Life Processes: Transport of Food and Minerals

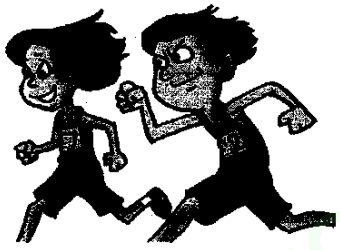
1

LEARNING OUTCOMES

- Circulatory system in humans: blood, heart, lymph, and blood vessels
- Blood transfusion and blood groups
- Pulse
- Plants: absorption, conduction, rise of cell sap, and transpiration

(a)

(b)



(c)

As we had discussed in class 7, our bodies require *energy* for carrying out various activities, such as those shown in pictures (a) to (c) above. Cells in our bodies release energy from *food* in the presence of *oxygen* through a process called respiration. For respiration to occur, food and oxygen must first be transported to different cells of the body. Do you know how this happens? How do food and oxygen reach, say, the cells in your toes?

A special organ system, called the *circulatory system*, is responsible for transporting materials such as food and oxygen from one part of the body to another. The circulatory system consists of the following parts:

(a) blood and lymph,
(b) heart, and
(c) pipelines or *vessels* that carry blood and lymph from place to place.

In this chapter we will learn about different parts of the circulatory system.

Circulatory system

- Blood and lymph
- Heart
- Blood vessels
  - Arteries
  - Veins
  - Capillaries

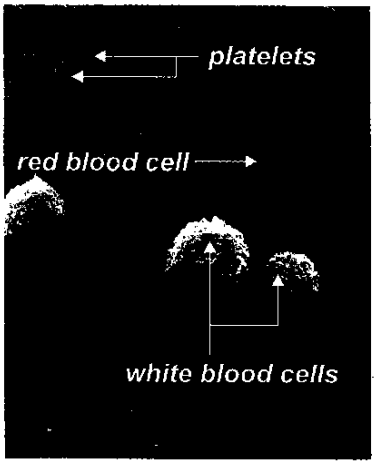


Fig. 1.1 Three types of blood cells

Blood

- Plasma (55%)
- Blood cells (45%)
  - Red blood cells (RBCs)
  - White blood cells (WBCs)
  - Platelets

TECH FILE

In addition to platelets, special proteins called clotting factors are involved in clotting blood. When a blood vessel is damaged, clotting factors help platelets to stick together and form a plug or clot at the site of injury, preventing loss of blood. Absence or low number of clotting factors can result in a rare condition called haemophilia, in which the blood of the affected person does not clot normally. People suffering from haemophilia are likely to bleed longer if they suffer an injury.

BLOOD AND LYMPH

These are fluids that transport materials to different parts of the body.

Blood

Blood is a complex liquid tissue that transports nutrients, respiratory gases, metabolic wastes, and other substances from one part of the body to another. It is not a homogeneous red liquid, as it appears to the naked eye. It consists of a straw-coloured watery part called the *plasma* (which makes about 55% of total blood volume) and the *blood cells* (which make about 45% of total blood volume). Water makes up 92% of the plasma, while the remaining 8% consists of salts, proteins, simple sugars, and fats.

Blood cells are of three types: red blood cells, white blood cells, and platelets (Fig. 1.1).

Red blood cells (RBCs) or *erythrocytes* are shaped like biconcave discs. Mature RBCs lack nuclei. A cubic millimetre of blood contains about 5 million of them. These cells carry an iron-containing respiratory pigment called *haemoglobin* that plays an important role in transporting oxygen from the lungs to different cells of the body. RBCs are formed in the bone marrow. Worn-out RBCs are destroyed in the liver and the spleen. The normal life span of RBCs is about 120 days.

White blood cells (WBCs) or *leukocytes* are of different types. They are larger than red blood cells and have large nuclei that are often lobed. The average WBC count varies from 6000 to 9000 per cubic millimetre. Unlike RBCs, these cells carry no pigment. WBCs are shapeless and are able to move on their own through intercellular spaces. They protect the body from disease-causing organisms. WBCs are produced chiefly in the bone marrow, lymph glands, and the spleen.

Blood platelets or *thrombocytes* are non-nucleated spherical or irregular bodies that are much smaller than RBCs. They are formed in the bone marrow. If blood vessels are damaged (e.g., when one suffers a cut or a wound), platelets prevent the loss of blood by forming a clot over the wound.

Find out

With the help of books/Internet, collect information on different types of white blood cells. Prepare a report based on your findings. Your report should include the name and function of each kind of white blood cell.

Functions of Blood

Blood is concerned with transportation, defense, and regulation of body functions. Let us examine each of these functions in detail.

Transportation

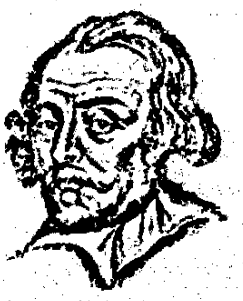
1. Blood transports respiratory gases: oxygen (from the lungs to the tissues as oxy-haemoglobin) and carbon dioxide (from the tissues back to the lungs in the form of carbonic acid).
2. It absorbs nutrients from the intestine and distributes them to cells in other parts of the body.
3. It drains out waste products from cells and transports them to the excretory organs for their removal from the body.
4. It transports the chemical messengers or *hormones* from the place where they are produced to the target organ or organs.

Defense mechanisms

1. Certain white blood cells help in preventing infections by destroying disease-causing microorganisms that enter the body.
2. Platelets prevent loss of blood from a wound by forming a clot over it.

Regulatory function

1. Blood maintains water content of the tissues and helps in the regulation of the fluid content in different tissues and organs of the body.
2. Blood regulates the acid-base balance of the body.
3. Water has favourable heat absorbing and cooling properties. Blood regulates body temperature because of its high water content.



William Harvey (1578–1657)
English physician William Harvey was the first to describe correctly how blood circulates inside the body. Harvey also recognized the role played by the heart in pumping blood throughout the body.

Functions of blood cells

- Red blood cells
  - Carry oxygen from lungs to tissues
  - Carry carbon dioxide from tissues to lungs
- White blood cells
  - Protect the body by destroying disease-causing microorganisms
- Platelets
  - Prevent loss of blood by forming a clot over wounds

Write the function of the blood cells shown in the picture given alongside

.....

.....

.....

Blood transfusion and blood groups

In certain cases it becomes necessary to inject blood taken from a healthy person into the body of another person (e.g., in case of severe accidents, during surgery, or in certain rare diseases). *Transfer of blood from one person to another is termed* ***blood transfusion***. The person giving the blood is called the *donor* and the one receiving it is called the *recipient*.

FACT FILE

Blood banks are specialized medical centres that collect and store human blood for transfusion. The blood collected by blood banks may be preserved as whole at low temperatures, using certain chemicals, or after separating it into its fractions, such as plasma, RBCs, and WBCs.

Before a blood transfusion is done, it is checked whether the blood of a particular donor can be given to a particular recipient. This is usually done by matching their *blood groups*. Blood groups are of four major types: A, B, AB, and O. The following criteria are used to distinguish between different blood groups.

1. There are substances called *antigens* attached to a person's RBCs. Members of different blood groups are characterized by the presence or absence of certain specific antigens on their RBCs. Members of the A group have antigen A on their RBCs. Members of the B group have antigen B on their RBCs. Members of the AB group have both A and B antigens present on their RBCs, while members of the O group lack both A and B antigens.

2. There are substances called *antibodies* in the plasma. Members of the A and B blood groups have specific antibodies in their blood plasma. The antibodies in A group plasma are called 'anti-B' because they cause B group RBCs to clump or stick to each other. Similarly, 'anti-A' antibodies is present in the B group plasma, which cause A-group red cells to clump. Members of the AB group have no antibodies in their plasma, whereas those of the O group have both anti-A and anti-B antibodies (Table 1.1).

Note: Clumping occurs due to the reaction between the *antigens* on the donor's RBCs and the *antibodies* in the recipient's plasma.

Based on the reaction they cause when mixed, two blood groups are said to be *compatible* (no clumping of RBCs when mixed) or *incompatible* (clumping of RBCs when mixed). Before a blood

Table 1.1 *Summary of antigen-antibody reactions*

Blood group	*Antigen on RBC surface*	*Antibody in blood plasma*	*Reaction*
A	antigen A	anti-B	clumping of B-group RBCs
B	antigen B	anti-A	clumping of A-group RBCs
AB	antigens A and B	none	none
O	none	anti-A and anti-B	clumping of A-group, B-group, and AB-group RBCs

transfusion is done, it is important to ascertain that the blood groups of the donor and the recipient are compatible. Otherwise, the donor's RBCs may clump and block the narrow blood vessels (capillaries) of the recipient, which could be fatal to the recipient.

Blood group compatibility is summarized in Table 1.2. From this table, it is clear that blood of A-group can only be given to a person with A and AB groups. Similarly, blood of B-group can only be given to a person with B and AB groups. Blood of AB-group can only be given to AB-group. However, a person with AB blood group can receive blood of any group and, hence, is referred to as a *universal recipient*. Blood of O group can be given to all the groups and, hence, a person with O-group is referred to as a *universal donor*.

Lymph

As blood flows through the capillaries, water and dissolved substances, along with a few white blood cells (but no red blood cells), pass through the capillary walls into the intercellular spaces (i.e., the spaces between cells). This fluid is called tissue fluid. Some tissue fluid enters tiny vessels called *lymph capillaries*, which go on to form *lymph vessels*. Lymph vessels, together with small, sac-like organs called *lymph nodes*, form the *lymphatic system*. The colourless fluid that flows within the lymphatic system is called *lymph*. Lymph contains more fatty substances and white blood cells than tissue fluid. Lymph vessels from different parts of the body join to form large tubes or *ducts*. The main lymph duct is called the thoracic duct. It carries lymph to the shoulder region where it is poured into the left shoulder vein, which brings it back to the blood.

Functions: White blood cells in the lymphatic system protect the body against diseases. The lymphatic system also carries excess tissue fluid back to the blood.

TECH FILE

Filarial worms transmitted by the bite of mosquitoes (*Culex and Aedes*) can obstruct lymph vessels. The clogged lymph vessels and glands swell up and the affected parts grow disproportionately, resulting in huge swellings called *elephantiasis*. The disease is prevalent in tropical countries and usually affects the lower extremities such as the legs and the genitals.

Table 1.2 Blood group compatibility (+ *means compatible;* – *means incompatible)*

Blood group donor (RBCs)	*Blood group of recipient (plasma)*			
	A	*B*	*AB*	*O*
A	+	–	+	–
B	–	+	+	–
AB	–	–	+	–
O	+	+	+	+

HEART

Heart is a muscular organ situated within the chest cavity, towards the left side. It is enclosed in a double-walled membrane called *pericardium.* The walls of the heart are chiefly made up of *cardiac muscle,* which has the capacity to contract rhythmically. These rhythmic contractions are triggered by a special tissue called the *pacemaker* or the *sinu-atrial node.* Between the two walls of the pericardium is the *pericardial fluid,* which provides lubrication during the contraction and relaxation of the heart. Figure 1.2 shows a diagrammatic representation of the internal structure of heart.

FACT FILE

The size of one's heart is about the size of one's fist.

Chambers of the heart Internally, the heart is divided into four chambers: two thin-walled upper chambers called *atria* (singular *atrium*) or *auricles* and two thick-walled lower chambers called *ventricles.* According to their position, the four chambers are

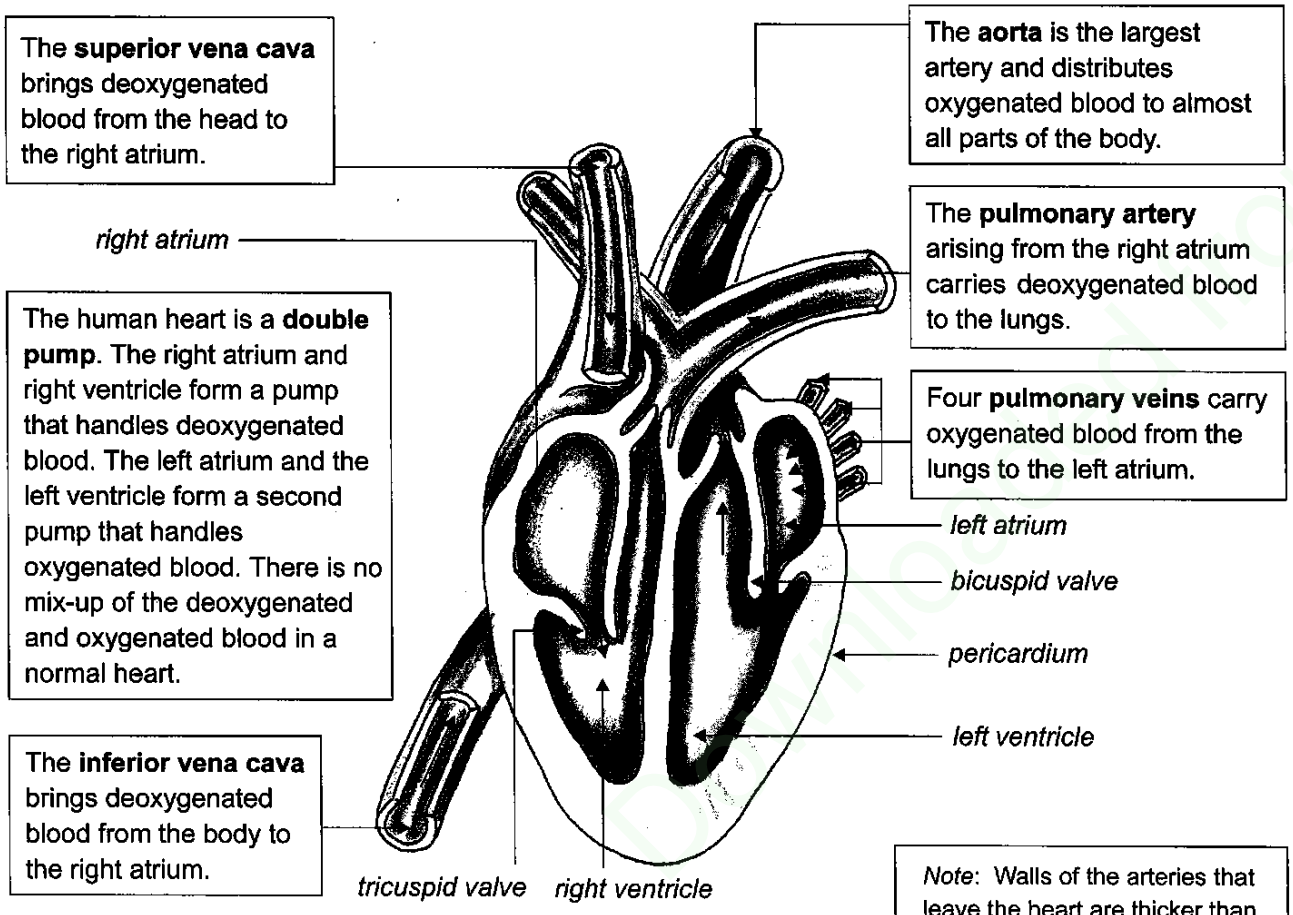


Fig. 1.2 *Internal structure of heart*

referred to as the right auricle, the left auricle, the right ventricle, and the left ventricle.

Thin-walled auricles receive the blood and thick-walled ventricles pump the blood out of the heart.

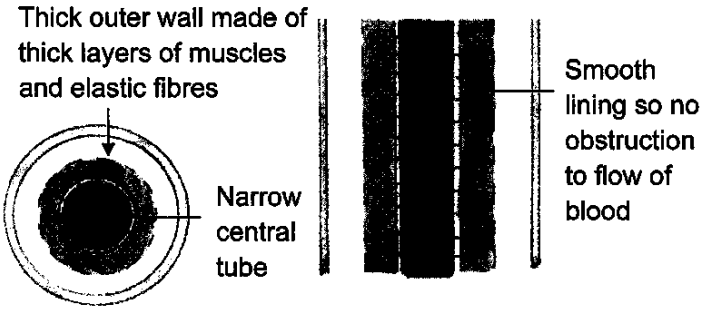


Fig. 1.3 Structure of an artery

Valves of the heart Blood flows from the veins into the auricles, from the auricles to the ventricles, and from the ventricles to the arteries. Muscular flaps called *valves* ensure the flow of blood in one direction inside the heart.

Blood from the right atrium passes through the *tricuspid valve* (which has three projections or *cusps*) into the right ventricle. Blood from the left atrium passes through the *bicuspid valve* (which has two cusps) into the left ventricle. Cusps of both valves are anchored to the walls of the respective ventricles by thread-like structures.

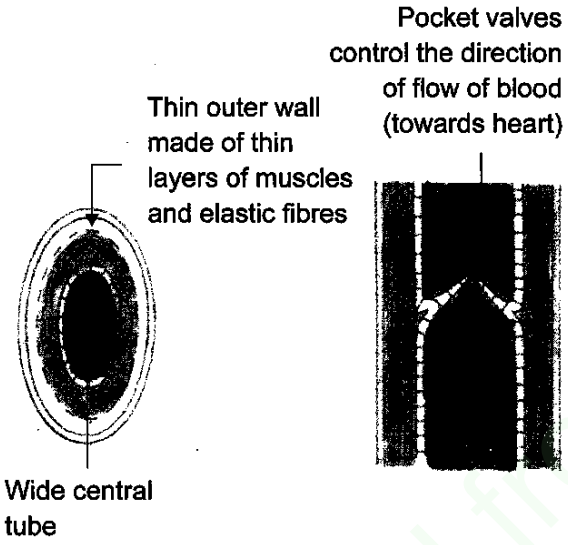


Fig. 1.4 Structure of a vein

BLOOD VESSELS

Blood vessels are the pipelines through which blood from the heart is carried to different organs of the body and again brought back to it.

There are three types of blood vessels in the body: arteries, veins, and capillaries.

Arteries These are thick-walled vessels that carry blood from the heart to different parts of the body (Fig. 1.3).

Veins These are thin-walled vessels that collect blood from the organs in different parts of the body and carry it towards the heart (Fig. 1.4).

Capillaries Between the arteries and the veins are networks of capillaries (Fig. 1.5). They serve as links between arteries and veins and bring about the exchange of materials, such as nutrients, metabolic wastes, and respiratory gases, between blood and the cells. The large surface area of the thin-walled capillaries makes the exchange of materials more efficient.

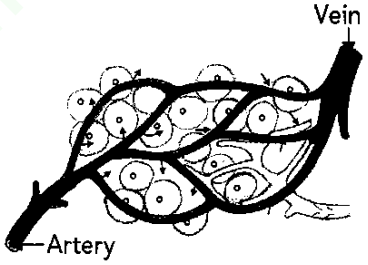
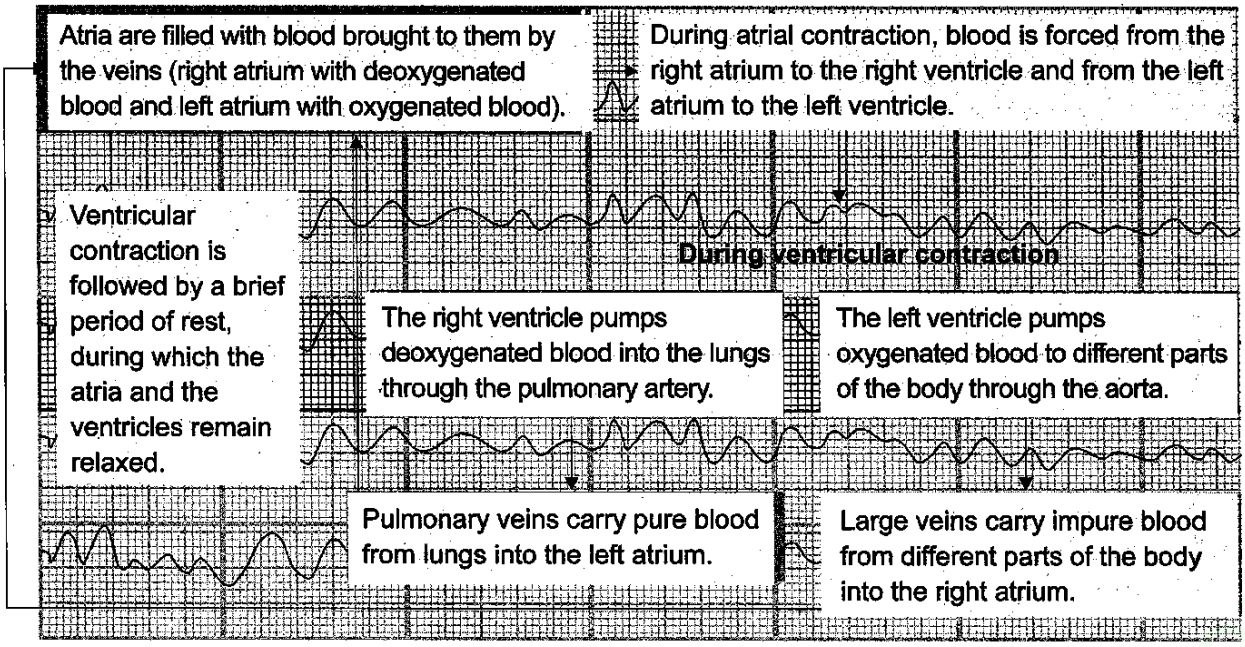


Fig. 1.5 Capillaries

Circulation of Blood

Continuous flow of blood inside the body is termed *circulation*. Contraction of the powerful muscles of the heart provides most of the force required to keep the blood in circulation. The action of the heart in pumping the blood follows a cyclic pattern.



FACT FILE

A hummingbird's heart beats as many as 1000 times per minute!

The contraction of the chambers (atria and ventricles) of the heart is referred to as *systole* and the relaxation is referred to as *diastole*. One complete contraction and relaxation of the heart is called a *heartbeat* or a *cardiac cycle*. The human heart normally beats 72 times per minute. The contraction of the muscles and the closure of the valves during a heartbeat produce the sounds of the heart. Figure 1.6 shows the circulation of blood inside the body.

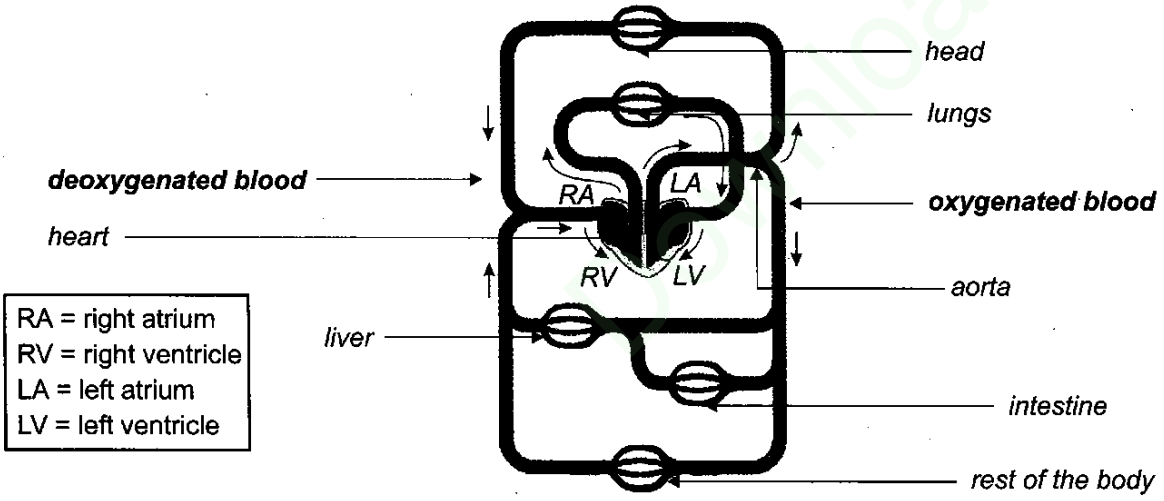


Fig. 1.6 *Circulation of blood inside the human body*

PULSE

Contraction of the ventricles forces blood into the arteries. High pressure generated by the inflow of blood causes the walls of the arteries to expand suddenly and then relax. This generates a wave of pressure that passes along the arteries as *pulse.*

Pulse is a pressure wave transmitted through the arterial system as the ventricular contraction injects fresh blood into it (Fig. 1.7).

Fig. 1.7 *Checking the pulse*

By checking the pulse of a patient, doctors can get important information on the condition of the heart and blood vessels.

Like animals, plants too have a transport system which allows materials to reach different parts of the plant. Next, we will discuss how transport of materials (water, mineral salts, and manufactured food) occurs in plants. Let us start by examining how plants absorb water and minerals from the soil.

ABSORPTION OF WATER AND MINERALS IN PLANTS

You must have studied in class 6 how different parts of a plant (roots, stem, and leaves, etc.) perform important functions for the plant.

The roots of a plant not only help in anchoring the plant, but also absorb water and minerals from the soil.

ACTIVITY

Aim: To determine one's pulse rate

Materials required: A watch that allows you to read time in seconds.

Procedure: Feel your pulse by placing the middle and index fingers of your right hand on the underside of the wrist of your left hand, just above the base of the thumb (see Fig. 1.7). Count the pulse for one minute. Now calculate the pulse

1. after you have been at rest for 10 minutes;
2. soon after you have exercised for 5 minutes; and
3. after 10 minutes rest.

Note: The normal pulse rate is 72 per minute

Aim: To find out the average pulse rate of your class

Materials required: A watch that allows you to read time in seconds.

Procedure:

1. Each student should count his/her own pulse per minute and write it down on the blackboard. The class monitor can add up all the data and then divide the total by the number of students in the class. This gives the average pulse rate for the class. Record it in your activity book.
2. Repeat the same soon after returning from your class PT and find the average pulse rate of your class. Record your results explaining the difference, if any.

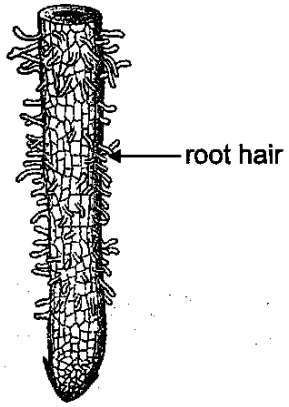
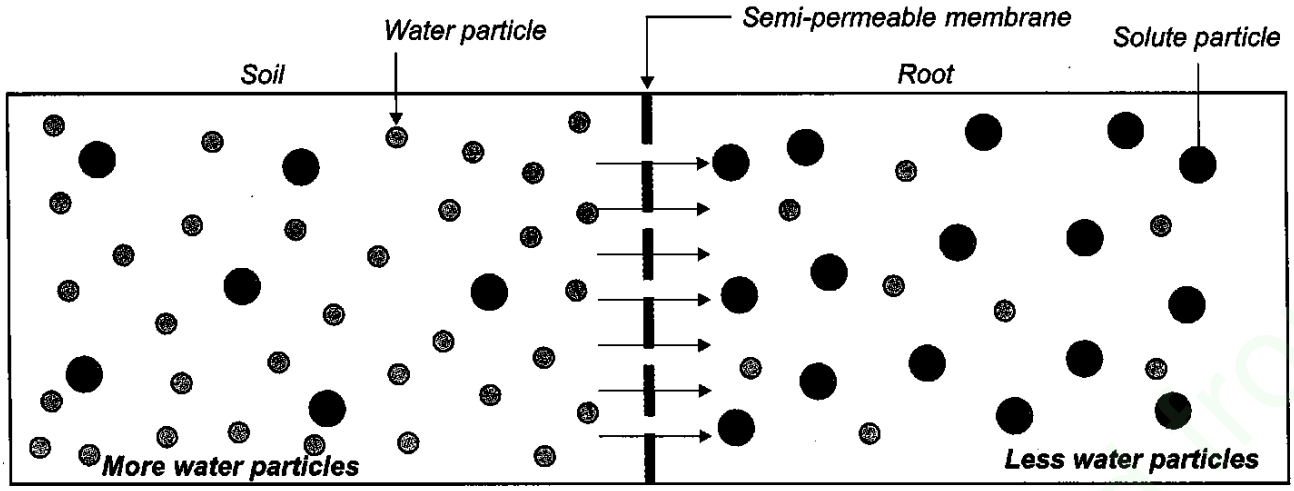


Fig. 1.8 Root hair

Absorption of water by roots

Absorption of water occurs through root hairs, which grow out of the outermost layer of cells (epidermal cells) in the region just behind the root tip (Fig. 1.8). Root hairs increase the surface area of roots, thereby increasing the rate of absorption. Roots absorb water by a process called *osmosis*. Osmosis is a process in which water particles move from a region of high water concentration to a region of low water concentration through a *semi-permeable membrane*. A semi-permeable membrane is a membrane that only allows select materials to pass through it. Figure 1.9 shows how roots absorb water.



In osmosis, water particles move from a region of high concentration (left) to a region of low concentration (right) through a semi-permeable membrane.

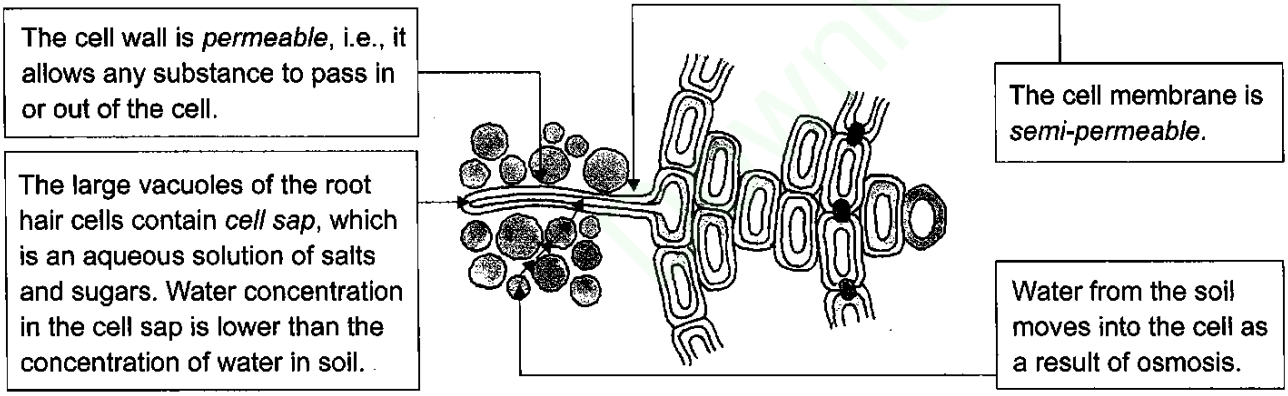


Fig. 1.9 Absorption of water by roots

Absorption of mineral salts by roots

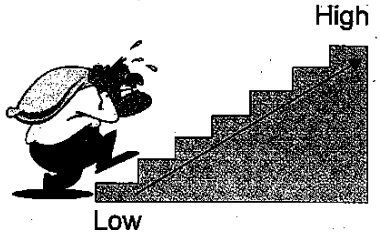
Roots absorb not only water from the soil but also mineral salts such as calcium, magnesium, and nitrogen. Depending on its concentration in the soil, two mechanisms are involved in the absorption of mineral ions by roots: *diffusion* and *active transport.*

Diffusion involves movement of particles from a region of high concentration to a region of low concentration, until their concentration in both regions is equal. If the concentration of dissolved mineral salts is higher in soil than inside the cytoplasm of root hair cells, mineral salts enter the cells by a process of diffusion [Fig. 1.10(a)].

Active transport involves transportation of particles *against a concentration gradient* (i.e., from a region of low concentration to a region of high concentration). Since mineral ions are being absorbed against the concentration gradient, this process involves expenditure of energy [Fig. 1.10(b)].

THINK QUEST

Why do plants absorbing minerals through active transport use large amounts of oxygen? (*Hint: Energy is released through respiration.*)



Transportation of particles against a concentration gradient involves energy

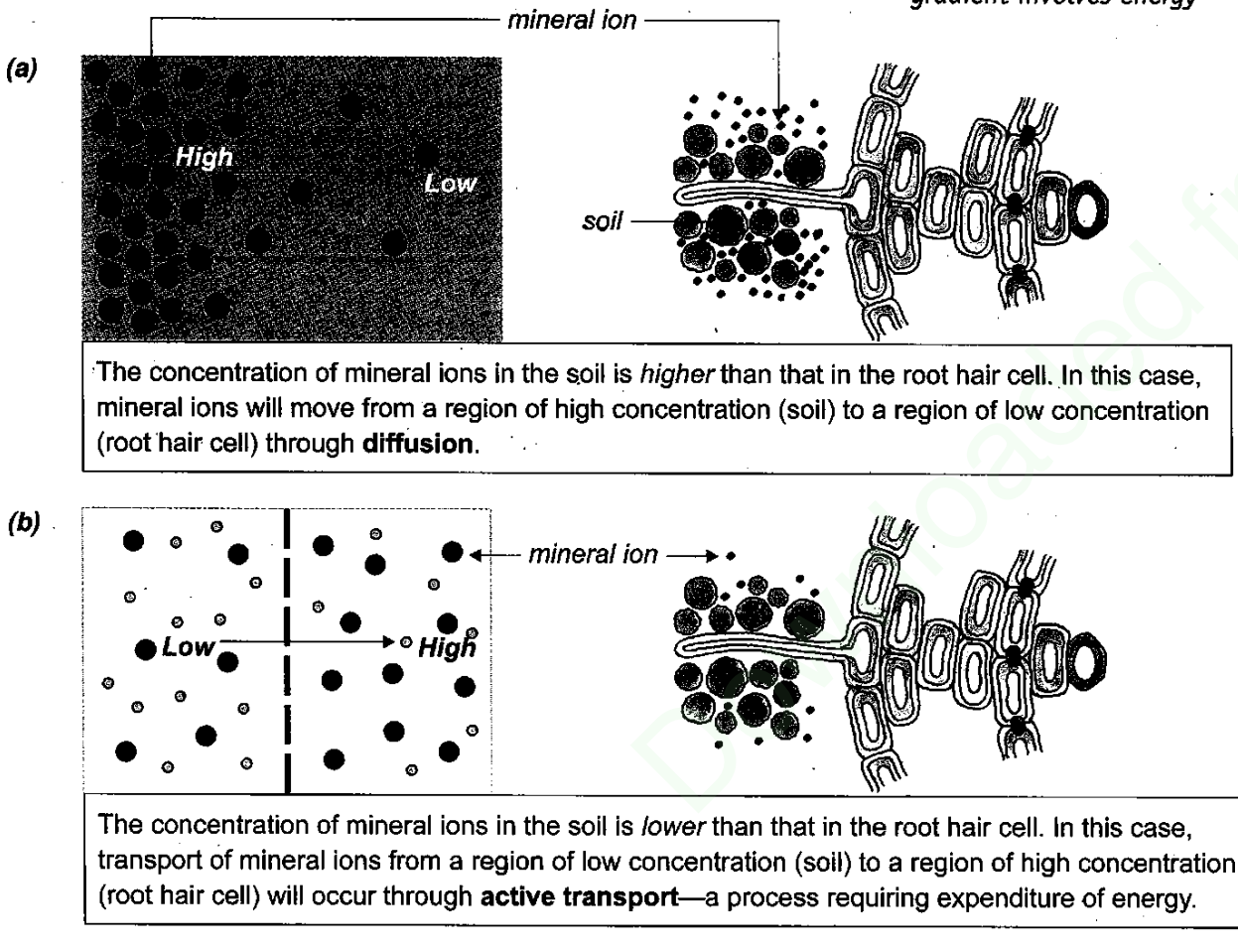


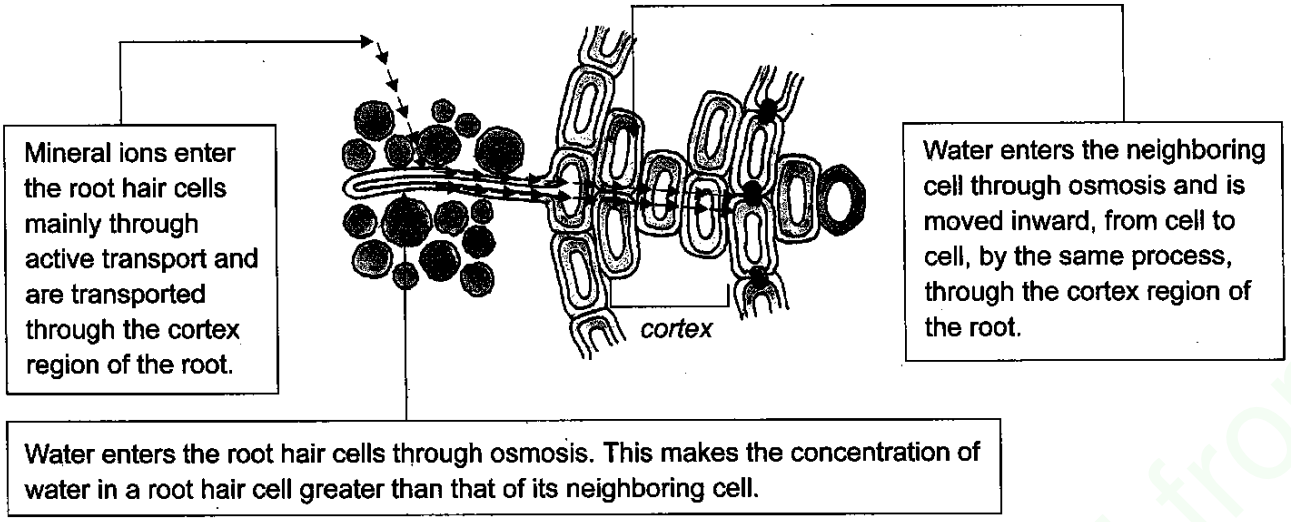
Fig. 1.10 *Absorption of mineral ions by (a) diffusion and (b) active transport*

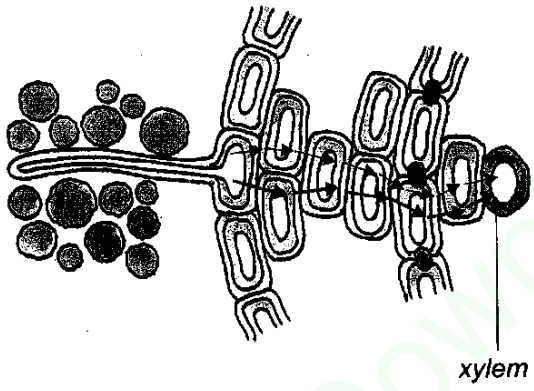
CONDUCTION IN PLANTS

Conduction in plants involves (a) the transport of water and minerals from roots to other parts of the plant and (b) the transport of manufactured food from leaves to different parts of the plant. Let us examine both these mechanisms separately.

Transport of Water and Minerals

The following images show how conduction of water and minerals occurs in plants.





Ascent of sap

The sap (which contains water and dissolved minerals) that has been brought to the xylem must now be transported up to the leaves, which are the food factories of the plant. This upward

movement of sap, referred to as the rise or *ascent of sap*, is performed by xylem, which consists mainly of *vessels* and *tracheids*. You must have learnt about vessels and tracheids in class 7.

Thus, in the plant body the roots (which absorb raw materials from the soil) remain connected to the leaves by a system of pipelines (vessels and tracheids). There are various forces involved in moving water and dissolved minerals up the stem. You will learn about these forces in class 10. In this chapter, we will briefly discuss one of these forces: transpiration pull.

Fig. 1.11 Stomata

Transpiration pull: Plants absorb large quantities of water from the soil through their roots. In fact, more water is absorbed than is required by the plant. The excess water escapes through the leaves in the form of water vapour.

The loss of water in the form of water vapour from a living plant is termed ***transpiration.***

As you must have learnt in class 7, transpiration occurs through openings called *stomata* (Fig. 1.11), which are generally present on the underside of leaves. During transpiration, water evaporates from the mesophyll cells of leaves and escapes (in the form of water vapour) through the open stomata. Water loss through evaporation lowers the concentration of water inside mesophyll cells. As a result, water enters mesophyll cells from neighbouring xylem vessels (present in the veins of leaves) through osmosis (Fig. 1.12). More water (along with the dissolved minerals) is 'pulled' upwards, through the xylem vessels in stem, from the roots to replace the water lost through transpiration. Thus, the 'pull' created by transpiration (or *transpiration pull*) causes water and dissolved minerals to move up the stem.

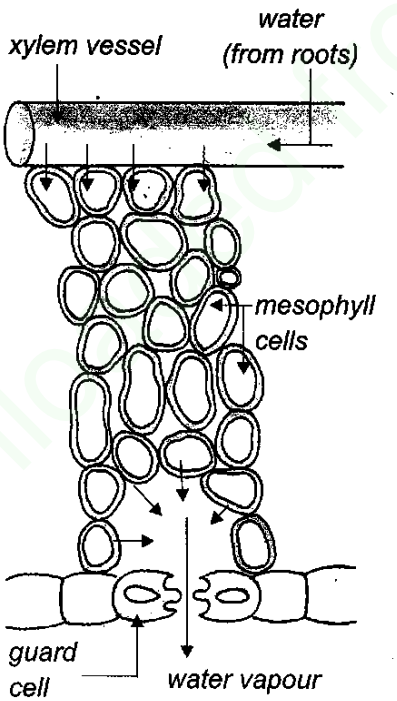


Fig. 1.12 Transpiration

Transport of Manufactured Food

Food manufactured in the leaves of the plant is transported to various parts of the plant through phloem. Phloem chiefly consists of *sieve tube cells* and *companion cells*, which you must have studied in class 7. Unlike xylem, which only transports materials in one direction (upwards), phloem can transport materials upwards and downwards, as required. Xylem and phloem form a continuous system of vascular tissue that extends throughout the plant.

KEYWORDS

Plasma Straw-coloured watery part of blood
Antibody A protein produced within the body to render an antigen harmless
Antigen A specific protein that stimulates the formation of antibodies
Arteries Blood vessels that carry blood away from the heart
Veins Blood vessels that carry blood towards the heart
Heart A muscular organ that acts as a pump to keep the blood in circulation
Auricles Chambers of the heart that receive blood
Ventricles Chambers of the heart that forward the blood to different parts of the body
Capillaries Network of thin-walled narrow blood vessels that connect veins with arteries
Pulse Expansion and contraction of the arterial wall passively produced by pressure changes during systole and diastole
Diffusion Spreading of molecules to regions of lower concentrations
Osmosis Spreading of water molecules to regions of lower concentrations across a semi-permeable membrane
Active transport Transport of substances against a concentration gradient using energy
Cell sap The liquid that fills up the vacuoles in the cell
Root pressure Collective pressure exerted by cells of the root cortex moving water into and up the xylem

SUMMARY

- Circulatory system is responsible for transporting materials such as food and oxygen from one part of the body to another.
- Circulatory system consists of fluids called blood and lymph, a muscular organ called heart, and vessels that carry blood and lymph from place to place.
- Blood consists of plasma (55%) and blood cells (45%). Blood cells are of three types: red blood cells, white blood cells, and platelets.
- Blood groups are of four major types: A, B, AB, and O.
- Transfer of blood from one person to another is termed blood transfusion. Before a blood transfusion is done, it is important to ascertain that the blood groups of the donor and the recipient are compatible.
- The human heart is divided into four chambers: two atria (or auricles) and two ventricles.
- The action of the heart in pumping the blood follows a cyclic pattern.
- Roots absorb water by osmosis. Absorption of mineral ions takes place through diffusion or active transport.
- Conduction in plants involves the transport of water and minerals from roots to other plant parts and transport of manufactured food from leaves to different parts of the plant.

EXERCISES

I. Review questions

A. Fill in the blanks

1. Red blood cells carry an iron-containing repiratory pigment called ..... (haemochromogen/haemoglobin).

2. ..... (Arteries/Veins) carry blood to the heart.
3. The two lower chambers of the heart are called ..... (atria/ventricles).
4. ..... (Antigens/Antibodies) are attached to a person's RBCs.
5. Bicuspid valve is found on the ..... (left/right) side of the heart.

B. Tick the correct answer

1. The number of chambers present in the human heart is
   (a) three (b) four (c) one (d) two
2. The valves in the heart prevent blood from
   (a) flowing backward (b) flowing forward
   (c) leaving the heart (d) entering the heart
3. The cells that initiate the process of blood clotting are
   (a) platelets (b) white blood cells
   (c) red blood cells (d) all of these
4. Blood cells that protect the body from infections are
   (a) platelets (b) white blood cells
   (c) red blood cells (d) all of these
5. In plants, ascent of sap takes place through
   (a) phloem (b) xylem (c) cortex (d) pith

C. Correct the statements that are false

1. Capillaries connect arteries to veins.
2. The right atrium receives deoxygenated blood.
3. Blood group A is compatible with 'B' and 'O'.
4. In the lungs, oxygen combines with haemoglobin to form oxy-haemoglobin.
5. A person having AB blood group can receive any type of blood.

D. Answer the following

1. Name the three types of blood cells.
2. Write any five functions of blood.
3. Name the four blood groups. What is the basis for this grouping?
4. Why is a person with O-group called a universal donor and a person with AB group called a universal recipient?
5. Draw a simple diagram to show the chambers of the heart, the blood vessels entering and leaving the heart, and the valves of the heart. Label them and draw arrows to indicate the direction of the flow of blood through the different chambers.
6. Define (a) circulation and (b) pulse.
7. Explain how water is absorbed by the roots of a plant.
8. What is active transport? How is it different from diffusion?
9. What is transpiration? How does transpiration pull cause sap to rise inside the stem?

II. Skill-based questions

E. Which of these donors can give blood to the following recipients?

Donors Rahim (blood group A) Anil (blood group AB) Tina (Blood group O)

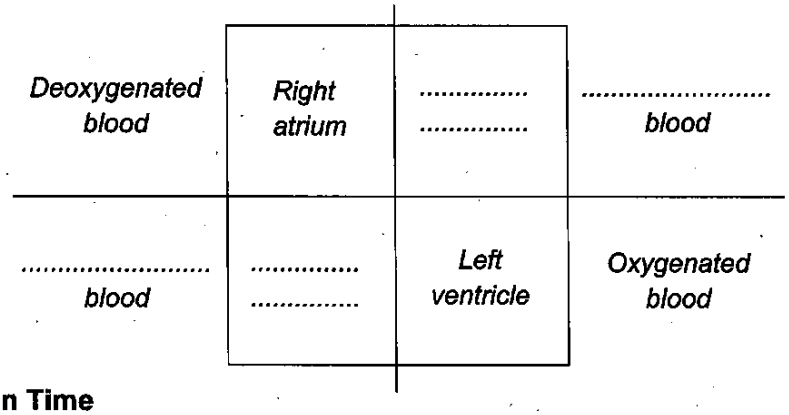
Recipients

Robert (blood group A) .....

Mohan (blood group AB) .....

Harjeet (blood group O) .....
Angela (Blood group B) .....

F. The following diagram represents the four chambers of the human heart. Study the diagram carefully and insert the missing labels.



III. Fun Time

Names of three types of blood vessels are hidden in the following maze. Can you find them? (Hint: The hidden words can appear horizontally, vertically, or diagonally; forward or backwards).

N	A	N	Q	S	P	D	K	N	Q	S	F	I
I	D	C	A	P	I	L	L	A	R	Y	P	N
E	O	M	K	Y	R	E	T	R	A	G	L	Q
V	B	C	L	O	Y	A	D	M	C	H	W	K

PROJECT IDEAS

- Students can write a report on the history of blood transfusions. They can use books/Internet for reference.

TEACHER'S NOTES

- Students could be shown permanent slides of RBCs and WBCs.
- Activity carried out in class 7 to locate vascular bundles (using a cut balsam stem and red ink/ eosin) could be repeated to demonstrate conduction in plants.
- A pathologist could be invited to the classroom to explain to students how blood tests can reveal the presence of infections and diseases.

Website references

http://www.mplsheartfoundation.org/kids/ (accessed 24 May 07)
http://www.innerbody.com/anim/heart.html [animation] (accessed 25 May 07)