

## **TRANSPORT IN PLANTS AND ANIMALS**

This refers to the movement of materials from one part of the organism to another. In plants, it is called translocation. It involves diffusion, osmosis and active transport in simple organisms and active transport in simple organisms and transport systems in large higher organisms, (Vascular & circulatory systems).

### **THE NECESSITY FOR TRANSPORT SYSTEM**

All living things need a continuous exchange of certain substances between their cells and the environment e.g. oxygen, food, materials carbon dioxide, waste products.

In large complex animals, most of the cells are located far from the surface thus the need for a transport system.

Flat worms are flattened to shorter distance for transport.

#### **Requirements of transport system**

- The materials to be transported
- The medium of transport
- The channels of transport
- Energy

#### **Materials to be transported**

In animals, they include respiratory gases oxygen and carbon dioxide, nitrogenous excretory products e.g. uric acid, nutrients e.g. glucose, amino acid.

In plants, they include oxygen and carbon dioxide.

Mineral elements for plant growth

Manufactured food (autotrophs)

Absorbed food (in saprophytes)

Vitamins, amino acids auxins

#### **The medium of transport**

The medium of transport in plants and lower animals is water and it is blood in vertebrates and in a few invertebrates like arthropods, annelids (earth worm).

#### **The channels of transport**

In most animals, these are blood vessels, in others e.g. earth worms, it is the body cavity (coelom). In higher plants, there is a vascular system or system of xylem and phloem.

#### **Energy**

Circulation of blood in animals requires energy supplied from respiration used in pumping of the heart and muscle contractions.

## **TRANSPORT IN PLANTS**

Transporting tissue in plant is xylem and phloem. It involves movement of water, salts and organic molecules (manufactured food).

### **THE XYLEM**

This Consists of xylem vessels and tracheids. Xylem vessels develop from cylindrical cells, arranged end to end, in which the cytoplasm die and cross- walls disappear leaving a dead empty tube. Through this:

Water, mineral salts, move from roots, stems, up to leaves. Xylem vessels are strengthened by lignin in their walls.

This strength gives support to the soft tissue of roots, stems, and leaves: it also prevents collapse of the vessels under tension as sap pressure changes.

#### **Structure of xylem**

#### **Tracheids**

They are similar to xylem vessels; except that they are typically 5 or 6 sided. In cross- section, instead of being open at each end, their tapering end walls are perforated by pit (tiny holes in lignified walls). Even xylem has pits in their walls.

NB

Tracheids are more primitive- they are found in gymnosperms e.g. cypress where there is control of transpiration, for water does not move very fast through them.

#### **Characteristics of xylem tubes**

- a) Consist of dead tubes
- b) They are hollow
- c) Its walls are lignified
- d) Has no protein filaments
- e) Has no cytoplasm
- f) Transports water and salts
- g) Transports water and mineral salts in one direction

#### **Types of thickenings in the xylem vessels/tissues**

##### **1. Annular lignification**

##### **2. Spiral lignification**

### 3. Reticulate lignification

#### PHLOEM TISSUE

This Consists of sieve tubes and companion cells. The sieve tubes are formed from cylindrical cells arranged end to end. Unlike the xylem vessels, the cross walls do not disappear but develop perforations of enlarged pits forming sieve plates. The protoplast of a sieve tube / elements remains living; although its nucleus disintegrates as the cell differentiates. Each sieve tube is closely associated with companion cells which are complete cells.

The companion cells regulate a metabolic activity of the sieve tubes.

#### Characteristics of phloem tissue/tube

- a) Consist of living cells
- b) Have a thin cytoplasm
- c) Associated with companion cells
- d) Consist of sieve cross walls
- e) Consist of protein filaments
- f) Transport food materials
- g) Transport materials in opposite direction

#### Structure of the phloem tissue

Sieve tubes have perforated cross walls called sieve plates. In between the plates are sieve pores which allow food substances to pass from one cell to another along the cytoplasmic filaments (protein filaments). Adjacent to sieve elements are the companion cells which provide the sieve tube with energy to transport the food substances.

#### Differences between xylem and phloem

<b>Xylem</b>	<b>Phloem</b>
Consists of dead cell walls xylem and phloem	Consists of living cells
Vessels are lignified	They are non- lignified
Consists of open ended vessels and tapering tracheids	Consists of sieve tubes with sieve plates and cytoplasmic strands
Transports water and mineral salts	Transports manufactured food
Transportation depends on transpiration pull	Depends on respiratory energy

## Structured comparison between xylem and phloem

### Similarities

- 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.

### Differences

<b>xylem</b>	<b>Phloem</b>
Consists of dead cells.	Consists of living cells
Both tracheids and vessels have lignified walls	Walls are not lignified
Vessels are often ended and tapering tracheids	Sieve tubes have sieve plates perforated with sieve pores.
Do not have companion cells	Have companion cells.
Lack micro filaments	Have micro filaments

### Function comparison

- In both, materials are transported in solution form.
- In both, transport involves use of energy e.g. in xylem, transpiration pull depend on solar energy and in phloem it depends on respiratory energy.

### Differences:

<b>Xylem transport</b>	<b>Transport in phloem</b>
Occur in one direction i.e. up the plant	Occur in two directions i.e. up and down.
Depend on transpiration pull/ solar energy	Depend on respiratory energy.
Transport water and dissolved minerals.	Manufactured food and auxins
Occur in dead cells	Occur in living cells
Both tracheids and vessels are used	Only sieve tubes are used
Occurs in cells with lignified walls	Not lignified cells

## TRANSPORT OF WATER FROM SOIL TO THE LEAVES

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

Root hairs in the soil are surrounded by a film of water containing mineral salts/ soil solution.

The soil solution once inside the root hair vacuole is called cell sap and is a strong solution than the soil solution( has a lower osmotic potential and the cell membrane of the root hair is semi permeable.

The above conditions enable water to move from the soil, passes through the cell membrane in to the vacuole by osmosis.

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 to and from the root hair to other cells of the cortex and through the cortex cells until it reaches the xylem which conducts water up the plant.

The water rises up the xylem by the following forces.

### **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 – tension 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.

This occurs because as water is lost by transpiration from the leaves, the water potential at the top of xylem vessels falls below that at the bottom of the xylem in the root. Water is now pulled by this potential difference because of the cohesion of the water molecules.

### **Adhesion**

This is the force of attraction between molecules of different substances (unlike)

Adhesion forces between walls of xylem and water molecules support a considerable weight of water within the xylem tissue and prevent the xylem vessels from collapsing.

### **Root pressure**

This is regarded as the pressuring force of the water up the stem from the roots

The root pressure is an active process confirmed by the fact that:

It occurs only in living tissues/ plants.

It is affected by the same factors that affect respiration in living cells like oxygen supply, temperature, starch supply and the presence of respiratory poison like cyanides.

The root pressure theory has been suggested as a result of a common observation that water tends to exude from the cut stem indicating that some pressure in a root is actually pushing the water up. This pressure has been measured using a monometer attached to the stem and it is this force which is normally called root pressure.

The root pressure depends on the type of plant species e.g. vines root pressure is up to 200 kpa has been demonstrated.

However, like capillary, root pressure is not sufficient on its own to push water to the leaves of the plant at the top of the tree and can slowly cause guttation in transpiring herbaceous plants.

### **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 into 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 in cells in turn get 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 the passing action on water in the xylem called transpiration pull.

### **HOW IS THE ROOT HAIR ADAPTED TO ITS FUNCTION OF WATER ABSORPTION**

- i) The root hair is slender and flexible and can therefore flow between the soils particles.
- ii) They are numerous which increase the surface area available for water absorption.
- iii) They lack the cuticle which would restrict water absorption.
- iv) They are long and narrow which increases surface area to volume ratio that increases the rate of water absorption.
- v) The cytoplasm of the root hair contains numerous mitochondria where respiration occurs to release ATP needed for active transport of mineral salts from the soil solution to the cytoplasm of the root hairs.
- vi) All the centre of the root hair is a vascular tissue which transports water and mineral salts to the rest of the plant.
- vii) The cell sap of the root hair contains sugars, amino acids and salts, and so its concentrated than the soil solution and this low osmotic potential enables water to enter it by osmosis

### **Longitudinal section of the root hair**

Root hairs vacuoles contain a high concentration of solute than the surrounding water. Water is absorbed by root hairs by osmosis. This causes the root hair, vacuoles to become less concentrated than those of the adjacent cortex cell. Water is then passed into the cortex cell by osmosis. Water then enters the xylem tissue.

Water moves through the root cortex from cell to cell by 3 path ways:

- i) Most of the water flows along the cell vacuole.
- ii) Some water travels in the cytoplasm.
- iii) Some water moves from vacuole to vacuole

The inner most region of cortex is made up of the endodermis strip which controls the movement of water from the cortex into the xylem.

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

### **Apparatus**

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

### **Procedure**

- A small plant with light coloured flowers 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**

The dye appears in the flower and along the veins of the leaves.

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

## **EXPERIMENT TO DEMONSTRATE ROOT PRESSURE**

### **Apparatus**

Potted plant with actively growing shoot, glass tubing, water, retort stand, rubber tubing.

### **Procedure**

- a) Cut the shoot of an actively growing potted plant leaving about 5 cm of stem above the ground/ soil
- b) Firmly fix the glass tubing about 30cm long to the cut end of the stem using rubber tubing
- c) Partly fill the glass tubing with coloured water and support it with a retort stand
- d) Make the level of water in the glass tubing
- e) Water the soil well and place the apparatus in a warm place for 3 hrs
- f) Control experiment is a dry plant.

### **Diagram**

### **Observation**

The level of coloured water rises in the glass tubing.

### **Conclusion**

Water was absorbed by the plant and travelled upwards the stem due to root pressure

### **Importance of water to the plant**

- 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
- Provides turgidity which provides support in non woody plants
- Cools the leaves of the plants during transpiration

### **ABSORPTION OF MINERAL SALTS BY THE ROOT HAIRS**

Mineral salts are moved in the plant in the xylem in solution with water. Roots absorb mineral salts in form of ions by diffusion and active transport. Active transport is the movement of the materials against the concentration gradient by the use of energy released from respiration.

### **TRANSPORT OF THE PRODUCTS OF PHOTOSYNTHESIS**

The process by which the soluble products of photosynthesis are carried in plants is called translocation. Translocation is the movement of manufactured food from the site of photosynthesis. Throughout the plant, sugars and amino acids are transported 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 leaves. This causes a high turgor pressure within the leaves.

Food substances in the roots are used for respiration or they are stored in the storage organs and these results in the low turgor pressure in the root cells. The difference between turgor pressure in the roots and leaves enables the food substances to move from leaves to other parts of the plant by a process called mass flow which is the major process of translocation.

There is also a minor process i.e. active transport where the sugars e.g. sucrose are actively transported from leaves to the storage organs.

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

#### **1) The Ring Experiment:**

Remove a ring of the bark from the stem at a point between the ground and the upper leaves. Leave another plant with the ring on.

The plants are left to stand for one week after which the observation is made.

#### **Observation**

The upper part of the stem of the ring plant swells immediately above the ring while the lower part of the stem remains un swollen.

The un ringed plant remains unchanged.



## **Conclusion**

The phloem transports manufactured food.

## **Explanation**

When a ring of a base is cut, the phloem tissue is removed along with it since it's found within the bark. This cuts off the supply of manufactured food to the lower parts of the plant as a result, the phloem in the upper part of the stem will transport the food to the part just above the ring. The food will then accumulate in this part hence it will swell.

When the ring is removed, the tree or plant also dries because the food supply to the root is cut off therefore the stored food in the roots gets exhausted then the roots die.

## **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 to the bark through the phloem.

## **3) Radio Active Tracers:**

If a plant is exposed to CO<sub>2</sub> labeled with radioactive C-14, the C-14 becomes incorporated into the end products of photosynthesis which are subsequently detected in the stem. That these substances are confined to the phloem and can be shown by cutting sections of the stem, placing the sections in contact with photographic film and making auto radiographing it is found that the sites of radioactivity correspond precisely to the positions of the phloem.

## **TRANSPIRATION**

This is a process by which plants lose water in form of water vapour mainly through leaves to the atmosphere. Transpiration can also occur from flowers.

### **TYPES OF TRANSPIRATION**

- 1. Stomatal transpiration:** This is the transpiration through the stomatal opening. This contributes up to 80-90% of water lost.
- 2. Cuticular transpiration:** This occurs through the leaf cuticle which amounts for about 20% of the water lost.
- 3. Lenticular transpiration:** This occurs through the stem pores called lenticels and accounts for about 0.1% of the water lost.

Water can also be lost from the plants as water droplets in a process called guttation through special structures called hydathodes found on leaf tips or margins

## **AN EXPERIMENT TO SHOW THAT WATER IS LOST MAINLY FROM LEAVES DURING TRANSPIRATION**

### **Apparatus**

Potted plant,  
Polythene paper,  
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**

A vapour forms inside the polythene and turns into drops / liquid 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**

Transpiration occurs from the leaves

### **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 still to the plant with glass slides.
- b) Tie the slides using the rubber bands
- c) Note the time taken for the Cobalt (ii) chloride paper on each slide to turn / 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

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 helps / assists to remove water vapour in the air around the leaf and creates more spaces that can take up more water vapour.

However, if the wind speed becomes too high transpiration stops due to mechanical closure of the stomata and the cooling effect the wind has on the leaf.

**4) Light intensity**

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

This is because high light intensity result in high rate of photosynthesis which increase the sugar concentration in the guard cells which lead to wide opening of the stomata leading to more evaporation from the plant ( also light provide heat which increase evaporation from the leaf stomata.

#### **5) Availability of water**

This affects the turgidity of the guard cells i.e. more water more turgidity which leads to opening of stomata and enable more water loss and to high transpiration rate.

#### **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.

### **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.

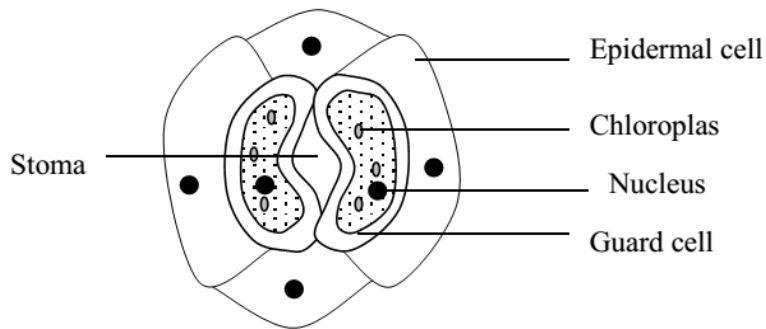
### **MECHANISM OF STOMATAL OPENNING AND CLOSURE**

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.

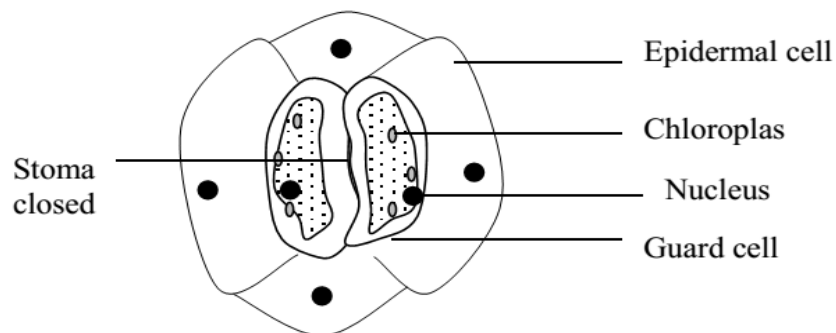
As a result, water moves into the guard cells by osmosis from the neighbouring epidermal cells. Turgor pressure of the guard cells increases which causes their outer thin elastic walls to expand and pull the inner thick inelastic walls outwards, hence opening the stoma.

### **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 open**



## **EXPERIMENTS TO MEASURE THE RATE OF TRANSPIRATION**

### **1. THE WEIGHING METHOD**

This is where a potted plant is weighed on the balance to determine the difference in weight before and after transpiration. The difference in weight shows the amount of water lost by the plant in a given period of time.

### **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 of the shoot and
- ✓ Indirectly measures rate of water loss / evaporation of water/ transpiration from the leaves.

**Set up of a potometer**

**Procedure:**

- a) A leafy shoot of a plant is cut under water to prevent air bubbles from entering as these would block the xylem vessels.
- b) The potometer is filled with water.
- c) The leafy shoot is fixed into the cork and then fitted into the mouth of the potometer vessel.
- d) Vaseline is smeared at the interface of the shoot and the cock to prevent entry of air into the apparatus.
- e) 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.
- f) At a given mark  $V_1$ , 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.

$$\begin{aligned}\text{Rate of transpiration} &= \frac{\text{distance moved air bubble}}{\text{Time taken}} \\ &= \frac{V_2 - V_1}{t}\end{aligned}$$

- g) In any given set of environmental conditions, about 3 experiments can be performed, resetting the air bubble after each experiment by opening the tap and then close.
- h) Average rate is then calculated and taken as the rate of transpiration in that environment.
- i) 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

**ADAPTATIONS OF PLANTS TO REDUCE TRANSPIRATION RATE**

- i) Shedding off of leaves in deciduous plants to reduce transpirations since most of it occur from the leaves
- ii) Reducing the number, size and distribution of the stomata and only on lower epidermis
- iii) Structural adjustments in stomata i.e. some plants have sunken stomata and others have hairy stomata which reduces evaporation from them.
- iv) Reduction in leaf structure i.e. some plant leaf are reduced to narrow or thorny / spines structures that reduce surface area over which transpiration occurs.
- v) Rolling of leaves to create a humid atmosphere around the stomata in order to reduce water loss.

- vi) Possession to thick cuticle of the leaves to prevent water loss through it.
- vii) Thick leaves that store water
- viii) Changes in the rhythm of stomata opening i.e. they close during day and open at night when temperatures are very low.
- ix) They shed off their leaves in extremely hot environment to cut down water loss.
- x) Reversed opening and closing of stomata. Stomata open at night and close during the day when it's rate of transpiration is likely to be higher.

### **IMPORTANCE OF TRANSPIRATION (FUNCTIONS / ADVANTAGES)**

- 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.

### **DISADVANTAGES / DANGERS OF TRANSPIRATION**

- a) Excessive water loss from the plant may lead to wilting, drying and even death of the plant.
- b) Water may lead to over cooling which affect metabolic activities
- c) Over absorption of mineral salts with water lead to soil exhaustion.

### **TRANSPORT OF MATERIALS IN ANIMALS**

The transport system in animals consists of a number of routes through which specific materials are distributed

Smaller organisms (protozoa) that have large surface area to volume ratio carry out transport by simple diffusion.

Transport system is important in large organisms (multicellular) because the increased size of the organisms and the great distance over which materials are supposed to move makes diffusion rate slow which in turn make it inadequate for the distribution of these materials

To overcome the physical limitation on size placed by diffusion, multicellular animals have the major adaptations.

They have organs that provide a large surface area for absorption of nutrients such as small intestines and exchange of gases such as lungs/ gills, without a great increase in total body volume. They have a transport (circular) system within the body, so that substances can be carried to cells that need them and waste products removed more quickly than in diffusion.

The circulatory system in mammals consist of closed tubes and heart which provide the forces that drives the fluid (blood) in these which include Arteries, capillaries and veins.

### **Plants do not use a circulatory system because:**

- The oxygen requirement of the plant is very low as compared to mammals.
- Plants have a continuous series of airspaces throughout the body opening to the atmosphere by the stomata and ventricles.

- 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.

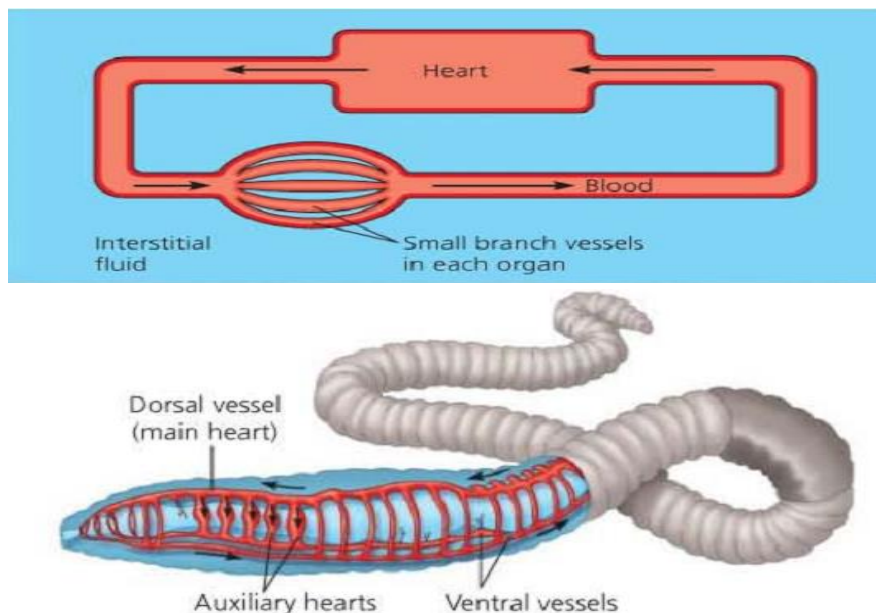
### **Types of transport systems in animals**

#### **1. Closed circulatory system:**

Closed circulatory system e.g. in earthworm, fish and mammals have blood enclosed in tubes. Here blood is pumped by the heart to tissues through the arteries and return to the heart through the veins.

The arteries and veins are connected by capillaries which are thin walled.

The body cells do not come in to direct contact with blood but are bathed in the tissue fluids. Substances diffuse out of the blood which is confined to blood vessels in to the tissue fluid and then across to cells membrane in to the cell.



#### **Advantages of closed circulatory system**

- ✓ Distribution of blood/materials is easily controlled.
- ✓ Blood moves or flows very fast leading to quick supply of materials.
- ✓ Blood flows at a high pressure leading to an effective system.

#### **Demerits of closed circulatory system**

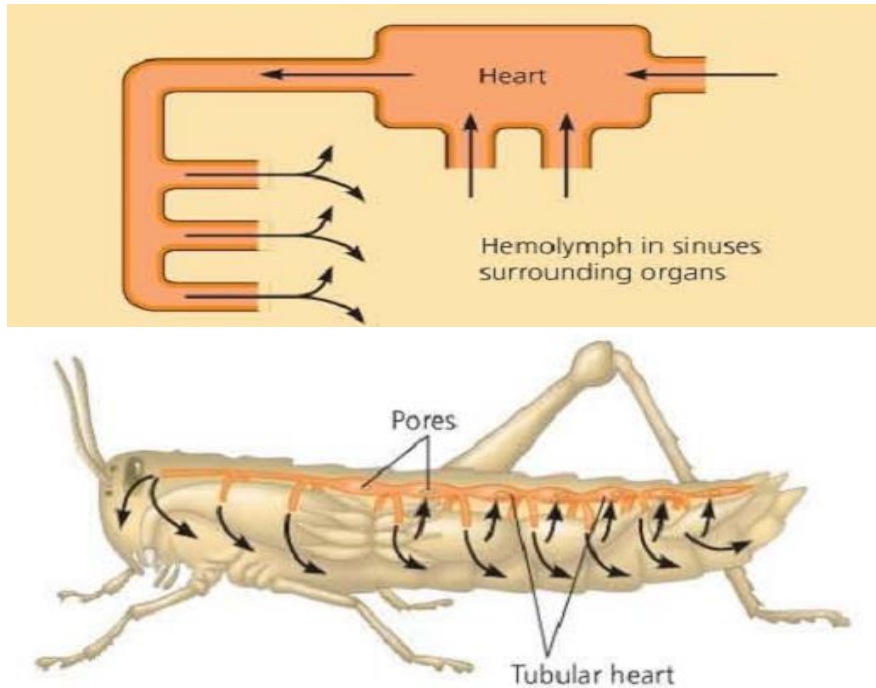
- ✓ It requires a special heart whose pumping action provides pressure for movement of blood.
- ✓ Blood movement meets a high resistance within vessels.

#### **2. Open circulatory system e.g. in molluses and arthropods**

Here the artery that leaves the heart is very short and blood empties in a large blood filled space called haemocoel. Then blood from these spaces return to the heart through the short veins.



The organism 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

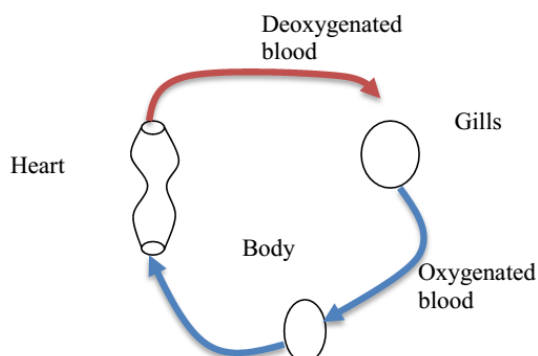
- ✓ Blood flows sluggishly/slowly leading to slow supply of materials.
- ✓ Blood flows at a low pressure.
- ✓ There is little control over distribution of materials or blood.

## TYPES OF CLOSED CIRCULATORY SYSTEM

### 1. 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 chambers i.e. one atrium and one ventricle e.g. in fish.

Diagram illustrating single circulation



The demerit of single circulation is that blood moves very slowly leading to slow supply of materials. Blood pressure is also greatly reduced by gill capillaries.

## **2. Double circulatory system**

In a double circulatory system, blood is pushed out in the heart in to a series of capillaries and the blood passes through the heart twice in each circulation. It involves two separate circulation ie

- Pulmonary circulation to the lungs
- Systemic circulation to the rest of the body

That is, blood from the right ventricle is pumped into the lungs through the pulmonary artery and return to the left atrium via the pulmonary vein and this is called **pulmonary circulation**.

Blood from the left ventricle is pumped through the aorta to the rest of the body and returns to the right atrium through the vena cava and this is called **systemic circulation**

Double circulation is further divided into 2;

- Incomplete double circulation
- Complete double circulation

### **Incomplete double circulation:**

Is a system in which blood flows through the heart twice for every complete cycle through a three-chambered heart. The heart has one ventricle through which both oxygenated and deoxygenated blood from the two atria flow. Mixing of oxygenated and deoxygenated bloody is prevented by ridges present in the ventricle. This system of blood circulation is found in amphibians e.g frogs.

### **Diagram of incomplete double circulation**

### **Complete double circulation**

Is a type of circulation where blood flows through the heart twice within a four-chambered heart for every complete cycle of circulation. Mixing of oxygenated and deoxygenated blood is prevented by a wall called septum. It is found in birds, reptiles and mammals.

### **Diagram showing complete double circulation**

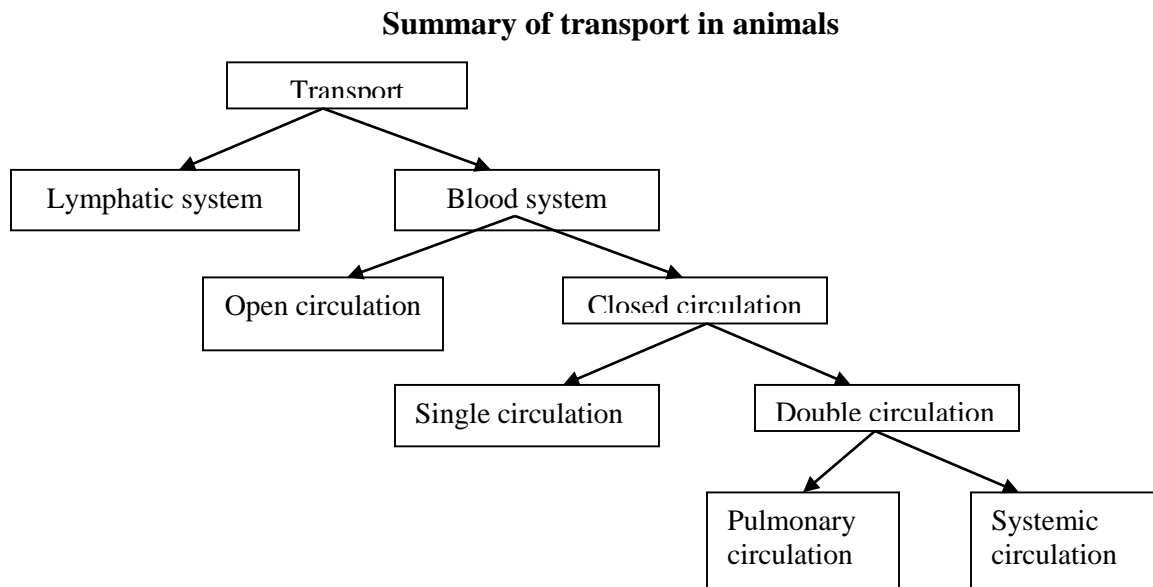
### **Advantages of double circulatory system:**

- ✚ 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.



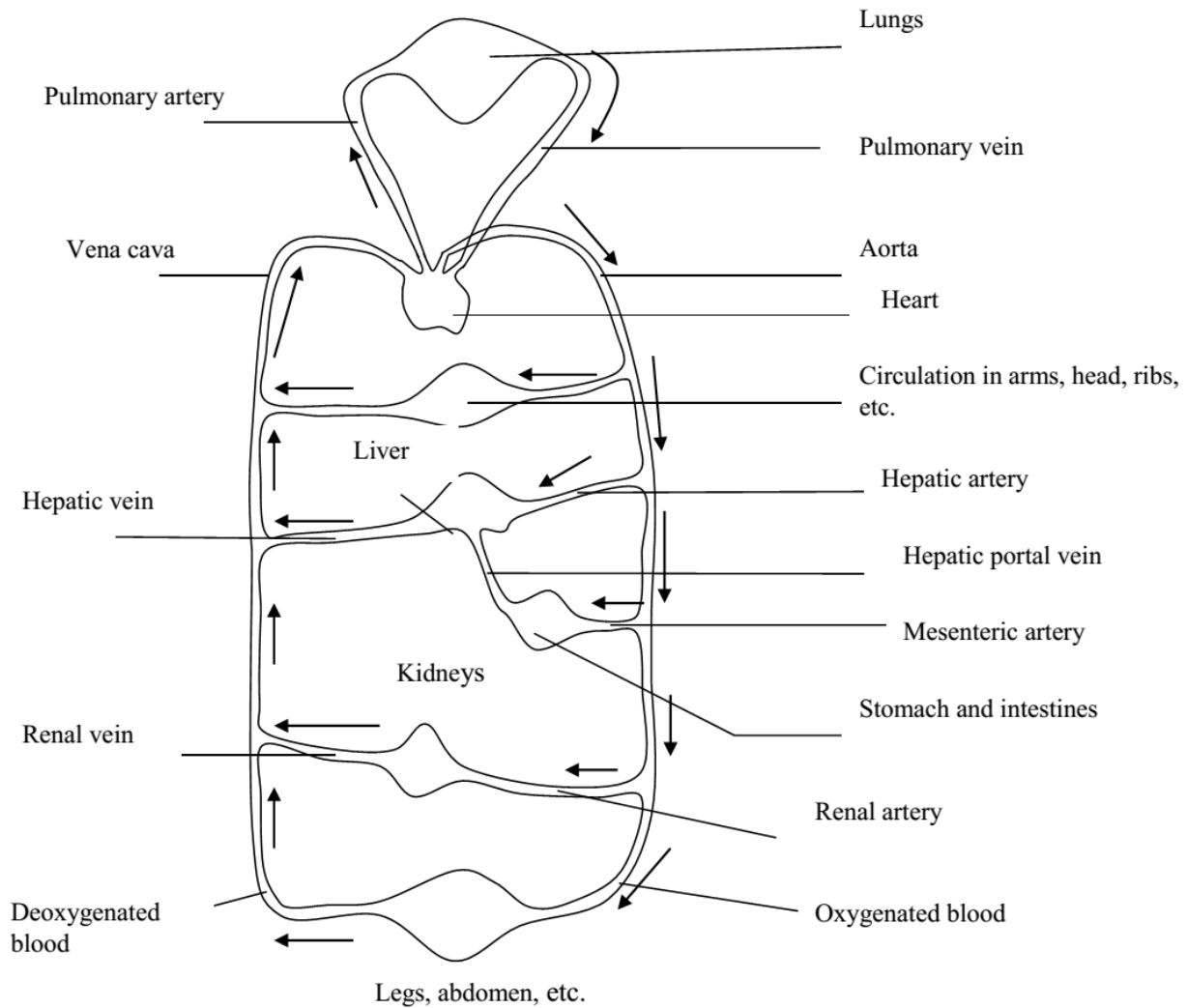
### **THE MAMMALIAN CIRCULATORY SYSTEM**

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 a mammal**



## BLOOD VESSELS

These are the tubes that carry blood throughout the body and they include: arteries, veins, and capillaries

Arteries and veins both have three layers in their walls but the layer of the muscles (elastic tissue) is much greater in arteries than in the veins.

### 1. ARTERIES:

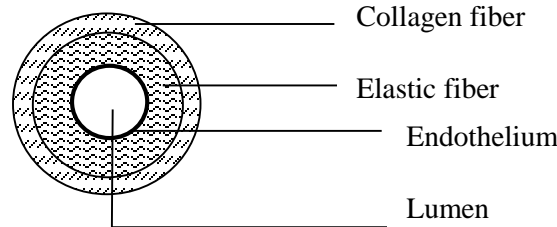
These carry blood from the heart to the body capillaries. Arteries divide into smaller vessels called arterioles which then divide repeatedly to form capillaries.

#### Characteristics of arteries

- Has three layered wall. These are strong to withstand the higher pressure as resulting from the pumping action of the 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 than veins which maintains blood flow at high pressure.
- 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. CAPILLARIES

These are the smallest blood vessels with thin walls to allow diffusion of materials between blood and the tissue fluid.

They connect arterioles to venules.

They pass very close to the cells taking to the cells food, oxygen, and mineral salts etc as well as taking away carbon dioxide, urea and other waste products from the cells.

They are responsible for the exchange of materials between blood and cells, because their walls are permeable allowing water, dissolved food substances to pass through except proteins because they have large molecules.

Blood pressure reduces in them as a result of their resistance, and blood flows in them slowly without pulse.

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

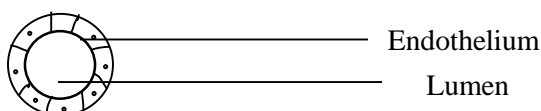
### Adaptations of capillaries to its functions

- They have a large surface area for exchange of materials.
- They have very thin walls for faster diffusion of materials.
- They have a high diffusion gradient leading to rapid diffusion of materials.
- Slow movement of blood in capillaries makes exchange of materials efficient.

### Characteristics of capillaries

- They carry both deoxygenated and oxygenated blood.
- They have a small lumen.
- They have permeable thin walls to allow diffusion of materials.
- They have no valves.
- Blood flows slowly.
- There is a decrease in pressure.

### Cross-section through a capillary



### 3. VEINS

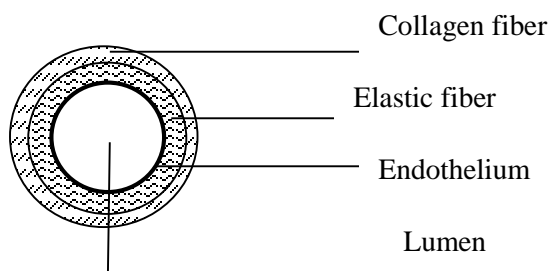
These carry blood from tissues to the heart. The pressure in them is steady and less than in arteries. All veins carry de-oxygenated blood except pulmonary vein. Blood in the veins flows slowly after losing pressure in the capillaries; however the sluggish flow of blood is maintained by:

- Possession of valves which prevent back flow.
- Having a wide lumen that offers a low resistance to blood flow.
- Action of skeletal muscles against veins as they contract during movement increases blood pressure in veins.
- Inhaling lowers the pressure in thoracic cavity leading to flow of blood towards the heart.

#### Characteristics of veins / Adaptations

- 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 / maintain flow of blood 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 near the body surface.

#### Cross-section through a vein



#### DIFFERENCES BETWEEN ARTERIES, VEINS AND CAPILLARIES

##### Structural:

Artery	Veins	Capillaries
Have thick walls with smooth muscles	have thin walls with smooth muscles	Have thinner walls with smooth muscles
have more elastic fibres	Have few 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	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 to and from the heart
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 (flow in pulse)	Blood flow at low pressure	Blood flow at intermediate pressure
Blood flow in pulse	Blood does not flow in pulse	Blood does not flow in pulses

## THE MAMMALIAN HEART

Its function is to pump blood around the body. The whole heart is surrounded by the pericardium which has two layers between which is the pericardial fluid that reduce friction between them.

The heart is made of tissues called cardiac muscles which have the potential to contract rapidly.

It's divided in to four chambers. The upper chambers are called atrium / auricle and the lower chambers are each called ventricle.

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

Movement of blood in the heart is maintained in a single direction ie from the auricle to ventricle and then to blood vessels.

Blood flow in one direction in the heart is maintained by the presence of valves.

The auricles receive blood from all parts of the body while the ventricles pump blood to the body e.g. the left atrium receives oxygenated blood from the pulmonary vein and pump it to the left ventricle through the bicuspid valve.

The right atrium receives deoxygenated blood from the rest of the body from the vena cava and pumps it to the right ventricle via the tricuspid valve.

The ventricle walls are more muscular (have thicker walls) than those of 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.

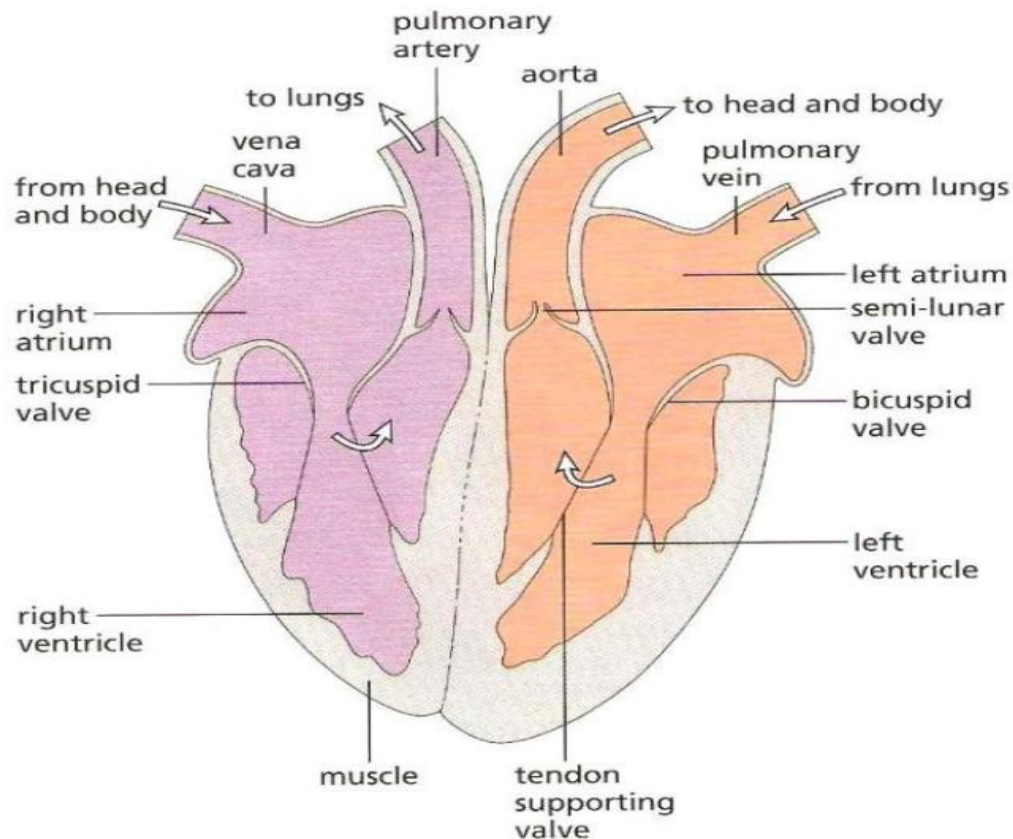
The walls of the left ventricle that pump blood in to the systemic circulation are thicker than those of the right ventricle which pump blood to pulmonary circulation.

### Flow of blood through the heart

Blood flows in to the heart from the rest of the body via the vena cava to the right atrium which pumps it to the right ventricle via the tricuspid valve.

The right ventricle pumps blood to the pulmonary artery to the lungs and blood flows back to the left atrium via the pulmonary vein which pumps it to the left ventricle via the bicuspid valve and then finally pumped to the rest of the body via the aorta.

### LONGITUDINAL SECTION OF THE HEART



### THE CARDIAC CYCLE

This refers to the sequence of events by which the heart pumps and is refilled with blood. The cardiac cycle involves two phases:

- Re-filling of the heart with blood
- Pumping of 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, the cardiac muscles in the walls of the atria relax and expand; blood from the vena cava and pulmonary vein enter the atria and becomes filled with blood. The walls of the ventricles relax and expand while those of the atria contract, forcing blood from the atria into ventricles via bicuspid and tricuspid valves as semilunar valves remain closed.

#### Diagram

**Reference:** *introduction to biology. Pg 99 fig 19.10 (a)*



During systole, cardiac muscles of the ventricles contract, forcing blood out of the heart via the semi lunar valves into the aorta and pulmonary artery. At this time, the atria relax and expand in order to be re-filled with blood. The cuspid valves close against high blood pressure to prevent the back flow of blood into the auricles. The closure of the valves produces the heart sound termed as ***lub***.

### **Diagram**

***Reference: introduction to biology. Pg 99 fig 19.10 (b)***

After expelling blood, ventricles relax and their pressure lowers compared to aorta and pulmonary artery pressure.

This would cause back flow of blood to the heart but is prevented by sudden closure of the semi lunar valves. The closure of the semi lunar valves causes a second heart sound called ***dub***.

The 2 sounds ***lub and dub*** are so close and often described as *lub-dub* and they form a single heartbeat.

### **Initiation and control of the heart beat**

Contraction of the heart is initiated by heart, heart muscles / cardiac muscles themselves.

Therefore the heart muscles are myogenic i.e. the rhythmic contraction arise from within the tissue itself.

Heart beat is controlled by collection of cells in the right atrium called pacemakers located in the sino atrio node (SAN) which are controlled by nervous impulse from the medulla oblongata of the brain that change the rate of heart beat.

### **Factors affecting the heart beat rate**

- Exercise.
- Lack of hormones in the body e.g. adrenaline
- State of health and diseases e.g. malaria
- Age i.e. its 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 / 72 times per minute.

## **BLOOD PRESSURE**

This is the force with which blood flows from one part of the body to another. The blood pressure is due to the pumping action of the heart as experienced by the blood vessels. The narrow blood vessels experience high blood pressure and wide vessels experience low blood pressure. Sometimes fats accumulate in the blood vessels making their lumens narrow. This increases blood pressure and it is the major cause of high blood pressure in fat people, however small people also experience high blood pressure. This is due to conditions like stress, anxiety, fear, etc. These conditions tend to increase the rate of heartbeat and more blood is pumped to the blood vessels causing high pressure in them.

## **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/nutrients of blood**

1. Red blood cells/erythrocytes/red corpuscles
2. White blood cells/leucocytes/white corpuscles
3. Platelets/thrombocytes
4. Plasma

### **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 regulates the amounts of chemicals such as glucose in the body.
9. It prevents loss of fluids and cells through forming blood clots.

## **THE RED BLOOD CELLS (ERYTHROCYTES)**

### **Characteristics of Red Blood Cells:**

- ❖ They have hemoglobin molecules which carry oxygen from the lungs to the tissues.
- ❖ They lack nuclei
- ❖ They have thin cell membranes which thinness reduces the diffusion distance for gases.
- ❖ They are manufactured from the red bone marrow
- ❖ On average, red blood cells last for four months after which they are destroyed by the liver to form bile pigment and the iron in haemoglobin is stored in the liver

- ❖ They have a biconcave disk shape
- ❖ They are approximately 5 million/mm<sup>3</sup> of blood.

### **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.

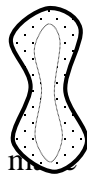
### **Adaptation of Red Blood Cells to carry out their function**

- 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 to 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.
- They lack nuclei which provides enough space for packaging of haemoglobin
- They lack mitochondria and generate their ATP exclusively by anaerobic respiration to prevent them from using the oxygen they are carrying.
- They have an enzyme, carbonic anhydrase which plays a role in carbon dioxide transport
- They are numerous per mm<sup>3</sup> 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.

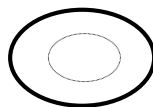
**NB:** The concentration of red blood cells increases as one climbs up a mountain because the concentration of oxygen in the air reduces with increase in height above sea level. So the body adopts by producing more red cells to increase the available total surface area to bind and carry oxygen to the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

### **Structure of the red blood cell.**

Side view.



Surface view



Red blood cells are made from the red bone marrow of short bones in adults and in the foetus, red blood cells are made in the liver. They last for approximately four months after which they are taken to the liver or spleen for their destruction. They are more numerous than any other cells in the blood. Red blood cells are responsible for transporting oxygen in the body.

### **THE WHITE BLOOD CELLS (LEUCOCYTES)**

These are blood cells made from the white bone marrow of long bones. They are also made in the spleen and lymphatic system. They are responsible for defense of the body against infection. They are fewer in blood than the red blood cells.

### **Characteristics of white blood cells**

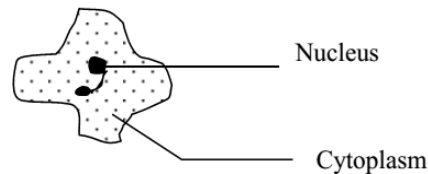
- They have no definite shape (they are amoeboid)

- ii) They have a nucleus even at maturity.
- iii) They are relatively few in blood but their number increases when the body is attacked by an infection.
- iv) They lack haemoglobin.
- v) They feed on foreign particles by Phagocytes

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

1. Phagocytes. These are white blood cells with a lobed nucleus. They ingest and destroy germs by phagocytes.
2. Lymphocytes. These are white blood cells, which defend the body by producing antibodies.

#### **Structure of a white blood cell**



#### **Production of red and white blood cells**

The red blood cells are manufactured from the red bone marrows in adults. Old red blood cells are taken to the liver for destruction.

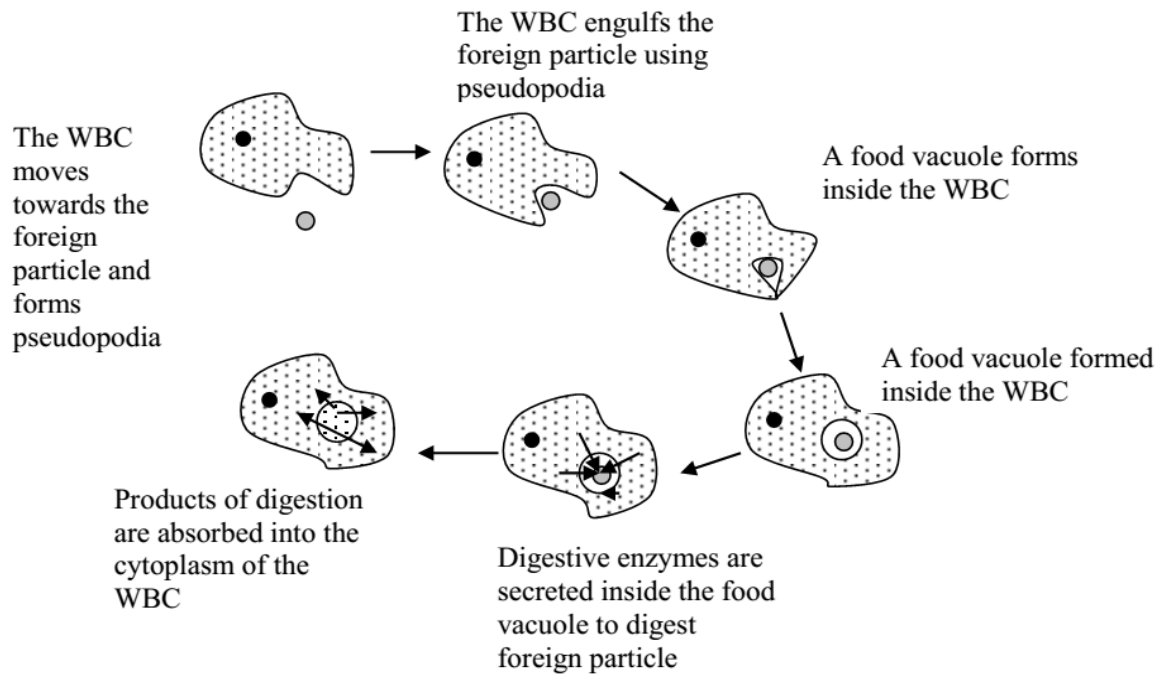
White blood cells are manufactured from the white bone marrows of long bones. Some white blood cells are manufactured from the lymph nodes. Worn out white blood cells are also taken to the liver for destruction. In the foetus, the liver manufactures blood cells.

#### **Action of white blood cells on the foreign particles**

Some white blood cells attack and destroy the foreign particles directly by themselves. These are called phagocytes and they destroy the foreign particles by Phagocytosis. In this process the white blood cells form pseudopodia, which they use to engulf the foreign particle by Phagocytosis.

After engulfing the foreign particle, a food vacuole is formed into which digestive enzymes are produced. The enzymes break down the particle and the important materials are absorbed by the white blood cell while the wastes are excreted out of the cell through the contractile vacuole.

#### **Illustration of Phagocytosis**



Some white blood cells destroy foreign particles by releasing antibodies, which destroy the particles. White blood cells, which produce antibodies, are called lymphocytes. There are four types of antibodies produced.

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

### **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 spherical in shape.
3. They do not have a nucleus.
4. They do not have haemoglobin.

#### **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.*** It is important because of the following reasons.

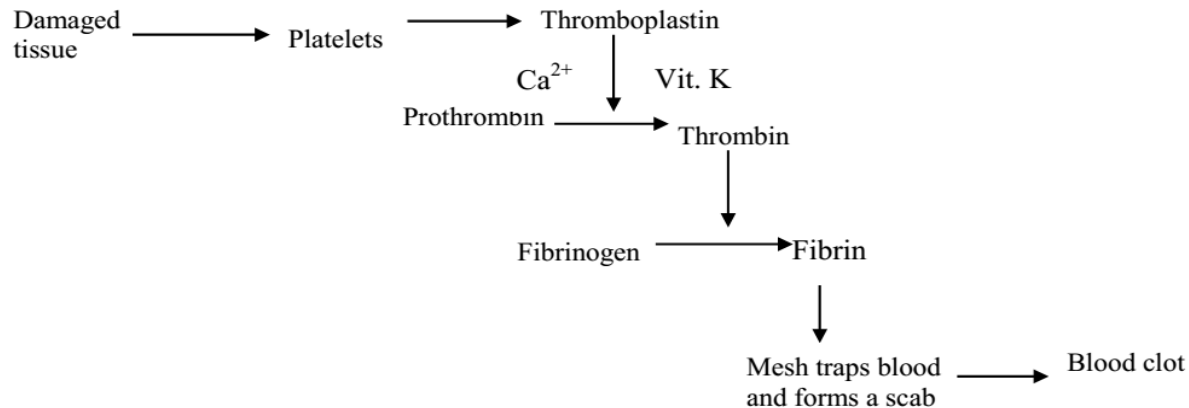
1. It prevents excessive loss of blood from the body.
2. It is a step towards healing of cuts and wounds.

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) A soluble protein

A soluble protein called **fibrinogen** that plays a role in blood clotting.

- j) Serum

- k) 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 LATER LYMPH.

As blood flows from arterioles into blood capillaries. Pressure builds up in the capillaries forcing small molecules like food materials 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 no longer called blood but tissue fluid. Once formed, the tissue fluid surrounds the cells. Body cells then get their requirements e.g. glucose, oxygen, etc. from the tissue fluid and they add excretory materials to the fluid. Some of the fluid returns in to the capillaries and the other is drained in to a system of narrow channels called lymph vessels. The fluid in these vessels is now called lymph. Lymph is therefore, tissue fluid in the lymph vessels.

### **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 fluid. The lymph fluid is transported through lymph vessels. The 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 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 cell, wastes and bacteria. Before reaching the blood, lymph passes through the lymph nodes where the wastes and bacteria are removed.

The lymph joins the blood circulation via the thoracic ducts, which join the vein in the neck. The right thoracic duct drains its contents of the right side and that of the left drains the left side. The lacteals of the ileum are also connected to the left thoracic duct.

### **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 assist in defense of the body.
4. It filters out bacteria before they reach the blood stream.
5. Transports hormones from glands to other body parts.

### **Differences between the lymphatic and blood system**

<b>Blood circulatory system</b>	<b>Lymphatic system</b>
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 selected muscle provides a force by which substances are moved.
4. Both have vessels through which materials are transported.

## BLOOD GROUPS

There are 4 main blood groups i.e.

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

When one has got less blood than necessary, blood transfusion is carried out. The one who gives blood to a patient is called a **donor** and the one receiving is known as a **recipient**. Doctors have to match the blood of the donor to that of the recipient because when incompatibles blood is mixed, the red blood cells stick together (agglutinate) and blood clots. This is a fatal situation.

Agglutination is caused by the presence of proteins called **antigens** on the surface of cells being mixed with specific **antibodies**, which work against them. Blood groups are determined by the type of antigens one has in blood. This means that one having antigen A belongs to blood group A. Those with antigen B belong to blood group B. Those with antigens A and B belong to blood group AB while those without antigens belong to blood group O. Each blood produces particular antibodies, which work against particular antigens when introduced into the body. For example, blood group A produces antibody b. This means that blood group A is anti (against) blood containing antigen B (blood group B).

**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<sup>+</sup>)** while a few do not have the Rhesus factor and are said to be **Rhesus negative (Rh<sup>-</sup>)**.

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 though he 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 factor with subsequent transfusion of Rhesus positive blood leading to agglutination.*

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; with such a 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 factor 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<sup>+</sup> can receive blood from a donor of (i) A Rh<sup>+</sup> (ii) A Rh<sup>-</sup> (iii) ORh<sup>+</sup> (iv) ORh<sup>-</sup>**

### IMMUNITY AND THE IMMUNE SYSTEM

Immunity is the ability of an organism to resist infection. The immune response is based upon recognition of a foreign particle and the release of chemicals that destroy it. 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 its life towards various diseases. It is divided into:

- Natural acquired immunity

- Artificial acquired immunity

### **Natural acquired immunity**

This is the immunity provided by antibodies which are naturally acquired. It is further divided into 2 types:

- Natural active immunity

- Natural passive immunity

### **Natural active immunity**

This is the type of immunity provided by antibodies produced by the body after being exposed to a particular disease. After production of the antibodies, the body becomes resistant to the subsequent similar infections e.g. contracting flu and recovering from it without using any drugs.

### **Natural passive immunity**

This is the immunity provided by antibodies acquired from another individual of the same species. It is a temporary type of immunity e.g. the body obtains antibodies from the mother through breast feeding colostrum.

### **Artificial acquired immunity**

This is the type of immunity provided by antibodies injected artificially from either the organisms of the same species or artificially made. It is divided into 2 types:

- Artificial active immunity

- Artificial passive immunity

### **Artificial active immunity**

It is a product of inducing the body to produce antibodies by artificially injecting one with a vaccine (weakened/attenuated pathogenic organism). This process is called vaccination or immunization.

### **Artificial passive immunity**

This is the immunity provided by antibodies artificially injected into an individual. It is temporary and the body is not induced to produce its own antibodies.