The heart and blood vessels

KEY TERMS

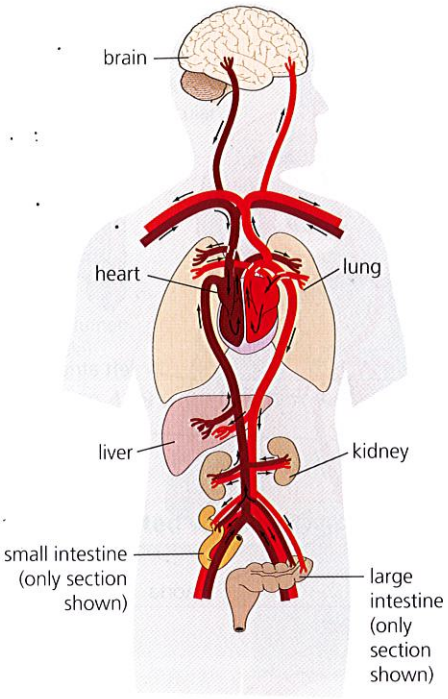
Artery A large blood vessel that takes blood from the heart.

Vein A large blood vessel that returns blood to the heart.

Capillary Blood vessel that joins arteries and veins. Substances pass through capillary walls to and from the surrounding cells.

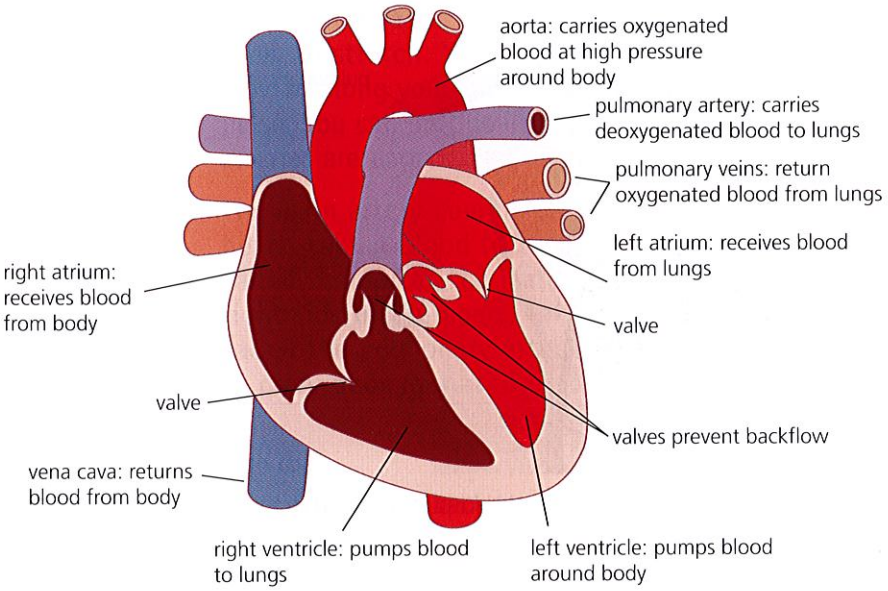
Many substances need to be moved around your body. For example, for respiration, you need oxygen and glucose to be taken to all your cells. You need the waste products of this reaction, carbon dioxide and water, to be removed. Other substances such as hormones are also needed in specific organs at specific times. All of these substances travel in the blood pumped through blood vessels by the heart. Transport is the function of your circulatory system. It is composed of:

- the heart, which pumps the blood around the body
- blood, which carries the blood cells and key molecules around your body
- **arteries**, which carry blood from your heart
- **veins**, which carry blood back to your heart
- **capillaries**, which join arteries and veins through tissues and organs.



▲ **Figure 4.13** The circulatory system, showing the main organs with which the blood exchanges substances. Dark red = blood without oxygen; red = blood containing oxygen.

The heart and double circulation

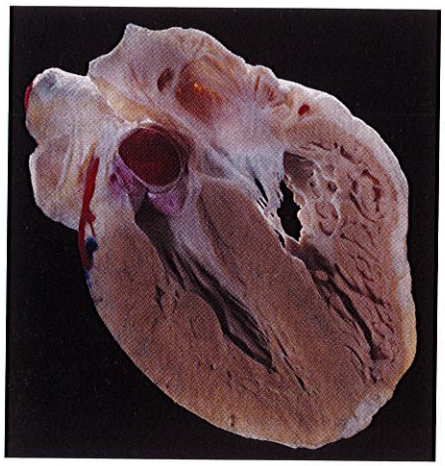


▲ **Figure 4.14** Diagram of a section through the heart. Note the positions of the valves and the wall thickness.

TIP

If you are looking at a picture of a heart in a book, the left and right sides are always labelled the opposite way around to those on your body. Pick the diagram up and put it over your heart. Now the sides should make sense.

The heart is a pump, which is responsible for pushing blood around your body. It is an organ made from muscle and nerve tissue. The muscle does the contracting and relaxing to push the blood around and the nerve tissue passes along electrical impulses to make sure the contractions happen correctly. The heart makes its own electrical impulses, which travel along its nervous tissue and cause the contractions. These electrical impulses are generated in the 'pacemaker' section, which is a small bunch of cells in the wall of the top right chamber (the right atrium). The pacemaker controls the rate of your heartbeat.



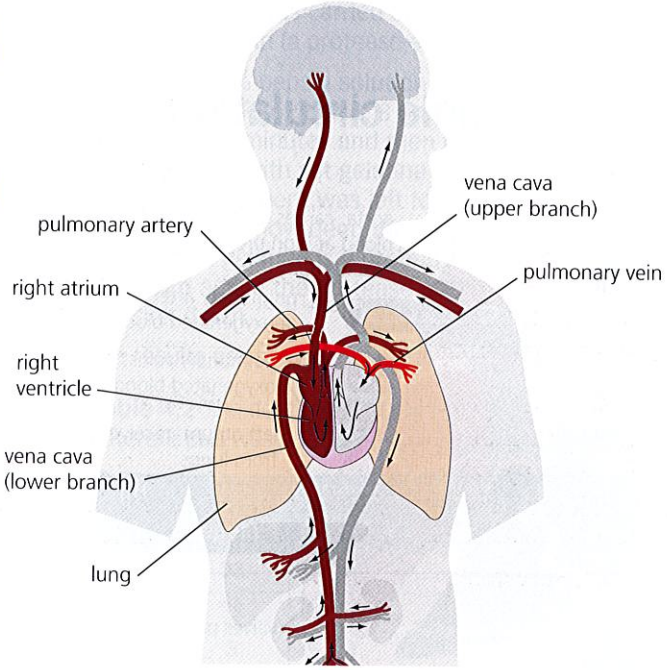
▲ **Figure 4.15** Cross-section through the heart. Note that the atria do not seem as big as shown in a diagram.

There are four chambers in your heart. The top two chambers are called the left and right atria (singular **atrium**). These collect the blood as it returns from your body. The bottom two chambers are called the left and right **ventricles**. The blood is pumped from the atria into the ventricles and then from the ventricles to the rest of the body. The blood on the left and right sides of the heart never mixes. So the blood goes through the heart twice on every circulation, which takes about 1 minute when at rest. This is called 'double circulation'.

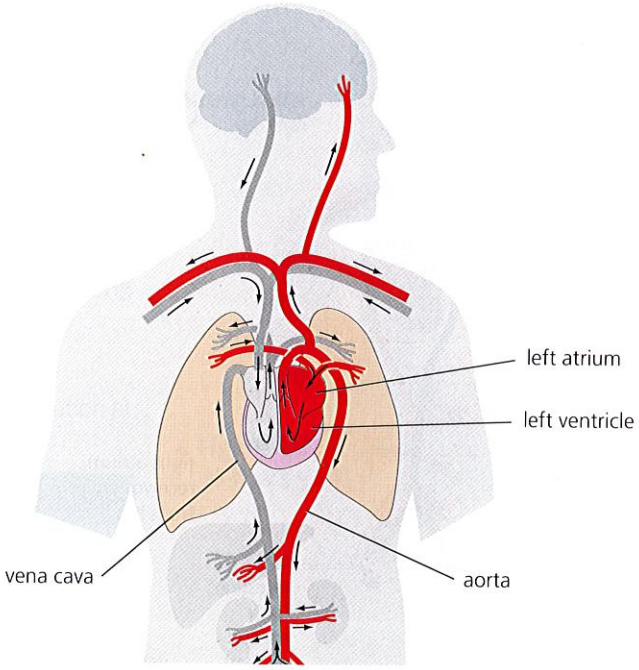
KEY TERMS

Atrium (plural atria) An upper chamber of the heart surrounded by a thin wall of muscle.

Ventricle A lower chamber of the heart surrounded by a thicker wall of muscle.



▲ **Figure 4.16** The right side of the heart pumps blood to the lungs to absorb oxygen and dispose of carbon dioxide.



▲ **Figure 4.17** The left side of the heart pumps oxygenated blood to the rest of the body.

Blood flow through the heart

Blood returns from the lungs and is collected in the left atrium. Because it has come from the lungs it is high in oxygen and low in carbon dioxide. When the heart contracts, this blood is pumped into the left ventricle. Here it is pumped a second time when the heart next contracts and goes to the rest of the body. This pushes blood high in oxygen to all the tissues and organs that need it. The blood then is taken back to the right atrium by the vena cava. Because it has been to the tissues and organs it now has low oxygen and high carbon dioxide levels. It enters the right ventricle and then is pumped to the lungs. Here diffusion removes the carbon dioxide and replenishes the oxygen. The blood then returns to where it began, the left atrium.

TIPS

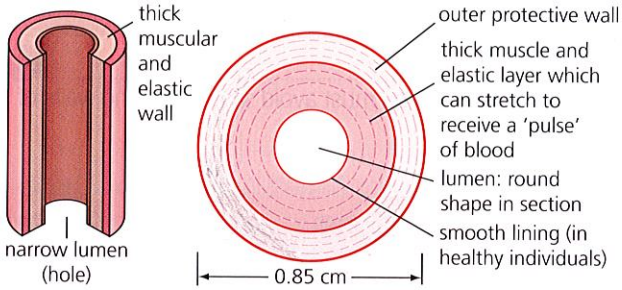
- It is important that you can explain how the structure of blood vessels relates to their function.
- Turn the text about blood flow through the heart into a flow diagram to help you remember this process. Choose a point to start from (e.g. the left atrium) and always revise the flow from this point.
- You do not need to know the names of the valves.
- When you move your arm, can you hear your biceps and triceps contracting and relaxing? Of course you can't. So why can you hear a heatbeat? It is the snapping shut of the valves in your heart that makes the characteristic 'lub dub' sound.

There are valves at the top of the atria (the base of the arteries) to stop blood being pumped backwards and to force it into the ventricles. There are also valves between the atria and ventricles to stop blood being pumped backwards into the atria when the ventricles contract.

If you look closely at the diagrams and photograph of the heart in this chapter you will see that the walls of the left ventricle are thicker than in the right ventricle. This is because the left ventricle needs to pump the blood further to the extremities of your body, whereas the right ventricle only needs to pump it to the lungs, which are much closer.

The blood vessels

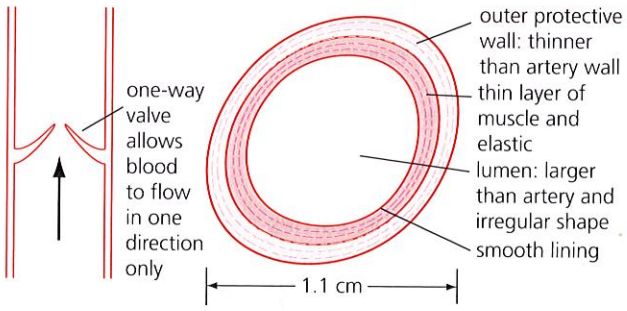
There are three types of blood vessel. Arteries move blood from the heart, veins take it back to the heart and capillaries carry it within tissues and organs.



▲ **Figure 4.18** Note the thickness of the artery wall.

KEY TERM

Deoxygenated Without oxygen.



▲ **Figure 4.19** Note the irregular shape and the thinner muscle and elastic layer of the vein.

Arteries

Arteries must cope with the blood under high pressure, as it has just been pumped from the ventricles. Because of this they have thick walls made from elastic and muscle tissue. This allows them to stretch. You can feel the surges of blood moving along your main arteries when you feel your pulse. You can do this in your wrist and neck, where arteries are particularly near the body surface.

The main artery coming from the left side of the heart, taking blood to the tissues and organs, is called the aorta. The main artery coming from the right side of the heart, taking blood to the lungs, is called the pulmonary artery. This is the only artery to carry **deoxygenated** blood.

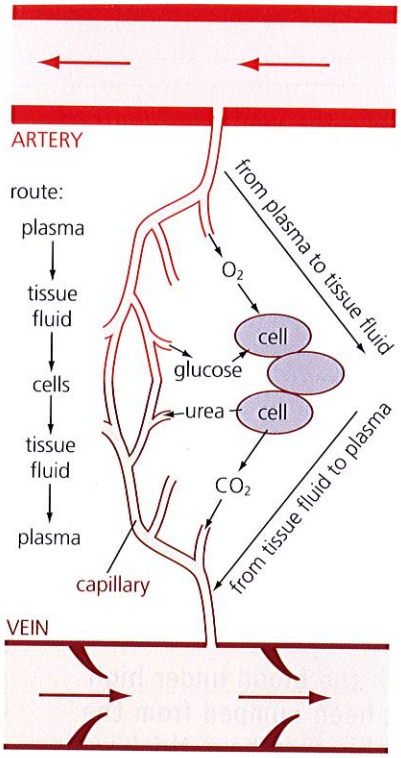
Veins

Veins carry blood back to the heart at low pressure. This pressure has been lost as the blood travels through the arteries and capillaries. Veins also have to carry blood back to the heart against gravity from the lower parts of your body. Veins are wider than arteries but have much thinner walls. They have one-way valves to keep blood flowing in the correct direction. These are not present in arteries.

TIPS

Arteries carry blood **A**way from the heart.

You only need to know the names of the aorta, pulmonary artery, pulmonary vein and vena cava.



▲ **Figure 4.20** Exchange between the blood and tissue cells in a capillary network.

KEY TERM

Blood plasma The straw-coloured liquid that carries our blood cells and dissolved molecules.

The main vein returning blood to the left side of the heart from the lungs is called the pulmonary vein. This is the only vein to carry oxygenated blood. The main vein returning blood to the right side of the heart from the tissues and organs is called the vena cava.

Capillaries

Capillaries are tiny blood vessels that spread out like the roots of a plant through your tissues and organs (including the heart muscle). You have billions and billions of these. They are extremely thin to allow as much oxygen as possible to diffuse from the blood into the cells and as much carbon dioxide as possible to diffuse the opposite way.

Blood plasma passes through capillary walls into the tissues (carrying oxygen and glucose with it), where it is called tissue fluid. This bathes the cells and helps provide them with the oxygen, glucose and other molecules they need. Waste products such as carbon dioxide pass into the tissue fluid and then into the blood.

TIP

Because animal cells do not have a cell wall you must avoid saying that the walls of capillaries are one cell thick.

Test yourself

9 In which direction does blood flow in arteries?
10 Name the two types of chamber in the heart.
11 Describe how veins are adapted for their function.
12 Describe why the left side of the heart is bigger than the right side.

Show you can...

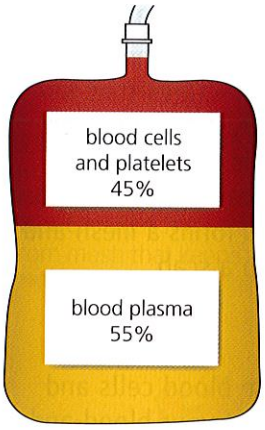
Explain how blood moves around your body from the left ventricle.

Blood

Blood looks red because it is the liquid that carries red blood cells and other cells and substances around your body. These include the products of your digestive system: glucose, amino acids, fatty acids and glycerol. These also include the gases oxygen and carbon dioxide from your lungs. Other molecules, including hormones and waste products, are also carried in your blood.

TIP

Blood is never blue, even if some books show it as being this colour in diagrams. It sometimes looks blue when the walls of vessels are looked at through your skin. If blood is oxygenated it is bright red and if not it is a darker red.



▲ **Figure 4.21** About 55% of blood is a pale yellow liquid called blood plasma. The other 45% is made up of red and white blood cells and platelets.

Components of blood

Red blood cells

The red blood cells are what give our blood its red colour. In a cubic centimetre of blood there are approximately five thousand million red blood cells.

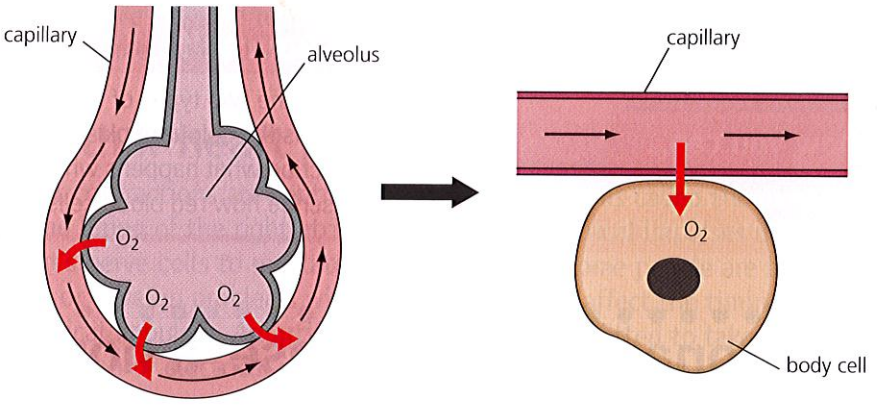
Red blood cells contain a substance called **haemoglobin**. This binds with the oxygen that diffuses into your blood in the alveoli. When it is carrying oxygen, it is called **oxyhaemoglobin**, and it turns the colour of the red blood cells from dark red to a brighter red. These red blood cells then move through arteries and capillaries to the organs and tissues that need the oxygen. Here oxygen diffuses from the red blood cell in a reverse of the reaction in the lungs. Red blood cells are adapted for carrying oxygen in many ways. Their biconcave shape gives a high surface are to volume ratio, and having no nucleus means there is more room for haemoglobin.

KEY TERMS

Haemoglobin The protein in red blood cells that can temporarily bind with oxygen to carry it around your body.

Oxyhaemoglobin The name given to the substance formed when haemoglobin in your red blood cells temporarily binds with oxygen.

▲ **Figure 4.22** The biconcave shape of red blood cells maximises their surface area to volume ratio.



▲ **Figure 4.23** Haemoglobin transports oxygen from the lungs to other organs as oxyhaemoglobin in the blood.

TIP

It is important that you can recognise images of different blood cells and explain how they are adapted to their function.

KEY TERMS

Phagocyte A type of white blood cell that engulfs pathogens.

Lymphocyte A type of white blood cell that produces antibodies to help clump pathogens together to make them easier to destroy.

Antibody A protein produced by lymphocytes that recognises pathogens and helps to clump them together.

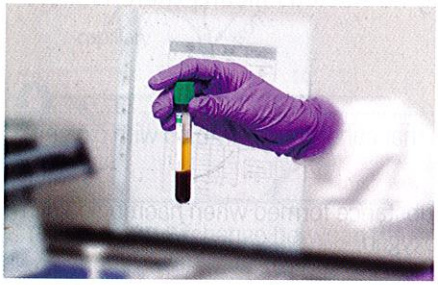
White blood cells

White blood cells are part of your immune system, and they fight off invading pathogens (disease-causing microorganisms, such as bacteria). In a cubic centimetre of blood there are approximately 7.5 million white blood cells. Unlike red blood cells, white blood cells have a nucleus. There are two types of white blood cell. **Phagocytes** engulf pathogens and use enzymes to break them down. **Lymphocytes** produce **antibodies** to help clump pathogens together for phagocytes to destroy.

KEY TERM

Platelets Small structures (not cells) in your blood that fuse together to form a scab.

▲ **Figure 4.24** A white blood cell among many red blood cells.



▲ **Figure 4.25** Blood after it has been spun in a centrifuge to separate the cells at the bottom from the plasma at the top.

Show you can...

Explain the functions of the components of your blood.

Platelets

Platelets are cell fragments. In a cubic centimetre of blood there are approximately 350 million platelets. They are small structures that join together to form a scab when you cut yourself. Shortly after your skin is cut platelets start the clotting process. They do this by releasing chemicals called clotting factors. These turn a chemical called fibrinogen, which is found in your blood plasma, into fibrin. This forms a mesh and acts as a glue to help stick platelets together to form a scab.

Blood plasma

Plasma is a straw-coloured liquid that red and white blood cells and platelets are suspended in. It makes up about 55% of your blood and in turn is made from over 92% water. You have about 3 litres of blood plasma in the 5 litres of total blood. Many molecules that your cells need, such as glucose and amino acids, and those that are waste, such as carbon dioxide and urea, dissolve in your plasma.

TIP

Squeezing a spot is a good opportunity to remember the parts of the blood! First you get white blood cells, then plasma and finally red blood cells. If you leave it for a while, platelets start to form a scab.

Test yourself

13 Name the two types of white blood cell.
14 What is the colour of plasma?
15 Describe what happens when red blood cells meet oxygen in the lungs.
16 Describe how red blood cells are adapted to their function.

Coronary heart disease: a non-communicable disease

KEY TERMS

Coronary arteries Arteries that supply the heart muscle with oxygenated blood.

Atherosclerosis A medical condition resulting from an unhealthy lifestyle that reduces the flexibility of arteries.

Cholesterol An important biological molecule for cell membranes but leads to atherosclerosis if found in high levels in the blood.

The heart is a large muscle that contracts to push blood through the blood vessels all around your body. But the muscle (and nerve) cells that make up the heart organ need to respire themselves to keep on contracting and relaxing. In order to do this they must be supplied with oxygenated blood. This comes through the **coronary arteries**. Glucose and oxygen diffuse from the blood in these arteries and their capillaries into the cells of the heart.

An unhealthy lifestyle can cause a build-up of fatty material in the coronary arteries and a reduction in the flexibility of the artery lining (**atherosclerosis**). This is caused by high blood pressure, smoking and drinking excessive amounts of alcohol. Two other factors are **cholesterol** and poor diet. These fatty deposits slow or stop the oxygenated blood reaching the cells of the heart. This can cause cells to die and eventually lead to a heart attack.

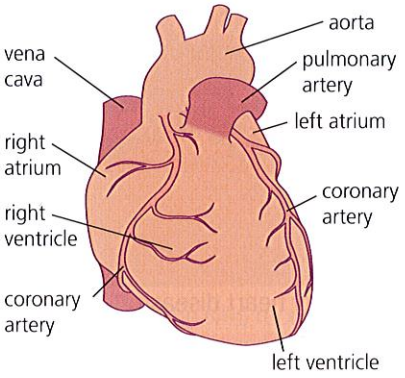
KEY TERMS

Heart bypass A medical procedure in which a section of less important artery is moved to allow blood to flow around a blockage in a more important one.

Stent A small medical device made from mesh that keeps arteries open.

In recent years coronary heart disease has become one of the major causes of death in the world. The traditional treatment for this was a **heart bypass** operation, in which a small section of artery is moved from another part of the patient's body to short circuit the blockage in the coronary artery. Now more patients are being treated by using less invasive **stents**. These are small devices made from mesh that are inserted into the arteries to keep them open. This operation is less dangerous and faster to recover from than a heart bypass.

Eating a balanced diet, stopping (or not starting) smoking, reducing alcohol intake, maintaining a healthy weight and regular exercise all reduce the risk of coronary heart disease. Drugs such as statins are also prescribed by doctors to reduce blood cholesterol, which in turn reduces the risk of coronary heart disease.



▲ **Figure 4.26** The coronary arteries serve the heart muscle tissue.

Faulty valves

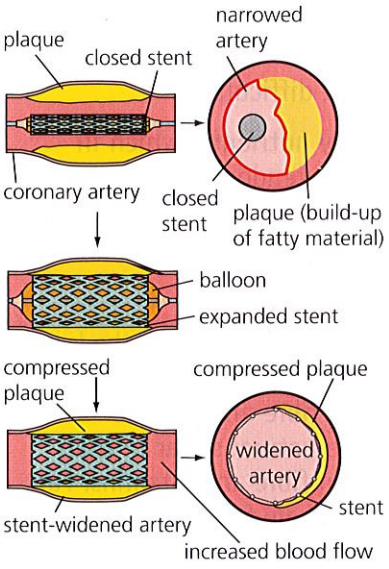
The heart has four valves inside it to stop blood flowing backwards. Any flow of blood backwards reduces the efficiency at which blood flows around the body. This means that fewer glucose, oxygen and other molecules reach the cells that need them.

Valves that are faulty might not open properly or not close completely to stop backflow. This may cause breathlessness, tiredness, dizziness and chest pain for the patient. The most common form of treatment for severe cases is replacement of the valves during open-heart surgery. These valves can be replaced by valves from donors (biological) or artificial mechanical valves.

Other heart problems

Heart contractions are controlled by a bundle of cells called the pacemaker in the lining of the right atrium. These send electrical impulses down the heart's nerve cells to regulate the contractions. Some people are born with or develop problems with these cells, which affect the timing of the electrical impulses. An artificial pacemaker can be fitted to take over the generation of electrical impulses.

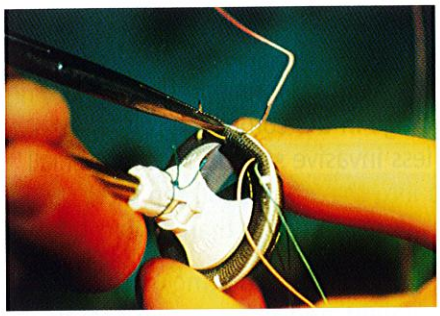
A small number of babies are born with a 'hole in the heart'. This is a small gap between the two sides of the heart, which means that deoxygenated blood in the right side can mix with oxygenated blood in the left. This also reduces the amount of glucose, oxygen and other molecules that reach the cells that need them. The small hole is repaired during an operation.



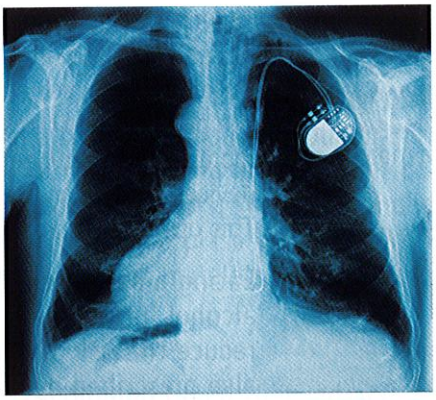
▲ **Figure 4.27** This stent allows blood to flow freely again.

Transplants

Heart failure is when a person's heart stops beating. If this happens, or is likely to happen, a person usually requires a heart or heart-and-lungs transplant. These are the most serious of all operations described in this section. As with all transplants, a match between the donor and the patient must be found to stop the transplant being rejected by the patient's immune system. Often patients are on long waiting lists until a suitable donor is found.



▲ **Figure 4.28** An artificial carbon-fibre heart valve.



▲ **Figure 4.29** An X-ray showing a pacemaker connected to a patient's heart.

TIP

- It is important that you appreciate that some people have religious or ethical objections to the use of human or animal tissue for transplants.
- It is important that you can evaluate the advantages and disadvantages of treating coronary heart disease by drugs, mechanical devices or transplants.

Test yourself

17 Define the term 'atherosclerosis'.
18 Name the three types of blood vessel.
19 Describe the function of the pacemaker.
20 Describe how to reduce the chances of coronary heart disease.

Show you can...

Explain the difference between using stents and bypass operations, including which one doctors prefer to use and why.

Health issues

Health is defined as the state of physical and mental wellbeing. So being healthy means you are mentally as well as physically fit. Both physical and mental health can be maintained or improved by:

- a well-balanced diet
- regular exercise
- reducing stress
- seeking medical help for mental or physical difficulties.

A well-balanced diet will provide you with key nutrients, which in turn help you strengthen your muscles, bones, tendons and lower your chances of developing some types of cancer.

▲ **Figure 4.30** A balanced diet represented as a food pyramid.

Well-balanced diet

A well-balanced diet means that you have the correct amount of the key food groups. This is often shown in a food pyramid, as shown in Figure 4.30. Vegetables are low in fat, high in fibre and provide your body with key vitamins. Fruits have more natural sugar in than vegetables, but are also low in fat, and high in fibre and vitamins. Fats should only be consumed in lower quantities and are found in fish and nuts as well as many processed foods. Dairy products include milk, yoghurt and cheese. These are high in protein and some vitamins but also fats and cholesterol. Recent research suggests that these negative effects of dairy