TRANSPORT IN PLANTS AND ANIMALS

Transport refers to the movement of materials from one part of the organism to another. In large, complex multicellular organisms, it involves transport systems such as vascular system in plants, the circulatory and lymphatic systems in mammals.

THE NEED FOR TRANSPORT SYSTEM

- To transport nutrients obtained from the environment to deep layers of the body
- To ensure that nutrients reach all cells in the body
- To move waste products from all body cells to be excreted

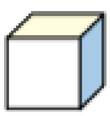
Problem of being large/multicellular

In small organisms such as amoeba and euglena, there is no need for a transport system because of a large surface area to volume ratio such that simple processes like osmosis, diffusion, phagocytosis and active transport are required.

However, the problem with large multicellular organisms is that as size increases, surface area to volume ratio decreases

Consider two organisms A of side 1cm and B of side 3cm below

A

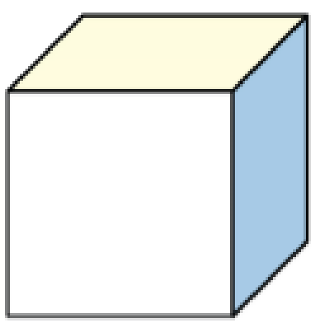


Surface area=side×side×No of sides
SA=1×1×6= 6cm^2

Volume (V) =S^3
Volume=1×1×1=1cm^3

Ratio of SA: V =6÷1 =6

B



Surface area=side×side×No of sides
SA=3×3×6= 54cm^2

Volume (V) =S^3
Volume=3×3×3=27cm^3

Ratio of SA: V =54÷27 =2

The illustrations show that **A** which is a smaller organism has a larger surface area to volume ratio while **B,** a larger organism has a smaller surface area to volume ratio.
This means that substances that move across the surface of organism **A** are enough to meet the volume requirements inside the organism while the substances that move across the surface of **B** are not enough to meet the volume requirements in the body of the organism.
Conclusion: *Organism **A** does not require a transport system while organism **B** requires a transport system Here, **A** is likened to an amoeba while **B** is likened to a human being.*

TRANSPORT IN ANIMALS

Structures involved in transport in animals

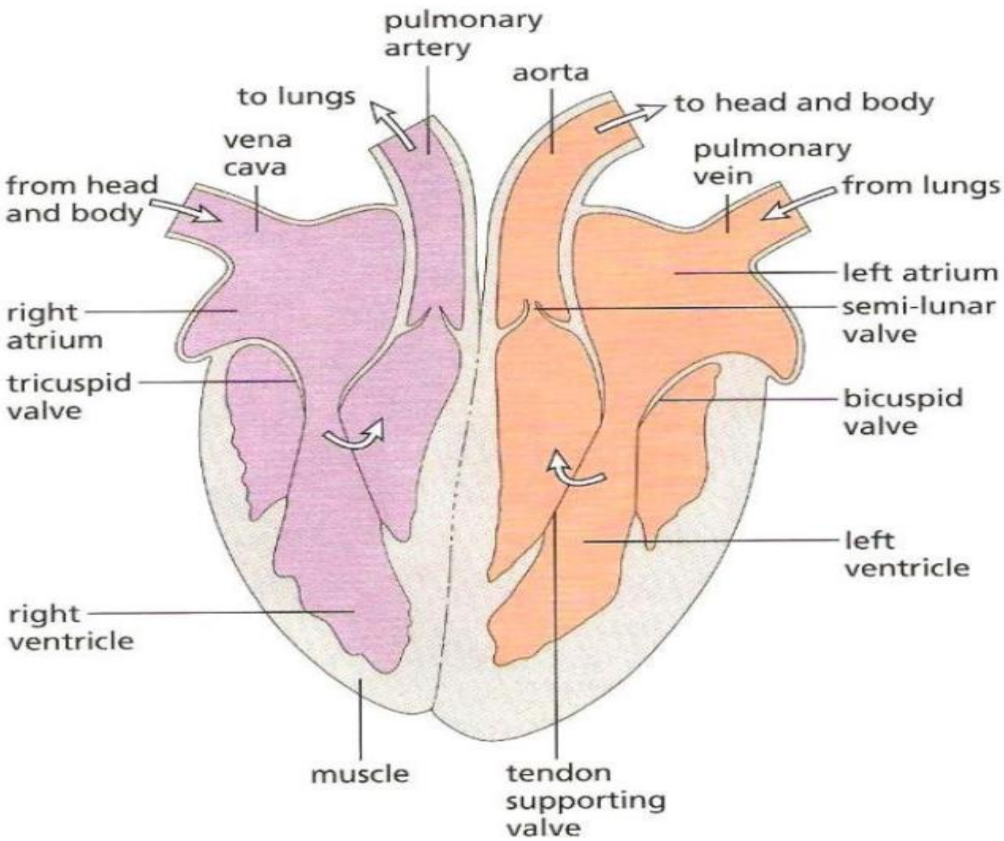
a) **Heart**
b) **Blood vessels (arteries, veins and capillaries)**
c) **Blood**
d) **Lymph**
e) **Lymph vessels**

THE MAMMALIAN HEART

Its function is to pump blood around the body. The whole heart is surrounded by a tissue called **pericardium** which has two layers. The pericardial fluid between the layers of pericardium reduce friction between them during the pumping action of the heart.

The heart is made of a unique muscle tissue called **cardiac muscle** which has ability to *contract on its own* and *does not fatigue*

DIAGRAM TO SHOW THE LONGITUDINAL SECTION OF THE HEART



It's divided in to four chambers. The two upper chambers are called **atria / auricles** and the two lower chambers are each called **ventricles**.

The heart is divided in to the left and right sections by a muscular **septum** whose function is to prevent mixing of oxygenated blood on the left with deoxygenated blood on the right

Flow of blood in the heart is maintained in a single direction i.e. from the auricle to ventricle and then out to blood vessels by **valves**.

There are two sets of valves

i. **Semilunar valves which** prevent backflow to the ventricles
ii. **Atrio-ventricular valves** which prevent backflow to the atria. The atrio-ventricular valves on the right are called ***tricuspid valves*** while those on the left are called ***bicuspid*** **valves**

The ***left atrium*** receives *oxygenated blood* from *lungs* through the **pulmonary vein** and pump it to the ***left ventricl***e.

The ***right atrium*** receives *de-oxygenated blood* from the *rest of the body* through the **vena cava** and pumps it to the ***right ventricle***.

The ventricle walls are **more muscular** (**have thicker walls**) than those or the auricles because the auricle pump blood to shorter distance i.e. to the ventricle while the ventricles pump blood longer distances i.e. to body and lungs.
The walls of the left ventricle that pump blood to the rest of the body through the **aorta** which is a longer distance away from the heart are **thicker** than those of the right ventricle which pump blood to lungs through the **pulmonary artery** which is a shorter distance away from the heart

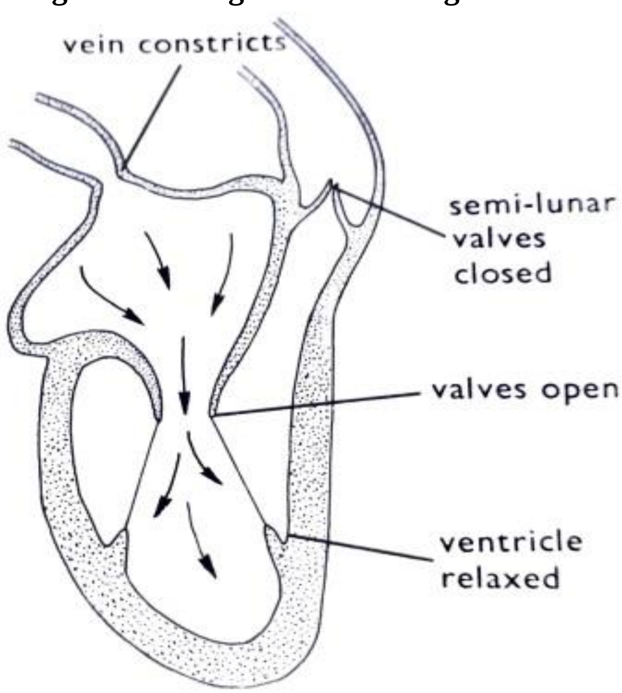
Flow of blood through the heart
De-oxygenated blood flows into the heart from the rest of the body via the vena cava to the right atrium which pumps it to the right ventricle.
The right ventricle pumps de-oxygenated blood through the pulmonary artery to the lungs. Oxygenated blood flows back to the heart through pulmonary vein to the left atrium which pumps it to the left ventricle. Oxygenated blood is finally pumped to the rest of the body via the aorta.
NOTE: ***blood supply to the heart is through coronary arteries***

THE CARDIAC CYCLE

This refers to the sequence of events by which the heart pumps and is refilled with blood.
The pumping action of the heart consists of alternate contraction and relaxation of cardiac muscles in the walls of the heart. Contraction of cardiac muscles is called ***systole*** while relaxation is called ***diastole***.

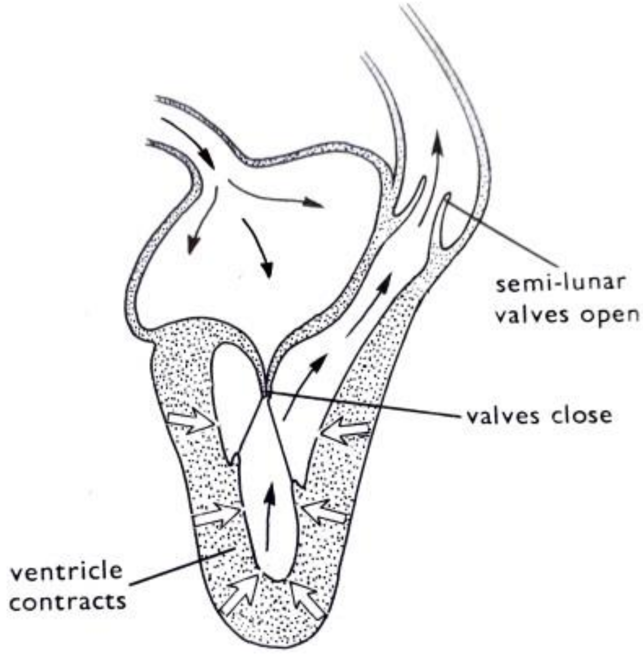
During diastole, atria relax such that pressure inside is low, blood from the vena cava and pulmonary vein enter the right and left atria respectively such that atria expand to fill with blood. The ventricles relax such that pressure in them reduces as they expand while atria contract, forcing blood from the atria into ventricles.

Diagram showing ventricle filling with blood



During systole, ventricles contract, forcing blood out of the heart into the aorta and pulmonary artery during this time, the bicuspid and tricuspid valves shut to prevent backflow of blood to atria. The atria are relaxed and expand to re-fill with blood. The closure of the valves produces the heart sound termed as ***lub.***

Diagram showing ventricle being emptied as it contracts



After expelling blood, ventricles relax and their pressure lowers compared to aorta and pulmonary artery pressure, the semi lunar valves close to prevent back flow of blood to ventricles.

The closure of the semi lunar valves causes a second heart sound, ***dub.***

The 2 sounds ***lub and dub*** are so close and often described as *lub-dub,* heard at the upper chest of an individual during a single heartbeat.

Initiation and control of the heart beat

Contraction of the heart is initiated by cardiac muscle itself, it is automatic and the heart muscle is said to be myogenic i.e. the rhythmic contraction arise from within the heart muscle itself and does not require nervous stimulation.

Because of this, the heart can be maintained active in the right solution of salts for some hours. Increase or decrease of heart beat is under control of the medulla oblongata of the brain

Factors affecting the heart beat rate

- Exercise.
- Effect of hormones e.g. adrenaline
- State of health, higher among sick e.g. malaria patients
- Age i.e. it's faster in infants than adults.
- Body size i.e. it is faster in small organisms than large
- Sex i.e. faster in female than in male.

NB: In normal adults at rest, heart contracts about 70 heart beats per minute.

BLOOD PRESSURE

Blood pressure is mainly due to the pumping action of the heart.

Blood pressure normally increases in periods such as exercising the body and effect of hormones such as adrenalin.

Blood pressure may also increase due to a decrease in size of the lumen of arteries as a result of fat deposition. In this case, the heart pumps blood more strongly to maintain adequate supply to all body parts resulting into higher blood pressure than normal.

BLOOD VESSELS

These are the tube like structures that carry blood throughout the body. They include; arteries, veins, and capillaries

- ✓ Both arteries and veins have three layers in their walls but with the elastic tissue in arteries much thicker than that in veins.
- ✓ Capillaries are however only one cell thick.

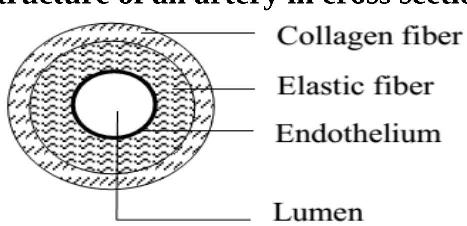
1. ARTERIES:

These carry blood from the heart to the various body parts. Arteries branch to form smaller vessels called arterioles which then divide repeatedly to form capillaries with in tissues.

Characteristics of arteries

- Has three layered wall.
- Have a thick elastic tissue to allow stretching due to high blood pressure from pumping action of heart
- They have fibrous outer wall so as to withstand high pressure
- They are found deeply in the body.
- They have a pulse beat corresponding to the heart beat.
- Their walls are elastic to allow stretching due to high blood pressure.
- They have no valves except at the base of the pulmonary artery and aorta.
- They have narrow lumen as compared to their size and to that of veins.
- They carry oxygenated blood except the pulmonary artery and umbilical artery.
- They all carry blood from the heart to other parts of the body.

Structure of an artery in cross section



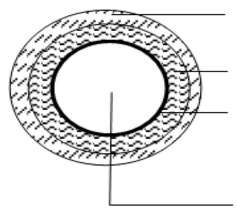
2. VEINS

These carry blood from tissues to the heart. The pressure at which blood flows in them is considerably lower and steady than in arteries.

Characteristics of veins

- They have wide lumen to encourage flow of blood at low pressure.
- They have thinner walls than arteries which are adequate to withstand low pressure.
- They have valves at intervals along their length which prevent blood from flowing backwards thus maintain blood flow in one direction.
- They are not capable of constricting.
- They transport deoxygenated blood except the pulmonary vein and umbilical vein.
- They have less elastic muscles.
- They are found close to the body surface.

Cross section through a vein



Blood in veins is able to move despite a low pressure due to the following;

- Possession of valves which prevent back flow.
- Having a wide lumen that offers a low resistance to blood flow.
- Action of skeletal muscles as they contract during movement against veins which is a source of pressure to enable blood flow in veins.
- Lowering of pressure in the thoracic region of the body when breathing in which enables blood flow from abdominal region and limbs to the heart.

3. CAPILLARIES

These are the smallest blood vessels in the body. They form numerous interconnections (network) in tissues called capillary bed where exchange of materials between them and tissue fluid takes place.

They connect arterioles to venules.

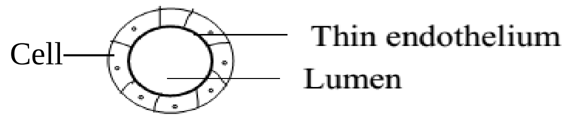
Due to the vast branching of capillaries, blood pressure within them reduces greatly. This facilitates exchange of materials between them and the tissue fluid in contact with cells.

The capillaries network is so dense and the capillaries unite to form large vessels called venules which join to form veins.

Characteristics of capillaries

- They have the narrowest lumen.
- Have a wide lumen in comparison to their size (diameter)
- Their walls are one cell thick
- They have no valves.
- Blood flows in them at very low pressure.
- They carry both deoxygenated and oxygenated blood.

Cross-section through a capillary



Adaptations of capillaries to functions

- Highly branched to form networks which provide large surface area for exchange of materials.
- They have very thin walls for faster diffusion of materials.
- Wide lumen in comparison to their size to transport sufficient amount of blood for exchange of materials in tissues.
- Slow movement of blood in capillaries o allow considerable time for exchange of materials.

Differences between arteries, veins and capillaries

Structural:

Artery	Veins	Capillaries
Have thick walls with smooth muscles	have thin walls with smooth muscles	Have thinnest walls with smooth muscles
have more elastic fibres	Have less elastic fibres	Do not have elastic fibres
Have smaller lumen relative to diameter	Have a wider lumen relative to diameter	Have largest lumen relative to diameter
Have no valves except at the base of aorta & pulmonary artery	Have valves throughout their length	Have no valves
Can constrict	Can’t constrict	Can’t constrict
Walls not permeable	Walls not permeable	Walls permeable

Functional

Artery	Vein	Capillaries
Carry blood away from the heart	Carry blood towards the heart	Carry blood in a direction to and from the heart in tissues
Carry oxygenated blood except pulmonary artery and umbilical artery	Carry deoxygenated blood except pulmonary vein and umbilical vein	Carry both oxygenated and deoxygenated blood
Blood flow at high pressure	Blood flow at low pressure	Blood flow at low pressure
Blood flow in pulse	Blood does not flow in pulse	Blood does not flow in pulses

CIRCULATION OF BLOOD IN THE BODY

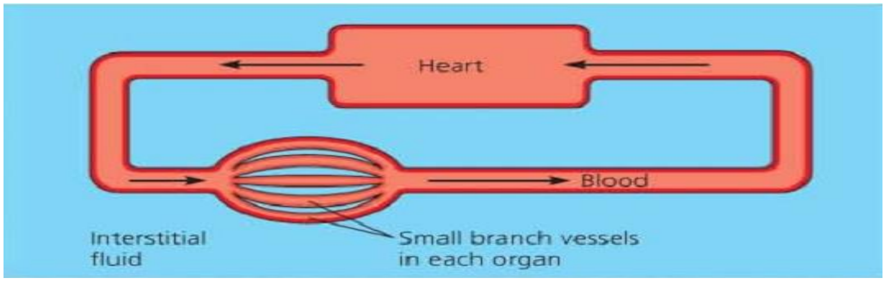
This refers to the movement of blood in the body of an organism. There are two main types of blood circulation in animals;

1. **Closed circulatory system**
2. **Open circulatory system**

1. *CLOSED CIRCULATORY SYSTEM*:

Closed circulatory system is a type of circulation in which blood flows through a system of tubes or vessels e.g. in earthworm, fish and mammals have blood enclosed in tubes

In closed circulatory system, cells do not come into direct contact with blood.



Advantages of closed circulatory system

- ✓ Distribution of blood/materials is easily controlled.
- ✓ Blood moves or flows very fast leading to quick supply of materials.

Demerits of closed circulatory system

- ✓ It requires a special heart whose pumping action provides pressure for movement of blood.
- ✓ Blood movement meets a high resistance within vessels.

2. Open circulatory system e.g. in molluscs and arthropods

This is a type of circulation in which blood does not move through a system of vessels. Blood fills the entire body cavity e.g. in arthropods.

The organism's cells are directly bathed in blood and materials diffuse out of the blood in to each cell across the cell membrane.

Advantages of open circulatory system

- ✓ Easy diffusion of materials due to absence of vessel barriers.
- ✓ It does not require special pumping hearts since blood is flowing through cavities with less resistance.

Disadvantages of open circulatory system

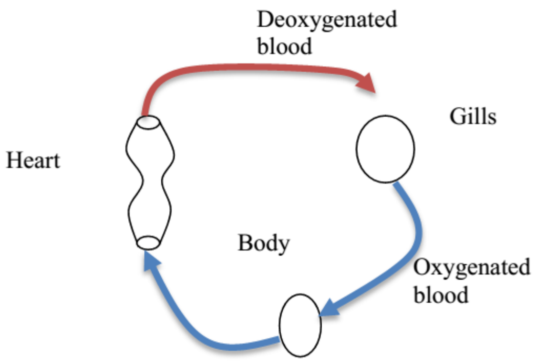
- ✓ Blood flows at low pressure leading to slow supply of materials.
- ✓ There is little control over distribution of materials or blood.

TYPES OF CLOSED CIRCULATORY SYSTEM

i. Single circulatory system

This is the type of circulation where blood from the body cells flows once through the heart and goes back to the body cells. It has a heart with only two 2 chambers i.e. one atrium and one ventricle e.g. in fish.

Diagram illustrating single circulation



The disadvantage of this is that there is a tendency of oxygenated blood mixing with deoxygenated blood.

ii. Double circulatory system

In double circulatory system, blood moves through the muscular heart twice before it is pumped to the rest of the body.

Double circulation consists of two distinct circulations;

- Pulmonary circulation; between heart and lungs
- Systemic circulation; between heart and the rest of the body

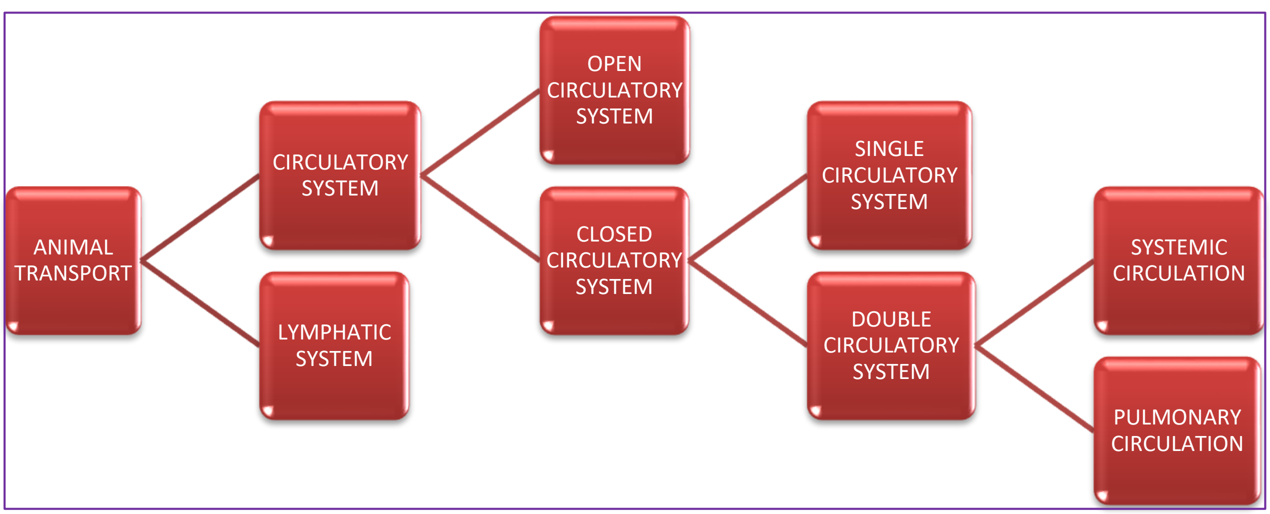
Advantages of double circulatory system:

- High blood pressures required for fast flow of blood is reached than in open circulation.
- Gives more rapid circulation since blood is returned rapidly to the heart for pumping.
- There is complete separation of oxygenated and deoxygenated blood which improves efficiency of oxygen distribution and can therefore sustain the high metabolic rate required by such animals that possess it.
- Blood is pumped directly to where it's needed

NB:

The amount of blood flowing to a certain organ can be regulated by changing the diameter of the blood vessel.

Summary of transport in animals

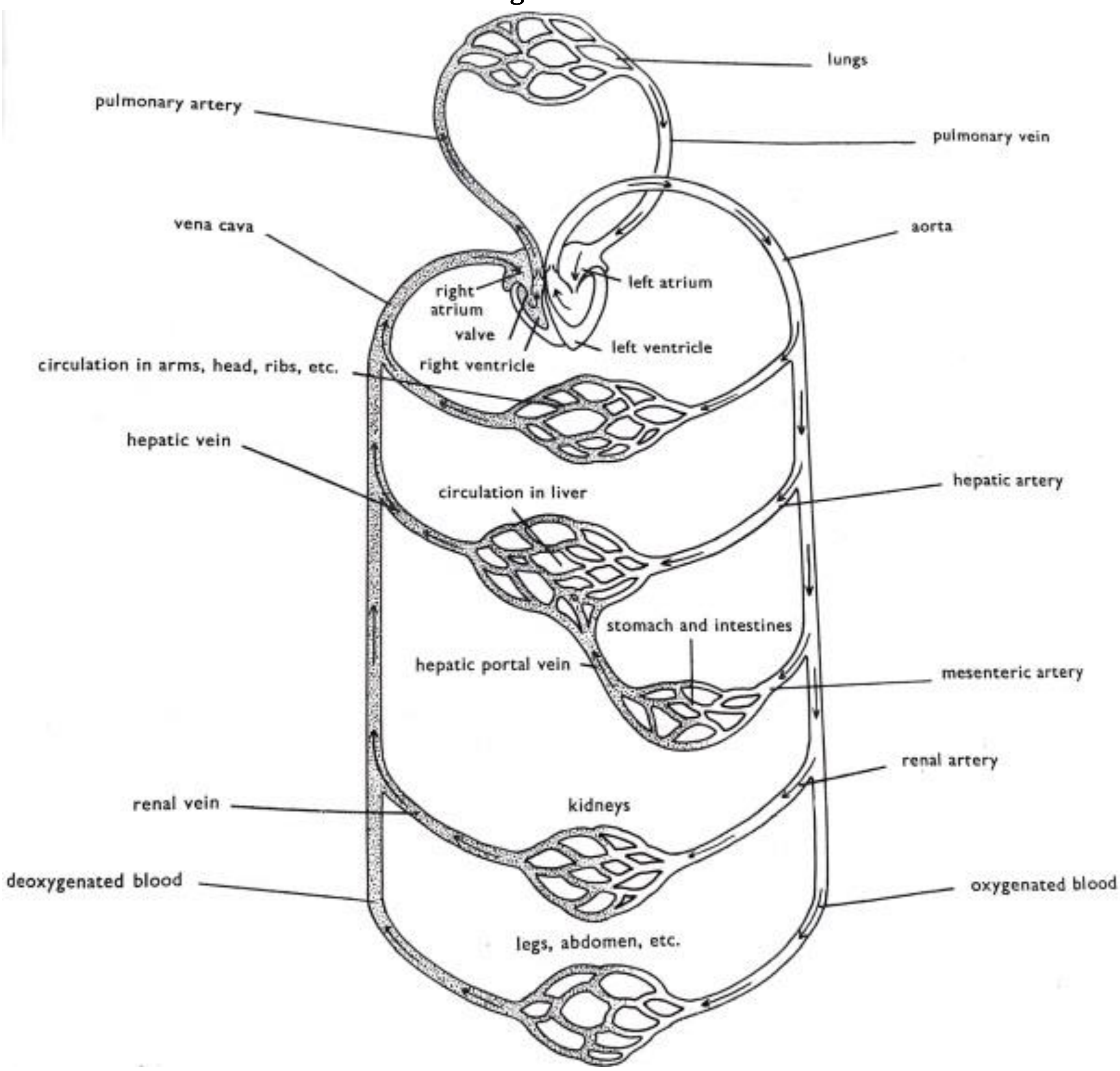


THE MAMMALIAN CIRCULATORY SYSTEM

The continual circulation of blood in mammals is due to the pumping action of the heart.
The circulation of blood in mammals is divided into two. That is;

1. **The pulmonary circulation**; this is the circulation of blood from the heart to the lungs and from the lungs back to the heart. It is the simplest circulation where blood moves a very short distance. This type of circulation involves the pulmonary artery and pulmonary vein.
2. **The systemic circulation**; this is the circulation of blood from the heart to the rest of the body apart from the lungs and from the rest of the body back to the heart.

Structure showing the flow of blood in man



BLOOD

Blood is a connective tissue made up of cells suspended in a fluid matrix called ***plasma.***
There are two types of cells in blood i.e. **White blood cells (leucocytes) and red blood cells (erythrocytes)**. The **platelets (thrombocytes)** are **fragments of cells.**
In an adult human being, there are five to six liters of blood with blood making up approximately 10% of the body weight.

Main Components of blood

1. Red blood cells (erythrocytes)
2. White blood cells (Leucocytes)
3. Platelets (thrombocytes)
4. Plasma

Other components of blood that may be periodically added include; **blood proteins like globulin, hormones *and* antibodies**

General importance of blood in the bodies of animals

1. It transports oxygen from the lungs to all parts of the body.
2. It transports digested food from the ileum to other parts of the body for use.
3. It transports Carbon dioxide from the tissues to the lungs.
4. It transports nitrogenous wastes from the liver to the kidney where they are excreted.
5. It transports hormones from their site of production to where they perform their functions.
6. It distributes heat and aids in temperature control.
7. It prevents infection by transportation of white blood cells.
8. It prevents loss of fluids and cells through forming blood clots.

THE RED BLOOD CELLS (ERYTHROCYTES)

They are manufactured from the red bone marrow in adults. In foetus, they are manufactured in the liver. They are approximately 5 million/mm^3 of blood.

On average, red blood cells last for four month after which they are destroyed by the liver to form bile pigment and the iron in haemoglobin is stored in the liver

Characteristics of Red Blood Cells:

- They have hemoglobin molecules which bind oxygen to be transported from the lungs to the tissues.
- They have no nuclei
- They have a biconcave disk shape
- They have thin cell membranes. This reduces the diffusion distance for gases.

Importance of Red Blood Cells:

They transport oxygen from gaseous exchange surfaces to the tissues

They transport carbon dioxide from tissues to the gaseous exchange surfaces.

Regulate blood pH.

Adaptation of Red Blood Cells to carry out their function

- They are biconcave in shape so as to avail a large surface area to volume ratio for absorption of oxygen.
- They have hemoglobin molecules that bind oxygen and transport it from the lungs to the tissues.
- They have a thin membrane which reduces the diffusion distance for the respiratory gases in and out of the cells.

- Have no nucleus which provides enough space for packaging of haemoglobin
- Have no mitochondria and generate their ATP exclusively by anaerobic respiration to prevent them from using the oxygen they are carrying.
- They are numerous per mm^3 to increase surface area for transportation of oxygen
- They have flexible membranes which make them able to squeeze through capillary networks as they exchange materials they transport with the surrounding tissues.

NB: The concentration of red blood cells increases as one slowly climbs up a mountain because the concentration of oxygen in the air reduces with increase in height above sea level. So the body acclimatizes by producing more red cells to increase the available total surface area to bind and carry oxygen to the tissues regardless the reducing oxygen concentration main.

Structure of the red blood cell.

THE WHITE BLOOD CELLS (LEUCOCYTES)

These are made in the white bone marrow, spleen and lymph nodes. They are responsible for defense of the body against infection. They are fewer in blood than the red blood cells. There are about 600 red blood cells to each white blood cell

Characteristics of white blood cells

i) They have no definite shape (they are amoeboid)
ii) They have a nucleus.
iii) They are relatively few in blood as compared to red blood cells.
iv) They carry out phagocytosis

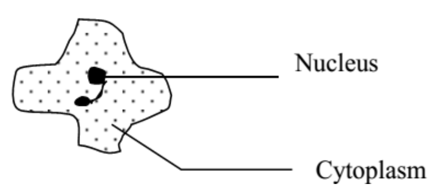
White blood cells are divided into two major categories. These are;

1. Granulocytes. These are white blood cells with granules in their cytoplasm
2. Agranulocytes. These are white blood cells which don’t have granules in their cytoplasm.

White blood cells defend the body against infection in two major ways;

a) by engulfing the pathogen during phagocytosis
b) by producing antibodies against antigens of the pathogen

Structure of a white blood cell

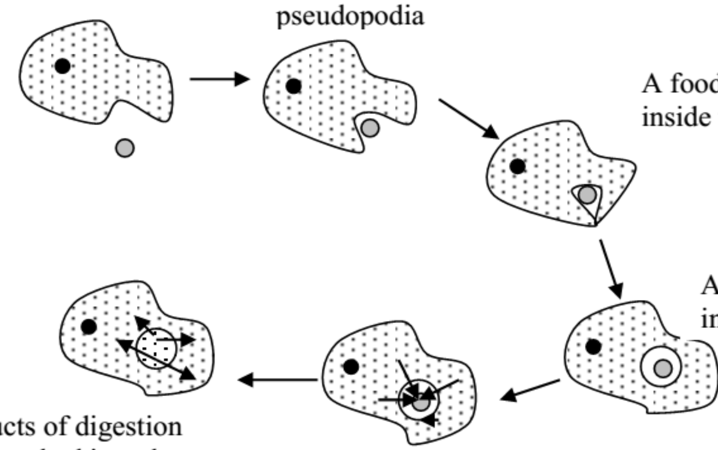


Action of white blood cells on the foreign particles

In this process the white blood cells form pseudopodia, surround the pathogen and engulf it by Phagocytosis.

After engulfing the foreign particle, a food vacuole is formed, digestive enzymes are introduced into the vacuole such that the enzymes break down the particle and useful materials are released into cytoplasm of white blood cell while the wastes are excreted out of the cell.

Illustration of Phagocytosis



Some white blood cells destroy foreign particles by releasing antibodies, which destroy the particles. White blood cells, which produce antibodies.

There are five types of antibodies produced and these include;

1) **Opsonins**; these attach to the outer surface of the foreign particle and make it easier for phagocytic white blood cells to ingest them, a process called **opsonisation**
2) **Agglutinins**; these cause the foreign particles to stick together. In this condition the foreign particles cannot invade the tissues. This is called **agglutination**
3) **Lysins**; these destroy bacteria by dissolving their outer coats. This is called **lysis.**
4) **Anti-toxins**; these combine with and so neutralize the toxins produced by foreign particles. This is called **neutralization.**

THE PLATELETS (THROMBOCYTES)

These are blood cells formed as fragments in the bone marrows during the formation of red blood cells. They are responsible for blood clotting.

Characteristics of platelets

1. They are cell fragments.
2. They are round or oval in shape.
3. They do not have a nucleus.
4. They are tiny

Functions:

They play a role in blood clotting which protects the body against excessive loss of blood and entry of pathogens through the injured part.

Blood clotting is the process by which blood stops oozing out of a cut or wound by formation of a clot.

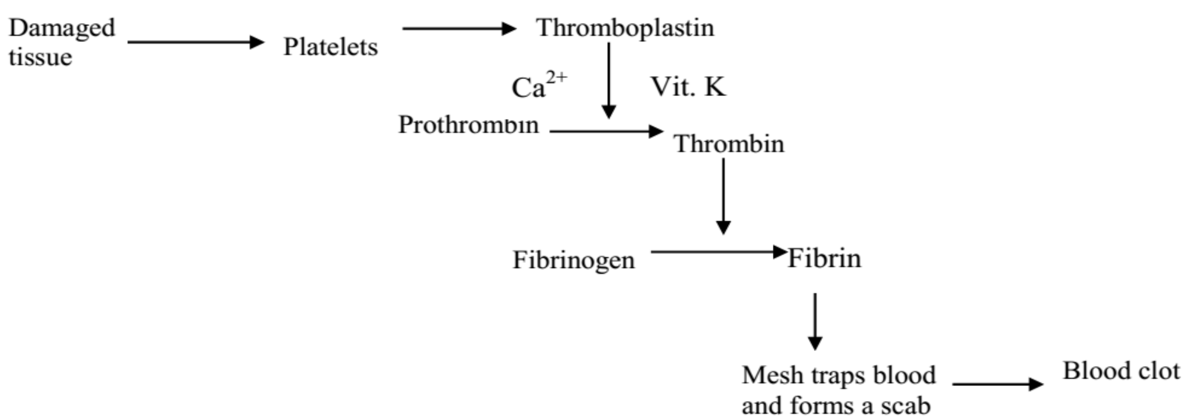
It is important because of the following reasons.

1. It prevents excessive loss of blood from the body.
2. It is a step towards healing of cuts and wounds.
3. The blood clot creates a barrier to prevent entry of bacteria and other pathogens in the body.

The Process of Blood Clotting:

When blood is exposed to air as a result of a cut or wound, the platelets in the blood at the damaged tissue stimulate the release of a chemical called **thromboplastin (thrombokinase)**. In the presence of **calcium ions** and **vitamin K**, **thromboplastin** stimulates the conversion of **prothrombin** to thrombin enzyme. **Thrombin** then catalyzes the conversion of soluble blood protein **fibrinogen** to the insoluble form **fibrin.** Fibrin forms fibers, which form a mesh and trap blood cells and proteins. This mesh dries to form a scab, which is called the blood clot.

Summary of blood clotting



BLOOD PLASMA

This is the fluid part of blood. It is made up of;

a) Soluble proteins

Soluble proteins include **globulin**, **albumin** and **fibrinogen**.

b) Serum

This is a watery fluid containing a variety of substances transported from one part of the body to another e.g. hormones, lipids, enzymes, urea carbon dioxide, plasma, proteins, amino acids etc.

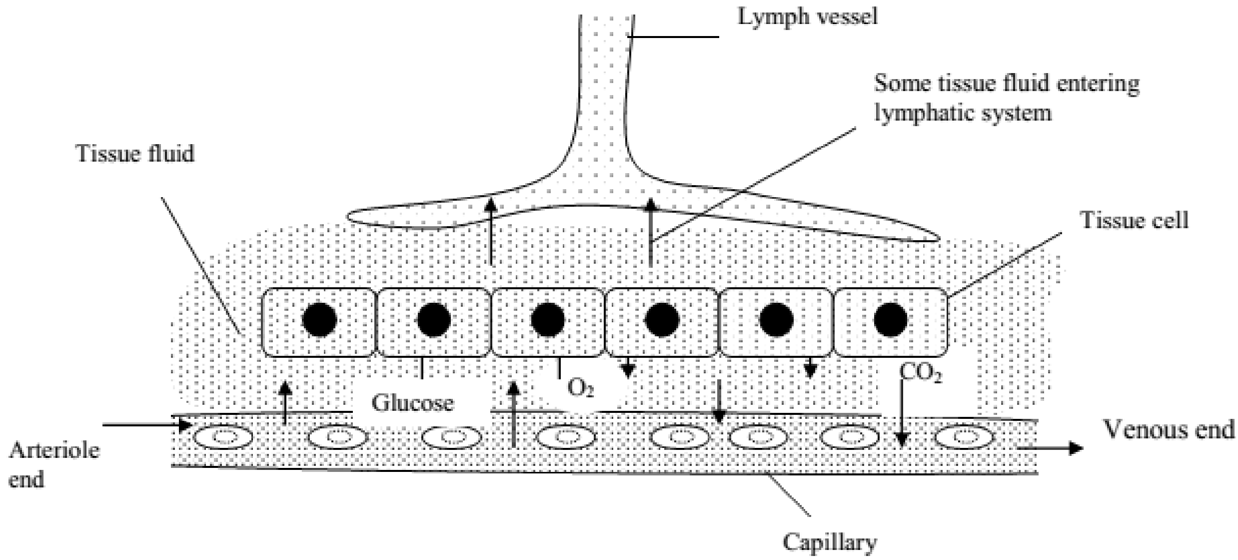
Use of Blood plasma:

- To transport hormones from gland producing them to the target sites.
- To transport food nutrients from the gut to the other parts of the body.
- To transport antibodies to the infected parts of the body.
- To transport Urea from the liver to the Kidneys for excretion.
- To transport carbon dioxide from the body muscles to gaseous exchange system.
- To transport heat from the liver and body muscles to other body parts hence maintaining a constant body temperature range.
- To transport platelets to injured sites on the body so as to initiate blood clotting.
- To distribute salts around the body so as to maintain the body’s electrolytes balance.

CAPILLARY EXCHANGE, FORMATION OF TISSUE FLUID AND LYMPH.

Pressure of blood from arteries through arterioles and then capillaries forces small molecules like glucose, amino acids, vitamins, hormones and the fluid part of blood to leave the capillaries and enter the intercellular spaces, leaving behind large molecules like proteins in plasma and cells.
Once the fluid is in the intercellular spaces of tissues, it is called **tissue fluid**.
Tissue fluid bathes body cells. Body cells obtain their requirements e.g. glucose, amino acids oxygen, etc. from the tissue fluid and they add excretory materials into the fluid.
Some of the fluid returns in to the capillaries and the other is drained in to a system of narrow vessels called lymph vessels. The fluid in these vessels is called **lymph**.
Note; lymph is formed from tissue fluid.

THE DIAGRAM BELOW ILLUSTRATES EXCHANGE OF MATERIALS BETWEEN BLOOD, TISSUE FLUID AND LYMPH



THE LYMPHATIC SYSTEM

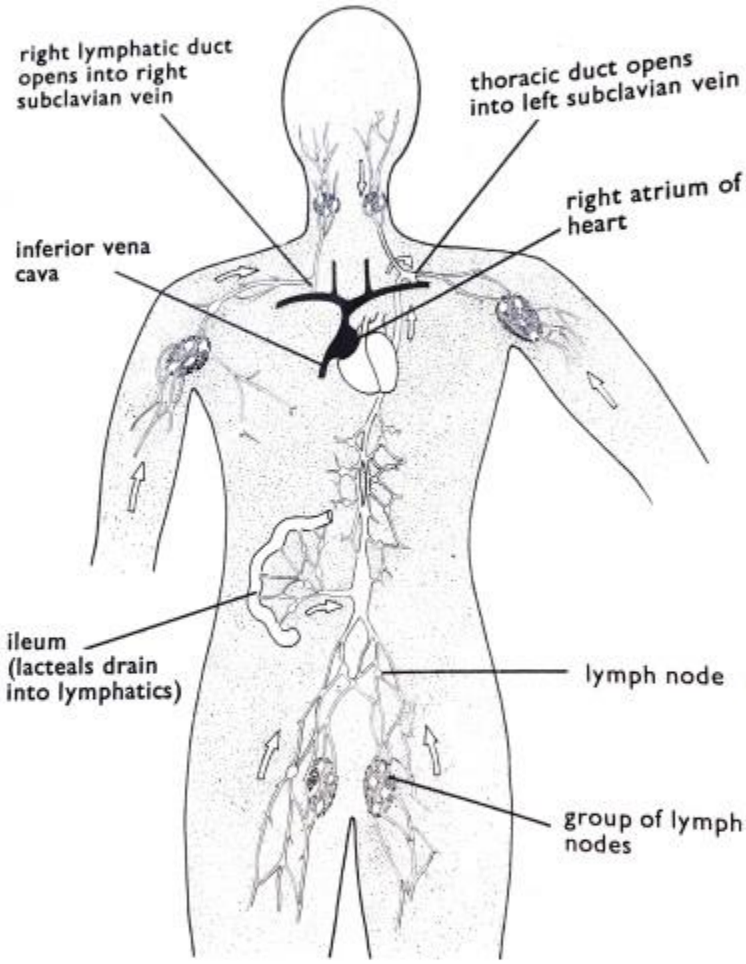
This is part of the vascular system. It forms the second type of circulation. Most of the tissue fluid as explained above goes back into the blood capillaries and the remainder enters the lymphatic system and becomes **lymph**.

- ✓ Lymph is transported through **lymph vessels**.
- ✓ Lymph vessels are similar to veins but they have more valves than the veins.
- ✓ The movement of the lymph fluid through the lymph vessels is due to the contractions of the surrounding skeletal muscles. As they contract and relax, they squeeze the lymph vessels to gain the force by which lymph moves. The walls of the lymphatic vessels have pores, which allow the entry of fatty acids, glycerol, wastes, bacteria and other small molecules.
- ✓ Before reaching the blood, lymph passes through the lymph nodes where pathogens like bacteria are removed.

The lymph joins the blood circulation via the thoracic ducts, which joins to the vena cava leading to the heart.

- ✓ The lacteals of the ileum are also connected to the left thoracic duct.

MAIN DRAINAGE ROUTES OF THE LYMPHATIC SYSTEM



Deep lying vessel cut open to show lymph moving in one direction due to action of valves

Functions of the lymphatic system

1. It transports fatty acids and glycerol from the ileum to the heart where they join the blood system.
2. It carries excretory substances from tissues to the blood stream.
3. It produces white blood cells, which carry out defense in the body.
4. It filters out bacteria before they reach the blood stream.
5. Transports hormones from glands to other body parts.
6. Temporary storage of fatty acids and glycerol before they join general blood circulation.

ELEPHANTIASIS

This is the gross enlargement of an organ whose lymphatic vessels have been infested with filarial worms, *Wuchereria bancrofti*.

Filarial worms are nematodes that cause elephantiasis and are spread by mosquitoes especially the culex mosquito.

Signs and symptoms of elephantiasis

- Swelling of legs
- Swelling of breasts
- Swelling of arms
- Swelling of the scrotum
- Dry skin
- Individuals experience fever

Elephantiasis can be treated by using anti parasitic drugs such as albendazole

Differences between the lymphatic and blood system

Blood circulatory system	Lymphatic system
Has a heart which acts as a pump	Has no pump
Blood flow is two way, i.e. from heart to body and back to the heart.	Lymph flow is one way, i.e. from body tissues to the heart.
Blood travels at high speed.	Lymph travels at a very slow speed
Valves are only found in veins	Have valves in all its vessels
Contains blood cells and proteins	Only white blood cells present. Proteins are lacking
Does not contain emulsified fats	Contains and transports fatty acids and glycerol.
Have no nodes	Have nodes that produce lymphocytes

Similarities between blood system and lymphatic system

1. Both have valves in their vessels.
2. Both are means of transporting materials in the body
3. In both a skeletal muscle provides a force by which substances are moved.
4. Both have vessels through which substances ate transported.

BLOOD GROUPS

There are 4 main blood groups i.e.

1) Blood group A
2) Blood group B
3) Blood group AB
4) Blood group O

Blood groups are determined by antigens found on one's red blood cells.

- ✓ An individual with antigen A has blood group A
- ✓ An individual with antigen B has blood group B
- ✓ An individual with both antigens A and B has blood group AB
- ✓ An individual with no antigen has blood group O

An antigen is defined as a molecule or substance that triggers an immune response. This means that during blood transfusion, care must be taken such that an immune response is not triggered in the body of the individual receiving blood (**recipient**) resulting from antigens on RBCs in blood of the individual donating blood (**donor)**.

When the immune system of the recipient reacts to RBCs in blood of the donor, agglutination of blood occurs. This is because antibodies in the recipient's blood attack antigens on donor's RBC.

The table below shows the blood groups, the antigens they carry and the antibodies they produce.

Blood group	Antigen present	Antibody produced
A	A	b
B	B	a
AB	A and B	None
O	No antigen	a and b

Note.

Antibodies are represented by small letters while antigens are represented by capital letters.

Before doctors can carry out transfusion, they carry out tests to make sure that the patient's and donor's blood are compatible (the recipient's blood must not contain antibodies that act on the antigens in the donor's blood. For example antigen A would agglutinate if mixed with blood containing antibody a. i.e. blood group B.

Table of compatibility:

Recipient

Donor

	A	B	AB	O
A	√	X	√	X
B	X	√	√	X
AB	X	X	√	X
O	√	√	√	√

Key

X --------- Incompatible

√ --------- Compatible

Note.

1) Blood group AB can receive blood from all other blood groups because it has no antibodies and it is therefore called a **universal recipient**.
2) Blood group O can donate blood to all blood groups because it has no antigens and it is therefore called a **universal donor**.

"RHESUS FACTOR" System

Rhesus factor is a protein (antigen) **ALSO** found on the cell membranes of the red blood cells.

Many individuals have the Rhesus factor and are said to be **rhesus positive (Rh^+)** while a few do not have the Rhesus factor and are said to be **Rhesus negative (Rh^-)**.

The Rhesus factor was first discovered in **a Rhesus Monkey** hence its name.

- ❖ A person who is **Rhesus factor positive** can receive a successful blood donation without agglutination from **a person of Rhesus positive** and **a person of Rhesus negative**.
- ❖ *However,* a person who is **Rhesus negative** can **only receive** a successful blood donation without agglutination from his fellow Rhesus negative person.
- ❖ A rhesus negative individual *can be transfused with blood which is Rhesus positive quite successfully **only once** and after this transfusion, his body produces **antibodies against** the Rhesus factor.* Such antibodies attack the Rhesus antigen causing rhesus positive blood to undergo agglutination the next time they receive such blood.

The same concept can be applied to ***pregnancy*** in that a Rhesus positive woman can successfully carry on a pregnancy where the fetus is **Rhesus positive or Rhesus negative**.

- ❖ *A **Rhesus negative woman** can successfully carry a pregnancy where the fetus is only **Rhesus negative.***

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- *For a rhesus negative woman, the first pregnancy with* ***Rhesus positive fetus*** *can be successful but during the pregnancy the woman's blood produces* ***antibodies against*** *the* ***Rhesus factor****. Such antibodies attack the Rhesus antigens if the woman gets subsequent pregnancies where the fetus is Rhesus positive.*

NB: During blood transfusion both the ABO system and the Rhesus factor system of blood groups are used together. So a person of blood group
ARh+ can receive blood from a donor of (i) A Rh^+ (ii) A Rh^- (iii) ORh^+ (iv) ORh^-

IMMUNITY AND THE IMMUNE SYSTEM

Immunity is the ability of an organism to resist and fight infection.

The immune response is based upon recognition of a foreign particle such that they can be destroyed. The foreign particle may be an antigen, bacteria, virus or any other pathogen. The substance that destroys these particles can be a white blood cell or antibodies produced by white blood cells.

Types of immunity

Inborn or innate immunity

This is the type of resistance to diseases that one is born with.

Acquired immunity

This is the type of immunity developed by the body during the life of an individual. It is divided into;

i. Acquired passive immunity
ii. Acquired active immunity

(i) Acquired passive immunity;

This is immunity that is obtained when antibodies from the body of another organism, either of the same or different species. It may be **natural acquired passive immunity or artificial acquired passive immunity**

- ✓ Natural acquired passive immunity is one passed on to an infant through breast feeding when antibodies from the mother move into the baby's system e.g. through colostrum
- ✓ Artificial acquired passive immunity is one in which antibodies against a particular pathogen may be obtained from a previously infected organism into another organism for example initially antibodies against tetanus were cultured in horse and then introduced into humans

(ii) Acquired active immunity

This is a form of immunity in which the body of an organism develops its own antibodies against an antigen. It may be **natural acquired active immunity** or **artificial acquired active immunity.**

- ✓ Natural acquired active immunity is one which an individual develops when they recover from an infection as the body makes antibodies against the disease causing antigens
- ✓ Artificial acquired active immunity is one which develops after vaccination.

Explain how the body's immunity may be weakened by disease or pathogens?

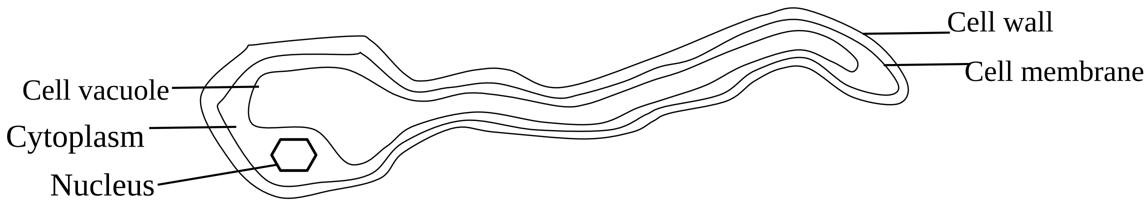
Some pathogens such as the HIV which attack white blood cells weaken the body's immunity. The receptor site of HIV is on special white blood cells called CD4 cells. Thus, the virus attacks the white blood cells and destroy them, reducing their count in the body.

This weakens the body's immune response making the body susceptible to attack by other secondary infections, called opportunistic infections or diseases like tuberculosis.

TRANSPORT IN PLANTS

Transport tissue in plants is xylem and phloem. Water and mineral salts are transported in the xylem while manufactured food is transported in the phloem.
Water and mineral salts are absorbed from soil by the root hairs.

Structure of a root hair cell.



Adaptations of root hair cell for absorption of water and mineral salts

- ✓ Long to increase surface area for absorption of water and mineral salts
- ✓ Cell wall is thin to reduce diffusion distance for both water and mineral salts
- ✓ High solute concentration of cytoplasm for easy absorption of water by osmosis.
- ✓ Mitochondria to provide energy needed for active transport of mineral salts from soil solution
- ✓ Slender and flexible to move through soil particles to absorb water
- ✓ Nucleus to control the activities that enable absorption of water and mineral salts.

Movement of water and mineral salts from soil solution to xylem of the root

Once the water and mineral salts are absorbed by the root hairs, the water moves from the root hair cell to neighbouring epidermal cells by osmosis while the mineral salts in solution move by diffusion. The water then moves to the cells in the cortex, to cells in the endodermis until it reaches the xylem in the root. The xylem now conducts the water and mineral salts to the shoot.

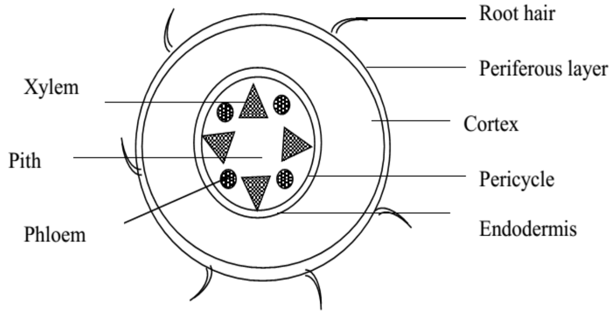
ACTIVITY

During the study of flowering plants in S.2, we learnt about the internal structure of;

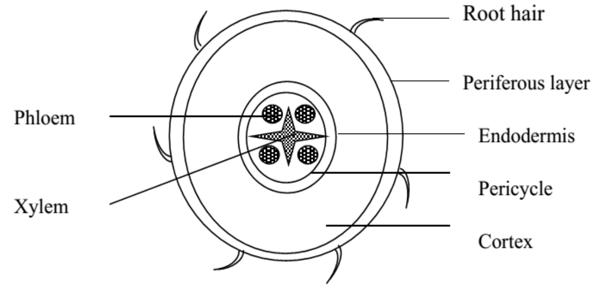
- ❖ Monocot and dicot root
- ❖ Monocot and dicot stem

Below are internal structures of monocot and dicot root, monocot and dicot stem. Study them and describe each before you continue writing the notes that follow. You will be required to present this work to your teacher.

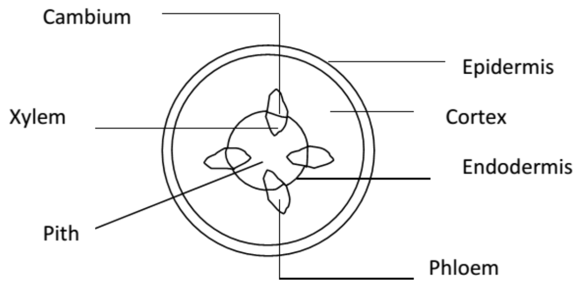
1. **Transverse section of a monocot root**



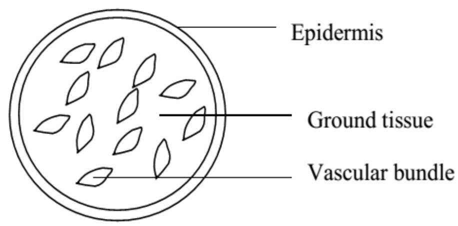
2. **Transverse section of a dicot root**



3. **Transverse section of a dicot stem**



4. **Transverse section of a monocot stem**



NB: remember to do the assignment before you continue copying the notes below!!!

PROCESSES INVOLVED IN UPTAKE AND REMOVAL OF SUBSTANCES FROM CELLS (movement in and out of cells)

The functional unit of all living organisms is a cell. For the life of a cell to be maintained, it must take in essential substances called nutrients and tae out waste materials of metabolism.
Movement of substances in and out of cells takes place either;
Actively; here, energy is required for example during <u>active transport</u>, OR
Passively; here, no energy is required and substances move down a concentration gradient e.g. <u>osmosis</u> and <u>active transport</u>

a) ACTIVE TRANSPORT

This is the movement of substances from a region where their concentration is low to where it is high using energy from a cell.
During active transport, molecules move against a concentration gradient. The energy used is derived from ATP formed during respiration.

Importance of active transport

- Mineral salts absorption by root hair cells
- Absorption of glucose in the ileum
- Reabsorption of amino acid, glucose and vitamins in nephrone
- Secretion of hormones into blood stream

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b) DIFFUSION

This is the movement substances from a region where their concentration is high to a region where their concentration is low.

Diffusion is possible for small molecules of gases and liquids because they are in constant random motion, unlike in solids where molecules are closely packed together and have no freedom of movement.

Diffusion only takes place where there is a difference in concentration of a substance.

EXPERIMENT TO DEMOSTRATE DIFFUSION ACROSS NON LIVING TISSUE

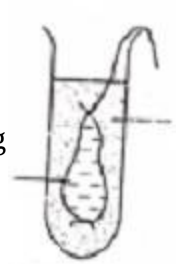
Materials

- boiling tube
- Two threads
- Visking tube
- Water
- Measuring cylinder
- Potassium permanganate solution

Procedure

- Tie one end of a visking tube using the short thread provided
- Pour 4cm^3 of potassium permanganate solution provided through the open end and tie it using the long thread.
- Wash the outside of the visking bag with distilled water to ensure no solute is attached.
- Add 10cm^3 of water into the boiling tube and suspend the visking bag in the water for 7 minutes

SET UP



Observation: *the solution in the beaker turns to purple*

Conclusion: *Potassium permanganate in the visking bag diffused into the water in the beaker*

FACTORS AFFECTING THE RATE OF DIFFUSION

1) Concentration gradient

Concentration gradient is the difference in concentration between the 2 regions where diffusion takes place. The higher the concentration gradient between the two regions, the faster is the rate of diffusion.

2) Temperature

The higher the temperature of the substances (molecules), the faster the rate of diffusion, because temperature increases the kinetic energy of diffusing molecules.

3) Size of diffusing molecules

The smaller the molecules, the faster the rate of diffusion. The larger the diffusing particle, the lower the rate of diffusion.

4) Distance over which diffusion occurs

The shorter the distance between the two regions of different concentration, the greater is the rate of diffusion like the alveoli of lungs or the epithelial linings of the ileum while the longer the diffusion distance, the lower the rate of diffusion .

5) Surface area over which diffusion occurs

The larger the surface over which diffusion is to take place, the faster the rate of diffusion e.g. diffusion surfaces like the ileum have numerous villi to increase the rate of diffusion. The smaller the surface area of a diffusion surface, the lower the rate of diffusion.

Significance of diffusion to organisms

i) Plant root hairs take up some salts by diffusion
ii) Unicellular microorganisms like amoeba, take in oxygen and pass out carbon dioxide through the cell membrane by diffusion.
iii) Digested food e.g. vitamins, mineral ions, glucose enter the blood from the gut by diffusion.
iv) Once dissolved in blood, the food substances diffuse out of the blood into the cells where they are needed.
v) Oxygen diffuses into blood and CO_2 out of blood in the lungs of mammals and gills of fish by diffusion.
vi) Waste products of metabolisms e.g. nitrogen containing substances like urea, diffuse out of the animal cells into blood.
vii) Important in reabsorption of mineral ions such as sodium ions, chloride ions in the nephrone

c) OSMOSIS

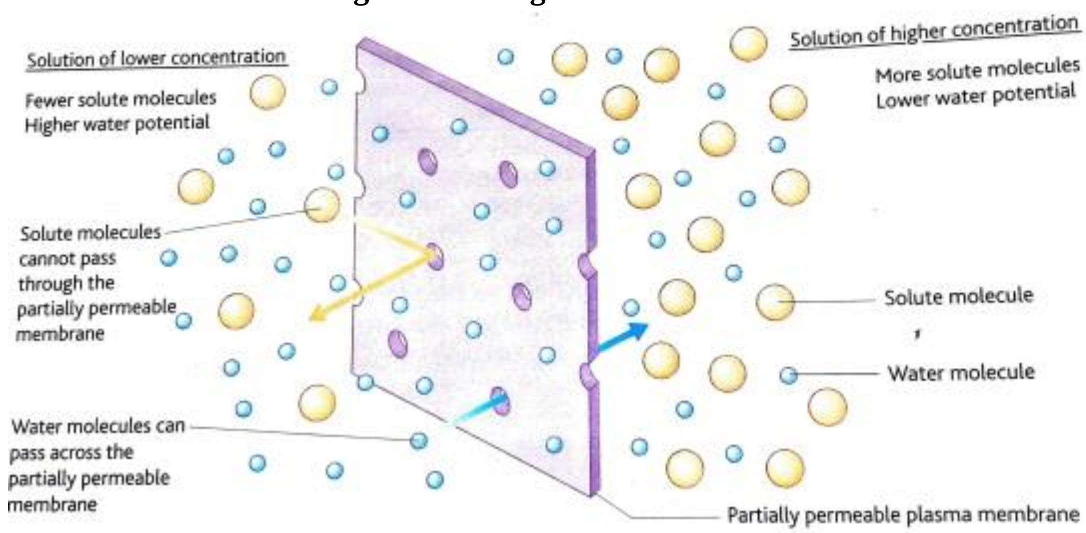
This is the ***movement of water molecules from a region of their high concentration to a region of their low concentration across a semi permeable membrane.***

Or

It is the ***movement solvent molecules from a solution of low solute concentration to a solution of high solute concentration across a semi permeable membrane.***

A semi/partially/selectively permeable membrane is one which allows the passage of some molecules and prevents other molecules from passing through it.

Diagram showing details of osmosis



When 2 solutions are separated by a semi permeable membrane having small pores, water molecules continue to move from a dilute solution to a concentrated solution through it.

Experiment to demonstrate osmosis in an artificial membrane

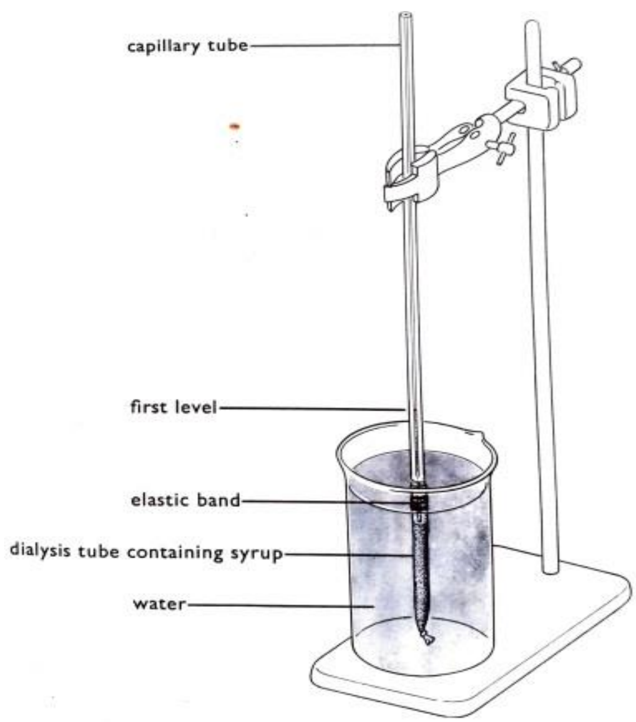
Materials

- ✓ visking tube/dialysis tube,
- ✓ Capillary tube,
- ✓ Beaker,
- ✓ sucrose solution(syrup),
- ✓ elastic band
- ✓ Thread
- ✓ Clamp
- ✓ $10cm^3$ measuring cylinder

Procedure

a) Tie one end of the visking tube using a thread.
b) Make a sucrose solution and pour $3cm^3$ of the solution in a visking tube through the open end.
c) The visking tube is then fitted at the end of a capillary tube using an elastic band.
d) Pour $60cm^3$ of water into a beaker.
e) Suspend the visking bag in water in the beaker and support the capillary tube vertically with a clamp.
f) Leave the set up to stand for 30 minutes and then remove visking bag from boiling tube
g) Measure the amount of solution in visking bag

SET UP



Observation

Visking bag expands, volume of solution is seen to rise up the capillary tube

Interpretation

Water molecules pass through the visking tube into the sucrose solution by osmosis, thus increasing its volume.

NOTE: *Membrane of the visking tube acts as the semi permeable membrane.*

From the experiment, above, water molecules move due to the state of solutions i.e. the concentration of solutes in the sucrose solution and the amount of water molecules in the boiling tube. The terms below can be used in relation to solute concentrations and amount of water molecules present.

TERMS USED IN OSMOSIS

1) **Osmotic potential:**
   This is the capacity of a solution to allow in water molecules by osmosis. Therefore a concentrated solution has a higher osmotic potential than a dilute one.
2) **Osmotic pressure:**
   This is the force that must be applied to a solution to stop water molecules from entering it i.e. a dilute solution has a higher osmotic pressure than a concentrated solution.
3) **Water potential of a cell:**
   This is the ability of water molecules to move out of a cell by osmosis. It is the concentration of water in a solution. A dilute solution has a higher water potential than a concentrated solution.
4) **Solute potential:**
   It is a measure of the amount of solute in the solution. It is also defined as the degree of lowering the water potential.
5) **Pressure potential:**
   This is a force extended on the cell contents by the cell wall.
6) **Hypotonic solution:**
   This is a solution with a higher water potential than cell cytoplasm. A hypotonic solution is thus more dilute as compared to cell cytoplasm
7) **Isotonic solution:**
   These are solutions with the same concentration as the cell cytoplasm.
8) **Hypertonic solution:**
   This is a solution with higher solute concentration than the cell cytoplasm. A hypertonic solution thus has a lower water potential than cell cytoplasm. A hypertonic solution has a higher osmotic pressure and is generally termed as more concentrated solution than cell cytoplasm.

OSMOSIS AND CELLS

Plant cell

a) **Placed in hypotonic solution;**

When a plant cell is placed in a hypotonic solution, water moves from the solution into the cell by osmosis. The cell vacuole fills with water, the volume of the cytoplasm increases such that the cell membrane pushes against the cell wall.

Being rigid, the cell wall exerts and opposite pressure on the cell membrane, this pressure is a called **turgor pressure** such that no more water enters the plant cell.

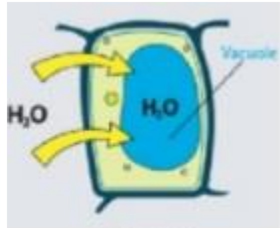
At this point, the plant cell is fully stretched, rigid and is said to be **turgid.**

Turgidity is responsible for support in herbaceous plants

Loss of turgidity folding of leaves of *Mimosa pudica*

Turgor pressure *is thus the pressure exerted on the protoplasm by the cell wall to counter flow of more water into the plant cell*

The illustration below shows a turgid cell

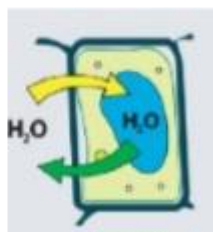


Turgid

b) Placed in isotonic solution;

Here, there is no net movement of water between the cell and solution since they have the same concentration of solutes. The amount of water that moves out of the cell is directly balanced by the amount of water that enters the cell. In this case, the cell is flaccid such that the protoplasm does not push against the cell wall.

The illustration below shows a flaccid cell

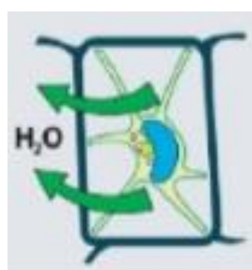


Flaccid

c) Placed in a hypertonic solution

When a plant cell is placed in a solution with higher solute concentration than the cell cytoplasm, the cell loses water by osmosis to the solution. Continued loss of water will cause the cell contents to shrink and the cell membrane pulls away from the cell wall. In this condition, the cell is said to be **plasmolysed.**

The illustration below shows a flaccid cell



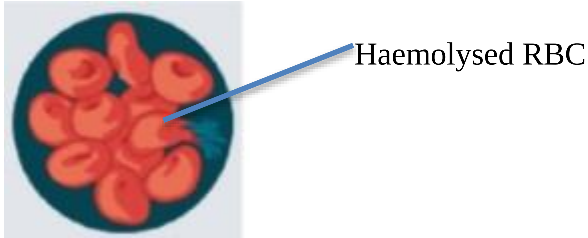
Plasmolyzed

Animal cell (red blood cell).

a) Placed in hypotonic solution;

When an animal cell is placed in a hypotonic solution, water moves from the solution into the cell by osmosis. The cell starts to increase in size as the cell membrane stretches.
However, as more water enters the RBC, due to lack of a rigid cell wall, the cell membrane soon breaks, cell bursts to release cell contents. This is called **haemolysis**.
Haemolysis is when an animal cell bursts when placed in a hypotonic solution.

The illustration below shows a haemolysed cell



b) Placed in isotonic solution;

Here, there is no net movement of water between the cell and solution since they have the same concentration of solutes. The amount of water that moves out of the cell is directly balanced by the amount of water that enters the cell.

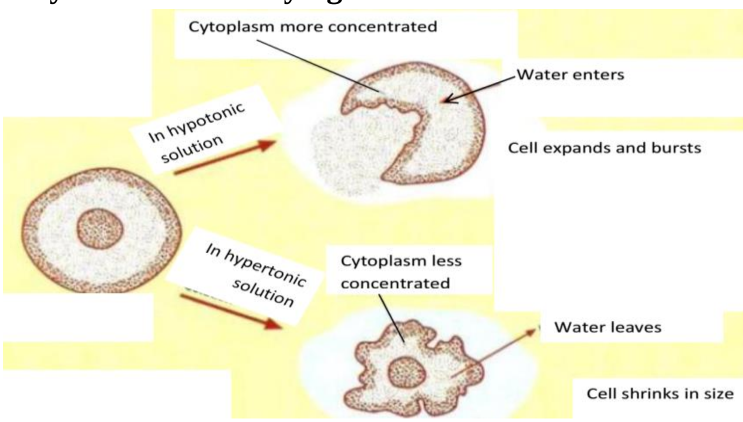
The illustration below shows animal cells in isotonic solution

c) Placed in a hypertonic solution

When an animal cell is placed in a solution with higher solute concentration than the cell cytoplasm, the cell loses water by osmosis to the solution. Continued loss of water will cause the cell contents to shrink, the cell becomes darker due to more concentrated haemoglobin and the cell is said to be **crenate.**

The illustration below shows RBC crenated

Summary of effects of varying concentrations of solution on RBC



EXPERIMENT TO DEMONSTRATE OSMOSIS IN A LITING TISSUE

Apparatus

- ✓ Fresh Irish potatoes,
- ✓ knife,
- ✓ Petri dishes,
- ✓ sugar or salt
- ✓ water

Procedure

a) 2 fresh Irish potatoes are peeled and cut transversely to obtain 3 equal halves, A, B and C. They are trimmed so that the opposite transverse sides are flat.

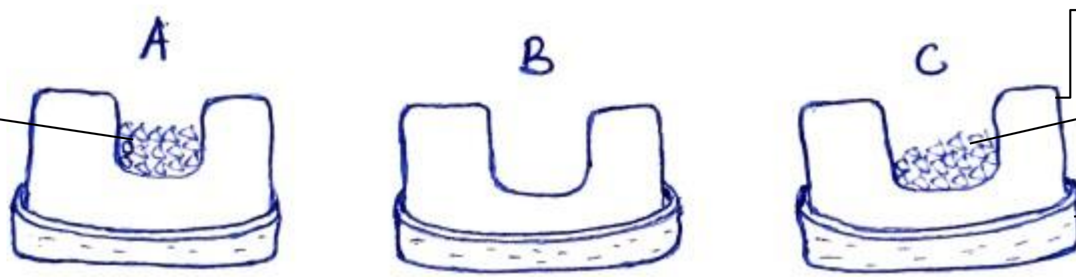
b) A cavity is created on one side of each of the three halves of the Irish potatoes.

c) In A, sugar crystals are placed in the cavity, while the cavity of B is left empty as a control.

d) C is boiled to kill the tissue and sugar crystals are put in the cavity.

e) All the potato cups are placed in water in Petri dishes. The experiment is let to run for 2hours.

SET UP



Observation

Solution forms in cavity of A, volume of water in the petri dish reduces.

Cavity of B remains empty, no solution forms, and level of water in petri dish remains constant

No solution forms in cavity of C and level of water in petri dish remains constant

Conclusion

Osmosis takes place in living tissues and does not take place in dead tissues. Boiling the Irish potato kills the tissue, destroying the semi permeable membrane

Experiment to demonstrate effect of osmotic flow of water on plant tissue

Materials

- ✓ Cock borer 5mm diameter
- ✓ Test tubes
- ✓ Water (C)
- ✓ 10% sucrose solution (A)
- ✓ Measuring cylinder
- ✓ Irish potato
- ✓ Razor blade
- ✓ 5% Sucrose solution(B)

Procedure

i) Peel the irish potato and using a cork borer, obtain three cylinders by boring through the long ends of the potato

ii) Trim the cylinders to a length of 4cm each

iii) Add $10cm^3$ of solution A into a boiling tube and label it A

iv) Repeat procedure (iii) using solution B and C

v) Add one cylinder in each of the boiling tubes

vi) Leave the setups for 30 minutes
vii) Remove cylinders, feel the texture of the cylinders, measure the length of each cylinder.
viii) Record your results in the table below

Initial length=4cm

Solution	Final length/cm	Change in length/cm	% change in length	Texture(soft/tough)
A	3.8			Soft and flabby
B	4.0			Relatively hard
C	4.3			hard

ACTIVITY:

i. Tabulate figures for change in length and percentage change in length, fill in the table above
ii. From the table, record suitable observations and conclusions regarding the state of the cylinders

Observation

A ……………………………………………………………………………………………
B……………………………………………………………………………………………
C……………………………………………………………………………………………

Conclusion

A……………………………………………………………………………………………
……………………………………………………………………………………………
B……………………………………………………………………………………………
……………………………………………………………………………………………
C……………………………………………………………………………………………
……………………………………………………………………………………………

Significance of osmosis in plants

i) Absorption of water by root hairs from soil
ii) It enables movement of water from root hairs via the cortex cells to the xylem in the root.
iii) For support in non- woody plants due to turgidity
iv) It facilitates opening and closing of stomata
v) In germination, the initial absorption of water is by osmosis

Significance of osmosis in animals

i) It enables movement of water across the villi
ii) Movement of water into unicellular protists
iii) Movement of water from tissue fluid to the cell
iv) It enables reabsorption of water into the blood stream via the kidney tubules.

MOVEMENT OF MATERIALS WITH IN A PLANT

As earlier discussed, the substances transported within plants are water, mineral salts, organic food materials and plant hormones.

Transport tissues in plants

The xylem transport water and mineral salts while phloem transport organic food materials.

Structure of the xylem

Xylem are dead cells; cells are tubular, elongated end to end with no cytoplasm and no end walls. The xylem has bordered pits along the side walls.

Xylem vessels have lignin which strengthens their cell walls.

Other functions; strengthening tissue that gives support to plant body.

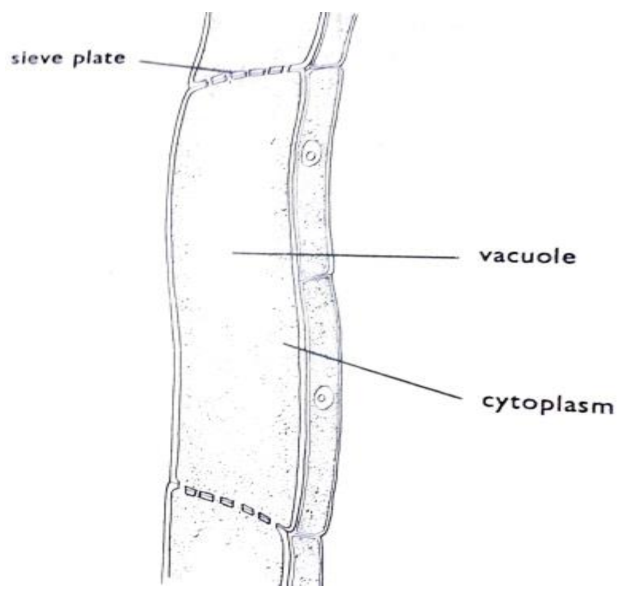
Structure of xylem

PHLOEM TISSUE

This consists of sieve tubes and companion cells. The phloem sieve tubes transport organic food materials. Transport of organic food materials is called **translocation**.

Structure of sieve tube

- These are living cells with cytoplasm but no nucleus or other cell organelles.
- They are elongated cells joined end to end.
- The end walls consist of sieve plates with sieve pores.
- Each sieve tube is closely associated with a companion cell. A companion cells regulates metabolic activities of the sieve tubes.



Similarities between xylem and phloem

- Both have cells without nucleus e.g. vessels and tracheids in xylem and sieve tubes in phloem.
- Both are perforated, i.e. xylem is bordered with pits and phloem has sieve pores in the sieve plates
- Both tissues are surrounded by parenchyma cells as packing tissues.
- Both consist of elongated cells.

Differences between xylem and phloem

xylem	**Phloem**
Consists of dead cells.	Consists of living cells
Both tracheids and vessels have lignified walls	Walls are not lignified
Transports water and mineral salts	Transports organic food materials
No cytoplasm	Contains cytoplasm
Have bordered pits	Have no bordered pits at side walls.
Transport of materials passive	Translocation of materials requires energy
Consists of vessels and tracheids	Consist of sieve tubes and companion cells
Open ended	Have sieve plates with sieve pores

TRANSPORT OF WATER FROM SOIL TO THE LEAVES

Up take of water is a continuous stream through the plant.

Root hairs absorb water containing mineral salts in solution. Water enters the root hairs by osmosis while mineral salts in solution are absorbed by diffusion and active transport.

Addition of water to the root hair all which is absorbed by osmosis makes it to attain higher osmotic potential as compared to the neighboring cells with stronger cell sap.

This enables water to move from the root hair cells to surrounding epidermal cells and then to cells of the cortex and through the cortex cells until it reaches the xylem by osmosis. Water then moves through the xylem of the root to stem and then to leaves.

The water rises up the xylem by ***capillarity, cohesion-adhesion forces, transpiration pull*** *and* ***root pressure.***

Capillarity

This is the ability of water to move up the fine tube. It is usually caused by the surface tension but because the capillary tube is narrow, the water rise is limited.

Cohesion forces

This is a force of attraction between the molecules of the same substance.

Cohesion between water molecules allows water in a continuous column without breaking.

Adhesion

This is the force of attraction between molecules of water and xylem. It enables water molecules to move up the walls of the xylem.

Root pressure

This is a pressure that pushes water up the xylem of the root to the shoot. It results from the water accumulated in the xylem of the root.

AN EXPERIMENT TO DEMONSTARTE ROOT PRESSURE

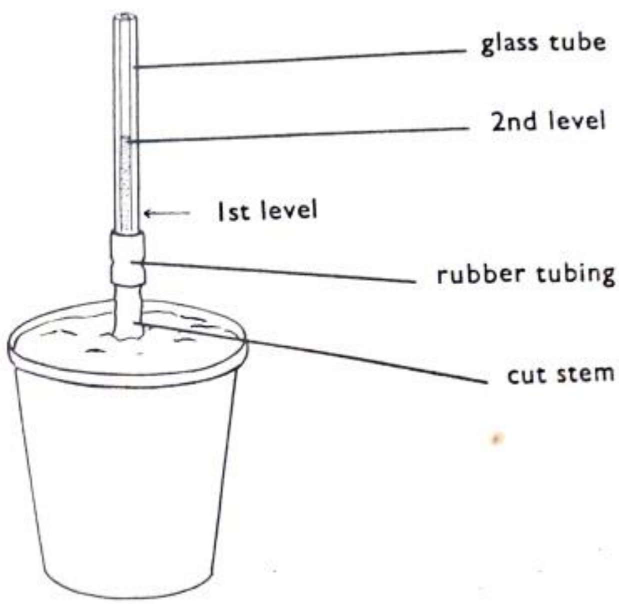
Materials

- ✓ Glass tube
- ✓ Rubber tubing
- ✓ Coloured water
- ✓ Transpiration pull
- ✓ Potted plant with shoot cut of at stem

Procedure

- A piece of glass tubing is connected by rubber tubing to a freshly cut stem of a potted plant
- A little coloured water is placed in the tube and its level marked
- The setup is left to stand for 1 hours

Set up



Observation: *the water level rises to a higher level*

Conclusion: *root pressure occurs in plants and results into upward movement of water in stem*

Transpiration pull

This is the pulling force generated by the evaporation of water from the leaves.

This is caused when the cells of the spongy mesophyll layer in the leaf lose water by evaporation in to the air spaces causing their cell sap to become more concentrated and as a result they draw the water from the surrounding cells by osmosis.

These cells in turn draw water from the xylem in the veins and then water from the xylem moves to replace the lost water by evaporation. This evaporation sets up a stream of water flow from the xylem in the root to replace lost water. This is called transpiration pull.

EXPERIMENT TO SHOW THAT WATER TRAVELS UP THE PLANT THROUGH THE XYLEM

Materials

- Small plant with flowers,
- beaker,
- water,
- dye,
- knife, and
- microscope

Procedure

- A small plant is placed in a beaker containing water with a dye.
- It is allowed to stay in the water for 24 hrs
- The stem and the roots are cut transversally and then observed under a microscope

Observation

It is observed that the xylem in the stem and roots are stained with the dye.

Importance of water to plants

- Raw material for photosynthesis
- Solvent for mineral salts and oxygen that enable them to diffuse into the roots.
- It is a constituent of the cytoplasm and all sap of the growing plants
- Uptake of water by plant cells results in turgidity, source of support in non-woody plants
- Cools the leaves of the plants when evaporated

TRANSPORT OF THE PRODUCTS OF PHOTOSYNTHESIS

The process by which the soluble products of photosynthesis are carried in plants is called **translocation**. Throughout the plant, sugars and amino acids are translocated in the phloem from the leaves to the **growing parts** of the plant or **storage organs**. Food substances may also move from the storage organs to the growing regions of the plants. In the phloem, food substances may move upwards/down wards.

The process of translocation process

The process of photosynthesis leads to accumulation of food substances in cells of leaves. The sugars especially sucrose are actively transported into the phloem sieve tubes using energy from mitochondria in companion cells.

Accumulation of sucrose results into low osmotic potential such that water is drawn from neighbouring cells into the sieve tubes, creating higher pressure in sieve tubes.

Lower down in storage organs and growth points, most sucrose and amino acids are utilized so there is lower pressure.

A pressure gradient is thus established between the phloem in the leaves and phloem in the organs of storage and growth, further away from leaves.

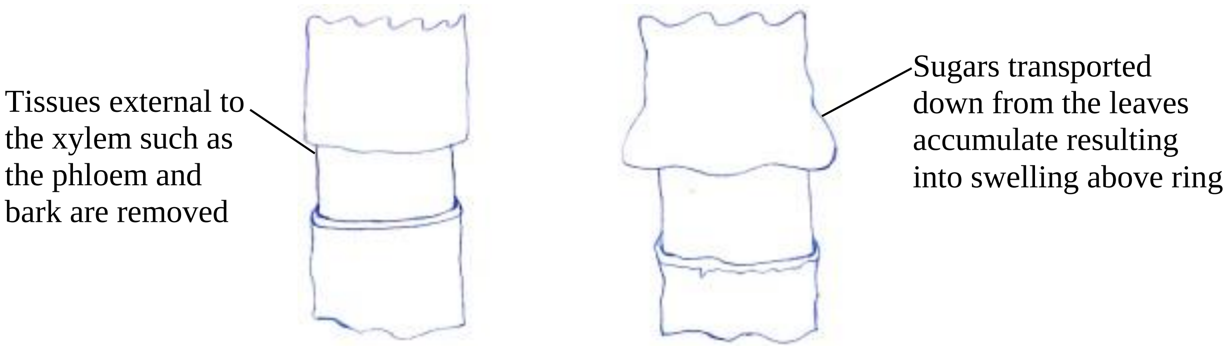
Food substances thus move from leaves to other parts of the plant by a process called mass flow.

EVIDENCE TO SHOW THAT FOOD MADE IN LEAVES IS TRANSLOCATED BY THE PHLOEM

1) The Ringing Experiment:

Removal of a complete ring of phloem from around the stem causes swelling of the part of the stem above the ring with no increase in size of the part of the stem below the ring.

Illustration



Explanation; *removal of the ring results into removal of phloem tissue which is located just beneath the bark such that flow of organic food materials is disrupted, causing the swelling as food accumulates*

Conclusion

Since phloem and not xylem were removed, translocation of manufactured food occurs in phloem.

2) Feeding Aphids:

When the proboscis of the sucking aphid is cut, it is found to have penetrated into the phloem tube and when its contents of the proboscis are analyzed, it is found to contain products of photosynthesis (sucrose) which are transported in the phloem.

3) Radio Active Tracers:

If a plant is exposed to CO_2 labeled with radioactive C-14, the C-14 becomes incorporated into the end products of photosynthesis which are subsequently detected in the phloem of section of the stem. The radioactivity of the carbon in organic materials transported precisely with the positions of the phloem.

FOOD STORAGE IN PLANTS

Once sugars especially sucrose has been moved to storage organs, they are normally condensed and converted into an insoluble form such as starch which is then piled for storage in organs such as leaves of bulbs, rhizomes, corms, roots such as in root tubers like the sweet potatoes and cassava, stems such as in stem tubers like irish potatoes.

However in some cases, the sucrose may be concentrated in certain storage organs of plants without being converted to starch for example in fruits of plants, plant stems such as in sugar cane.

ACTIVITY

a) Draw the structures of the following;

i. Onion bulb and clearly label; lateral bud, stem, scale leaf, terminal bud and adventitious roots
ii. Rhizome and clearly label the lateral, leaves and stem
iii. Irish potato tuber and clearly label; lateral bud and scale leaf.

TRANSPIRATION

This is a process by which plants lose water in form of water vapour to the atmosphere.

Transpiration mainly occurs through the stomata of leaves, ***stomatal transpiration***. However, some transpiration may also occur through surfaces with a cuticle, ***cuticular transpiration*** e.g. on leaves and stems of herbaceous plants.

In woody plants, transpiration may also occur through pores on stems called lenticels, ***lenticular transpiration***

NB; *Transpiration is not the only way plants lose water to the atmosphere. In highly humid environments at low temperatures water can also be lost from the plants as water droplets, a process called **guttation** through special structures called **hydathodes** found on leaf types or margins*

AN EXPERIMENT TO SHOW THAT WATER IS LOST DURING TRANSPIRATION

Apparatus

Potted plant,

Polythene bag,

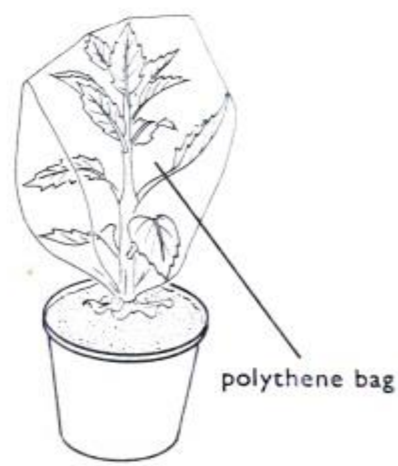
String,

Cobalt (ii) chloride paper or anhydrous copper (ii) sulphate.

Procedure

a) Tie polythene around the tin of the potted plant. Using a string to avoid evaporation of water from the soil surface.
b) Tie transparent polythene around the leafy shoot of the plant.
c) Set up another similar control experiment but with leaves removed and dry plant.
d) Leave the experiment to settle for 3 hours in bright sunlight.
e) Remove the polythene around the leafy shoot and test the drops of liquid inside the polythene using anhydrous copper (ii) sulphate / cobalt (ii) chloride paper.

Diagram



Observation

Colourless droplets form inside the polythene which turn anhydrous copper (ii) sulphate from white to blue or blue cobalt (ii) chloride paper to pink.

No vapour is observed from experiment with no leaves / dry plant.

Conclusion

Water is given off during Transpiration

Note:
A bell jar may be used instead of polythene
A control experiment may also be a covered pot where the plant shoot has been cut off.

EXPERIMENT TO COMPARE TRANSPIRATION RATES ON BOTH SURFACES OF A LEAF

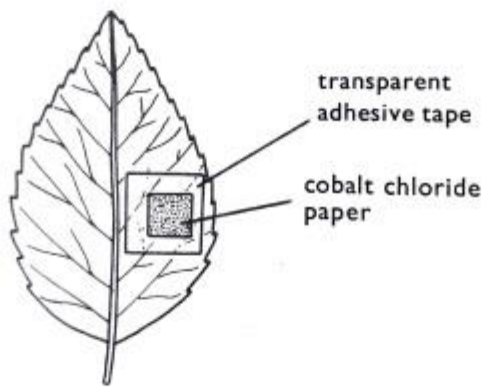
Apparatus

- ✓ Potted plant,
- ✓ glass slide
- ✓ Cobalt (ii) chloride paper
- ✓ Rubber bands

Procedure

a) Fix pieces of Cobalt (ii) chloride paper on the upper and lower surfaces of a leaf on a potted plant using transparent adhesive tape.
b) Note the time taken for the Cobalt (ii) chloride paper on each surface change colour from blue to pink.

Diagram



Observation
The lower surface cobalt (ii) chloride paper turns pink faster than that on the upper surface.

Conclusion
The lower surface has a higher transpiration rate than the upper surface
REASON: This is due to numerous stomata on the lower surface of the leaf.

FACTORS AFFECTING RATE OF TRANSPIRATION

1) Temperature

Increase in temperature increases the rate of transpiration. This is because high temperatures provide latent heat of vaporization which increases the evaporation of the water leading to more water to be lost.

Temperatures also increases the kinetic energy of the air molecules around the leaf which causes them to move further apart and this increases rate of diffusion from the leaf

2) Relative humidity

Humidity is the amount of water vapour in the atmosphere. As humidity increases, the rate of transpiration decreases. This is because the environment becomes saturated with the water vapour. The water then can be absorbed from the plant decrease which reduces the rate of transpiration.

3) Wind

Rate of transpiration is higher in windy air than in still air. This is because wind easily blows away water vapour in the air around the leaf and creates more space that can be taken up by more water vapour.

However, if the air is still, there is no diffusion gradient of water vapour created, thus low rate of transpiration.

4) Light intensity

Rate of transpiration is high during the presence of light and low in the dark.

This is because light triggers stomata to open thus increased rate of transpiration. When the light intensity is low, most stomata remain closed thus low rate of transpiration.

5) Availability of water

With water available, a continuous stream of water is present, continuously delivering water to leaf air spaces from which it's lost to the atmosphere. However when little water is available, little can be lost during transpiration.

6) Atmospheric pressure

Humidity decreases with decrease in atmospheric pressure. Hence decrease in atmospheric pressure greatly increases the rate of transpiration due to decreased humidity while an increase in atmospheric pressure results into a decrease in transpiration rate.

Non environmental factors

7) Distribution of stomata

The rate of transpiration is low when more stomata are on the lower side and is higher when more stomata are on the upper side of the leaf.

8) Number of stomata

The greater the number of stomata, the higher the rate of transpiration because more water vapour is lost through the stomata.

9) Surface area for transpiration

Plants with wide/broad leaves have a larger surface for transpiration thus they experience a higher rate of transpiration. But that with small leaves e.g. desert plants have a small surface area hence low rate of transpiration.

10) Thickness of the plant cuticle

The rate of transpiration decreases with increase in thickness of the cuticle. For that reason, plants found in deserts have extremely thick cuticle than those in tropical regions.

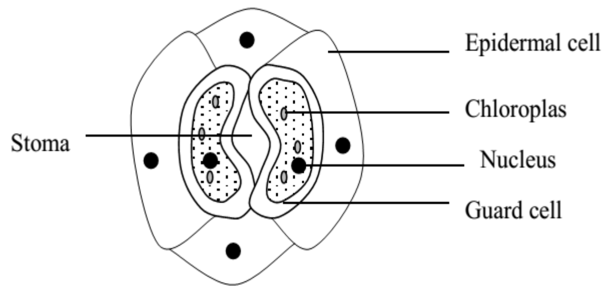
MECHANISM OF STOMATAL OPENNING AND CLOSURE

Stomata open during day and close at night.

During the day, photosynthesis takes place in the guard cells in the presence of sunlight. This leads to accumulation of sugars in the guard cells which lowers their water potential.

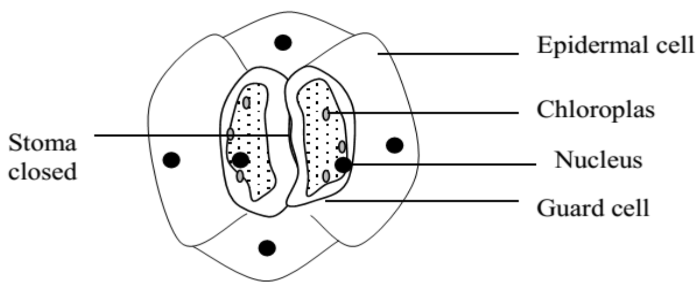
As a result, water moves into the guard cells by osmosis from the neighbouring epidermal cells. Turgor pressure of the guard cells increases which causes their outer thin elastic walls to expand and pull the inner thick inelastic walls outwards, hence opening the stoma.

Diagram showing a stoma open



At night, there is no photosynthesis due to absence of light. Osmotic pressure inside guard cells decreases/ water potential increases. This causes the guard cells to lose water to the neighbouring epidermal cells by osmosis. Turgor pressure inside guard cells lowers, making the inner walls to move closer together and the stoma closes.

Diagram showing a stoma closed



EXPERIMENTS TO MEASURE THE RATE OF TRANSPIRATION

1. THE WEIGHING METHOD

This is where a potted plant is weighed on the balance before and after transpiration has taken place. Difference in weight resulting from transpiration is determined. The difference in weight shows the amount of water lost by the plant in a given period of time thus giving the transpiration rate.

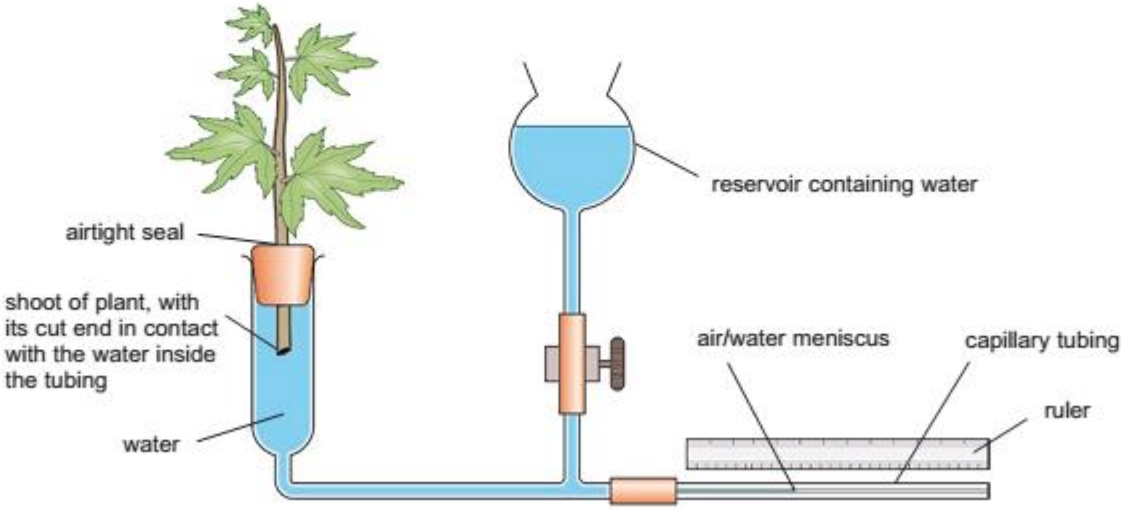
2. POTOMETER METHOD

This is done using an instrument called a **potometer**. The potometer works on assumption that water lost from the leaves during transpiration equals water absorbed by the plant.

Therefore the potometer:

- ✓ Directly measures the rate of water uptake/ absorption
- ✓ Indirectly measures rate of water loss / evaporation of water/ transpiration from the leaves.

Set up of a potometer



Procedure:

d) A leafy shoot of a plant is cut under water to prevent air bubbles from entering as these would block the xylem vessels.
e) The potometer is filled with water.
f) The leafy shoot is fixed into the cork and then fitted into the mouth of the potometer vessel.
g) Vaseline is smeared at the interface of the shoot and the cock to prevent entry of air into the apparatus.
h) A single air bubble is introduced at the open end of the capillary tube by touching the open end briefly under water and then release.
i) At a given mark V_1 on the ruler reached by the air bubble, a clock is started and after a given time t, the new position of the air bubble V_2, is noted and recorded.

$$\text{Rate of transpiration} = \frac{\text{distance moved air bubble}}{\text{Time taken}}$$

$$= \frac{V_2 - V_1}{t}$$

j) In any given set of environmental conditions, about 3 experiments can be performed, resetting the air bubble after each experiment by opening the tap for water to push it to the starting mark and then close.
k) Average rate is then calculated and taken as the rate of transpiration in that environment.
l) The set up can be moved to different environmental conditions and rate of transpiration determined in the same way.

Precautions taken when using a potometer in order to ensure accurate results

1. A leafy shoot should be used to ensure significant water loss.
2. The shoot must be cut under water to prevent air from entering and blocking the xylem vessels.
3. The whole apparatus must be full of water.
4. A single air bubble must be present in the capillary tube for each experiment.
5. Air bubble must be reset to zero mark before each experiment

6. A graduated capillary tube must be used in order to clearly read results.
7. Air bubble should not cross the T- function at the reservoir
8. Vaseline should be used to seal any air spaces at junctions to make the set up airtight.

ADAPTATIONS OF PLANTS TO REDUCE TRANSPIRATION RATE

i) Shedding off of leaves by deciduous plants to reduce transpirations since most of it occur from the leaves
ii) Having low number of stomata restricted to the lower epidermis
iii) Some plants have sunken stomata in pits of leaves to reduce exposure for transpiration to occur.
iv) Some plants have hairs around stomata which reduces evaporation from them.
v) Reduction in leaf surface area e.g. some plant leaves are reduced to leaf spines to reduce surface area over which transpiration occurs.
vi) Rolling of leaves to create a humid atmosphere around the stomata in order to reduce water loss.
vii) Possession to thick cuticle of the leaves to prevent water loss through it.
viii) Thick leaves that store water
ix) Changes in the rhythm of stomata opening i.e. they close during day and open at night when temperatures are very low.
x) Some plants have a mechanism of changing the orientation of their leaves so us to prevent sunlight from directly striking them to reduce transpiration

SIGNIFICANCE OF TRANSPIRATION

a) Results in the absorption of water and its movement up the plant to aid processes like photosynthesis.
b) Contribution to maintenance of continuous stream of water throughout the plant.
c) Transported water keeps the plant cells turgid and cools the plant.
d) Results in the movement of mineral salts up the plants to where they are needed.
e) Evaporative loss of water cools the plant during high environmental temperatures

DISADVANTAGES / DANGERS OF TRANSPIRATION

a) Excessive water loss from the plant may lead to wilting, drying and even death of the plant.
b) Results into shading of leaves thus reducing surface area for photosynthesis

Plants do not use a circulatory system because:

- The oxygen requirement of the plant is very low as compared to mammals.
- In plants oxygen from the air diffuses through the stomata opening in to the airspaces and from the air spaces in to the cells by diffusion. And the oxygen dissolved in the soil water also diffuses through the root hairs in to the plant sap.
- The carbon dioxide produced during respiration is used up during photosynthesis.