

The walls of the alveoli are only one cell thick and they are surrounded by tiny blood vessels called capillaries. Oxygen dissolves in the moist surface of the alveoli and moves by a process called diffusion across the short distance from the space inside an alveolus to the blood. Figure 3.2.5 illustrates this process.

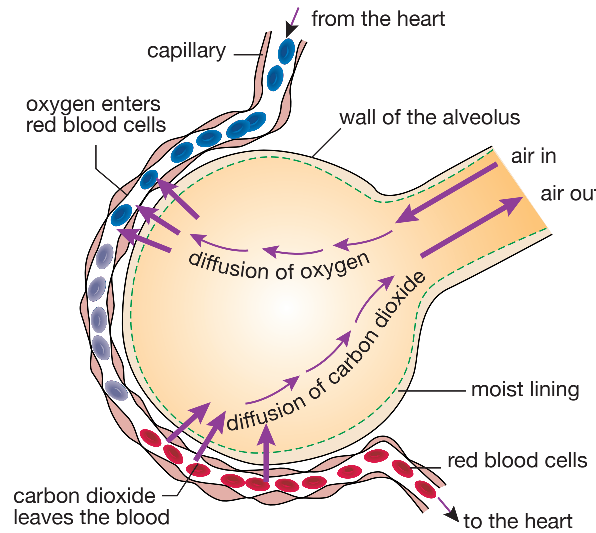


Figure 3.2.5 The walls of the alveoli are only one cell thick. So are the walls of the blood capillaries. Gases are exchanged where the surface of the alveolus and the blood capillary are in contact.

Once in the blood, the oxygen enters the red blood cells, and the flow of blood carries the oxygen to the cells where it is needed. The blood flowing from the lungs is therefore rich in oxygen and is bright red.

The cells use the oxygen to release energy from food. As they do this, carbon dioxide is produced. Carbon dioxide is a waste product that would harm your body if you did not get rid of it. Carbon dioxide moves from your cells into the blood and from your blood into the alveolus, where it mixes with the remaining air. It then leaves the body with the next outward breath.

Table 3.2.1 compares the air you breathe in (inhale) with the air you breathe out (exhale). The role of the respiratory system is summarised in Figure 3.2.6.

Table 3.2.1 Comparison of the composition of air when it is breathed in and breathed out

Gas	Percentage (%)	
	Inhaled air	Exhaled air
Nitrogen	78	78
Oxygen	21	17
Other gases	1	1
Carbon dioxide	0.04	4
Water vapour	little	carries all it can hold

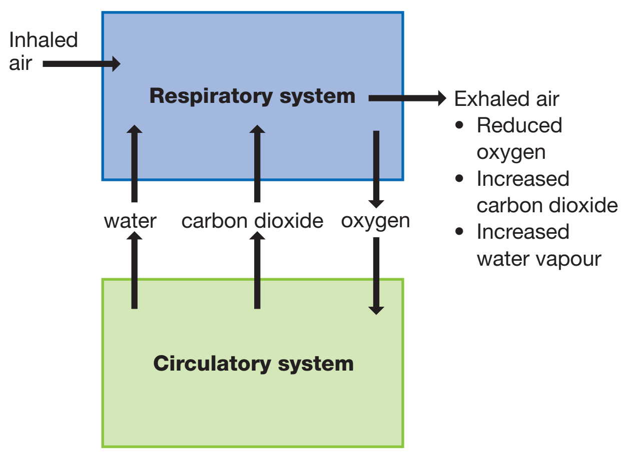


Figure 3.2.6 Summary of what happens in the respiratory system

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Breathing

The air in the alveoli is constantly replaced when you breathe. Breathing is involuntary. Although you can force yourself to stop breathing for a while, breathing is something you do without thinking, all day, every day.

As you breathe in, the muscles between your ribs contract. This pulls the rib cage up and out. At the same time the **diaphragm**—a sheet of muscle that separates the chest from the abdomen—contracts and flattens. This situation is shown in Figure 3.2.7.

These changes increase the volume of the space inside your chest. Your lungs expand, which causes the air pressure in them to decrease. Air is sucked in through the nose (and mouth) to fill up the extra space. This makes the air pressure inside your lungs equal to the air pressure outside the body.

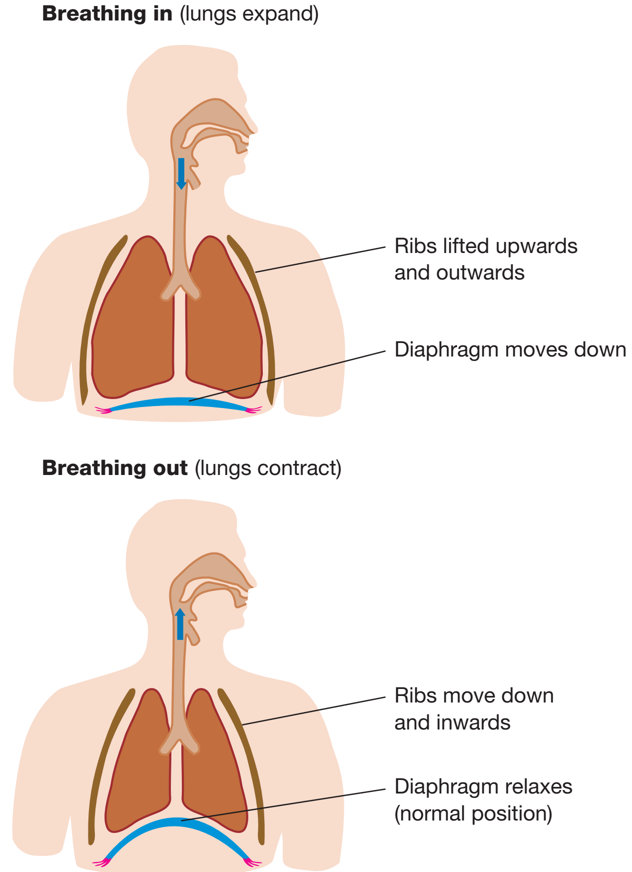


Figure 3.2.7 Your diaphragm flattens and your lungs expand when you breathe in. The opposite happens when you breathe out.

When you exhale, the opposite happens. All the muscles relax. The ribs therefore move down and in, and the diaphragm arches upwards. The volume inside the chest returns to its normal size and the air pressure increases. Air is therefore forced out of the lungs through the nose (and mouth).

In the cells

Respiration begins once the oxygen and glucose are together in the cells. The two chemicals react together. Carbon dioxide and water are produced in the reaction, and energy is released. It is this energy your body uses for all its activities (Figure 3.2.8).

The chemical reaction for respiration can be represented by a word equation.

oxygen + glucose → carbon dioxide + water + energy

The more energy your body requires, the faster this reaction has to take place, and therefore more oxygen and glucose are required.

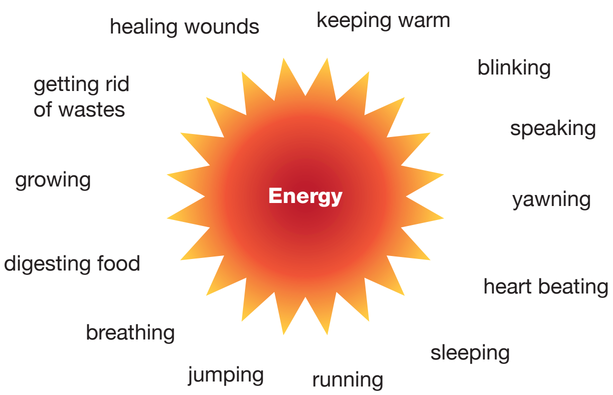


Figure 3.2.8 Just a few of the ways you use energy

SKILL BUILDER

Chemical equations

A chemical equation is one way of recording what happens when substances react together. On one side are the substances that react together. These are known as the reactants.

On the other side are the substances that are produced. These are known as the products.

Between the reactants and products is an arrow indicating the direction of the change. The substances to which the arrow is pointing are the products. For example in the equation:

$$A + B \rightarrow C + D$$

the arrow is pointing to the C and D. Therefore they are the products.

Because the names of the chemicals are used in the following chemical equation it is known as a word equation.

The reaction of respiration is represented by the word equation:

oxygen + glucose → carbon dioxide + water + energy

Oxygen and glucose are the reactants. Carbon dioxide and water are the products, along with the energy, that are released.

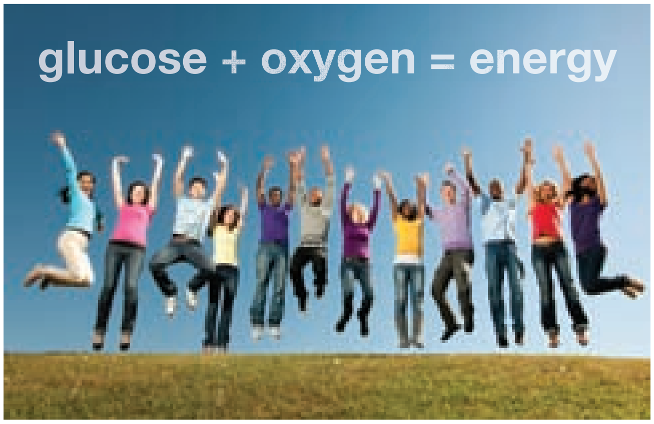


Figure 3.2.9 Glucose and oxygen are both required to provide the energy your body needs.

Energy and oxygen

The amount of energy you consume in your food needs to balance the amount of energy you use (Figure 3.2.9). When you consume more energy than your body requires, the excess nutrients are converted to fat and stored in a layer under your skin and around your internal organs. Your mass increases, and over a long period of consuming too much you could become overweight or obese. Becoming overweight may cause health problems because your joints have to support too much mass, your heart has to work a lot harder, and your blood vessels may become blocked by a build-up of a fatty substance called cholesterol.

If you take in less energy in your food than your body requires, you use up any fat stores (stores of energy) and lose mass. This is not a problem if you have extra mass to lose, but if you do not have stores of fat, then your body starts to get energy by using muscle tissue, including heart muscle. The muscles of your arms and legs become weak and your heart is weakened.

To get more oxygen into your cells you have to breathe more quickly or more deeply. You then have to move the oxygen more quickly around the body. To achieve this, you need to build up your heart muscles and the muscles associated with breathing. Just as your arms and leg muscles get stronger with exercise, the muscles of your heart get stronger when it is made to work harder. Strong heart muscles mean that the heart is able to pump more blood out of the heart with each beat.

SciFile

Couch potato!

You sometimes use more energy sleeping than you do watching TV! While sleeping, you use about 250 kilojoules per hour. While watching TV, you can use as little as 200 kilojoules per hour.

2 p97
3.6

3.2 Unit review

Remembering

1 **State** the word equation for respiration.

2 **List** in order the parts of the respiratory system that air would pass through as it was breathed out.

3 **Name** the part of the respiratory system where gas exchange takes place.

4 **Name** the gas that is taken into the body and used by the cells.

Understanding

5 **Explain** the advantage of having lungs with many small alveoli compared to having lungs like balloons that have no alveoli.

6 Air rich in oxygen that is breathed in enters the alveoli. Air rich in carbon dioxide is breathed out of the body. **Describe** the events that occur at the surface of the alveoli between these two events.

7 **Describe** the function of the diaphragm in the breathing process.

8 **Explain** why humans die within a few minutes if they cannot breathe, but can live for a few days without water and for a longer time without food.

9 a **Describe** what happens to your breathing rate as you walk along, and then start to run, run faster, and then stop running.

b **Explain** why this would happen.

Applying

10 a Adult lungs are capable of holding about 6 litres of air. However, only about 500 mL is breathed in and out in a normal breath. **Calculate** the percentage of the lungs that is used for normal breathing.

b **Use** the table below to **calculate** the volume of oxygen that enters the blood from each inhalation.

Gas	Percentage (%)	
	Inhaled air	Exhaled air
Nitrogen	78	78
Oxygen	21	17
Other gases	1	1
Carbon dioxide	0.04	4
Water vapour	little	carries all it can hold

11 **Identify** each of the parts labelled A–E in Figure 3.2.10.

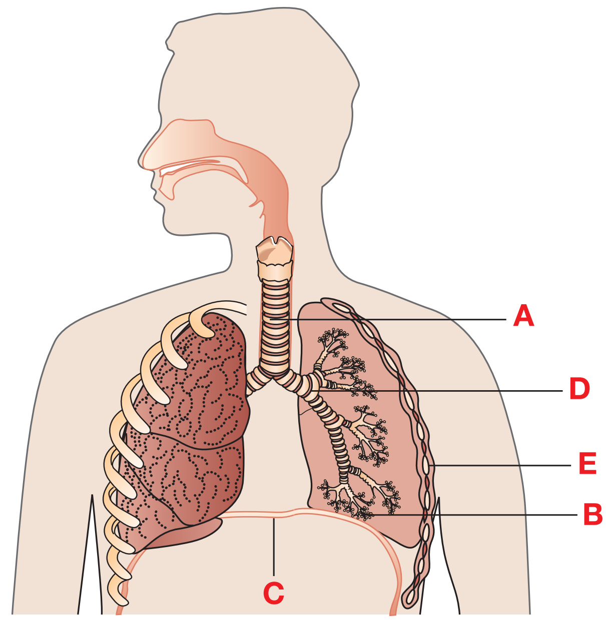


Figure 3.2.10

Analysing

12 **Contrast** breathing and respiration.

13 Figure 3.2.11 represents the lungs of a frog.

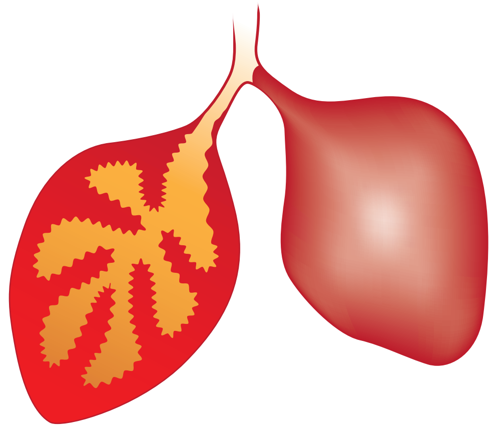


Figure 3.2.11

a **Compare** the structure of the frog's lung with the structure of the human lung.

b **Compare** the effectiveness of each in terms of gas exchange.

Evaluating

14 **a** Limewater is a clear liquid that turns milky when carbon dioxide is added to it. **Deduce** what would happen to limewater if:

- **i** air that you breathe in was bubbled through it
- **ii** you blew air into it through a straw.

b **Justify** your answers to part a.

15 **Propose** the advantage to the functioning of your body of having many blood capillaries surrounding the alveoli.

16 Some lung infections cause a build-up of fluid in the lungs and the infected person is short of breath. **Propose** a reason for this symptom.

17 **Propose** which part of the respiratory system is affected by bronchitis.

Creating

18 **Design** an experiment to test the effect of exercise on breathing rate.

19 Figure 3.2.12 shows a model that is often used to show how the lungs work.

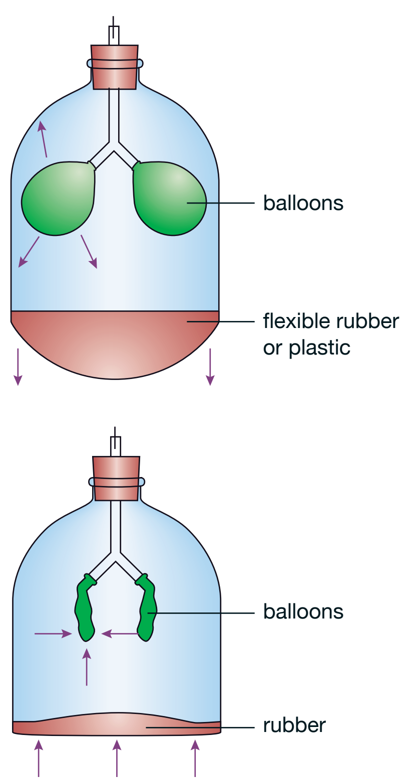


Figure 3.2.12

a **Use** Figure 3.2.12 as a guide and materials found around the home to **construct** a working model of the respiratory system.

b For each part of the model **state** the part of the respiratory system it represents.

c **Compare** the working model and the respiratory system.

Inquiring

1 Research to find out what hiccups are and what causes them.

2 Research to find out what would happen to you if you did not get rid of the carbon dioxide your body produces.

3 **a** Research to find out what happens in the lungs when a person has an asthma attack.

b Find out what asthma inhalers such as Ventolin® do.

Figure 3.2.13 Inhalers like this one can be used to control asthma.

3.2 Practical activities

1 Changing air

Purpose
To compare inhaled and exhaled air.

Materials
- bromothymol blue
- disposable straw
- flasks or large test-tubes and glassware as shown in Figure 3.2.14
- rubber tubing
- digital camera or mobile phone with video function (optional)

SAFETY

Ask your teacher or lab technician to check your set-up before you start.

Do not swallow any of the liquid.

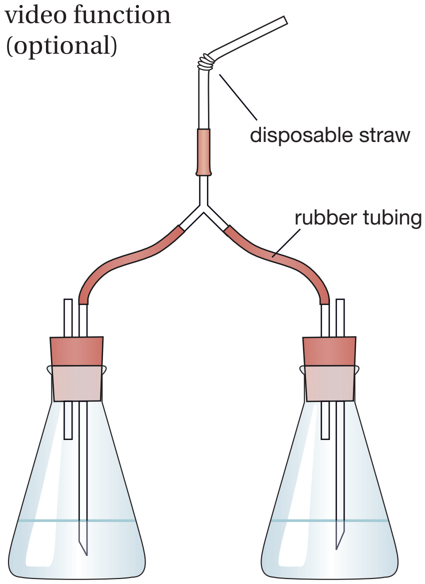


Figure 3.2.14

Procedure
1. Set up the equipment exactly as shown in Figure 3.2.14. Only one tube in each flask should extend below the level of the liquid. All the joins should be airtight.
2. Add a few drops of bromothymol blue to the water in each flask.
3. Ask your teacher to check your set-up before proceeding.
4. Place your lips over the disposable straw and breathe in and out continuously for a few minutes. You could use your mobile phone or digital camera to video what happens.

Results
1. Construct a diagram of the apparatus. Add arrows that show the passage of air as you breathed in and out.
2. On this diagram, record any changes to the colour of the liquid in the flasks.

Discussion
1. **Identify** the flask in which any colour change occurred. Was it the flask through which air was inhaled or exhaled?
2. Bromothymol blue is an indicator that changes from blue to yellow-green in the presence of carbon dioxide. **Explain** the cause of any colour change in the flasks.
3. **Explain** how the results of this activity relate to the changes that take place in the respiratory system.

2 Energy production

Heat is a form of energy and is produced as a by-product of respiration.

Purpose

To record evidence that energy is released in respiration.

Materials

- 2 wide-mouthed thermos flasks
- 2 thermometers
- cotton wool
- 40 germinating pea or bean seeds
- boiling water
- mild disinfectant
- 2 × 250 mL beakers

SAFETY

Take care with boiling water.

Pour it carefully so that it doesn't splash.

Procedure

1. Label the two flasks 'Live seeds' and 'Killed seeds'.
2. Divide the germinating seeds into two equal groups.
3. Place one group of seeds in a beaker and add boiling water. Leave it for 1–2 minutes to kill the seeds.
4. Allow the beaker and killed seeds to cool, pour off the cooled water and add cold tap water to return their temperature to room temperature.
5. Soak the killed seeds in disinfectant, and then place them into the flask labelled 'Killed seeds'.
6. Place the other group of seeds into the flask labelled 'Live seeds'.
7. Set the two flasks up as shown in Figure 3.2.15.
8. Record the temperature in both the flasks at the start of the experiment and then another three or four times in the next 24 hours.

Results

Record the temperatures in a table like the one below.

Time (h)	Temperature (°C)	
	Live seeds	Killed seeds

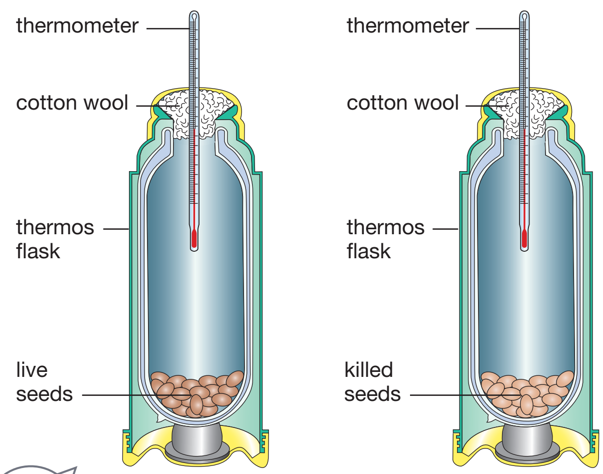
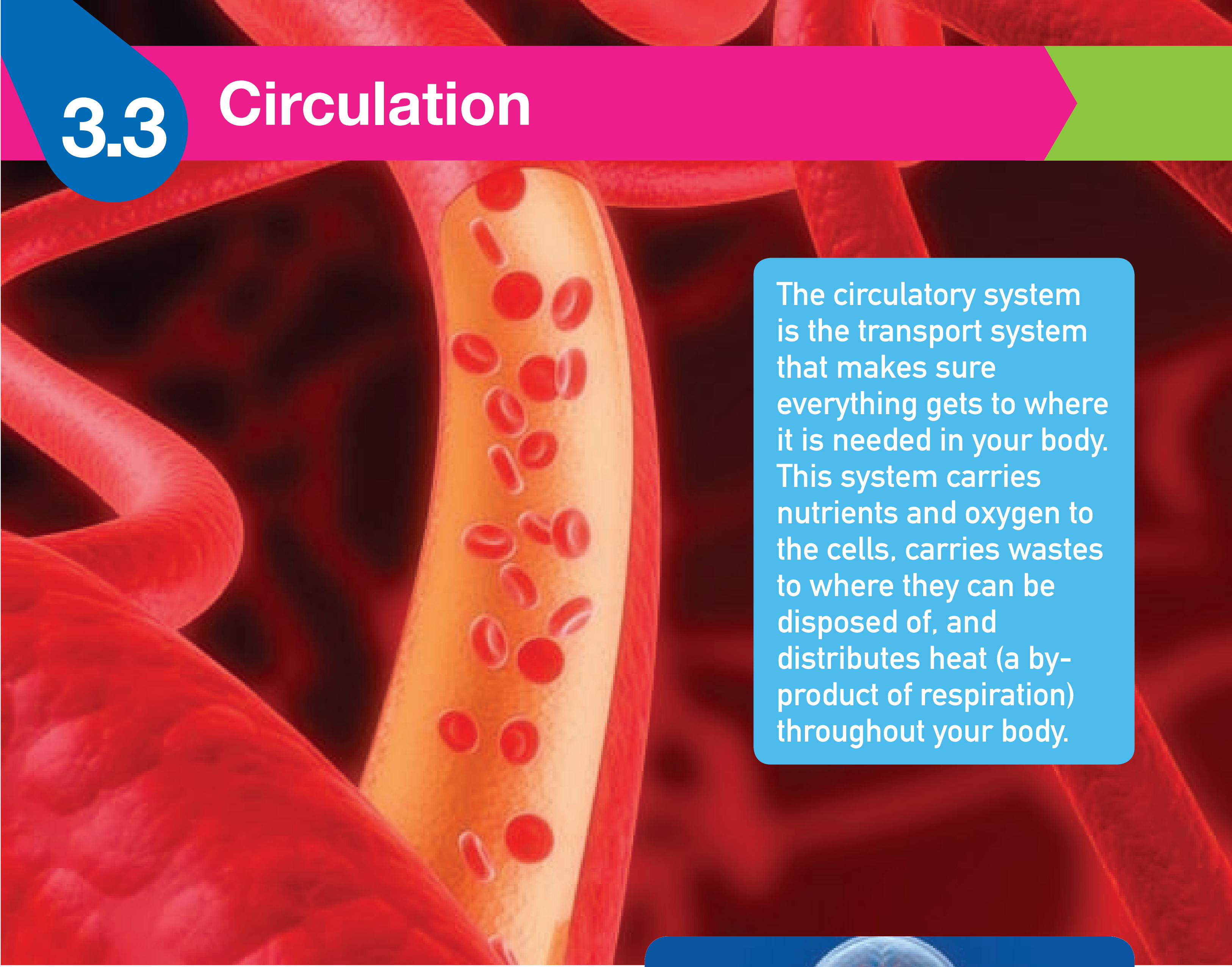


Figure 3.2.15

Discussion

1. **Explain** why a change in temperature in the flasks can be used as evidence of energy release.
2. **Compare** any change in temperature in the two flasks.
3. **Explain** any differences in the changes in temperature.
4. **Explain** why the flask with the killed seeds was included in the experiment.
5. **Explain** why the killed seeds were soaked in disinfectant and what could have occurred if this was not done.
6. **Explain** how the results of this experiment relate to respiration in human cells and the uses made of energy.

3.3 Circulation



The circulatory system is the transport system that makes sure everything gets to where it is needed in your body. This system carries nutrients and oxygen to the cells, carries wastes to where they can be disposed of, and distributes heat (a by-product of respiration) throughout your body.

The circulatory system

Your **circulatory system** consists of your heart, blood vessels and blood. The heart is the engine room of the circulatory system. It pumps continuously to keep the blood moving. The blood carries all the materials needed by the body through the blood vessels. The blood vessels are the motorways, main roads and side streets along which the blood flows and are shown in Figure 3.3.1.

Figure 3.3.1 The blood vessels of your body are like motorways. Instead of cars and trucks transporting goods, it is blood and blood cells that carry materials to their destination.

Blood vessels

In your body there are three types of blood vessels: arteries, veins and capillaries.

Arteries

Arteries carry blood away from the heart. When the heart beats, blood moves along the arteries under pressure. To be able to withstand the pressure, the walls of the arteries (shown in Figure 3.3.2) need to be tough and elastic, bouncing back into shape after each beat. If an artery is cut, then the high pressure within it causes blood to spurt out very quickly. Within a very short time, most of the blood would be lost from the body. All major arteries are protected deep in the body. In a few places, the regular expansion and contraction of the arteries in response to the heartbeat can be felt. This is your pulse. You can feel it most easily in your neck and wrist.

Figure 3.3.2 The walls of arteries have thick layers of muscle and elastic tissue. The thick-walled artery is a sharp contrast to the vein beside it.

Where does it fit?

There are about 97 000 km of blood vessels in the body of a child and 161 000 km in the body of an adult. End to end they would go round the Earth about four times!

SciFile

Capillaries

As they extend through the body, arteries branch into smaller and smaller blood vessels. Eventually the very finest of the blood vessels, called capillaries, reach nearly every cell of the body. **Capillary** walls are only one cell thick. This allows dissolved materials to pass through them. Materials needed by the cell pass out of the capillary and into the cell, and waste materials from the cell pass into the capillary. The blood then carries the wastes back towards the heart. The capillaries join together to form larger and larger blood vessels called veins. This is shown in Figure 3.3.3.

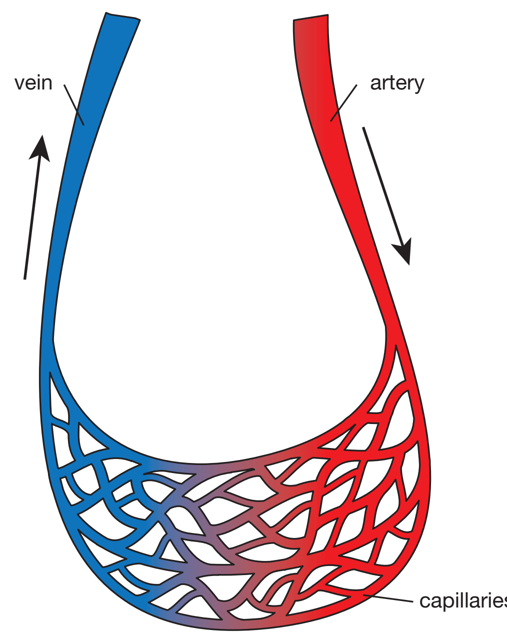


Figure 3.3.3 The capillaries are a network that joins the arteries and veins, allowing blood to flow continuously.

Veins

Veins carry blood back to the heart. The pressure of the heartbeat is lost as the blood flows through the very narrow capillaries, so the veins do not need thick muscular walls like the arteries do.

Blood is pushed back up to the heart by the contraction of the muscles of your body pressing against the veins. To make sure that the blood flows in one direction only, there are valves along the length of veins. The valves open when the blood is flowing upwards and close if the blood flows downwards. This is shown in Figure 3.3.4 on page 100. If you sit still for very long periods of time, then the flow of blood in the veins slows and blood can 'pool' in the veins. The blood may thicken and form a dangerous blood clot called a thrombosis.

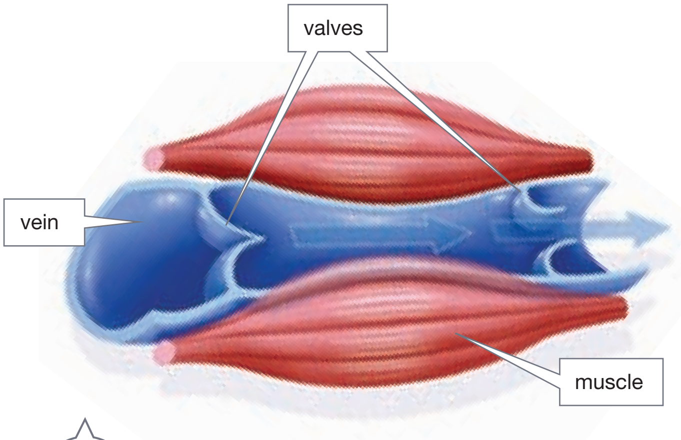


Figure 3.3.4 Blood flowing along the vein towards the heart forces the valves against the vein wall and the blood can flow freely. The valves close preventing blood flow in the opposite direction.

Bruises

When you bump yourself hard, some of the tiny capillaries near the skin burst and the blood leaks out into the surrounding tissue. Immediately after the injury, an angry red mark appears where blood has leaked into the tissue. Gradually the bruise fades to purple and then yellow as the blood is broken down and cleared away by the body.

The heart

Your heart is about the size of your fist and is situated in the middle of your chest behind the breastbone. This is shown in Figure 3.3.5. The heart is made of a special type of muscle called **cardiac muscle**. Cardiac muscle does not get tired like the muscles of your legs and arms do. Cardiac muscle works continuously in response to signals from an area of the heart called the pacemaker. A dissected view of the heart is shown in Figure 3.3.6.

The human circulatory system is referred to as a double system because there are two separate circuits through which the blood flows. As can be seen in Figure 3.3.7, both circuits start with the heart. In one circuit, the blood flows from the heart to the body and back to the heart. This circuit carries nutrients and oxygen to the cells. At the cells, it collects wastes, including carbon dioxide. The other circuit goes from the heart to the lungs. In the lungs, carbon dioxide passes out of the blood and oxygen passes into the blood. The blood rich in oxygen then returns to the heart to be pumped around the body.

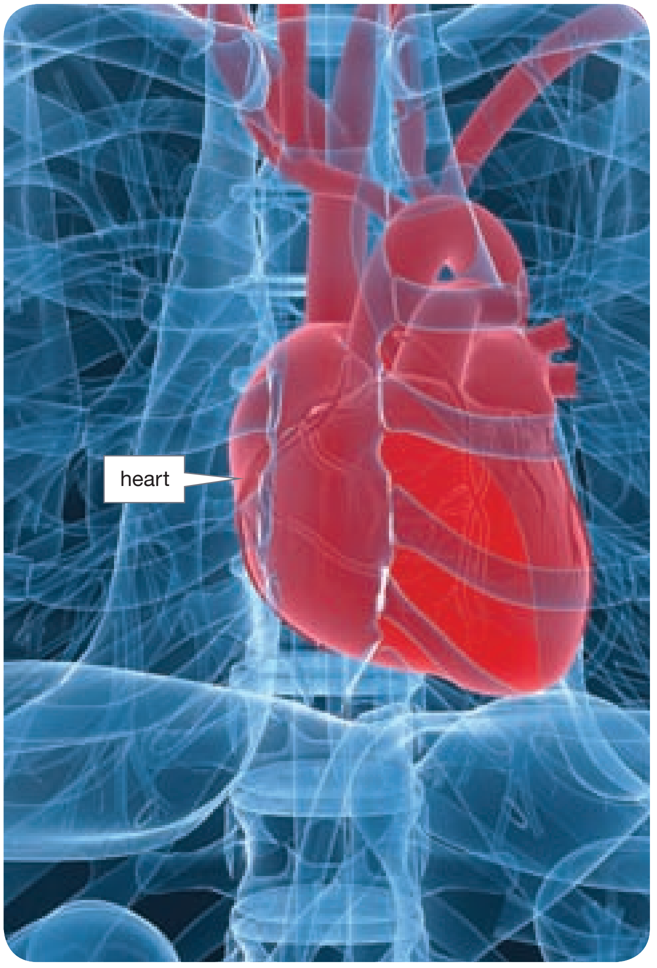


Figure 3.3.5 Your heart lies within your chest protected by your breastbone, ribs and vertebral column (spine).

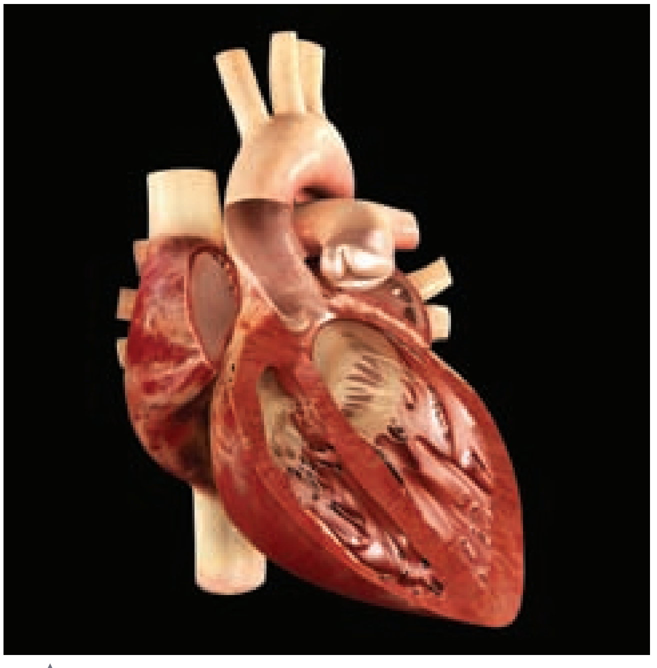
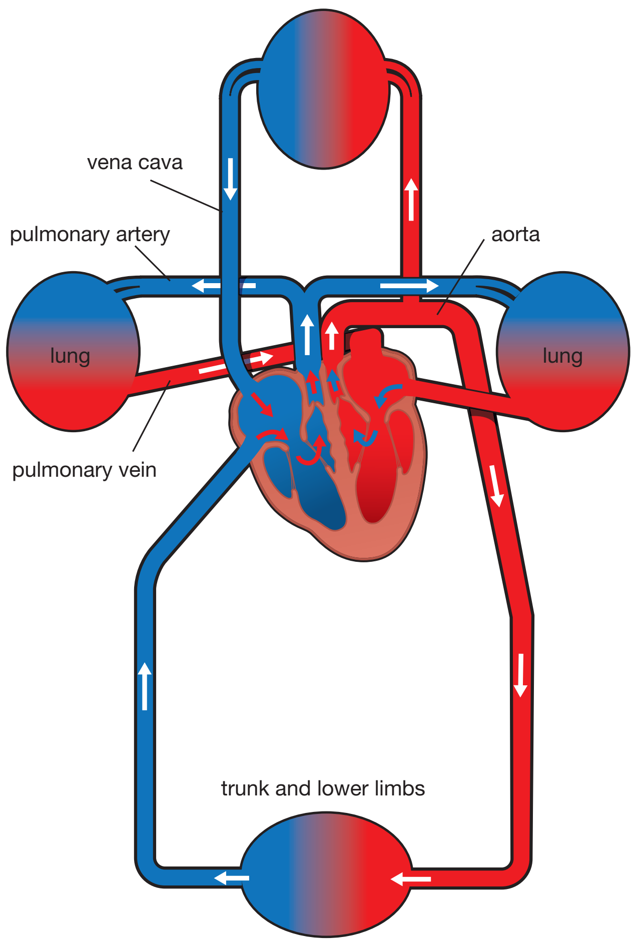


Figure 3.3.6 A model of a human heart



For the circulatory system to work, the blood rich in oxygen (**oxygenated blood**) and the blood with carbon dioxide (**deoxygenated blood**) must be kept separate where the two systems meet in the heart. The heart has four chambers. Two of the chambers collect blood from the lungs and pump it round the body. The other two chambers collect blood from the body and pump it to the lungs. Figure 3.3.8 shows these four chambers.

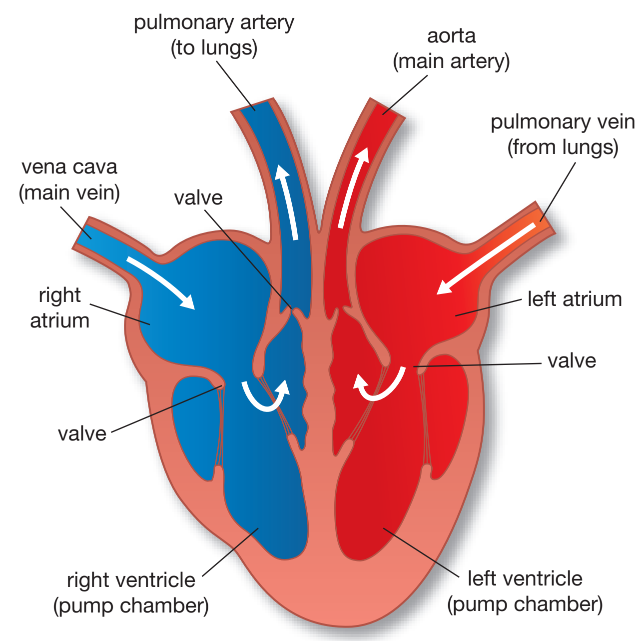


Figure 3.3.7 Your blood follows two separate pathways in your body. One pathway is from the heart to the body and back to the heart. The other pathway is from the heart to the lungs and back to the heart again.

Figure 3.3.8 One side of the heart collects and pumps out deoxygenated blood (shown here in blue). The other side of the heart is completely separate. It collects and pumps out oxygenated blood (red).

3.7

INQUIRY science 4 fun

No blood

Can you make the blood stop flowing in your veins?

Yes

Do this ...

1 Hold your hand out and turn it over so that the inside of the wrist is facing you.

2 You should be able to see veins as blue lines coming from the base of your palm and your thumb into your arm.

3 Place the index finger of your other hand on the vein coming from the middle of your palm. Firmly but gently move your finger along the vein back towards the hand. The blood should empty from the vein.

Record this ...

Describe what happened.
Explain why you think this happened.

Heartbeat

There are three main phases of a heartbeat.

- The two atria (plural of atrium) contract, pushing blood down into the ventricles.
- The ventricles contract, forcing blood out of the heart to the body and lungs.
- The heart muscle relaxes and the atria fill with blood.

When the atria or ventricles are contracting, valves open or close to make sure that the blood flows in the correct direction. An electronic recording of a heartbeat is shown in Figure 3.3.9.

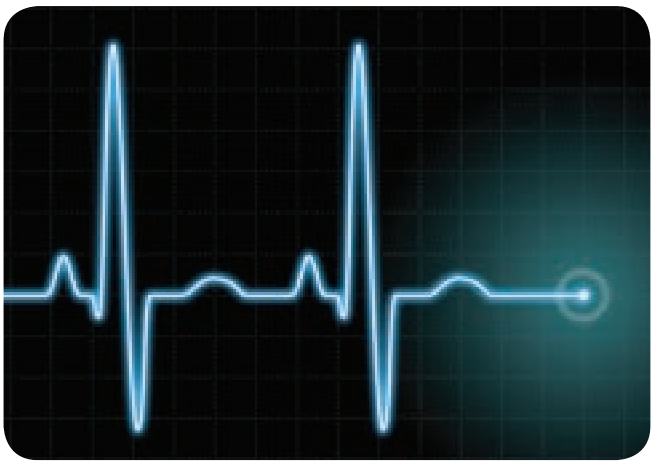


Figure 3.3.9 An electronic recording of a heartbeat. Contraction of the atria creates a small peak followed by a large peak as the strong muscles of the ventricles contract. Between the contractions, the heart is resting.

3.8 1 p106 2 p108

Heart disease

Cholesterol is a type of fat that is part of all animal cells. It is essential for health, but can block arteries if it builds up in them. If you have too much fatty food in your diet, cholesterol will eventually start to build up. This can be seen in Figure 3.3.10. Coronary arteries supply the muscles of the heart with blood. When cholesterol builds up in coronary arteries, blood flow to the heart muscles is reduced. Since blood carries oxygen, reduced blood flow also means that oxygen supply is reduced.

A lack of oxygen to the heart muscle causes a condition known as **angina**. A person suffering an angina attack experiences severe chest pain.

If the arteries become completely blocked, then the part of the heart they normally supply with oxygen dies and the person has a heart attack. If a large area of the heart is affected, then the heart attack is severe.

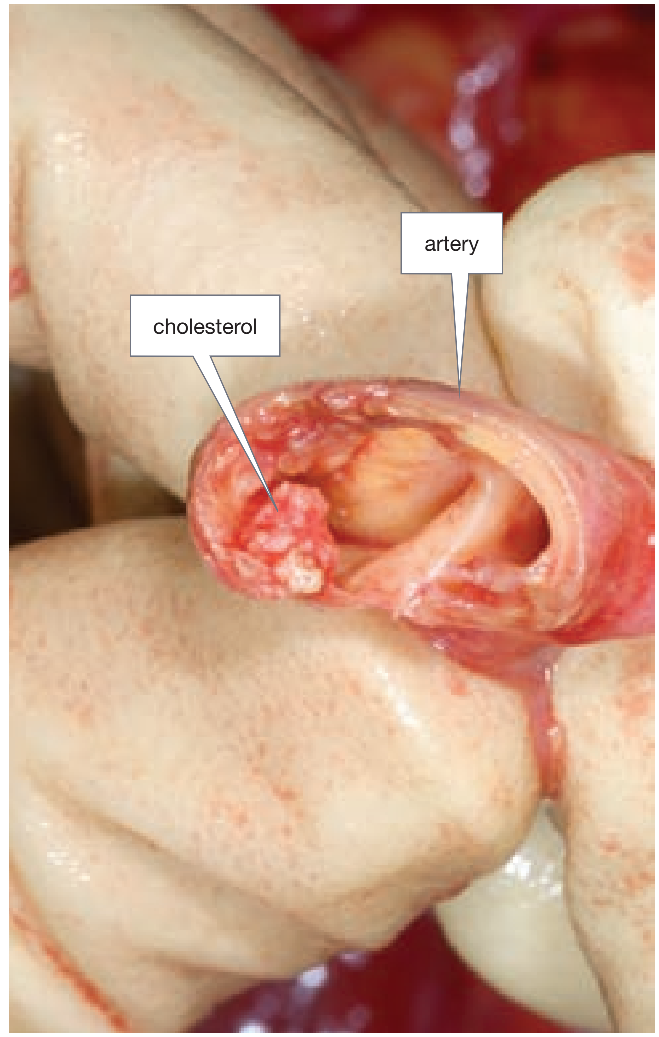


Figure 3.3.10 A surgeon's gloved hands hold an artery partly blocked by cholesterol.

Blood

Blood is the only organ of the body that exists as a liquid. The average-sized adult has about 5 litres of blood. Blood carries oxygen, nutrients and water to the cells and carries carbon dioxide and other wastes away from the cells. Blood also helps maintain your body temperature by spreading the heat around. In blood, there are red blood cells, white blood cells, platelets and plasma.

SciFile

That's hot!

It would be possible to boil 30 litres of water with the heat generated by the average human adult in one day!

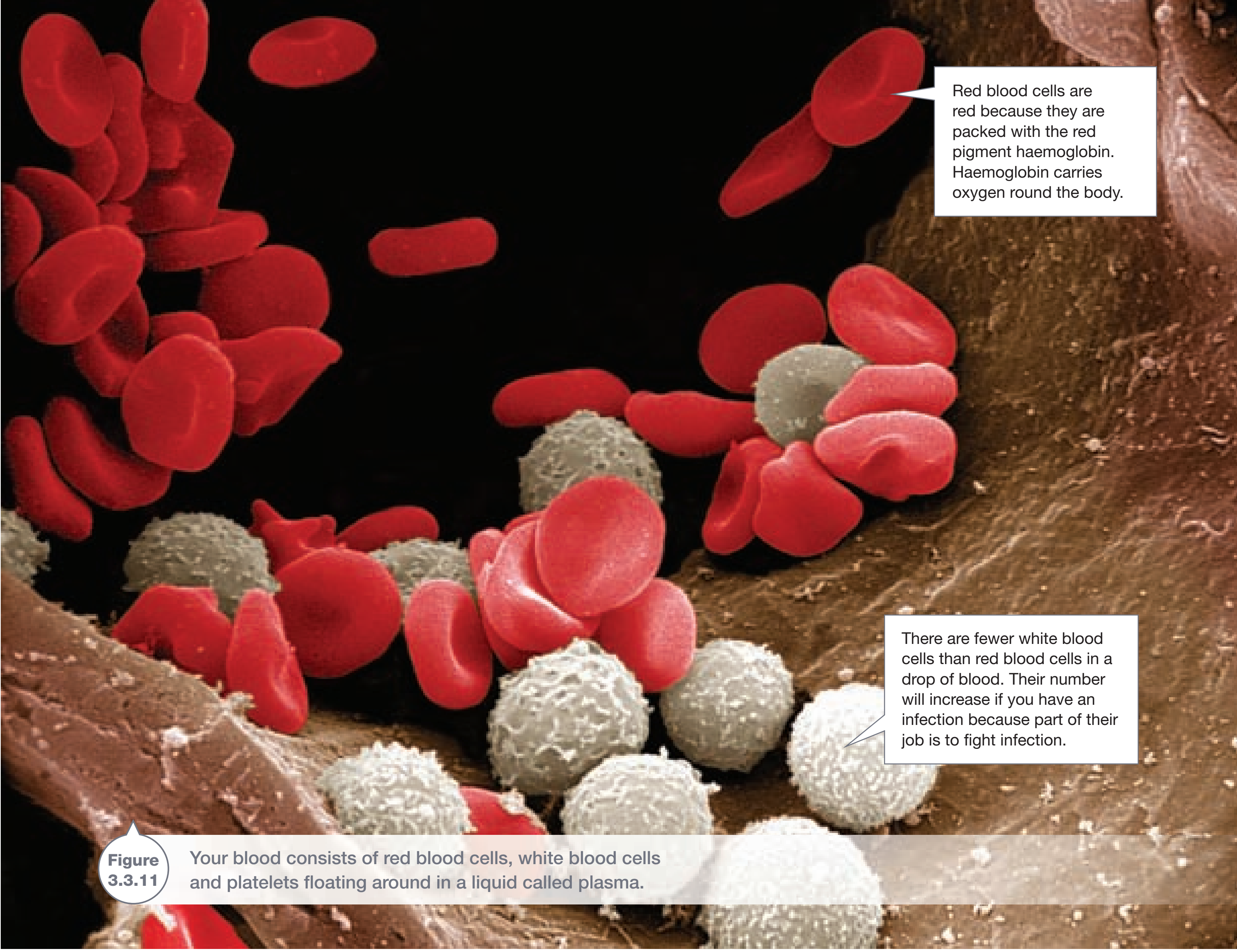


Figure 3.3.11 Your blood consists of red blood cells, white blood cells and platelets floating around in a liquid called plasma.

Red blood cells

Red blood cells are made in the bone marrow of long bones such as the femur (the thigh bone) and ribs. They contain the chemical **haemoglobin**. Haemoglobin is a pigment that gives the cells their red colour. Haemoglobin contains iron, and its job is to carry oxygen around the body. When it is carrying oxygen, haemoglobin is a bright red. Oxygen is carried to cells as oxyhaemoglobin. There are about 300 million red blood cells in one drop of blood. Some red blood cells can be seen in Figure 3.3.11.

White blood cells

White blood cells are bigger than red cells. There are only about 400 000 in a drop of blood. White blood cells are part of the immune system that helps fight disease.

Platelets

Platelets are broken up bits of cells produced in the bone marrow. They help blood to clot. If you do not have enough platelets, then you could bleed excessively. However, too many platelets can cause blood to clot in the blood vessels. A blood clot in the blood vessels of the heart can cause angina and a heart attack. A blood clot in the brain can cause a stroke, where a part of the brain is starved of oxygen and dies.

Plasma

Plasma is a clear yellowish liquid that is 90% water. The other 10% is dissolved materials such as nutrients and wastes. Red blood cells, white blood cells and platelets are suspended in plasma.

SCIENCE AS A HUMAN ENDEAVOUR

Use and influence of science

Transplants

This kidney has been cooled and the blood has been flushed from it to prepare it for transplant. Figure 3.3.12

An organ transplant is when a diseased organ in one person is replaced with a healthy one from someone else. There are stories that are over 200 years old of early doctors performing transplants. We do not know if they were successful. However, it is likely that the immune system caused problems.

A person's immune system fights disease by attacking and destroying bacteria and viruses. It responds to transplanted organs in the same way—by destroying transplanted organs in a process called rejection. Anti-rejection drugs developed in the 1980s made transplanting organs less risky and transplantation surgery is now relatively common. The person who provides the organ is called the donor. The person who receives the organ is called the recipient.

Living donors

Tissues and organs that can regrow can be donated by living donors. Blood and bone marrow are easily replaced by the body if only small amounts are taken. We have two kidneys. One can be given as a live donation. The one that remains will grow larger and take over the function of the one that was donated.

Deceased donors

Most organs for transplant are taken from people who have died, but only if the person has registered as an organ donor or their family agrees. Death is usually declared when the heart stops beating and cannot be restarted. With no blood (and therefore no oxygen), the organs start to break down. Within 40 minutes many are unsuitable for transplantation. However, if hearts can be recovered from the body and stored correctly, they can be kept for 4 hours before transplantation. Kidneys can be stored for about 24 hours. This gives the transplant teams a little time to find and prepare a suitable recipient who is waiting for a new organ.

The removal procedure

When organs are removed, all the blood has to be flushed out to prevent blood clots forming in the tiny capillaries. Clots would prevent the recipient's blood reaching those parts of the organ and it would die. The organ is cooled to about 4°C and all the veins and arteries are filled with preservatives. This is why the kidney in Figure 3.3.12 looks so pale.

Implanting an organ

Transplanted hearts and lungs are placed in the correct position in the body. However, transplanted kidneys are often placed inside the pelvis where they are attached to blood vessels and the urinary tract. The recipient's kidneys are not usually removed unless they are so diseased that they could become a health risk.

Once the transplant is completed, the recipient will take a large variety of medicines to prevent rejection of the new organ by their body.

3.3 Unit review

Remembering

1 **Name** the three different types of blood vessels found in the human body.

2 **Name** the four chambers of the heart.

3 **State** what the difference is between oxygenated and deoxygenated blood.

4 **Name** the part of the blood that helps with clotting.

5 **List** three things carried by the blood.

Understanding

6 **Describe** the characteristics of capillaries that suit them to their function.

7 **Outline** the flow of blood around the body, starting and finishing with the right atrium.

8 **Explain** the importance of keeping the oxygenated and deoxygenated blood separate in the heart.

9 **Describe** the double circulation system of the human body.

Applying

10 **Identify** the labelled parts of the heart in Figure 3.3.13.

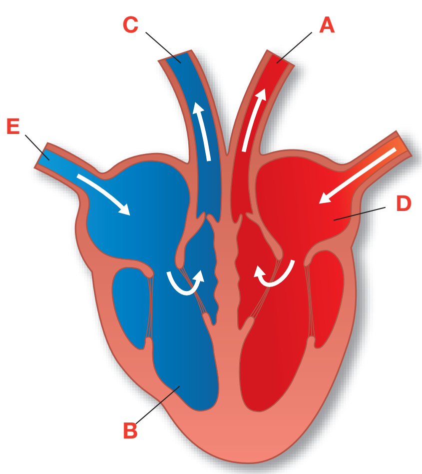


Figure 3.3.13

Analysing

11 **Compare** by listing their similarities and differences:

a an atrium with a ventricle

b a heart attack with a stroke.

12 **Contrast** the right and left ventricles.

13 a Refer to page 107 and then **calculate** the pulse rate for the students listed in the table below.

Student	Beats counted	Time (s)
Jo	15	10
Karl	22	15
Jack	12	5

b **Analyse** the data and **identify** which student was most likely to be the one who had just finished playing soccer.

c **Identify** which results would provide the most accurate measure of pulse rate.

d **Justify** your response.

Evaluating

14 Figure 3.3.14 is a graph of a person's pulse rate. **Deduce** from the graph the person's physical activity levels at times A, B and C.

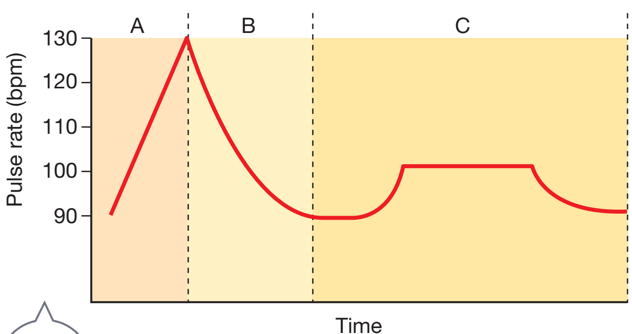


Figure 3.3.14

Inquiring

1 Research to find out about heart transplants in Australia and the famous heart surgeon Victor Chang.

2 Research to find out what deep vein thromboses are and why people taking long plane flights are given advice on how to avoid them.

3 Some children are born with a hole in their heart. Research to find out what this is and why it is a problem.

3.3 Practical activities

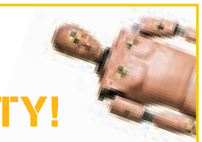
1 Heart dissection

Purpose

To investigate the structure of the heart.

Materials

- scalpel
- tweezers
- blunt probe
- disposable gloves
- dissection board
- sheep or bullock heart



SAFETY!

Take care with sharp instruments.

Wear disposable gloves when handling the heart.

Wash your hands thoroughly after you have completed the dissection.

Procedure

1. Place the heart on the dissecting board as shown in Figure 3.3.15.
2. Identify as many of the external features as you can: right and left atria, right and left ventricles, aorta, vena cava, pulmonary arteries and veins.
3. Use the blunt probe to investigate which chamber of the heart the blood vessels enter or leave. Use the scalpel to make cut 1 as shown in Figure 3.3.15. Cut with the blade pointing upwards and away from you.
4. Observe the thickness of the wall of the right ventricle.
5. Open out the ventricle.
6. Observe the tendons (thread-like structures) and the valves (flaps of tissue) to which they are attached.
7. Work out how the valves work to control blood flow.
8. Observe the flaps of skin at the base of the pulmonary artery. These are the semilunar valves.
9. Make cut 2 to open up the left ventricle. Continue the cut up into the aorta.
10. Observe the thickness of the wall of the left ventricle.
11. Find the position of the semilunar valves at the end of the aorta.
12. Just above the semilunar valves you should be able to find two small openings from the aorta. These are the branches of the coronary arteries. Use the probe to find out where they go.

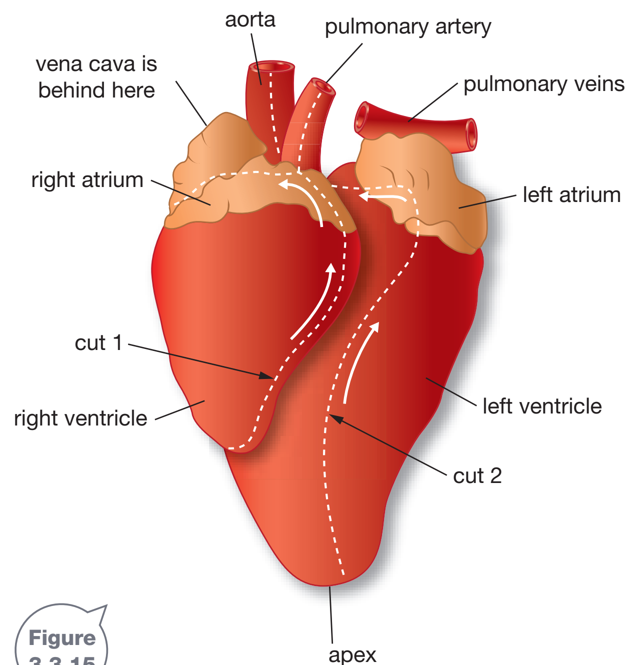


Figure 3.3.15

Discussion

1. **Compare** the thickness and texture of the aorta and vena cava.
2. **Use** diagrams to **explain** how the valves between the atria and ventricles control the direction of blood flow.
3. a **Use** diagrams to **explain** how semilunar valves work.
   b **Propose** a reason why these values are known as *semilunar*.
4. a **Compare** the thickness of the walls of the right and left ventricles.
   b **Propose** a reason for the difference.
5. a **Describe** where the coronary arteries go.
   b **Propose** a reason why this organ is supplied with fully oxygenated blood.
6. **Construct** a diagram of the heart and use arrows to show the path of blood flow through the heart.

SKILL BUILDER

Measuring your pulse

Your pulse is a measure of your heart rate—the number of times your heart beats per minute. Two of the easiest places to feel your pulse are at the wrist and neck, as shown in Figure 3.3.16. The pulse on your wrist is known as the radial pulse. The pulse in your neck is the carotid pulse.

Figure 3.3.16 Your pulse can be felt on your wrist or neck.

To take your pulse you need a stopwatch, a digital watch or a watch with a second hand.

To measure the radial pulse:

1. Turn your hand so that the palm is facing upwards.
2. Place your index and middle fingers of your opposite hand on your wrist, approximately 2.5 cm below the base of your thumb.
3. Gently but firmly press your fingers in the area between the tendons of the wrist and the outside bone. You should feel a throbbing which is your pulse.
4. Count the number of beats for 15 seconds, then multiply this number by 4. This will give you your heart rate for one minute.

For example, if you count 18 beats in the span of 15 seconds, then multiply $18 \times 4 = 72$. This means your pulse rate is 72 and your heart rate is 72 beats per minute.

To measure the carotid pulse:

1. Place your fingertips gently on one side of your neck, below your jawbone and halfway between the large neck muscle behind your ear and your windpipe.
2. Count the number of beats and calculate the pulse rate in the same way.

When taking a resting pulse rate—your pulse rate when you have been sitting still for some time—the longer you count the pulse the more accurate the measurement will be. In that situation, count the pulse for 20 or even 30 seconds. If you count the pulse for 20 seconds, then you would multiply the number of beats by 3 to get beats per minute. Counting for 30 seconds means you multiply by 2.

Ten seconds is long enough if you are taking your pulse directly after exercise when it could be changing rapidly. In this instance, you would multiply the number of beats by 6 to get the heart rate.

3.3 Practical activities

2 Heart rate and exercise

Purpose

To investigate the effect of exercise on heart rate.

Materials

- stopwatch or timer
- graph paper
- ruler and pencil

SAFETY

Do not run or jog if you have been ill recently or if you have asthma or a heart condition.

Procedure

1. When you are sitting quietly, find your resting pulse rate (the number of beats per minute). Do this by finding your pulse on your wrist or at the side of your neck and counting the number of pulses for 15 seconds. Multiply this number by 4. For more advice on taking your pulse, see the Skill builder on page 107.
2. Repeat this step twice more and calculate an average by adding up the results and dividing by 3.
3. Run or jog on the spot for 3 minutes.
4. When you stop, immediately take your pulse rate again.
5. Sit down and take your pulse rate every minute until it does not get any lower.

Results

1. Record all your results in tables like the ones shown.

Resting pulse rate

Trial	1	2	3	Average
Resting pulse rate				

Pulse rate following activity

Time after end of jog (min)	Pulse rate (per minute)
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	

2. Construct a line graph from the results in the second table.

Discussion

1. **State** what happened to your pulse rate when you started exercising.
2. **Propose** reasons for this change.
3. **Describe** the change in your pulse rate after you stopped exercising.
4. **Propose** reasons for these changes.
5. **Compare** your results with those from other members of the class.
6. **Account** for differences in the results.
7. **Predict** from these results what changes would be expected if you:
   a. ran a lot faster for 3 minutes
   b. ran faster and for a longer period of time
   c. walked slowly round the room.

3.4 Muscles and bones

Buildings such as houses have a frame that supports the roof and keeps the walls upright. Your body also has a supporting frame—your skeleton. Without a skeleton you would not be able to stand upright, you would not be able to move, and important organs such as your heart and brain would have no protection. Your skeleton works with your muscles to give you shape, protect your insides and allow you to move.

The skeleton

Your **skeleton** is your body's frame. It is made up of **bones**. The skeleton has three main functions.

- Support for your soft tissues. Without a skeleton, your skin and the organs inside your body would collapse to resemble a jellyfish stranded on the beach (Figure 3.4.1). A jellyfish does not have a skeleton and is supported by the water in which it lives (Figure 3.4.1). You live on land and are surrounded by air. Air does not provide the same support as water; therefore, you need a skeleton.

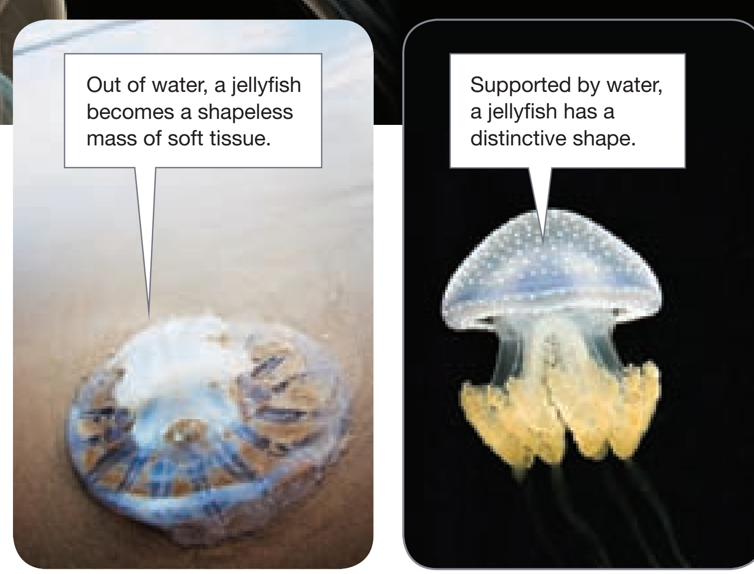


Figure 3.4.1 A jellyfish has no skeleton and needs water to support it.

- Protection for your organs. This is the main role of your **axial skeleton**, which is made up of 80 bones. It includes your skull (which protects your brain), vertebral column (which protects your spinal cord), and ribs and breastbone (which protect your lungs and heart). Your axial skeleton is shown in yellow in Figure 3.4.2.
- To allow movement. This is the main role of your **appendicular skeleton**, which is constructed from 126 bones. It includes your shoulder blades and the bones in your arms and legs. It is coloured blue in Figure 3.4.2. Joints within the skeleton allow your body to move.

Bones

The main bones of your body are shown in Figure 3.4.3. Bones need to be strong so that they do not snap or crumble during normal activity. Compression forces squash bones and tension forces stretch them. Your leg bones experience compression forces when you are standing. Your neck is usually under compression too, especially when carrying a load on your head like the woman in Figure 3.4.4. Your arms experience tension forces whenever you carry shopping bags or when you hang off a bar like the gymnast in Figure 3.4.4.

Bones also need to be slightly elastic. They must be able to flex and twist a little and then return to their original shape and size when the force is removed from them.

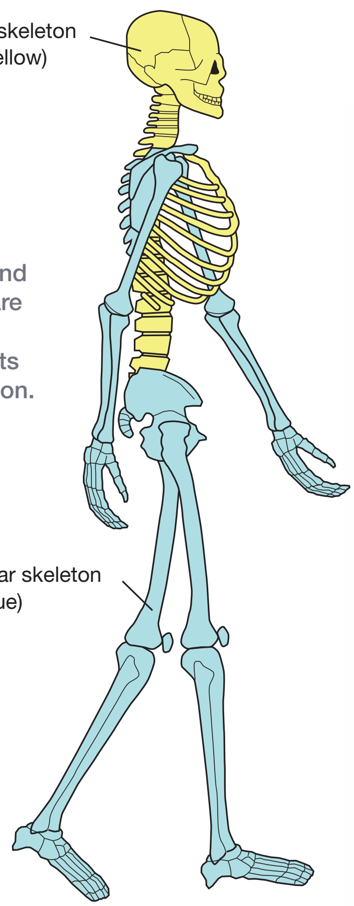


Figure 3.4.2 Protection and movement are provided by different parts of the skeleton.

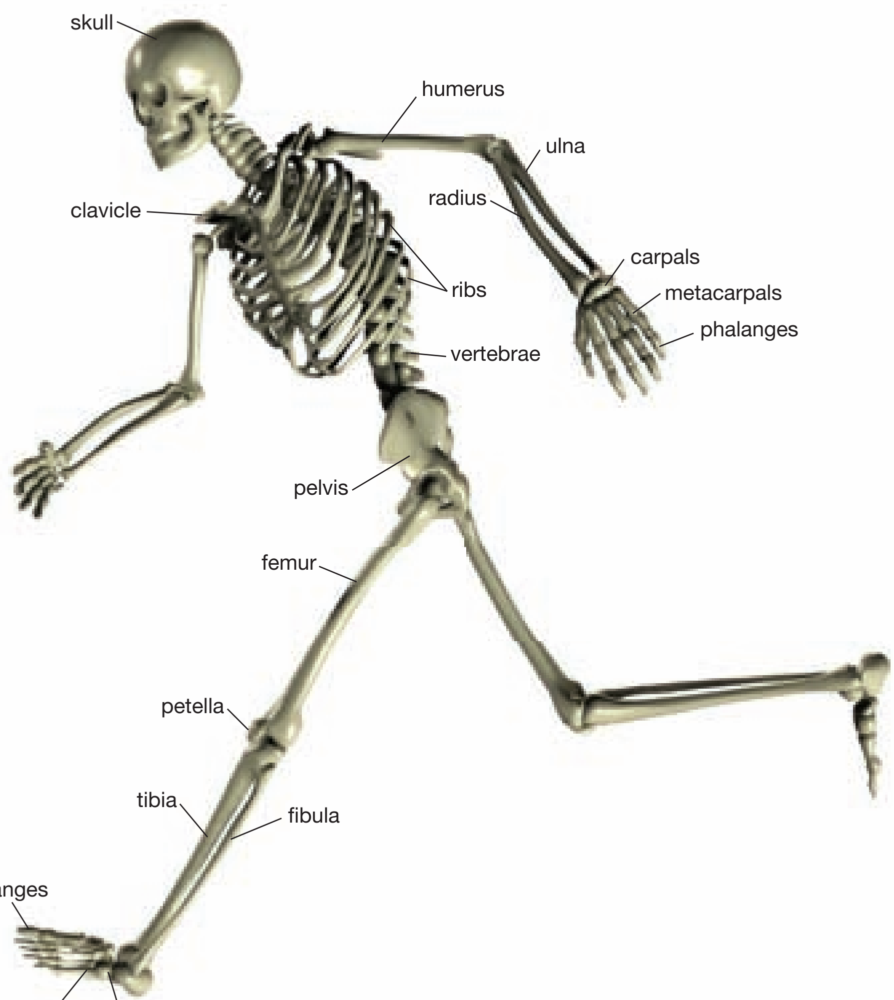


Figure 3.4.3 Your skeleton and its joints allow you to be active, relax and stand upright.

SciFile

Sexist bones!

Men usually have bulkier and heavier muscles than women and so a man's bones need to be a little larger and heavier to support them. Some bones, such as the pelvis, also have a different shape. Forensic scientists can use these facts to determine the sex of a skeleton.

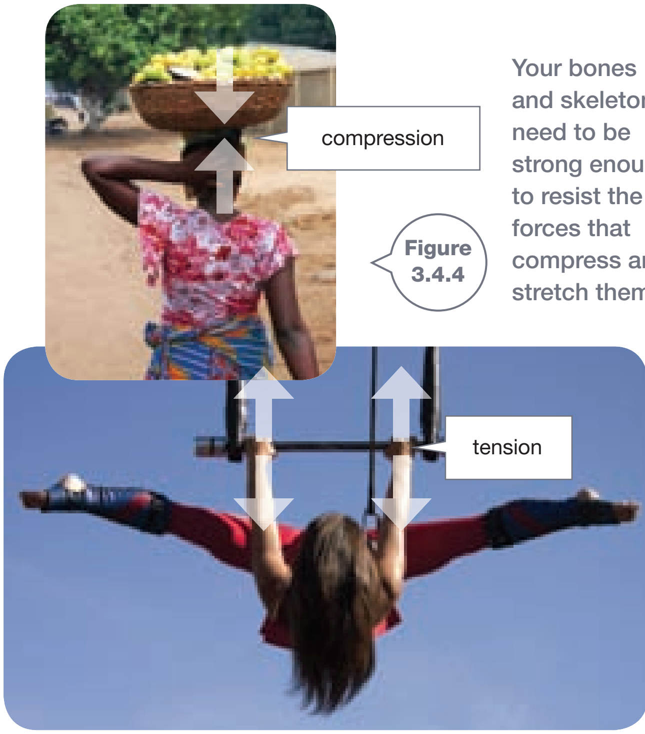


Figure 3.4.4 Your bones and skeleton need to be strong enough to resist the forces that compress and stretch them.

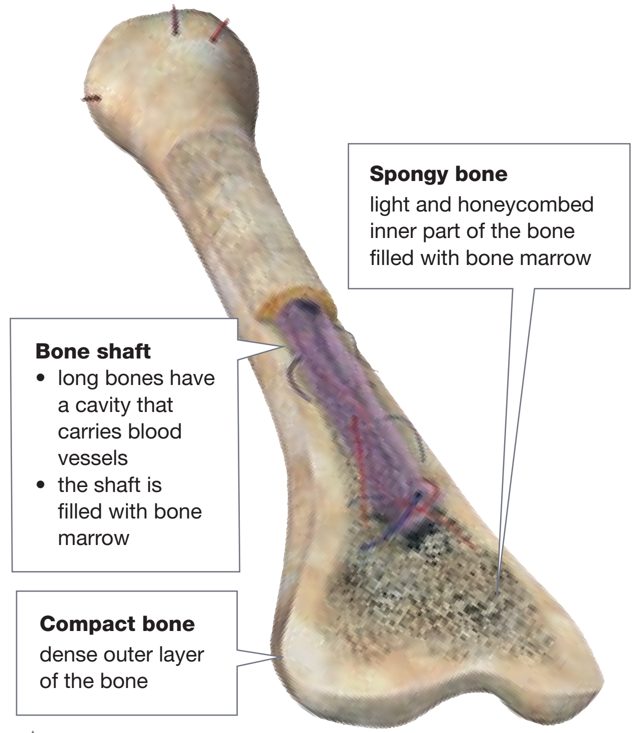


Figure 3.4.5 Bones are lightweight and living. This makes them easy enough for your muscles to move and allows them to renew and repair themselves.

Bones must also be light enough for your muscles to move. The strength and lightness of bones comes from their structure. Bone tissue has two different forms.

- **Compact bone** makes up the outer layer of the bone. Compact bone is dense and heavy and gives the bone much of its strength.
- **Spongy bone** resembles honeycomb. It is light yet provides a strong inner structure to the bone. Gaps in spongy bone are filled with a fatty, jelly-like material called bone marrow. Red blood cells and platelets are made in **bone marrow** along with some of your white blood cells.

Bones are living tissues. They contain living cells that are surrounded by calcium phosphate, a substance that makes the bone hard. They also contain collagen, a material that provides elasticity. Blood vessels supply bone with the nutrients it requires. Because they are living, bones are able to repair themselves and replace worn-out cells. The structure of a typical bone is shown in Figure 3.4.5.

Joints

A **joint** is a place in the body where two bones come together. Most joints allow movement and the type of joint determines the range of movement of the bones. Bone moving against bone would cause pain and the bone would wear down.

To protect your bones from wear, joints have:

- **cartilage**, a smooth and slippery material that covers the ends of bones that are moving against each other. It helps to cushion the impact of movement
- **synovial fluid**, which lubricates the bone ends and allows them to slide over each other freely.

These are both shown in Figure 3.4.6.

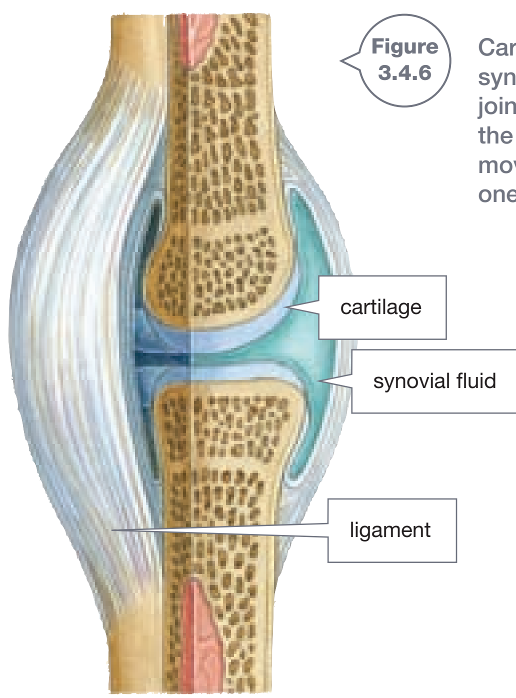
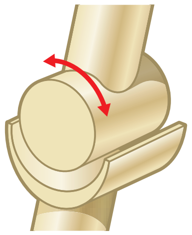


Figure 3.4.6 Cartilage and synovial fluid in joints ensure that the bones can move freely over one another.

Types of joints

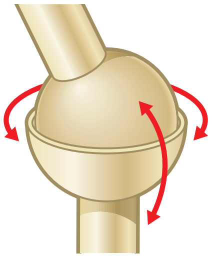
When you are sitting on a chair, your lower leg can move only forwards or backwards. The joint at the knee does not allow the lower leg to move from side to side. Using the hip joint, you can move your leg to make a complete circle with your toes. This is because the joints in your hip and knee are different types of joints.

Hinge joint



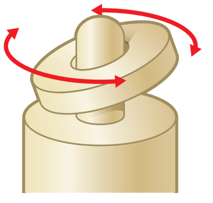
In a **hinge joint** the ends of the bones are shaped so that movement is allowed in only one plane—backwards and forwards like the hinge of a door. There is a hinge joint between the bone of the upper arm (humerus) and the larger bone of the lower arm (ulna). Other examples are the knee joint and joints in your fingers.

Ball-and-socket joint



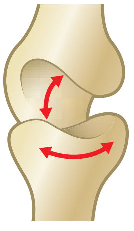
In a **ball-and-socket joint**, one bone has a ball-shaped surface that fits into an area shaped like a cup (socket) in the other bone. The bone with the ball at its end is able to complete all types of movement. Ball-and-socket joints are found in the hip and the shoulder.

Pivot joint



A **pivot joint** moves by a ring-shaped bone turning around a bone shaped like a finger. A pivot joint allows a wide range of movement. The joint at the base of your skull that allows you to turn your head is a pivot joint.

Saddle joint



A **saddle joint** allows movement in two directions but does not allow the same amount of movement as a ball and socket joint. Saddle joints are found in the ankle and base of the thumb.

3.9

1 p116

Ligaments

Ligaments are bands of tough, flexible tissue that hold the bones in a joint together. Ligaments prevent the bones of the joint from moving too far apart. Figure 3.4.7 shows the ligaments in the foot.

Figure 3.4.7 Ligaments, shown here in pink, hold all the bones of the foot together. Without them the foot would not be able to work as a single unit.

INQUIRY science 4 fun

Flexing muscles

Can you feel your muscles contract and relax?

Yes

Do this …

1. Relax your right arm so that it hangs beside you. Wrap your left hand around your lower right arm (below the elbow) and hold onto it. Then clench your right hand into a fist. Unclench and repeat.
2. Wrap your left hand around your upper right arm (above the elbow). Clench your right fist then raise it to your chin. Lower your arm and repeat.
3. Stand near a wall and place your right hand on it. Wrap your left hand around your upper right arm as before and lean into the wall so that your elbow is bent. Lean further in, then straighten up (as though you were doing single-handed push-ups against the wall).

Record this …

Describe what happened.
Explain why you think this happened.

Muscles

It is your **muscles** that move bones. Muscles are tissues that are able to contract and be stretched. You have 640 muscles, regardless of whether you are a couch potato or a body builder. Some of the main muscles are shown in Figure 3.4.8. **Tendons** are tissues that attach muscles to bones and hold the muscles in position. When activated, muscles contract, becoming fatter and shorter. They pull on the bones they are attached to, causing them to move.

Muscles can only pull. They cannot push. Therefore, another muscle is required to return the bone to its original position. For this reason, your muscles are arranged in antagonistic pairs that work in opposition to each other. The biceps and triceps are antagonistic muscles in your upper arm. When activated, the biceps contracts, pulling your forearm up. The biceps then relaxes. To lower the forearm, the triceps contracts. The relaxed biceps is stretched back to its original shape and the arm is straightened. This action is shown in Figure 3.4.9.

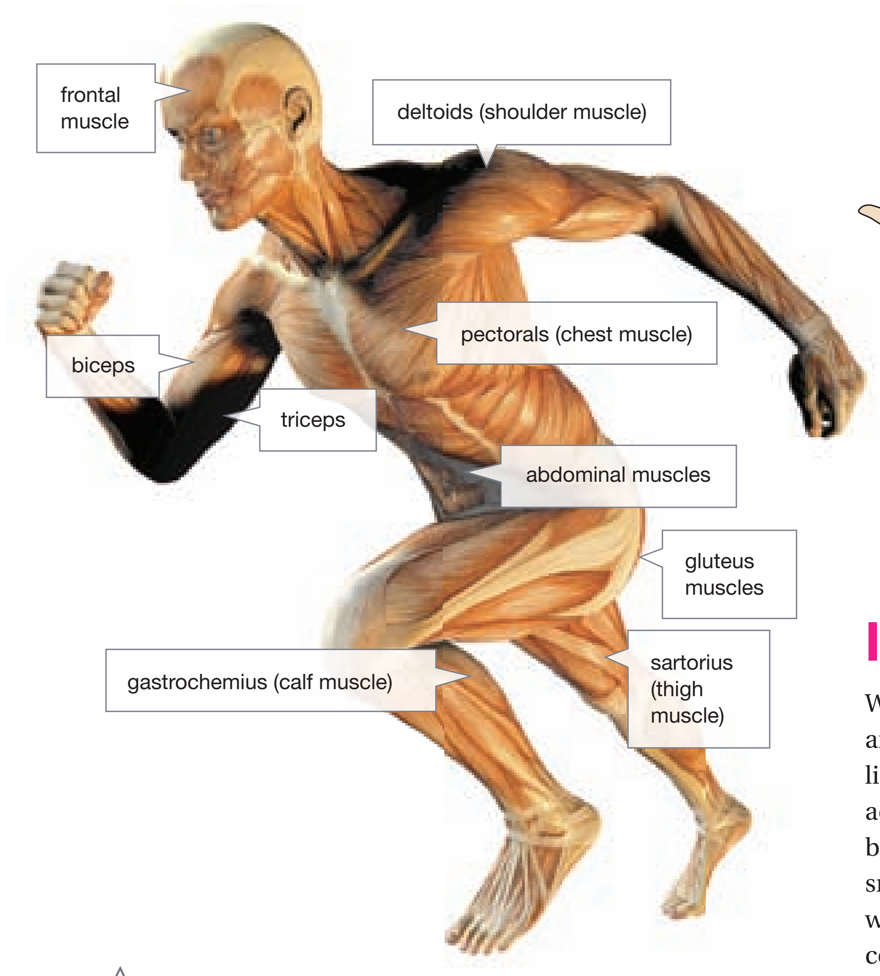


Figure 3.4.8 The human muscular system. The pale areas are tendons joining muscles to bones.

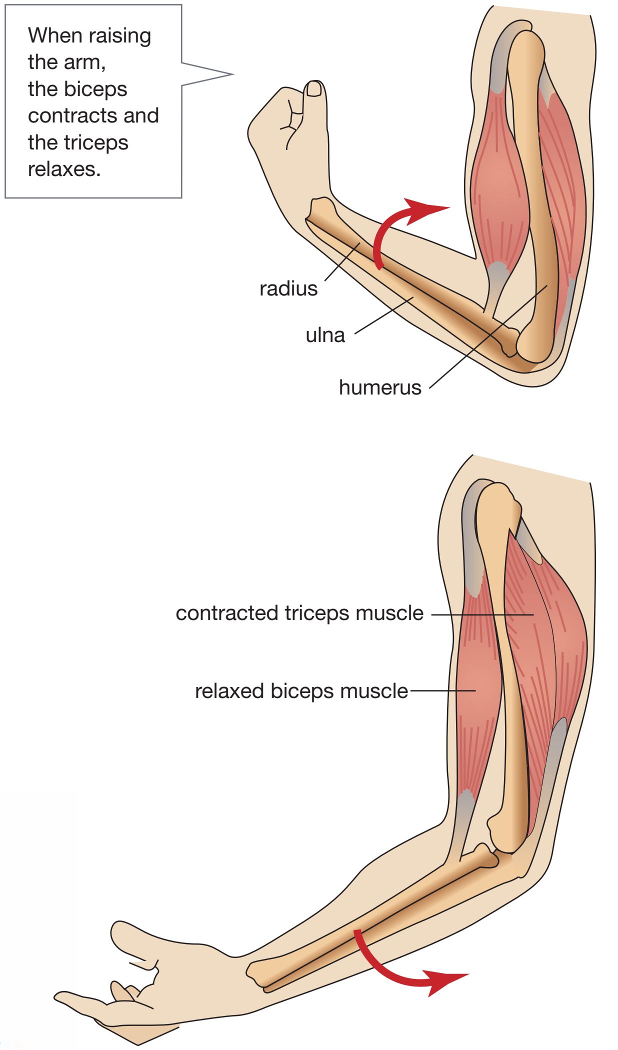


Figure 3.4.9 Muscles work in antagonistic pairs. The biceps flexes the arm while the triceps straightens it.

2 p116
3 p117

Injuries

When you are young, your skeleton and muscles are usually able to withstand the forces of normal life. However, the forces involved in sport and accidents are sometimes great enough to cause bones, muscles, tendons and ligaments to split, snap or tear. As you age, your bones and muscles weaken and these types of injuries become more common, even when you are not playing sport!

Broken bones

Bones can stretch, squash and twist slightly but, like any material, will fracture (break or crack) if too much force is applied to them. Figure 3.4.10 shows what can happen. However, bone is a living material and will eventually mend if broken. This process takes around 6 weeks in adults and a little less in children.
A cast is usually needed to ensure the bones mend in the correct shape and position. This can be made of plaster or fibreglass, or may even be inflatable. Very bad breaks may need additional reinforcing with stainless steel plates or pins, like the ones shown in Figure 3.4.11.

Figure 3.4.10 Both the bones in the lower leg were broken by the twisting action of a skiing accident.

Figure 3.4.11 Pins and plates are often used to hold and strengthen bones in serious breaks.

Sprains and strains

Ligaments are strong but elastic. They hold the bones in place at the joint but allow some movement in different directions. If a ligament is stretched too far, it can tear, causing an injury called a **sprain**. Ligaments in ankles and wrists are commonly sprained by a fall.

A **strain** is an injury to a muscle or tendon. Muscles are made to stretch but if they are stretched too far, or stretched while they are contracting, then either the muscle or the tendon may tear, causing a strain. You hear of footballers and other sports people suffering from torn hamstrings. The hamstring is the muscle running along the rear of the upper leg (connecting the pelvis to the knee).

Repetitive activities may also cause a sprain or strain when the muscles, tendons and ligaments are stretched continuously.

Minor strains and sprains can be treated by the RICE method. RICE stands for **R**est, **I**ce, **C**ompression and **E**levation.

3.10

3.4 Unit review

Remembering

1 **State** how many bones there are in the:
  a axial skeleton
  b appendicular skeleton
  c adult human skeleton.

2 **List** the characteristics of bones.

3 **State** the number of muscles found in the human body.

4 a **State** what the RICE method is.
  b **State** what each of the letters in RICE represents.

Understanding

5 The bones in your arm need to perform well under both compression and tension. **Explain** why.

6 **Predict** what the movement of your head would be like if its pivot joint was replaced with a hinge joint.

7 **Describe** where the following are found and what they do.
  a ligaments
  b tendons
  c cartilage

8 Broken bones need to be kept in a cast for 6 weeks. **Explain** what would happen if they weren't kept in a cast.

Applying

9 **Identify** the property of cartilage that reduces friction in a joint.

10 **Use** the biceps and triceps to **explain** why muscles need to be arranged in antagonistic pairs.

Analysing

11 **Contrast**:
  a the axial and appendicular skeleton
  b compact with spongy bone.

12 **Compare** the amount and direction of movement allowed by a hinge joint and a:
  a ball-and-socket joint
  b saddle joint.

13 **Contrast** a strain and a sprain.

Evaluating

14 **Propose** reasons why your wrists and ankles have extra ligaments forming 'cuffs' around them.

15 Your spine extends from the base of your skull to the base of your pelvis. It holds your body upright but also allows you to flex and bend. **Propose** how this is achieved.

Creating

16 **Construct** a diagram showing the position of the muscles of the leg that cause the knee to bend and straighten.

Inquiring

1 Find out why adults have nearly 100 fewer bones than babies.

2 Research brittle bone disease. Find out what it is, who it affects, what causes it and how it is treated.

3 Search the internet using the keywords *EdHeads* to carry out your own virtual knee and hip replacement surgery.

4 The footballer in Figure 3.4.12 below has torn his hamstring. Find out what a hamstring is, how it is torn and ways of minimising the risk of such tears when playing sport.

Figure 3.4.12

3.4 Practical activities

1 Model joints

Purpose

To construct models of the different joints found in the human body.

Materials

- selection of junk materials

Procedure

1 Refer to page 112 and decide which joint you are going to build a model of.

2 Analyse the joint, how it is 'strapped' with ligaments, and what materials could represent each part.

3 Construct your model and demonstrate it to the class.

Discussion

1 **Describe** the movement that this type of joint gives the bones attached to either side of the joint.

2 **Identify** where in your body these types of joints are most likely to be found.

2 Dissecting an animal structure

Purpose

To investigate the structure of a chicken wing.

Materials

- uncooked chicken wing
- dissecting kit (scalpel, scissors, tweezers/forceps)
- dissecting board
- newspaper
- disinfectant
- access to stereo microscope

SAFETY!

Take care with sharp instruments.

Wear disposable gloves while dissecting the chicken wing.

Wash your hands thoroughly after completing the dissection.

Procedure

1 Cover your workbench with newspaper and then set the dissecting board on top of it.

2 Lightly cut the skin of the wing down its length.

3 Use the tweezers to help you gently peel back the skin to expose the muscles. Record what they look and feel like and how they connect to the bones.

4 Once the muscles are exposed, flex the wing so that it opens and shuts. Record what happens.

5 Cut the muscle and fat off the wing to expose the bone. Record how the different bones of the wing connect to each other.

6 Try to break one of the bones. If successful, carefully look at the inside of the bone or its fragment, perhaps under a stereo microscope. Record what you see.

Discussion

1 **State** whether or not you saw an antagonistic muscle pair in the wing.

2 **Describe** the function of the muscles in the chicken wing.

3 **Describe** what tendons do.

4 Bird bones are extremely light and much less dense than the bones in most other animals. **Propose** a reason why.

3 Muscle fatigue

Purpose

To test how quickly muscles fatigue (get tired).

Materials

- springy test-tube clamp or similar
- stopwatch or access to clock or watch with second hand

Procedure

1. Use the hand you normally write with to hold the test-tube clamp with your thumb and first two fingers.
2. When your prac partner says 'Go', squeeze the test-tube clamp until your thumb meets or touches your fingers. Then relax. Keep squeezing and relaxing. As you go, count out aloud how many complete squeezes you are up to.
3. Your prac partner needs to take note of the time and record how many squeezes you complete every 30 seconds.
4. Keep squeezing and relaxing until you have reached 2½ minutes or have tired out.
5. Swap roles and repeat.

Results

1. Construct a table in your workbook like the one below to show your results.

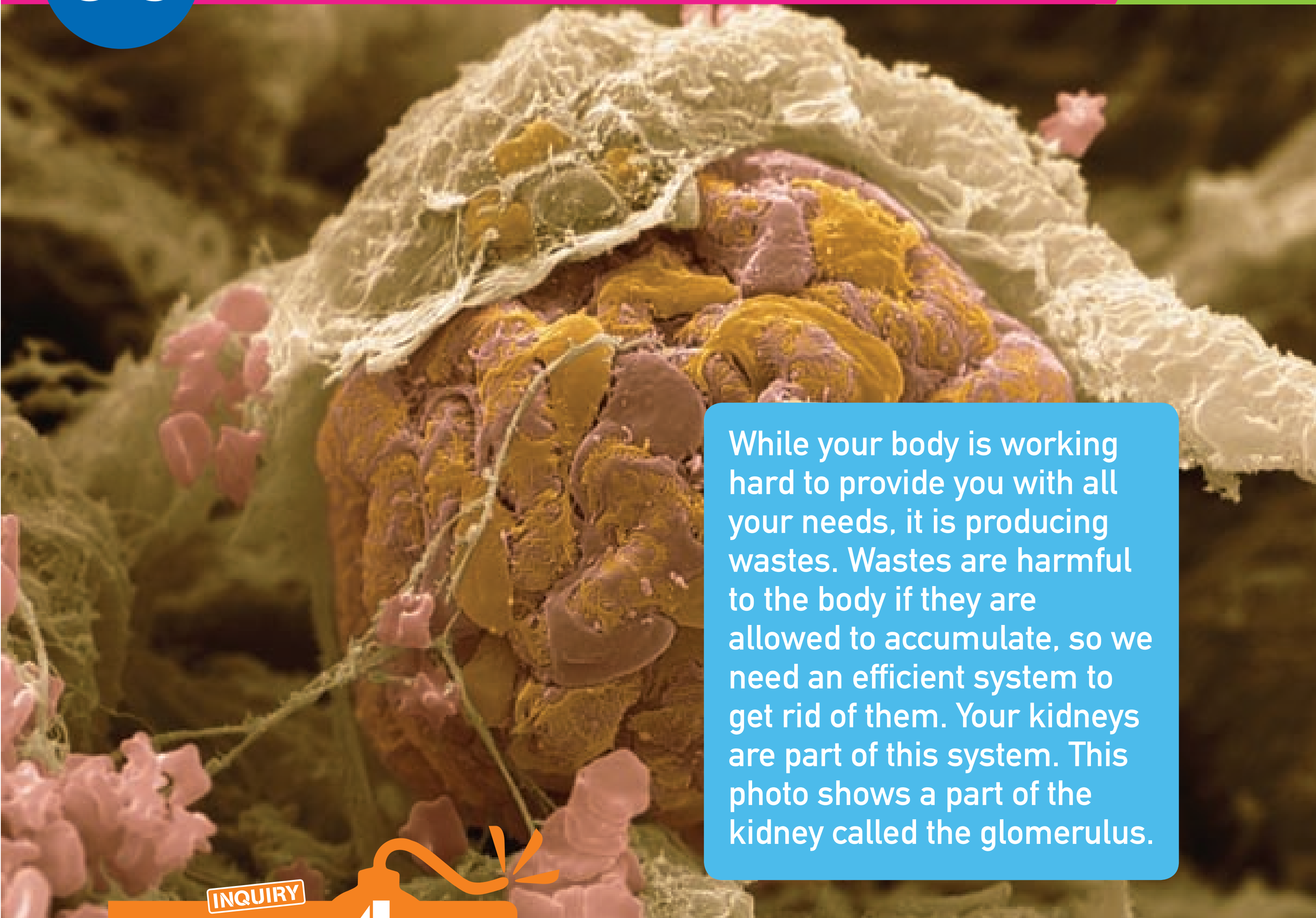
Time (s)	Number of squeezes completed by me	Number of squeezes completed by my partner
30		
60		
90		
120		
150		

2. Plot a line graph showing the number of squeezes completed against time. Place the number of squeezes on the vertical axis and time on the horizontal axis.

Discussion

1. **Describe** what happened as time progressed in this experiment.
2. **Propose** a meaning for the term *muscle fatigue*.
3. **Propose** reasons why some people experience muscle fatigue more quickly than others.

3.5 Waste disposal



While your body is working hard to provide you with all your needs, it is producing wastes. Wastes are harmful to the body if they are allowed to accumulate, so we need an efficient system to get rid of them. Your kidneys are part of this system. This photo shows a part of the kidney called the glomerulus.

INQUIRY

science 4 fun

Yes

It smells!

Does what you eat affect the smell of your urine?

Collect this ...

- tin of asparagus or freshly cooked asparagus

Do this ...

1. Eat the asparagus.
2. Next time you urinate, pay attention to the smell.

Record this ...

Describe what happened.
Explain why you think this happened.

Defecation

The process of getting rid of solid waste (faeces) from your body is known as **defecation**. Faeces is undigested material that has passed through your digestive tract. It is waste because it is material that your body has not been able to use.

Excretion

Getting rid of the wastes your body has produced is called **excretion**. It is the function of the **excretory system**. The lungs, skin, liver and kidneys are all involved in excretion.

Lungs

Respiration produces carbon dioxide and water as waste products. These are carried back to the lungs and breathed out. The lungs are part of the excretory system as well as being part of the respiratory system.

Liver

Your liver carries out many processes. Some are involved in excretion.

Amino acids are the end products of protein digestion. They are used by your body to make proteins and for growth and repair. Amino acids cannot be stored. If you have more than needed, they are broken down and excreted. The liver breaks amino acids down into a substance called **urea**.

Poisonous substances may enter the body from the digestive tract. These are carried to the liver, where they are broken down into harmless substances. The harmless substances are then returned to the blood and from there they pass to the kidneys.

The liver breaks down old red blood cells. Any unwanted haemoglobin is added to bile and passes with the bile into the intestines.

Skin

Chemical reactions taking place in your body produce heat as a by-product. Some of this heat is required to maintain your body temperature at 37°C, but you usually produce more than you need. If you did not get rid of the excess heat, then your temperature would rise. This could be fatal. You lose much of your excess heat through your skin by sweating, as shown in Figure 3.5.1. Sweat also contains a very small amount of urea.

Figure 3.5.1 Your body gets rid of excess heat by sweating.

SciFile

Airhead!
The whole of the human skin weighs twice as much as the brain.

Kidneys

The kidneys are very important excretory organs. If you place your hands on your hips with your thumbs to the back, then your thumbs will be sitting over your kidneys. They are two bean-shaped organs about the size of a fist. They are filters that process about 50 litres of blood every hour. Figure 3.5.2 shows the position and relative size of the kidneys.

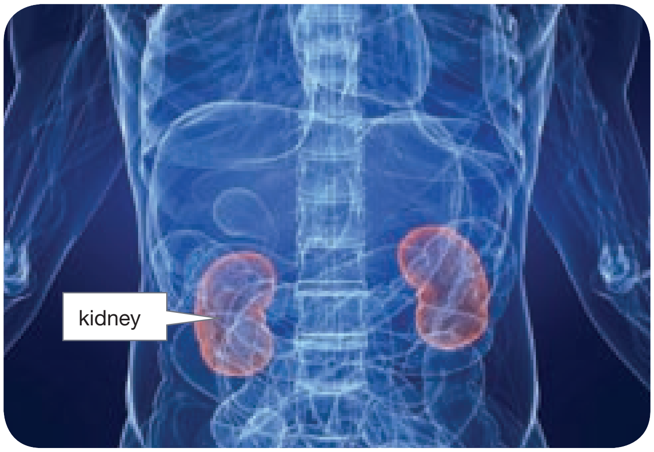


Figure 3.5.2 Although your kidneys are not large, they are very important. About 20% of the blood leaving your heart flows to the kidneys first before continuing its circulation of the body.

The kidneys excrete urea. The kidneys also control the level of water in the body. If you have drunk more than you require, then extra water is taken out of the blood as it is filtered through the kidneys and very dilute urine is produced. If your body is short of water, then the kidneys take out less water and produce more concentrated urine.

Your kidneys also control salt levels in the blood. Too much or too little salt in the blood prevents cells from working correctly. So it is very important that the concentration of salts is controlled. Excess salt is removed in the urine.

Figure 3.5.3 shows the structure of a kidney.

Urine

Urine is the waste material that has been filtered out of the blood by the kidneys. Urine is 95% water. The other 5% is urea, with small amounts of salts and pigment. The pigment comes from the breakdown of haemoglobin and gives urine its yellow colour.

Urine passes from the kidneys down narrow tubes called **ureters** and into the **bladder**, where it is stored. The bladder is a muscular bag. It can expand to hold about 500 mL of urine.

The **urethra** is a tube that carries the urine to the outside of the body. At the end of the urethra is a sphincter muscle that controls the emptying of the bladder.

Together, the kidneys, bladder, ureters and urethra are called the **urinary tract**.

The male urinary tract system is shown in Figure 3.5.4.

1 p124

2 p125

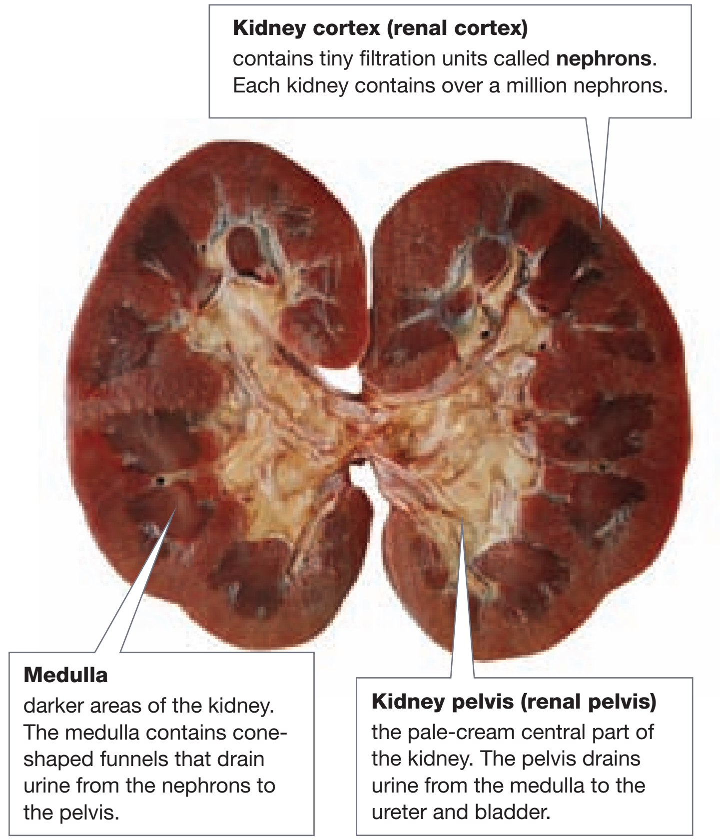


Figure 3.5.3 A dissected kidney. The image used in the introduction to this unit was of a glomerulus. Glomeruli are part of the nephrons in your kidneys.

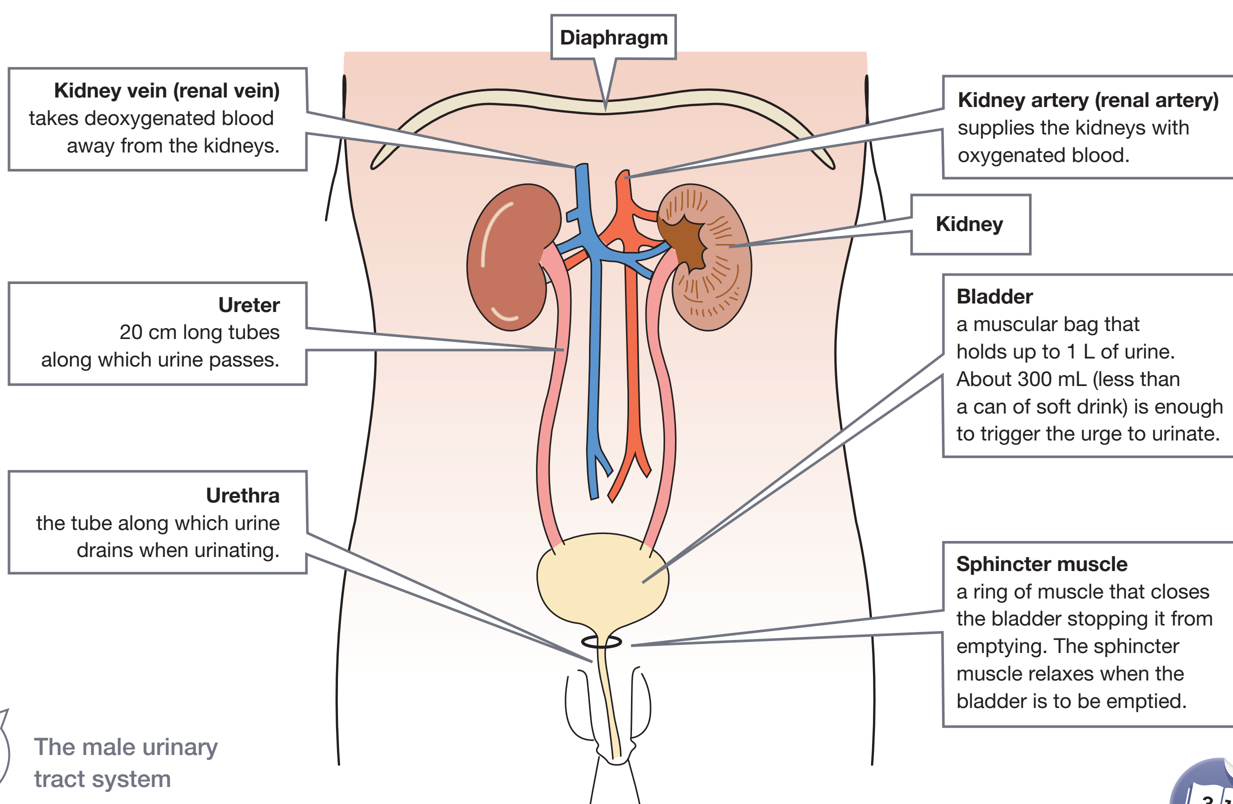


Figure 3.5.4 The male urinary tract system

3.11

Kidney disease

More than 500 000 Australians a year consult their doctors about kidney disease and urinary tract infections. High blood pressure, kidney stones and infections are some of the causes.

High blood pressure

Your blood travels a relatively short distance to your kidneys. Very little pressure from the heartbeat is lost, so blood entering the kidneys is under pressure. This pressure helps the filtering process carried out by the kidneys. However, abnormally high blood pressure can easily damage the capillaries where the blood is filtered. This affects the functioning of the kidneys.

Kidney stones

Kidney stones occur when chemicals normally present in the urine combine to create hard crystals. If they are small enough, the crystals will pass out of the kidneys with the urine. However, larger stones (like those shown in Figure 3.5.5) can block the fine tubes within the kidney, causing pain and preventing the flow of urine.

Large kidney stones may have to be removed in an operation but more commonly they are shattered into tiny pieces using ultrasound waves. The smaller pieces should then pass naturally from the body.

Substances in the urine usually prevent kidney stones from forming. However, in some people these substances do not work and they suffer the pain and discomfort of this disease.

You can help keep your kidneys healthy by drinking. Water is the best drink (Figure 3.5.6). You should drink enough to produce about 2 litres of urine in every 24-hour period.

Infections

The structure of the urinary tract prevents any backflow of urine from the bladder to reduce the chance of infections of the kidneys. However, infections of the urinary tract sometimes occur. Most are caused by bacteria.

Urine is normally sterile, so the bacteria have to come from another source. They usually enter through the urethra. Most infections are caused by *Escherichia coli* (*E. coli*), a bacterium common in the digestive tract, which spreads to the urethra from the anus.

Figure 3.5.5 The red dots in this X-ray are kidney stones.

Figure 3.5.6 Drinking plenty of water helps to keep the kidneys healthy.

SCIENCE AS A HUMAN ENDEAVOUR

Nature and development of science

Ultrasound imaging

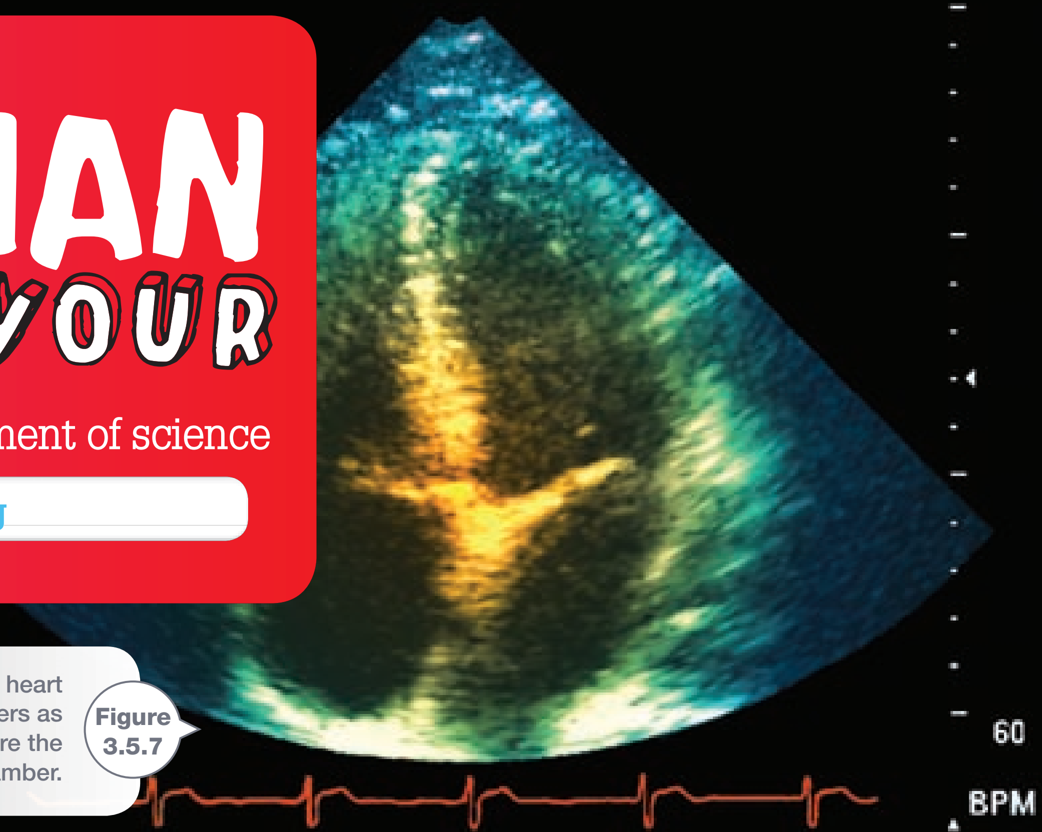


Figure 3.5.7 This ultrasound image of a human heart clearly shows the four chambers as dark patches. The light areas are the inner walls separating the chamber.

You will probably have heard of ultrasound imaging and may have seen an ultrasound image of yourself as a baby inside your mother's uterus. The ability of medical practitioners to create ultrasound images is due in part to the work of Australian scientists.

Figure 3.5.8 Ultrasound image of a baby at 12 weeks with its thumb up.

Australians George Kossoff and David Robinson did not invent ultrasound imaging but they made a significant contribution to its development when they introduced 'grey-scaling'. Grey-scale produces images that have many shades of grey ranging from almost black to almost white. Before this innovation, the images produced were in black and white and interpreting the images could be difficult.

When grey-scale was introduced to ultrasounds, such as the one in Figure 3.5.8, the image was improved. It was easier to distinguish between liquid and solid tissues and to see the boundary between them.

In 1970 Kossoff and Robinson published one of the earliest scientific papers relating to the diagnosis of development problems in fetuses, using ultrasound technology.

Grey-scale ultrasound imaging is used for finding cancers in various parts of the body; observation of the direction and speed of blood flow; and checking the internal structure of the eye.

A recent (2010) innovation using ultrasound is in the area of dentistry. David Hsiao-chuan Wang (a PhD student) and his supervisor, Professor Simon Fleming from the Institute of Photonics and Optical Science at the University of Sydney, have developed the dental laser ultrasound. This instrument uses laser-generated sound waves to detect early signs of tooth decay. The technique is painless and replaces potentially harmful X-rays and painful probing with sharp instruments. It may also eliminate the need for surgery.

3.12

3.5 Unit review

Remembering

1 **Recall** the function of the bladder.

2 **List** the wastes produced by respiration.

3 **List** the wastes excreted by the lungs.

4 **List** three functions of the kidneys.

5 **Recall** the missing steps in the pathway followed by urine:

kidney → ______ → bladder → ______

Understanding

6 On average, urine is 95% water and 5% urea and salts. **Predict** how the composition of urine would change if you:

a drank very little water on a hot day

b drank very large amounts of water

c ate a diet high in salt.

7 **Explain** the difference between excretion and defecation.

8 **Describe** the involvement of the liver in excretion.

Applying

9 Kidneys process about 50 L of blood every hour. Your body contains about 5.5 L of blood. **Calculate** how often any drop of blood would pass through the kidneys in:

a 1 hour

b 1 day.

10 Figure 3.5.9 is a diagram of the excretory system. **Identify** the parts labelled A–D.

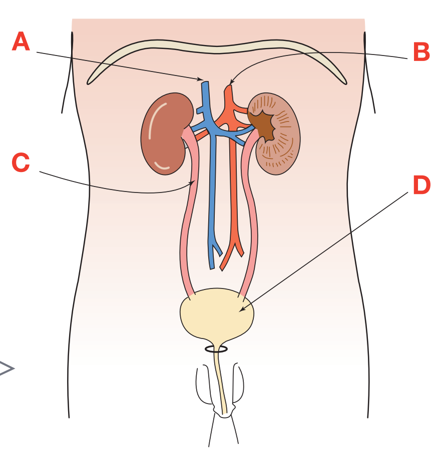


Figure 3.5.9

Analysing

Questions 11–13 refer to the following table. It compares blood and urine.

Component	Percentage in blood	Percentage in urine
Water	92	95
Protein	7.5	0
Glucose	0.1	0
Urea	0.03	2
Salts	0.37	3

11 **Compare** the data for blood and urine and **identify** the substances that are:

a more concentrated in the urine

b not excreted by the kidneys.

Evaluating

12 Decide whether the person from whom the data were collected had adequate water in their body or was dehydrated. **Justify** your response.

13 **Propose** a reason for glucose not being excreted.

14 **Propose** why drinking water should reduce the chance of developing kidney stones.

Creating

15 **Use** the following eleven key terms to **construct** a concept map.

excretion	excretory system	defecation
urea	urine	kidneys
skin	lungs	ureter
bladder	urethra	

Inquiring

1 People who have donated a kidney and those who have received a transplant survive with only one kidney. Research to find out how this is possible.

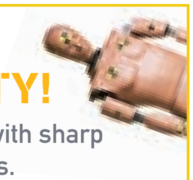
2 Research to find out what changes occur in your body if you become dehydrated and overheated.

3.5 Practical activities

1 Kidney dissection

Purpose
To dissect a kidney and look at its structure.

Materials
- dissecting board
- scalpel
- disposable gloves
- sheep or bullock kidney



SAFETY!
Take care with sharp instruments.
Wear disposable gloves when handling the kidney.
Wash your hands thoroughly after you have completed the dissection.

Procedure
1. Place the whole kidney on the dissecting board and examine it. Look for any tubes entering or leaving the kidney. It may be possible to identify three tubes: ureter, renal artery and renal vein. (*Renal* is a word used in relation to the kidney.)
2. Use the scalpel to cut the kidney in half lengthwise as shown in Figure 3.5.10.
3. Identify the parts of the kidney as shown in Figure 3.5.3 on page 120.

Results
Draw a labelled diagram of the cut surface of the kidney.

Discussion
1. **Compare** the texture in the three different areas of the kidney.
2. **Compare** the kidney you have dissected with the human kidney shown in Figure 3.5.3. How similar are the two kidneys?
3. **Use** this comparison to **compare** human excretion with excretion in sheep (or bullocks).
4. **Describe** the function of each part of the kidney.

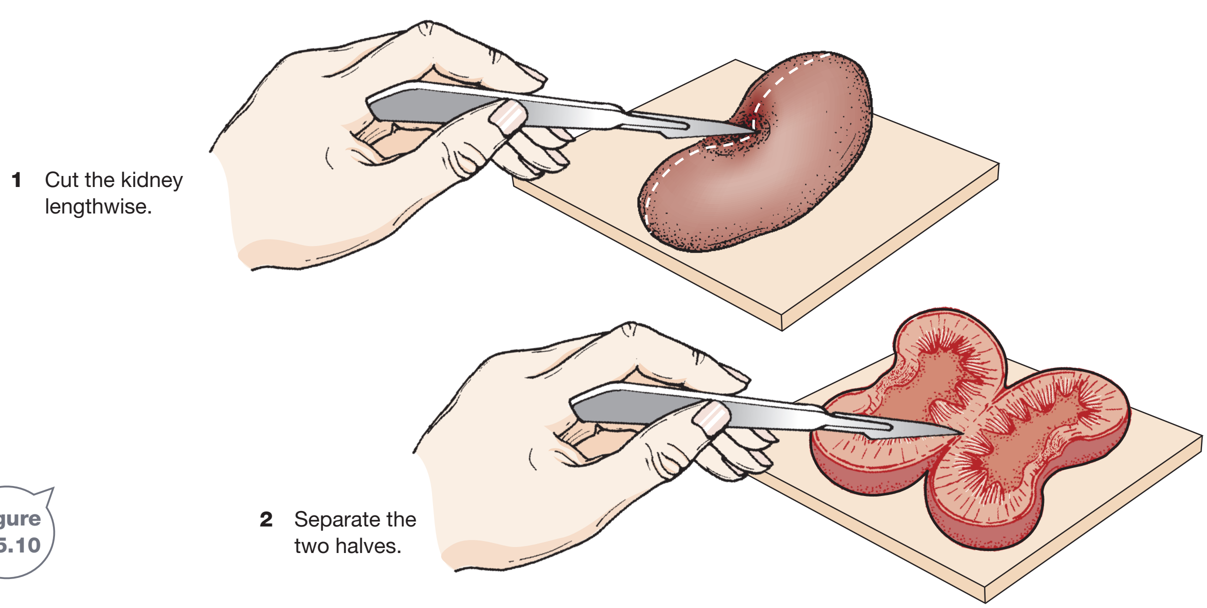


Figure 3.5.10

2 Water and wee

Purpose

To gather information about the relationship between drinking and urinating.

Materials

- notebook and pencil
- graph paper
- liquids that are normally drunk in a day

Procedure

1. Read through the complete activity. Make a prediction about the relationship between urination and consuming liquids. The prediction could be to do with the amounts or the timing.
2. Construct a table like the one below to record the:
   a. amount that you drink
   b. time the drink was consumed
   c. time you urinated.
3. For a 24-hour period, record the volume of all the drinks you consume and the time that you consumed them.
4. Record the times that you urinated for the same 24-hour period.

Results

1. Construct a table like the one shown below.

Time drink consumed	Amount drunk (mL)	Time urinated

2. Construct a bar graph with time along the horizontal axis. Use one colour to show when and how much liquid was consumed.
3. Use a different colour to record when urination took place.

Discussion

On average, the adult bladder can hold between 500 mL and 1 litre of urine. Assume that your bladder is a little smaller than that of an adult and that it is not filled to capacity when you urinate. Assume that each time you urinate, the volume of urine is 300 mL.

1. **Calculate** the total amount you drank in the 24-hour period.
2. **Calculate** the total amount of urine you produced in the 24-hour period.
3. **Compare** the two amounts. Explain the difference.
4. **Calculate** the length of time between drinking and urinating. Explain any relationship you identified.
5. **Discuss** the idea that not all the water in your body has come from the liquid you have drunk.
6. **Identify** any activities that you engaged in that could have reduced the amount of urine produced. Is there any evidence to support this idea in the data you have collected or other observations you may have made, such as the colour of your urine?

3 Chapter review

Remembering

1 **Name** the system that distributes heat evenly through your body.

2 **State** whether the following statements are true or false.
- a The diaphragm contracts as you inhale.
- b You exhale because the air pressure in the chest cavity has decreased.
- c Mechanical digestion changes food chemically.
- d Arteries carry blood towards the heart.
- e Veins have valves in them to help the flow of blood.
- f In humans there are two separate parts to the circulatory system.

3 **List** these organs in the order food will pass through them in the digestive tract:

small intestine, mouth, stomach, large intestine, duodenum, oesophagus

4 **Name** three things produced in the bone marrow.

5 **Name** three organs in the excretory system.

Understanding

6 **Explain** why the lungs are included in both the respiratory system and the excretory system.

7 **Explain** why urine is a darker colour on a hot day.

8 **Describe** three situations in the body where a large surface area helps the functioning of a system.

9 Major arteries are a long way from the body surface. **Explain** why.

10 **Explain** the advantage of bone being a living tissue.

11 **Describe** the function of:
- a tendons
- b ligaments
- c joints.

Applying

12 You take in about 500 mL of air in one breath, and breathe 12 times a minute. **Calculate** how much air you take into your body every hour.

13 **Identify** the organs labelled A–J in Figure 3.6.1.

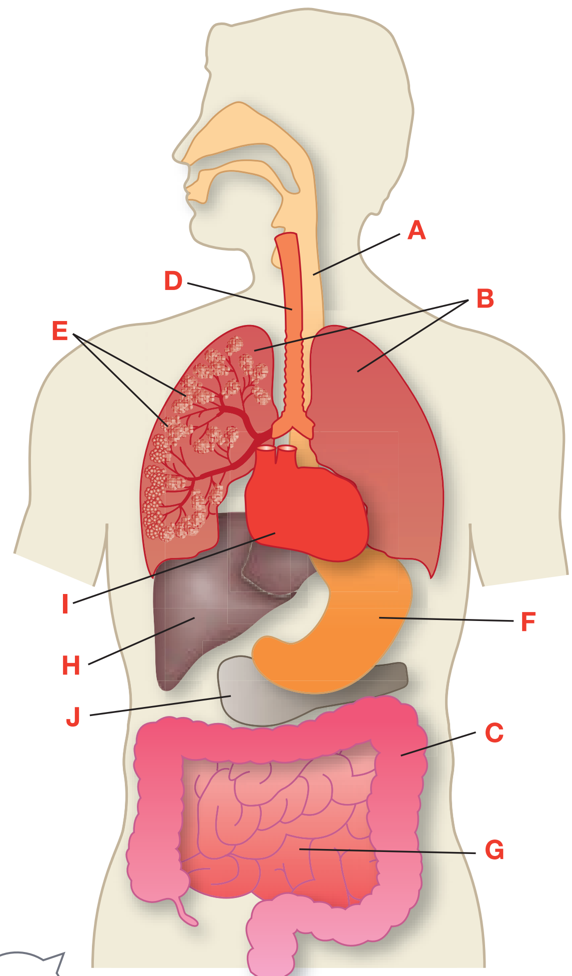


Figure 3.6.1

14 **Identify** each of the following body parts.
- a A slippery elastic tissue found on the ends of bones
- b The structure that carries urine out of the body
- c The joint that allows movement in two directions
- d A tissue that can contract and be stretched but cannot expand

Analysing

15 a **Use** the information in the table below to **calculate** the amount of oxygen that enters your blood for 1 hour while you are sleeping.

b **Calculate** the amount of carbon dioxide you would breathe out in that time.

c i **Compare** the amount of oxygen and carbon dioxide breathed out during sleep and during exercise.

ii **Account** for any differences.

d i **Compare** the amount of nitrogen breathed in and out.

ii **Account** for any differences.

Gas	Composition of air (%)		
	Breathed in	Breathed out during sleep	Breathed out during exercise
Nitrogen	78	78	78
Oxygen	21	16	11
Carbon dioxide	0.03	4	9.5
Water vapour	a little	saturated	saturated

16 **Compare** the part of the lungs where gas exchange takes place with the lining of the small intestine.

Evaluating

17 a **Interpret** Figure 3.6.2 to identify the organs or parts of systems that are represented in the Aboriginal drawing below.

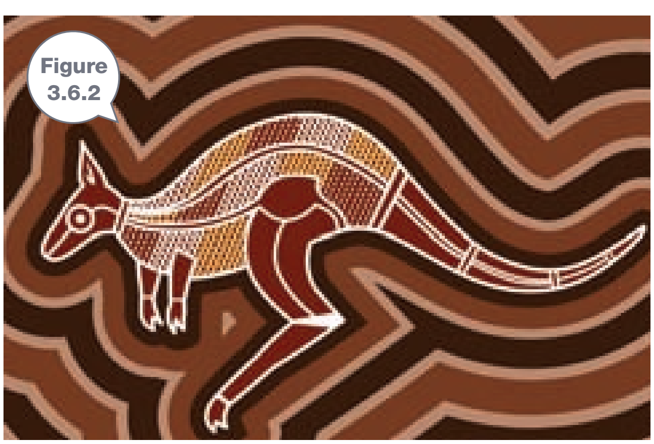


Figure 3.6.2

b **Propose** why Aboriginal Australians would have represented these organs or systems in their art.

18 There have been situations where people have drunk their own urine to survive in the desert when they had run out of water. **Assess** how this would change the composition of the urine they would produce the following day.

19 Some athletes strap their wrists, ankles, knees and shoulders when playing sport. **Propose** reasons why.

20 Birds have hollow bones with very little compact bone. **Propose** an advantage of this characteristic.

21 Dialysis is a process that uses a machine to filter wastes out of blood. The process is used if a person's kidneys stop working efficiently. Dialysis must take place at least three times a week and requires the person to be hooked up to the dialysis machine for 4–6 hours each time.

a **Use** this information to **calculate** the minimum time a person needs to be connected to the dialysis machine each week.

b **Propose** a list of disadvantages of kidney dialysis.

Creating

22 Some people say that we should drink 2 litres of water every day and that tea or soft drink should not be included in the 2 litres. Others say that any drink is equally good at hydrating the body. **Design** an investigation that would help settle the argument.

23 **Use** the following ten key terms to **construct** a visual summary of the information presented in this chapter.

digestion
respiration
excretion
circulatory system
heart
enzymes
diffusion
glucose
oxygen
breathing

3.13

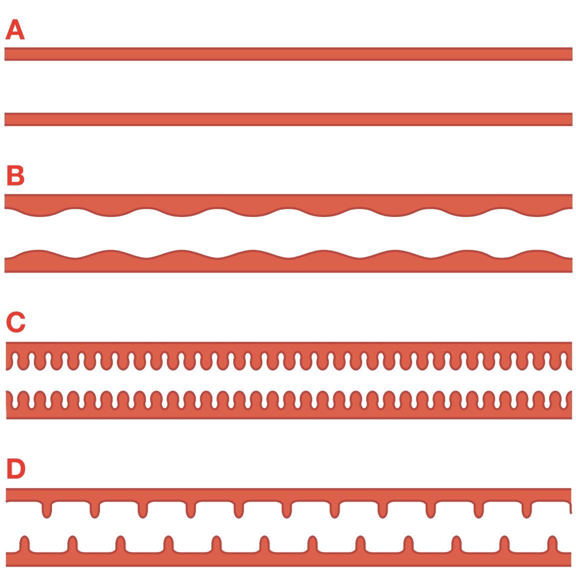
Thinking scientifically

Q1 Analyse the information in the table to decide which parts of the body had increased blood flow during exercise.

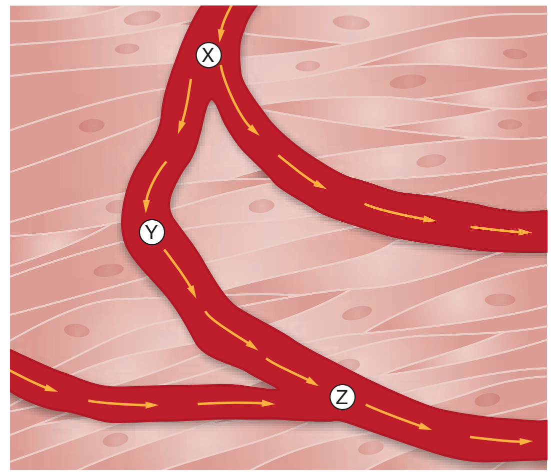
Part of body	Blood flow (L/min)		
	At rest	During light exercise	During medium exercise
Heart muscle	250	350	800
Leg muscle	1100	4600	13 000
Brain	750	750	750
Kidneys	1000	850	700
Digestive system	1300	1100	550
Skin	500	1500	1800

A heart, brain and skin
B leg muscle, heart and skin
C gut, brain and kidneys
D gut, leg muscle and skin

Q2 The lining of the small intestines of four animals was examined. These are the diagrams that were produced. The intestines were all the same length. Deduce which of these four animals would be able to absorb most nutrients from its food.



Q3 The diagram below shows blood flowing through the tiny blood vessels of the muscles of a runner involved in a race. Select the statement about the amount of oxygen in the blood that is most likely to be true.



A It is highest at point X.
B It is highest at point Y.
C It is highest at point Z.
D The amount of oxygen present will be the same in all the blood vessels shown.

Q4 When urine is analysed, it is found to contain many different substances. The following diagram represents a possible analysis.

Urine

0.05%	ammonia
0.18%	sulfate
0.12%	phosphate
0.6%	chloride
0.01%	magnesium
0.015%	calcium
0.6%	potassium
0.1%	sodium
0.1%	creatinine
0.03%	uric acid
2%	urea
95%	water

Identify the substance that is found in the highest concentration in urine.

A sulfate
B urea
C potassium
D ammonia

Glossary

Unit 3.1

Anus: a sphincter muscle at the end of the digestive tract

Bile: a greenish liquid responsible for mechanical digestion of fats

Bolus: food rolled into a ball by the tongue

Cells: the building blocks of all living things

Digestion: the process of breaking down food into a useable form

Digestive system: the system of the body where digestion takes place

Duodenum: the first part of the small intestine

Epiglottis: the flap of skin in the oesophagus that stops food entering the windpipe

Gastric juice: a mixture of chemicals produced by cells in the stomach wall

Large intestine: the final section of the digestive tract

Liver: the largest internal organ, it produces bile

Oesophagus: the part of the digestive system that connects the mouth to the stomach

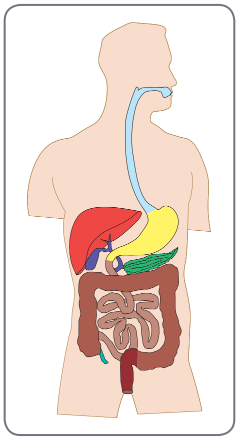
Organ: a structure that contains at least two different types of tissue that work together to complete a task

Peristalsis: the process of pushing food through the digestive tract by alternating contraction and relaxation of muscles

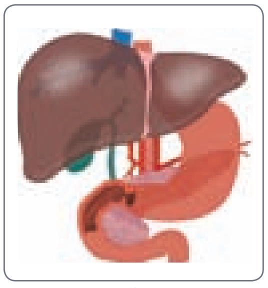
Small intestine: the longest part of the digestive tract

Sphincter: a circle of muscle

Tissue: a group of cells of the same type that carry out the same job in the body



Digestive system



Liver

Villi: microscopic 'fingers' that greatly increase the surface area of the wall of the small intestine

Unit 3.2

Alveoli: a cluster of sacs at the end of the bronchioles where gas exchange takes place

Bronchi: tubes formed by the division of the trachea

Bronchioles: small tubes formed by the division of the bronchi

Diaphragm: a sheet of muscle that separates the chest from the abdomen

Pharynx: the cavity at the back of the nose, connecting the mouth and nose to the oesophagus

Respiration: the series of chemical reactions that takes place in cells to release energy

Respiratory system: the system of organs and tissues that takes the air into the body

Trachea: the tube that carries air from the nose and mouth into the chest cavity

Unit 3.3

Angina: severe chest pain caused by lack of oxygen being supplied to heart muscle

Artery: a blood vessel that carries blood away from the heart

Capillary: the narrowest blood vessel that reaches nearly every cell of the body

Cardiac muscle: the type of muscle found in the heart

Cholesterol: a fatty chemical that can cause blockages in arteries

Circulatory system: the system that carries materials around the body; it consists of the heart, blood vessels and blood

Circulatory system

Deoxygenated blood: blood with carbon dioxide

Haemoglobin: a pigment that gives red blood cells their colour

Oxygenated blood: blood rich in oxygen

Vein: blood vessel that carries blood back to the heart

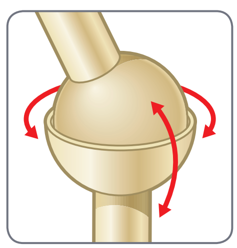
Unit 3.4

Antagonistic muscles: pairs of muscles that work in opposition to each other

Appendicular skeleton: bones that allow movement

Axial skeleton: bones that protect the organs

Ball-and-socket joint: a joint in which one bone has a ball-shaped surface that fits into a cup-shaped socket of another bone. The bone with the ball at its end is able complete all types of movement

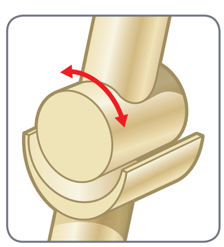


Ball-and-socket joint

Bone marrow: jelly-like material in which new blood cells are made

Bones: structures that make up the skeleton

Cartilage: tissue with a smooth and slippery surface allowing smooth movement of a joint



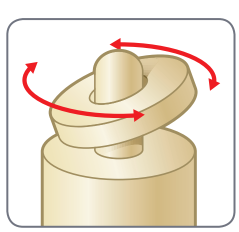
Hinge joint

Compact bone: dense tissue forming the outer layer of a bone

Joint: the point where two bones meet

Hinge joint: a joint that allows movement in only one plane.

Ligaments: fibrous bands of tissue that hold bones together in a joint

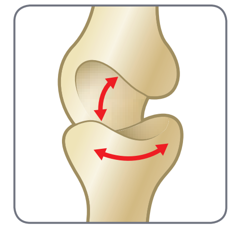


Pivot joint

Muscles: tissues that can contract and, when attached to bones, cause the bones to move.

Pivot joint: a joint like the one at the base of your skull that allows a wide range of movement.

Saddle joint: a joint that allows movement in two directions



Saddle joint

Skeleton: bony structure that holds the body upright, protects its organs and allows movement

Spongy bone: honeycombed bone structure, makes up much of the inner structure of a bone

Sprain: injury to a ligament

Strain: injury to a muscle or tendon

Synovial fluid: lubricating liquid in a joint

Tendons: elastic tissue that attaches the muscles to the bones

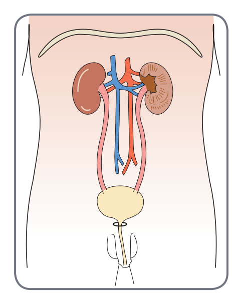
Unit 3.5

Bladder: a muscular bag where urine is stored before it is expelled from the body

Defecation: getting rid of solid waste

Excretion: getting rid of the wastes that the body has produced

Excretory system: the system in the body that gets rid of the wastes that the body has produced



Excretory system

Urea: substance formed by the liver when amino acids are destroyed

Ureters: narrow tubes that carry urine to the bladder

Urethra: a tube that carries the urine to the outside

Urinary tract: kidneys, bladder, ureters and urethra