CHAPTER 3

Transport System

PERFORMANCE OBJECTIVES
At the end of this chapter, students should be able to

- define diffusion.
- explain the inadequacy of diffusion alone as a transport system for complex organisms.
- explain the necessity of a transport system in complex organisms.
- identify source of materials and where they are transported to
- discuss the different types of transportation media such as cytoplasm, cell sap, lymph and blood.
- describe the mechanisms of transportation in various animals.
- compare and contrast various mechanisms of transportation.
- demonstrate experimentally the flow of materials in plants

INTRODUCTION

Diffusion is the process by which molecules of substances such as liquids and gases move ran- domly from a region of higher concentration to a region of lower concentration until there is an even distribution.

Osmosis is the flow of water or solvent molecules from a dilute or weaker solution to a concentrated or stronger solution through a selectively permeable membrane.

The principle behind the two processes is that the molecules of substances such as gases, liquids and solvent (water) move from where they are of higher concentration to where they are of lower concentration leading to uniformity or same concentration.

Diffusion ensures that fine particles (mole- cules) flow in and out of cells of living things and it can also occur in non-living materials.

TRANSPORT SYSTEM IN LARGE ORGANISMS

As organisms become larger, their body surface area increases by the square of dimensions, whereas the volume increases by the cube. Hence, as organisms increase in size, their surface area to volume ratio (SA) decreases.
V

This implies that small organisms have larger surface area in relation to their volume (i.e., per unit of volume) than larger organisms. This could be illustrated by considering three cubes of 1 mm, 6 mm and 10 mm (Figure

3.1).

In the 1 mm-sided cube, there are 6 mm2 of surface area per mm3. The surface area to volume ratio

SA = 6 = 6. In the 6 mm-sided cube, V1 SA there is 1 mm2 of surface area per mm3. The V

216 = 1. In the 10 mm-sided cube, there is 0.6 mm2 216 SA 600

surface area per mm3. The V ratio is 1000 = 0.6

NEED FOR SUBSTANCES TO MOVE OVER GREATER DISTANCES

From the explanation above, because small organisms have large surface area to volume ratio, the movement of materials in and out of them can be done efficiently by diffusion. In multicellular organisms with a small body surface relative to their large volume, diffusion is inad- equate for the exchange of metabolic materials within their body and between them and their external environment. This is because large quantities of nutrients and waste products have to be transported over long distances to and from their numerous body cells.

In other words, as the V ratio in multicellular organisms decreases with increasing sizes, the rates at which substances diffuse into and out of their cells decreases. Hence, most multicellu- lar organisms have developed transport system. The transport system in animals is very similar to the city transport or water system. There is order- liness, and everything is highly organised.

MATERIALS FOR TRANSPORTATION

The organs used for transportation are arteries, capillaries, veins and vascular bundles. The materials transported in the organism include water, digested foods, gases, excretory products, hormones, auxins and other materials. Table 3.1 summarises some materials that are commonly transported in organisms.

STRUCTURE OF ARTERIES

These are wide vessels that generally transport blood from the heart to the limbs and organs (Figure 3.8). There is one artery to each of the organs of the body. They are muscular, thick walled

TABLE 3.1 Materials transported in organisms

MATERIAL TRANSPORTED	SOURCE	DESTINATION	END USE/FATE
Oxygen	Gas exchange organs (e.g., lungs and leaves)	Living cells	Respiration
Water	Cells	Kidney, skin, lungs and leaves	Excreted
Carbon (IV) oxide	Living cells	Leaves, lenticels, lungs, gills and trachea	Excreted
Nitrogenous waste products	Living cells	Liver, kidney, alkaloids in tree barks	Excreted or stored (e.g., alkaloids)
Amino acids	Gut and plant cells	Living cells	Growth and repair
Glucose	Gut and leaves	Living cells	Respiration or storage
Lipids	Gut and plant cells	Living cells	Respiration and storage

and elastic and are able to withstand the high pres- sure caused by the heartbeat. The arteries branch in the organs to form arterioles. The arterioles also branch repeatedly to form a network of blood capil- laries, which permeate every living cell of the body.

STRUCTURE OF CAPILLARIES

These are tiny vessels with very thin walls, which are often one cell thick (Figure 3.2c). Their walls allow water and dissolved substances, except proteins, to pass in and out of them. The capillar- ies branch within the tissues. Through their thin walls, dissolved food and excretory products are

exchanged with the tissues around them. The capillary network is so dense that no living cell is far from food and oxygen supplies. The capil- laries rejoin to form veins. Through the capillary network, blood flows from the arterial end to the venous end (Figure 3.8).

STRUCTURE OF VEINS

Usually, veins carry blood from the tissues to the heart. They are wider and have thinner walls than arteries (Figure 3.2a). They have valves at inter- vals, which allow blood to flow in one direction from other organs towards the heart.

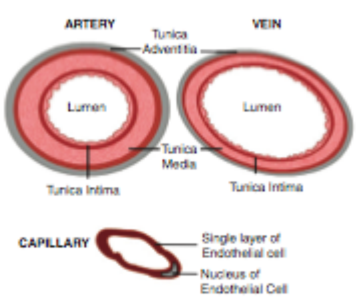


FIGURE 3.2 (A) & (B) Structure of an artery, a capillary and vein

TABLE 3.2 Comparison of the three blood vessels

ARTERIES	CAPILLARIES	VEINS
Thick, elastic muscular walls	Walls are a cell thick	Walls thinner, less elastic than arteries
Except aorta and pulmonary arteries, most lack valves	Valves absent	Valves present
Carry blood away from the heart	Join arteries to veins	Carry blood to the heart
Carry oxygenated blood except pulmonary arteries	Blood loses oxygen and gains carbon (IV) oxide except in the lungs.	Carry deoxygenated blood except pulmonary veins
Blood flows at high pressure	Blood pressure fluctuates	Blood flows at low pressure

STRUCTURE OF VASCULAR BUNDLES

Vascular tissues are grouped together in bundles within the plant body. The vascular tissues of plants are made up of a network of long tubes called vascular bundles. They are called veins in the leaves. A vascular bundle consists mainly of xylem and phloem tissues. But in the roots and stems of dicotyledons, a layer of cambium cells exists between the xylem and phloem tissues. Hence, vascular bundles are found in the roots, stems and leaves of flowering plants.

The xylem tissue consists mainly of dead cells with lignified cell walls and perforated end walls, which may be absent. It transports water and mineral salts from the roots to other plant parts and also gives support to the plant.

The cambium is made up of narrow, living cells with thin walls and dense cytoplasm. They are able to divide and multiply, thereby enabling the plant to produce secondary xylem and phloem. This results in the growth, width or girth of the trunks or stems of trees called secondary thickening.

The phloem tissue consists of thin-walled living cells with dense cytoplasm, which have perforated cross-walls. It conducts manufactured foods from the leaves and the storage organs to the other parts of plants.

MEDIA OF TRANSPORTATION

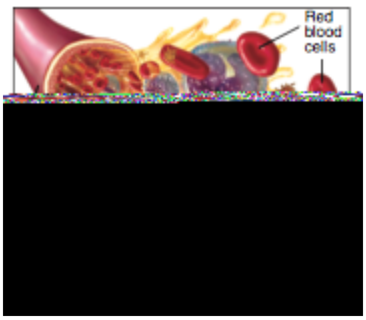
In all organisms, a liquid or fluid is the medium of transportation of materials. It includes blood, lymph and tissue fluid in most animals; latex or cell sap in many plants and cytoplasmic fluid in small organisms such as protozoans, protists and coelenterates.

STRUCTURE OF BLOOD

The mammalian blood comprises four main components the plasma, red corpuscles, white corpuscles and platelets (Figure 3.3).

(i) Plasma: The plasma is a pale yellow liq- uid made up mainly of water (about 90%) with many substances dissolved in it. These include digested foods, mineral salts, vita- mins, hormones, dissolved oxygen and excretory products such as urea and carbon (IV) oxide. The plasma also contains larger molecules, the plasma proteins, such as fibrinogen, which assist in the clotting of blood in damaged tissues.

(ii) Red corpuscles or erythrocytes: They are tiny, biconcave, disc-like cell without any nucleus in adult mammals. They contain a red pigment – haemoglobin, a protein that contains iron. This enables the red corpuscles to readily combine with oxygen in area of high oxygen concentration (i.e., the alveoli of lungs) to form oxyhaemoglobin. This is the form in which oxygen is carried to all body tissues. They also readily give oxygen



n places where the oxygen concentration is low (e.g., all the tissues except those near the alveoli). Erythrocytes are synthesised in the red bone marrows of sternum, ribs and vertebrae. There are about 51â„2 million of them in a cubic centimetre of blood. They live for about 120 days and are destroyed in the liver or spleen.

(iii) White corpuscles or leucocytes: There are many types of white corpuscles all of which have nuclei. They are made in the red bone marrow, the lymph node or the spleen. They live for many months. Those that are irregular in shape, i.e., the phagocytes, are the commonest. They are large with lobed nuclei. Like the Amoeba, they have pseudopodia and are able to pass through the walls of the capillaries into the tissue fluid. In the lymphatic system, they ingest bacteria, viruses and dead cells, and help in preventing diseases. The ingestion of materials is called phagocytosis and hence such white corpuscles are called phagocytes.

Those that produce antibodies are called lymphocytes and are produced in the lymph glands. They produce chemicals called antibodies, which stick to the surface of germs and kill them. White corpuscles are fewer than the red corpuscles. There are about 5000 of them in a cubic millimetre of blood.

(iv) Platelets: These are tiny, irregularly- shaped particles formed in the red bone marrow. They lack nucleus. In damaged tissues, they break down and liberate an enzyme, which catalyses the first of a series of reactions involved in blood clotting. In the final reactions, fibrinogen, a blood protein, is converted to threads of fibrin, which form a mesh that plugs the wound. This stops the bleeding.

FUNCTIONS OF THE BLOOD

The mammalian blood performs several functions which could be grouped into three: transport, pro- tection and body regulation.

TRANSPORT

(i) It carries oxygen from the lungs to the tis- sues and carbon (IV) oxide from the tissues to the lungs for excretion.

(ii) It carries digested foods from the gut to the

various parts of the body.

(iii) It carries nitrogenous waste products from the tissues to the kidneys, which get rid of them.

(iv) It carries hormones and antibodies from one part of the body to another.

PROTECTION

(i) It protects the body from the attacks of germs, which cause diseases, by killing the germs.

(ii) It protects the body from excessive bleed- ing by clotting when a body tissue is cut or wounded.

REGULATION

(i) It helps to regulate the quantity of water in the tissues (osmoregulation).

(ii) It helps to regulate the quantities of the various chemical materials in the tissue (homoeostasis).

(iii) It helps to keep the body temperature fairly constant by distributing heat evenly around the body.

In many plants, the medium of transportation of materials is the latex or cell sap. The cell sap is made up primarily of water, dissolved materi- als like synthesised foods, growth substances and inorganic salts. The sap is transported to all the parts of a plant through the phloem tissue. Different plants have latex (cell sap) of different colours. For example, the latex of rubber plant cassava (Manihot) is white. A few plants have red or colourless latex.

MECHANISM OF TRANSPORTATION

In many multicellular animals, materials are trans- ported from one part of the body to another in a circulatory system. There are two main circula- tory systems in animals, namely open and closed systems.

In the open circulatory system, the blood ves- sels leave the heart but end up in blood spaces called haemocoels within the body. The blood comes in contact with the body cells after which it is sent back to the heart; example is found in arthropods (Figure 3.2) and in some molluscs.

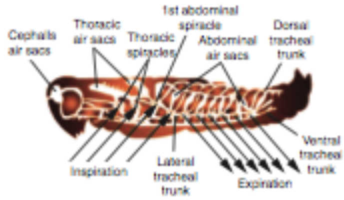


FIGURE 3.4 The open circulatory system of an insect

In the closed circulatory system, blood is restricted to branching blood vessels. Through them, blood is pumped to the body by one or more hearts. This is found in the annelids and vertebrates.

In unicellular organisms, such as Amoeba, and in some multicellular organisms, such as spirogyra, nutrients, gases and metabolic wastes move in and out of their body by diffusion. In a few other unicellular organisms, such as para- mecium, food substances in food vacuoles are carried along a specific route by a process called cyclosis.

In vascular plants (pteridophytes, gymno- sperms and angiosperms), there is a circulatory system in which materials are carried to and from all body parts. The circulatory system consists of vascular tissues, which is a system of nar- row tubes. Plants that have vascular tissues are called vascular plants. The vascular tissues con- sist of compact strands called vascular bundles. Each bundle consists of the xylem near the stem centre and the phloem towards the outer sur- face of the stem. The cambium is usually found in between the xylem and the phloem in dicoty- ledonous roots and stems (Figure 3.11), and monocotyledonous plants do not have cambium.

Other mechanisms of transportation in plants are root pressure and transpiration stream, and protoplasmic streaming occurs both in plants and animals.

Protoplasmic streaming (cytoplasmic stream- ing) in living cells is a process by which the cytoplasm continuously circulates along the length of a given cell carrying with it dissolved sub- stances at the same rate. It has been observed that strands of moving cytoplasm continuously pass through the pores of adjacent sieve tube ele- ments in living phloem cells of plants from one cell to another. Such movement does not need very large pressure to move the solutions. It is also independent of turgor pressure gradient. In proto- zoans, materials are transported from one part of the protoplasm to the other not only by diffusion but also by cytoplasmic streaming.

Body movements such as amoeboid and euglenoid motions, which change protozoans body shapes, also play some roles in the trans- portation of materials.

SIMILARITIES AMONG MECHANISMS OF TRANSPORTATION

The main similarities in the various mechanisms of transportation in all organisms are as follows:

(i) In all organisms, nutrients and excretory products are transported in solution.

(ii) The medium of transportation is a fluid or liquid such as latex, blood and lymph.

(iii) Many materials are transported by diffusion in unicellular animals and plants and some primitive, large animals with low rates of metabolism.

(iv) In most multicellular animals and plants, nutrients are transported efficiently through a circulatory system.

(v) In vertebrates, the heart, arteries, veins and capillaries form the circulatory system, while in higher (vascular) plants, the xylem and phloem tissues form the circulatory system.

(vi) In both open and closed circulatory sys- tems, blood is pumped from the heart to all the body parts.

MECHANISM OF TRANSPORTATION IN HIGHER ANIMALS

As a result of the repeated contractions of the heart, the blood circulates through the circula- tory system (i.e., arteries, capillaries and veins) throughout life. All mammals have double circu- lation. These are the systemic (body) circulation and pulmonary circulation.

(i) Systemic (body) circulation in which blood is carried from the left ventricle to all body parts except the lungs and back to the right auricle.

(ii) Pulmonary circulation in which blood is carried from the right ventricle to the lungs through the pulmonary veins.

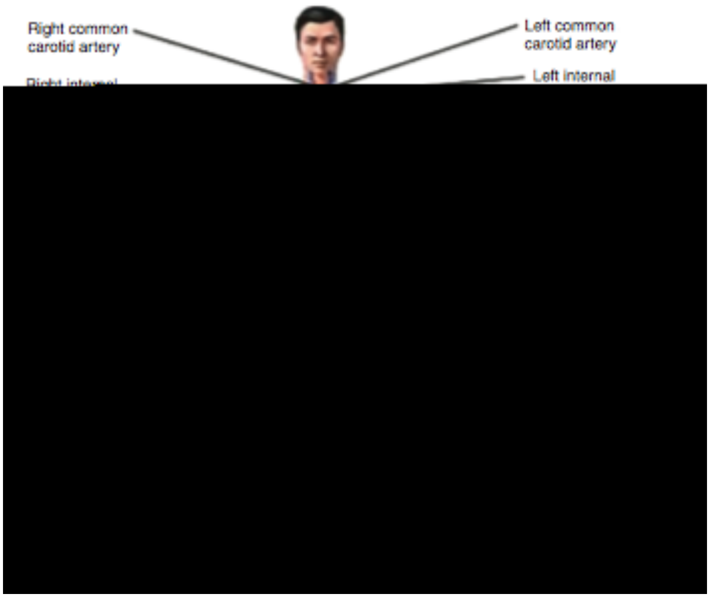
1. The heart like other organs has a blood

supply. The coronary arteries, which branch from the aorta near the heart, carry blood to the heart muscles. The flow of blood through these muscles is called coronary circulation.

The heart continues to beat repeatedly throughout the life and pump blood to the two main circulations and the coronary circulation. When the body is at rest, normal heart beats about 70 times per minute. The rate of the heart beat increases when one is very active or excited. The liver is the only organ in the body that receives blood from a vein and artery. It is sup- plied by the hepatic artery and hepatic portal vein. The hepatic portal vein carries blood rich in digested food from the stomach and small intestines into the liver. The hepatic portal vein carries blood from the liver into the inferior vena cava.

STRUCTURE OF THE MAMMALIAN HEART

The heart is the pumping organ of the circulatory system. It is divided into four chambers. The right and left auricles or atria (singular atrium) and the



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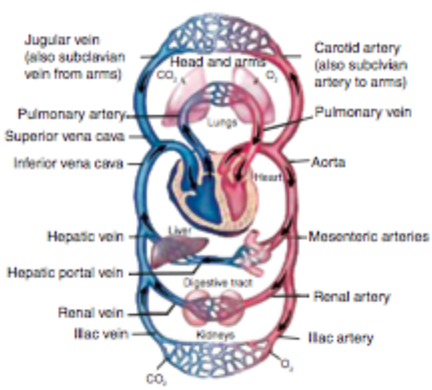


▲ FIGURE 3.6 (A) & (B) Diagrammatic illustration of systemic and pulmonary circulation

right and left ventricles (Figure 3.7). The walls of the ventricles are normally thicker than those of the auricles. The wall of the left ventricle is thicker and more muscular than that of the right ventri- cle. This is because it is through it that blood is pumped to all the body parts.

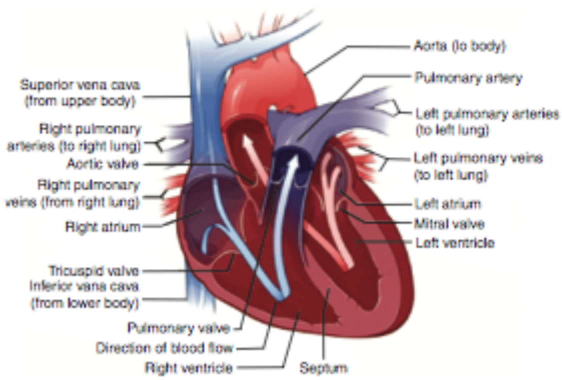


FIGURE 3.7 Longitudinal section of a mammalian heart

to the walls of the ventricle and prevent the valves from turning inside out when the ven- tricles contract.

HOW THE HEART WORKS

1. (i) Deoxygenated blood from all the body parts is carried into the right auricle through the inferior vena cava.
2. (ii) When the walls of the auricles contract, blood passes through the tricuspid valve under high pressure into the right ventricle.
3. (iii) When the walls of the ventricles contract, the tricuspid valve is forced to close and deoxygenated blood passes through the pulmonary arteries into the two lungs.
4. (iv) At the same time, oxygenated blood from the lungs enters the left auricle through the pulmonary veins.
5. (v) When the walls of the auricles contract, blood in the left auricle is forced through the bicuspid valve into the left ventricle.

   (vi) When the ventricle walls contract, the bicuspid valve closes.

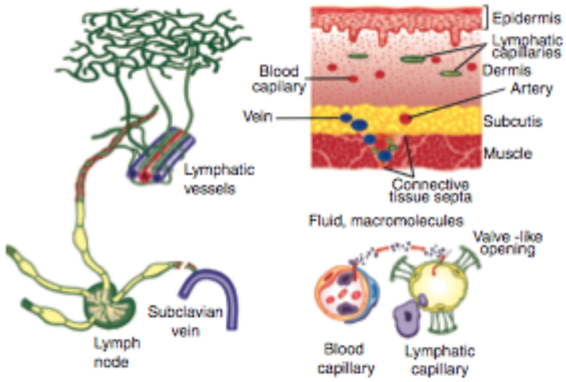
   (vii) Blood is then pumped out of the heart through the aorta and is transported to other body parts after passing through semilunar valves.

It is important to note that oxygenated and deoxygenated blood never mix as they circu- late through the left and right side of the heart, respectively. This is because the left and right side are separated by a muscular tissue called septum.

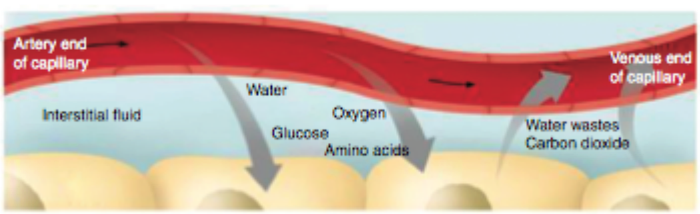
EXCHANGE BETWEEN CAPILLARIES, TISSUE FLUID AND LYMPHATICS: Blood reaches the arterial end of a capillary at a very high pressure. This forces the plasma out through the capillary walls (Figure 3.8). This fluid is called tissue fluid. It consists of many substances including water, glucose, amino acids, fatty acids and glycerol, and mineral salts. The tissue fluid is similar to the blood plasma but contains less plasma proteins.

It is from the tissue fluid that living cells extract the nutrients they need. At the same time, the body cells excrete their waste products such as nitrogenous compounds and carbon (IV) oxide into the tissue fluid.

At the venous end of the capillary, the blood pressure is low. This facilitates the exchange of materials by diffusion between the plasma and the tissue fluid (Figure 3.10b). The blood plasma osmotic pressure is high due to the removal of more protein from it and also due to the removal of some tissue fluids. This causes



▲ FIGURE 3.8 Relationship between capillaries, tissue fluid and lymphatics



▲ FIGURE 3.9 Blood tissue, fluid and lymph

the tissue fluid containing urea and carbon (IV) oxide to be absorbed by osmosis through the capillaries into the blood stream. Any tissue fluid that is not absorbed passes into the lym- phatic system.

LYMPHATIC SYSTEM: Lymph vessels, usually called lymphatics, start as thin walled blind-ended tubes within the capillary beds.

They are almost as numerous as the capil- laries. The tissue fluid, which is not absorbed into the blood stream through the capillaries, drains into these lymphatics and is called the lymph (Figure 3.11). The small lymphatic vessels join together to form large lymphatics. The lymphat- ics, like veins, have valves, which ensure that the lymph flows only in one direction. They are situated among the muscles, which squeeze the lymph along as the muscles contract. The lymph is similar to the plasma but contains less protein. At intervals along the lymphatics are structures called lymph nodes.

These consist of narrow channels through which the lymph passes. Large phagocytes, called lymphocytes, are found in the lymph nodes. They destroy bacteria and dead cells in the lymph. Large lymph nodes are located in the neck, under the arms and groin (Figure 3.10).

The thoracic duct, which collects lymph from the intestine and lower half of the body, is the larger of the two lymphatic ducts. The lac- teals from the small intestines open into the lymphatic system. Thus, after a meal consist- ing lipids, the lymph appears milky due to the fat droplets absorbed by the lacteals. The large lymphatic vessels unite into two main lymphatic ducts, which open their contents into the blood

stream at the subclavian vein near the heart. Finally, all the tissue fluid drains back into the blood stream.

MECHANISM OF TRANSPORTATION IN HIGHER PLANTS

Plants need sufficient quantities of many materi- als, which are transported in them. These include water, mineral salts and manufactured foods. In aquatic, unicellular and simple multicellular plants, gases enter and leave their cells by dif- fusion. Water enters the cells of these plants by osmosis, whereas manufactured foods and wastes are transported by diffusion.

In flowering plants, the gases are absorbed mainly through stomata in the leaves and len- ticels in the stems, whereas mineral salts are absorbed through the root system.

Inside the plants, gases move by diffusion. They are always dissolved in water of the moist cell walls before entering the cells. Water, mineral salts and soluble foods are transported in vascu- lar tissues.

STRUCTURE OF VASCULAR BUNDLES: Vascular bun- dles are the conducting tissues in higher plants; they are located in the roots, stem and leaves. There are about 10–12 vascular bundles in the skin of sunflower. Each vascular bundle consists of wood (xylem) and phloem tissues.

The vascular tissues of plants are made up of a network of long tubes called vascular bundles. They are called veins in the leaves. These veins are reticulate in appearance in dicotyledonous leaves, whereas they are parallel in the leaves of monocotyledonous plants. A vascular bundle

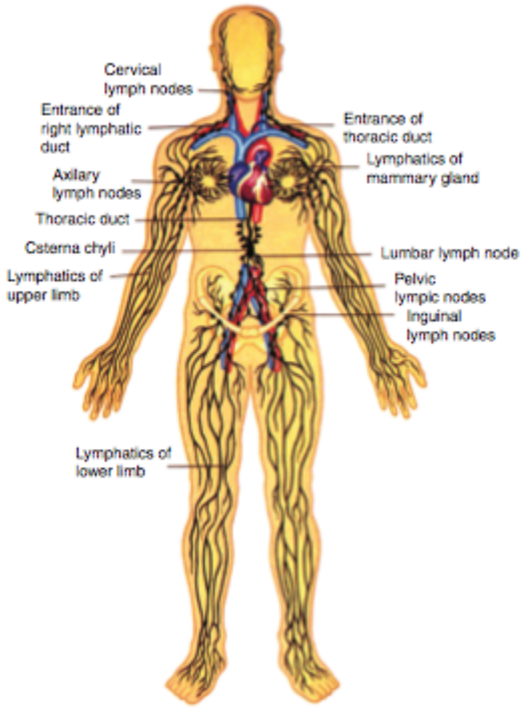


FIGURE 3.10 Human lymphatic system

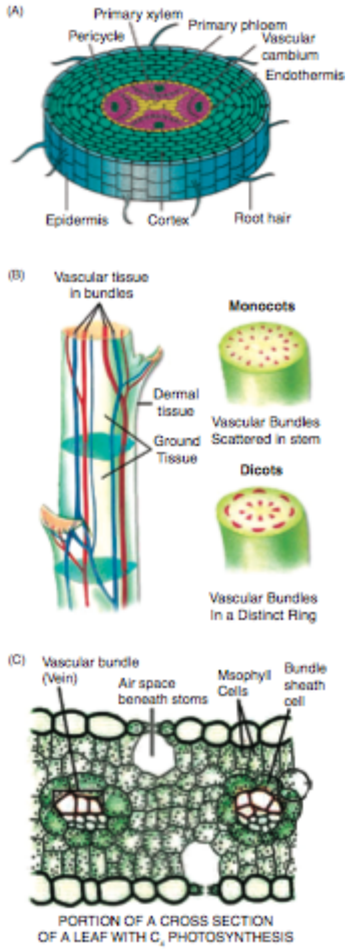
consists mainly of the xylem and phloem tissues. But in the roots and stems of dicotyledonous plants, a layer of cambium cells exists between the xylem and phloem tissues. Hence, vascular bundles are found in the roots, stems and leaves of flowering plants (Figure 3.11).

The xylem tissue transports water and mineral salts from the roots to all plant parts, whereas the

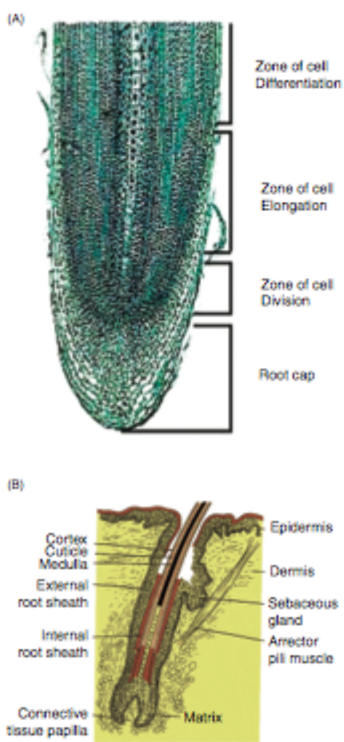
phloem tissue transports soluble manufactured foods to different parts of the plant.

MOVEMENT OF WATER IN PLANTS

Plant roots carry out two main functions: they anchor the plant firmly in the soil and they absorb water and mineral salts from the soil through



▲ FIGURE 3.11 Distribution of vascular bundles in the (A) root (B) stem (C) leaf



▲ FIGURE 3.12 (A) Longitudinal section and (B) Transverse section of root hair region their root hairs. Roots hairs are very tiny, finger- like projections produced just behind the region of elongation of the root. They are normally very many and have a large surface area for absorb- ing water and mineral salts. Each root hair is unicellular.

Root hairs penetrate the soil particles, which are usually surrounded by a film of water with mineral salts in very dilute solution. The

cell sap, inside the vacuoles of the root hairs, contains a stronger solution of salts than the surrounding soil solution. As a result, water enters the root hair cells by osmosis. Its cell membrane acts as a differentially or selectively permeable membrane. From the root hair cells,water enters the cells of the root cortex by osmosis until it reaches the xylem vessels at the middle of the root. It is through transpirational pull that water is drawn up to the leaves, especially tall trees.

ROOT PRESSURE: There is some evidence that the roots may pump water actively into the xylem. This evidence is a phenomenon called root pres- sure. This occurs most frequently during the rainy season, when the cut ends of some stems exude water for a long time, showing that water is under pressure in the xylem.

Root pressure varies from one plant to the other and from time to time. However, it is inad- equate on its own to pump water to the tops of tall plants particularly trees. Root pressure serves mainly in filling the xylem vessels with water at the base of the shoot. The movement of water up these vessels is mainly done by a process called transpiration stream (pull).

EXPERIMENT 1

AIM: To demonstrate root pressure in plants

METHOD

Cut the stem of an actively growing and well-watered plant (e.g., balsam) a few centimetres from the soil surface.

- Attach a glass tube to its stump (Figure 3.13).
- Put a drop of water on the cut end.
- Measure the initial level of water in the glass tube.
- Observe the experiment you set up for 5–7 days and measure the level of water in the tube daily.

OBSERVATION

It could be observed that water rises up several centimetres in the tube daily for several days.

CONCLUSION

It can be concluded that water enters the xylem vessels of the root due to root pressure.

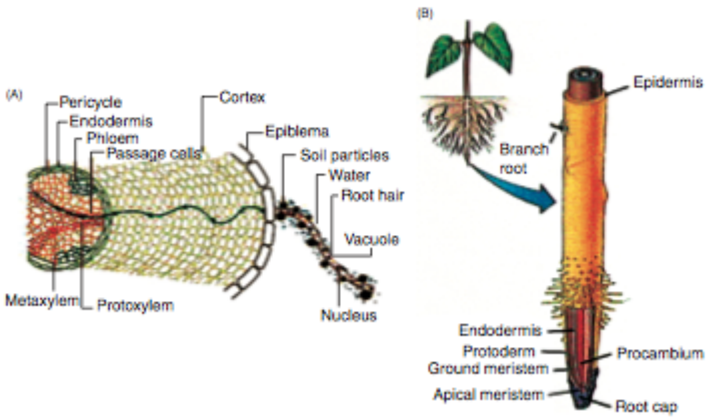


FIGURE 3.13 (A) Absorption of soil water by a root hair (B) Demonstrating root pressure

SUGGESTED PRACTICALS

Structure of the mammalian heart

(a) Examine the heart of a mammal such as pig or goat obtained from a butcher and cut open.

(b) The more rounded (convex) side is the ventral side. Identify the two atria and the ventricles. How do they differ in size and shape?

(c) Feel the atria and ventricles with your fingers.

(d) Look at the large blood vessels. Can you identify aorta, pulmonary artery, pulmonary vein and vena cava as shown in Figure 3.7?

(e) How do the arteries differ from the veins?

CHAPTER SUMMARY

- Large multicellular organisms need transport systems because diffusion is inade- quate to carry nutrients, other useful materials and waste products to and from their numerous body cells. This is due to the fact that they have a very small surface area relative to their body volume.

- The materials transported in organisms include water, digested foods, nitrogenous waste products, gases (e.g., oxygen and carbon (IV) oxide), auxins and hormones.

- In plants, the medium of transportation of mineral salts is the cell sap or latex, whereas in vertebrates, it is the blood, tissue fluid and lymph.

- In multicellular animals, there are two types of circulatory system: open and closed systems. In the open system, blood vessels leave the heart but end up in blood spaces called haemocoels. In the closed system blood is limited to branching blood vessels through which one or more hearts pump blood.

- The mammalian blood consists of four main components: the plasma (a liquid in which several materials are suspended), the white corpuscles, the red corpuscles and the platelets, each of which has specific functions.

- The blood has three principal functions: for transporting nutrients and waste mate- rials in the body, protecting the body from attack by harmful microorganisms and regulation of body temperature, body fluid and chemicals.

- The mammalian circulatory system comprises the heart, blood vessels and lymphatics.

- The three types of blood vessels are the arteries, capillaries and veins. The arteries are thick-walled and carry oxygenated blood from the heart to each body organ. The veins are thin-walled and carry de-oxygenated blood from the body tissues to the heart, whereas the capillaries, which permeate every body tissue, join the arteries to the vein.

- The heart is the pumping organ of the circulatory system. It consists of chambers: the two upper parts, the auricles or atria, and the two lower parts, the ventricles. The ventricles are thicker than the auricles.

- Deoxygenated blood is always found in the right auricle and right ventricle, whereas the left auricle and ventricle always contain oxygenated blood.
- Mammals have two main types of circulatory system: systemic and pulmonary!
- In the systemic circulation, blood is carried from the left ventricle to all body parts except the lungs and back to the right auricle. In the pulmonary circulation, blood is carried from the right ventricle to the lungs through the pulmonary arteries and back to the left auricles through the pulmonary veins.
- Tissue fluid is formed when the blood plasma is forced through the capillary walls under high pressure at the arterial end of a capillary. It is similar to the blood plasma but contains less plasma protein.
- Any tissue fluid, which is not absorbed through the blood capillaries into the blood stream, forms the lymph, which drains into the lymphatic system.
- The lymph is similar to the blood plasma but contains less protein. In the lymph nodes are phagocytes, which destroy bacteria and dead cells in the lymph.
- In plants, materials are transported in vascular tissues. Water and

mineral salts are carried in the xylem vessels from the roots to the leaves. Manufactured foods from the leaves and in storage organs are carried to different part of the plant through the phloem vessels in soluble forms (translocation).

- Water from the soil enters the root cortex through the root hairs by osmosis. Mineral salts enter the root hairs by active transport against a concentration gradient.
- Water reaches the leaves of tall trees through the transpiration stream set up in the leaf mesophyll.

REVISION QUESTIONS

OBJECTIVE QUESTIONS

Choose the correct options to the following questions.

1. Which of the following statements about transport system is false?
a. Large organisms have a large surface area to volume ratio, whereas small organisms have a small surface area to volume ratio.

b. Small organisms have a large surface area to volume ratio, whereas large organisms have a small surface area to volume ratio.

c. In large organisms, simple diffusion is inadequate carrying substances to and from their body parts.

d. The blood, lymph, tissue fluid and cell sap are media of transportation in mammals.

2. All the *following statement about the mammalian blood is correct except*
a. it protects the body from germs.
b. it synthesises bile and hormones.
c. it carries dissolved nutrients and waste products to specific parts of the body.

d. it helps to keep the amount of water in the body fairly constant.