Unit **1A**

Chapter 6

The transport system

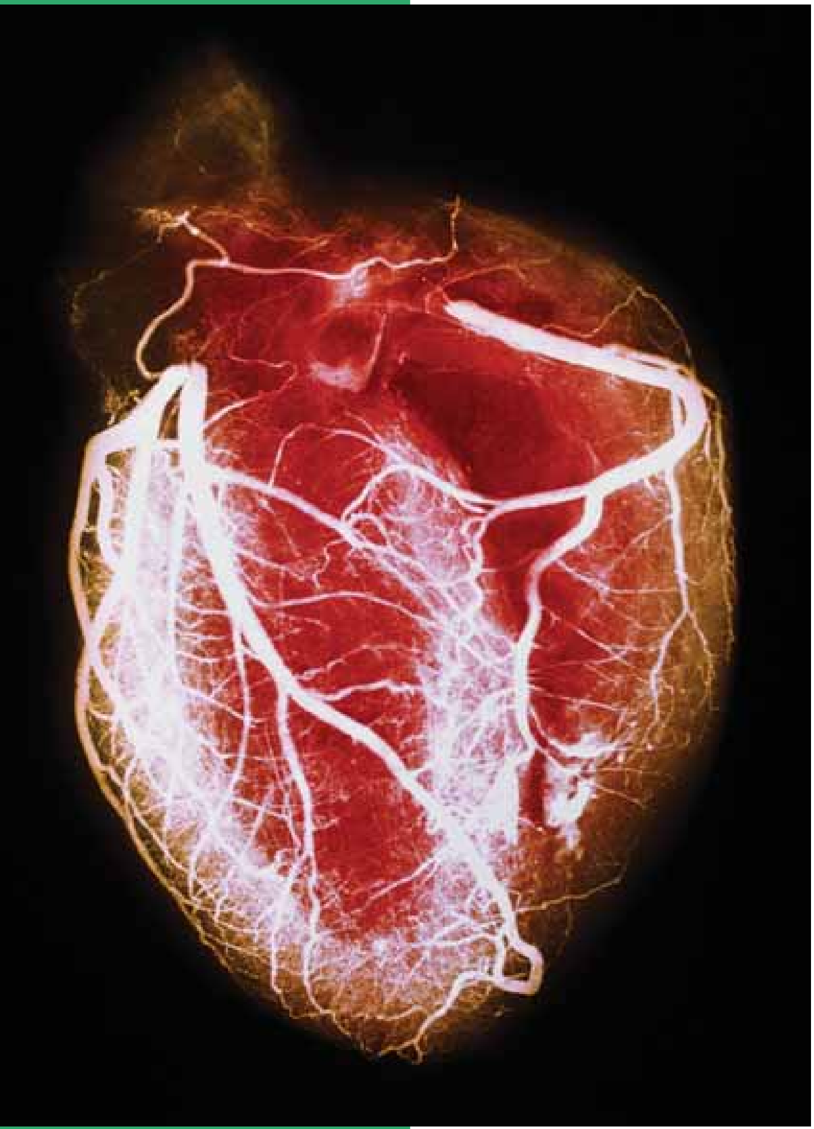


Figure 6.1 Blood vessels supplying the heart muscle

Unit content

Body systems

The body is organised from cells to tissues, organs and systems. The major body systems are the digestive, excretory, skeletal, muscular, respiratory, circulatory, nervous, endocrine, immune and reproductive systems and are related to the life processes.

Organisation:
- hierarchy of organisation in the body
- location of organs associated with each body system in the body.

Functions:
- function of each organ system related to life processes.

The cells in the muscles of your big toe are a long way from the lungs, the place where oxygen is taken into the body. Your brain cells are some distance from your intestines, where nutrients are taken into the body. Your kidneys remove waste that is produced by cells all over the body. Any large multi-cellular organism, like a human, must have a transport system to carry materials to and from cells in every part of the body. The body's transport system is the circulatory system.

The circulatory system

The circulatory system is made up of the heart, the blood vessels and the blood. Transported materials are carried in the blood, which is pumped by the heart through the blood vessels.

For an animation showing the circulation go to http://www.kscience.co.uk/animations/blood_system.swf

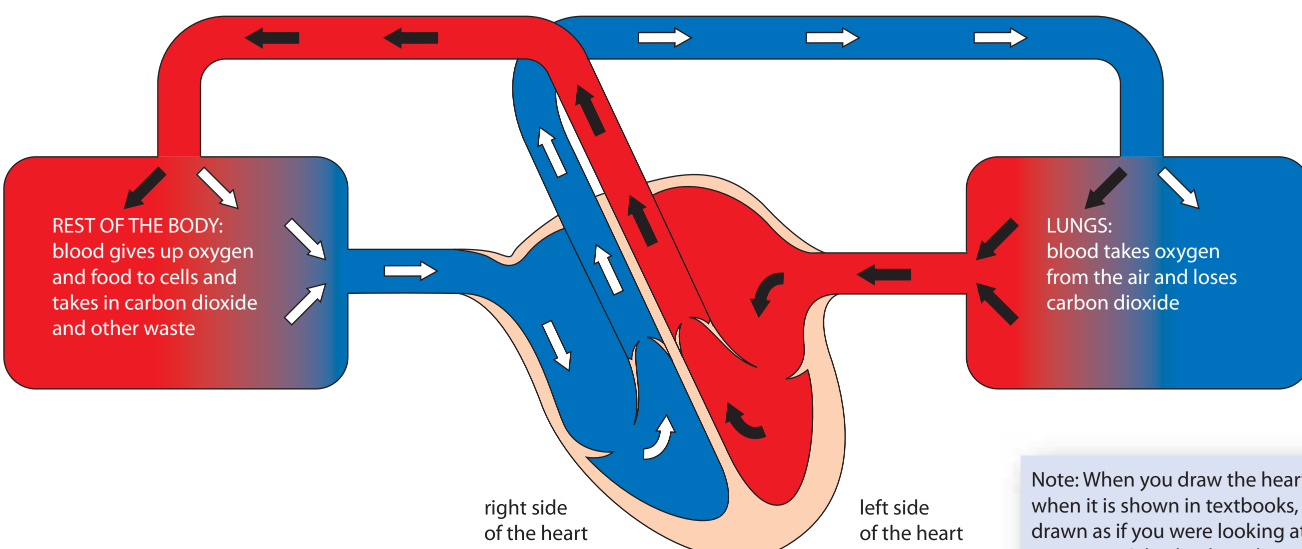
The heart

The heart pumps blood to the lungs and to the body. As the blood flows through the tiny blood vessels in the lungs or the body, it loses most of its pressure. After going through the lungs, the blood pressure is so low that the blood must return to the heart to be pumped again before going to the rest of the body.

More about heart structure can be seen at http://www.trinityqc.com/files/flash/heartanat.swf

Thus, the heart is really a double pump—the right side of the heart pumps blood to the lungs and the left side pumps blood to the body. This is shown in Figure 6.2.

Figure 6.2 The circulation



Note: When you draw the heart, or when it is shown in textbooks, it is drawn as if you were looking at it in a person's body. Thus, the right side of the heart is on the left of the drawing

The heart is in the middle of the chest above the diaphragm. The bottom tip of the heart is on the left, so although the heart is in the middle of the chest, you can feel it beating more on the left side (see Fig 6.3).

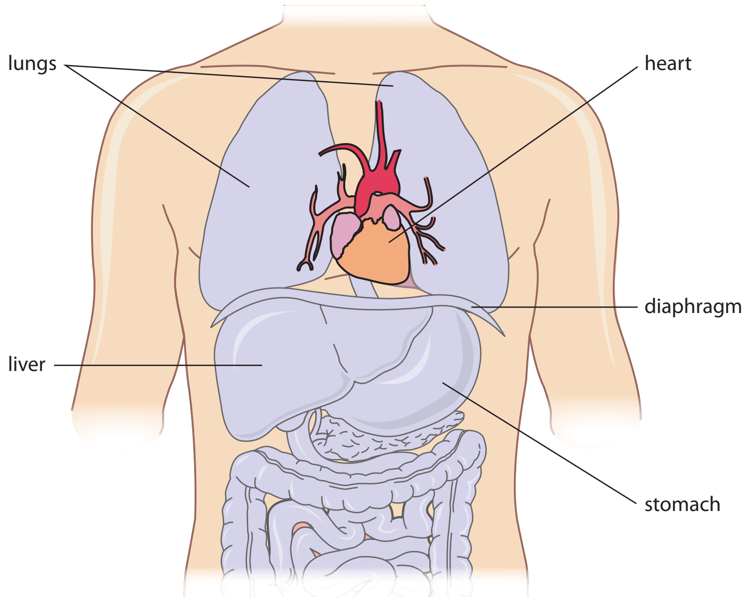


Figure 6.3 The position of the heart

The heart is hollow and the walls are made of **cardiac muscle** (heart muscle). **Arteries** take blood away from the heart and **veins** carry blood into the heart. Figure 6.4 shows the structure of the heart and the functions of the various parts.

Valves in the heart make sure that the blood can only flow in one direction. Between the atria and the ventricles are the **atrioventricular valves**. These are flaps of thin tissue with the edges held by tendons. When the ventricles contract, the blood catches behind the flaps and they billow out, like a parachute, sealing off the opening between the atria and the ventricles. Blood must then leave the heart through the arteries (Fig 6.5).

Where the arteries leave the heart is a second set of valves that stop blood from flowing back into the ventricles when the ventricles relax. These are the

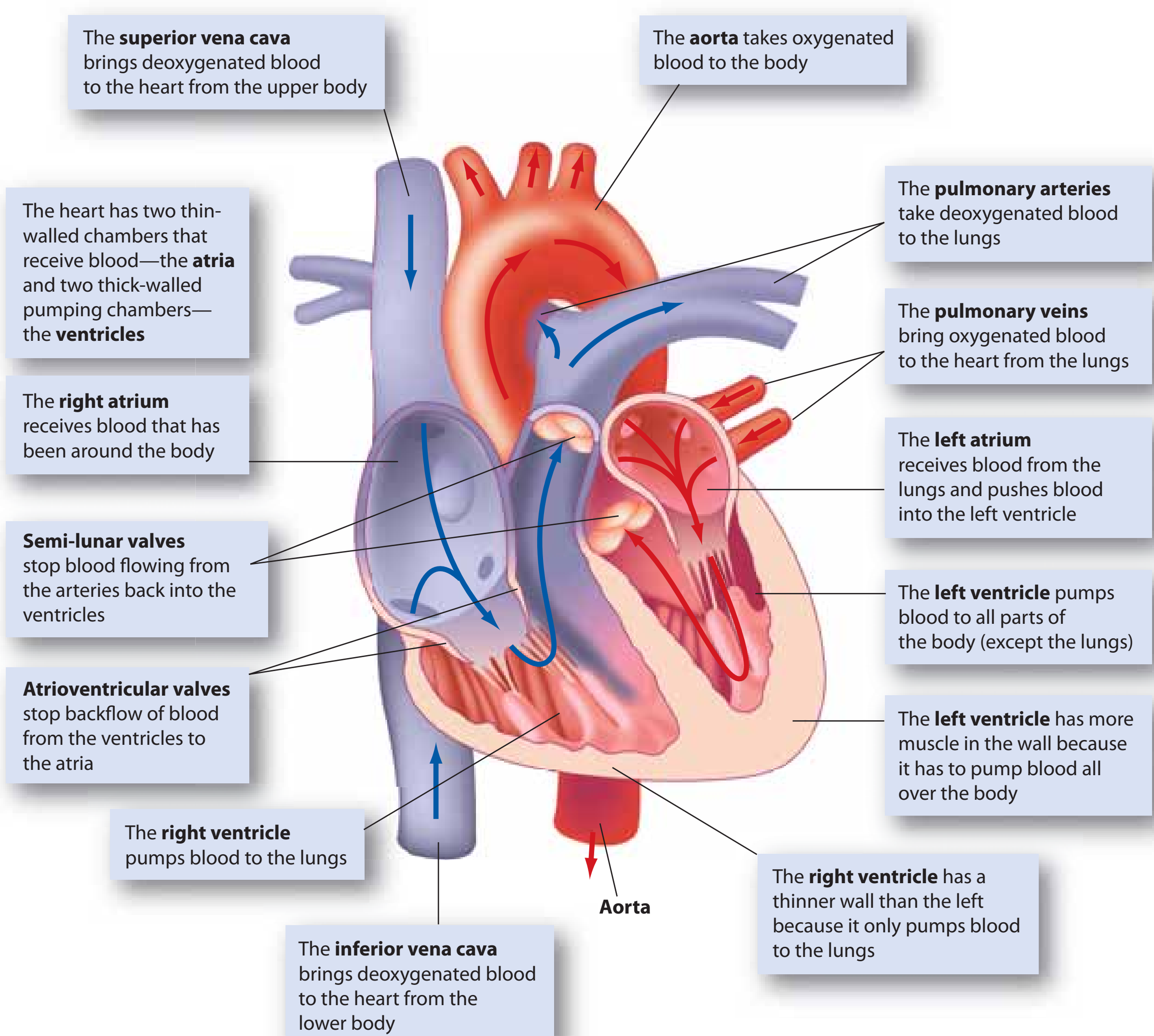


Figure 6.4 The structure of the heart and the functions of its parts

semi-lunar valves. Each semi-lunar valve has three cups. When blood flows into the artery the cups are pressed flat against the artery wall. When blood tries to flow back into the ventricle, the cups fill out and seal off the artery (see Fig 6.6).

Heart beat

In the average adult the heart beats about seventy-two times per minute. This means that each complete beat lasts about 0.8 second. Contraction of the atria takes about 0.1 second. It is followed by contraction of the ventricles, which takes about 0.3 second and then, for about 0.4 second, both the atria and ventricles are relaxed (Fig. 6.7).

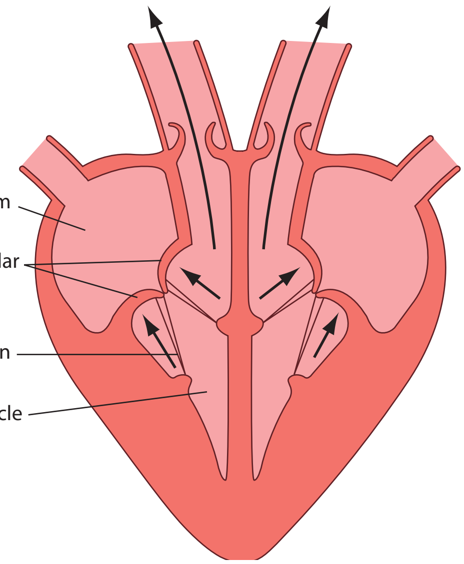


Figure 6.5 The working of the atrioventricular valves: when the ventricles contract the flaps of the valve are pushed up as far as the tendons will allow and blood cannot flow back into the atria

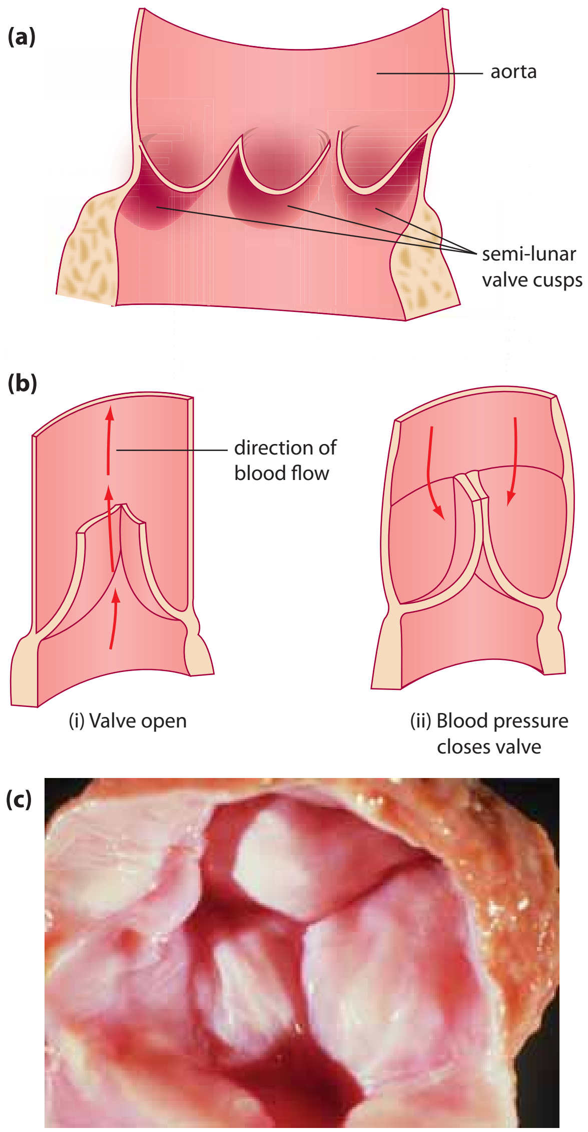


Figure 6.6 An artery cut open to show:
(a) the three cups of the semi-lunar valves;
(b) the action of the semi-lunar valves;
(c) photograph showing a semi-lunar valve in the closed position

For an animation showing the beating heart go to http://www.kscience.co.uk/animations/heart.swf
For one with explanations go to http://www.ahealthyme.com/Imagebank/heart.swf

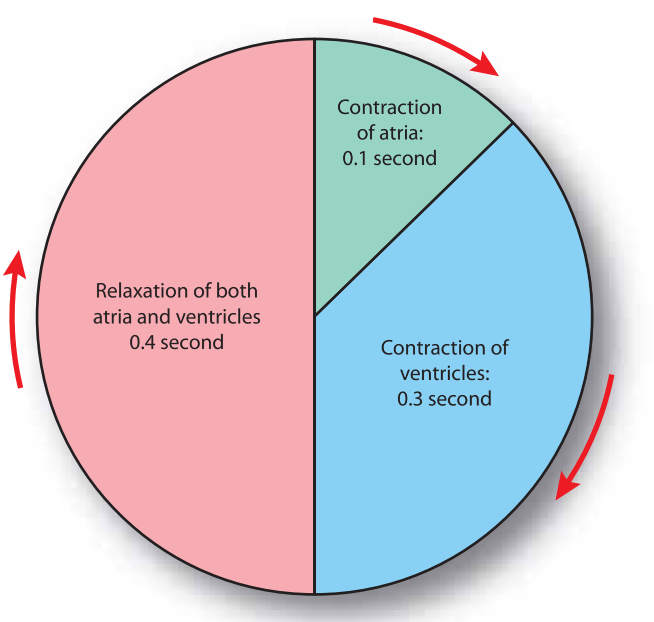


Figure 6.7 One heart beat

Blood vessels

Arteries carry blood away from the heart. The pressure of blood in the arteries is high because blood is pumped into them by the ventricles. As the ventricles contract the pressure increases, making the walls of the arteries stretch. This stretching of the artery wall can be felt as the **pulse** in the wrist, neck or at other places on the surface of the body. Due to the high blood pressure artery walls must be thick and because the pressure is not constant they must be elastic.

The large arteries divide into smaller and smaller arteries that eventually end in capillaries. **Capillaries** are microscopic blood vessels that form a network through the tissues. They carry the blood close to the cells so that the cells can get oxygen and nutrients and can get rid of their waste. The walls of capillaries are only one cell thick so that substances can easily pass into, and out of, the blood (see Fig. 6.8).

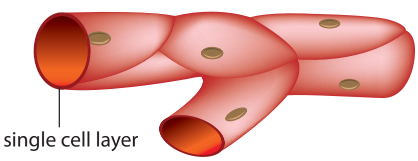


Figure 6.8 A blood capillary showing the wall consisting of a single layer of cells

Veins carry blood towards the heart. The capillaries join into small veins that then join up to make larger veins. Blood pressure in the veins is relatively low because the blood loses most of its pressure as it flows through the tiny capillaries. The walls of veins are therefore much thinner than those of arteries (see Fig 6.9); also, the pressure in veins is constant so the walls do not have to be elastic. Because of the low blood pressure many veins have valves to prevent the blood from flowing backwards. Figure 6.10 shows how the valves in the veins work.

Figure 6.9 A transverse section of an artery (right) and a vein (left) showing the difference in the thickness of the walls

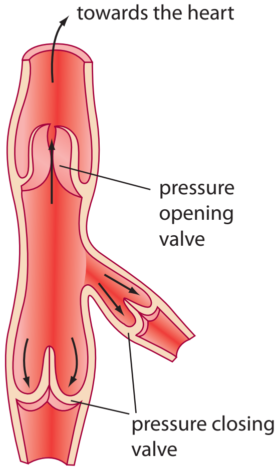


Figure 6.10 Diagram of the valves in a vein

Table 6.1 Differences between arteries and veins

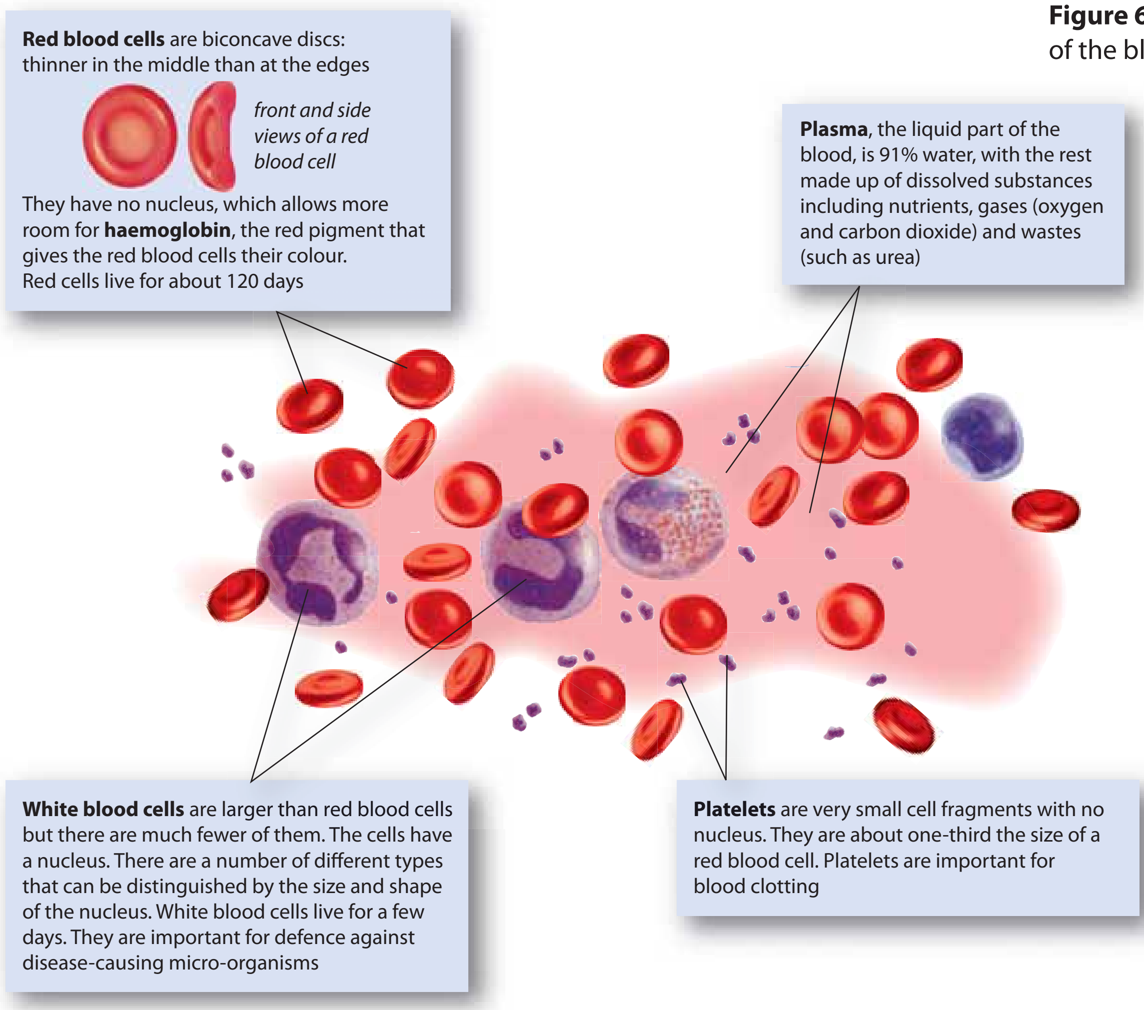
Arteries	Veins
Carry blood away from the heart	Carry blood towards the heart
Have a blood pressure that is high when the ventricles contract and lower when the ventricles relax	Have a constant, relatively low blood pressure
Have thick, muscular, elastic walls	Have thin walls that are not elastic and have little muscle
Have no valves	Often have valves

Blood

Blood is a fluid tissue. The matrix of blood, the material between the cells, is a liquid called plasma. Blood **plasma** makes up about 55% of the volume of the blood. The other 45% is made up of cellular material. Of the cellular material, the most numerous are the red blood cells. There are also white blood cells and platelets (see Figs 6.11 and 6.12).

For more about blood and blood disorders go to http://kidshealth.org/parent/general/body_basics/blood.html

Figure 6.11 The structure of the blood



Red blood cells contain a red substance called **haemoglobin**. In places where there is plenty of oxygen, such as in the lungs, haemoglobin combines with the oxygen to form **oxyhaemoglobin**. Most of the oxygen in the blood is carried by the red cells as oxyhaemoglobin. In places where there is less oxygen, such as in the tissues where cells are using up oxygen, oxyhaemoglobin breaks down and releases its oxygen.

White blood cells are able to leave the blood capillaries and go through the tissues to areas that are infected by micro-organisms. The cells are able to change their shape and surround bacteria, dead cells or cell fragments. These particles are taken into the cell and destroyed (see Fig. 6.13).

Platelets are tiny fragments of cells that have no nucleus. If blood vessels are damaged, such as by a cut or other injury, the platelets release enzymes that begin the process of blood clotting.

Learn more about blood, the heart and blood vessels at http://www.fi.edu/learn/heart/index.html

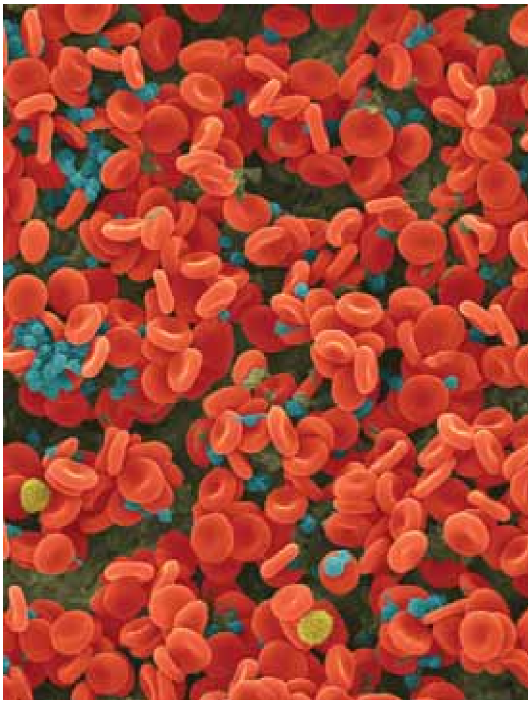


Figure 6.12 Scanning electron micrograph of blood showing red cells, white cells (yellow) and platelets (blue)

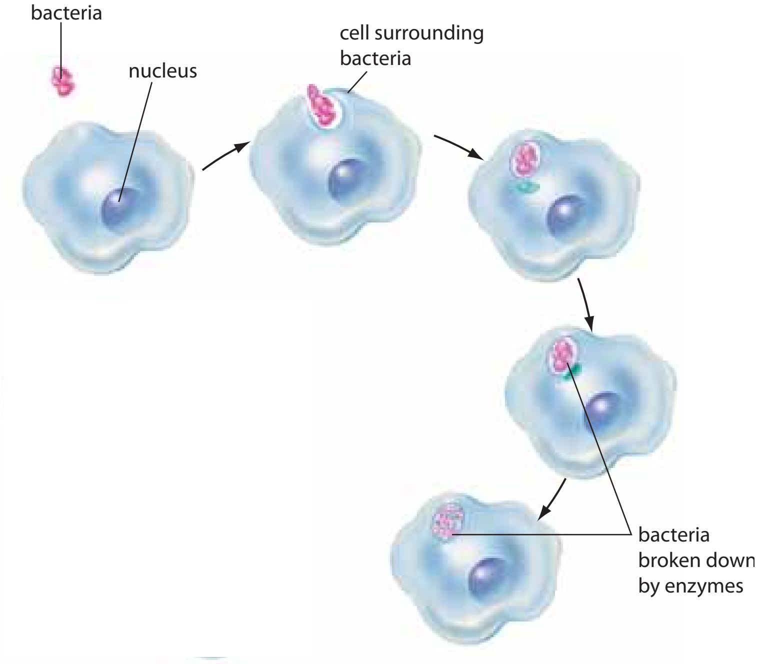


Figure 6.13 White blood cells taking in and destroying bacteria

Some disorders of the circulatory system

Anaemia

Anaemia occurs when the number of red cells in the blood, or the amount of haemoglobin, is lower than normal. Because of the lack of red cells, or haemoglobin, anaemic blood cannot carry as much oxygen as usual and the tissues do not get enough oxygen. Oxygen is needed for the chemical reactions that release energy in the cells. Anaemia is therefore accompanied by fatigue, tiredness and lack of energy. The skin may appear pale because of the reduced amount of haemoglobin in the blood.

Some of the causes of anaemia are:

- loss of large quantities of blood, such as from large wounds, ulcers of the stomach or intestine, or severe menstrual bleeding
- iron deficiency, due to insufficient iron in the diet or poor absorption of iron in the alimentary canal; each haemoglobin molecule contains four iron atoms, and without sufficient iron, haemoglobin production is reduced
- inability to absorb adequate amounts of vitamin B_{12} from the alimentary canal: vitamin B_{12} is required for the normal development of red blood cells (this type of anaemia is called **pernicious anaemia**)
- inherited genes resulting in abnormal haemoglobin.

Leukaemia

Leukaemia is a form of cancer where there is uncontrolled production of abnormal white blood cells. These white blood cells prevent red blood cell production, which results in anaemia.

Bruising

A **bruise** results from an injury that damages capillaries so that blood leaks into the surrounding tissue. The bruise usually begins as a dark blue or crimson colour due to the haemoglobin in the damaged tissues. As the haemoglobin breaks down it forms substances that are greenish or yellow-brown in colour.

Hardening of the arteries

Hardening of the arteries is a degeneration of the walls of the arteries. It includes changes such as the loss of elasticity of the artery walls, the narrowing of the diameter of the arteries, and the development of any roughness or obstruction of the artery wall. The roughening and obstruction of the artery wall may lead to a heart attack or stroke.

Heart attack

A **heart attack** occurs when blood flow to a part of the heart muscle is stopped completely. The affected part of the heart muscle does not get enough oxygen to function normally.

Deep vein thrombosis

Thrombosis means the formation of a blood clot in a blood vessel or in the heart. A deep vein thrombosis (DVT) is a blood clot that forms in a vein, usually in the lower leg or thigh. Deep veins run through the centre of the leg and are surrounded by muscle. If the clot is large, it may partly or totally block the flow of blood through the vein. This can lead to pain and/or swelling in the leg and may damage the valves in the vein.

Serious problems can occur if part of the clot breaks away and is carried in the blood to lodge in the heart, brain, lungs or other vital organ. Severe damage to the organ or even death can occur.

Some of the factors that increase the risk of DVT are:

- being aged over 40 years
- having had recent surgery, especially to the hips or knees
- obesity
- sitting for long periods, such as on long air flights or bus trips.

Working scientifically

Activity 6.1 Heart structure

Although the hearts of mammals differ greatly in size, they are all basically similar. This activity will help you to learn about the structure and functioning of your own heart.

Your teacher may wish you to dissect a mammal heart yourself, may demonstrate the dissection or may refer you to a video for this activity.

You will need

Heart of a sheep, pig or cow; dissecting board; dissecting instruments; disposable gloves

What to do

Refer to Figure 6.4 as you do the activity.

1. Identify the four chambers of the heart. Part of each atrium may have been removed when the heart was cut from the animal.
2. Identify the left and right sides of the heart. Feel the ventricle walls—the left ventricle has a much thicker wall and feels much firmer than the right ventricle. Also, the tip of the heart is part of the left ventricle.
3. Identify the aorta and the artery to the lungs. Look for the pulmonary veins and venae cavae (veins from the body) but they may have been cut off by the butcher.
4. Do step 1 of 'Studying your observations'.
5. Follow your teacher's instructions to cut open the heart. This involves identifying the groove on the outside of the heart that marks the division between the left and right ventricles, then cutting open the left ventricle along a line parallel to and about 2 cm from the groove.
6. Open the ventricle and locate the flaps of the valve between the atrium and the ventricle. Note the tendons attached to the edges of the flaps.
7. Continue your cut through the wall of the atrium and through the wall of the aorta. Open out the aorta and locate the three cups of the semi-lunar valve. These will be close to where the aorta leaves the ventricle. You may have cut through one of the cups.
8. Open the right side of the heart in a similar way and identify all the structures on that side.

Studying your observations

1. Arrange the heart as you would see it if you were looking at it in a person's chest. Draw the heart and label all the external features.
2. Measure the thickness of the wall of each of the four heart chambers. List the chambers in order from that with the thinnest wall to that with the thickest wall.
3. In your own words describe the appearance of the atrioventricular valves. Are there any differences between the left and right atrioventricular valves?
4. Describe the appearance of the semi-lunar valves. Are there any differences between the semi-lunar valves of the aorta and those of the pulmonary artery?
5. Describe any differences that you observed between the veins and arteries.
6. Why does the heart have two types of chamber—atria and ventricles?
7. Why does the heart have two of each chamber—two atria and two ventricles?

Activity 6.2 Observing capillaries

Your teacher may demonstrate, or you yourself may observe, the blood flowing through capillaries in the tail of a small fish such as a goldfish or Gambusia.

1. Place the fish in half a Petri dish and cover the front half of the animal with wet cotton wool. Put the Petri dish on the stage of a microscope. Using the lowest magnification, focus on the tip of the fish's tail. Do not keep the fish out of water for more than three minutes.
2. Describe what you saw.

3. How did the diameter of a blood cell compare with the diameter of the smallest capillary?

Activity 6.3 Sense the working of your heart

1. Take your pulse by placing two fingers on the inside of your wrist where the pulse is felt most strongly. Locate the pulse in your neck by placing two fingers at the side of your neck under the jawbone. See if you can also locate a pulse in your temple.
   (a) Would the pulse rate be the same at all locations in the body?
   (b) Make a list of all the factors that you think may influence your pulse rate.
2. Place a stethoscope on your chest and listen to the heart sounds. The sounds are usually described as 'lubb-dupp'.
   (a) Do you agree with this description of the sounds or can you think of a better way to describe what you heard?
   (b) Would you expect the heart sounds and the pulse to occur at the same time? Give a reason for your answer. Check to see whether your prediction is correct.

Activity 6.4 Blood

Examining blood with a microscope will help you to appreciate and remember the structure of the blood.

You will need

Microscope; microscope lamp; prepared slide of blood smear; minigrid

What to do

1. Examine a prepared slide of a blood smear. The blood cells on this slide will have been stained. Find the cells first on low or medium power then gently change to high power. Identify each of the types of cells that you can see.
2. Use a minigrid to determine the field diameter of your microscope on low or medium power (see Activity 3.1 and Fig. 3.16 on page 32). Calculate the field diameter on high power and then estimate the diameter of a red blood cell.

Studying your observations

1. Describe the appearance of a red blood cell. What does the appearance tell you about the structure of the cell?
2. Draw a diagram showing a red blood cell and each of the types of white blood cell.
3. What is the approximate difference in size between red blood cells and white blood cells?
4. What is the approximate ratio of numbers of red blood cells to white cells?
5. Were you able to see any platelets? Suggest why platelets are difficult to see with a school microscope.

REVIEW QUESTIONS

1. Why is it necessary for the body to have a transport system?
2. The heart is a double pump. After passing through the capillaries of the body, the blood returns to the heart to be pumped again before going through the lungs. Explain why the blood must be pumped twice for each complete circulation through the body and lungs.
3. **(a)** Why are valves necessary in the heart?
   (b) Explain how the atrioventricular valves work.
   (c) Explain how the semi-lunar valves work.
4. Describe what happens in the heart during one complete heart beat.
5. List three differences between arteries and veins.
6. List three differences between red blood cells and white blood cells.
7. What is the function of:
   (a) red blood cells
   (b) white blood cells
   (c) platelets?
8. **(a)** What is anaemia?
   (b) What are the symptoms of anaemia?
   (c) What are four possible causes of anaemia?
9. Explain what happens when you bruise yourself.

APPLY YOUR KNOWLEDGE

1. List as many points as you can to show how the structure of the heart enables it to do its job of pumping blood.
2. If the heart contracts seventy times per minute, how many times does it contract in a day (twenty-four hours), and how many times in a week?
3. Which do you think is more important to the body, the heart or the capillaries? Explain your answer.
4. **(a)** Why is blood red?
   (b) Royalty is sometimes described as having 'blue blood'. See if you can find out why they are described in this way.
5. If you were on a long flight, what precautions could you take to avoid deep vein thrombosis?
6. At one time it was believed that disease was caused by 'bad blood'. Taking large amounts of blood from a sick person by bleeding (bloodletting) was widely used to try to cure disease. Louis XIII of France once had blood taken forty-seven times in six months; Louis XV was bled thirty-eight times and Charles II of England had blood taken numerous times even just before his death. Describe some of the effects that removal of large quantities of blood would have on a person.
7. People living near sea level have about 5 million red blood cells in 1 mm^3 of blood. People living at an altitude of 5500 m above sea level have about 7.5 million red blood cells per mm^3 of blood. Suggest an explanation for this difference.