1. TRANSPORT IN PLANTS AND ANIMALS.

Transport defined.

- This is the movement of substances from one part of the body of an organism to another.
- It involves the movement of materials to the sites where they are required and the removal of metabolic wastes from the site of production to the site of elimination.

Importance of a transport system.

- It facilitates the distribution of nutrients and oxygen to all living cells of the body.
- It facilitates the removal of metabolic waste products (e.g. nitrogenous wastes and carbon (IV) oxide from the body cells.

Transport in unicellular organisms.

- The unicellular organisms (e.g. bacteria) have **a large surface area to volume ratio** hence transport of substances is through **diffusion** across their cell membranes and within the cells of the organism.

Transport in multicellular organisms.

- They have **a small surface area to volume ratio .**This makes the tissues and organs far removed from the site of supply of the materials.
- This requires a transport system to supply materials to the deep seated organs and also remove metabolic wastes.

TRANSPORT IN PLANTS

- Simple plants e.g. mosses and liverworts lack specialized transport system hence the transport of substances occur through diffusion, osmosis and active transport.
- Higher plants have specialized transport system called **vascular system.**
- The vascular bundle consists of:

1. **xylem-** it transports water and mineral salts from the soil to other parts of the plant.
2. **Phloem-** it transports manufactured food substances e.g. glucose from the leaves to other parts of the plant.

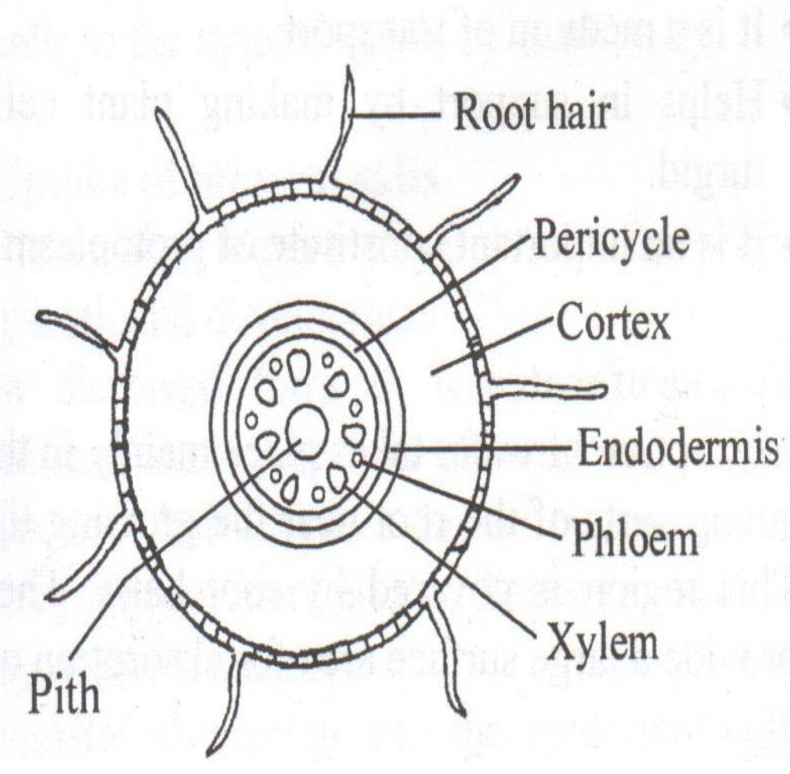
STRUCTURE OF A ROOT.

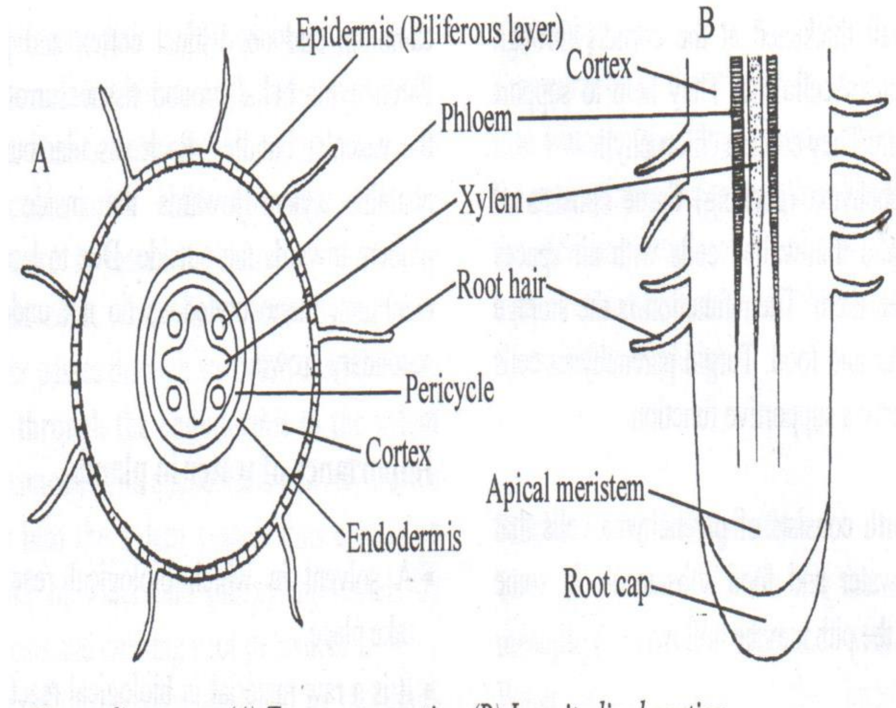
- The root is the part of the plant which is embedded in the soil.

Functions of the root.

1. **Anchorage-** holding the plant firmly in the soil.
2. **Absorption-** of water and mineral salts.

INTERNAL STRUCTURE OF A ROOT





Young dicot root: (A) Transverse section (B) Longitudinal section

1. **Root cap-** it consists of simple parenchyma cells that protect the root tip/ apical meristem as the root tip pushes past soil particles.
2. **Piliferous layer-** this is a special epidermis of young roots whose cells form/ which give rise to root hairs.
3. **Cortex-** it consists of loosely packed parenchyma cells. It acts as storage tissue.
4. **Pericycle-**this is a single layer of cells below the endodermis that gives rise to lateral roots.
5. **Vascular bundle-** it consists of xylem and phloem. In monocot root, the xylem alternates with phloem. In dicot root, xylem is star shaped and the phloem is located between the arms of the xylem.
6. **Endodermis-** this is a single layer of cells which surround the vascular bundle. It controls the amount of water and mineral salts entering the vascular bundle. It is characterized by;

a) Starch grain that stain **blue-black** with iodine.

b) Casparian strip which has impervious deposit on the radial and cross walls.

7. **Root hairs-** they arise from the epidermal cells. They provide a large surface area for absorption of water and mineral salts.

Adaptation of root hairs

1. They are long to provide a large surface area for absorption of water and mineral salts.
2. They are thinned walled to reduce the distance hence faster diffusion of water and mineral salts.
3. They are numerous to increase the surface area for absorption.
4. They have numerous mitochondria to provide energy for active uptake of mineral salts.
5. They have large sap vacuole whose sap exerts a high osmotic pressure necessary for water absorption

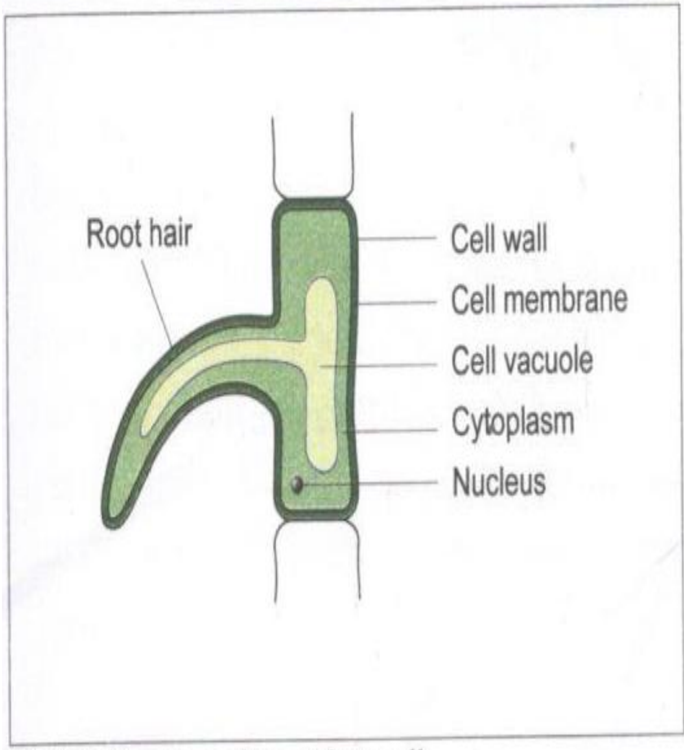


Fig 1.2: *Structure of a root hair cell.*

Differences between dicot root and monocot root

Dicot root	Monocot root
1. Xylem is star shaped at the centre with phloem within the arms	1. Xylem and phloem are arranged alternately in a ring
2. It lacks pith	2. It has a pith

THE STEM

- This is the part of the plant above the ground onto which the branches and leaves are attached.

Functions of a stem

1. Supports and exposes the leaves and flowers to the environment.
2. Conducts/ transports water and mineral salts from the roots to the other parts of the plant.
3. Conducts/ transports manufactured food from leaves to other parts of the plant.
4. Storage of food and water in some plants e.g. cactus.
5. Vegetative propagation (perennation) e.g. in cassava.
6. Gaseous exchange in woody plants

INTERNAL STRUCTURE OF A STEM

1. **The epidermis-** it is a single layer of cells covering all plants.

- Epidermal cells lack chloroplasts and their outer walls are covered by a waxy cuticle:

a) That prevents excessive loss of water through evaporation.

b) Protects the inner tissues from infection and mechanical injury.

c) Prevents entry of pathogens.

- Young stems have stomata on the epidermis through which air moves in and out of the underlying stem tissues.

2. **The pith-** this is the central region in the dicot stem.

- It consists of parenchyma cells that store water and food substances.

3. **Vascular bundles-** it consists of:

a) **Xylem-** which transports water and mineral salts from soil to other parts of the plant and provides mechanical support.

b) **Phloem-** transports manufactured food from leaves to other parts of the plant.

4. **The cortex-** this is the region below the epidermis. It consists of the following tissues:

a) **Collenchyma tissue-** it is found below the epidermis.

- The cells are elongated with pointed ends.
- The walls are thickened with cellulose and pectin hence serves as strengthening tissue/ providing mechanical support.

b) **Parenchyma / Chlorenchyma tissue-** the cells are irregular in shape, thin walled and loosely packed.

- This creates intercellular spaces filled with air.
- The cells act as storage tissue for water and food.
- They also contain chloroplasts hence manufacture food/ photosynthesize and make some stems green.

c) **Sclerenchyma tissue-** it is found in close association with the vascular bundles. The walls are thickened with lignin which provide mechanical support.

Differences between monocot stem and dicot stem.

Dicot stem	Monocot stem
1. Has cambium.	1. Lacks cambium
2. Vascular bundles are arranged in a ring.	2. Vascular bundles are scattered within the cortex.
3. It has a pith.	3. It lacks a pith

Differences between monocot stem and monocot root

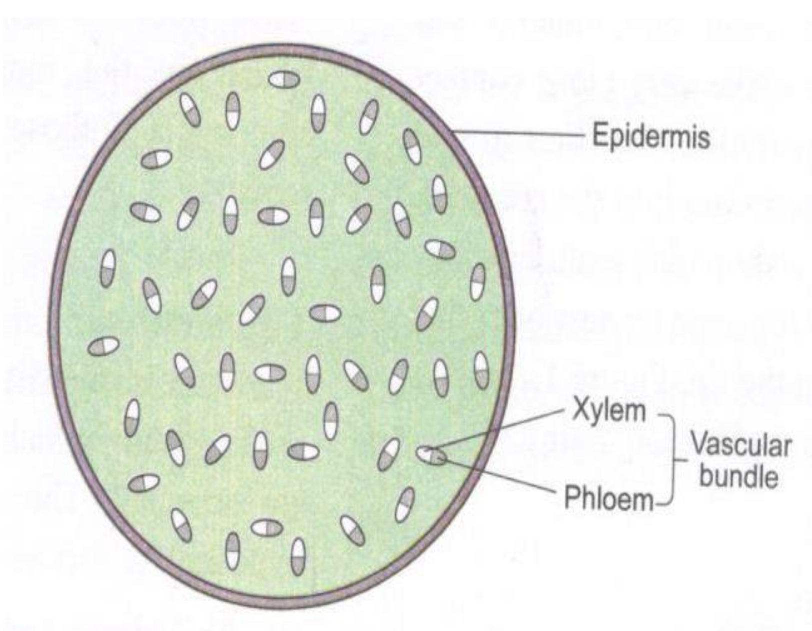
Monocot stem	Monocot root
1. Vascular bundles are scattered within the cortex.	1. Vascular bundles are arranged in a ring.
2. It lacks pericycle.	2. It has pericycle
3. Phloem and xylem are closely associated	3. Phloem and xylem are separate.
4. It lacks a pith	4. It has apith
5. It lacks root hairs.	5. It has root hairs

Differences between a dicot root and dicot stem

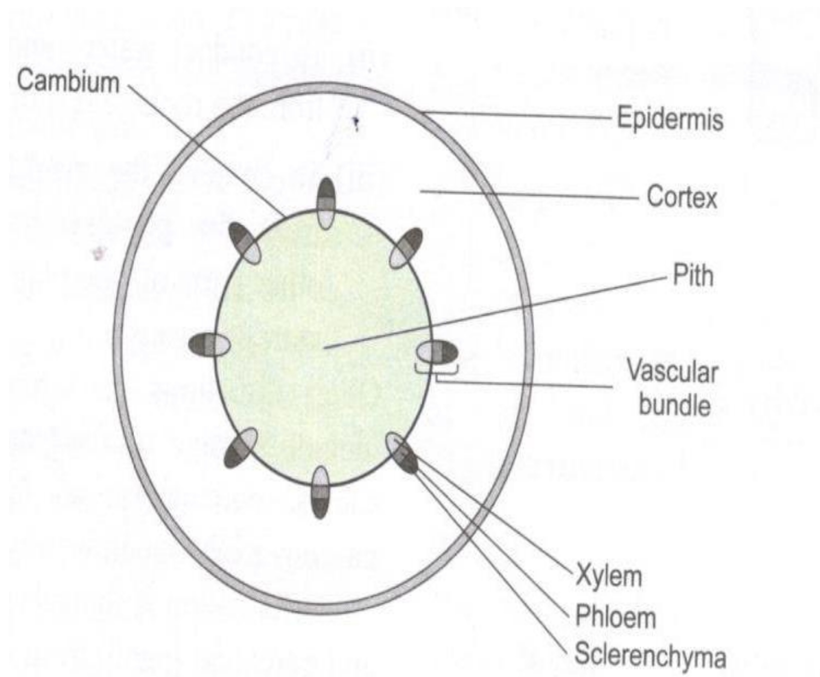
Dicot root	Dicot stem
1. Xylem is star shaped with phloem located within the arms.	1. Xylem and phloem are arranged in a ring, separated by cambium with phloem on the outside and xylem on the inside.
2. It has root hairs	2. It lacks root hairs.
3. It lacks a pith.	3. It has a pith.
4. It lacks cambium.	4. It has cambium.

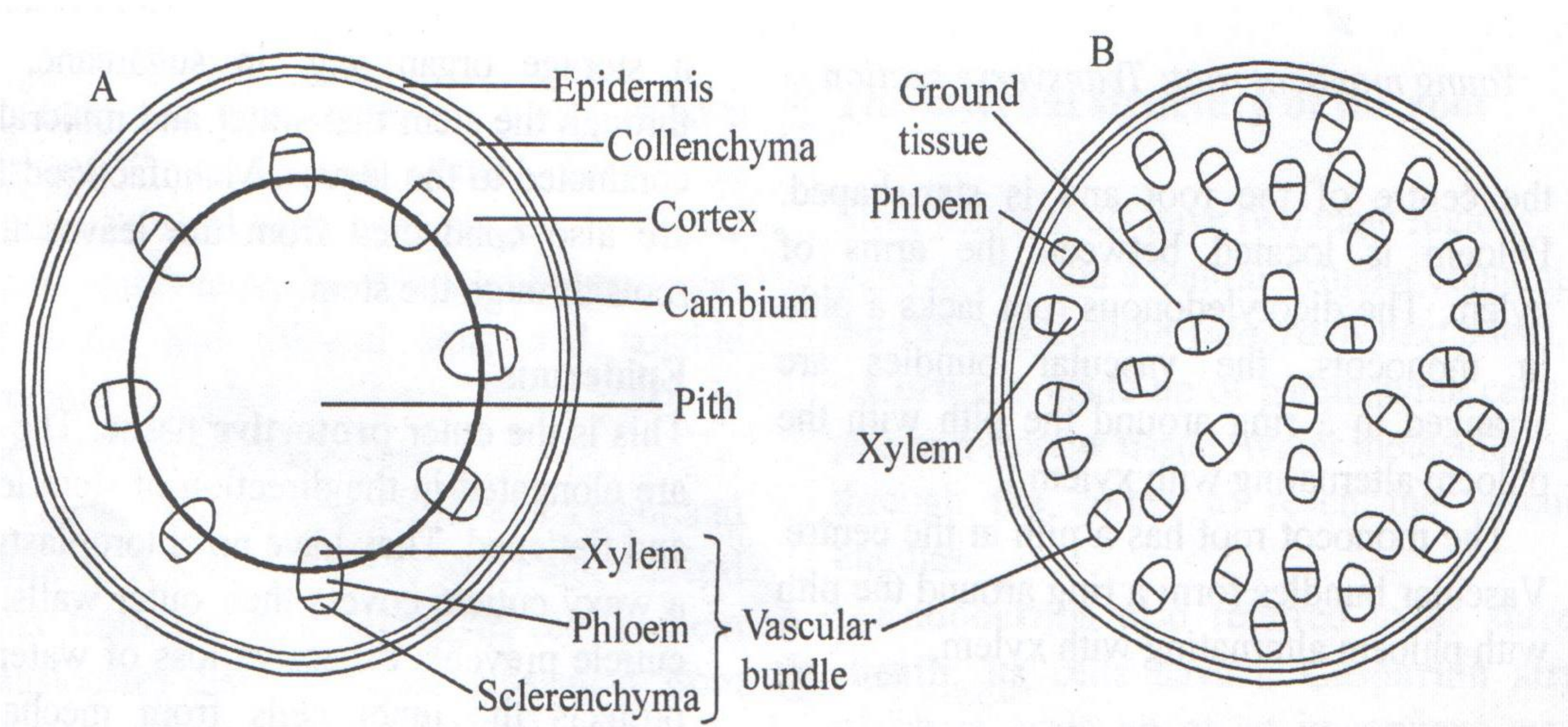
INTERNAL STRUCTURE OF A STEM

Monocot stem



Dicot stem





Transverse section of young dicot stem (A) and young monocot stem (B)

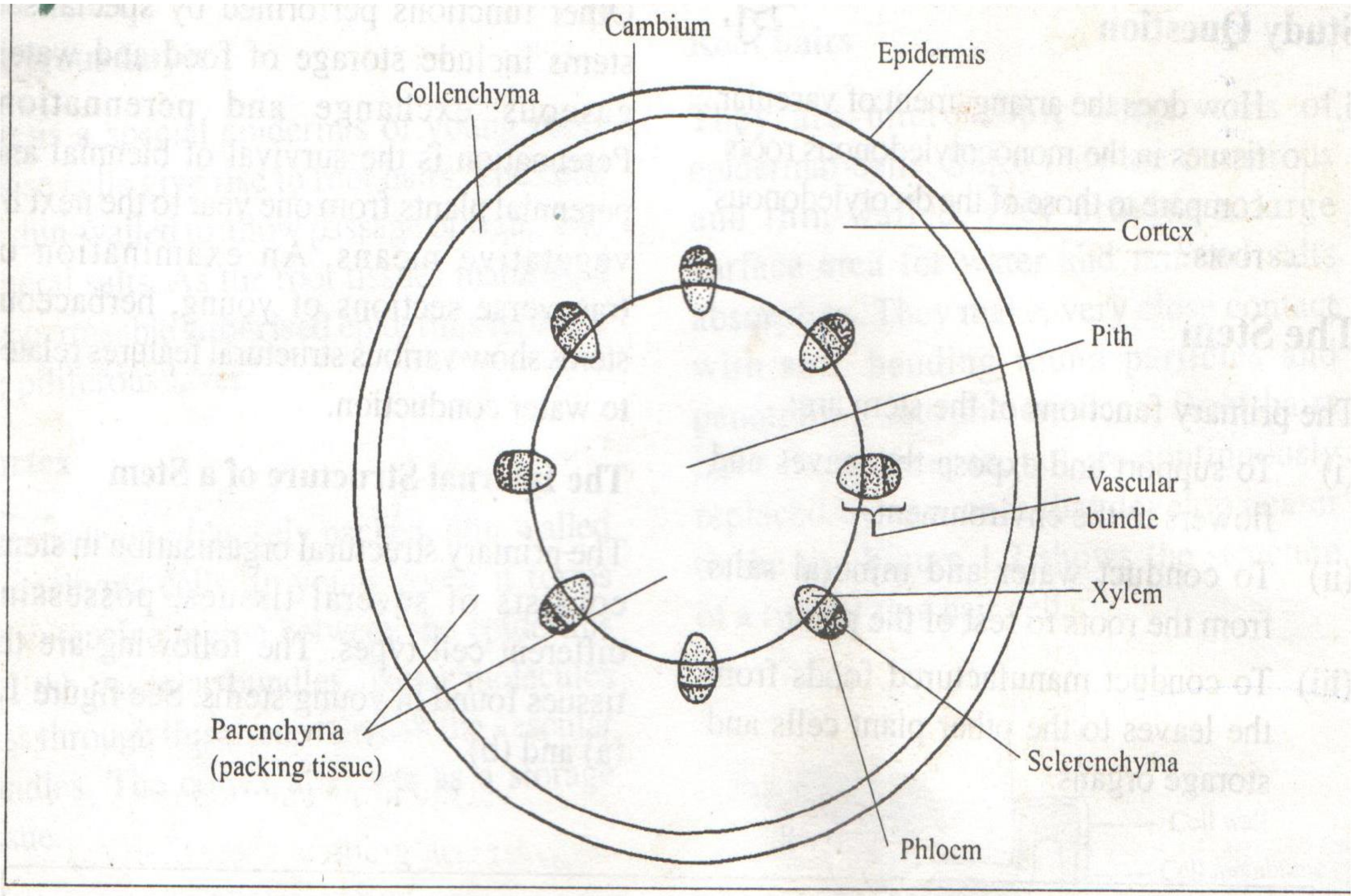


Fig. 1.3(b): Transverse section of a young dicotyledon stem

ABSORPTION OF WATER AND MINERAL SALTS.

Role/ importance of water to plants.

1) It is a raw material for photosynthesis
2) It is a medium of transport of materials and a medium of metabolic reactions.
3) It acts as a solvent for solutes in the plant body.
4) It provides mechanical support because when the plant cells are turgid they are firm and rigid.
5) It has a cooling effect to the plant after transpiration due to its higher latent heat of vaporization.

a) **Absorption and movement of water from roots to leaves and atmosphere.**

- ✓ Water is absorbed/ drawn into the root hairs by **osmosis.**
- ✓ Soil particles are surrounded by film of water and the cell sap of the root hair is more concentrated than soil water.
- ✓ Due to difference in concentration between cell sap and water in the soil, water moves into the root hair by osmosis across the semi permeable cell membrane.

- ✓ This reduces concentration of the cell sap in the root hair hence water moves into neighboring cells by osmosis.
- ✓ This continues until water reaches the xylem of the root, through cell sap to cell sap, cytoplasm to cytoplasm and through intercellular spaces into xylem of stem.
- ✓ Once inside the stem water moves up aided by capillarity/ narrowness of xylem vessels, root pressure, attraction of water molecules to each other/ cohesion, attraction of water molecules to the walls/ adhesion from xylem of stem to xylem of leaves.
- ✓ Once inside the leaves, water enters the mesophyll and by osmosis moves from cell to cell into the sub-stomatal air spaces where it evaporates into the air creating transpiration pull.

b) **Absorption of mineral salts.**

- Soil water contains dissolved mineral salts which plants require for their growth and proper functioning.
- Generally, the concentration of the cell sap in the root hairs is greater than that of soil.
- Therefore the mineral salts/ions enter the root hairs against the concentration gradient/ through **active transport.**
- Mineral salts whose concentration is higher in the soil solution than the root hairs are taken up by **diffusion.**
- The mineral salts/ ions then move into the vascular tissues of the root then into the xylem of the stem.
- Inside the xylem of the stem the mineral salts/ ions and water move up the stem by a combination of the following forces, **osmosis, diffusion, root pressure and capillary attraction.**

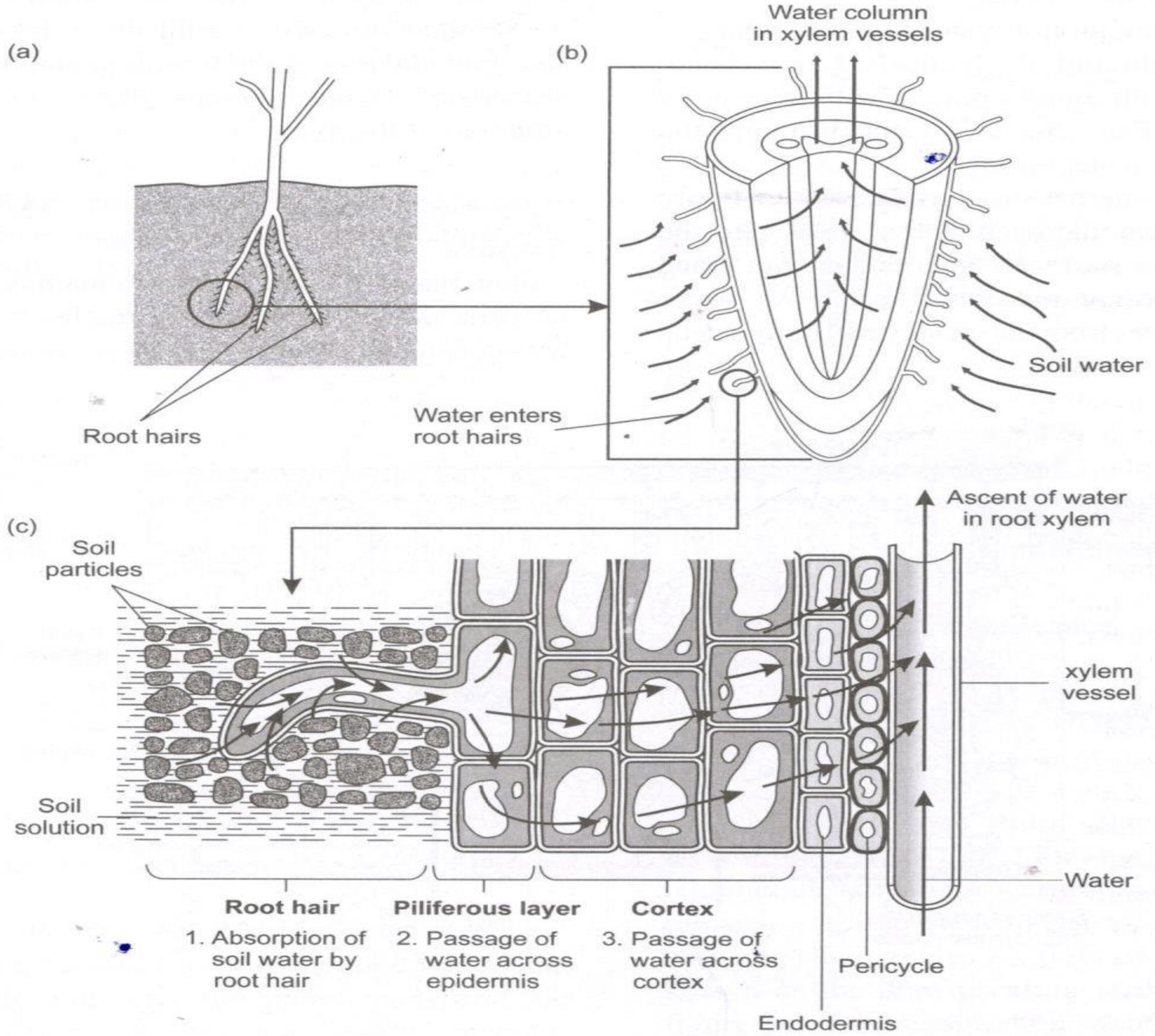


Fig 1.4: *Absorption of water by plants*

TRANSPIRATION.

- **Transpiration** is the process by which plants lose water in form of vapour into the atmosphere.
- **Wilting** is the process which occurs when the rate of water is more than the rate of absorption, and the plant droops.
- Wilting is important because it causes rolling of leaves which reduce the surface area for transpiration/ water loss. This prevents further loss of water.

Structures used for transpiration.

i. Stomata
ii. Lenticels
iii. Cuticle.

Types of transpiration.

i. **Cuticular transpiration-** loss of water through the cuticle.
ii. **Lenticular transpiration**- loss of water through the lenticels. Lenticels are areas with loosely packed cells on woody stems
iii. **Stomatal transpiration**- loss of water through the stomata.

Advantages/significance of transpiration.

i. Helps in transportation of dissolved mineral salts in the plant.
ii. It brings about the cooling effect on the plant during the hot day.
iii. It helps in uptake of water up the xylem vessels.
iv. It removes excess water from plants.
v. It helps to maintain turgor of the plant cells.

Process of transpiration.

- As water vaporizes from the spongy mesophyll cells into the sub-stomatal air spaces their cell sap becomes more concentrated than the adjacent cells.
- This increases the osmotic pressure of the spongy mesophyll cells.
- The higher osmotic pressure of spongy mesophyll cells causes water to flow from other surrounding cells, which in turn take in water from the xylem vessels of the leaf veins.

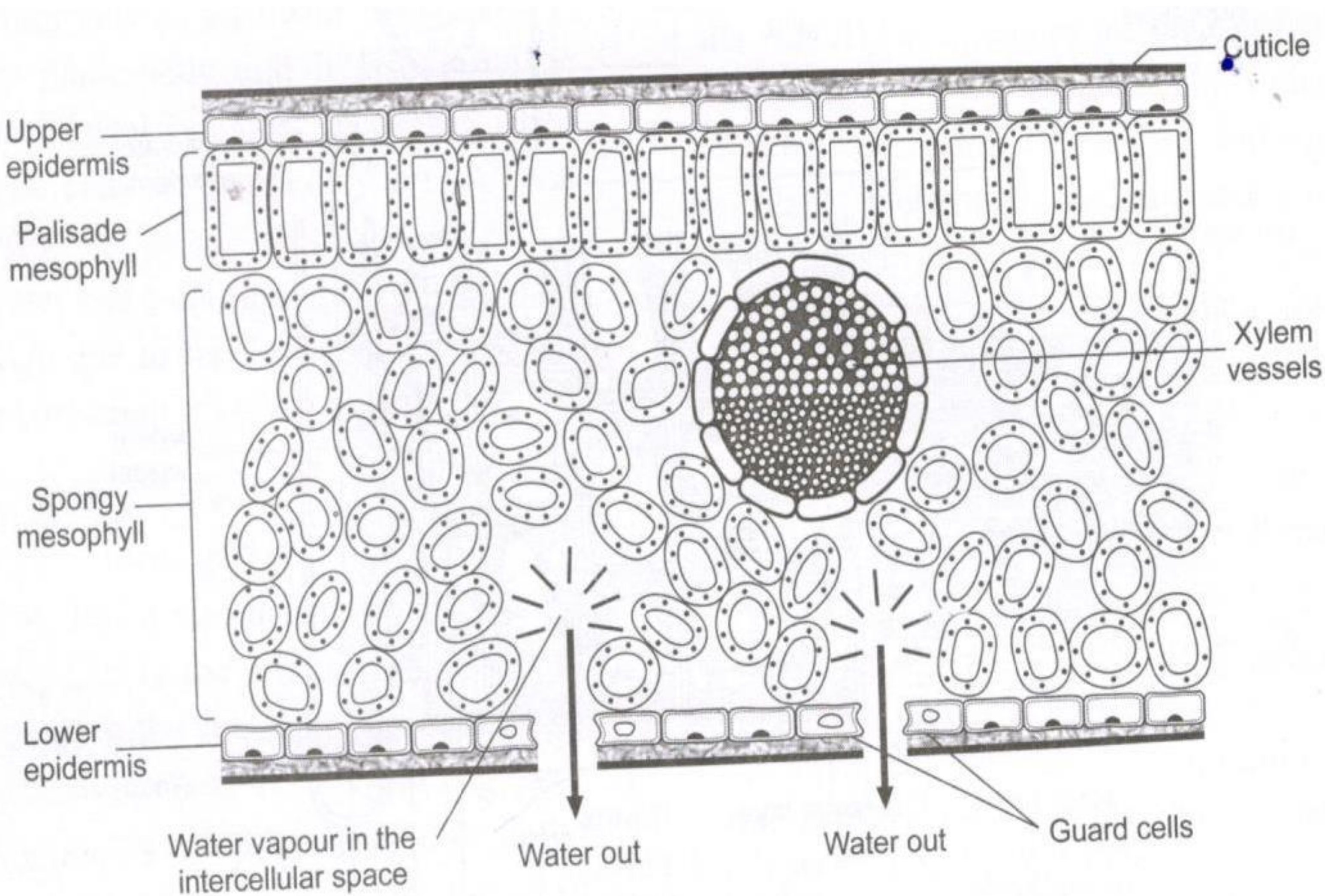


Fig 1.5: *The internal structure of a leaf*

STRUCTURE AND FUNCTION OF XYLEM

- The functions of xylem are:

i. Transport of water and mineral salts

ii. Has lignified walls that provide mechanical support

- Xylem consists of:

i. Xylem vessels

ii. Tracheids

A. XYLEM VESSELS.

- They are tubular and non-ling tissues. The non-living material in the vessel reduce resistance to water flow allowing for smooth uninterrupted flow of water
- They are more efficient in transportation of water than tracheids because they are hollow.
- Their walls are strengthened by lignin to provide mechanical support and prevent them from collapsing.
- They have pits/ are perforated at the cross walls to allow lateral movement of water to the cells surrounding the xylem.
- The pattern of lignification can be:

i. Annular lignification.

ii. Spiral lignification.

iii. Pitted lignification.

iv. Reticulate lignification.

Adaptations of xylem vessels for conduction of water

i. They are hollow for continuous flow of water from roots to leaves.

ii. They have dead cells to allow flow of water and mineral salts without interruption.

iii. The walls are strengthened with lignin to prevent collapsing.

iv. They have narrow lumen to enhance capillarity.

v. They have pits on the side walls for lateral movement of water.

B. TRACHEIDS.

- They are dead cells with tapered ends / chisel shaped with pits to allow flow of water.
- They have pits/ are perforated at the cross walls to allow lateral movement of water to the cells surrounding the xylem.
- The tapered which are perforated make them less efficient in transportation off water than vessels.
- Their walls are strengthened by lignin to provide mechanical support and prevent them from collapsing.

Similarities

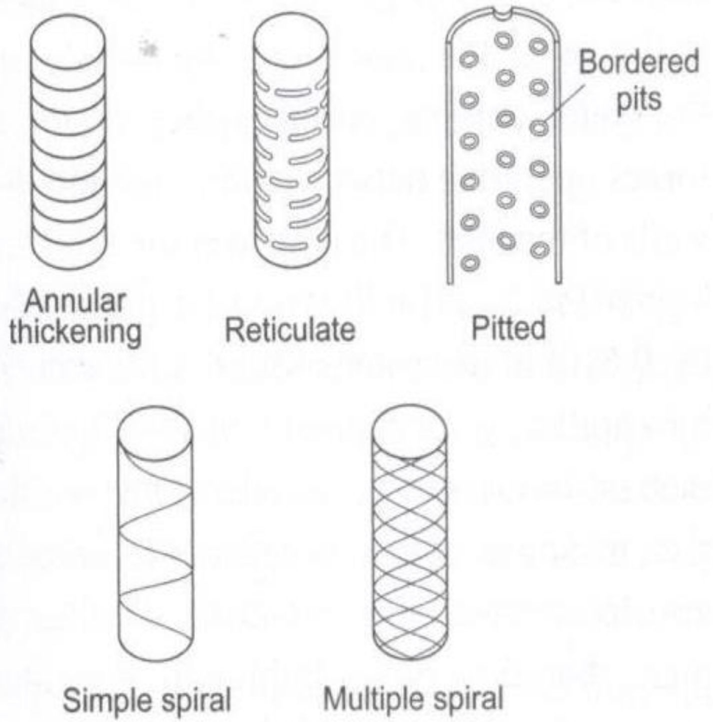
- Both have lignified walls.
- Both have lateral pits on cross walls.
- Both have dead cells.

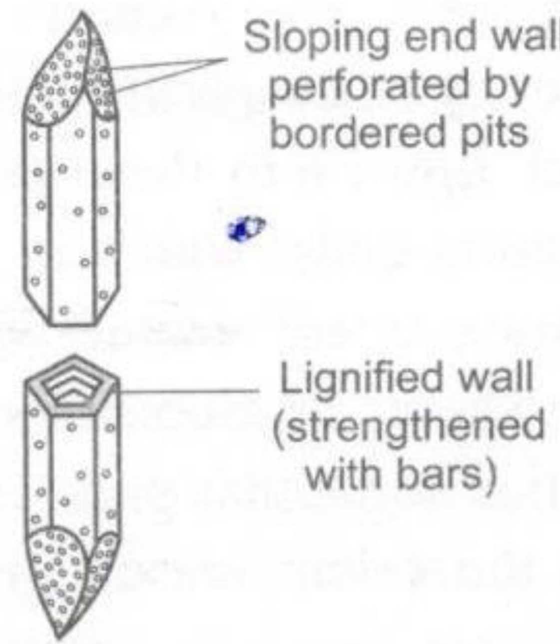
Difference between xylem tracheid and vessel

Tracheid	Vessel
1. Has tapered end	1. It is hollow/ tubular

Different types of thickening in xylem vessels

Tracheid





FORCES INVOLVED IN WATER MOVEMENT IN THE XYLEM.

- They include:

A. Root pressure.
B. Cohesion and adhesion.
C. Capillarity.
D. Transpiration pull.

A. Root pressure.

- This is the force that pushes water up the stem.
- It results from the active uptake of mineral salts by the roots increasing the osmotic pressure in the root xylem.
- This causes water to move into the root xylem through osmosis causing an increase in pressure.
- This pressure in the root causes the upward movement of water in the xylem of the stem.
- This process requires energy and respiratory inhibitors e.g. cyanide reduce root pressure.

B. Cohesion and adhesion.

- Cohesion is the force that keeps water molecules together. Water molecules attract each other maintaining a continuous and uninterrupted water column in the xylem.
- Adhesion is the force between water molecules and the walls of xylem vessels. Water molecules are attracted/cling to the surface of xylem.
- The combination of cohesion and adhesion causes a continuous flow of water up the xylem.

C. Capillarity.

- This is a tendency of water to rise up in narrow tubes.
- The xylem vessels are narrow to facilitate capillarity.

D. Transpiration pull

- This is the suction force that pulls a stream of water from the xylem vessels in the stem and roots.
- As water vaporizes from the spongy mesophyll cells into the sub-stomatal air spaces, their cells become more concentrated than adjacent cells.
- As a result, water flows into these cells from the surrounding cells through osmosis which in turn take in water from the xylem vessels within the leaf veins. This causes transpiration pull.
- Transpiration pull is important because it replaces water lost from the plant through transpiration.

FACTORS AFFECTING THE RATE OF TRANSPIRATION

A. **STRUCTURAL FACTORS.**

1. **Cuticle .**

- Thick cuticle (e.g. in cactus and aloe plant) **increases the distance of diffusion of water vapour** hence reduces the rate of transpiration.
- Thin cuticle increases the rate of transpiration to get rid of excess water.

2. **Glossy leaf surface.**

- Glossy/ waxy and shinny leaf surfaces reflect light landing on the leaf surface. This reduces internal heating of the leaf and stomatal opening reducing the rate of transpiration.

3. **Leaf size and shape**

- Broad leaves **increase the surface area** for water loss hence higher rate of transpiration.
- Small and needle like leaves reduce the surface exposed hence low rate of transpiration.

4. **Hairy leaves**

- Hair on leaves trap a layer of moist air on the surface of leaves reducing the concentration gradient hence reduces transpiration.

5. <u>Stomata</u>

- Few stomata reduce the surface area reducing the rate of transpiration
- More stomata on the upper surface than the lower part increases the rate of transpiration.
- Some plants have reversed stomatal rhythm (opening during the night and closing during the day) reduces the rate of transpiration.
- Small stomatal apertures reduce the rate of transpiration.
- **Sunken stomata (located on the inner part of the epidermis)** lowers the rate of transpiration. This is because **<u>water vapour accumulates in the pits/depressions of the stomata reducing the concentration gradient</u>** hence low rate of transpiration.
- Some plants close their stomata on a hot dry sunny day to lower the rate of transpiration. This is called **<u>midday closure</u>** to protect the plants from wilting.

B. **ENVIRONMENTAL FACTORS**

1. **Temperature.** High temperature increases internal temperature of the leaf which in turn **increases the latent heat of vaporization** leading to high rate of transpiration.
2. **Wind-** On a windy day the rate of transpiration is high because wind blows away/ carries the water vapour on the leaf surface.

- This increases the concentration gradient between the inside of the leaf and the outside of the leaf.

3. **Humidity-** It refers to the amount of water vapour in the atmosphere.

- High humidity (a lot of vapour in the atmosphere) **reduces the transpiration/concentration gradient** between the inside and outside of the leaf hence lowering the rate of transpiration and vice versa.

4. **Light intensity-** it affects the rate of transpiration through stomatal opening.

- High light intensity causes the stomata to open fully. This increases the rate of transpiration.

5. Atmospheric pressure.

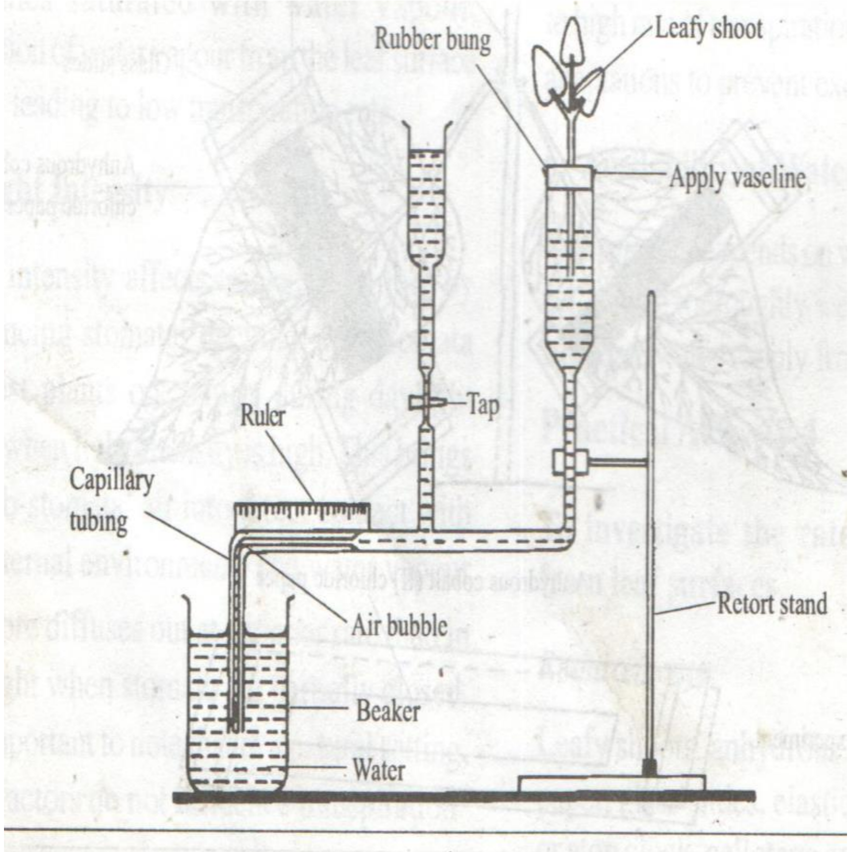
- Higher atmospheric pressure **can hold a lot of water vapour in the atmosphere reducing the concentration gradient/concentration deficit** hence reduces the rate of transpiration and vice versa.

6. Availability of water.

- When less water is available, plants close their stomata thus reducing the rate of transpiration.

EXPERIMENT TO INVESTIGATE THE RATE OF TRANSPIRATION

- It is done by use of a **potometer.**
- Arrange the apparatus as shown below.



Set-up of a potometer

Precautions taken.

i. The leafy shoot should be cut under water to prevent the entry of air bubble into the xylem tissue.

ii. There should be no air bubble in the apparatus at the beginning.

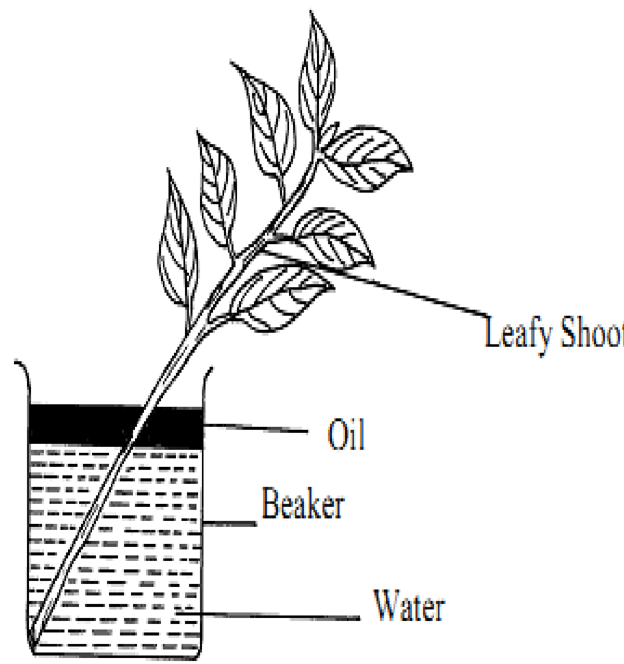
- Air bubble is removed by opening the tap for water to flow.
- To introduce one air bubble the end of the tube is exposed for a few seconds.
- To control the movement of the bubble the tap is opened slowly so that water flow from the reservoir.
- The air bubble should be at the end of the capillary tube
- The movement of the bubble is recorded against time hence the rate calculated as:

Rate of transpiration= Distance moved by water bubble

Time taken in minutes

Study question.

An experiment shown below was set-up to investigate a certain physiological process in plants.



a) What process was being investigated?

Transpiration.

b) Give the role of the oil layer in this experiment.

Prevent evaporation of water from the surface.

c) What observation did the students make after leaving the set-up in bright sunlight for two hours.

The level of water drops.

d) Explain the observation in **(c)** above .

Bright sunlight increases internal temperature/latent heat of vaporization hence faster rate of transpiration.

e) What effect will the following have on the observation made?

(i) Fanning the shoot.

Faster drop in water level.

(ii) Removing all the leaves from the shoot.

No change in water level.

(iii) Placing the set-up in the dark.

Slower/very slow drop in water level.

f) Suggest a suitable control for this experiment.

Another set up using a leafless twig.

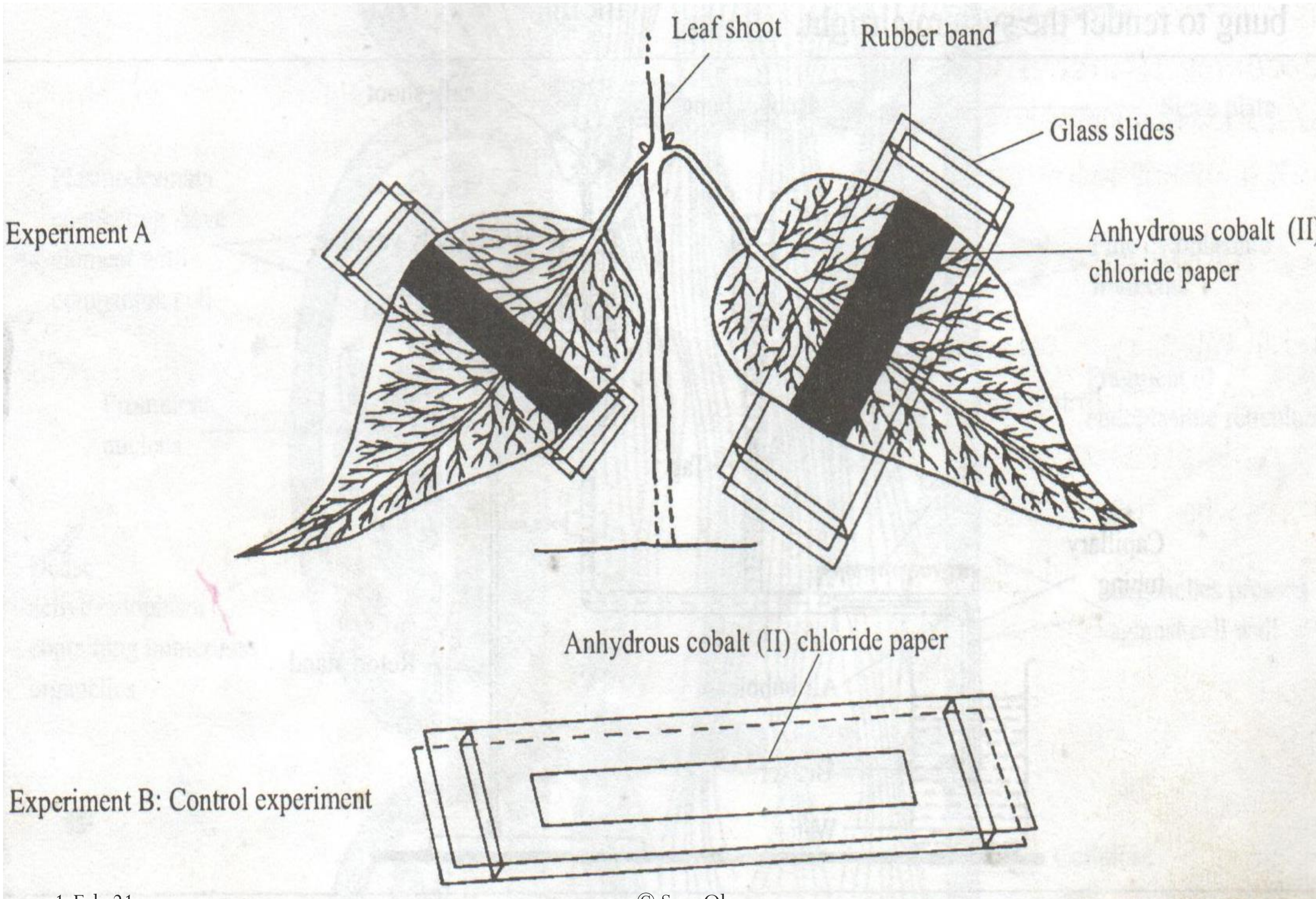
EXPERIMENT TO INVESTIGATE THE RATE OF TRANSPIRATION FROM LEAF SURFACES

Requirements.

i. Leafy shoots.
ii. Anhydrous cobalt (II) chloride paper.
iii. Glass slides.
iv. Elastic bands.
v. Stop watch/clock.
vi. Cellotape.
vii. Pair of forceps.

Procedure.

i. Select one healthy leaf.
ii. Pick two pieces of anhydrous cobalt (II) chloride paper and note their colour.
iii. Place each piece on the two surfaces of the leaf.
iv. Quickly cover them with dry glass slides holding them in position by use of bands.
v. Notice the time each of the two papers take to turn pink i.e. as soon as the pink spot appears and the time when the whole paper turns pink.
vi. Hold a covered anhydrous cobalt (II) chloride paper to **act as a control.**
vii. Record the time taken for the Anhydrous cobalt (II) chloride paper to turn pink in air, above the leaf surface and under the leaf surface.


Leaf shoot
Rubber band
Glass slides
Experiment A
Anhydrous cobalt (II) chloride paper
Anhydrous cobalt (II) chloride paper
Experiment B: Control experiment

Observation and conclusion

- The paper on the upper side of the plant takes longer to turn pink. This is because there are fewer stomata on the upper side hence low rate of transpiration.
- The paper on the lower side take a shorter time to turn pink. This is because there are many stomata on the lower side hence faster rate of transpiration.
- The control experiment is used to provide a contrast to the experiment.
- The bare hands should not used to hold the paper because they would be moist hence affecting the Anhydrous cobalt (II) chloride paper.

TRANSLOCATION OF ORGANIC COMPOUNDS/MANUFACTURED FOOD

- Translocation refers to the transport of manufactured food materials/ organic compounds from one part of the plant to the other.
- It takes place in the **phloem.**
- The food materials transported include sugar/ glucose, amino acids and vitamins.
- The processes involved in translocation of manufactured food include;

i. Diffusion

ii. Cytoplasmic streaming.

- The material are translocated to various parts of the plant where they are required, for example:

a) The growing and developing regions of the plant e.g. young shoots, leaves, flowers, fruits and roots.

b) The storage organs or tissues e.g. tubers, corms, bulbs, rhizomes and seeds.

c) Secretory organs e.g. nectar gland in insect pollinated plants e.g. banana (*Musa* sp)

Structure of the phloem.

- The phloem is a living tissue which consists of:

A. Sieve tubes/ elements.

B. Companion cells.

A. Sieve tubes.

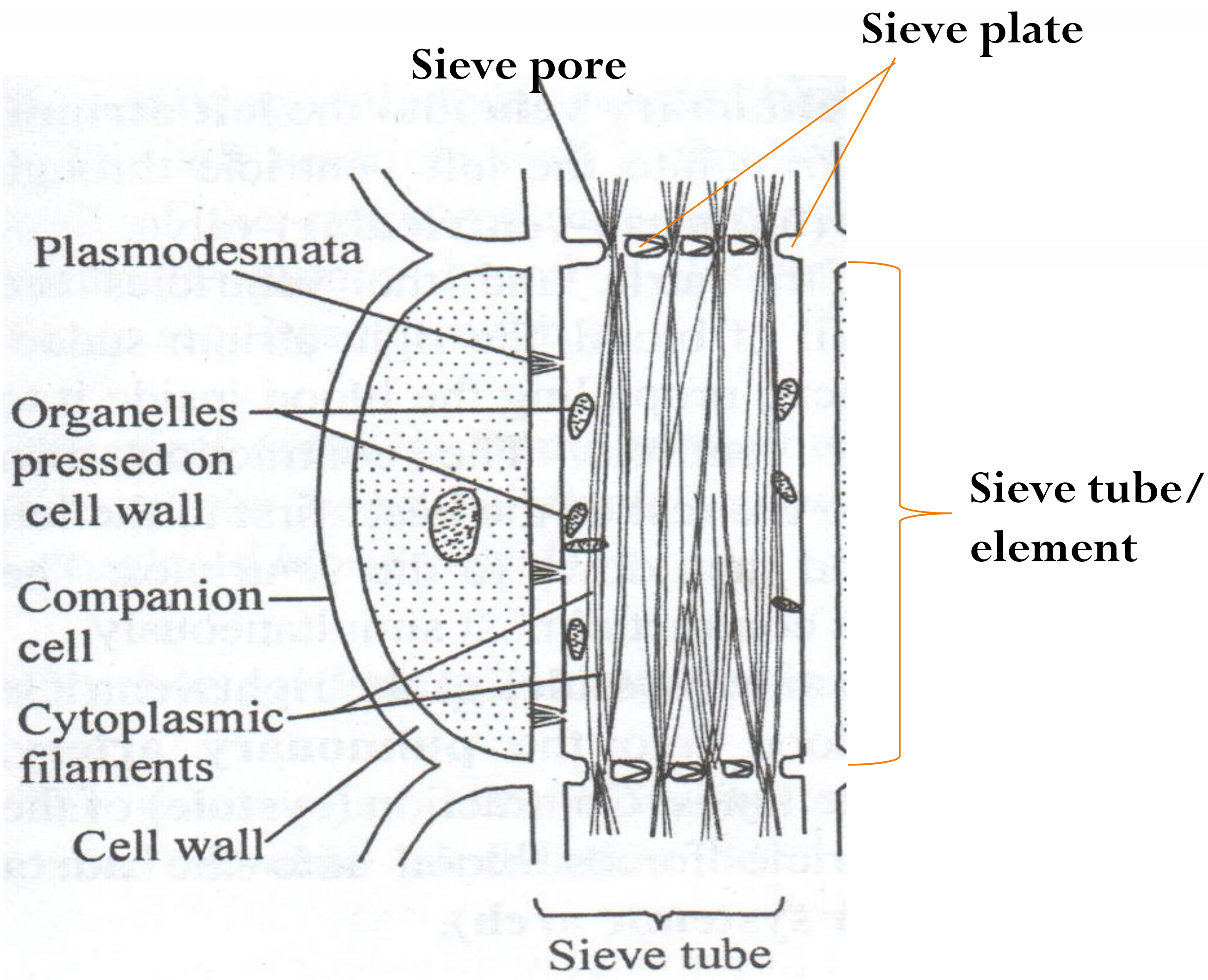
- A sieve tubes are arranged end to end separated from each other by **sieve plates.**
- Sieve plates have perforations/holes/pores called **sieve pores.** This allows continuous flow of substances.
- Sieve tubes have fine **cytoplasmic strands** that run from one tube element to another passing through the **sieve pores.**
- Cytoplasmic strands provide room/passage for translocation of manufactured food.

B. Companion cells.

- A companion cell is a cell connected to each sieve element.
- It has a dense cytoplasm, prominent nucleus and cell organelles e.g. mitochondria.
- They communicate with the sieve elements/tubes through pores called **plasmodesmata.**

Functions of companion cells.

- It regulates the activities of the sieve tubes/elements
- It contains numerous mitochondria to supply energy to the sieve tubes for translocation of food

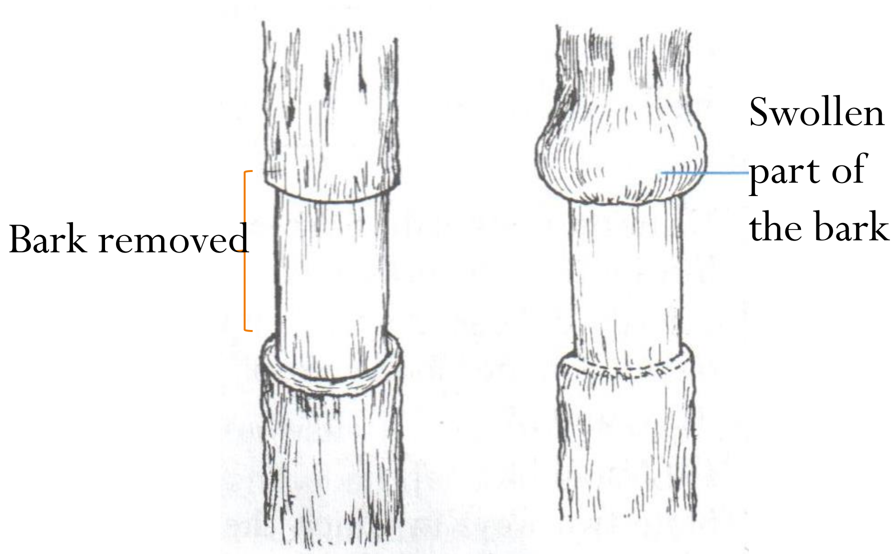

Sieve pore
Sieve plate
Plasmodesmata
Organelles
pressed on
cell wall
Companion
cell
Cytoplasmic
filaments
Cell wall
Sieve tube
Sieve tube/
element

ADAPTATION OF THE PHLOEM TO ITS FUNCTIONS.

1. It contains companion cells with numerous mitochondria to supply energy for active translocation of food.
2. Cytoplasmic strands are contractile in nature and are able to push materials from one tube element to the next.
3. Sieve tubes are hollow/ lack other cell organelles to allow movement of materials/food from one element to the next.
4. Have sieve pores that allow the movement of materials from one element to the next.
5. It has plasmodesmata (between sieve elements/ tubes and companion cells) to allow exchange of materials between the companion cells and the sieve tube.
6. Has sieve plates that support the phloem tissue.

EXPERIMENT TO DEMONSTRATE TRANSLOCATION OF FOOD (RINGING EXPERIMENT)

- The bark (phloem) of the tree is removed and the xylem is left intact to the plant for four weeks.



Before the experiment After the experiment

Observation.

- After 4 weeks it is observed that the upper part is swollen.
- There is no swelling on the lower part.

Explanation.

- The translocated materials from the leaves accumulated on the upper part of the plant stem leading to swelling.

DIFFERENCES BETWEEN XYLEM AND PHLOEM

Xylem	Phloem
1. Made up of dead cells.	1. Made up of living cells
2. Walls are lignified for mechanical damage.	2. Lack lignin and support is by fibres
3. Transport water and mineral salts.	3. Transport organic materials
4. Lack companion cells.	4. Have companion cells

TRANSPORT IN ANIMALS

- In unicellular organisms transport of materials occurs through simple diffusion because they have a large surface area to hence called **intracellular transport.**
- In multicellular organisms diffusion is not sufficient because:

i. Body organs are bulky.

ii. The organisms are complex with organs separated from each other.

- Therefore they have a circulatory system with vessels, transporting medium/fluid (blood) and a pumping organ.
- Transport in multicellular organisms is called **extra cellular transport.**

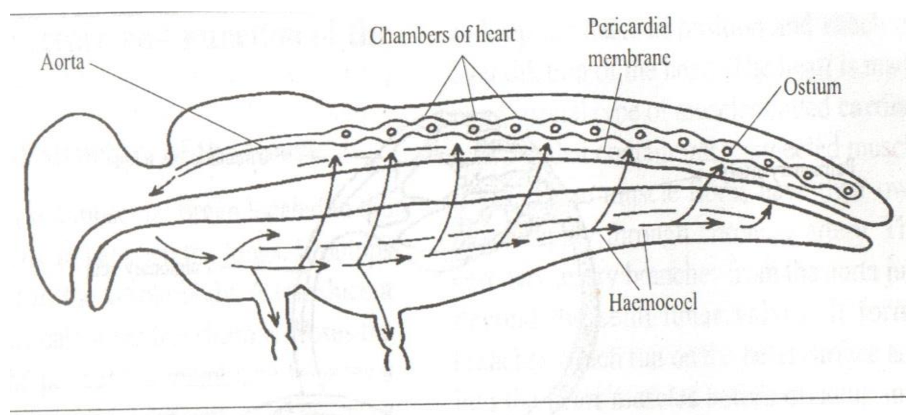
Types of circulatory system.

A. Open circulatory system.

B. Closed circulatory system.

A. OPEN CIRCULATORY SYSTEM

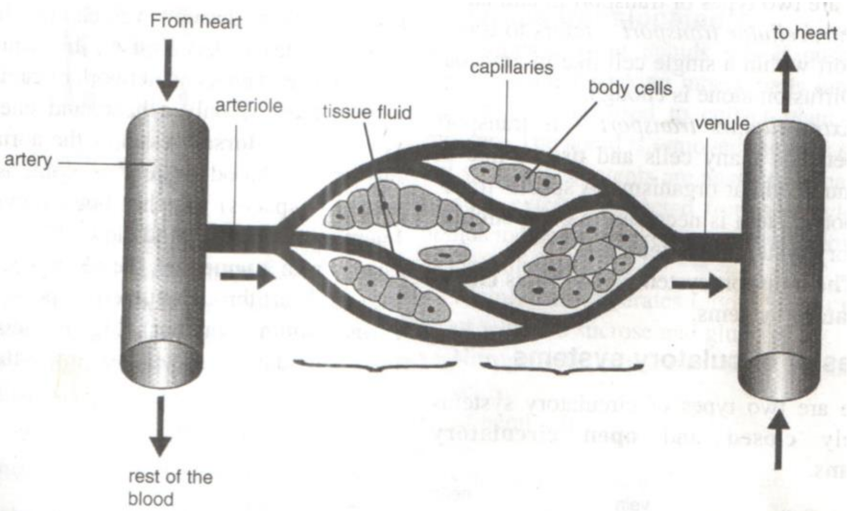
- In this system blood flows in general body cavities called **coelom/haemocoel.**
- The fluid involved in the transport is called **haemolymph** and in direct contact with the body tissues.
- Haemolymph consists of white blood cells and
- It is found in Arthropods e.g. insects which have one heart and main blood vessel called **dorsal vessel/aorta.**
- The aorta empties the haemolymph into sinuses in the head.
- Blood flows from the heart to the haemocoel and back to the heart through the openings called **ostia (sing. Ostium).**
- The heart has valves that prevent back flow of haemolymph.



Open circulatory system in a cockroach

B. CLOSED CIRCULATORY SYSTEM.

- It consists of blood vessels and muscular heart.
- The heart pumps blood into blood vessels which carry blood to the body tissues and back to the heart.
- It is found in vertebrates.



Closed circulatory system

DIFFERENCES BETWEEN OPEN AND CLOSED CIRCULATORY SYSTEM

Open circulatory system.

1. Transport fluid is in contact with the tissues.
2. Pressure is low.
3. Transport fluid flows slowly.
4. Facilitates slow rate of activity in the organism.
5. Tissues receive nutrients and other requirements slowly and metabolic wastes got rid off slowly.
6. Transport fluid has no pigment since it is not involved in the transport of oxygen and carbon (IV) oxide.

Closed circulatory system.

1. Transport fluid is not in direct contact with tissues/ are found in blood vessels.
2. Pressure is high.
3. Transport fluid flows faster.
4. Facilitates higher rate of activity in organisms.
5. Tissues receive nutrients and other requirements faster and metabolic wastes are got rid off at a higher speed.
6. Transport fluid has a red pigment called haemoglobin for transportation of oxygen and carbon (IV) oxide.

TYPES OF CLOSED CIRCULATORY SYSTEM/CIRCULATION

i. Single circulatory system/circulation.

ii. Double circulatory system/circulation.

i. Single circulatory system/circulation.

- In this type blood flows to the heart once for every complete circulation e.g. in fish.
- This is called **single circulation.**

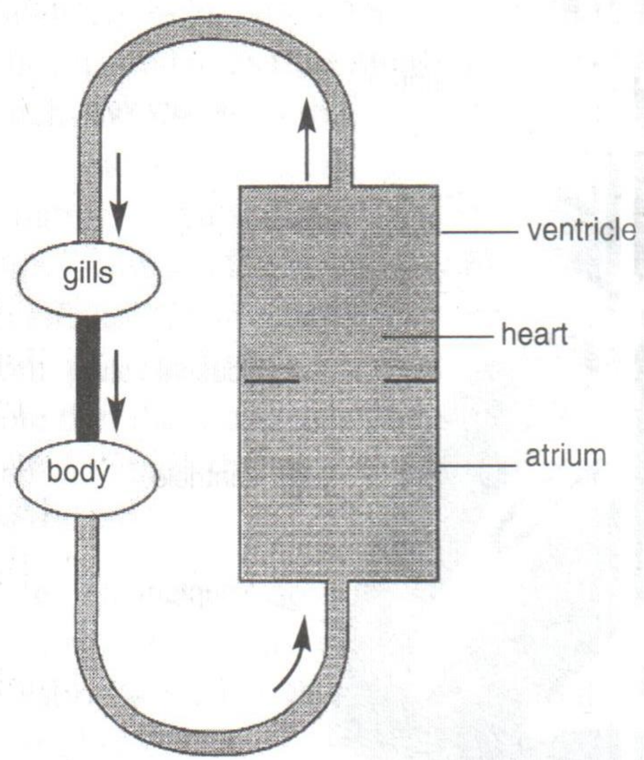


Fig 6.10: Single circulation in a fish

ii. Double circulatory system/circulation.

- In this type blood flows through the heart twice in every complete circulation e.g. in mammals and birds.
- This is called **double circulation.**

Advantages of double circulation over single circulatory system

1. Blood flows at a higher pressure since it is pumped twice.
2. Oxygenated blood does not mix with deoxygenated blood

- These two advantages enable the birds and mammals to be physically more active than animals with single circulatory system

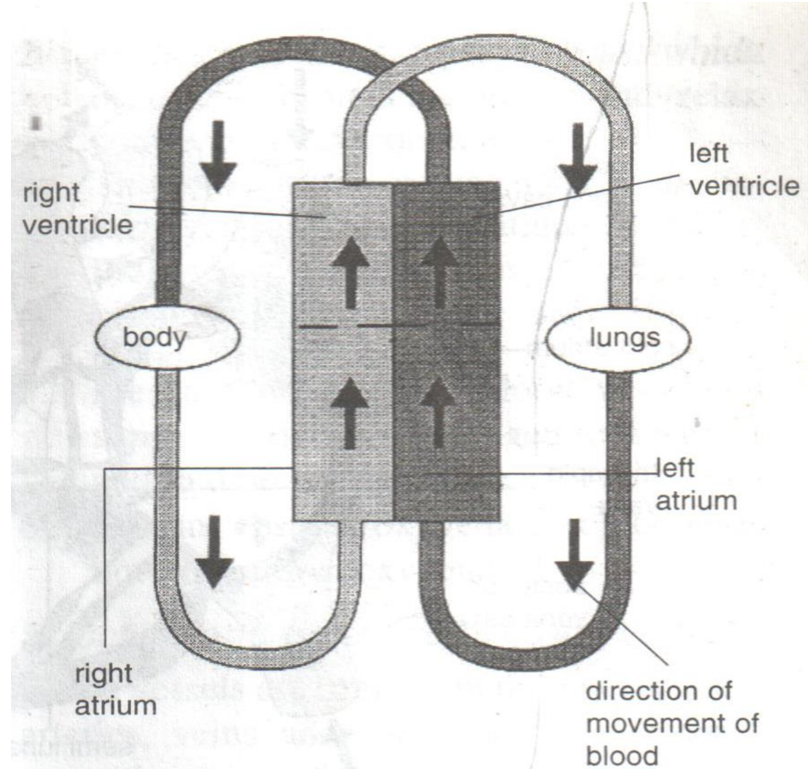


Fig 6.11: Double circulation in a mammal

TYPES OF DOUBLE CIRCULATION/CIRCULATORY SYSTEM

1. Pulmonary circulatory system/circulation.
2. Systemic circulatory system/circulation.

1. **Pulmonary circulatory system/circulation.**

- In this type blood is pumped to the **lungs through pulmonary artery** and back to the **heart through pulmonary vein .**
- It is called pulmonary circulation.
- It helps in oxygenation of blood.

2. **Systemic circulatory system/ circulation.**

- In this type blood flows from the **heart** to the rest of the body parts through the Aorta and back to the **heart through Venacava.**
- It is called systemic circulation.
- It helps to supply oxygen and nutrients to the body cells and also remove waste metabolic materials and carbon (IV) oxide.

MAMMALIAN CIRCULATORY SYSTEM

- It consists of:

i. Heart (muscular pump).

ii. Blood.

iii. Blood vessels.

- The main blood vessels include Arteries, Veins and Capillaries.

- The arteries divide into smaller vessels called **Arterioles** which divide to form much smaller vessels called **capillaries** which spread out in a network fashion in the tissues.
- The capillaries eventually re-unite to form **venules** which in turn form **veins.** The veins take blood back to the heart.

MAMMALIAN HEART

- It is located between the lungs in the chest cavity.
- It is covered by a membrane called **pericardium.**

Functions of pericardium membrane.

i. Secretes a fluid (pericardial fluid) which lubricates the heart when it is working/ absorbs shock.

ii. It keeps the heart in position preventing over dilation/over relaxation during pumping.

- On the outside of the pericardium there is a fat layer that acts as a shock absorber.

EXTERNAL STRUCTURE OF THE HEART

- The heart consists of the muscle called **cardiac muscle** which brings about the pumping action of the heart.
- The muscle contracts continuously hence the heart pumps blood continuously throughout the life time/without fatigue and is **myogenic (contract without nervous stimulation).**
- It has a **coronary artery (which branches from the Aorta)** which supplies blood containing nutrients and oxygen to the heart.
- It has a **coronary vein** to remove blood containing nitrogenous waste products and carbon (IV) oxide from the heart cells.

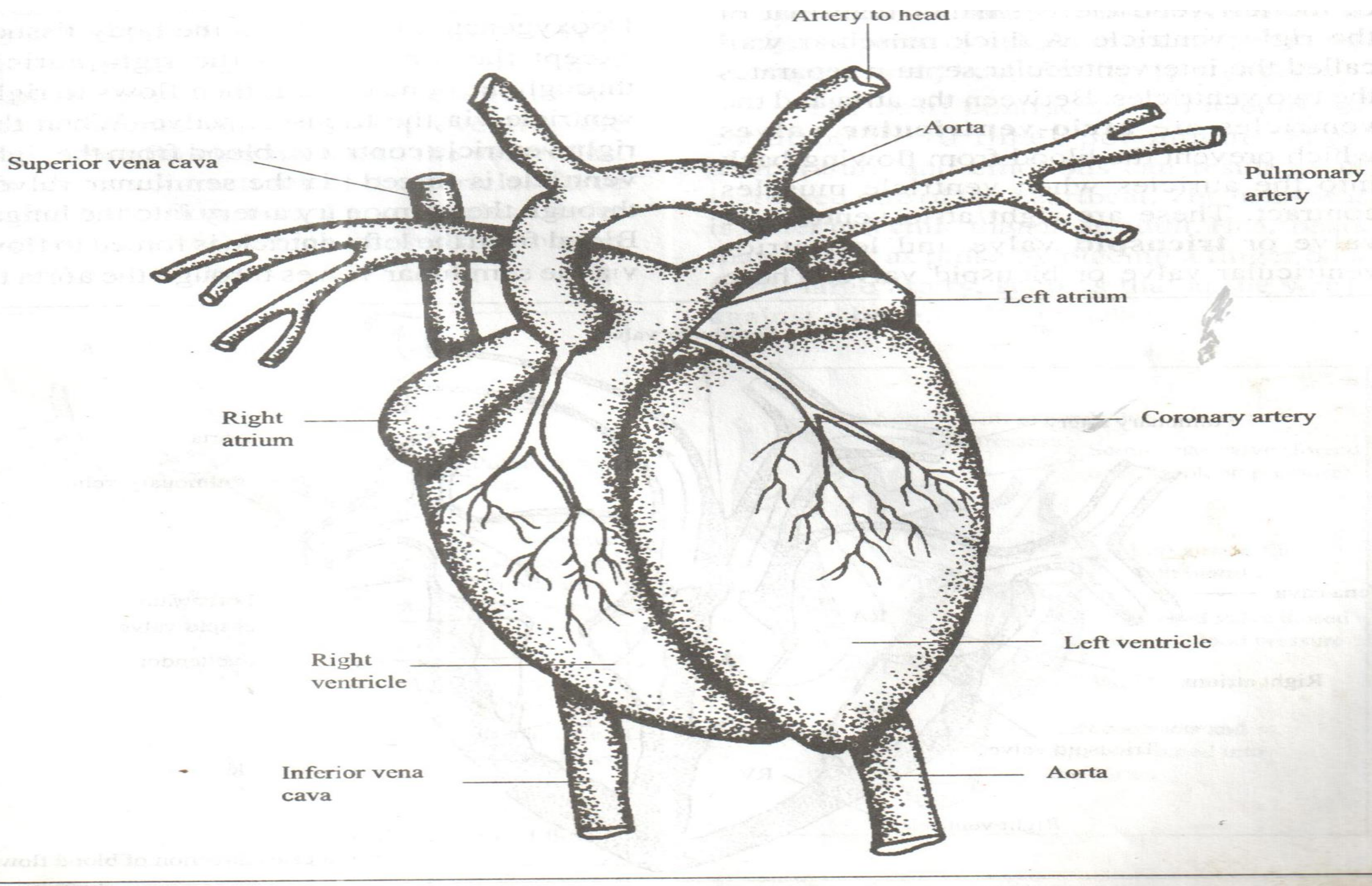


Fig. 1.15: External structure of the mammalian heart

INTERNAL STRUCTURE OF THE HEART

- It has left and right sides separated by a thick muscular wall called **septum** which prevents mixing of deoxygenated and oxygenated blood.
- It consists of 4 chambers:

i. Right auricle/atrium.

ii. Left auricle/atrium.

iii. Right ventricle.

iv. Left ventricle.

- The auricles/atria are thin walled and receive blood into the heart.
- The right atrium/auricle receives deoxygenated blood from the rest of the body parts except the lungs through the **venacava.**
- The left atrium/auricle receives oxygenated blood from the **lungs** through the **pulmonary vein.**

- Ventricles are thick walled and pump blood out of the heart.
- The left ventricle is **<u>thicker walled than the right ventricle to generate high pressure pump blood to distant parts of the body.</u>**
- The right ventricle is thinner walled to pump blood to a short distance to the lungs for oxygenation.
- Between the ventricles and atria/auricles there are **<u>atrio-ventricular/ cuspid valves</u>** which prevent the back flow of blood into the atria when ventricles contract.
- On the left side (between the left atrium and left ventricle) the valve is called **bicuspid valve (it has 2 flaps).**
- On the right side (between the right auricle and right ventricle) it is called **tricuspid valve (it has 3 flaps).**
- The valves are joined to the wall of the heart by structures called **tendons** which **<u>prevents the atrio-ventricular valves from turning inside out when under pressure when the ventricles contract.</u>**
- At the base of aorta and pulmonary artery there are valves called **semi-lunar valves** which prevent the back flow of blood into the **ventricles** when the ventricles relax.

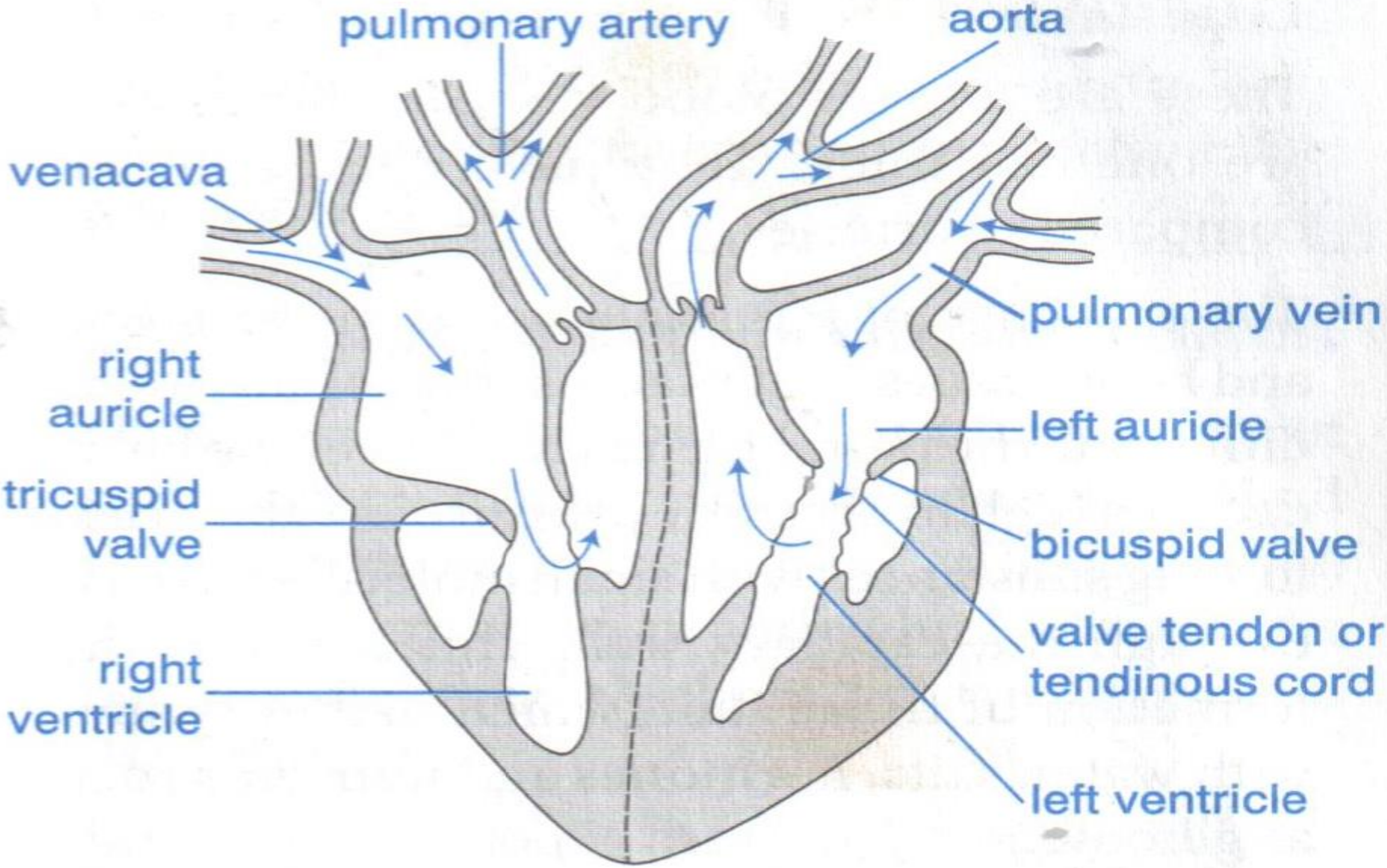


Fig. 5.8 Internal structure of the mammalian heart

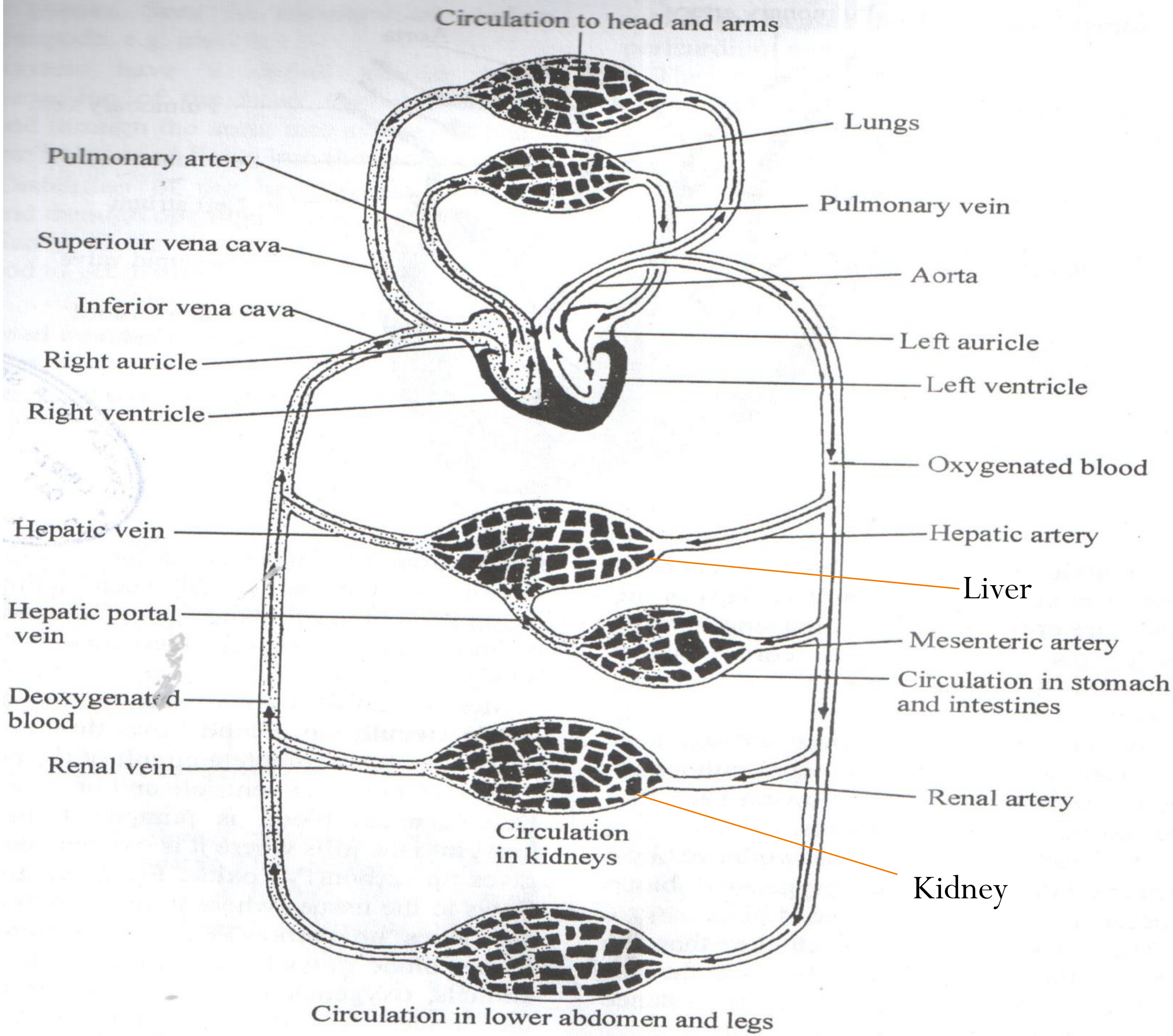
BLOOD CIRCULATION.

- Deoxygenated blood (full of carbon (IV) oxide and dull in colour) from the body tissues enters the right auricle/atrium through the **vena cava.**
- The right atrium/auricle contracts pumping blood to the right ventricle through **tricuspid valve** which prevents backflow of blood.
- When the right ventricle contracts, blood from the right ventricle is forced/ pumped into the lungs through the **pulmonary artery** through the **semi-lunar valve** for oxygenation (i.e. pick up oxygen and release CO2).
- Oxygenated blood from the lungs (which is bright red in colour) flows to the left auricle/atrium through the **pulmonary vein.**
- The left atrium/auricle pumps blood into the left ventricle through the **bicuspid valve** which prevents the back flow of blood into the auricle.
- The left ventricle contracts pumping blood through the semilunar valve and aorta to all parts of the body.

BLOOD VESSELS CARRYING BLOOD TO DIFFERENT BODY PARTS

1. **Hepatic artery** carries oxygenated blood the **liver.**
2. **Hepatic vein** carries deoxygenated blood from the **liver** to the heart
3. **Hepatic portal vein** carries blood from the intestines and stomach to the liver.
4. **Mesenteric artery** carries oxygenated blood from the heart to the **intestines and stomach.**
5. **Renal artery** carries oxygenated blood into the **kidney.**
6. **Renal vein** carries deoxygenated blood from the **kidney.**

- **N/B** Blood has to flow into the liver from the stomach/intestines before getting into the heart then into body parts/general circulation **for excess glucose to be converted into glycogen and excess amino acids to be deaminated.**


Circulation to head and arms
Lungs
Pulmonary artery
Pulmonary vein
Superiour vena cava
Aorta
Inferior vena cava
Left auricle
Right auricle
Left ventricle
Right ventricle
Oxygenated blood
Hepatic vein
Hepatic artery
Liver
Hepatic portal vein
Mesenteric artery
Circulation in stomach and intestines
Deoxygenated blood
Renal vein
Renal artery
Circulation in kidneys
Kidney
Circulation in lower abdomen and legs

PUMPING MECHANISM OF THE HEART.

- For every heart beat, the heart goes through relaxation (diastole) and contraction (systole) of cardiac muscles. These events are called **Cardiac cycle.**

A. **DIASTOLE**

- The ventricles and auricles/ atria relax.
- This increases their volume, decreasing pressure.
- The cuspid valves open while the semi-lunar valves close.
- Oxygenated blood flows from the right auricle/atrium to the right ventricle.
- Deoxygenated blood flows from the left auricle/ atrium to the left ventricle.

B. **SYSTOLE (CONTRACTION).**

- There are two types of systole;

1. **Atrial systole-** when atria/ auricles contract, while the ventricles remain relaxed. The high pressure causes the cuspid valves to open and blood flows to the ventricles.
2. **Ventricular systole-** The ventricles contract, their volume decreases while pressure increases.

- The semi-lunar valves open while the cuspid valves close preventing blood from flowing back into the while the auricles.
- Blood flows out of the heart to the lungs through the pulmonary artery or to all parts of the body through the aorta.

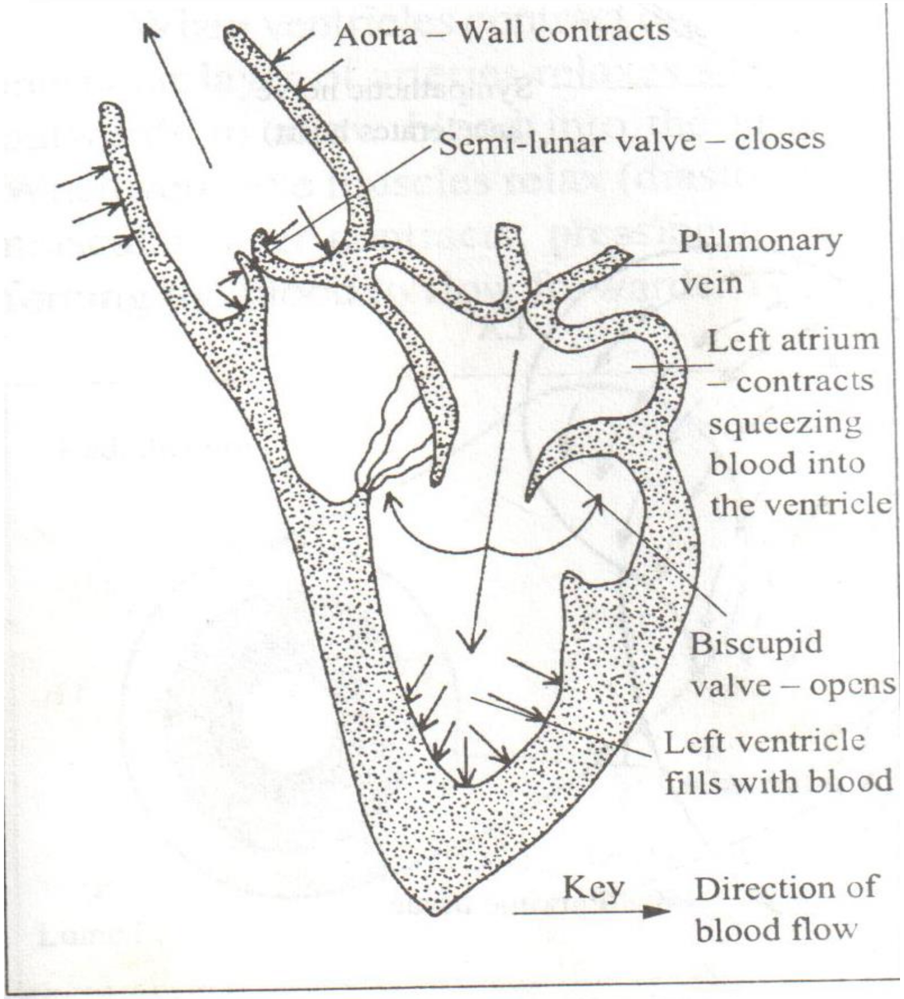


Fig. 1.17(a): Diastole — ventricle relaxes

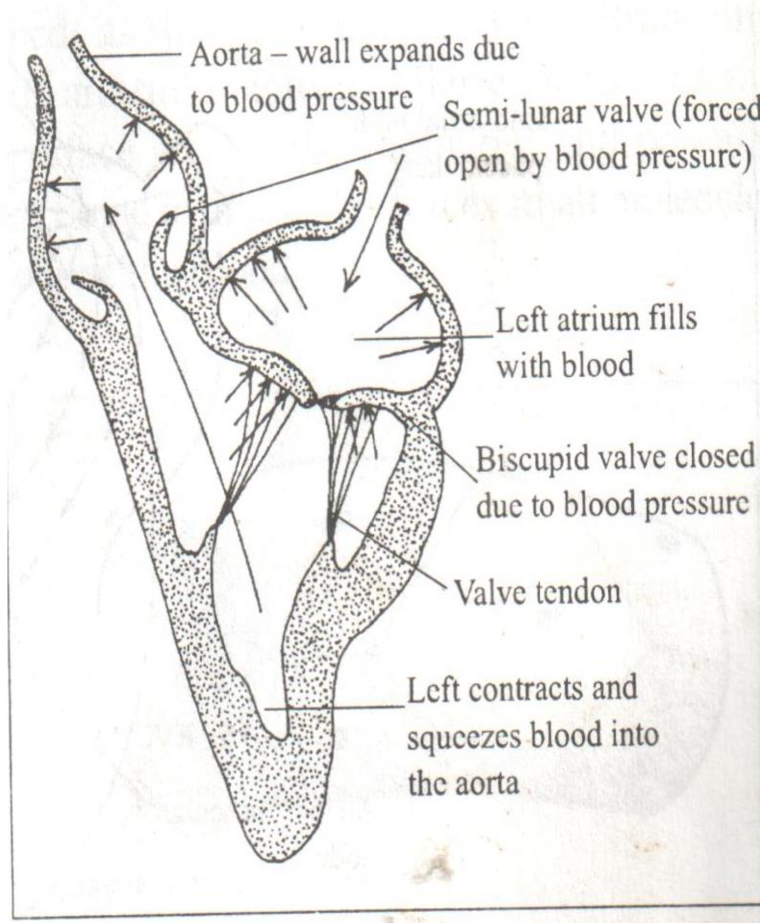


Fig. 1.17(b): Systole — ventricle contracts

WORKING OF THE HEART

- When the ventricular muscles contract, the cuspid valves close preventing back flow of blood into auricles.
- Increased pressure in the ventricles forces the semi lunar valves to open and blood flows out of the heart to the lungs through **pulmonary artery** and to all parts of the body through **Aorta.**
- When the ventricular muscle relax, the pressure inside decreases. The cuspid valves open to allow blood flow from the atria into ventricles.
- The semi-lunar valves close preventing back flow of blood into the ventricles slight contraction of the atria forces blood into ventricles.

HEART BEAT.

- This is the contraction and relaxation of heart/cardiac muscles. The cardiac muscle contracts and relaxes without fatigue.
- The cardiac muscle in **myogenic** i.e. contraction and relaxation arises from the heart muscles without nervous stimulation. The heart beats about 72 times per minute and is felt at the hand wrist.
- The heart beat is initiated by a group of cells called **sino atrial node (SAN)/ pacemaker** located at the wall of the right atrium located near the vena cava.
- The heart has **atrioventricular node (AVN)** located between the atria and ventricles which relays contraction waves from **sino atrial node (SAN)** to the purkinje tissue.
- The **purkinje tissue/fibres** relay waves from the **atrioventricular node (AVN)** to the ventricular myocardium causing the ventricles to contract.
- Heart beat is controlled by the part of the brain called **hypothalamus.**
- The rate of heart beat is controlled by the following nerves;

1. **Vagus nerve-** which slows down the rate of heart beat.
2. **Sympathetic nerve-** which speeds up the rate of heart beat.

Significance/ importance of heart beat in blood circulation.

- It generates high pressure that drives blood out of the heart to all parts of the body.

Factors affecting the heart rate.

1. **Age-**The rate of heart beat is higher in children than in adults. This is because they **have a large surface area to volume ratio** hence oxygen and nutrients have to be circulated faster.
2. **Physical activity of the body-** The person performing an exercise has faster heart beat.
3. **Emotions-** Emotions lead to increased heart beat because of increase in level of **adrenalin**.

Study questions.

a) If the nerve supply to the heart of a mammal is cut/ severed, the rhythmic movements of the heart will still on the heart continues to beat.

- ***The rhythmic contraction of the heart arises from within the heart muscle and it is said to be myogenic.***

b) Name the nerves that control the heart beat.

- ***Vagus nerve.***
- ***Sympathetic nerve.***

c) What is the importance of heart beat in blood circulation?

- ***It generates high pressure that drives blood out of the heart to all parts of the body.***

ADAPTATIONS OF THE MAMMALIAN HEART TO ITS FUNCTION.

1. It has **valves** which prevent the back flow of blood.
2. Cuspid valves have **tendons/tendinous cords/strands of connective tissues /chordaetendinae/ cordaetendinae** that prevent the valves from turning inside out (evert) during systole/when ventricles contract.
3. The ventricles have **thicker walls** to generate high pressure to pump blood.
4. The wall of **left ventricle thicker than the right ventricle** to pump blood over longer distance.
5. It has **cardiac muscles** which contract and relax continuously without fatigue
6. The cardiac muscles are **myogenic** i.e. contract and relax without nervous stimulation.
7. Cardiac muscles are interconnected/a cyncitium/ form a network of fibres to rapidly and uniformly spread the contractions.
8. The cardiac muscles have numerous mitochondria to generate energy for the muscular contraction.
9. It has **sino atrial node (SAN)** that acts as pace maker.

10. It has **atrioventricular node (AVN)** which relay contraction waves from **sino atrial node (SAN)** to the purkinje tissue.
11. Has **purkinje tissue/fibres** to relay waves from the **atrioventricular node (AVN)** to the ventricular myocardium.
12. It has **coronary artery** to nourish the heart/ supply nutrients and oxygen to the heart muscles.
13. It has **coronary vein** to remove Carbon (IV) oxide and metabolic wastes.
14. It is divided into **4 chambers** for the atria to receive blood and the ventricles to pump blood out of the blood.
15. It has a **septum** to prevent the mixing of oxygenated and deoxygenated blood/for double circulation.
16. It is enclosed by **pericardium** to prevent over dilation/ overstretching of the heart/keep the heart in position.
17. The pericardium secretes **pericardial fluid** to reduce friction /lubricate the heart/absorb the shock.
18. Has vena cava and pulmonary vein to supply blood to the heart.
19. Has aorta and pulmonary artery to transport blood away from the heart.

BLOOD VESSELS

- They include:

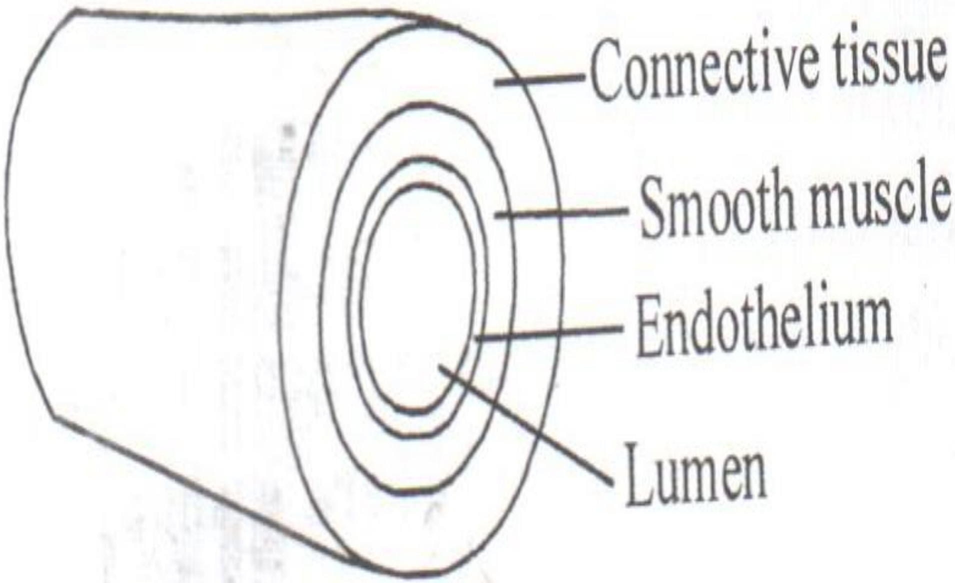
A. Arteries.
B. Veins.
C. Capillaries.

A. **ARTERIES.**

- They are blood vessels that originate from the heart and carry blood away from the heart. They are deep seated in the muscles.
- They carry oxygenated blood from the heart to all parts of the body except **pulmonary artery** which carries deoxygenated blood to the lungs.
- They have thick elastic muscular wall to resist high blood pressure due to pumping action of the heart.
- The elastic muscle fibres contract and relax adjusting the diameter of the lumen during pumping **hence blood flows in pulses.**

- They have thin lumen to ensure that blood flows under high pressure.
- They do not have valves except at the bases of pulmonary artery and aorta.
- Blood is under high pressure and flows fast due to the pumping action of the heart.

- The innermost layer of blood vessel is called **endothelium** which provides a smooth lining providing least frictional resistance to blood flow.
- They branch to form arterioles, the arterioles further branch to form blood capillaries.



Artery

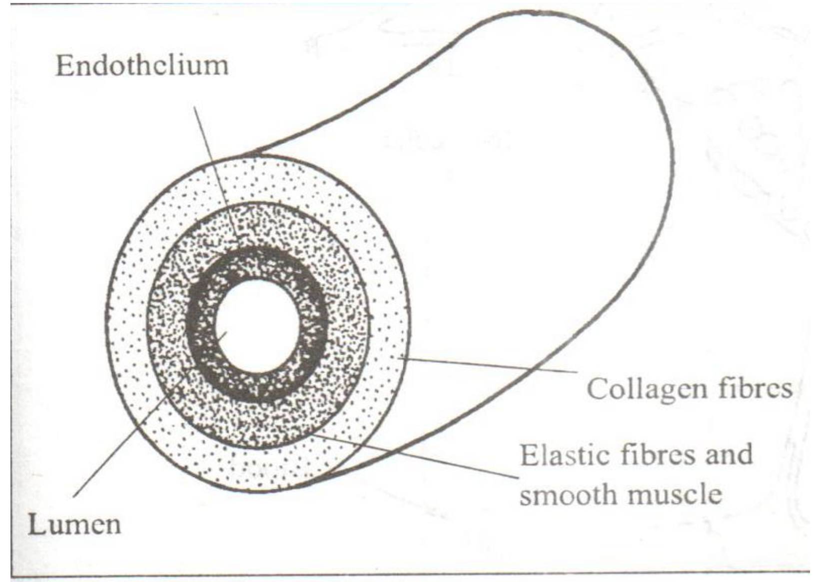
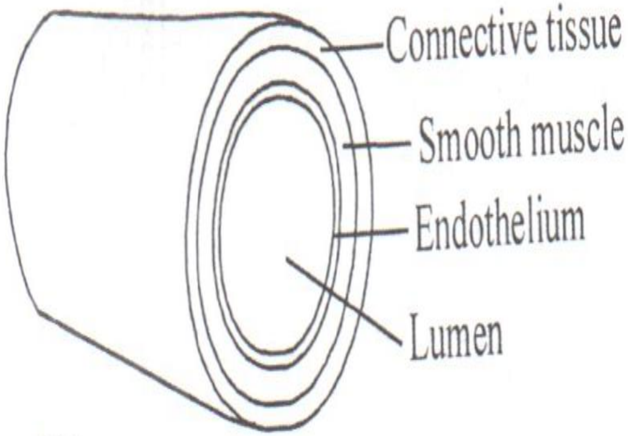


Fig.1.20 (a): Structure of the artery

B. VEINS.

- They carry deoxygenated blood into the heart except the **pulmonary vein** which carries oxygenated blood from the lungs into the heart.
- They lie close to the body surface and have thin and less elastic walls.
- Because the muscles are less elastic the walls cannot contract hence there is no pulse in the veins.
- They have a wider lumen, providing minimum resistance to blood flow.
- Blood is under low pressure because of resistance to the flow at the capillaries.
- The veins have valves throughout their length to prevent the back flow of blood and ensure that blood flows only towards the heart.

- Forward flow of blood is also maintained through contraction of skeletal muscles because large veins in legs and arms are located between the skeletal muscles. This explains the need for physical training.
- Blood contained in veins contain high levels of metabolic wastes and low level of nutrients except **renal vein** which has low level of nitrogenous wastes.
- This is because they have been removed in the kidney and **hepatic portal vein** which contains high amount of nutrients that have been absorbed in the gut.



Vein

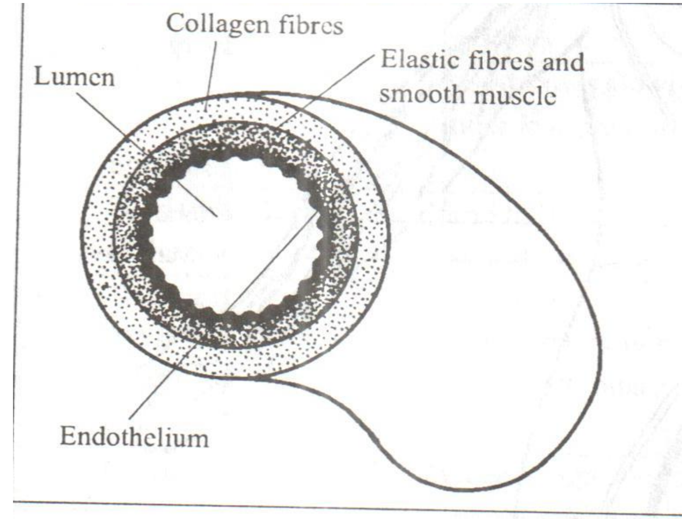
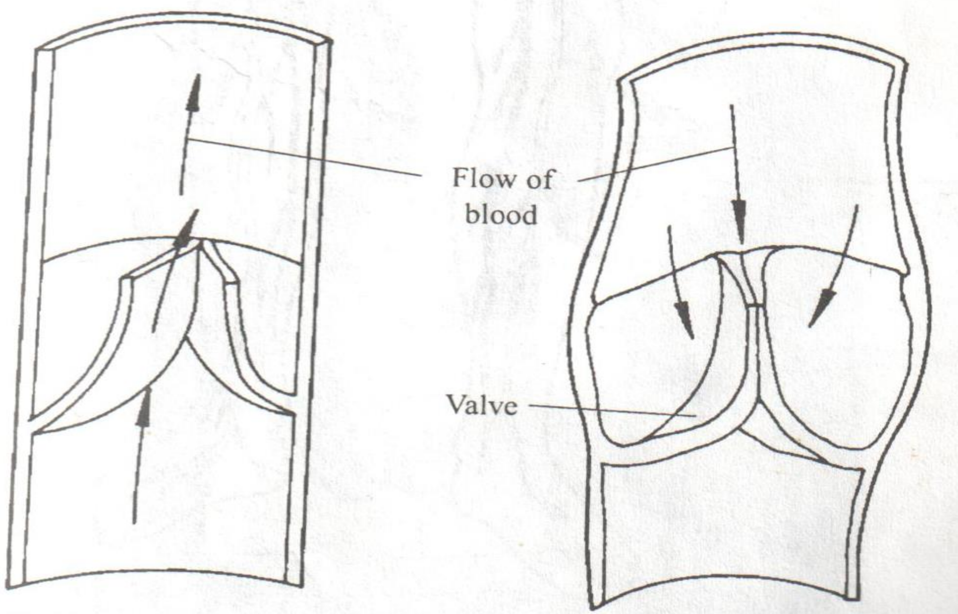


Fig. 1.20 (d): Veins



(i) Valve open

(ii) Valve closed

STRUCTURAL DIFFERENCES BETWEEN ARTERIES AND VEINS

Arteries	Veins
1. Have thick, muscular and more elastic muscular wall.	1. Have thin, less muscular and less elastic walls.
2. Have a narrower lumen.	2. Have wider lumen.
3. Have no valves except at the bases of pulmonary vein and aorta.	3. Have valves at intervals throughout their length.
4. Have numerous elastic fibres.	4. Have fewer elatic fibres.

FUNCTIONAL DIFFERENCES BETWEEN ARTERIES AND VEINS

Arteries	Veins
1. They carry blood away from the heart.	1. They carry blood towards the heart.
2. Blood flows rapidly under high pressure.	2. Blood flows slowly under low pressure.
3. They carry oxygenated blood except pulmonary artery.	3. They carry deoxygenated blood except the pulmonary vein.
4. Blood flows in pulses.	4. Blood flows smoothly with no pulses.
5. They have ability to change diameter of their lumen i.e. constrict and dilate.	5. They have no ability to change diameter of their lumen.

C. CAPILLARIES

- They branch from the arterioles and branch to form venules.
- They are numerous and very close to the body tissue and each cell is near the blood capillary.
- Exchange of substances take place between the blood and the cells/ tissues across the capillary wall.
- This is because the wall of capillary is made up of endothelium which is thin/ one cell thick which reduces the distance hence faster diffusion of substances.

Adaptations of capillaries.

1. They are numerous to increase the surface area for diffusion of substances.
2. They are thin/ one cell thick/ have single celled endothelium for faster diffusion of substances.
3. They are selectively permeable for passage of materials.
4. They have narrow lumen to maintain pressure.

Substances that diffuse out of blood in capillaries into the cells.

1. Glucose.
2. Oxygen.
3. Vitamins.
4. Amino acids.
5. Hormones.
v. Mineral salts.
vi. Fatty acids and glycerol.
vii. White blood cells.

Substances that diffuse out of cells into blood in capillaries.

1. Carbon (IV) oxide.
2. Nitrogenous/Metabolic wastes.

Study questions.

1. A doctor performing an operation cut two blood vessels by mistake. He notices that from one of the blood vessels, blood spurts out while from the other blood flows out steadily.

a) Identify the type of each blood vessel in which:

i) Blood spurts out- ***Artery***

ii) Blood flows smoothly- ***Vein***

b) Give a reason for your answer in a) above.

- ***Blood spurts out of the artery because of high pressure and pumping action of the heart.***
- ***Blood flows steadily in a vein because blood is under low pressure because of the resistance at the capillaries.***

2. Give two reasons for high pressure in the artery.

- ***Pumping action of the heart.***
- ***Narrower lumen which creates resistance.***

3. The amount of blood flowing through certain parts of the mammalian body at different levels was measured and the results tabulated as shown in the table below.

Parts of the body	Blood flow (cm3/ minute)		
	At rest	During light exercises	During strenuous exercises
Alimentary canal	1,100	780	250
Cardiac muscles	100	200	1,300
Skeletal muscles	900	4,600	15,000

Account for:

a) The high blood-flow through the cardiac and skeletal muscles during strenuous exercises. (4mks)

- ***During exercises, the heart beat / pulse rate is increased or there is more contraction and relaxation of cardiac muscles and also increased contraction of skeletal muscles.***
- ***This increases blood supply/ more blood flows to supply more oxygen and nutrients and also remove metabolic wastes.***

b) The results obtained from the alimentary canal at rest. (2mks)

- ***At rest more blood flows to the alimentary canal/ gut. This is because digestion is at optimal to transport digested / absorbed food materials and eliminate metabolic wastes.***

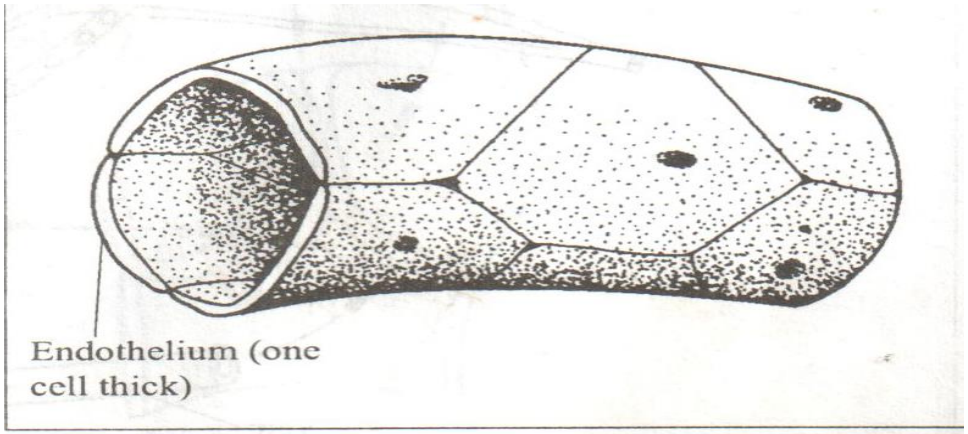
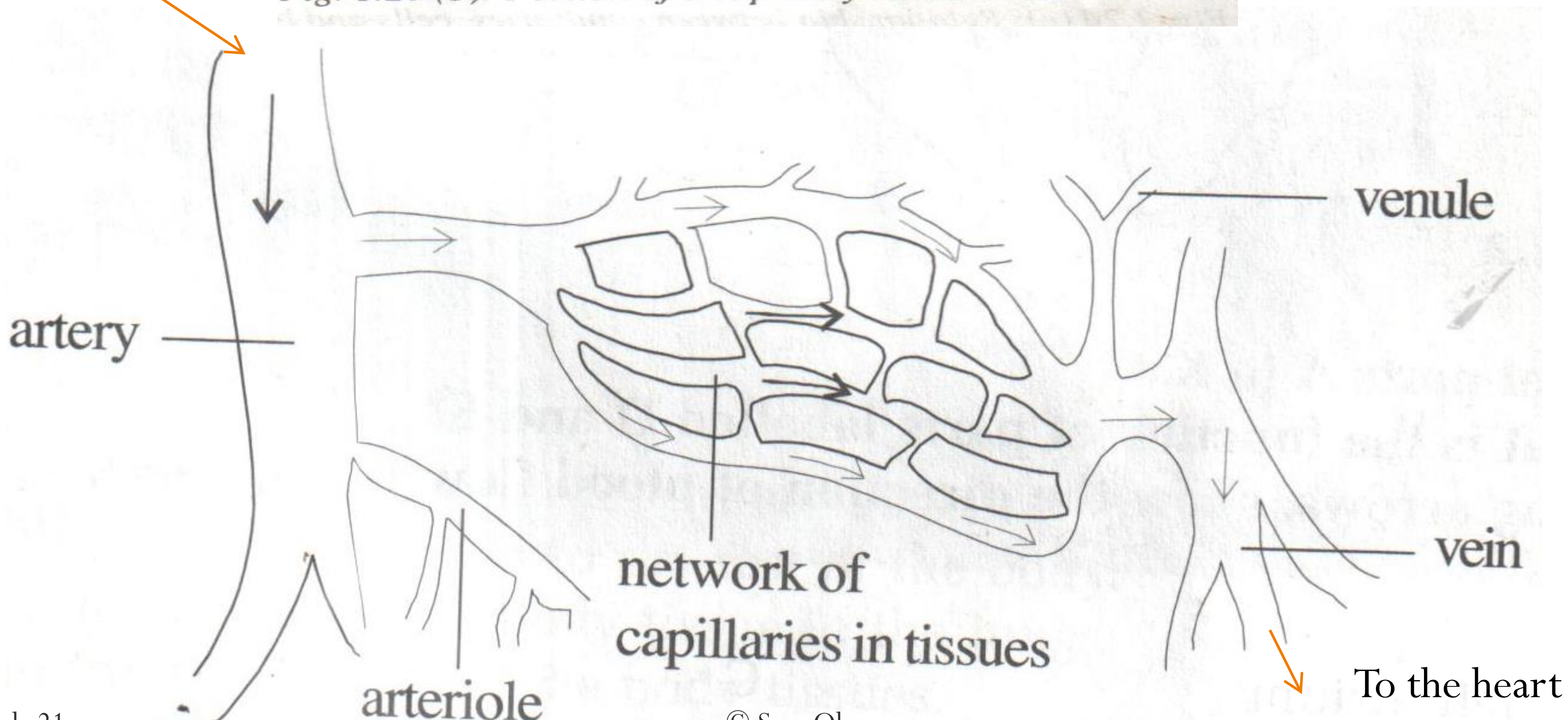


Fig. 1.20 (b): Portion of a capillary blood vessel

From the heart



DISEASES AND DEFECTS OF THE CIRCULATORY SYSTEM.

- They are called cardiovascular diseases because they affects the heart and blood vessels.

1. **ARTERIOSCLEROSIS./ANTHEROSCLEROSIS/ ANTHEROMA**

- Arteriosclerosis is the hardening of the walls of arteries due deposition of calcium and cholesterol in the walls of the arteries.
- This causes the arteries hard and lose elasticity leading to high pressure. Healthy arteries are flexible, strong and elastic.

Causes.

i. Stress.
ii. A lot of fats in diet.
iii. Overweight.
iv. Ageing.

Control.

i. Use of drugs that reduce cholesterol.
ii. Regular exercise

2. THROMBOSIS.

- This is the formation of a clot in blood vessels. The clot blocks blood vessel which hinders smooth supply off blood to body organs.
- The clot may be due to:

i. Accumulation of cholesterol on the artery wall.

ii. Internal bleeding leading to formation of blood clot.

iii. Arteries becoming increasingly fibrous losing their elasticity.

Causes.

i. High intake of fats/ cholesterol.

ii. Intake of alcohol.

iii. Smoking.

iv. Stress.

v. Overweight.

- If the clot occurs inside the coronary artery it is called **coronary thrombosis.**
- This blocks blood supply to the heart leading to less oxygen and nutrients to the heart muscles.
- In severe cases it causes damage to the heart muscles leading to heart attack **(Myocardial infarction)** leading to death.
- If it occurs in the blood vessel supplying blood to the brain it is called **cerebral thrombosis.**
- This reduces oxygen and nutrients supply to the brain leading to stroke leading to death.

Control.

i. Avoid a lot of cholesterol/ fats in diet.

ii. Exercise regularly.

iii. Avoid smoking and alcohol intake.

iv. Avoid stress.

v. Surgery to remove the clot.

3. VARICOSE VEINS

- These are swollen superficial veins below the knee and at the back of legs **due to failure of valves to function properly.**
- This leads to retention of tissue fluid.

Control.

i. Regular physical exercise.

ii. Wearing special compressing stockings to enhance circulation.

4. HYPERTENSION/ HIGH BLOOD PRESSURE.

- This is a condition where blood flows at a high pressure.
- The normal blood pressure varies between 90/60 to 140/90. The numerator (90-140) stands for **Systole pressure during contraction** while the denominator (60-90) stands for **diastolic pressure during relaxation.**
- Hypertension will lead to:

i. Overworking of the heart leading to heart failure.

ii. Bursting of arteries and capillaries. If the blood vessels in the brain burst, it leads to a stroke. The stroke may lead to paralysis of some parts of the body.

Causes

i. Intake of alcohol.

ii. Smoking.

iii. Taking large amounts of salt in diet.

iv. Stress.

v. Arteriosclerosis.

Control

i. Regular exercise.

ii. Intake of less salt.

iii. Avoid use of alcohol.

iv. Avoid smoking.

v. Avoid stress.

BLOOD

- This is a fluid which transports materials in mammals.

General functions of blood.

i. Transport of materials/substances.
ii. Regulation of body temperature/ distributes heat round the body.
iii. Protection of the body against infections.
iv. Regulation of pH of body fluids.
v. Clotting/prevents bleeding/blood loss

Protective functions of blood.

i. Contain lymphocytes that produce antibodies that defend the body from foreign pathogens/ provide immunity to the body.
ii. Has phagocytes that engulf the pathogens.
iii. Has platelets that help in blood clotting prevent entry of pathogens and preventing excessive blood loss.

Transport functions of blood.

1. Transports metabolic wastes e.g. Urea, uric acid, ammonium salts, creatinine and carbon (IV) oxide from cells to the excretory organs (e.g. kidney); for elimination from the body;
2. Transports hormones from the endocrine glands to target organs.
3. Transports antibodies within the body to provide immunity.
4. Transports nutrients from the ileum to liver then to other parts of the body.
5. Transports heat around the body hence it is important in temperature regulation.
6. Transports oxygen from the lungs to the cells/ tissues.

Study questions.

1. State general functions of blood.
2. List protective function of blood.
3. List transport functions of blood.

COMPONENTS/COMPOSITION OF BLOOD.

- Blood consists of:

A. Blood plasma
B. Blood cells.

A. BLOOD PLASMA

- This is a blood without blood cells. It consists mainly of water (90%) and dissolved substances, namely:

1. Nutrients i.e. Glucose, Amino acids, Fatty acids and glycerol, Vitamins and Mineral salts.
2. Oxygen.
3. Waste substances- Urea and carbon (IV) oxide.
4. Hormones.
5. Plasma proteins i.e. Antibodies, Albumin, Fibrinogen and Globulins.

- Blood plasma without plasma proteins is called **serum.**

FUNCTIONS OF BLOOD PLASMA.

1. Transports metabolic wastes e.g. Urea and carbon (IV) oxide from cells to the excretory organs for elimination from the body.
2. Transports hormones from the endocrine glands to target organs.
3. Transports antibodies within the body to provide immunity.
4. Transports nutrients from the ileum to liver then to other parts of the body/ tissues.
5. Distributes heat around the body hence it is important in temperature regulation.
6. Transports small amounts of dissolved oxygen and carbon (IV) oxide.
7. Regulation of pH of body fluids.

B. BLOOD CELLS

- They include:

1. Red blood cells (RBC)/erythrocytes.
2. White blood cells (WBC) /leucocytes.
3. Blood platelets/thrombocytes.

1. RED BLOOD CELLS (RBC)/ERYTHROCYTES.

- They have red colouring matter/ respiratory pigment called **haemoglobin** hence the name. Haemoglobin is a protein which contains iron.
- They are produced in the bone marrow of short bones e.g. sternum, ribs and vertebrae.
- In the embryo, they are made in the liver and spleen.
- They have a lifespan of 4 months after whi8ch they disintegrate in the **liver and spleen.** Iron released from breakdown of old red blood cells is used to manufacture new red blood cells.

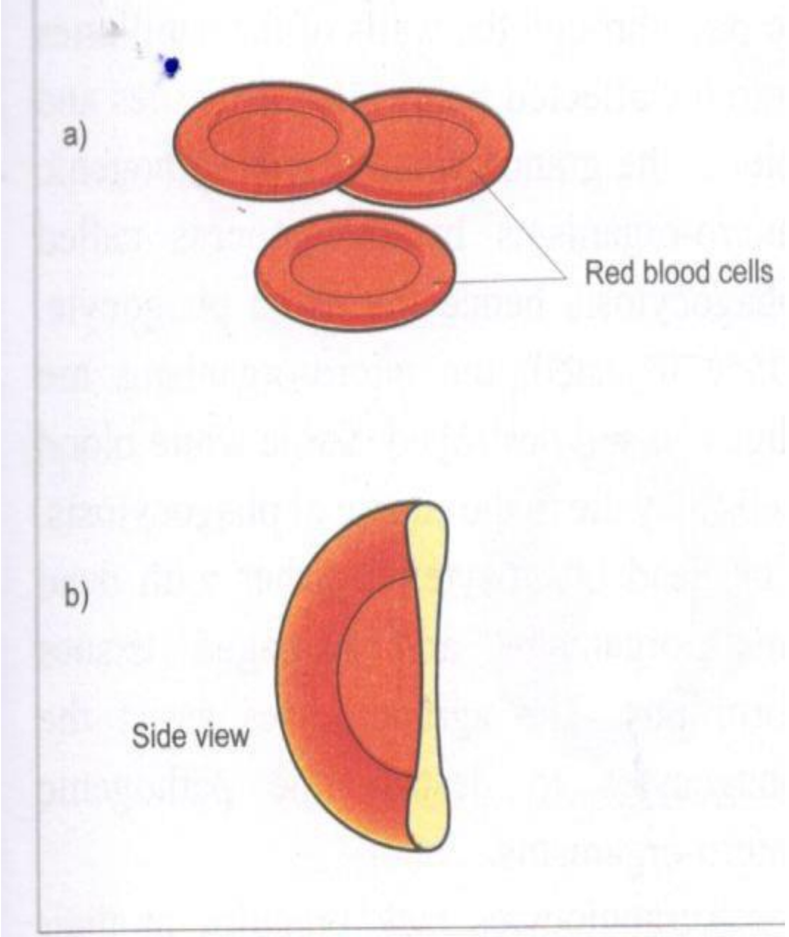


Fig 1.28: Red blood cells

Functions of Red Blood Cells.

i. They transport oxygen from the lungs to the body tissues.
ii. Transport carbon (IV) oxide from the body tissues to the lungs.

Adaptations of red blood cells.

1. Have biconcave shape to increase the surface for diffusion of respiratory gases
2. They are pliable/flexible to squeeze through the narrow lumen of capillaries.
3. They lack cell organelles to reduce their metabolic processes so that they don't consume the oxygen they carry.
4. They contain hemoglobin which readily combines with oxygen to form unstable oxyhaemoglobin and release the oxygen in various body tissues.
5. They contain an enzyme carbonic anhydrase that facilitate the transportation of carbon (IV) oxide as bicarbonate.
6. They lack nucleus to create room/ increase surface area for package of more haemoglobin (which carry more oxygen).
7. They have thin membrane for faster diffusion of gases.

TRANSPORTATION OF OXYGEN

- Oxygen is in higher concentration in the alveoli/ lungs than in the blood capillaries hence it diffuses into blood and into red blood cells.
- In the red blood cells it combines with haemoglobin to form unstable oxyhaemoglobin; which is then transported by blood into tissues where there is low oxygen concentration.
- Oxyhaemoglobin dissociates/ breaks down into oxygen and haemoglobin.
- The oxygen diffuses out of the red blood cells and through the capillary wall/ endothelium into the tissues.
- The haemoglobin is then free to pick more oxygen at the lungs.

Haemoglobin + Oxygen $\rightleftharpoons$ Oxyhaemoglobin

TRANSPORT OF CARBON (IV) OXIDE.

- Carbon (IV) oxide is in higher concentration in tissues than in blood; it diffuses out of the tissues into blood and transported in form of:

1. **Hydrogen carbonate ions-** 85% of carbon (IV) oxide diffuses into red blood cells where the enzyme **Carbonic anhydrase** speeds up the reaction between carbon (IV) oxide and water to form **weak carbonic acid.**

- Weak carbonic acid breaks into hydrogen carbonate ions and hydrogen ions.
- Hydrogen carbonate ions diffuses from the RBC into the plasma which is transported to the lungs.

2. **Weak carbonic acid –** About 5% of carbon (IV) oxide dissolves in plasma to form weak carbonic acid; to prevent changes in blood pH;
3. **Carbamino haemoglobin-** Some carbon (IV) oxide (10%) combines with haemoglobin to form carbaminohaemoglobin; which is transported to the lungs; where it dissociates/ breaks down into haemoglobin and carbon (IV) oxide which is expelled during exhalation.

Importance/ advantage of transportation of carbon (IV) oxide in Red Blood Cells than in plasma.

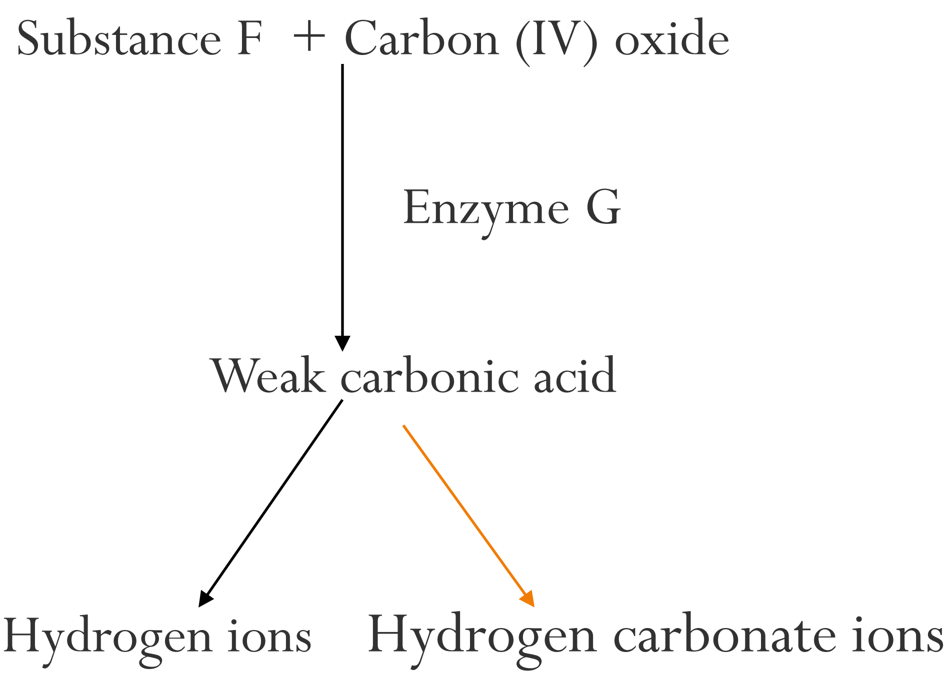
i. It prevents accumulation of acidity/maintains the pH of blood.
ii. It is faster due to catalytic effect of carbonic anhydrase OR Carbonic anhydrase facilitates faster off loading and loading of carbon (IV) oxide.

Reason why more carbon (IV) oxide is transported in form of hydrogen carbonate/ bicarbonate ions.

- This is because of presence of carbonic anhydrase enzyme which speeds up the conversion of carbon (IV) oxide to weak carbonic acid
- Weak carbonic acid dissociates into hydrogen ions and hydrogen carbonate ions.
- Hydrogen carbonate ions diffuses out of the red blood cells into blood plasma.

Study questions.

1. The diagram below illustrates the role played by red blood cells in the transportation of carbon (IV) oxide.



a) Other than the carbon (IV) oxide transportation in the red blood cells, name the other forms of carbon (IV) oxide transportation in humans.

1. *Weak carbonic acid in plasma.*
2. *Carbamino haemoglobin.*
3. *Hydrogen carbonate ions.*

b) Name the enzyme marked G.

- *Carbonic anhydrase.*

c) State the role of the enzyme named in b) in the reaction.

- *It speeds up/catalyzes the reaction between carbon (IV) oxide and water to form weak carbonic acid OR it catalyzes the conversion of carbon (IV) oxide to weak carbonic acid.*

d) Name substance F.

- *Water.*

2. Explain the role of carbonic anhydrase in red blood cells.

It converts carbon (IV) oxide into weak carbonic acid, which easily dissociates into hydrogen and bicarbonate/ hydrogen carbonate ions for easier transportation. This reduces the acidity in blood.

3. The table below shows variations in the form of carbon (IV) oxide is transported in the blood at rest and during physical exercise.

Form of transport	**At rest (Mole/ Litre)**	**During exercise (Mole/ litre)**
Dissolved carbon (IV) oxide	0.52	0.97
Hydrogen carbonate ions	12.34	13.68
Carbon (IV) oxide bound to protein.	0.26	0.16
Total carbon (IV) oxide in plasma	13.12	14.81
pH of blood	7.42	7.09

a) Explain why more carbon (IV) oxide is transported in the form of hydrogen carbonate ions.

- ***The presence of carbonic anhydrase enzyme which speeds up/ catalyzes the conversion of carbon (IV) oxide to weak carbonic acid which dissociates into hydrogen ions and hydrogen carbonate ions.***
- ***The hydrogen carbonate ions diffuses out of the red blood cells into the blood plasma.***

b) Account for the high total plasma content of carbon (IV) oxide during exercise.

- ***There is high rate of respiration to provide more energy for exercise/ muscular activity. This releases more carbon (IV) oxide into blood plasma***

c) Explain how one's involvement in the exercises affects blood pH.

The high rate of respiration during physical exercises results into production of more carbon (IV) oxide / faster accumulation of lactic acid. This lowers the pH of blood plasma / increases acidity of blood plasma.

d) Name the protein responsible for transport of carbon (IV) oxide in the blood.

- ***Haemoglobin.***

CARBON (II) POISONING.

- In a poorly ventilated room with charcoal burner, Carbon (II) oxide is produced which readily combines with haemoglobin to form **carboxyhaemoglobin** which is stable and does not dissociate/break down easily.
- This reduces the capacity of the haemoglobin to carry oxygen leading to suffocation.
- Therefore, carbon (II) oxide is said to be **a respiratory poison.**

Advantage of oxyhaemoglobin over carboxyhaemoglobin

- ✓ Oxyhaemoglobin is unstable/ freely dissociates releasing oxygen to the tissues leaving haemoglobin molecules free to take up more gaseous molecules.
- ✓ This ensures constant supply of oxygen to the respiring tissues.
- ✓ Carboxyhaemoglobin is stable/ does not dissociate easily hence haemoglobin is not free to pick oxygen gas.
- ✓ This reduces supply of oxygen to the tissues hence starving them of oxygen leading to suffocation/ death.

Factors that affect the number of red blood cells.

a. Altitude .

- The number of red blood cells count increases with increase in altitude so as to increase the oxygen carrying capacity by haemoglobin molecules in blood.
- This is because oxygen concentration is lower at higher altitude.
- Athletes practice on higher altitude areas to increase the number of RBC and haemoglobin content.

b. State of health.

- People with anaemia have few RBC.

Study questions.

1. Explain why red blood cells count increases with altitude.

✓ ***This is to increase the oxygen carrying capacity by haemoglobin molecules in blood because oxygen concentration is lower at higher altitude.***

2. Explain why chances of nose-bleeding increase with altitude in humans.

✓ ***Atmospheric pressure decreases with increase in altitude. The imbalance between the atmospheric pressure at high altitude and the internal pressure generated by the heart causes bursting of blood vessels thus causing nose-bleeding.***

2. WHITE BLOOD CELLS/ LEUCOCYTES.

- They are formed in the bone marrow of long bones and lymph nodes.
- They are different from red blood cells in the following ways:

a) They have a nucleus.

b) They lack haemoglobin hence appear colourless.

c) They are fewer in number but the number increases during infection.

d) They are larger in size.

Role/ function.

- They protect the body against infections/ pathogens (bacteria, protozoa, viruses).

Adaptations of the white blood cells/ leucocytes.

i. They have a prominent nucleus which controls the activities of the cell.

ii. They are large in size to be able to engulf bacteria.

iii. They make amoebic movement hence can be able to engulf bacteria and pass through capillary wall.

Study question

Explain why white blood cells count remains at whatever altitude/ does not change with change in altitude.

✓ ***White blood cells serve to protect the body against harmful micro-organisms/ pathogens and the quantities of pathogens/ vulnerability of the body to microbial attack is not dependent on altitude.***

Types of white blood cells.

- They include:

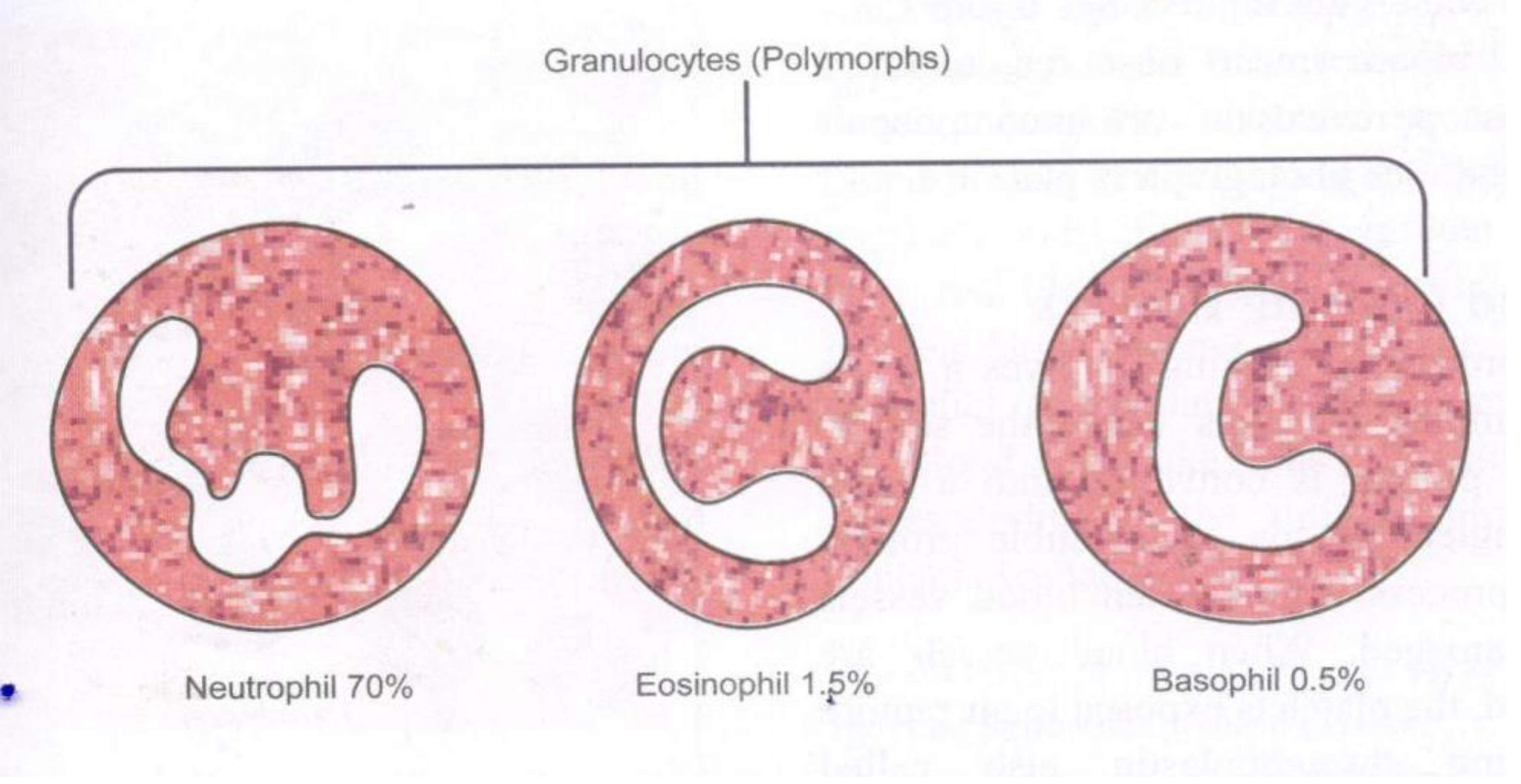
A. Phagocytes/Granulocytes/ polymorphs.

B. Agranulocytes- Monocytes and lymphocytes

A. PHAGOCYTES/GRANULOCYTES

- They have lobed nucleus and granulated cytoplasm.
- They protect the body against infection by engulfing the pathogens through **Phagocytosis.**
- They use amoebic movement to pass through the walls of the capillaries into the affected tissue.
- Once the pathogens are engulfed/ ingested they produce enzymes that digest and destroy them.
- Some white blood cells may die during phagocytosis. The dead phagocytes, dead micro-organisms and damaged tissues form pus.

A. PHAGOCYTES/GRANULOCYTES



B. <u>AGRANULOCYTES.</u>

- They lack granules in their cytoplasm and they are of two types, namely:

1. **<u>Monocytes-</u>** they have a large lobed nucleus and are produced in the bone marrow.

- They show amoebic movement hence are able to move to the sites of infection/ enter the tissues and transform into microphages.
- Microphages are large phagocytic cells that ingest the pathogens and tissue debris.

2. **<u>Lymphocytes-</u>** they have large rounded nuclei and are produced in **<u>thymus</u>** and **<u>lymph glands.</u>**

- They protect the body by producing antibodies. The antibodies include:

i) **<u>Antitoxins-</u>** they neutralize the toxins/ antigens produced by pathogenic micro-organisms.

ii) **<u>Agglutinins-</u>** they bind to antigens/ pathogens clumping them together for phagocytic activity.

✓ This stops the micro-organisms from multiplying and finally die, after which they are ingested by phagocytes.

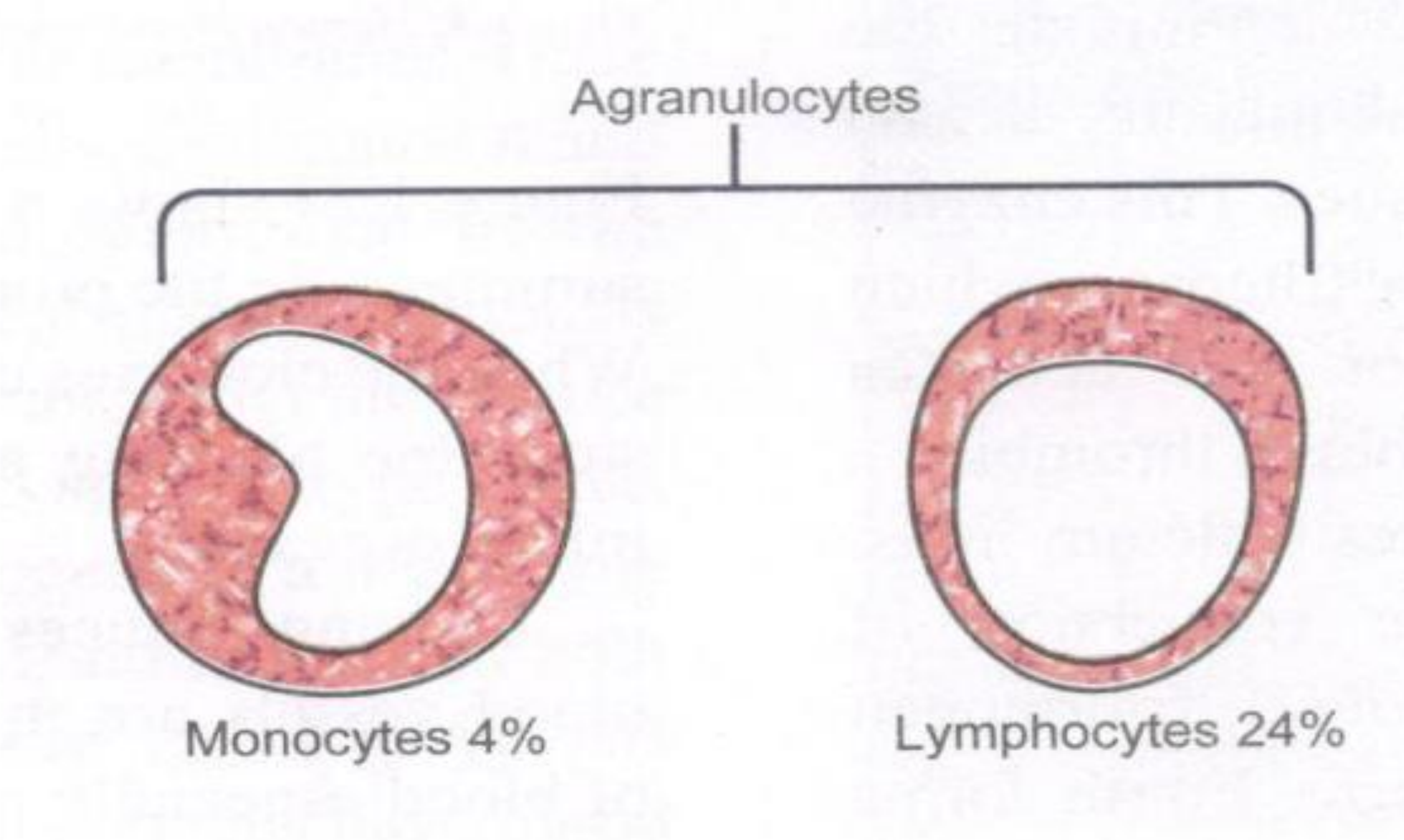
iii) **<u>Lysins-</u>** they destroy the micro-organisms by digesting their cell membranes or walls.

iv) **<u>Opsonins-</u>** they stick/ adhere to the outer surface of micro-organisms making it easier for phagocytes to ingest them.

3. PLATELETS/ THROMBOCYTES.

- They are irregularly shaped, unnucleated (without nucleus) fragments of large cells in the bone marrow.
- They are sensitive to exposure to air or rough surfaces.
- **They help in blood clotting** preventing excessive loss of blood/bleeding, entry of pathogens and healing of the wound.

GRANULOCYTES- MONOCYTES AND LYMPHOCYTES



PLATELETS

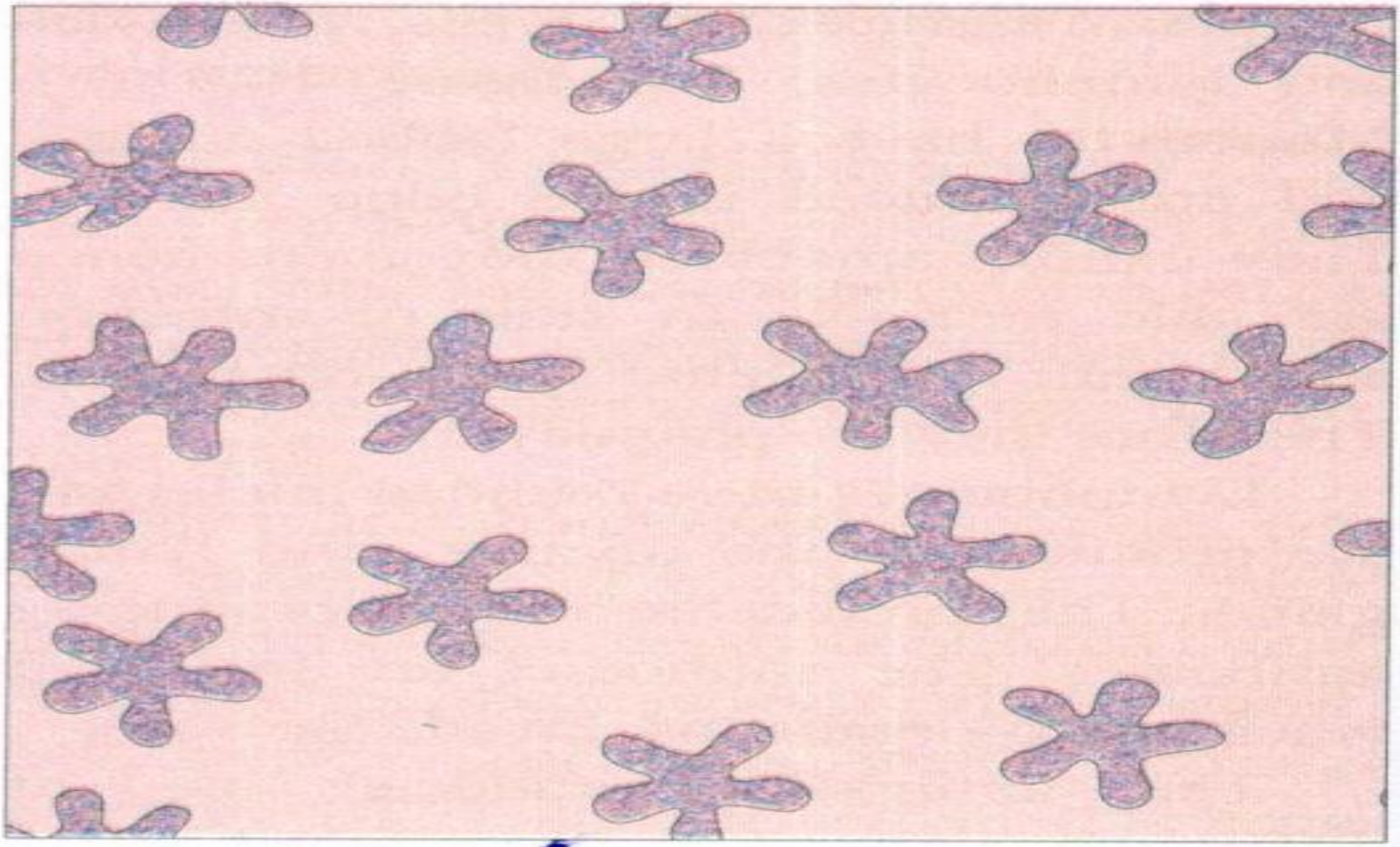


Fig 1.30: *Platelets*

BLOOD CELLS

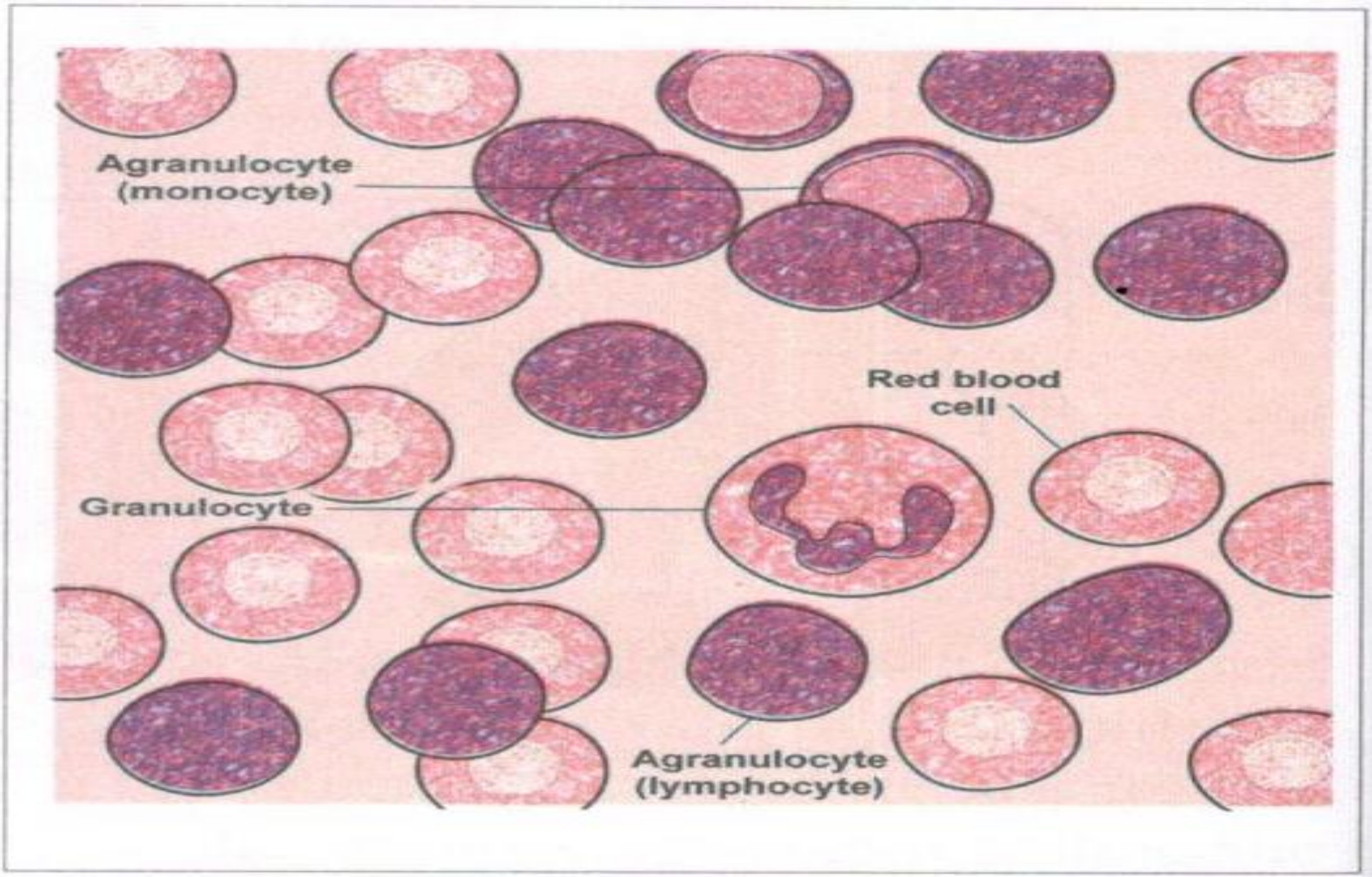


Plate 1.4: *Human blood smear*

Study question

- **Describe how the cellular components of mammalian blood are adapted to their function.**

a) **Red blood cells**

- ✓ They are biconcave disc-shaped to increase surface area for diffusion of gases.
- ✓ They lack nucleus to create room for package of more haemoglobin.
- ✓ They lack organelles to reduce their metabolic processes so that they don't consume the oxygen they carry.
- ✓ They are pliable/ flexible to squeeze through narrow capillaries.
- ✓ They contain haemoglobin that readily combines with oxygen to form oxyhaemoglobin and release the oxygen in various body tissues.
- ✓ They have an enzyme carbonic anhydrase that facilitates transport of carbon (IV) oxide as hydrogen carbonate/ bicarbonate.

b) **White blood cells**

- ✓ They are large, irregularly shaped, nucleated cells that protect the body against pathogens.
- ✓ They neutralize toxins and confer resistance against parasites.
- ✓ They are of two types, granulocytes and agranulocutes. Granulocytes lave lobed nuclei and use amoebic movement to pass through capillary walls.
- ✓ They engulf/ destroy pathogens through phagocytosis.
- ✓ Agranulocytes include monocytes and lymphocytes. Monocytes have large lobed nuclei and enter the tissues and transform into microphages (large phagocytic cells that ingest pathogens and tissue debris)
- ✓ They lymphocytes produce antibodies which bind to the antigens/ pathogens clumping them for phagocytic activity.

c) **Platelets.**

- ✓ These are irregularly shaped unnucleated cell fragments.
- ✓ They are sensitive to exposure to air or rough surfaces and initiate the process of clotting process.

TISSUE FLUID/INTERCELLULAR FLUID.

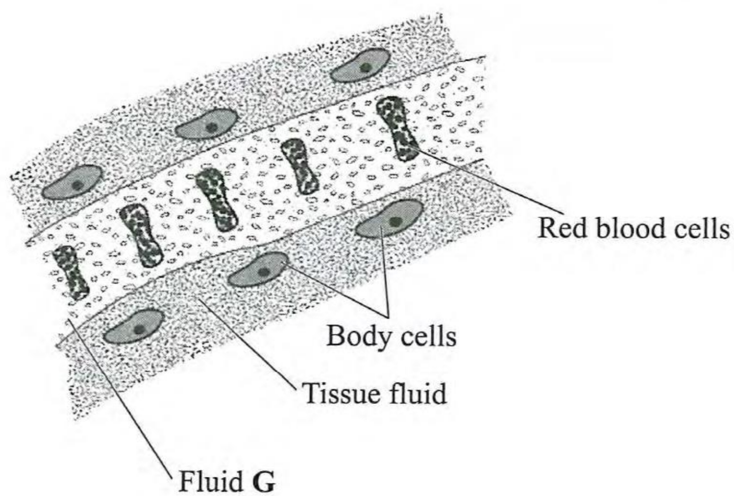
- This is a fluid/blood plasma that filters out of blood capillaries and bathes/covers the cells i.e. circulates in the spaces between the cells.
- It similar to plasma in composition except that it lacks proteins, red blood cells and some white blood cells.
- Some phagocytic white blood cells can squeeze through capillary wall into tissue fluid.
- There is exchange of materials between the cells and the tissue fluid.
- Cells obtain glucose, oxygen, amino acids, vitamins, hormones and mineral ions from tissue fluid.
- The cells release metabolic wastes e.g. carbon (IV) oxide, urea and lactic acid into tissue fluid.

Importance of tissue fluid.

1. It is a medium of exchange of substances/ materials between capillaries and body cells.
2. Supply nutrients to cells / supply oxygen to cells / remove waste products from cells.

STUDY QUESTIONS

1. The diagram below illustrates tissue fluid and cells surrounding a capillary.



a)

b) Give two ways by which fluid G is different from tissue fluid. (2mks)

- ***Has more large proteins / platelets while tissue fluid lacks proteins***
- ***Has red blood cells while tissue fluid lacks red blood cells.***
- ***Has high hydrostatic pressure while tissue fluid has low hydrostatic pressure***

2. Explain the difference between blood plasma and serum.

- ***Blood plasma contains plasma proteins while serum is blood plasma without plasma proteins.***

Formation of tissue fluid.

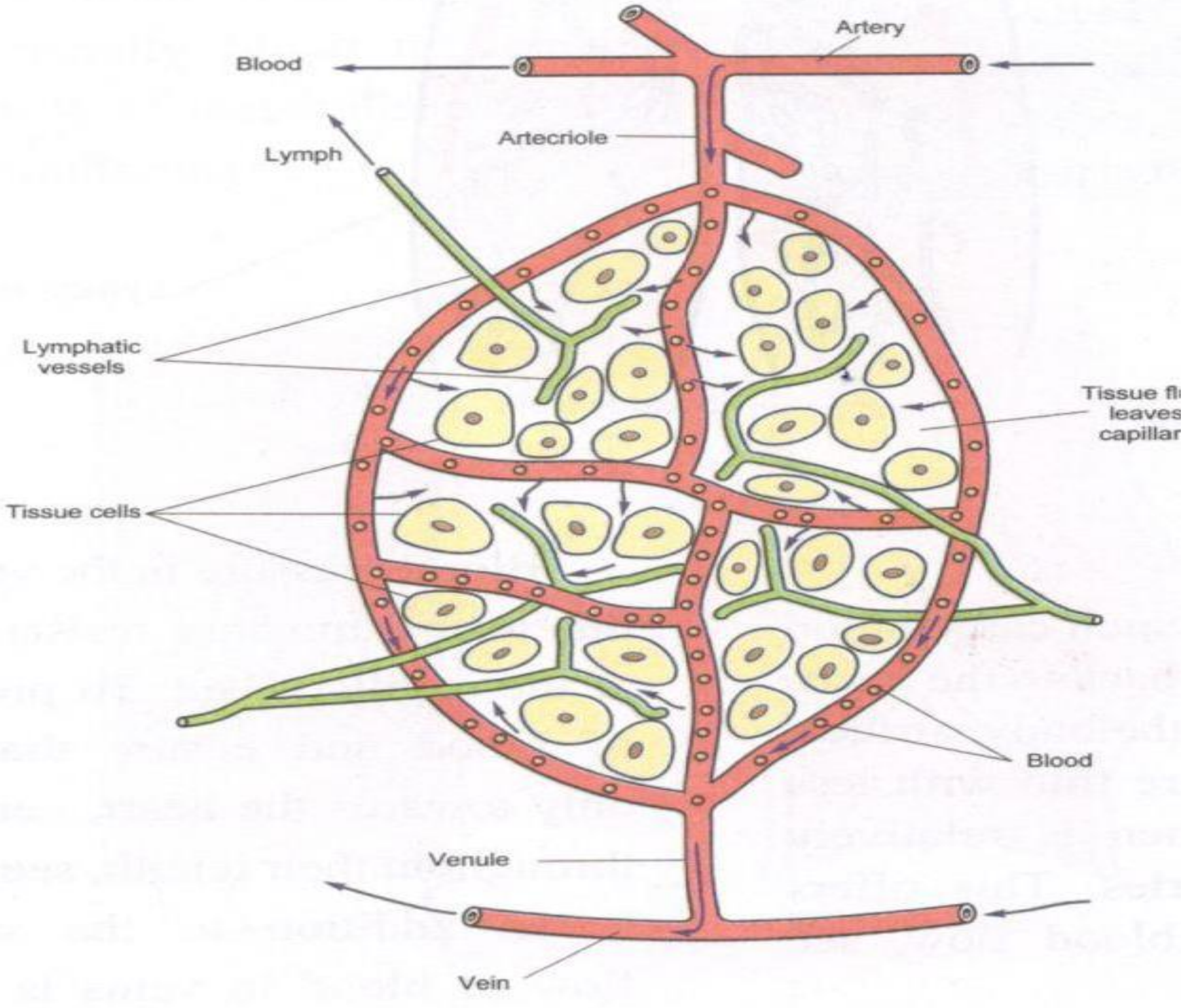
- It is formed through the process of **ultrafiltration/ pressure filtration.**
- Blood entering the arteriole has a higher pressure due to pumping force from the heart and narrow lumen of capillaries.
- The higher pressure forces water and small solutes to filter out of the capillary walls into the intracellular space forming tissue fluid.
- Ultrafiltration results into a drop in pressure such that at the venule end of the capillary bed, the blood pressure is lower than that of the tissue fluid.

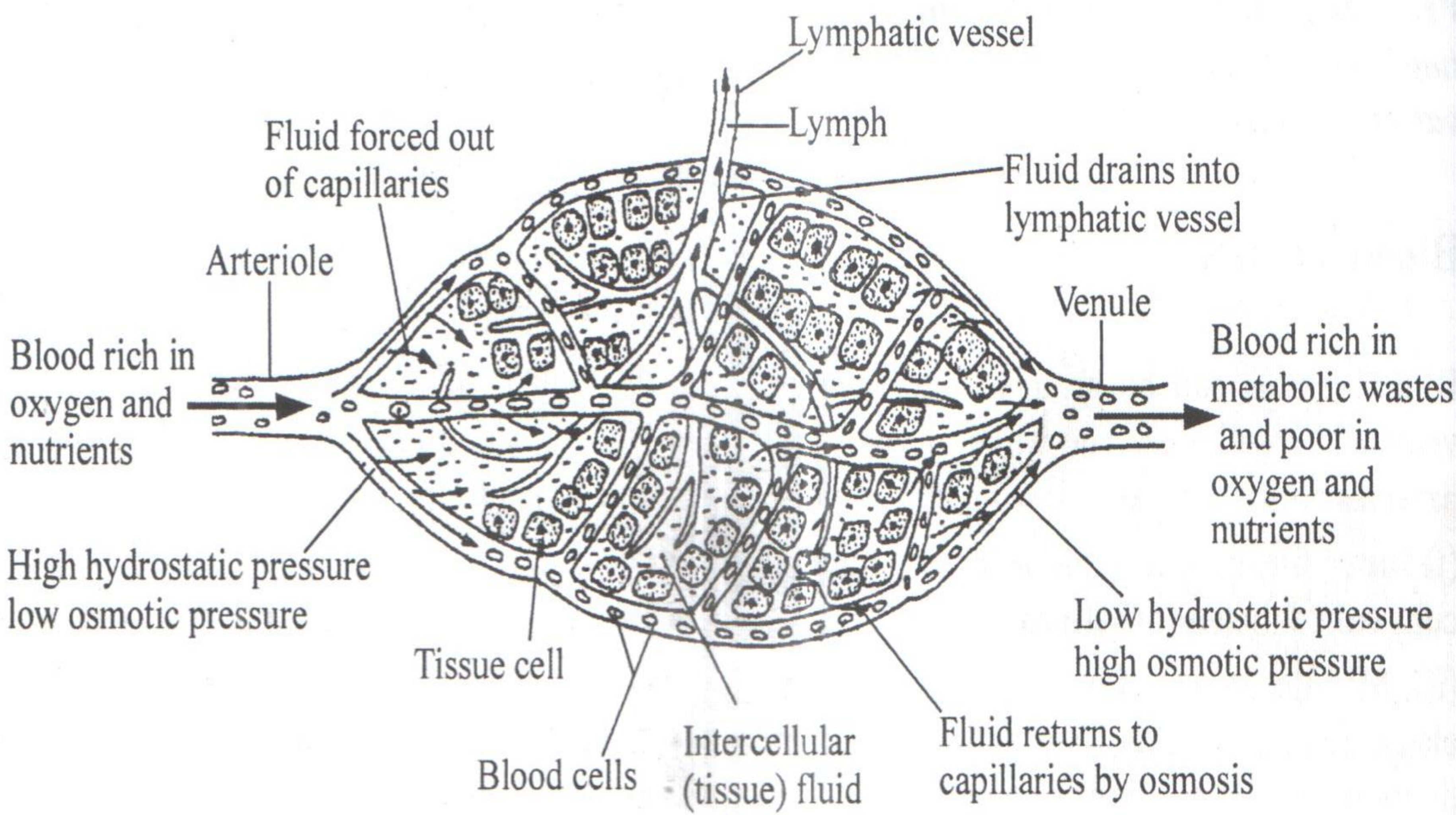
Draining of the tissue fluid.

i. Some tissue fluid enters the bloodstream on the venule end through osmosis.

- The proteins retained in the capillaries during ultrafiltration increase osmotic pressure at the venule end of capillary.
- This causes much of the tissue fluid to drain back into blood stream by osmosis and other waste substances e.g. carbon (IV) oxide to diffuse into blood.

ii. The rest of the fluid enters into the **lymphatic vessels** forming **lymph.**


Artery
Blood
Artecriole
Lymph
Lymphatic vessels
Tissue fl
leaves
capillar
Tissue cells
Blood
Venule
Vein


Lymphatic vessel
Lymph
Fluid forced out of capillaries
Fluid drains into lymphatic vessel
Arteriole
Venule
Blood rich in oxygen and nutrients
Blood rich in metabolic wastes and poor in oxygen and nutrients
High hydrostatic pressure low osmotic pressure
Low hydrostatic pressure high osmotic pressure
Tissue cell
Blood cells
Intercellular (tissue) fluid
Fluid returns to capillaries by osmosis

BLOOD CLOTTING

- This is the formation of a clot to seal the blood vessels that have been cut or damaged.
- It is brought about by blood cells called **platelets/ thrombocytes.**

Importance of blood clotting.

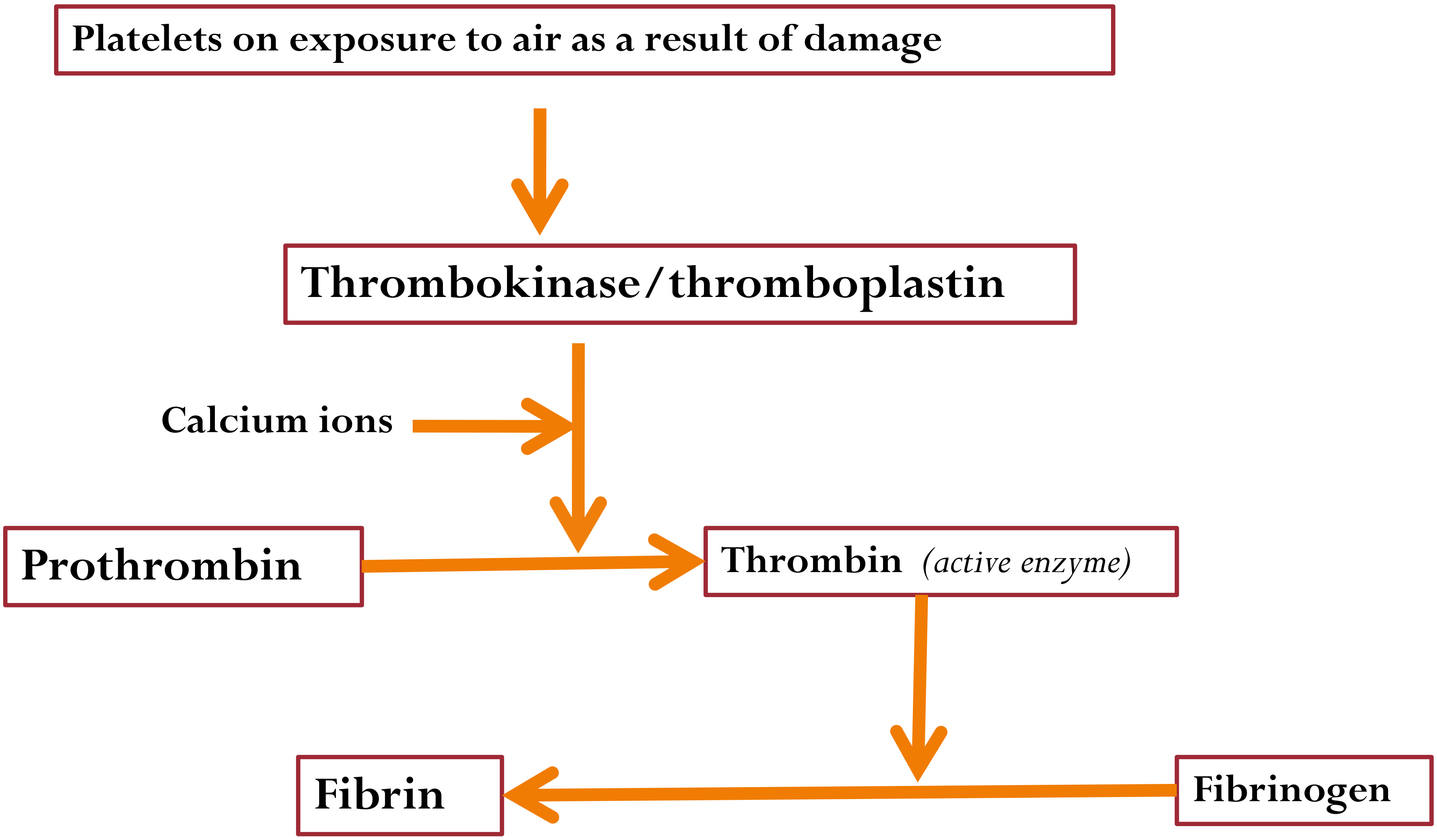
1. Prevents further loss of blood/ bleeding.
2. Prevents the entry of pathogens/ infection.
3. Leads to the healing of the wound.

Mechanism/process of blood clotting

- When the blood vessel is injured/cut, platelets or thrombocytes (or damaged tissue/ wound sustained) is exposed to air, an enzyme **thrombokinase /thromboplastin** is released.
- Calcium ions activate **thrombokinase /thromboplastin** to neutralize heparin (anti-clotting factor) and to activate the conversion of **prothrombin to thrombin.**

- **Vitamin k (Phylloquinone)** is needed/required in the formation of **prothrombin** in the liver.
- **Thrombin** (which is active enzyme) activates the conversion of **Fibrinogen** (soluble protein) into **fibrin** (insoluble protein) which forms a meshwork/network of fibres across a wound forming a clot.
- The clot formed prevents excessive bleeding/blood loss, entry of pathogens/ microbes/micro-organisms/disease agents and heals the wound.

N/B. Blood clotting does not take place in undamaged vessel. **This is because of the presence of heparin (anticlotting factor) which prevents the conversion of prothrombin to thrombin and neutralizes any thrombin which may be formed accidentally.**


Platelets on exposure to air as a result of damage
Thrombokinase/thromboplastin
Calcium ions
Prothrombin
Thrombin *(active enzyme)*
Fibrin
Fibrinogen

BLOOD GROUPS

- Blood group is determined by a special type of proteins called **antigens** which are found on the surface/plasma membrane of Red Blood Cells.
- The antigens (proteins) include:

i. Antigen A.

ii. Antigen B.

- A person with antigen A on the surface of red blood cells is said to belong to **blood group A.**
- A person with antigen B belongs to **blood group B.**
- A person with both antigen A and B belongs to **blood group AB.**
- A person with no antigens belong to **blood group O.**

- Blood plasma has also other proteins called **antibodies.**
- The antibodies include:

i. Antibody a

ii. Antibody b

- A person with antigen A (blood group A) cannot have **antibody a** but will have **antibody b.**
- Similarly, a person with antigen B(blood group B) will have **antigen a.**
- If the antigens and antibodies correspond, **antigen-antibody reaction/haemagglutin ation/ agglutination (clumping of red blood cells)** will take place blocking blood flow in vessels which leads to death.
- For example, if an individual with antigen A (blood group A) has antibody a, agglutination will take place.

	ANTIGEN	ANTIBODY
BLOOD GROUP A	A	b
BLOOD GROUP B	B	a
BLOOD GROUP AB	A and B	No antibody
BLOOD GROUP O	No antigen	Antibody a and b

BLOOD TRANSFUSION

- Blood transfusion is the transfer of blood from a donor to the circulatory system of the recipient.
- The person who gives blood is called **a donor** while the person who receives blood is called **a recipient.**

Factors to consider during blood transfusion.

i. Blood group
ii. Age of the donor.
iii. State of health of the donor.

Importance of blood transfusion/ conditions that require blood transfusion.

- It helps to increase the volume of blood due to:

i. Excessive bleeding during an accident.
ii. Surgery.
iii. A woman losing of a lot of blood during giving birth.
iv. Anaemia/ anaemic condition.

Precautions taken during blood transfusion.

1. Blood of the donor and recipient should be compatible i.e. the antigen of the donor should not correspond to the antibody of the recipient.
2. Blood should be free from pathogens e.g. HIV virus, hepatitis virus, malaria parasite
3. Donated blood should not be used after one month.

- This is because the red blood cells have a lifespan of about 120 days, hence most of them would have died after a month.

- To check the compatibility of blood, **blood typing is done.**
- **Blood typing** is a process of determining the antigens and antibodies of donor and recipient blood to ensure safe transfusion.
- This is to avoid **agglutination/ haemagglutination (clumping of the donor's blood cells)** which can cause blockage of small blood vessels which may lead to death.
- A person with blood group O can donate blood to all blood groups hence called **universal donor.**
- This is because he/she lacks antigens which will react with the antibodies of the recipient.
- A person with blood group AB can receive blood from all blood groups hence called **universal recipient.**
- This is because he/she lacks antibodies in blood which would react with the antigens of the donor.

Recipient / Donor	Blood group A (antibody b)	Blood group B (antibody a)	Blood group AB (no antibody)	Blood group O (antibody a and b)
Blood group A (antigen A)	No agglutination	Agglutination	No agglutination	Agglutination
Blood group B (antigen B)	Agglutination	No agglutination	No agglutination	Agglutination
Blood group AB (antigen A and B)	Agglutination	Agglutination	No agglutination	Agglutination
Blood group O (no antigen)	No agglutination	No agglutination	No agglutination	No agglutination

RHESUS FACTOR/RHESUS ANTIGEN/ANTIGEN D

- This is another type of protein/antigen found on the plasma of the red blood cells.
- Individuals with rhesus factor are said to be **rhesus positive (Rh+)** while individuals without rhesus factor are **rhesus negative (Rh-).**

Example 1

- If Rh+ blood is given/ donated to Rh- recipient, the recipient will respond by producing the corresponding antibodies against antigen D.
- Because the antibodies are produced slowly they will have little effect in the recipient body in first transfusion.
- If the same recipient is transfused with Rh+ blood, antibody-antigen reaction will take place leading to agglutination which can block blood vessels leading to death.

STUDY QUESTIONS

1. An individual is of blood group **B** positive.

a) Name the antigens in the individual's blood.

- ***Antigen B***
- ***Antigen D/rhesus antigen/rhesus factor.***

b) Give the reason why the individual cannot receive blood from a blood group A donor.

- ***Has antibody a in the blood plasma which corresponds with antigen A in the donor's blood, hence there will be antigen-antibody reaction/agglutination.***

2. a) Why is it important to screen blood before transfusion?

- ***To check the pathogens e.g. HIV, plasmodium etc.***

b) Name two diseases that can be transmitted through blood transfusion.

i. ***HIV and AIDS.***

ii. ***Malaria.***

iii. ***Hepatitis.***

2. In an experiment, serum samples from people with blood groups A and B were mixed with whole blood from another person X. In both cases, agglutination did not take place. Explain giving reasons the blood group of person X.

Answer.

- ***The person has blood group O, because she/ he lack antigens on red blood cells hence there was no antigen-antibody reaction.***

IMMUNE RESPONSES

- Immune responses are reactions that involve production of antibodies by lymphocytes due to the presence of antigens in the body.
- **An antigen** is a substance that is foreign to the body and provokes/ causes the body's immune system to produce antibodies.
- Antigens can be pathogens, their toxins or molecules.
- **Antibodies-** are proteins produced by the lymphocytes in response to the presence of an antigen in the body.
- The antibodies have chemical composition which compliments the antigen i.e. they combine against a particular antigen to make it harmless.

Types/groups of antibodies

1. **Agglutinins-** they cause the pathogens to clump together.
2. **Lysins-** adhere to pathogens causing them to disintegrate.
3. **Opsonins-** they are absorbed on the surface of the pathogens making it easier for phagocytes to engulf them.
4. **Antitoxins-** they neutralize the toxins produced by micro-organisms.

IMMUNITY.

- This is the ability of an animal to resist infection or counter the effects of toxins produced by antigens.

Types of immunity.

1. **Natural/ inherited/ innate immunity-** is a type of immunity that one is born with and is passed from parent to offspring.

- It is non-specific because it offers protection against many types of infections.

2. **Acquired immunity-** it is a type of immunity that is not inherited but it develops as one interacts with the environment.

- It is specific as it offers protection against specific antigens.

- Acquired immunity can develop naturally or actively and can either be active or passive in nature.
- **Active immunity** –is a form of acquired immunity in which the body produces its own antibodies against infection.
- **Passive immunity**-is a form of acquired immunity in which an individual is protected against infection by receiving antibodies.

TYPES OF ACQUIRED IMMUNITY

1. **Natural acquired immunity-**it develops when one is attacked by diseases (e.g. small pox, chicken pox, measles, mumps and poliomyelitis) and recovers completely. It

- If such individual are attacked by the same pathogens again they do not become seriously ill because the immune system produces antibodies against the pathogens.
- This type is long lasting and may last for a lifetime hence called **natural active acquired immunity.**
- During pregnancy the mother passes the antibodies across the placenta to the foetus or through breast milk in colostrum.
- This provides immunity to the baby for some time hence called **natural passive acquired immunity.**

2. **Artificial acquired immunity-** it is developed through vaccination/ immunization.

- When a vaccine is introduced into the body of a healthy individual, the antigens in the vaccine stimulate the production of corresponding antibodies.
- When the body is attacked again by the same disease, it produces the specific antibodies which destroy the actual pathogens/ antigens hence called **artificial active acquired immunity.**
- Sometimes antiserum (serum with antibodies) is injected into the body to provide immunity for a few weeks. This is called **artificial passive acquired immunity.** This is because the body is not activated to produce its own antibodies.

VACCINATION/IMMUNIZATION

- This is the introduction of a vaccine into the body of an organism to provide immunity against diseases/infection.
- **A vaccine** is a preparation containing a pathogen which is dead, weakened/ attenuated or chemically treated toxins called **toxoids.**
- A vaccine stimulates the production of specific antibodies by the body such that next time the body gets infected by the actual pathogens, there will be no serious illness caused.
- Vaccination is important because it protects the body against infections.

Importance/ role of vaccination.

i. To prevent the spread of diseases.
ii. To give protection against infections/to provide the body with immunity against infections.

Diseases controlled through vaccination.

i. Tuberculosis
ii. Poliomyelitis/ Polio
iii. Measles
iv. Diphtheria
v. Whooping cough
vi. Tetanus
vii. Typhoid fever
viii. Small pox.
ix. Hepatitis B.
x. Influenza

ALLERGIC REACTIONS

- An allergic reaction/ allergy is a hypersensitive response of the body immune system to an antigen.
- They are brought about when the body reacts by overproducing antibodies against harmless antigens.
- Allergic people are hypersensitive to materials like dust, pollen grains, some foods, some drinks, some drugs (e.g. penicillin, chloroquine and asprin), some pollutants, fungal spores, feathers, fur, strong perfumes. Examples are Asthma, Hay fever,
- The antigen-antibody reaction occurs on the surface of the body cells which burst open and release a chemical called **histamine**.
- Histamine increases the permeability of epithelial cells of capillaries making the intercellular spaces become filled with tissues fluid and the tissue swells up. Histamines cause inflammation, itching, swelling, pain, breathing difficulties, constricting of bronchi, dilation of capillaries, excessive secretion of mucus, diarrhoea, vomiting, sneezing, coughing and wheezing

Asthma

- This is an example of respiratory tract allergy in which allergic reaction takes place in the lower respiratory tract. This cause the bronchioles to constrict hindering the smooth flow of air. It is characterized by difficult breathing.
- It is precipitated by emotions **e.g. fear, anger, anxiety and frustrations.**
- A severe condition called **anaphylaxis** sometimes occurs in which blood vessels get dilated and this may lower the blood pressure causing death. This is how bee stings cause death.

Control of allergy.

1. Avoiding allergens.
2. Administration of antihistamines drugs when allergic reactions occur.

ORGAN TRANSPLANTS

- It refers to the transfer/ replacement of damaged organs with similar organs from one organism to another.
- The parts of organs or tissues transplanted onto larger parts of the recipient are called **grafts.**
- **Organ rejection may occur** i.e. when graft is not accepted by tissues of the recipient due to immune response in the recipient.

TYPES OF GRAFTS.

1. **Allograft-** involves transplant from another person not identical genetically.
2. **Xenograft-** involves transplant from other animal species e.g. pig valve to replace human valve.
3. **Isograft-** it involves transplant from genetically identical twin.
4. **Autograft-** it is obtained from self e.g. a skin graft from thigh to the face.

2. GASEOUS EXCHANGE

- This is the process by which respiratory gases (carbon (IV) oxide and oxygen) are passed across the respiratory surface.
- This is brought about by the concentration gradient between the body of living organisms and the surrounding medium.
- In simple organisms gaseous exchange takes place through simple diffusion **because they have larger surface area to volume ratio** while complex organisms have special organs for gaseous exchange.

Importance/significance of gaseous exchange.

i. It enables cells to obtain oxygen for respirations and facilitate removal of carbon (IV) oxide as a metabolic waste.

ii. It enables the green plants to obtain carbon (IV) oxide necessary for photosynthesis.

GASEOUS EXCHANGE IN PLANTS.

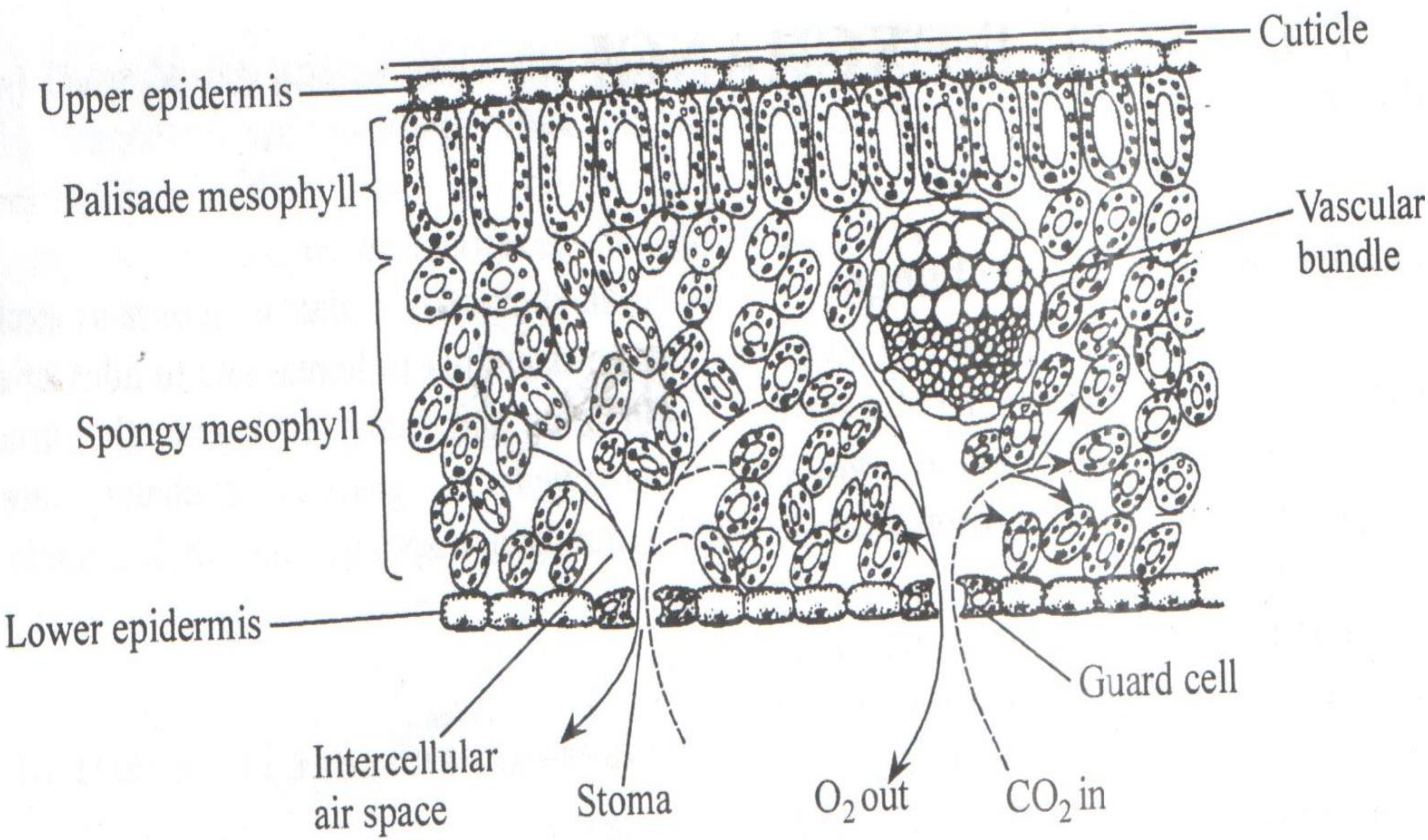
- Gaseous exchange in plants involves two respiratory gases, oxygen and carbon (IV) oxide.
- During the daytime, green plants take in carbon (IV) oxide used for photosynthesis and oxygen produced as a by-product of photosynthesis is released to the atmosphere .
- Some oxygen is used for respiration during the day and since the rate of photosynthesis proceeds faster than respiration at daytime, excess oxygen is removed.
- At night respiration proceeds in the absence of photosynthesis in plants, hence plants take in oxygen for respiration and give out carbon (IV) oxide.

STRUCTURES USED FOR GASEOUS EXCHANGE IN PLANTS.

1. Stomata- on the leaves.
2. Lenticels- on woody stem and root.
3. Epidermis – in roots.
4. Cuticle
5. Pneumatophores – in roots.

Structural adaptations of the leaf for gaseous exchange.

1. It has broad/ flat leaf (lamina) to provide large surface area for gaseous exchange.
2. It is thin to reduce distance for faster diffusion of gases.
3. It has numerous stomata whose opening is controlled by guard cells so that gases can diffuse into and out of the cells.
4. It has large intercellular air spaces that create a large surface area for diffusion of gases in and out of cells.
5. The spongy mesophyll cells have a thin film of moisture to dissolve gases so that they diffuse in solution form.



Gaseous exchange in a plant that is carrying out photosynthesis

Study question.

A group of students placed a fresh leaf in warm water. They observed that air bubbles formed on the surface of the leaf.

a) What biological process were they investigating?

Gaseous exchange.

b) Name the structures from which the air bubbles were coming from.

Stomata.

c) Explain the distribution of the structures named in (b) above on the leaf surfaces.

They are more on the lower surface and fewer on the upper surface of terrestrial plants to reduce the rate of transpiration.

Experiment 1

- **Aim-** To investigate the release of carbon (IV) oxide by plants.

Requirements

1. 2 freshly plucked leaves from a plant.
2. 2 boiling tubes.
3. 2 labels.
4. Bicarbonate indicator solution (red in colour)
5. Aluminium foil.

Procedure.

1. Label the boiling tubes A and B.
2. Put 2ml of diluted bicarbonate indicator in the boiling tube labeled A and B.
3. Cover boiling tube A with aluminium foil and leave boiling tube B uncovered.
4. Using a piece of thread, suspend the leaf above the indicator in each of the boiling tubes.
5. Place a cork to cover the mouth of the boiling tubes as shown below.

Note: Bicarbonate indicator is red at the beginning of the experiment.

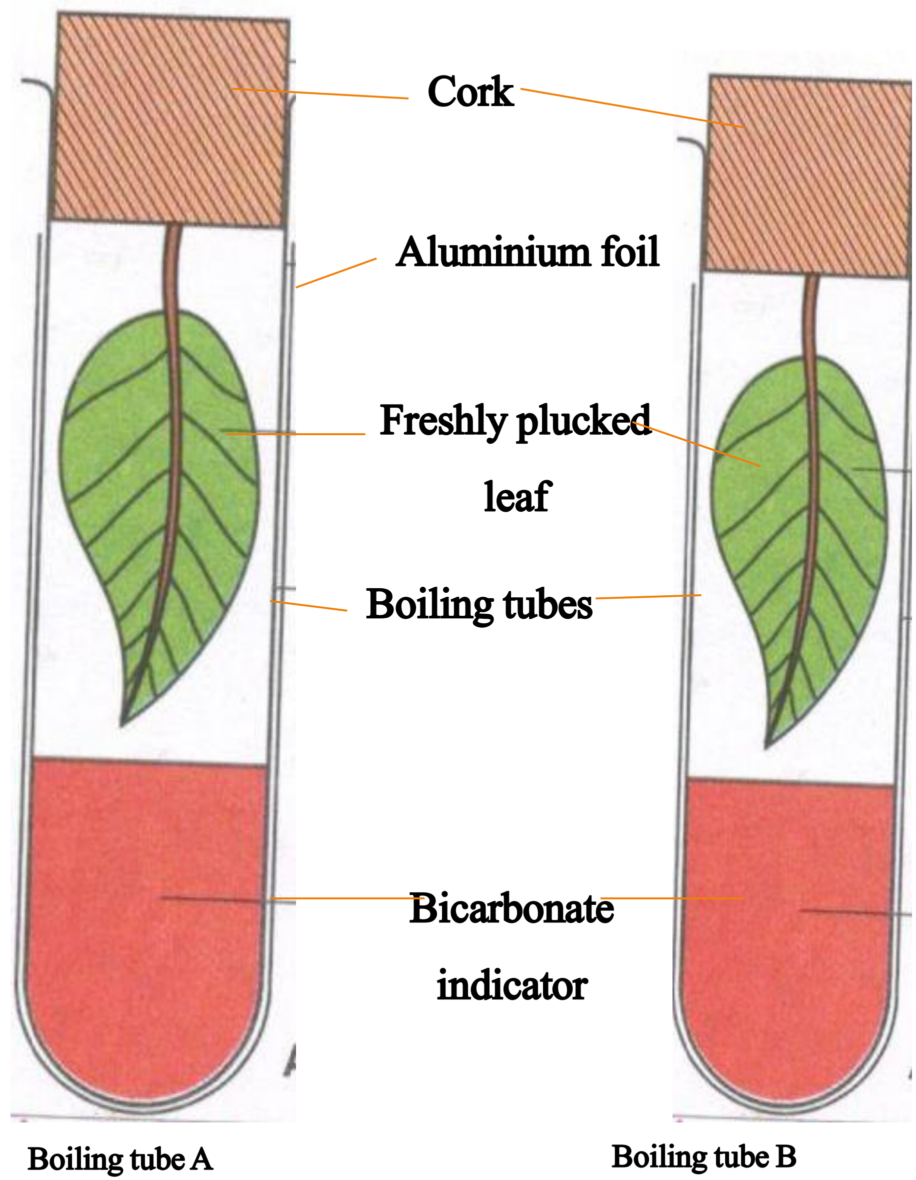
Study questions

1. Why was boiling tube A covered with aluminium foil?

To prevent light penetration for photosynthesis.

2. Account for the colour change observed in boiling tubes A and B.

- ***In boiling tube A the bicarbonate indicator changes from red to yellow.***
- ***This is because there is no light hence the leaf carries out respiration releasing carbon (IV) oxide which causes the indicator to turn yellow.***
- ***In boiling tube B, the leaf carried out photosynthesis using up all the carbon (IV) oxide and the bicarbonate indicator remains unchanged.***



Experiment 2

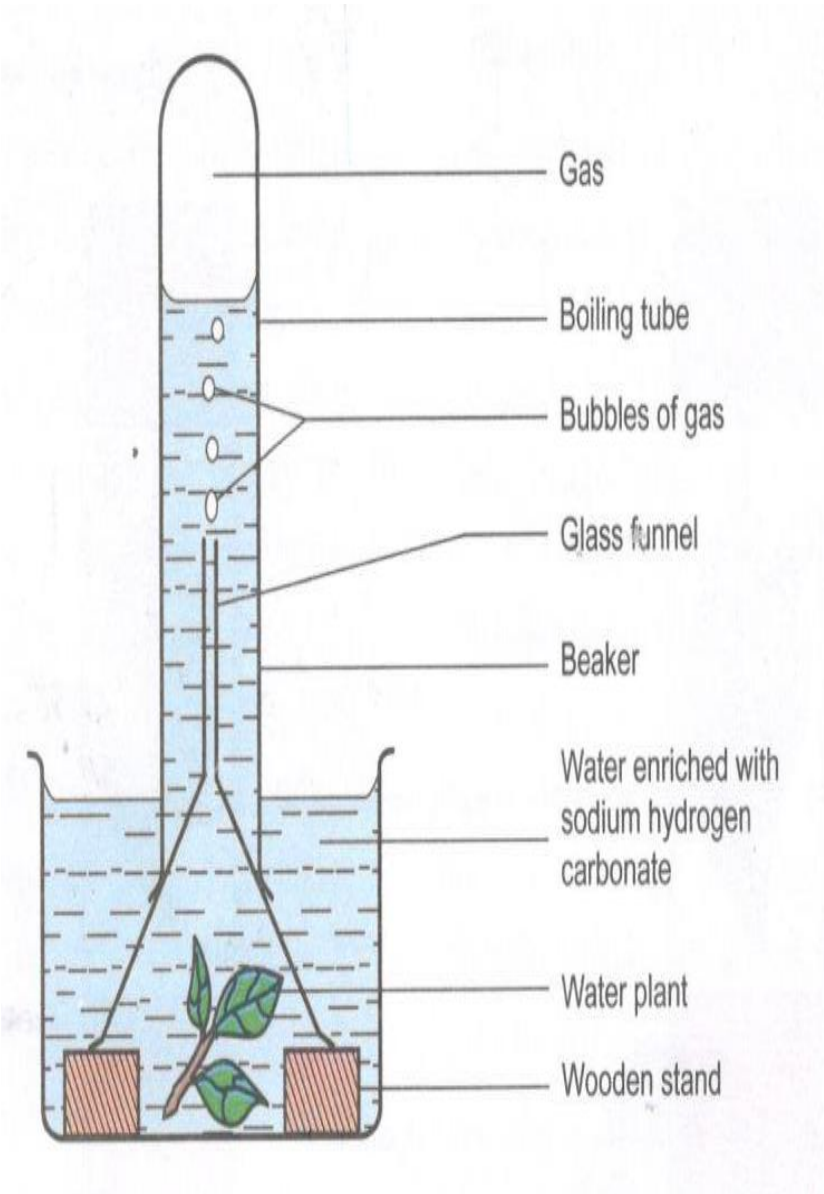
Aim: To investigate the release of oxygen by plants.

Requirements.

1. Water plant.
2. Glass funnel.
3. Beaker.
4. Boiling tube.
5. Wooden block.
6. Wooden splints.
7. Sodium hydrogen carbonate
8. Source of heat.

Procedure

1. Set up the experiment as shown below.
2. Place the set-up in the sunlight.
3. Leave the set up in the sunlight until sufficient gas has collected in the boiling tube.
4. Test the gas produced using a glowing splint.



Study questions.

1. Why was the set up placed in the sunlight?

- ***To allow photosynthesis to take place.***

2. What happens when the gas collected is brought near the glowing splint?

- ***Glowing splint relights.***

3. What is the role of sodium hydrogen carbonate?

- ***To add/ enrich water with carbon (IV) oxide.***

3. a) Identify the gas produced above and explain how the plants produce it.

- ***The gas is oxygen which is produced from the process of photosynthesis after photolysis of water.***

b) State the confirmatory test of the gas produced.

- ***It relights a glowing splint.***

STRUCTURE OF STOMATA

- Stomata are tiny openings on the epidermis/ surface of the leaf surrounded by guard cells.
- Guard cells are specialized epidermal cells that carry out photosynthesis/ contain chloroplasts.
- The stomata are more on the lower surface but fewer on the upper surface and they open mostly at day time but close at night.
- The environmental factors that influence the opening and closing of stomata include **light and availability of water.**

FUNCTION OF STOMATA AND GUARD CELLS.

- The stomata allow gaseous exchange to take place in plants.
- The guard cells control opening and closing of stomata.
- Their distribution on the leaf surface is related to their habitat e.g.

1. Xerophytes (found on dry areas) have **fewer stomata which are smaller in size and sunken and on the lower side of the leaf** to minimize water loss through transpiration.
2. Mesophytes (found on areas with good water supply) have fairly **large number of stomata of medium size on both sides of the leaf** for gaseous exchange.
3. Hydrophytes (found in water) have many stomata which are large in size on the upper side of the leaf to maximize water loss.

Structural adaptations of guard cells.

1. They have thinner outer elastic walls which bulge outwards.
2. They have thicker and less elastic inner wall which curves to open the stoma and straightens to close the stoma.
3. They have chloroplasts for photosynthesis/synthesis of sugar which is osmotically active.

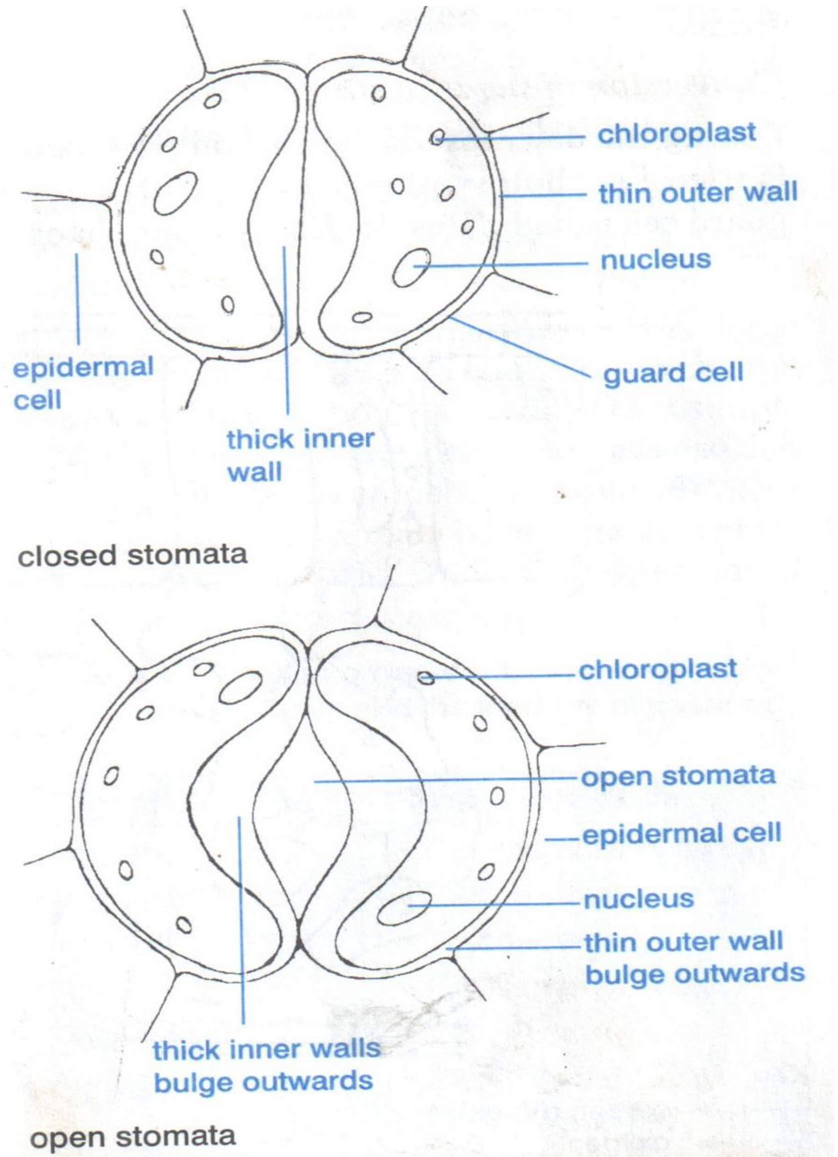


Fig. 6.1 The stomata

Advantage and disadvantage of having stomata on either side of the leaf.

Advantage- it ensures efficient gaseous exchange.

Disadvantage- the side exposed to direct light will cause more water loss.

MECHANISM OF OPENING AND CLOSING OF STOMATA.

- The following theories explain the opening and closing of stomata namely:

1. Photosynthetic theory.
2. pH theory (sugar-starch inter conversion theory).
3. Potassium ions/active transport theory.

1.PHOTOSYNTHETIC THEORY

a) Opening of the stomata.

- ✓ During the day photosynthesis takes place, producing glucose.
- ✓ Glucose being osmotically active increases the osmotic pressure of the guard cells.
- ✓ Water is drawn into the guard cells (from adjacent epidermal cells).
- ✓ the guard cells become turgid.
- ✓ The guard cells bulge outwards opening the stomata.

b) Closing of the stomata.

- ✓ At night photosynthesis does not take place.
- ✓ Sugar/ glucose is converted to starch.
- ✓ Starch is osmotically inactive hence lowers the osmotic pressure of the guard cells.
- ✓ The guard cells lose water to the adjacent epidermal cells through osmosis.
- ✓ The guard cells lose turgidity.
- ✓ The guard cells become plasmolysed leading to closure of stomata.

2. pH/ STARCH- SUGAR INTERCONVERSION THEORY.

a) Opening of stomata.

- ✓During the day photosynthesis takes place using carbon (IV) oxide.
- ✓This makes the pH to rise/ lower acidity in the guard cells favoring the conversion of starch into glucose.
- ✓ Glucose being osmotically active increases the osmotic pressure of the guard cells
- ✓ Water is drawn into the guard cells (from adjacent epidermal cells).
- ✓The guard cells become turgid
- ✓The guard cells bulge outwards opening the stomata.

Closing of stomata

- ✓At night photosynthesis does not take place hence carbon (IV) oxide is not used.
- ✓ Carbon (IV) oxide accumulates in the guard cells lowering the pH/ increasing acidity.
- ✓This favors the conversion of glucose into starch.
- ✓Starch is osmotically inactive hence lowers the osmotic pressure of the guard cells.
- ✓ The guard cells lose water to the adjacent epidermal cells through osmosis.
- ✓The guard cells lose turgid.
- ✓The guard cells become plasmolysed leading to closure of stomata.

3. POTASSIUM ION THEORY

a) Opening of stomata.

- ✓During the day photosynthesis takes place producing energy in form of ATP.
- ✓ATP accumulates in the guard cells making the guard cells to draw potassium ions (from surrounding epidermal cells).
- ✓The osmotic pressure increases in the guard cells.
- ✓Water is drawn into the guard cells through osmosis.
- ✓This makes guard cells turgid.
- ✓The guard cells bulges outwards opening the stomata.

b) Closing of stomata.

- ✓At night photosynthesis does not take place.
- ✓The number of ATP molecules falls rapidly.
- ✓Potassium ions diffuse from the guard cells to adjacent epidermal.
- ✓This lowers the osmotic pressure of the guard cells.
- ✓The guard cells lose water to the adjacent epidermal cells through osmosis.
- ✓The guard cells become plasmolyzed and the stomata close.

MECHANISM OF GASEOUS EXCHANGE IN TERRESTRIAL PLANTS

- Gaseous exchange takes place in a spongy mesophyll.
- During the day air diffuses into large air spaces of spongy mesophyll through stomata the Carbon (IV) Oxide in the air diffuses into Photosynthetic cells in solution form
- During photosynthesis Carbon (IV) Oxide is used while oxygen is produced. Oxygen diffuses out of the leaf through stomata.
- During the night air diffuses into the air spaces (of spongy mesophyll), the air dissolves into film of moisture then oxygen diffuses into the cells and is used in respiration during which carbon (IV) oxide is produced.
- Carbon (IV) Oxide diffuses out of the leaf through stomata due to concentration/ diffusion gradient.
- Gaseous exchange also takes place through epidermis (of young leaves and stems).
- Epidermis of the root carries out gaseous exchange with air in the soil.
- Some plants have pneumatophores/breathing roots in which gaseous exchange occurs.
- Gaseous exchange also occurs through lenticels; (found in older stems)

A. ROOTS.

- Roots of young terrestrial plants obtain oxygen from the soil air by diffusion through the epidermis.

Adaptation of root's epidermis to gaseous exchange.

1. It has flattened cells to reduce diffusion distance.
2. It lacks cuticle to facilitate rapid/ faster diffusion of gases.

Mechanism of gaseous exchange in the roots.

- Oxygen is in higher concentration in the soil particles than in the roots hence diffuses into the cells/roots through the cuticle.
- Carbon (IV) oxide is in higher concentration in the roots than in the soil hence diffuses out of the cells/roots through the cuticle.
- In water logged soils gaseous exchange takes place through breathing roots called **pneumatophores**

Pneumatophores.

- These are specialized breathing roots in aquatic plants/ plants that grow on water logged soils.
- They contain pores used for gaseous exchange.

Adaptation of pneumatophores to gaseous exchange.

1. They are long and thin to increase surface area for diffusion of gases.

Mechanism of gaseous exchange through the pneumatophores.

- Oxygen is in higher concentration in the atmosphere than in the pneumatophores hence diffuses in through the pores.
- Carbon (IV) oxide is in higher concentration in the pneumatophores than in the atmosphere hence diffuses out through the pores.

2. STEMS.

- Gaseous exchange is through **lenticels**.

LENTICELS.

- These are openings found on the stems and roots of some woody plants.
- They are formed by loosely packed cork cells
- They are used for gaseous exchange.

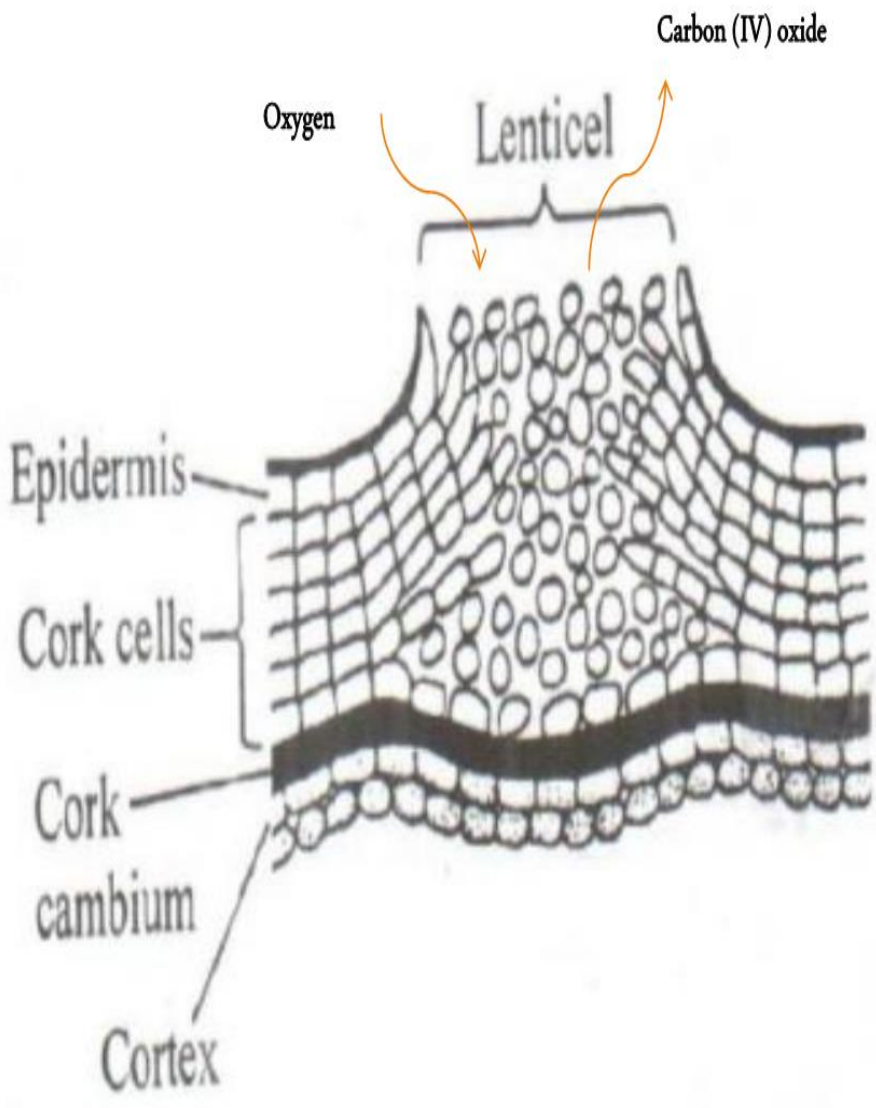
Adaptation of lenticels for gaseous exchange.

a) Cells are loosely arranged to create large air spaces to facilitate gaseous exchange.

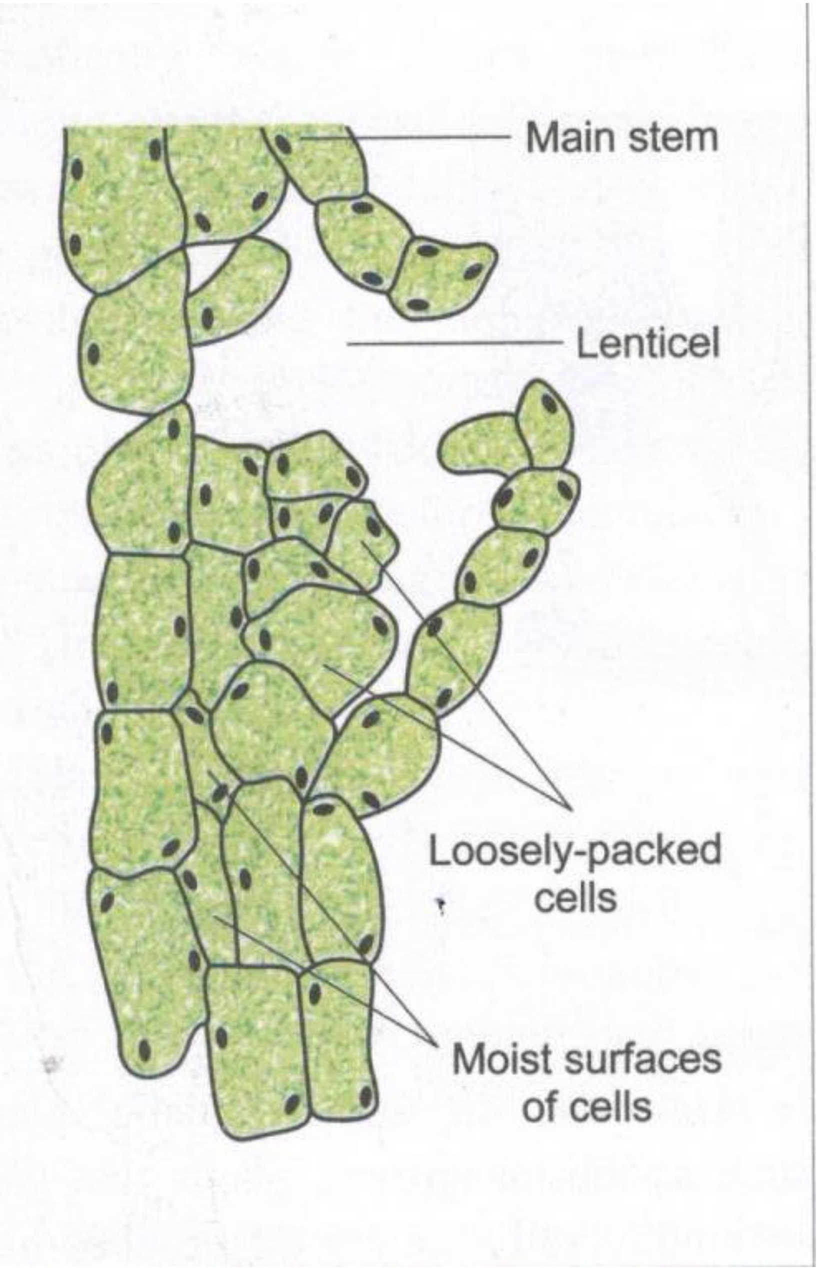
b) The cells have a film of moisture to dissolve respiratory gases allowing them to diffuse in solution form.

Mechanism of gaseous exchange through the lenticels.

- Oxygen concentration is higher outside/in the atmosphere than inside the lenticels. Oxygen then diffuses through the lenticels into the cells.
- Carbon (IV) oxide concentration is higher inside the lenticels than the outside. Carbon (IV) oxide then diffuses out through the lenticels into the atmosphere.



Structure of a lenticel



3. LEAVES.

- They use the stomata for gaseous exchange.
- The stomata have a film of water/moisture to dissolve the gases before they diffuse.

Mechanism of gaseous exchange through the stomata.

During the day.

- Carbon (IV) oxide concentration is higher outside the leaves/intercellular air spaces than the outside, it then diffuses in through the stomata and used for photosynthesis producing oxygen.
- Oxygen concentration increases in the sub-stomatal air spaces than the atmosphere, hence diffuses out through the stomata.

During the night.

- Oxygen concentration is higher in the atmosphere than intercellular/sub-stomatal air spaces.
- Oxygen then diffuses through the stomata then into the cells and is used for respiration producing carbon (IV) oxide.
- Carbon (IV) oxide concentration increases inside the leaves/intercellular air spaces than the outside. Carbon (IV) oxide then diffuses out of leaves into the atmosphere through the stomata

MECHANISM OF GASEOUS EXCHANGE IN AQUATIC PLANTS.

- Aquatic plants/ hydrophytes (e.g. water lily, water lettuce, water hyacinth**,** nymphaea) have numerous stomata on the upper surface of the leaf for gaseous exchange and for maximum water loss.
- They also contain **aerenchyma tissue** for gaseous exchange.

Ways in which floating leaves of aquatic plants are adapted to gaseous exchange.

1. Stomata found on upper epidermis to allow efficient gaseous exchange.
2. Presence of large air spaces/Aerenchyma tissues to enable it float/for buoyancy/ storage of air/gaseous exchange.
3. Absence of cuticle to enhance gaseous exchange.
4. Leaves of submerged plants are deeply dissected or highly branched to increase surface area for gaseous exchange.

Adaptations of aerenchyma tissue.

i. It has large air spaces to store air for gaseous exchange and for buoyancy/ floating on water.

ii. It is thin walled/ the cells are thin walled to reduce the distance travelled by gases hence faster diffusion of gases.

Mechanism of gaseous exchange through the aerenchyma tissue.

- Oxygen concentration is higher in the water than in aerenchyma tissue. Oxygen then diffuses into the aerenchyma tissue.
- Carbon (IV) oxide concentration is higher inside the aerenchyma tissue than water. Carbon (IV) oxide then diffuses out of aerenchyma tissue into water.

Study question

Describe how the gaseous exchange structures in plants are adapted to their function. (20mks)

- ✓The leaf has broad lamina to provide a large surface area for diffusion of gases.
- ✓The leaf blade is thin for carbon (IV) oxide/ gases to diffuse across a short distance.
- ✓The leaf has numerous stomata whose opening and closing is controlled by guard cells so that gases can diffuse in and out of the cell.
- ✓A leaf has large intercellular air spaces that create a large surface area for diffusion of gases in and out of the cells.
- ✓Spongy mesophyll cells have a thin film of moisture for gases to dissolve so as to diffuse in solution form.
- ✓Leaves and stem of hydrophytes have aerenchyma tissues with large air spaces for storage of air.
- ✓The cells of aerenchyma have thin walls for faster diffusion of gases.
- ✓Leaves of submerged plants are deeply dissected/ highly branched to increase surface area for diffusion of gases.
- ✓Epidermis of roots has thin flattened cells to reduce diffusion distance.
- ✓The epidermis lacks cuticle to facilitate rapid diffusion of gases.
- ✓Pneumatophores of hydrophytes are long and thin to increase surface area for diffusion of gases.
- ✓Lenticels are composed of loosely packed, thin walled cork cells to allow circulation of gases in the stem.
- ✓The cells (lenticels) have thin films of moisture for gases/ oxygen to dissolve and diffuse in solution form.

GASEOUS EXCHANGE IN ANIMALS.

Respiratory surfaces in animals.

Type of respiratory surface	Environment/ medium of gaseous exchange	Example of organism
1. Cell membrane.	Water	Amoeba
2. Gill filaments.	Water	Fish
3. Tracheoles.	Air	Insects
4. Alveoli	Air	Mammals. Birds. Frogs. Reptiles.
5. Skin.	Water. Air	Frog. Earthworm.
6. Buccal cavity.	Air	Frog.

Characteristics of respiratory surfaces of animals

1. They have a large surface area.
2. They have a moist surface.
3. They have large capillary network.
4. They have a thin lining/ they are thin.

Adaptations of respiratory surfaces of animals.

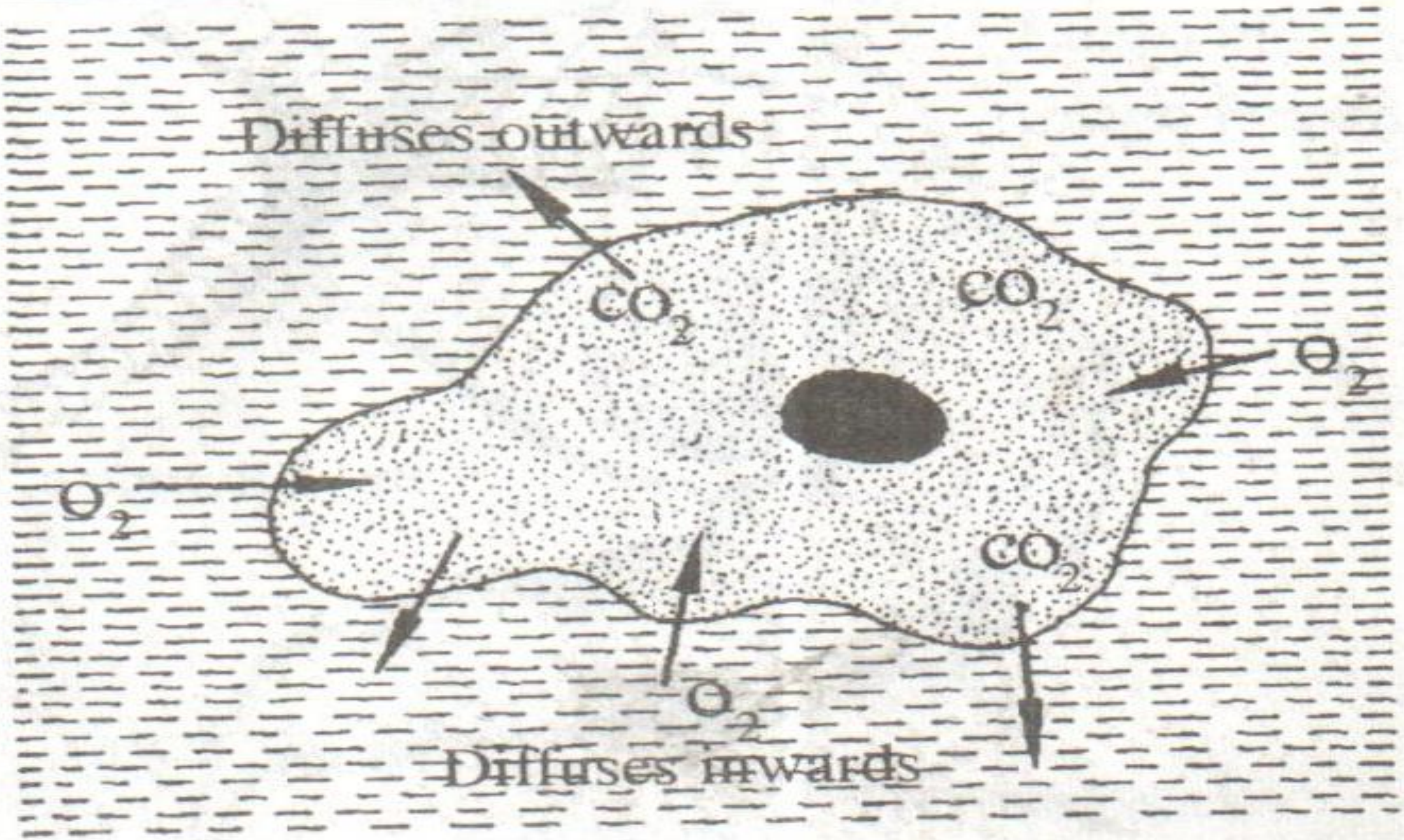
1. They are many/numerous/highly branched/dissected to provide a large surface area across which large amount of gases diffuse.
2. They are moist to dissolve gases/allow them diffuse in solution form.
3. They are made of thin membrane/epithelium/one cell thick wall to reduce diffusion distance for faster diffusion of gases.
4. They are highly vascularized/have dense network/many capillaries to carry away oxygen and bring carbon (IV) oxide/ create a steep concentration/ diffusion gradient, for efficient diffusion of gases.
5. They have a large surface area for efficient gaseous exchange.

1. GASEOUS EXCHANGE ON PROTOZOA (AMOEBA)

- Amoeba is a single celled organism found in water.
- Its entire body is in contact with the surrounding water and has a large surface area to volume ratio hence does not require elaborate/ complex gaseous exchange system..
- Therefore gaseous exchange is through simple diffusion across the cell membrane.

Mechanism of gaseous exchange in amoeba.

- Oxygen dissolved in the surrounding water is in higher concentration than in the cytoplasm hence diffuses into the cytoplasm across the cell membrane.
- Carbon (IV) oxide is in higher concentration in the cytoplasm than the surrounding water hence it diffuses out into the water across the cell membrane.



. 2.6: Gaseous exchange in an amoeba

2. <u>GASEOUS EXCHANGE IN INSECTS e.g. grasshopper/ locust.</u>

- The gaseous exchange/ breathing system in insects is called **<u>tracheal system.</u>**

<u>Parts of a tracheal system</u>

A. **<u>Spiracles-</u>** these are external openings found on either side of the abdomen and thorax of an insect. They allow entry of air from the atmosphere into the body.

<u>Adaptation of spiracle.</u>

i. It has a muscular valve that controls its opening.

ii. It has hairs to trap dust and prevent excessive loss /evaporation of water from body tissues.

B. **<u>Trachea-</u>** this is a tube which arises from spiracles.

<u>Function/ role of trachea.</u>

- It carries oxygen to and carbon (IV) oxide away from tracheoles.

<u>Adaptations of trachea.</u>

i. It has spiral bands of chitin to keep them open and prevent them from collapsing during breathing.

C. **<u>Tracheoles-</u>** they branch from the trachea and branch into the body tissues/ cells.

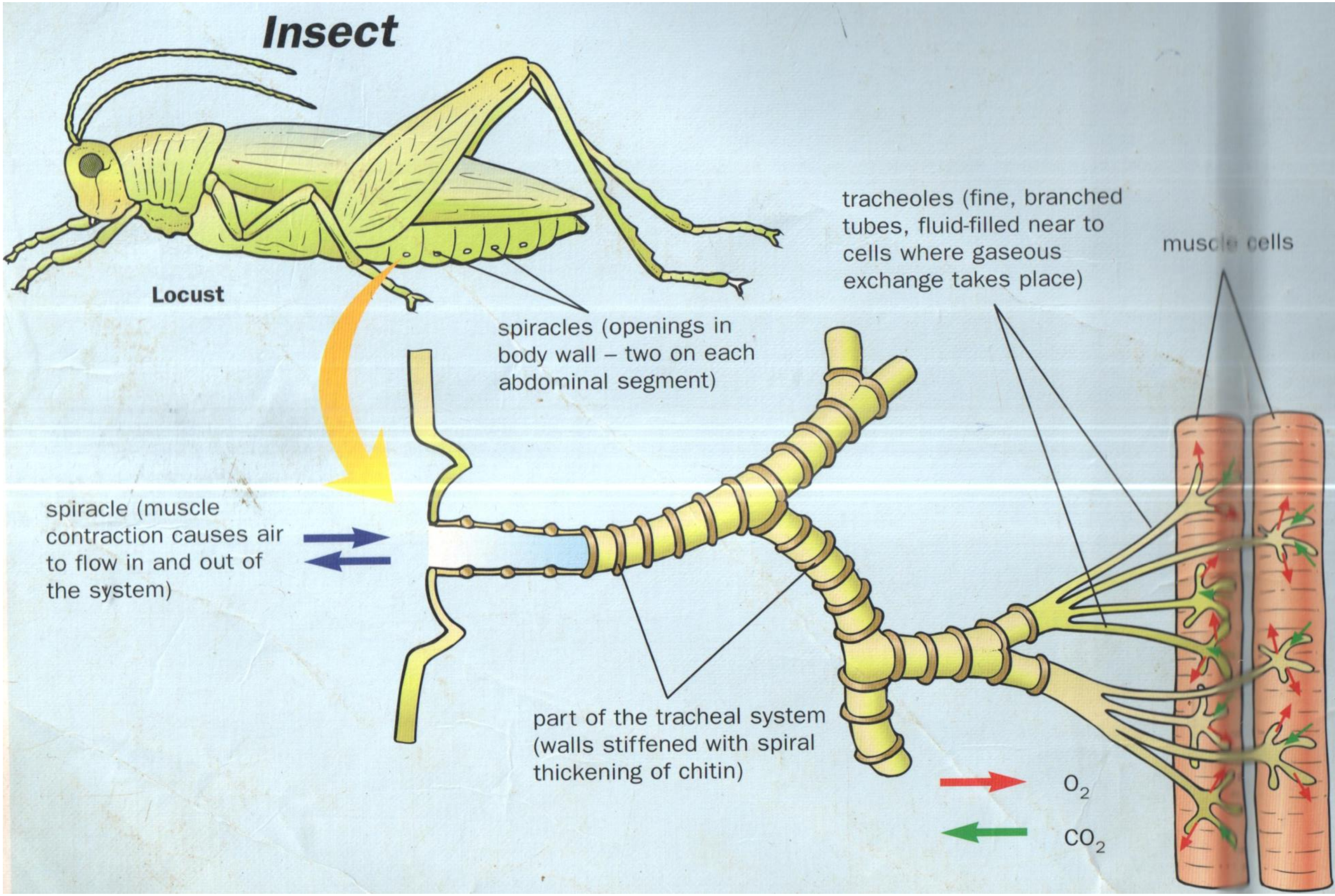
<u>Adaptations of tracheoles.</u>

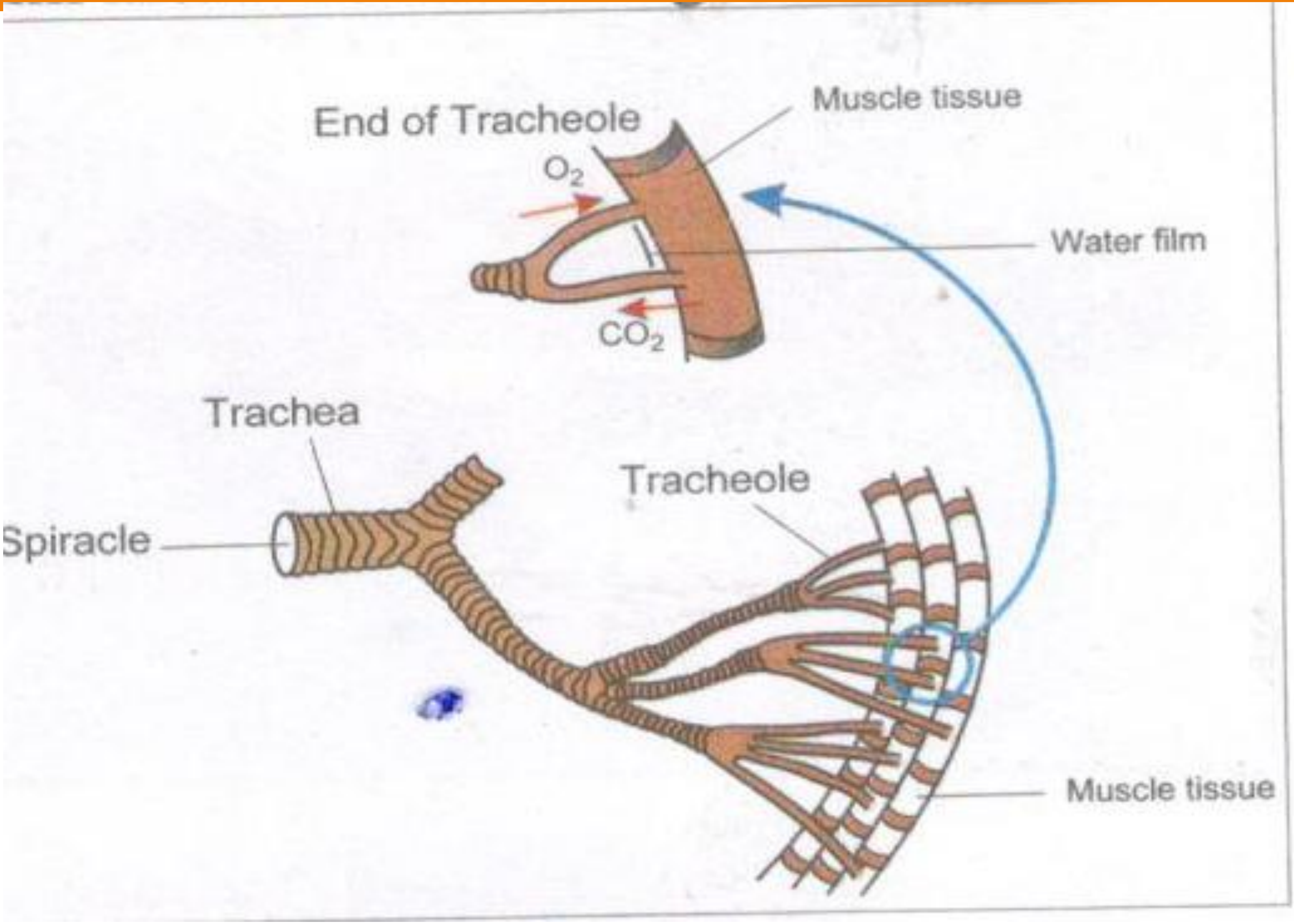
i. Tracheoles are many/numerous to increase the surface area for gaseous exchange.

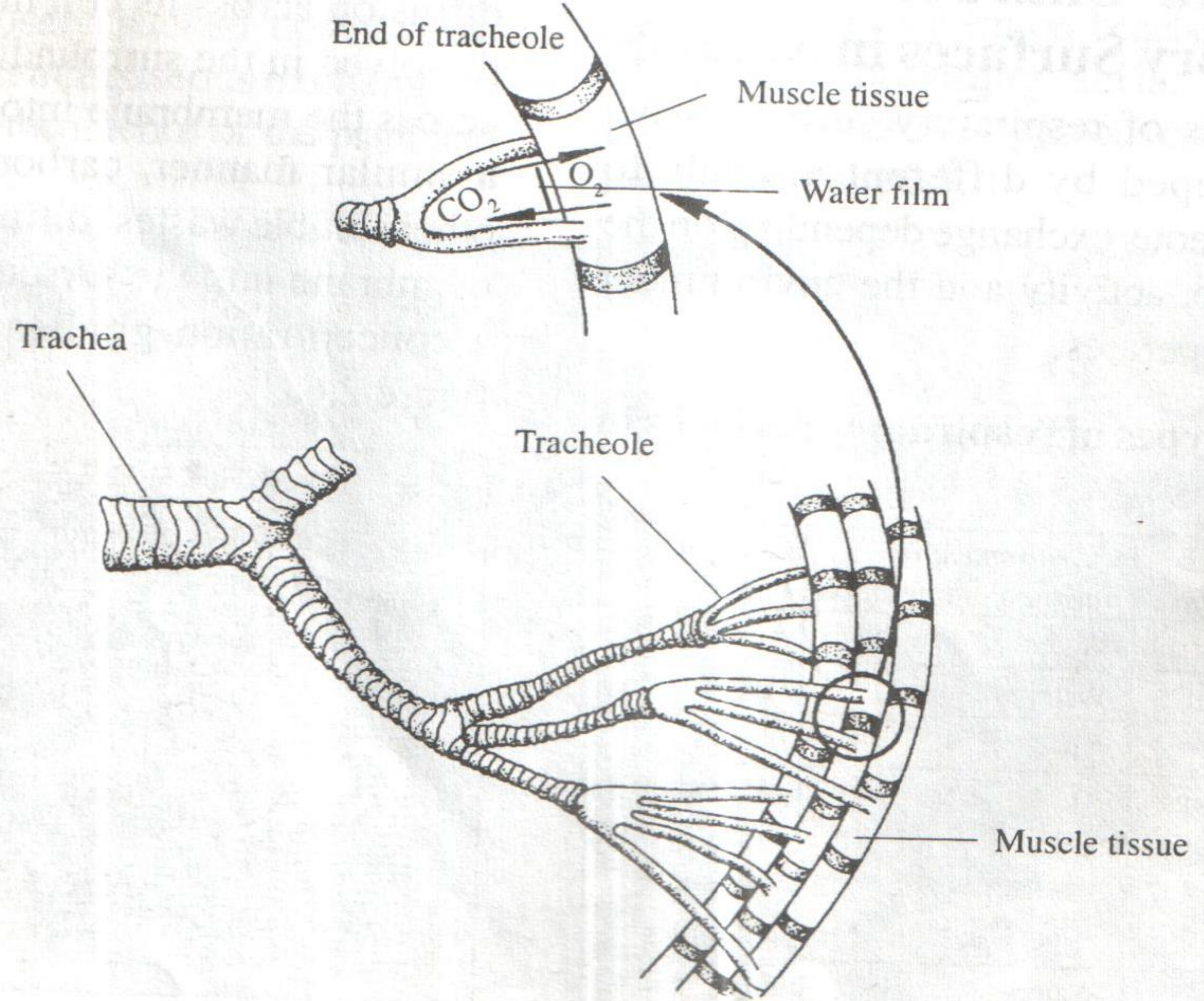
ii. The tracheoles are moist to dissolve gases allowing them to diffuse in solution form.

iii. Tracheoles walls are thin thus reducing the distance of diffusion hence faster diffusion of gases.

iv. Tracheoles lack chitin to provide a large surface area for gaseous exchange and make them thin to reduce distance for diffusion of respiratory gases.


Insect
Locust
spiracles (openings in body wall – two on each abdominal segment)
tracheoles (fine, branched tubes, fluid-filled near to cells where gaseous exchange takes place)
muscle cells
spiracle (muscle contraction causes air to flow in and out of the system)
part of the tracheal system (walls stiffened with spiral thickening of chitin)
O_2
CO_2


End of Tracheole
O_2
CO_2
Muscle tissue
Water film
Trachea
Spiracle
Tracheole
Muscle tissue



End of tracheole
Muscle tissue
O_2
CO_2
Water film
Trachea
Tracheole
Muscle tissue

MECHANISM OF GASEOUS EXCHANGE IN INSECTS.

Inhalation/inspiration/breathing in.

i. Abdominal muscles relax making the tracheal system and the abdomen to expand.

ii. This increases the volume of the tracheal system decreasing pressure.

iii. The spiracle valves open and air rushes in after which the valves close.

iv. Air is forced into the trachea and finally into the tracheoles by muscle movements.

v. Oxygen diffuses into watery fluid in the tracheoles and finally into the cells.

vi. Carbon (IV) oxide which is at higher concentration within the cells diffuse into the fluid in the tracheoles and then into tracheal system.

Exhalation/breathing out/expiration.

i. Abdominal muscles contract reducing the volume of the tracheal system increasing pressure within the tracheal system.

ii. This forces air from the tracheoles to the trachea and out through the spiracles.

GASEOUS EXCHANGE IN AQUATIC INSECTS.

- Insects that live in water e.g. dragonfly or mayfly larvae-nymphs use tracheal gills for gaseous exchange.
- Other aquatic insects e.g. mosquito larvae use external gills for gaseous exchange.
- The mosquito pupae use spiracles located on respiratory siphon.
- When the larvae comes to the surface of water the siphon opens to take in water and is closed by valves when the larva submerges.
- Some adult insects e.g. water beetles and water bugs use water bubbles of air trapped by hairs on their body surface.

Study question.

- Name the structure used for gaseous exchange in:

a) Mosquito larvae- ***external gills.***

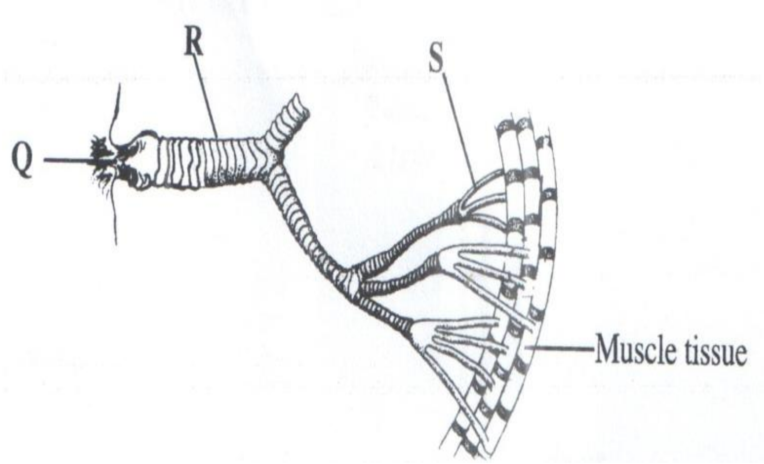
b) Mosquito pupae- ***Siphon.***

c) Mayfly nymph- ***tracheal gills.***

d) Adult grasshopper- ***tracheoles.***

Study questions

1. The diagram below shows a gaseous exchange system in a locust.



a) Name the parts labelled Q, R and S.

Q- Spiracle; R- Trachea; S- Tracheole

b) State the function of part labeled R.

- ***It carries oxygen to and carbon (IV) oxide away from tracheoles.***

c) How are the parts labeled Q, R and S adapted/ suited to their function?

Part Q

- ***It has a muscular valve that controls its opening.***
- ***It has hairs to trap dust and prevent excessive loss /evaporation of water from body tissues.***

Part R

- ***It has spiral bands of chitin to keep them open and prevent them from collapsing during breathing.***

Part S.

- ***It is thin walled to reduce the distance travelled by gases hence faster diffusion.***
- ***It lacks spiral bands of chitin to increase the surface area for gaseous exchange.***

2. Describe the route taken by air from the atmosphere to the cells in insects.

- ***From the atmosphere air enters into the trachea through the spiracles, then into the tracheoles and finally into the cells***

3. A rare disease was found to attack the respiratory system of insects. Giving a reason, name the parts of the insect that are likely to be affected by the disease.

- ***Spiracles, trachea and tracheoles because they form the respiratory system of insects.***

3 . GASEOUS EXCHANGE IN AMPHIBIANS e.g. frog.

- Amphibians e.g. frogs live both in land and water.
- They use the following structures for gaseous exchange:

a) Mouth/ buccal cavity.

b) Lungs.

c) Skin.

A) **BUCCAL/ MOUTH CAVITY.**

- The lining of the mouth cavity is thin, moist and well supplied with blood capillaries (vascularised) and gaseous exchange takes place across the lining.

MECHANISM OF EXCHANGE THROUGH THE BUCCAL CAVITY

Inhalation/breathing in/inspiration.

a) The mouth floor is lowered, increasing the volume in the mouth cavity and decreasing pressure.

b) The air in the atmosphere flows into the mouth cavity through the nostrils.

c) Concentration of oxygen is higher in inhaled air hence it diffuses into blood capillaries across the lining of the mouth cavity and is carried by haemoglobin to all parts of the body.

d) Carbon (IV) oxide which is higher in concentration in blood diffuses into the mouth cavity through the lining.

Exhalation/expiration/breathing out.

a) The floor of the mouth is raised.

b) This decreases the volume in the mouth cavity increasing pressure.

c) Air is forced out of mouth cavity into the atmosphere through the nostril.

B) LUNGS.

Inhalation/breathing in/inspiration.

i) The floor of the mouth is lowered causing the nostrils to open.

ii) The volume of the mouth cavity increases, decreasing pressure

iii) Air rushes in through the nostrils into the mouth cavity.

iv) When air is in the mouth, the nostrils close.

v) The floor of the mouth cavity is raised.

vi) This reduces the volume but increases pressure in the mouth.

vii) Air is forced into the lungs where exchange of gases take place.

Mechanism of gaseous exchange in the alveoli.

- Oxygen which is at higher concentration in the inspired air than in blood. It dissolves into the moist lining of the alveoli and diffuses across the wall of capillaries into blood and transported to all parts of the body by haemoglobin.
- Carbon (IV) oxide is in higher concentration blood than alveolar cavity hence it diffuses across the wall of capillaries into alveoli.

Exhalation/expiration/breathing out

i. The nostrils and the mouth remain closed.

ii. The floor of the mouth is lowered. This increases the volume of the mouth cavity but decreases pressure.

iii. This forces air from the lungs to the mouth cavity.

iv. The mouth floor is raised and the nostrils are opened.

v. This decreases the volume of the mouth cavity increasing pressure.

vi. This forces air out through the nostrils.

C) **SKIN.**

- The frog's skin is thin, moist and highly vascularised.

Mechanism of gaseous exchange through the skin.

- Oxygen is at a higher concentration in the atmosphere/ water than in the blood, it diffuses from the atmosphere/ water into the blood capillaries through the moist skin.
- Carbon (IV) oxide is at a higher concentration in the blood of the frog than in the atmosphere/ atmosphere, it diffuses from the blood into water or atmosphere through the moist skin.

4. **GASEOUS EXCHANGE IN BONY FISH E.G. TILAPIA.**

- Fish lives in water that contains dissolved respiratory gases.
- The respiratory surfaces of fish are gill filaments.
- The breathing system of fish consists of:

a) Mouth/ buccal cavity.

b) Gills.

c) Opercular cavity.

d) Operculum- which protects the gills.

PARTS OF A GILL.

1. **Gill bar/ gill arch-** it is a bony structure which is curved to provide large surface area for attachment of gill filaments and gill rakers.

- It is hard/ bony to provide a surface for attachment of gill filaments and rakers.

2. **Gill rakers-** they are **teeth/rake-like**/ **sharp pointed** to trap/filter solid particles present in water preventing them from reaching and destroying the delicate gill filaments/ to protect the delicate gill filaments from mechanical damage.

3. **Gill filaments-** they provide a site for gaseous exchange/ form the surface over which gases diffuse in and out of blood.

Adaptations of the gill filaments.

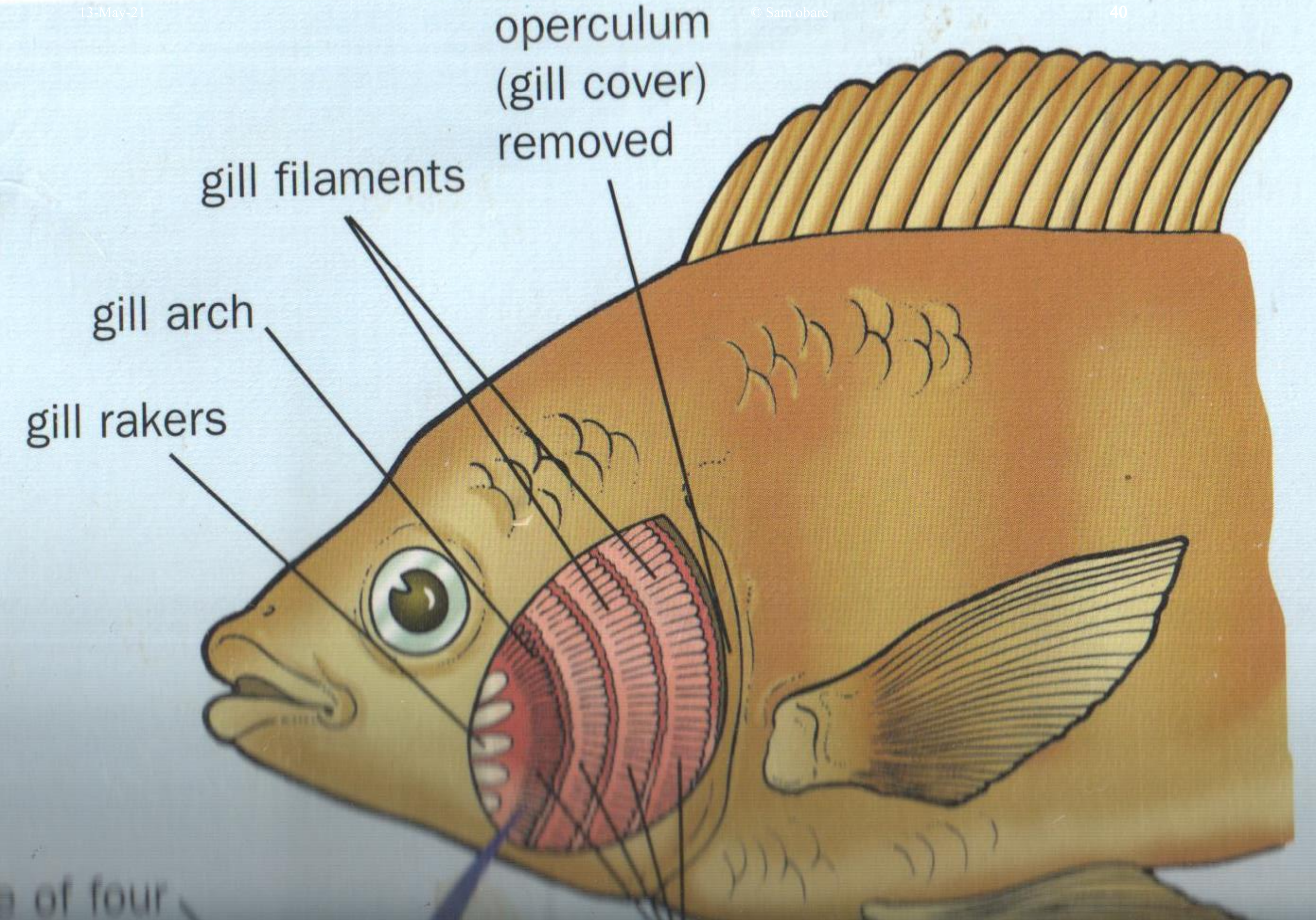
a) They are well supplied with blood capillaries (well vascularised) for transportation of respiratory gases (i.e. to bring in carbon (IV) oxide and carry away oxygen.

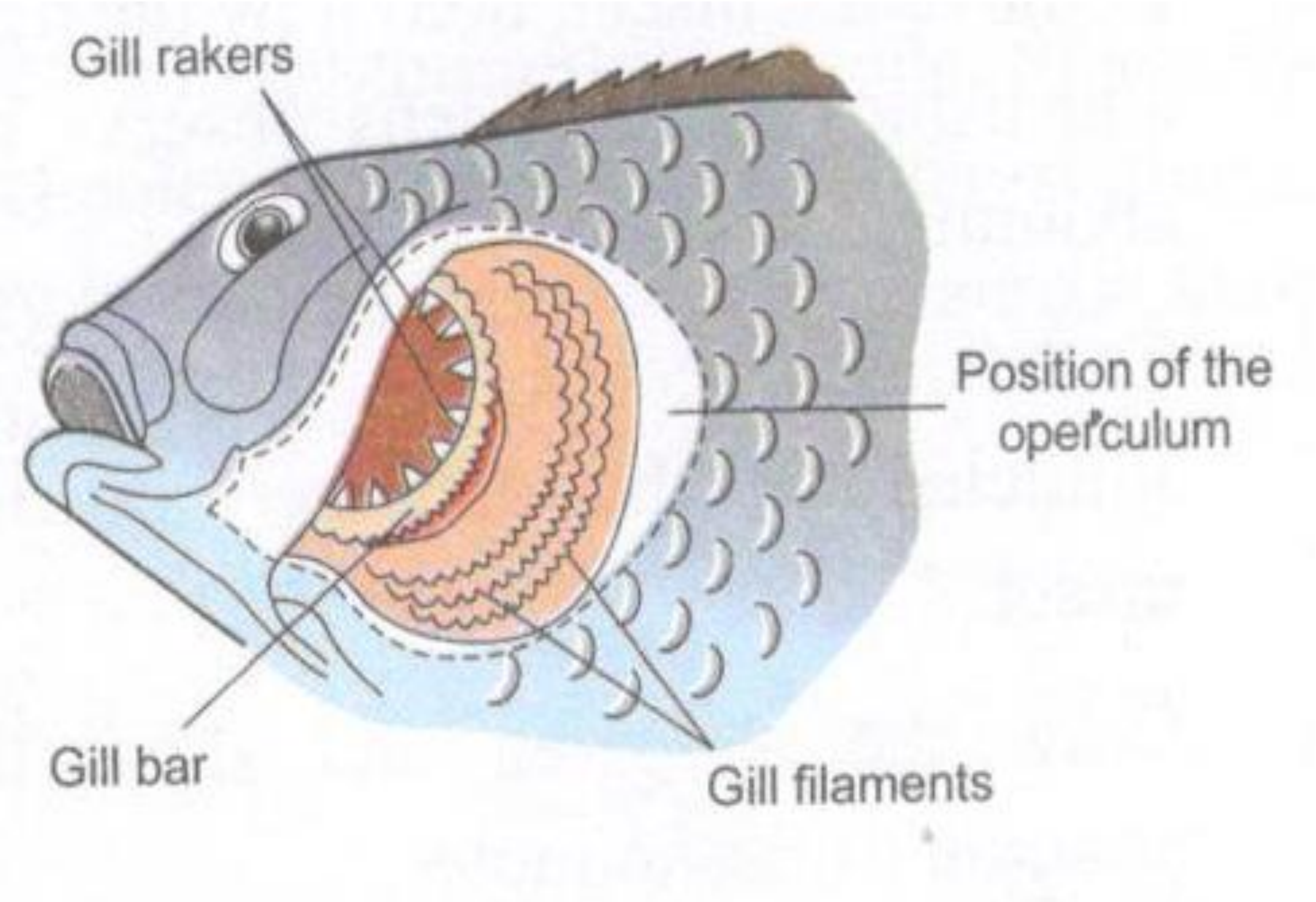
b) They are many/numerous and long to increase the surface area for gaseous exchange.

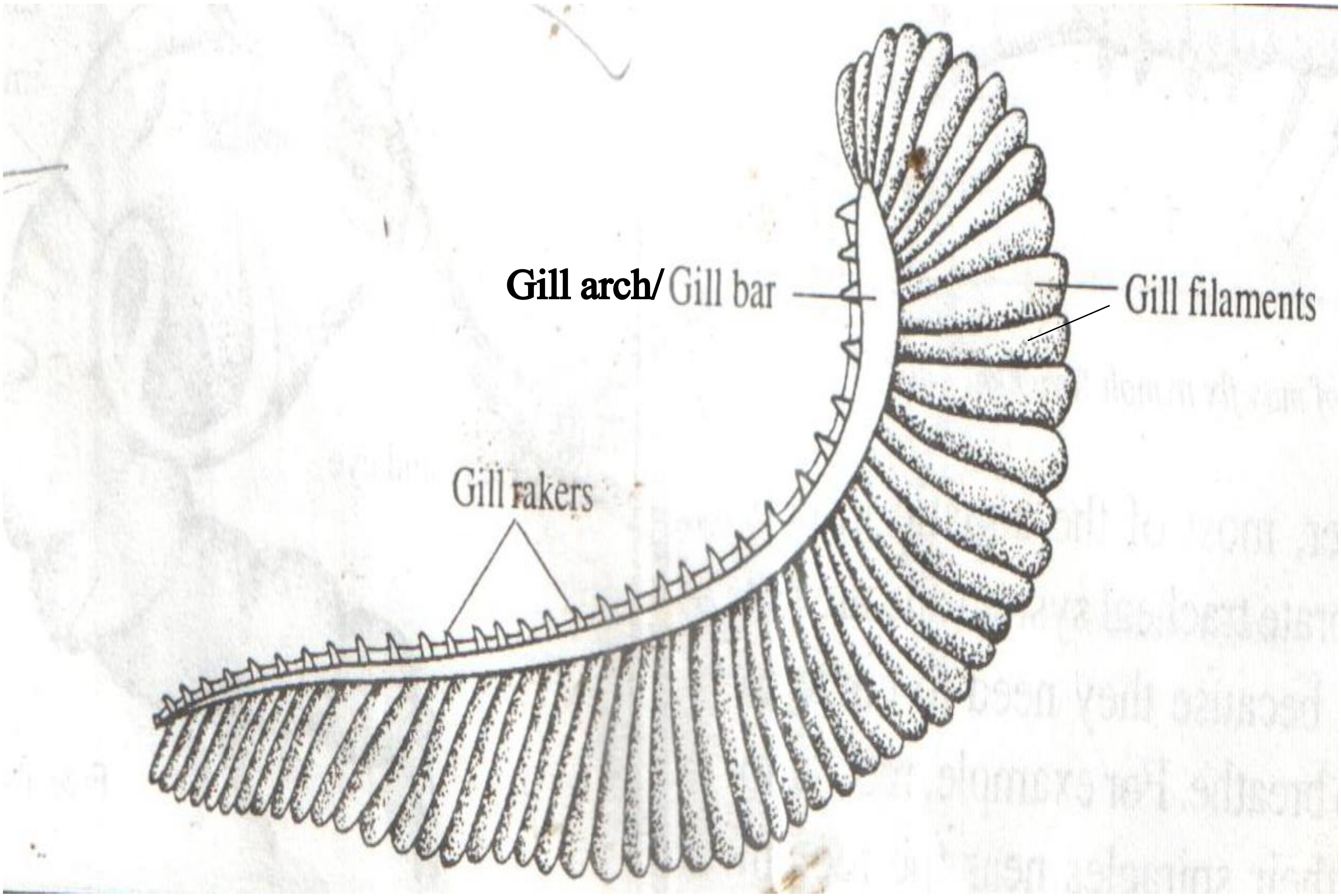
c) They are covered with a thin epithelium to reduce distance hence faster diffusion of respiratory gases.

Study question

How is the gill of a fish adapted to its function?


operculum
(gill cover)
removed
gill filaments
gill arch
gill rakers
of four


Gill rakers
Position of the operculum
Gill bar
Gill filaments



Gill of fish

MECHANISM OF GASEOUS EXCHANGE IN THE GILLS OF A BONY FISH

i. The floor of the mouth cavity is lowered/ the mouth is opened.

ii. This increases the volume of the mouth cavity and reduces pressure.

iii. Water rushes/ flows into the mouth/ mouth cavity.

iv. The fish closes the mouth/ the floor of the mouth is raised.

v. This decreases the volume but increases the pressure.

vi. The operculum bulges outwards increasing the volume of the opercular cavity and decreasing its pressure.

vii. Water from the mouth enters the gill chamber/ opercular cavity and flows over the gills in a countercurrent direction to blood flow in the capillary.

viii. Oxygen which is in higher concentration in water diffuses into blood capillaries.

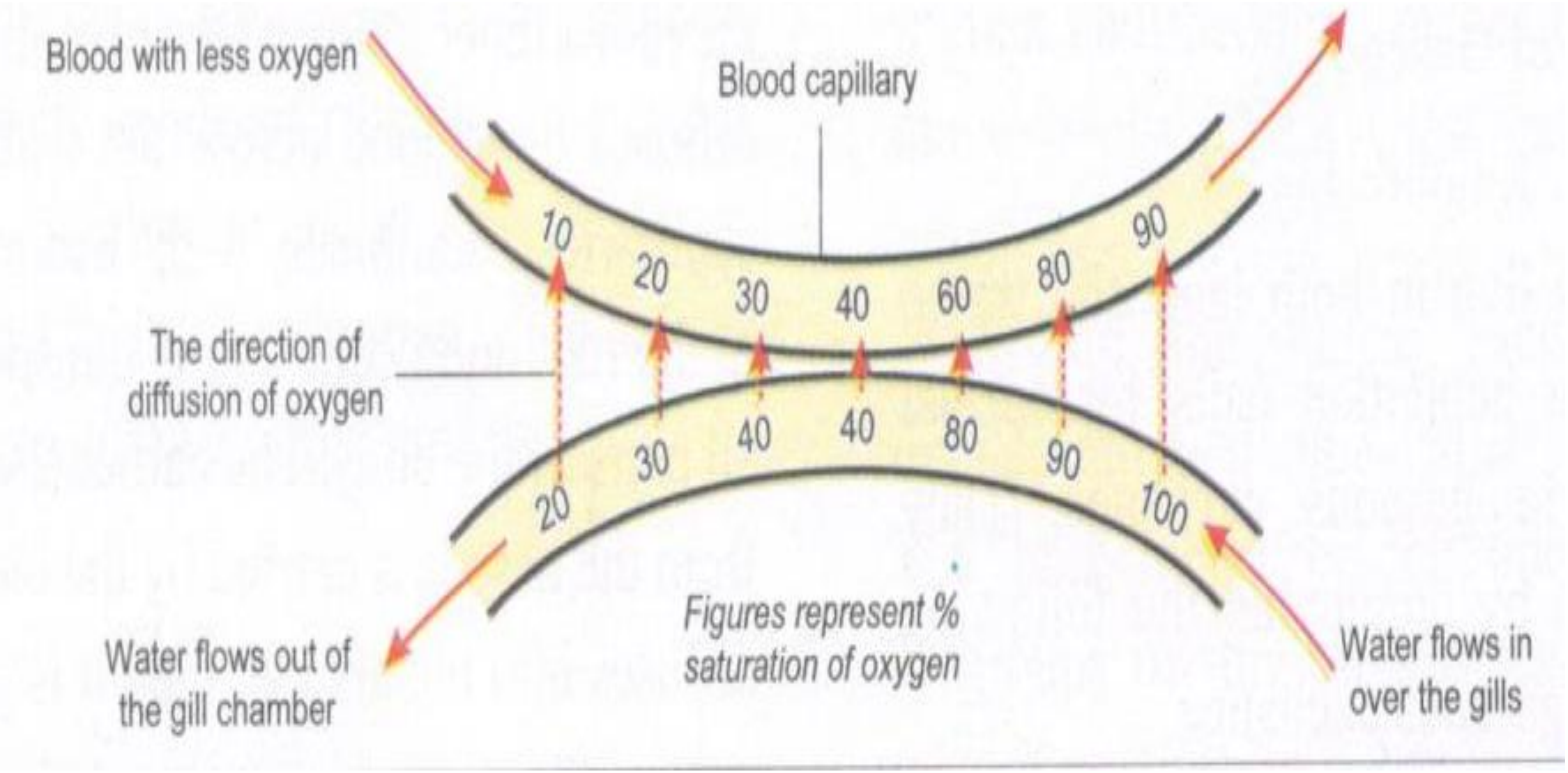
ix. Carbon (IV) oxide which is in higher concentration in blood diffuses out into water.

x. Water then flows out of gill chamber through the opercular opening.

Importance of countercurrent flow.

- It creates and helps maintain a steep concentration gradient necessary for maximum gaseous exchange.

Counter current flow in fish



Study questions

1. Describe how oxygen dissolved in water reaches the capillaries inside the gill filaments.

- *The fish opens the mouth increasing volume and lowering the pressure in the mouth/ buccal cavity and water rushes in.*
- *The mouth closes lowering the volume and increasing pressure which forces water into the gills/ gill chamber/ opercular cavity.*
- *Water containing a lot of oxygen flows over the gills/ gill filaments in a counter current direction to the blood in the capillary.*
- *Oxygen which is in higher concentration in water diffuses into the capillaries in the gill filaments.*

2. Explain why a bony fish dies shortly after being removed from water.

- *Fish uses dissolved oxygen for gaseous exchange and after removal from water the gill filament epithelium dries up, gill filaments clamp together reducing the surface area for gaseous exchange.*
- *Oxygen therefore lacks a moist surface to dissolve causing death due to suffocation.*

5. GASEOUS EXCHANGE IN MAMMALS e.g. Man.

- Mammals use alveoli for gaseous exchange.
- The breathing system in mammals consists of the following:

a) **Nose-** It has two openings called nostrils.

Adaptations.

i) Has hairs to trap dust and other solid particles thus preventing them from entering into the lungs.

ii) It has mucus secreting cells which produce mucus that traps dust and other micro-organisms.

iii) It is highly vascularized in order to warm the air entering into the lungs.

iv) Has olfactory cells which detect smell thus enabling the organism escape unpleasant or poisonous fumes.

Study question

Why is it advantageous to breathe through the nostrils?

- Air passing through the nostrils is filtered by hairs and mucus to trap dust particles.
- Air is also warmed by blood ensuring that it is clean and warm unlike in the mouth.
- Controlled amount of air is taken through the nose.
- An individual is able to detect the smell of air breathed in.

b) **Trachea/ wind pipe**

Adaptations.

i) It is made up of C shaped rings of cartilage to keep it open/ prevent them from collapsing during breathing.

- The rings are incomplete/c-shaped to reduce friction/ discomfort during swallowing.

ii) It has mucus secreting cells which secretes mucus to trap dust particles and moisten the air.

iii) The lumen of trachea has ciliated epithelium, cilia beat in waves and move mucus and foreign particles towards the pharynx away from lungs.

Note: During swallowing, the **epiglottis** prevents food from entering into the trachea.

- The trachea enters the lungs and divides to form to bronchi (singular- bronchus)

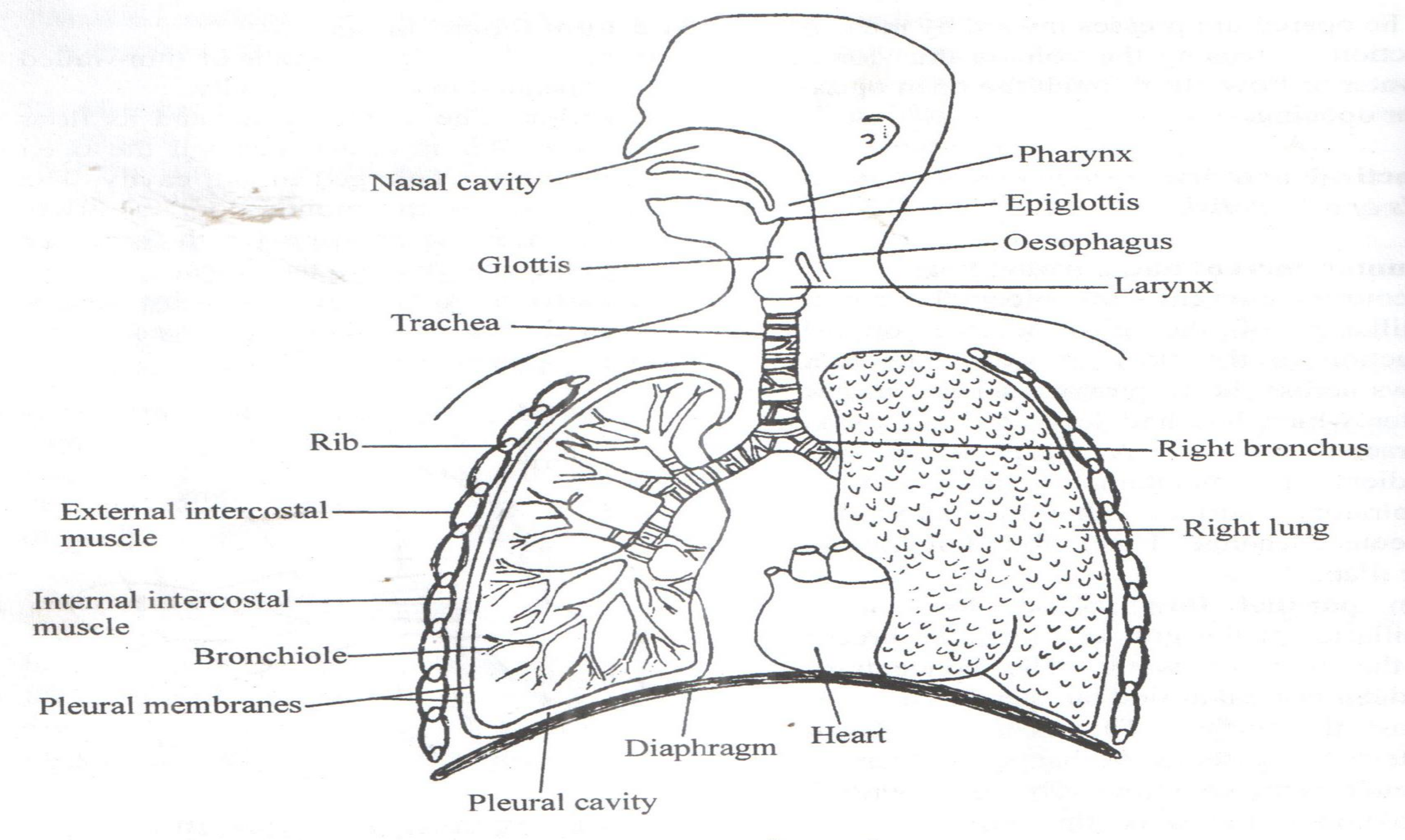
c) **Lungs-** they are found in the chest cavity and enclosed by a double membrane called **pleural membranes** which secrete **pleural fluid.**

- The space between the two membranes is called **pleural cavity** which is filled with a fluid called **pleural fluid.**
- The pleural fluid reduces friction during breathing hence makes the lungs move freely in the chest cavity.
- The bronchi in the lungs have rings of cartilage to keep them open.
- Each **bronchus** divides to form **bronchioles,** bronchioles divide to form **alveoli (singular- alveolus)** which is covered by a fine network of capillaries.

Adaptations of mammalian lungs

1. They are highly vascularized/ supplied with numerous capillaries to remove respiratory gases from the surface to avoid saturation.
2. They are moist to allow respiratory gases diffuse in solution form.
3. Has highly folded alveoli with many air sacs to increase surface area for gaseous exchange.
4. The alveoli are thin to reduce diffusion distance hence faster diffusion of respiratory gases.
5. They are elastic/ spongy to allow expansion/ accommodate large volume of gases.
6. They are ventilated/ connected to outside/ supplied with bronchi to avail gases for exchange.

Respiratory system in man.



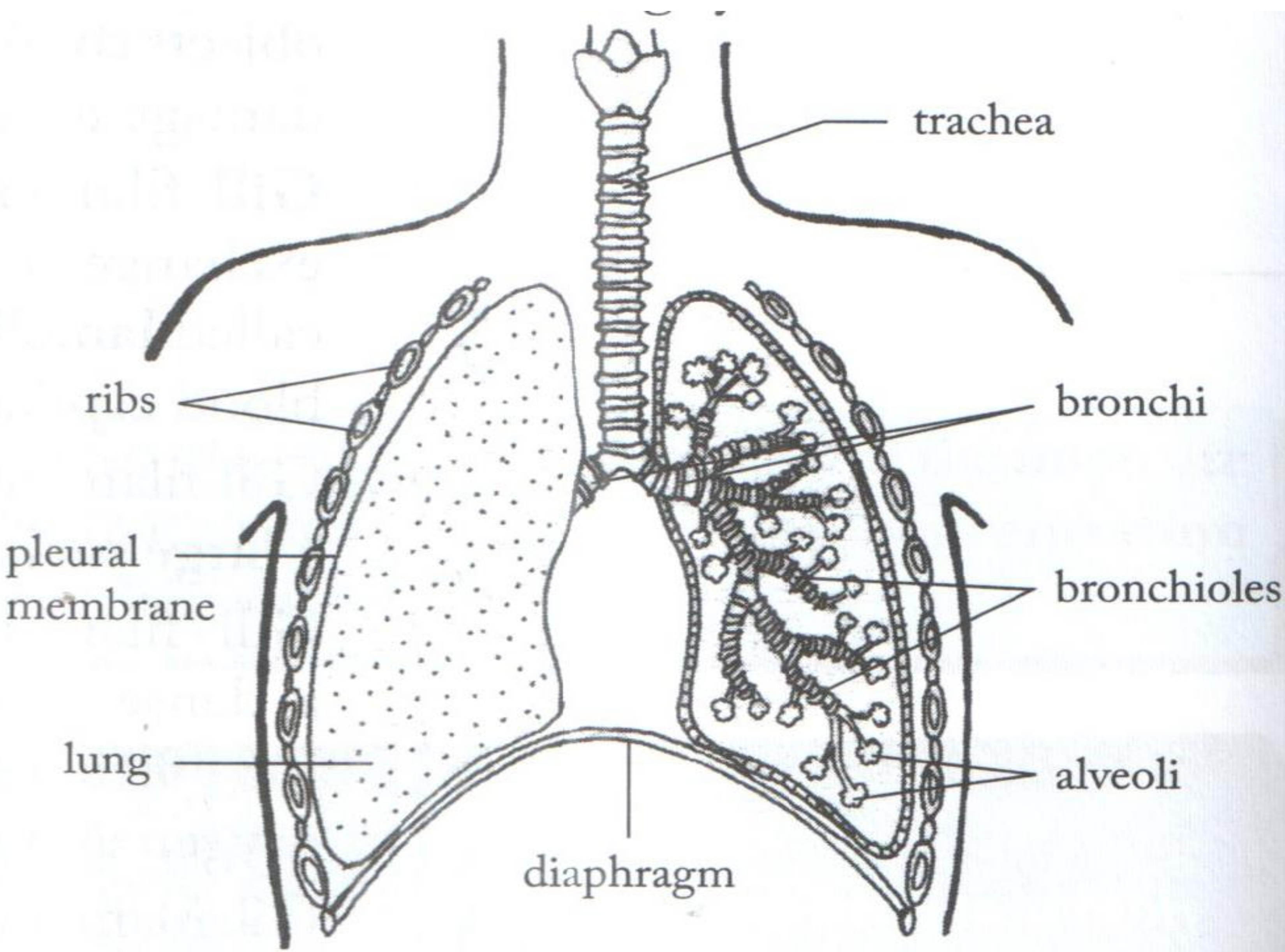
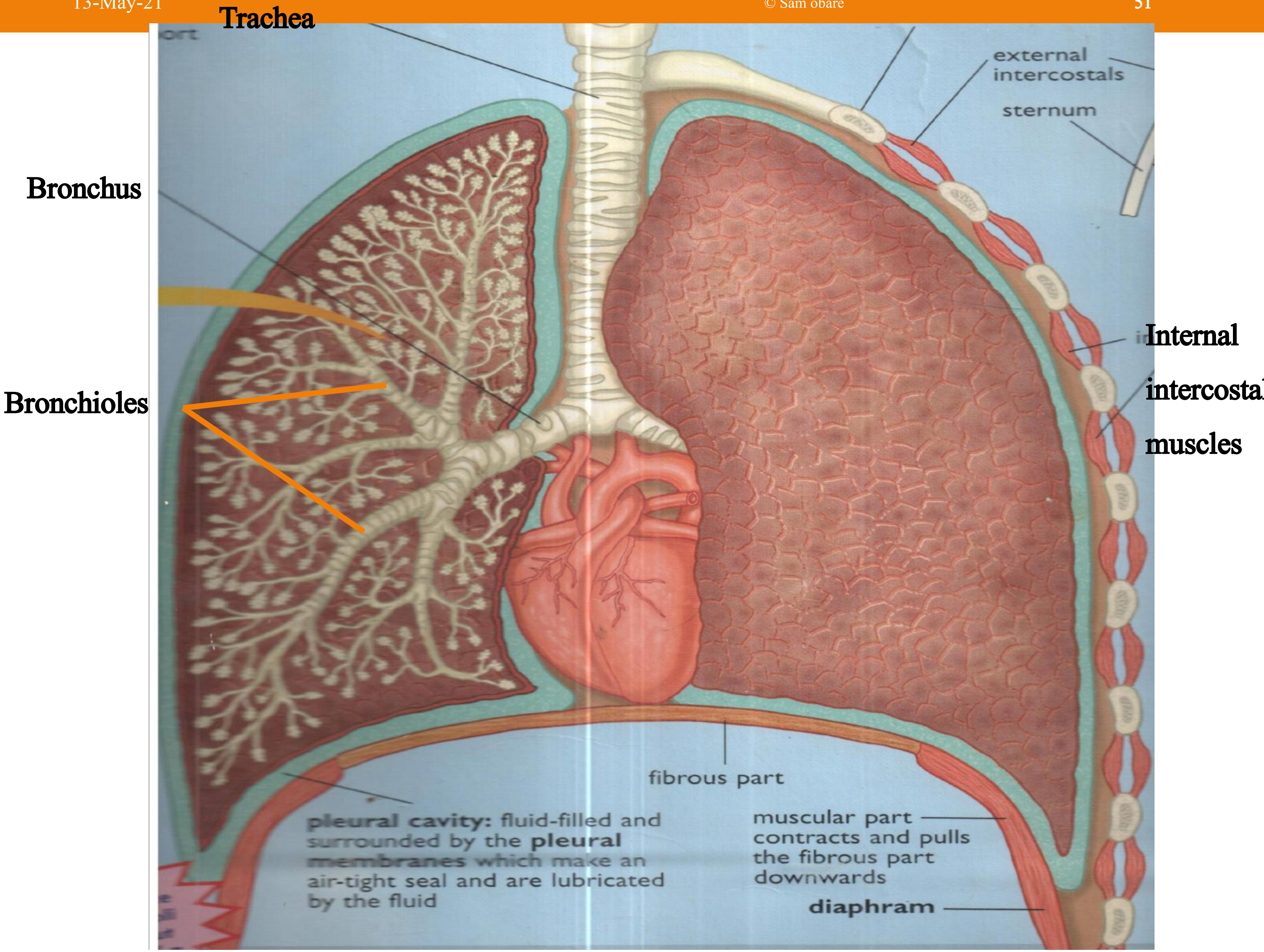
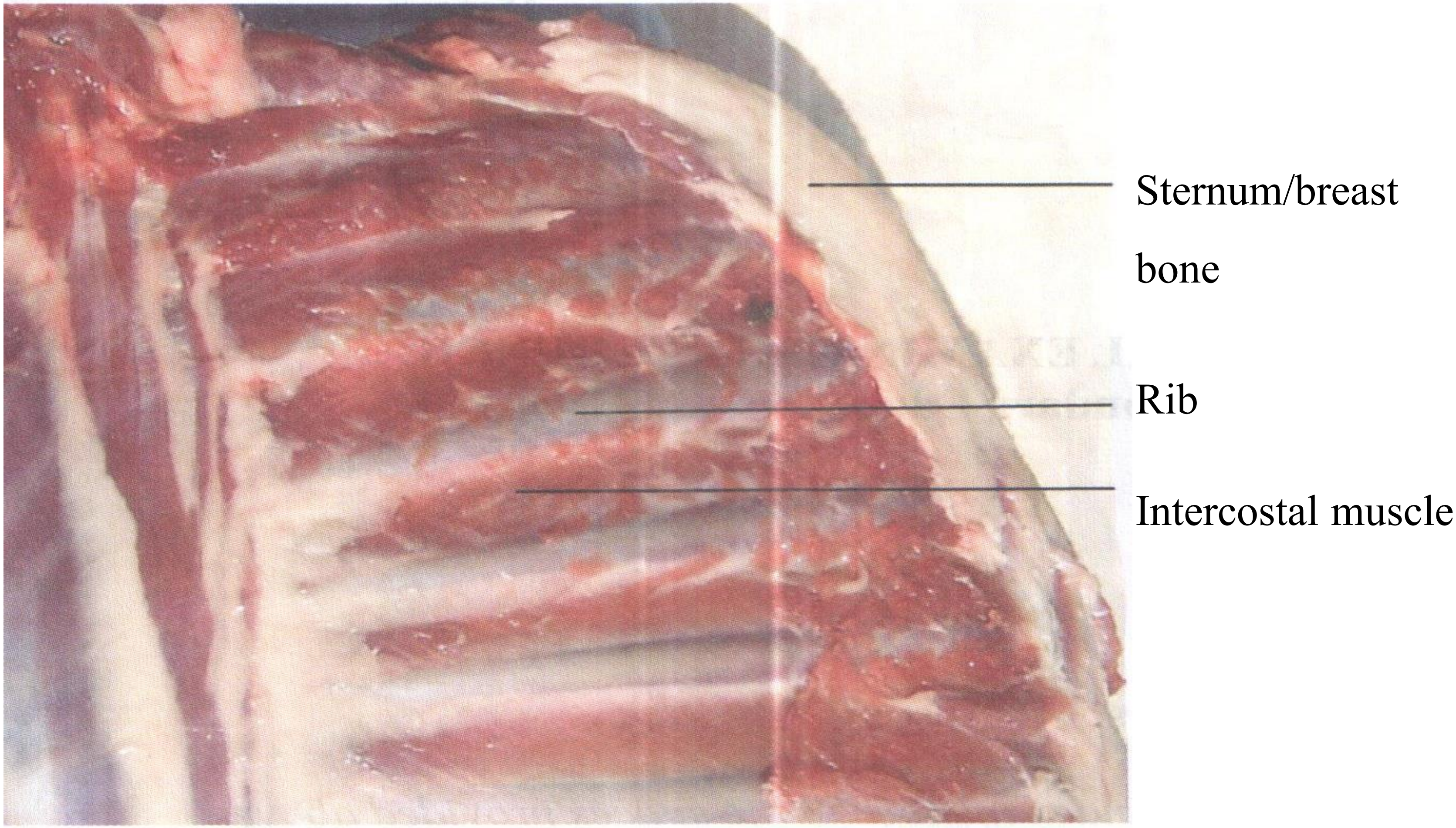


Fig 3.25: Mammalian breathing system


Trachea
Bronchus
Bronchioles
external intercostals
sternum
Internal intercostal muscles
fibrous part
pleural cavity: fluid-filled and surrounded by the pleural membranes which make an air-tight seal and are lubricated by the fluid
muscular part contracts and pulls the fibrous part downwards
diaphram


Sternum/breast
bone
Rib
Intercostal muscle

MECHANISM OF BREATHING IN MAMMALS.

Inhalation/inspiration/breathing in.

i. Internal intercostal muscles relax while external intercostal muscles contract.

ii. This causes the rib cage (ribs) to move upwards and outwards.

iii. The diaphragm muscles contract which causes the diaphragm to flatten from its normal dome shape.

iv. This increases the volume of thoracic cavity and decreases the pressure inside it.

v. The atmospheric pressure being higher than the pressure inside the thoracic cavity forces air to rush into the lungs through the nose and trachea inflating the lungs.

Expiration/exhalation/breathing out.

i. Internal intercostal muscles contract while external intercostal muscles relax.

ii. This causes the rib cage to move downwards and inwards.

iii. The diaphragm muscles relax causing the diaphragm to assume a dome shape.

iv. These movements decrease the volume of the thoracic cavity while increasing pressure.

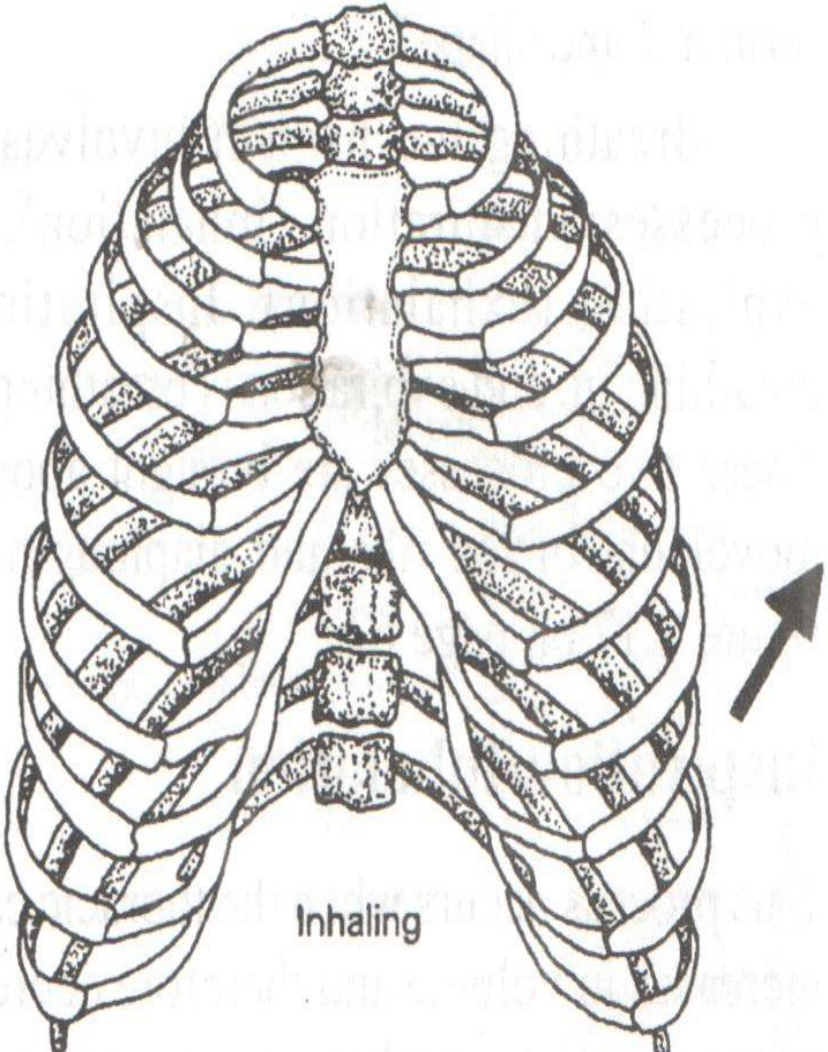
v. These movements decrease the volume of thoracic cavity and increase pressure inside it.

vi. The air is forced out of the lungs into the atmosphere and the lungs deflate.

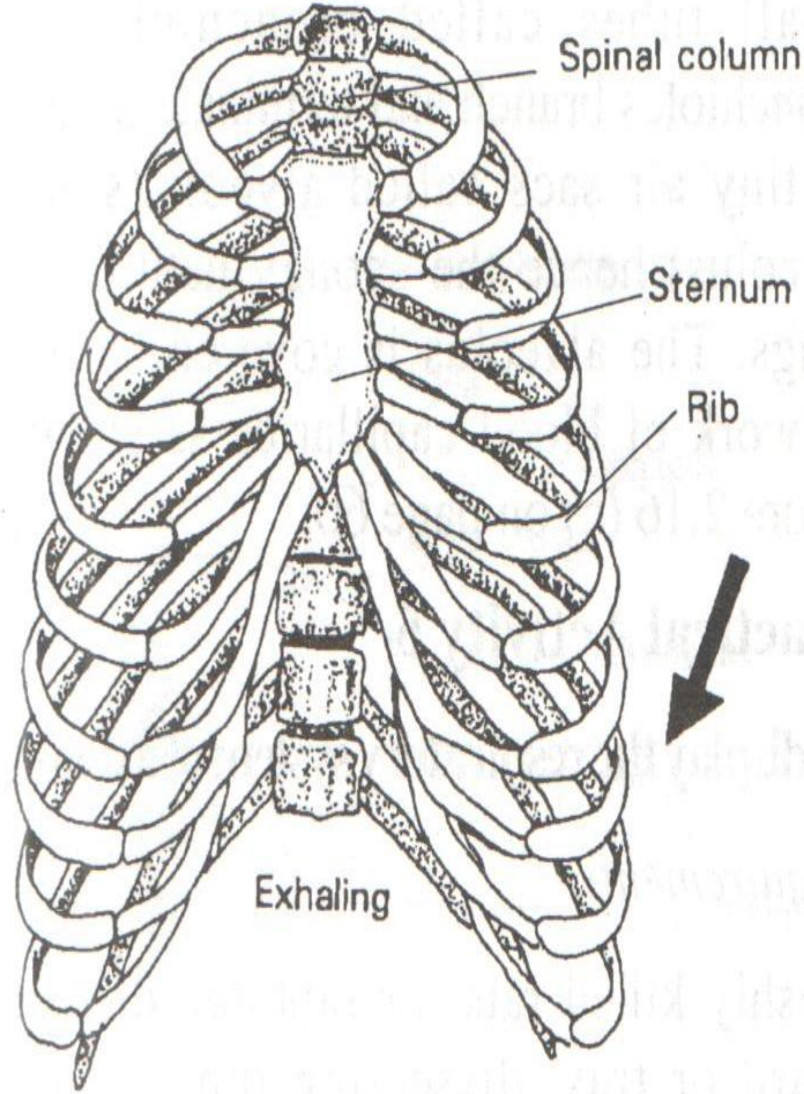
Note. Breathing is controlled by the part of the brain called **medulla oblangata.**

Role of diaphragm in breathing

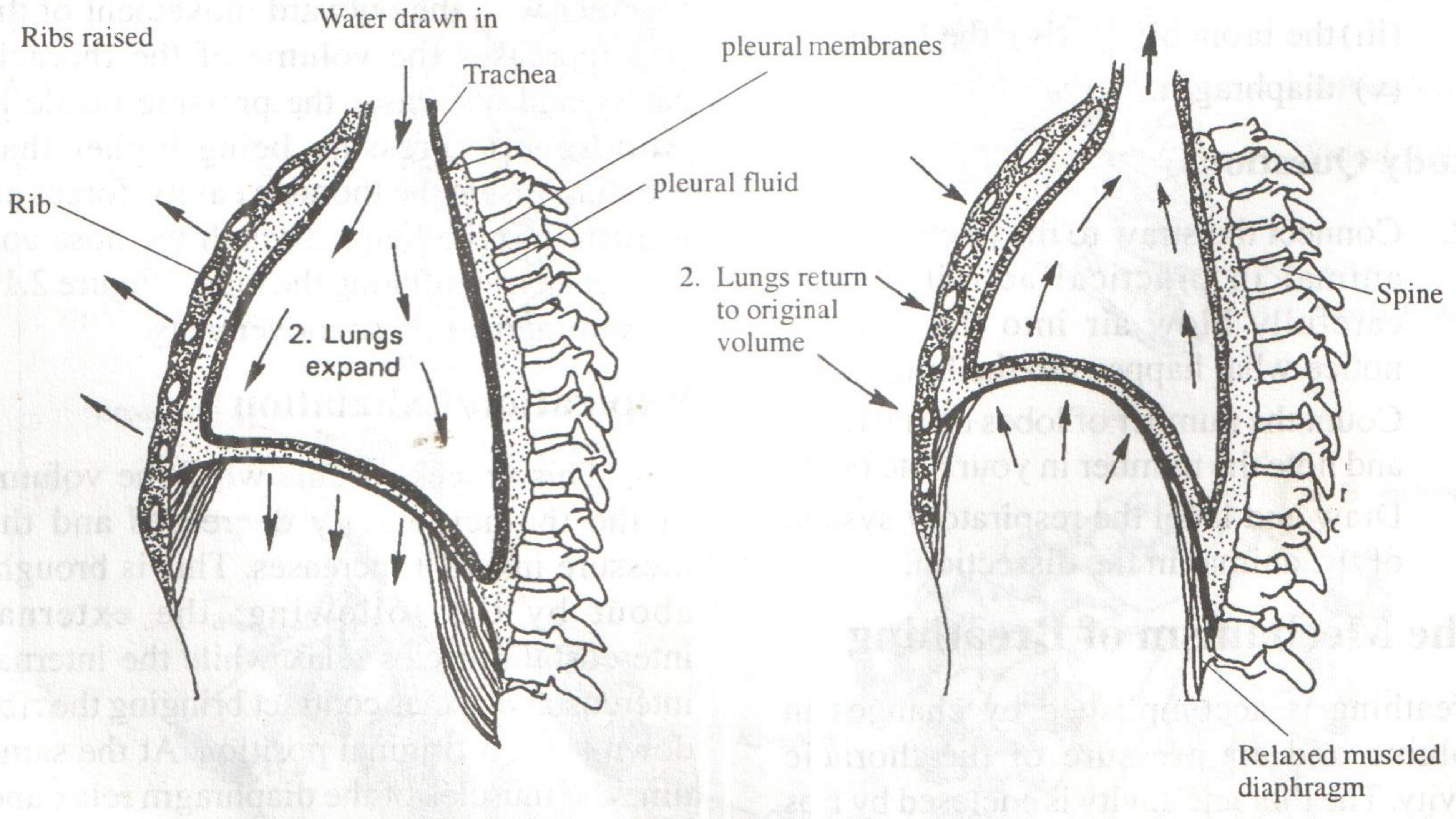
- It contracts and relaxes increasing/ decrease volume and pressure of thoracic cavity facilitating breathing.



Inspiration: Ribs move up and increase volume of thorax.



Expiration: Ribs move down and reduce volume of thorax.



Diaphragm flattened increase volume of thorax

(a) INSPIRATION

Diaphragm relaxes and returns to its dome shape and reduces volume of thorax

(b) EXPIRATION

Fig. 2.17: Movement of ribs during breathing

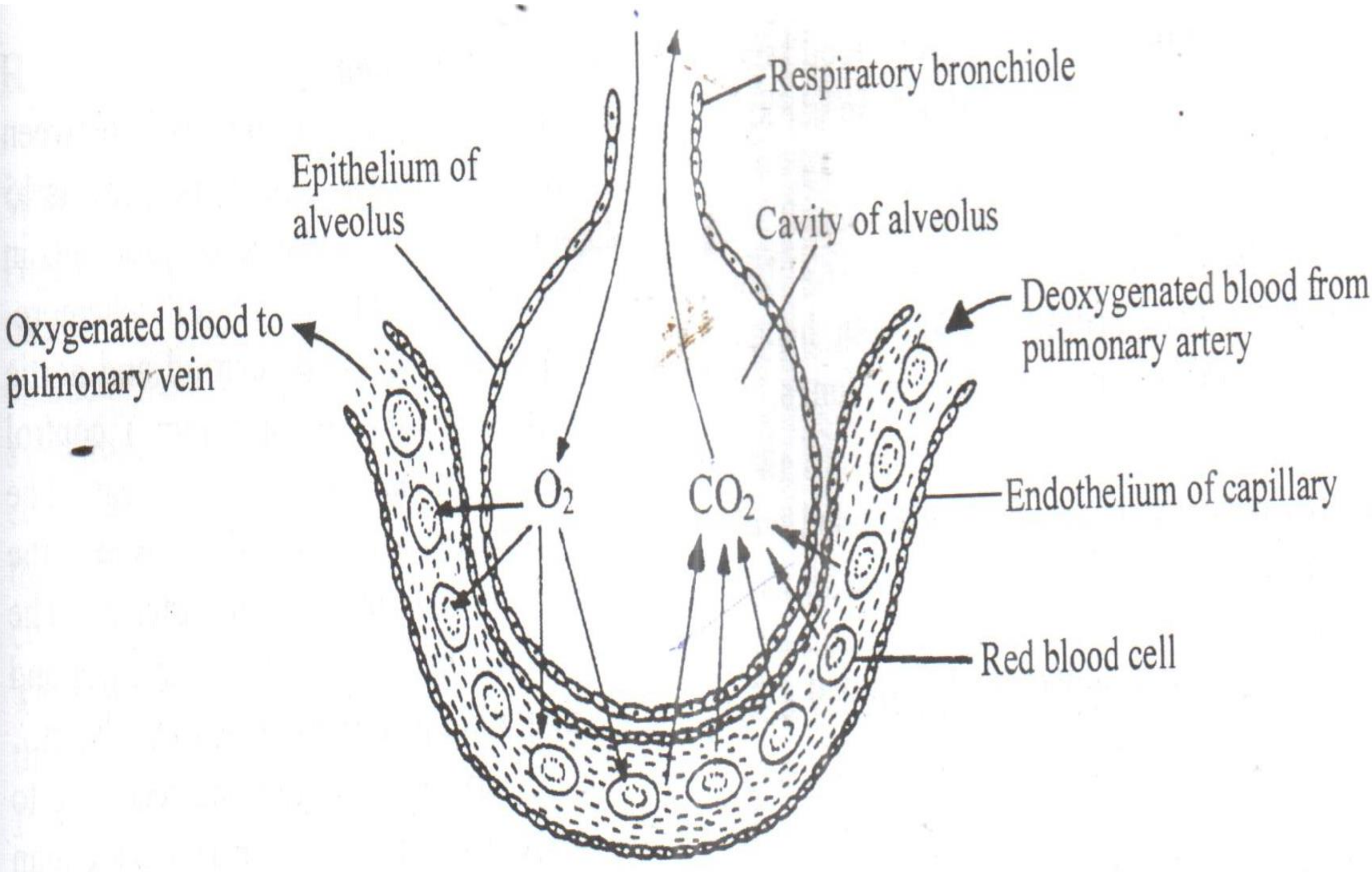
Mechanism of gaseous exchange in the alveolus

- Oxygen is in higher concentration in the alveolar cavity than blood (in the capillary), it then diffuses into the capillary through the epithelium of alveolus, capillary wall/endothelium and the plasma into the red blood cells where it combines with haemoglobin.
- Carbon (IV) oxide is in higher concentration in blood than alveolar cavity, hence diffuses out of blood into alveolar cavity and is expelled during exhalation. Water vapour passes out of the blood by the same process.

Adaptations of alveolus.

- They are many/ numerous to increase surface area for gaseous exchange.
- They are covered by moist epithelium to dissolve gases/allow them diffuse in solution form.
- They are made of thin membrane/ epithelium/ one cell thick wall to reduce diffusion distance for faster diffusion of gases
- They are highly vascularized/have dense network/many capillaries to carry away oxygen and bring carbon (IV) oxide/ create a steep concentration/diffusion gradient.

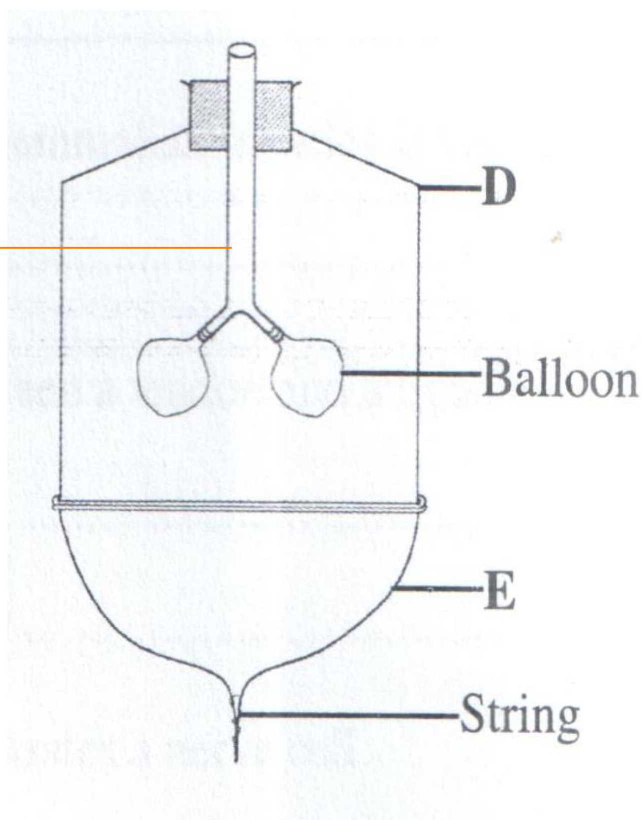
Alveolus



Respiratory bronchiole
Epithelium of alveolus
Cavity of alveolus
Deoxygenated blood from pulmonary artery
Oxygenated blood to pulmonary vein
O_2
CO_2
Endothelium of capillary
Red blood cell

Study question

The diagram below represents a model used to demonstrate breathing in mammals.



a) Name the mammalian structure represented by the parts labeled D and E.

D-Rib cage, E-Diaphragm, F- Trachea

b) State the observation made when the string is pulled downwards.

Lungs inflate/expand.

c) Explain the observation in (ii) above.

The volume of the thoracic cavity increases and pressure decreases. Atmospheric pressure being higher than inside the thoracic cavity forces air to the lungs, lungs inflate.

Difference in mechanism of exchange in insects and mammals

Insect.

1. Muscular movement of abdominal walls allow in and out of air.
2. Gases enter and leave through the spiracles.

Mammal.

1. Muscular movement of the intercostal muscles and diaphragm muscles allow air in and out.
2. Gases enter and leave through the nostrils.

FACTORS AFFECTING RATE OF BREATHING IN HUMANS.

1. **Exercise-** vigorous physical activity increase the rate of breathing so as to increase amount of oxygen and eliminate extra carbon (IV) oxide produced during respiration.
2. **Emotions-** emotions e.g. fear, anxiety, anger and fright increase production of adrenaline which increases general metabolism hence increasing the rate of breathing
3. **Health-** disease increases metabolic rate leading to higher rate of breathing. Some respiratory diseases block respiratory tract making breathing difficult.
4. **Age:** Young people are actively growing hence have higher demand of oxygen hence have faster rate of breathing.
5. **Temperature-** higher temperature increases the rate of breathing/ gaseous exchange. Too high temperature reduces the rate of breathing.
6. **Altitude:-**the rate of breathing increases with increase in altitude. This is because the atmospheric pressure is low/ low amount of oxygen.

Note.

- People living at high altitude acclimatize by having an increased number of red blood cells and increased haemoglobin content to increase the oxygen carrying capacity of blood.
- This is the reason why athletes practice in high altitude areas/ mountains.

EXPERIMENT.

Aim: **To compare the amount of carbon (IV) oxide in inhaled and exhaled air.**

Procedure:

i. Set up the apparatus as shown below.

ii. Close clip B and open clip A, then breathe in.

iii. Open clip B and close clip A, then breathe out.

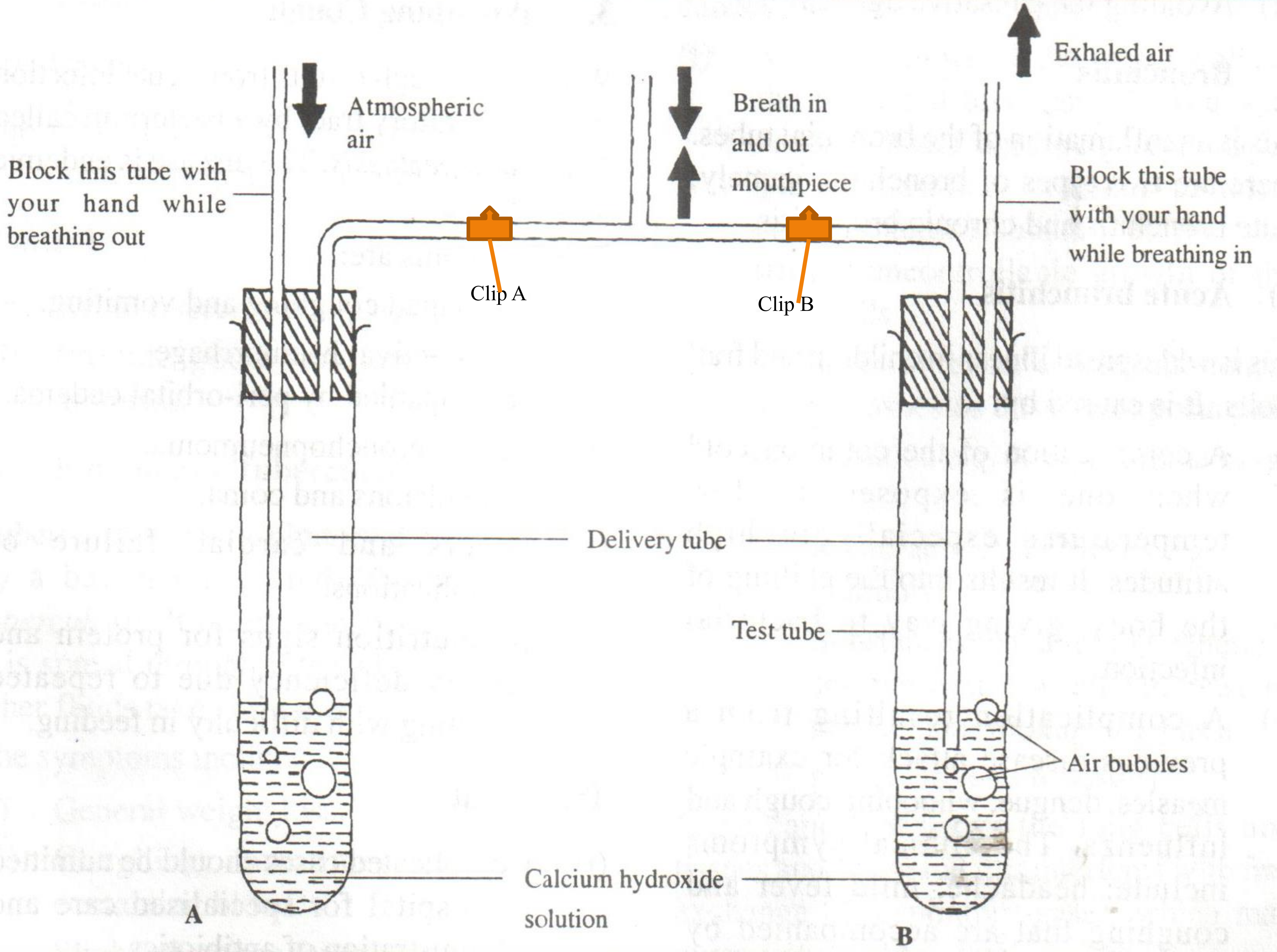
iv. Repeat the procedure several times and note the changes in lime water (calcium hydroxide) in test tubes A and B.

Points to note.

- Clip A is closed while clip B opened to prevent the entry of air into tube A during exhalation /breathing out.
- Clip B is closed while clip A opened to prevent the entry of air into test tube B from the atmosphere during inhalation.

Observations and conclusion.

- Lime water/calcium hydroxide solution in test tube A is less cloudy while in test tube B the solution is more cloudy.
- **Air breathed in** contains low amount of carbon (IV) oxide.
- **Air breathed out** contains high amount of carbon (IV) oxide.



Atmospheric air
Breath in and out mouthpiece
Exhaled air
Block this tube with your hand while breathing out
Block this tube with your hand while breathing in
Clip A
Clip B
Delivery tube
Test tube
Air bubbles
Calcium hydroxide solution
A
B

DISEASES OF RESPIRATORY SYSTEM

1. **BRONCHITIS-** this is inflammation of bronchial tubes. They are of two types: acute bronchitis and chronic bronchitis.

a) **Acute bronchitis-** it is caused by:

i) A complication of common cold when one is caused to low temperature. It causes chilling of the body leading to bacterial infection.

ii) A complication caused by previous attack by diseases e.g. measles, whooping cough and influenza.

Symptoms of acute bronchitis.

i) Headache.

ii) Mild fever.

iii) Coughing and uncomfortable feelings behind the sternum.

b) **Chronic bronchitis-** it develops after several repeated attacks of acute bronchitis.

Symptoms of chronic bronchitis.

i) Production of thick sputum (phlegm) which is greenish/ yellow in colour.

ii) Difficulty in breathing, walking and sleeping.

Treatment and control of bronchitis.

i) Seeking medical assistance early to avoid complications.

ii) Administration of antibiotics.

2. PULMONARY TUBERCULOSIS.

Causes.

- Caused by the bacterium *Mycobacterium tuberculosis.*

Mode of transmission.

- Breathing in airdrops from cough or a sneeze of an infected person.
- Taking in infected cow's milk or other drinks taken as meal.

Symptoms.

i. Weight loss.

ii. Coughing with blood stained sputum.

iii. Slight afternoon fever.

iv. Profuse night sweats.

v. Difficulty breathing.

vi. Death if not treated.

Control

i) Vaccination.

ii) Pasteurization of milk.

iii) Proper diagnosis to detect the disease early for proper management.

iv) Avoid overcrowded places and poorly ventilated areas.

v) Proper nutrition to improve immunity.

3. ASTHMA.

Causes.

i) Allergy to allergens e.g. pollen grains, dust, animal fur, scent, certain drugs and foods and emotions.

ii) Lung and bronchial infections.

Symptoms.

i. Difficulty in breathing.

- ***This is because of allergen-antibody reaction which cause the release of histamine. Histamine causes the bronchi to contract and overproduce mucus which hinder smooth flow of air***

ii. Wheezing sound due to narrowing of the airways.

iii. Chest pains.

iv. Coughing.

Treatment and control

i) Use of inhalers which relax the muscles allowing for normal breathing.

ii) Avoiding the allergens

iii) Early treatment of respiratory infections

iv) Administration of drugs.

4. WHOOPING COUGH.

Causes.

- Caused by the bacterium ***Bordetella pertussis***.

Symptoms

i. Prolonged coughing.
ii. Convulsions and coma.
iii. Ulcers and cardiac failure/ complications.
iv. Difficulty in breathing.
v. Vomiting.
vi. Malnutrition because of repeated vomiting.

Treatment

i. Use of antibiotics.
ii. Proteins should be fed on a balanced diet.
iii. Early vaccination/ immunization for children.

5. **PNEUMONIA-** this is an inflammation of the lungs caused by bacteria, virus or fungi.

- Bacterial pneumonia is common caused by ***Streptococcus pneumoniae.***
- It is airborne disease i.e. the pathogen is transmitted through the air.

Symptoms.

a) Coughing

b) Fever.

c) Chest pains.

d) Shortness of breath.

e) Difficulties in breathing.

Control and treatment.

a) Vaccination.

b) Avoid exposure to low temperatures.

c) Avoid overcrowded and poorly ventilated places.

d) Proper diagnosis for proper treatment.

e) Treatment using antibiotics.

6. **LUNG CANCER-** it is caused by uncontrolled division of abnormal cells in the body causing tumors.

- It is caused by smoking.

How does smoking cause lung cancer?

- Tobacco contains tar which is carcinogenic/ it is cancer causing substance.

Symptoms.

a) Persistent cough.

b) Blood in sputum.

c) Chest pain.

Control and treatment.

a) Avoid smoking.

b) Surgery to remove tumour.

c) Radiotherapy to destroy cancerous cells.

d) Chemotherapy to destroy cancer cells.

Study questions

1. Explain how too much dust particles may affect the respiratory system.

- ***Dust particles stimulate production of large quantities mucus along the air passages. This may eventually clog air passages interfering with air passage to the lungs. This may result into respiratory diseases e.g. bronchitis and asthma***

2. Severe Acute Respiratory Syndrome (SARS) is a disease transmitted through air and in china spread and killed people in Europe.

a) Name the parts of the body that are likely to be infected.

- ***Nostrils, trachea, bronchus, bronchioles and alveoli.***

b) What would be the easiest way of preventing the spread of the disease from one person to another?

- ***Covering the nostrils and mouth.***
- ***Quarantine.***
- ***Vaccination.***

3. A student divided a small airtight box into two chambers with a wire mesh. In one chamber he kept a number of rats and in the other a number of potted plants. What was likely to happen if the box was placed in the dark for two hours? Explain.

- ***Plants and rats use oxygen in respiration and produce carbon (IV) oxide.***
- ***Absence of light means photosynthesis will not take place in the plants. Carbon (IV) oxide level will go up hence both will suffocate and die due to lack of oxygen.***

3. RESPIRATION/ TISSUE RESPIRATION/ INTERNAL RESPIRATION

- **Respiration** is the **chemical** process by which food substances are chemically broken down in all living cells to release ***heat energy, carbon (IV) oxide, water, alcohol/lactic acid.***
- Respiration takes place in the **mitochondria** slowly and is controlled by respiratory enzymes so that energy is produced continuously and in small amounts.
- This prevents cells from burning up if all the energy in the food were to be released all at once.
- **Gaseous exchange** is the **physical** exchange of gases across the respiratory surfaces.

Study question 1.

- What is the difference between respiration and gaseous exchange?

Study question 2

a) Explain why plants have lower respiratory rates compared to animals

✓ Plants are less active than animals hence require less energy than animals.

b) State two situations in plants when the rate of respiration rises more than normal

✓ During germination.
✓ During rapid growth/ cell division.
✓ During active uptake/ transport of substances/ mineral salts.

Significance/ importance of respiration.

- It produces energy which is used for:

a) Muscular contraction.
b) Conduction of nerve impulses.
c) Secretion of enzymes and hormones.
d) Growth and repair of worn out tissues.
e) Functioning of body organs e.g. kidney, heart, brain.
f) Active uptake of nutrients.
g) Digestion of food e.g. peristalsis, absorption of digested food, chewing, churning, secretion of mucus/ digestive enzymes

Practical activity

Aim

- To investigate what gas is given off when food is burnt.

Requirements.

i. Starch powder/crushed beans/maize flour/milk powder.
ii. Test-tube.
iii. Boiling tube.
iv. Calcium hydroxide solution(lime water).
v. Rubber stopper.
vi. Anhydrous blue cobalt chloride paper.
vii. Source of heat, delivery tube.
viii. Retort stand.

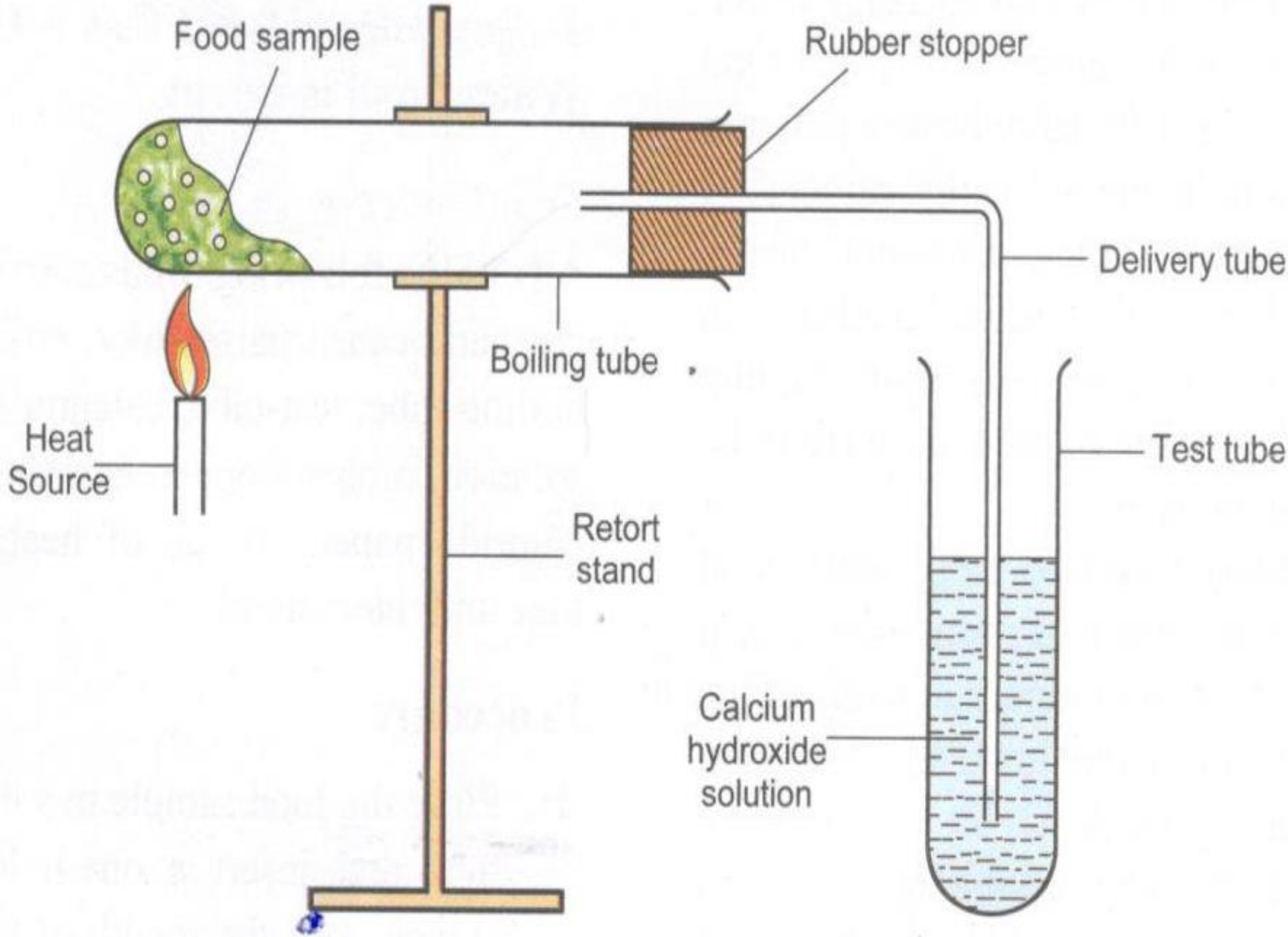
Procedure.

1. Place some food sample in a dry boiling tube.
2. Hold the test-tube containing the food sample horizontally.
3. Pour a little calcium hydroxide solution (lime water) into another test-tube and support it.
4. Using a delivery tube connect the boiling tube to the test tube ensuring the free end of the delivery tube dips into calcium hydroxide solution/ lime water.

5. Heat the boiling tube containing the food sample strongly.
6. Observe and record what happens to the food sample, calcium hydroxide solution and the upper sides of the boiling tube with the food sample.
7. Disconnect the apparatus and rub anhydrous blue cobalt (II) chloride paper on the inner upper side of the test-tube containing the food sample.
8. Record the colour change observed on the blue cobalt (II) chloride paper.

Observation and conclusion.

- When food is burnt, carbon (IV) oxide is produced which turns lime water milky.
- Water vapour is also produced that accumulate on the inner upper side of the test tube which turns anhydrous cobalt (II) chloride paper pink.


Food sample
Rubber stopper
Delivery tube
Boiling tube
Test tube
Heat
Source
Retort
stand
Calcium
hydroxide
solution

DIFFERENCES BETWEEN RESPIRATION AND PHOTOSYNTHESIS

RESPIRATION	PHOTOSYNTHESIS
1. It takes place in all living cells.	1. It takes place in cells with chlorophyll e.g. guard cell, palisade, spongy mesophyll cell.
2. It takes place continuously in the presence or absence of light.	2. It takes place only in the presence of light.
3. It leads to the breakdown of complex organic molecules into simple inorganic compounds.	3. It leads to the synthesis of complex organic molecules from simple inorganic compounds.
4. It uses oxygen.	4. It releases oxygen.
5. It releases energy.	5. It stores energy.
6. It releases carbon (IV) oxide and water.	6. It uses carbon (IV) oxide and water.
7. It takes place in mitochondria.	7. It takes place in chloroplasts.

STRUCTURE AND FUNCTION OF A MITOCHONDRION

- Mitochondria (**sing**. **Mitochondrion)** are small round or rod shaped cell organelles found in cells and **provide sites for respiratory activity/ respiration.**

Adaptation of mitochondrion.

1. It has numerous cristae to increase surface area for attachment of respiratory enzymes.
2. It has a fluid-filled matrix that contains numerous enzymes that catalyze respiratory reactions.

- Living cells e.g**. the kidney cells, the flight muscle of insects and birds, the sperm cells and muscle cells** require high amount of energy hence they have large numbers of mitochondria.

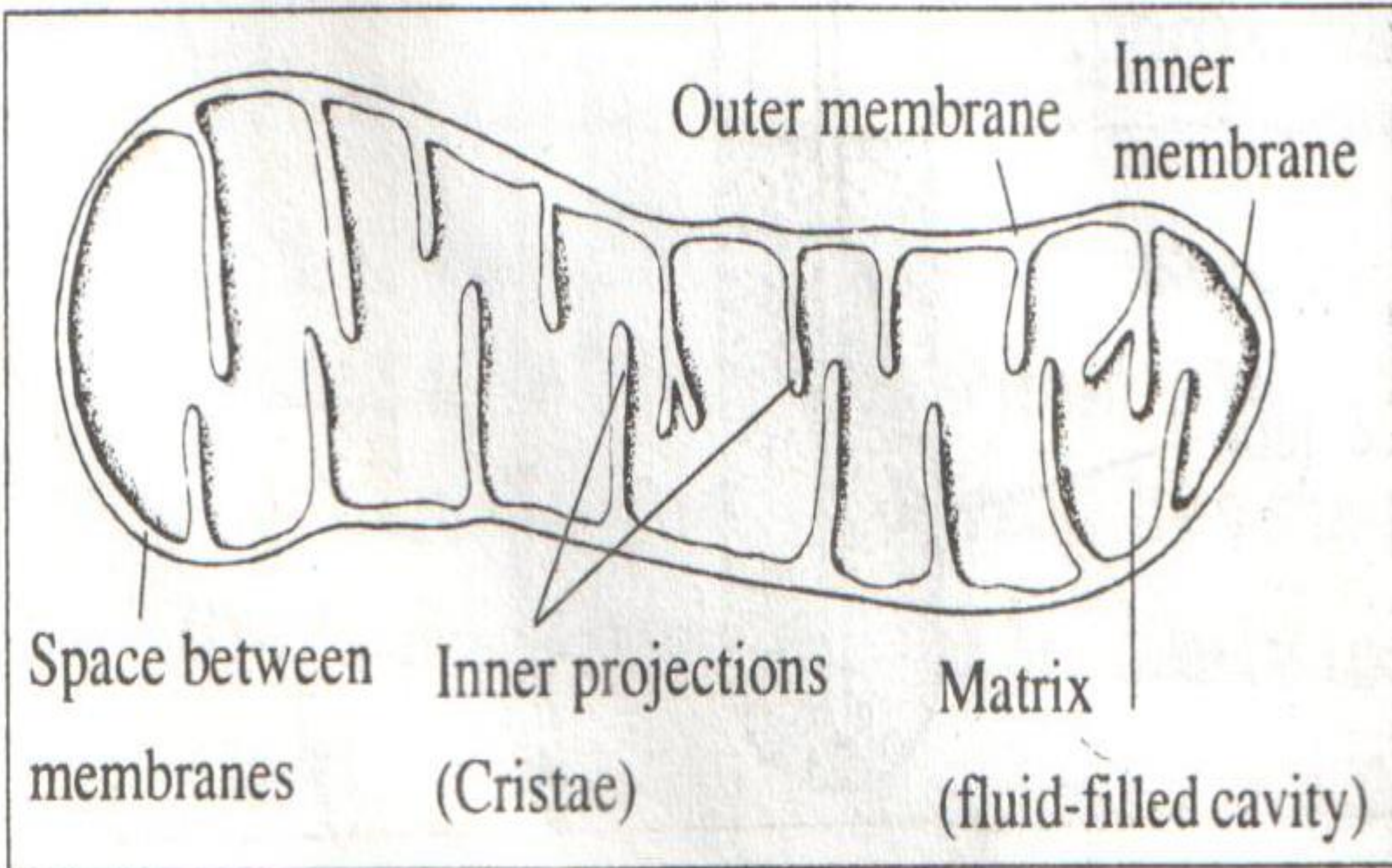


Fig. 3.2: The structure of the mitochondrion

TYPES OF RESPIRATION

- They include:

a) Aerobic respiration- it takes place/ occurs in the presence of oxygen.

b) Anaerobic respiration- it takes place/ occurs in the absence of light.

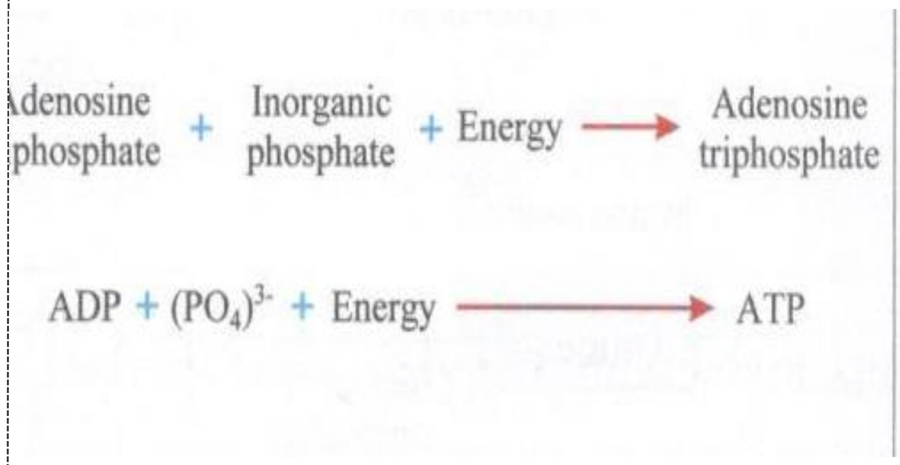
A. AEROBIC RESPIRATION.

- Aerobic respiration is the process in which food substances (e.g. glucose) are broken down **in the presence of oxygen** in tissue cells to release **energy, water and carbon (IV) oxide.**
- A lot of energy produced at the end of aerobic respiration/ oxidation is very high.
- If all the energy were released once in form of heat, it would burn the body cells.
- To protect the cells from burning, the heat energy is released in small quantities in stages.
- 38 ATP molecules are produced.

$$C_6H_{12}O_6 + 6O_2 \xrightarrow[\text{enzymes}]{\text{Respiratory}} 6CO_2 + 6H_2O + \text{Energy (ATP)}$$

$$\text{Glucose} + \text{Oxygen} \longrightarrow \text{Carbon(IV)oxide} + \text{Water} + \text{Energy}$$

- Some of the energy produced is stored in form of ATP (Adenosine Triphosphate)/ used to form a chemical compound called ATP.
- In the formation of ATP, the energy causes a reaction between a two-phosphate molecule ADP (Adenosine Diphosphate) molecule with inorganic phosphate to form ATP
- ATP molecules store the energy released during respiration in their bonds and readily avails the energy to the cells when required.



PHASES/ STAGES OF AEROBIC RESPIRATION

A. **GLYCOLYSIS-** It takes place in the cytoplasm without using oxygen.

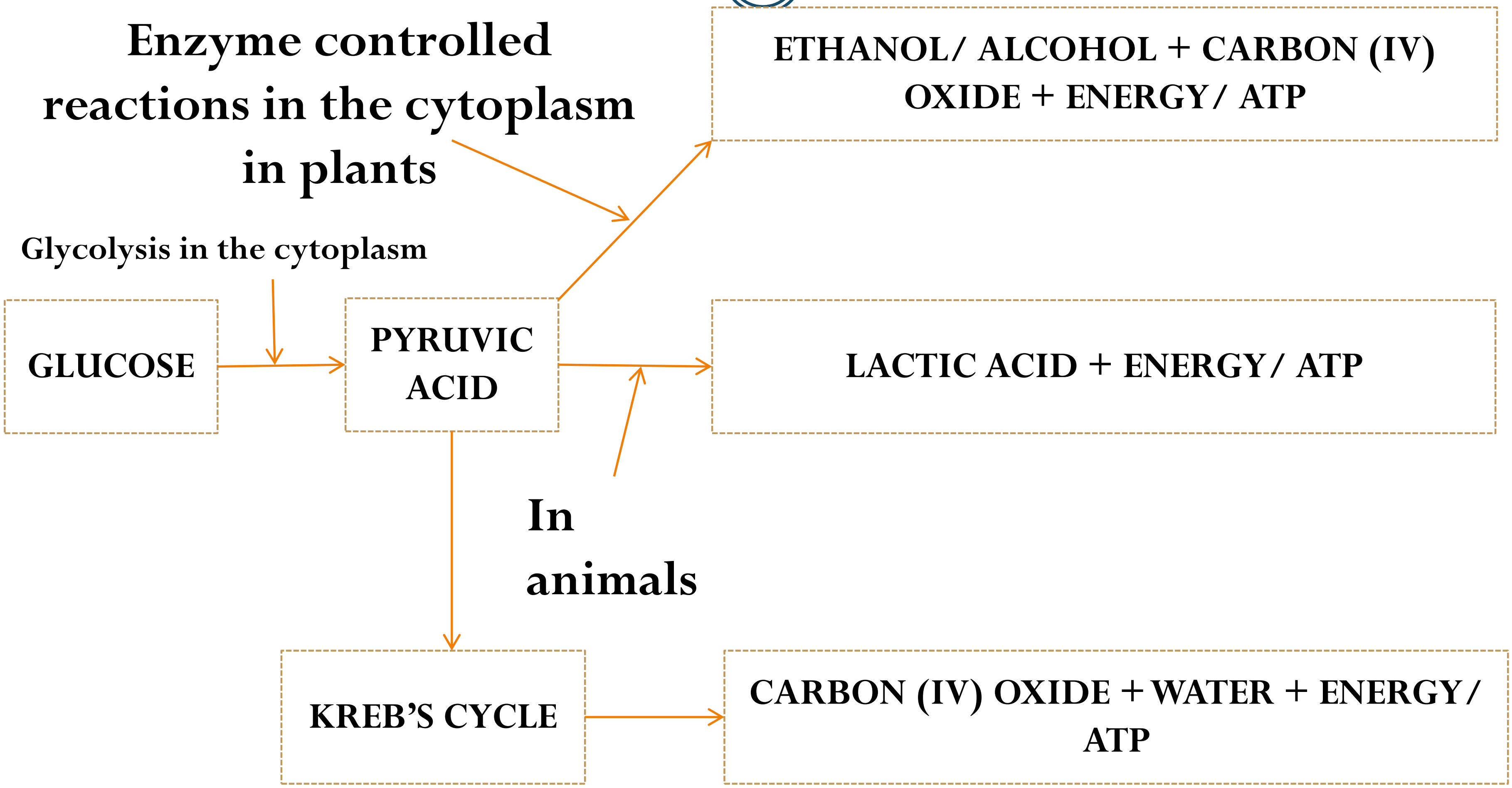
- It involves the breakdown of glucose into **pyruvic acid and 2 ATP molecules.**
- If oxygen is not supplied to the cell pyruvic acid is partially broken down to lactic acid (in animals) and ethanol/ alcohol (in plants).
- If oxygen is sufficient, pyruvic acid enters into the second phase (Kreb's cycle) in the mitochondria.

B. **KREB'S CYCLE-** it takes place in the matrix of the mitochondria involving a series of enzyme-controlled reactions using oxygen.

- Pyruvic acid formed in glycolysis is broken down to form **energy, carbon (IV) oxide.**
- One glucose molecule yields 38 molecules of ATP.

Differences between glycolysis and Kreb's cycle.

Kreb's cycle	Glycolysis
1. It requires oxygen.	1. Oxygen is not required.
2. It occurs in the mitochondria.	2. It occurs in the cytoplasm.
3. Produces a lot of energy/ 36 ATP molecules.	3. Produces less energy/ 2 ATP molecules.
4. Involves complete breakdown of **pyruvic acid** into **carbon** (IV) **oxide**, **water** and **energy.**	4. There is incomplete breakdown of **glucose** into **pyruvic acid.**



Enzyme controlled reactions in the cytoplasm in plants
ETHANOL/ ALCOHOL + CARBON (IV) OXIDE + ENERGY/ ATP
Glycolysis in the cytoplasm
GLUCOSE
PYRUVIC ACID
LACTIC ACID + ENERGY/ ATP
In animals
KREB'S CYCLE
CARBON (IV) OXIDE + WATER + ENERGY/ ATP

Conditions necessary to maintain the process of respiration in the living cells.

1. The cells must be provided with glucose or food.
2. Oxygen must be taken in and react with the glucose.
3. There must be respiratory enzymes to catalyze the reaction.
4. Favourable temperature should be maintained for efficient enzyme functioning.
5. The end products of the reaction i.e. carbon (IV) oxide, water and energy must be constantly removed from the mitochondrion.

B. ANAEROBIC RESPIRATION/ FERMENTATION.

- Anaerobic respiration is the process by which food substances such as glucose are broken down **without using oxygen.**
- It takes place in the **cytoplasm and** glucose is not broken down completely into **carbon (IV) oxide** and **water** to release energy.
- Instead, an intermediate compound, **alcohol /ethanol in plants and lactic acid in animals**, is produced.
- The incomplete breakdown of glucose result into production of less energy and the rest of the energy remains locked up in bonds of lactic acid molecule.
- **Lactic acid** in animals and **ethanol/alcohol** in plants should be eliminated immediately.
- This is because these end products become toxic to the organism if they are left to accumulate within the cells.

In plants

$$C_6H_{12}0_6 \rightarrow 2C_2H_5OH + CO_2 + \text{Energy}$$

Glucose Ethanol Carbon (IV) oxide + Energy

In animals

$$C_6H_{12}O_6 \rightarrow 2C_3H_6O_3 + \text{Energy}$$

(Glucose) (Lactic acid)

- Anaerobic respiration that results in the accumulation of alcohol is referred to as **anaerobic fermentation.**
- Alcoholic fermentation involves the break down of simple sugars by yeast into energy, carbon (IV) oxide and ethanol/ alcohol.
- Some bacteria breakdown ethanol anaerobically into ethanoic acid.
- When sugars are broken down by micro-organisms into energy and lactic acid in animal tissues is called **lactic acid fermentation.**
- The breakdown of milk sugar by bacteria results in the production of energy and lactic acid which causes milk to become sour.

- Lactic acid formation also occurs in muscles during strenuous exercises.
- Unlike alcoholic fermentation, lactic acid can be further be broken down to release energy.
- This is the reason why the process of lactic acid fermentation causes an organism to experience **oxygen debt.**

Differences between products of anaerobic respiration in plants and

In plants	In animals
1. Ethanol/ alcohol is produced.	1. Lactic acid is produced.
2. Carbon (IV) oxide is produced.	2. Carbon (IV) oxide is not produced.

DIFFERENCES BETWEEN AEROBIC AND ANAEROBIC RESPIRATION

Aerobic respiration	Anaerobic respiration.
1. Oxygen is necessary for the process to take place.	1. Oxygen is not required.
2. High amount of energy is released.	2. Low amount of energy is released.
3. The substrate is broken down completely.	3. The substrate is not broken down completely.
4. The end products are water, carbon (IV) oxide and energy.	4. The end products are alcohol/ ethanol and energy in plants and lactic acid and energy in animals.
5. It occurs in the cytoplasm and mitochondria.	5. It occurs in the cytoplasm only.
6. It occurs in 2 stages i.e. **glycolysis** and **kreb's cycle.**	6. It occurs in one stage i.e. **glycolysis.**

OXYGEN DEBT

- This is the extra amount of oxygen required to get rid of the lactic acid that accumulates in the body tissues when the supply of oxygen is less than the demand.
- Under these conditions the animal tissues respire anaerobically causing the lactic acid to accumulate in the muscles. The lactic acid causes fatigue and result in muscle cramps.
- A short distance runner/ diver holds his/ her breathe while running/ diving.

Side effects of lactic acid accumulation.

i. Fatigue/muscle cramps.
ii. Can lower the pH of blood.
iii. Can increase the osmotic pressure of blood.
iv. It is toxic and can affect muscular activity.

How does the body deal with lactic acid?

i. Can be excreted through the kidney in urine.
ii. It is taken to the liver and converted into glycogen for storage.
iii. It can be converted into fat for storage.
iv. It can be broken down to carbon (IV) oxide, water and energy.

How is oxygen debt paid back?

- Oxygen debt is paid back by the person breathing more quickly and more deeply (panting) in order to increase the supply of oxygen to the muscles.
- The rate of heartbeat increases so as to:

i. Transport oxygen faster to the muscle cells

ii. Transport/ remove lactic acid from the muscles to the liver.

AEROBES AND ANAEROBES

- **Aerobes** are organisms that cannot survive in the absence of oxygen e.g. ***man.***
- **Anaerobes** are organisms that respire anaerobically.
- There are two types of anaerobes, namely:

i. **Obligate anaerobes-** they survive/respire in the absence of oxygen e.g. ***clostridium*** bacteria.

ii. **Facultative anaerobes-** they survive/respire in the presence or absence of oxygen e.g. ***yeast.***

APPLICATION OF ANAEROBIC RESPIRATION/ FERMENTATION IN INDUSTRIES AND HOME.

1. **Baking industry-** Yeast is used to produce carbon (IV) oxide that causes the dough to rise in the making of products e.g. bread and cakes.

- The starch in wheat flour is broken down into glucose which is then broken down to carbon (IV) oxide giving bread the spongy structure and softness and ethanol/ alcohol that gives it flavor.

2. **Brewing industries-** yeast is used to break down sugar in barley, grapes, sorghum and malt to produce various beverages e.g. beers and wines. Distillation of alcohol results in acts as a substitute for petrol in automobiles.

3. **Production of organic acids-** bacteria break down ethanol anaerobically to produce organic acids e.g. ethanoic acid/ vinegar, citric acid, oxalic acid and butanoic acid.

4. **In the dairy industry-** bacteria breaks down the sugars in milk to release lactic acid which makes it possible to make products e.g. Yoghurt, cheese, cream, butter and ghee. The lactic acid gives these products a characteristic flavour.

5. **In pharmaceutical industry-** it utilizes anaerobic respiration to produce drugs e.g. penicillin.
6. **Sewage treatment-** Bacteria are added into raw sewage and they help to break organic wastes anaerobically into simpler substances.

- The solid materials are then separated from water and used as manures. The water is treated and recycled for later use.

7. **Biogas production-** Animal solid waste is fermented to produce methane gas(biogas). The gas is channeled in pipes and used for cooking or lighting.
8. **Production of compost manure-** bacteria is used to break down organic materials anaerobically to form compost manure.
9. **Silage formation-** bacteria break down organic materials in animal feed to produce lactic acid which preserves the silage.

RESPIRATORY SUBSTRATES

- These are the food substances that are broken down during respiration to produce energy.
- The main substrates used in respiration include:

1. **Carbohydrates-** they are the main substrates in form of glucose, fructose and galactose.
2. **Proteins-** they are oxidized during extreme cases of starvation when there are no carbohydrates and fats. They are first converted into carbohydrates then broken down to release energy.
3. **Lipids/ fats-** they produce more energy than carbohydrates or proteins but they are not the main substrates of carbohydrates because:

i) They are not very soluble and therefore not easily transported to the sites of respiration.

ii) They require more oxygen for oxidation.

RESPIRATORY QUOTIENT (RQ).

- Respiratory quotient is a ratio showing the relationship between the amounts of carbon (IV) oxide produced against the amount of oxygen used in respiration.

$$RQ = \frac{\text{Volume of carbon (IV) oxide produced}}{\text{Volume of oxygen used}}$$

Significance of respiratory quotient.

1. It shows the type of substrate oxidized e.g.

   i. Carbohydrates have RQ of 1

   ii. Lipids(fats and oils) have RQ of 0.7

   iii. Proteins have RQ of 0.9

2. It shows the type of respiration taking place (aerobic/ anaerobic respiration) e.g if RQ is less than 1, then the amount of oxygen used is more.

Study questions.

1. Calculate the respiratory quotient in the equation below.

$$C_6H_{12}O_6 + 6\,O_2 \longrightarrow 6\,CO_2 + 6\,H_2O + Energy$$

$$RQ = \frac{\text{Volume of carbon (IV) oxide produced}}{\text{Volume of oxygen used}}$$

$$= \frac{6}{6}$$

$$= 1.0$$

2. Study the equation below.

a) Calculate RQ.

$$2\,C_{51}H_{98}O_6 + 145\,O_2 \rightarrow 102\,CO_2 + 98\,H_2O + Energy$$

$$RQ = \frac{\text{Volume of carbon (IV) oxide produced}}{\text{Volume of oxygen consumed}}$$

$$= \frac{102}{145}$$

$$= 0.70345$$

$$\approx 0.7035$$

b) State the type of substrate used.

- **Lipids .**

c) State the type of respiration that took place and give a reason.

- **Aerobic respiration. Because the volume of oxygen used is more leading to aerobic respiration.**

Factors that affect respiratory quotient (RQ)

1. The type of substrate.
2. Type of respiration.
3. Age.
4. Temperature of the surrounding.
5. State of health.

FACTORS THAT AFFECT THE RATE OF RESPIRATION.

1. **Age-** young organisms have higher metabolic rates hence a higher demand for energy hence higher rate of respiration.
2. **Body size-** Babies **have a large surface area to volume ratio** hence lose heat at faster rate hence have a higher rate of respiration than adults.
3. **Sex-** Males are more muscular than females of the same age hence have higher rate of respiration.
4. **State of health-** Sick people require a lot of energy to restore energy hence have higher rate of respiration.
5. **Physical activity/occupation-** Physically active individuals/ manual workers require more energy than passive individuals thus they have a higher respiration rate.
6. **Basal metabolic rate (BMR)-** This is the energy required by the body when it is at rest. The higher the BMR the higher the energy requirement hence higher rate of respiration.

7. **<u>Oxygen Concentration-</u>** When the amount of oxygen is low the rate of respiration slows down and when the amount of oxygen is high, the rate of respiration increases.
8. **<u>Substrate concentration-</u>** When sugar/glucose concentration increases the rate of respiration also increases and when the glucose/ sugar concentration decreases the rate of respiration also decreases.
9. **<u>Hormones.</u>** Certain hormones in the body such as **adrenaline** and **thyroxine** are known to increase respiratory activities.
10. **<u>Temperature-</u>** respiration is an enzyme controlled process. Temperature above optimum denatures/ destroys enzymes lowering the rate of respiration. Temperature below the optimum inactivate the enzymes lowering the rate of respiration.

Experiment 1

Aim:

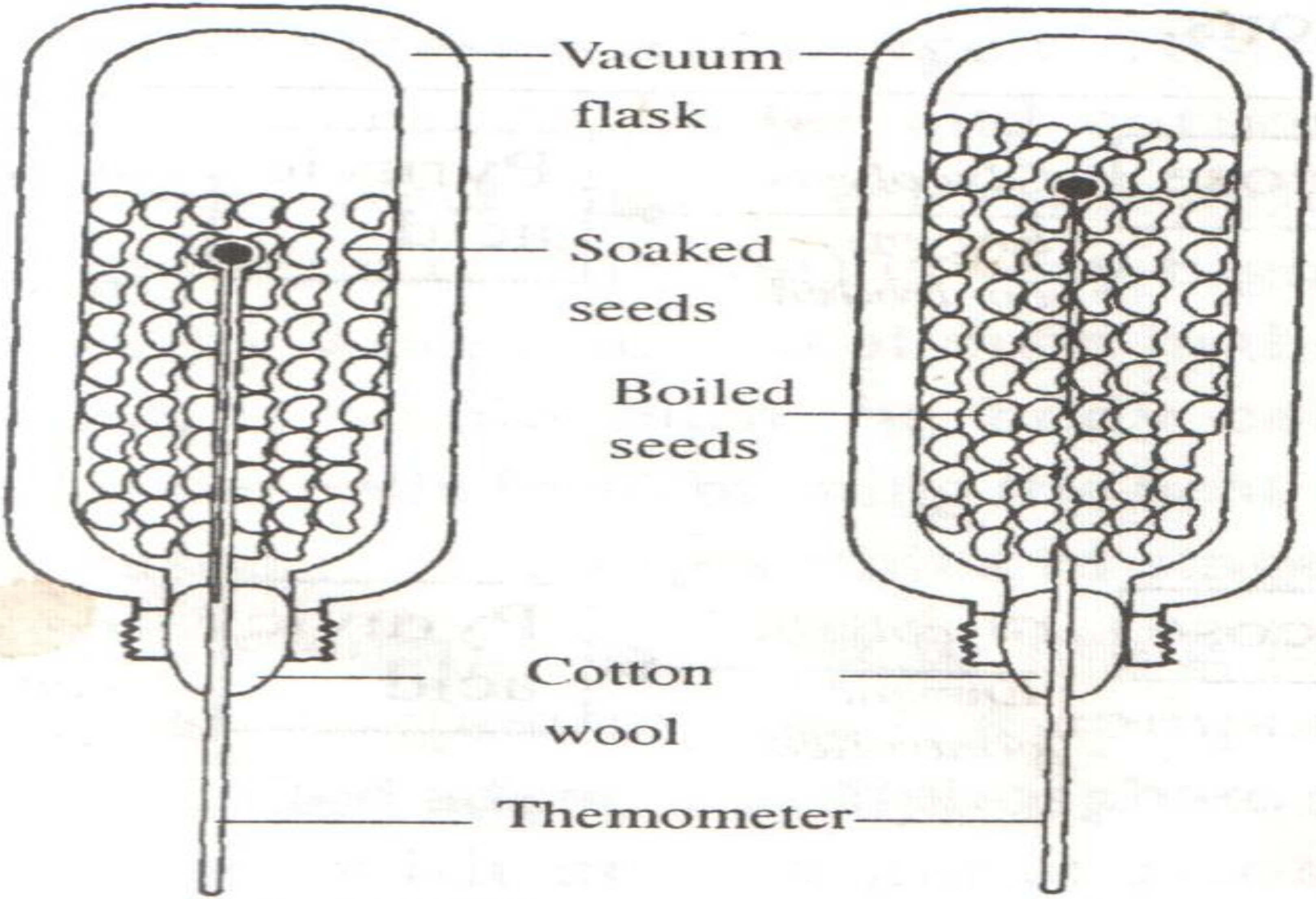
- To investigate production of heat by germinating seeds.

Requirements:

i. Boiled bean seeds.
ii. Soaked bean seeds.
iii. Vacuum flasks.
iv. Cotton wool.
v. Two thermometers.
vi. 10% formalin (methanol).
vii. Retort stand.

Procedure.

1. Soak the seeds for 24 hours and then divide them into two equal portions.
2. Boil one portion of seeds for ten minutes, let them cool and wash them in 10% formalin/ methanol.
3. Fill one vacuum flask with unboiled seeds and the other one with boiled seeds.
4. Place a thermometer in each flask such that the bulb is surrounded by seeds.
5. Hold each thermometer with cotton wool as shown below and record the initial temperature.
6. Record the temperature every morning and evening for a week.


Vacuum
flask
Soaked
seeds
Boiled
seeds
Cotton
wool
Themometer

Questions

a) State the observation made.

- ***There is a rise in thermometer reading.***

b) Explain the observation made in a) above.

- ***This is because seeds respire to produce energy required for germination. Some of this energy is lost in form of heat. The heat energy raises the temperature in the flask.***

c) Why was the vacuum flask used?

- ***It does not allow heat loss or entry.***

d) Give a reason why beans were washed in formalin/ methanol.

- ***To kill pathogens.***

e) What alteration would be made in the set up to make the results more reliable?

- ***Flasks should be filled with seeds to ensure that the bulb is covered.***
- ***Wash the seeds with antiseptic to avoid heat production by microbial activities.***

Experiment 2.

Aim:

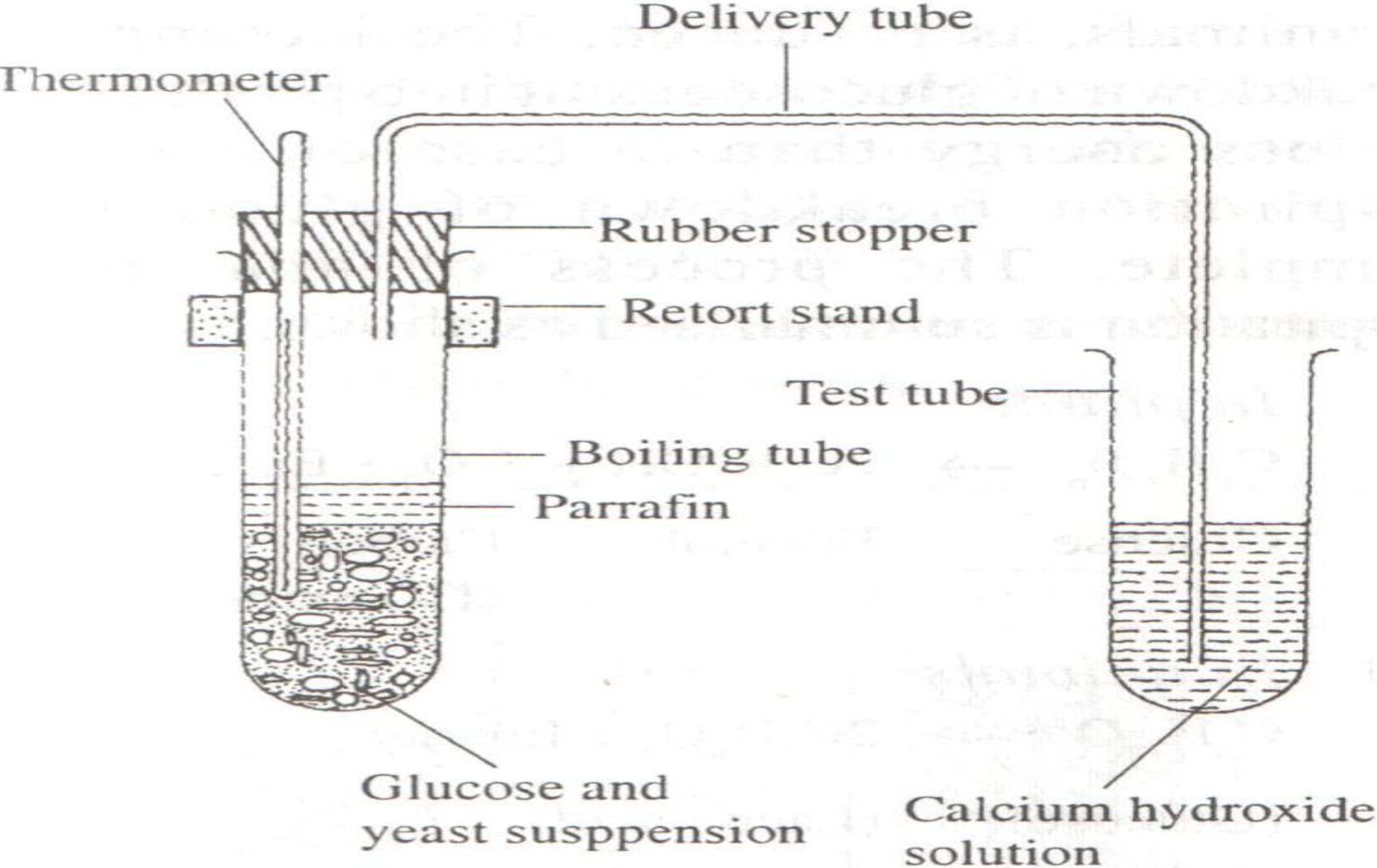
- To investigate the gas produced during fermentation.

Requirements:

1. Boiling tube.
2. Measuring cylinder.
3. Test-tubes.
4. Thermometer.
5. Delivery tube.
6. Rubber stopper
7. 10% glucose solution
8. Yeast
9. Kerosene/oil
10. Retort stand
11. Means of heating.

Procedure

1. Boil about 20 cm^3 of glucose in a tube and cool to 40 °C add some yeast.
2. Pour onto the glucose and yeast suspension some kerosene/ oil.
3. Leave this for about one hour.
4. Put some calcium hydroxide (lime water) in test tube and connect this test-tube to the boiling tube using the delivery tube and rubber stopper as shown below.
5. Record the changes that occur in lime water and thermometer reading.


Delivery tube
Thermometer
Rubber stopper
Retort stand
Test tube
Boiling tube
Parrafin
Glucose and
yeast susppension
Calcium hydroxide
solution

Questions

a) Why was glucose solution boiled?

- ***To remove oxygen from the solution;***

b) Account for the change in the test tube containing calcium hydroxide/ lime water.

- ***Lime water (Calcium hydroxide) turns milky/cloudy. This is because the yeast cells break down glucose anaerobically forming carbon (IV) oxide which reacts with lime water forming a white precipitate/ which turns lime water milky.***

c) Account for the temperature change in the boiling tube.

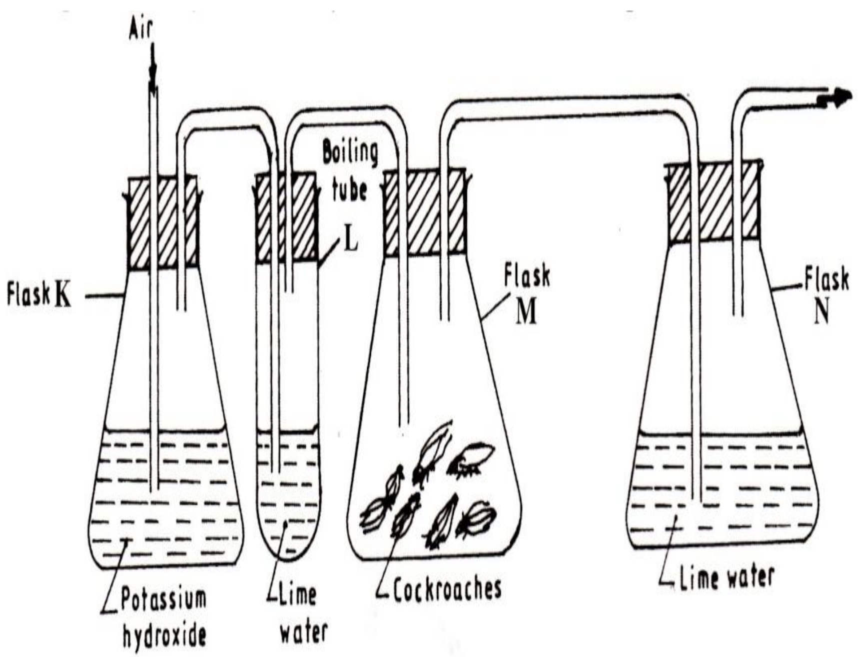
- ***There is rise in temperature / rise in thermometer reading. This is because anaerobic respiration produces energy in form of heat.***

d) Why as oil/ paraffin layer added to the suspension?

- ***It was added to prevent entry of air so as to allow anaerobic respiration take place.***

Study questions

1. The diagram below represents a set-up that students used in an investigation.



i. Name the physiological process that was being investigated.

Respiration.

ii. State the role of potassium hydroxide in flask **K**.

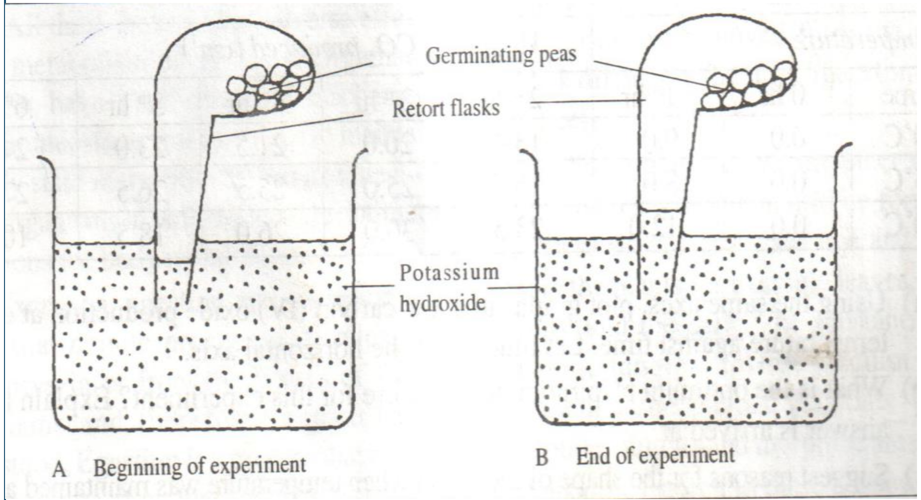
It removes/absorbs CO_2 from atmospheric air.

iii. Account for the observation in boiling tube **L** and flask **N**.

Boiling tube L- Lime water remains clear because carbon (IV) oxide has been removed..

Flask N- Lime water turns milky/cloudy because the respiring cockroaches produce carbon (IV) oxide .

2. The figure below represents an experiment on germinating peas.



a) What changes are observed at the end of the experiment in figure b?

- ***The level of potassium hydroxide in the retort flask has risen.***
- ***This is because germinating seeds use oxygen in aerobic respiration to produce carbon (IV) oxide which is absorbed by potassium hydroxide.***
- ***Pressure in the retort flask is reduced, atmospheric pressure forces potassium hydroxide to rise up the retort flask.***

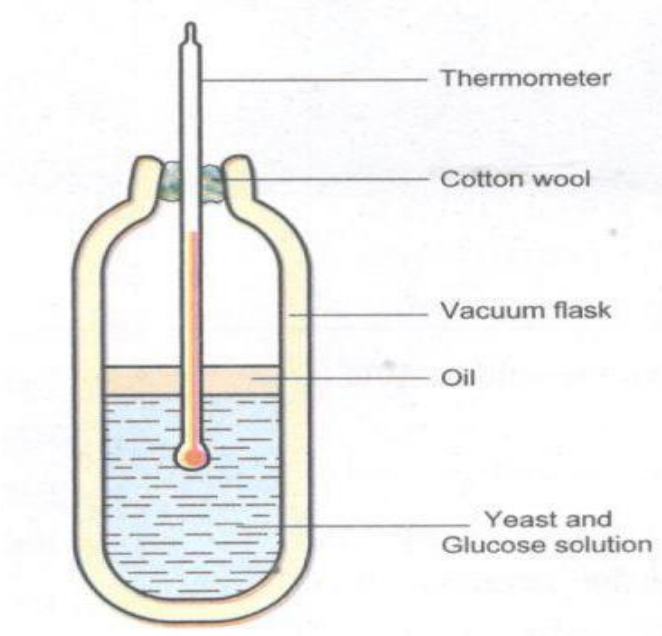
b) What chemical change is taking place in the germinating peas?

- ***Aerobic respiration.***

c) If water had been used instead of potassium hydroxide solution in the experiment, what would be observed?

- ***The level of potassium hydroxide would not change.***

3. The diagram below illustrates an experimental setup that was used to investigate a certain physiological process.



a) What was the aim of the experiment?

- ***To investigate anaerobic respiration using yeast.***

b) State the observations made in the vacuum flask.

- ***Rise in thermometer reading / rise in temperature.***
- ***Air bubbles in the flask.***
- ***Smell of ethanol / alcohol in the flask.***

c) Explain the observations made in the flask.

- ***Yeast cells break down glucose anaerobically to produce heat energy, carbon (IV) oxide and alcohol / ethanol. Heat energy increases the temperature / thermometer reading and carbon (IV) oxide causes bubbling.***

d) Why was the vacuum flask used?

- ***To prevent loss or entry of heat.***

e) Why was oil/ paraffin layer added to the suspension?

- ***It was added to prevent entry of air so as to allow anaerobic respiration take place.***

f) Suggest a control for the experiment.

- ***A similar set up without yeast / using boiled yeast.***

4. EXCRETION AND HOMEOSTASIS

Definition of terms.

1. **Excretion** is the process by which living organisms separate and remove/eliminate metabolic waste products from the body cells.

- These waste products include: carbon (IV) oxide, nitrogenous wastes, excess water, mineral salts, tannins, excess quinine and resins.

Need/significance/ importance of excretion.

- It prevents accumulation of metabolic wastes which may become poisonous/ toxic to the cells. This would alter the conditions under which cells function efficiently leading to death.

2. **Egestion/excreation** is the removal of indigestible and undigested food materials from the gut/ alimentary canal.
3. **Secretion** is the production and release of useful substances produced by the cells e.g. hormones, enzymes, sebum, oxalates and mucus.
4. **Homeostasis** is the maintenance of internal environment constant despite the changes in the external environment.
5. **Osmoregulation** is the process by which the **osmotic pressure of blood** and **tissue fluids** is **kept constant.**
6. **Thermoregulation** refers to **maintenance** or **keeping the body temperature constant.**

EXCRETION IN PLANTS.

Reasons why plants lack complex excretory organs.

1. Plant metabolic activities are few and produce/ release metabolic wastes slowly.
2. Plants produce less toxic wastes because they mainly break down carbohydrates to produce carbon (IV) oxide and water.
3. Some excretory products are reutilized within the plant body e.g. carbon (IV) oxide and water are used for photosynthesis and some oxygen used for respiration.
4. Most products are converted into non-toxic/ harmless form/ products.
5. Plants wastes are stored in temporary structures in less toxic form which then fall off e.g. leaves, flowers, fruits and the bark.

Reasons why plants are able to accumulate their wastes for long.

1. Most of the products are harmless/less toxic.
2. Most products are converted into non-toxic/ harmless form/ products.

METHODS OF EXCRETION IN PLANTS/PROCESS OF EXCRETION IN PLANTS/ HOW DOES EXCRETION OCCUR IN PLANTS?

1. **Transpiration** -excess water is excreted in form of water vapour through the stomata/lenticels.
2. **Diffusion**- carbon (IV) oxide (from respiration) and oxygen (from photosynthesis) are eliminated through diffusion through lenticels, cuticle and stomata.
3. **Deposition/storage in non toxic form-** some wastes (e.g. calcium oxalate, caffeine, nicotine and quinine) are stored in tissues (e.g. leaves, fruits, flowers, bark) in non-toxic form.
4. **Tissue/organ fall-** plants store some of their wastes in flowers, fruits, seeds, old leaves and the bark and when these organs fall off from the plants, the wastes are eliminated.
5. **Exudation-** some wastes (e.g. latex, salts, gum, calcium pectate, resins) are excreted in semi-solid form.
6. **Guttation-** excess water is excreted in form of droplets through **hydathodes.**

<u>Economic importance of plant excretory products.</u>

1) **<u>Tannin-</u>** it is deposited in dead tissues of wood and barks of acacia, wattle and mangrove trees.
- It is used in leather treatment/ tanning /softening of leather.
- Also used in making ink.

2) **<u>Caffeine-</u>** it is stored in coffee berries and tea leaves.
- It is used as a mild stimulant (to increase mental activity and reduces fatigue).

3) **<u>Quinine-</u>** it is stored in the bark of cinchoma tree and aloe leaves.
- It is used for treatment of malaria.

4) **<u>Cocaine-</u>** it is obtained from the leaves of cocoa plant.
- It is used as a local anaesthesia/ pain killer.

5) **<u>Cannabis-</u>** it is stored in fruits, flowers and leaves of bhang *(Cannabis sativa)*
- Used to treat cancer.
- It is a pain killer.

6) **<u>Nicotine-</u>** it is found in leaves of tobacco plants.
- It is used to manufacture insecticides and narcotic drugs.

7) **<u>Rubber-</u>** it is made from latex of rubber plant.
- It is used in shoe industry.
- It is used to manufacture chewing gums.

8) **<u>Colchicine-</u>**
- Used to treat gout disease.
- It is used in cancer therapy.
- Induces polyploidy in plants/hinders cell division/used in genetic engineering/ animal and plant breeding research.

9) **Gum arabica-** it is obtained from acacia trees.

- It is used in food processing and printing industry.

10) **Papain-** it is obtained from raw pawpaw fruit skin.

- It is used as meat tenderizer.

11) **Khat-** it is obtained from miraa.

- It acts as a mild stimulant and medicinal purposes.

12. **Morphine**- it is obtained from poppy plant.

- It is used as a pain killer and anaesthesia (to make the senses of the patient dull and relax)

13. **Heroine-** it is obtained from morphine.

- It is used as a narcotic drug.

14. **Pyrethrin-** it is obtained from pyrethrum.

- ✓ It is used to manufacture insecticides.

EXCRETION AND HOMEOSTASIS IN UNICELLULAR ORGANISMS E.G. PROTOZOA.

- Unicellular organisms such as amoeba and paramecium live water and their waste products include **carbon (IV) oxide, excess water** and nitrogenous wastes like **ammonia.**
- The main methods of excretion in unicellular organisms include:

A. Diffusion across cell membrane.

B. Use of contractile vacuole.

A. Diffusion (across cell membrane)

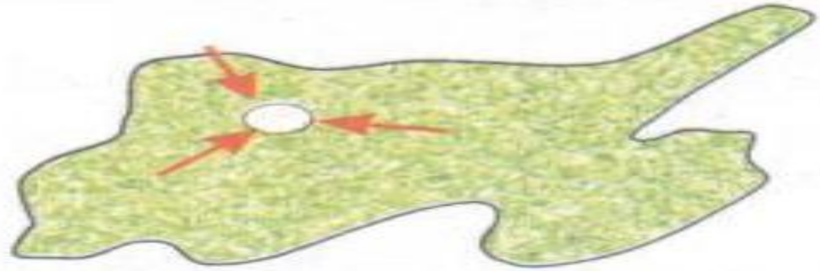
- Used to excrete ***carbon (IV) oxide*** *and* ***ammonia*** **.**
- The bodies of unicellular organisms have **large surface area to volume ratio** hence excretion takes place through diffusion.

Mechanism of excretion through diffusion.

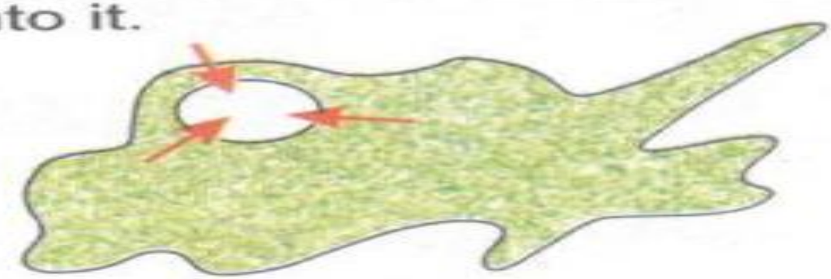
- Carbon (IV) oxide and ammonia gases are in higher concentration in the cytoplasm than surrounding water hence they diffuse out across the cell membrane into the surrounding water where their concentration is low.

B. Use of contractile vacuole.

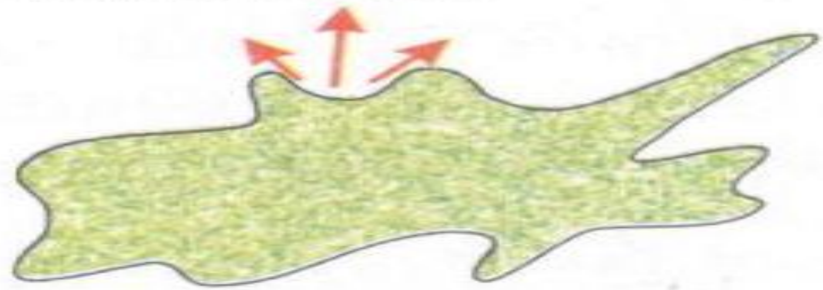
- It is used to excrete excess **water** and **dissolved chemicals (used for osmoregulation)**.
- Excess water and dissolved chemicals accumulate in the contractile vacuole. After reaching the maximum size, a contractile vacuole moves to cell surface and bursts releasing the wastes to the surrounding.
- Soon afterwards, other contractile vacuoles form in the cytoplasm, accumulate more wastes and the process continues.



a) Contractile vacuole and waste start to collect into it.



b) Contractile vacuole enlarging to maximum size, pushes cytoplasm as it moves towards the membrane.



c) Contractile vacuole burst and releases contents to the surrounding through the nearest part of the membrane

Fig 4.1: *Excretion in Amoeba*

<u>EXCRETION AND HOMEOSTASIS IN ANIMALS.</u>

- In animals excretion and homeostasis is carried out by complex excretory tissues and organs and do not depend on simple diffusion.
- This is because their bodies are complex and have greater number of cells.

<u>Reasons why animals need elaborate excretory system.</u>

1. Animals are more active hence produce more metabolic wastes.
2. Animals do not recycle their wastes as plants do.

<u>Examples of metabolic wastes in animals.</u>

1. **<u>Carbon (IV) oxide-</u>** this is produced during respiration in the cells. It diffuses out of the cells into blood then transported to the lungs for excretion.
2. **<u>Ammonia</u> –**It is a nitrogenous waste excreted by fresh water animals e.g. tilapia fish. This is because it is highly toxic and requires a lot of water (to dilute it) for excretion.
3. **<u>Urea</u>**- It is nitrogenous waste excreted by mammals and adult amphibians. This is because **<u>it is less toxic, soluble, smaller hence easily filtered in the kidney, requires less water for excretion.</u>**
4. **<u>Uric acid</u>-** It is nitrogenous waste excreted by animals found in arid and semi arid areas (e.g. birds, insects and reptiles). This is because it is less toxic hence requires less water for excretion.
5. **<u>Trimethylamine oxide-</u>** It is nitrogenous waste excreted by marine bony fish. This is because it is less toxic (than ammonia) hence requires less water for excretion.

HOMEOSTASIS

- Homeostasis is the maintenance of internal conditions constant despite changes in the external environment.
- The external environment is the immediate surrounding of the organism e.g. aquatic or terrestrial while internal environment is the immediate surrounding of the body cells (tissue or interstitial fluid).
- Internal conditions kept constant include: Osmotic pressure of bloo0d and tissue fluid, Temperature, pH of tissue fluid and blood, Glucose (blood sugar) concentration, Ionic concentration.
- Homeostasis is controlled by the part of the brain called **Hypothalamus.**

Significance of homeostasis.

i. To maintain optimum conditions for proper functioning of the body cells.

ii. It enables organisms to inhabit/adapt to a wider range of environments and habitats.

Principle of homeostasis./ Feed back mechanism.

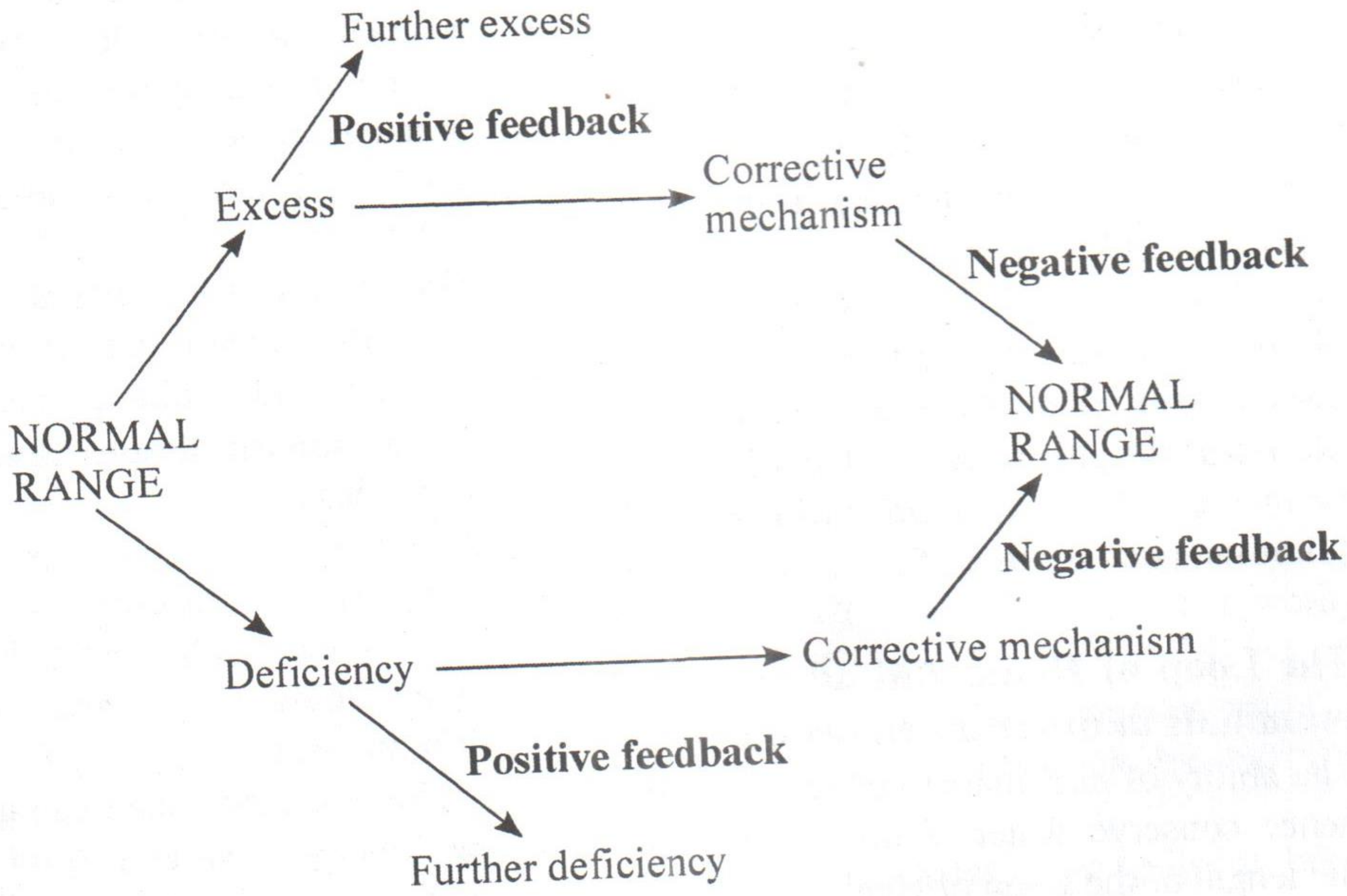
- **A feed back mechanism** is any mechanism involved in regulating the internal environment of an organism.
- There are two types of feedback mechanisms:

1. **Negative feedback-** corrective measure /action taken to restore the condition back to normal. Such action is either:

a) An increase in the level (e.g. temperature) back to normal if it was dropping,

b) A decrease in the level (e.g. temperature) back to normal if it was rising.

2. **Positive feed back-** a change below or above the normal is not corrected leading to further rise or drop in the condition from the normal.


Further excess
Positive feedback
Excess
Corrective
mechanism
Negative feedback
NORMAL
RANGE
NORMAL
RANGE
Negative feedback
Deficiency
Corrective mechanism
Positive feedback
Further deficiency

PROCESSES INVOLVED IN HOMEOSTASIS.

1. **Osmoregulation/salt and water balance.**

- This is the process by which the **osmotic pressure of blood , protoplasm** and **tissue fluids** is **kept constant.**
- Osmoregulation helps to maintain optimum osmotic pressure in the body tissues and fluids for proper functioning of the cells.
- For example, if the osmotic pressure of tissue fluid falls below that of cells, the cells will take in water by osmosis, swell and may burst (haemolyse).
- If the osmotic pressure of tissue fluid is higher than that of cells, the cells will lose water through osmosis and shrink.

2. **Thermoregulation.**

- It refers to regulation of body temperature/ maintenance of body temperature constant.
- Body enzymes work best under a narrow range of temperature. Very high temperature/ above optimum **denature/destroy** enzymes**,** while very low/below optimum inactivates the enzyme.

3. **Regulation of ionic content-** it involves regulation of body ions (e.g. sodium ions, chloride ions, calcium ions, phosphate ions) within their optimum concentration.

- This is because they are important for proper functioning of the body processes e.g. protein synthesis, respiration, nervous coordination and muscle contraction.

4. **Blood sugar/glucose regulation.**

- Low blood glucose level leads to low rate of respiration as glucose is the main substrate in respiration hence less energy available to the body.
- High blood glucose level results in an increase in the osmotic pressure of tissue fluid. This causes the cells to lose water through osmosis leading to **crenation.**

Study questions

1. Explain the osmoregulatory changes that would take place in marine amoeba if it was transferred to a fresh water environment.

- ***More water will enter the amoeba through osmosis and more contractile vacuoles are formed to excrete more/ excess water.***

2. Explain how marine fish regulates its osmotic pressure.

- ***It swallows plenty/ a lot of water to increase the amount of water in the body.***
- ***It has chloride secretory cells in the gills to remove excess salts.***
- ***It eliminates nitrogenous wastes in form of Trimethylamine oxide which requires less water for excretion/ elimination.***
- ***It has small and few glomeruli thus slowing down filtration rate in the kidneys.***

ORGANS USED FOR EXCRETION AND HOMEOSTASIS IN ANIMALS.

- They include the skin, lungs, kidney and liver.

A. **LUNGS.**

- The functions of the lungs are:

1. Gaseous exchange.
2. Excretion.

- The excretory product of the lungs are Carbon (IV) oxide and water/ moisture.

Adaptations of the lungs to excretion.

1. Lungs have many small air sacs called **alveoli** which increase the surface area for diffusion of carbon (IV) oxide.
2. Alveoli have a thin epithelium for faster diffusion of carbon (IV) oxide.

Mechanism of excretion in the lungs.

- Carbon (IV) oxide is in higher concentration in blood capillaries (around the alveoli) than the alveolar cavity/ space.
- It diffuses out of blood into the alveolar space/ cavity which is then expelled from the lungs through exhalation.
- The exhaled air is moist leading to loss of water/ moisture.

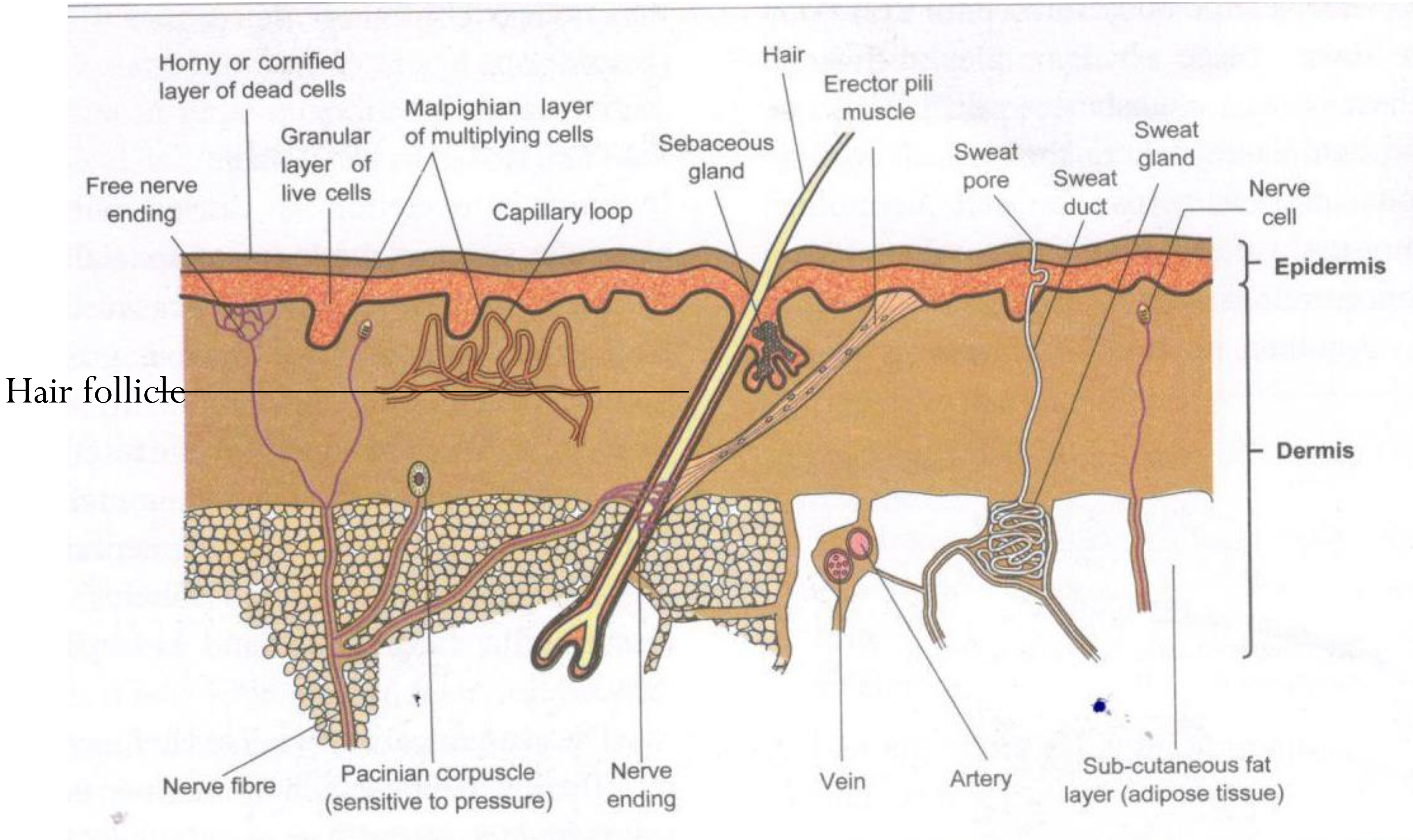
B. **SKIN**

- The skin is used to excrete **urea, excess water, salts, ammonia.**

Functions of the skin.

1. Protection of the underlying tissues from entry of micro-organisms, physical damage and ultra violet rays from the sun.
2. Regulation of body temperature/thermoregulation.
3. Excretion.
4. Reception of stimuli of heat, cold, pain, touch and pressure.
5. Synthesis of vitamin D.
6. Storage of fats.

CROSS SECTION OF A MAMMALIAN SKIN



ADAPTATION TO FUNCTION OF DIFFERENT PARTS OF THE SKIN.

- The skin consists of two main layers: **epidermis** and dermis.

A. **The epidermis-** it consists of 3 layers: **cornified layer, granular layer and malpighian layer.**

1. **Cornified layer-** it is the outermost layer of the skin made up of dead cells that are covered with flexible substance called **keratin** that;

a) Provides protection against mechanical/ physical damage.

b) Provides protection against entry of pathogens.

c) Reduces loss of water by evaporation.

- The cells of cornified layer are continuously lost through friction and are replaced by cells from granular layer.
- The thickness of cornified layer varies in the body e.g. it is thickest in areas of high friction like palms of hands and soles of feet but thinnest on lips and eyeballs.

2. **<u>Granular layer</u>** this is a middle layer consisting of living cells that give rise to the cornified layer.
3. **<u>Malpighian layer-</u>** this is the innermost layer consisting of actively dividing cells that give rise to the new epidermis.

- The cells also have a pigment called **<u>melanin</u>** that gives the skin its colour and protects it against harmful effects of ultra violet (UV) rays from the sun.

B. **<u>The dermis-</u>** it consists of:

1. **Sweat/ sudorific glands-** consists of secretory cells secrete more sweat from surrounding blood vessels and tissues (consisting of excretory wastes e.g. excess water, traces of urea, lactic acid, ammonia and excess mineral salts) when it is hot.

- ✓ Sweat is brought/ flows to the skin surface through sweat duct. Water in sweat evaporates/sweat evaporates carrying with it latent heat of vaporization thus cooling the body/ reducing body temperature.

- And it also helps in excretion of lactic acid, traces of urea, excess water, ammonia and excess mineral salts and regulation of salt and water balance (osmoregulation).
- In cold weather, little or no sweat is produced thus heat is conserved.

2. **<u>Blood vessels/arterioles</u>** Blood vessels contain blood that supplies nutrients and oxygen to skin tissues and remove waste products and carbon (IV) oxide.

- When it is hot/ when temperature rises above optimum the arterioles dilate (vasodilate), more blood flows near the skin surface hence more heat is lost through conduction and convection.
- When it is cold/ temperature fall below normal, the arterioles constrict (vasoconstrict), less blood flows near the skin surface hence less heat is lost/ heat conserved/ insulates the body against heat loss.

3. **<u>Hairs and erector pili muscle.-</u>** Hairs grow in hair follicles. Erector pili muscle attaches the hair follicle to the epidermis. **<u>Hair follicle is supplied with sensory nerves to increase sensitivity of the skin and blood vessels that supply nutrients and remove waste products.</u>**

- They are also used in **<u>thermoregulation</u>**. When it is cold/ when temperature drops below normal, erector pili muscles contract, causing the hairs to stand erect. Hairs trap air which is a poor conductor of heat, preventing heat loss/ conserving heat.
- When it is hot/ when temperature rises above normal, erector pili muscles relax, hairs lie flat on the skin surface, trapping less air hence more heat is lost.

4. **<u>Sebaceous glands</u>**.- They are attached and open into the hair follicle.

- They secrete sebum which keeps the hair and epidermis flexible/ supple/soft and waterproof. Sebum also contains antiseptic substances for protection against bacteria.

5. **Nerve endings of nerve cells-** they detect stimuli of pain, pressure and temperatures of the external environment to enable organism to respond to changes in the environment.
6. **Subcutaneous layer/adipose tissue**.- this is a layer of fat cells beneath the dermis.

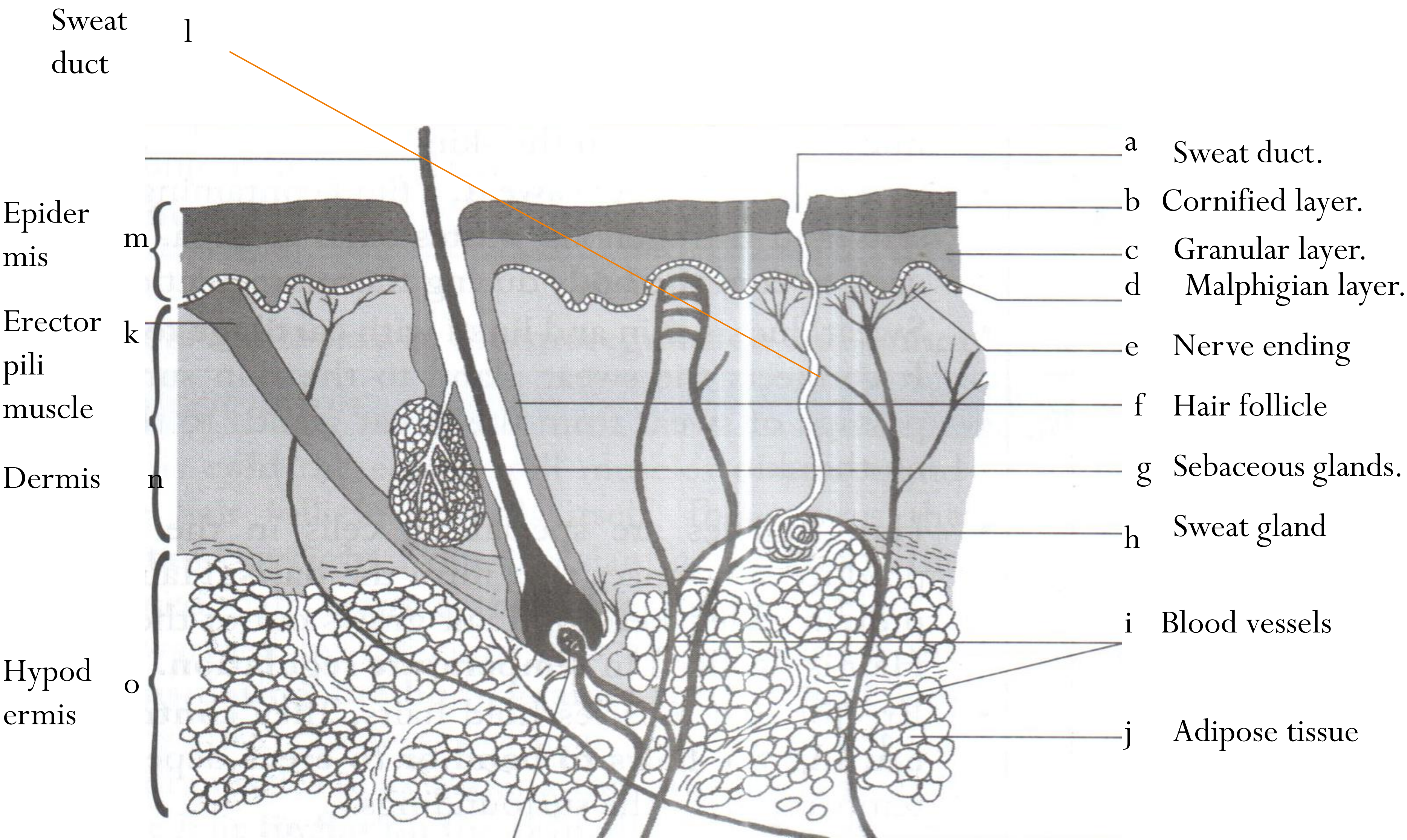
- It binds the skin to the muscles and other organs deep in the body.
- It also stores fats and acts as an insulator against heat loss/ conserves heat.
- It also contains a special type of cells that manufactures vitamin D when exposed to the sun.

Study question

How is the skin adapted to protection?

- The cornified layer is made of dead cells; which protects the body against physical/mechanical injury/ damage; prevents entry of pathogens and poisonous chemicals;
- The sebaceous gland produces an oily secretion /sebum; that protects the skin against invasion by micro-organisms (acts as antiseptic).
- Malpighian layer contains melanin; which protects the body against harmful ultra-violet rays;

RECAP



Sweat duct
l
Epider mis
m
Erector pili muscle
k
Dermis
n
Hypod ermis
o
a Sweat duct.
b Cornified layer.
c Granular layer.
d Malphigian layer.
e Nerve ending
f Hair follicle
g Sebaceous glands.
h Sweat gland
i Blood vessels
j Adipose tissue

ROLE OF SKIN IN EXCRETION AND HOMEOSTASIS.

Role of the skin in excretion.

- Sweat glands secrete sweat containing excess water, mineral salts, ammonia, traces of urea, lactic acid. Sweat flows through the sweat duct to the skin surface and the wastes are lost.

Adaptations/ role of the skin in homeostasis.

a) **Osmoregulation.**

- The skin has sweat glands that secrete sweat containing excess water and mineral salts/ ions and other wastes e.g. urea hence maintaining water and ions balance.
- The water and mineral lost in the sweat contributes to osmotic changes of the body cells and fluids.
- On a hot day, the body loses a lot of water and some mineral salts, resulting in the sensation of thirst being felt due to tissue dehydration.
- The osmotic balance is however restored by drinking large volumes of water and intake of mineral salts in the diet.

b) **<u>Thermoregulation.</u>**

- It has blood arterioles/ vessels that vasodilate (vasodilation) when it is hot/ when the body temperature rises above normal, the hypothalamus is stimulated which sends impulse to the skin causing more blood flows near the skin surface hence more heat is lost.
- When it is cold/ when the body temperature falls below normal, the arterioles constrict/ vasoconstrict (vasoconstriction), less blood flows near the skin surface hence less heat is lost/ heat is conserved.
- It has erector pili muscles which contract when it is cold/ when the body temperature falls below normal.
- This causes hairs to stand erect trapping more air. Air which is a poor conductor of heat insulates the body against heat loss/ prevents heat loss.
- When the temperature is raised above the normal/when it is hot, erector pili muscles relax, hair lies flat on the skin surface, less air is trapped and more heat is lost.

- It has sweat glands which secrete more sweat when the temperature is raised above the normal/when it is hot.
- Water in sweat evaporates/sweat evaporates, taking up heat from the body hence the body is cooled/temperature lowered.
- When it is cold/ when temperature drops below normal sweat glands are less stimulated/there is less sweating leading to less vaporization of water/less heat loss.

Study question.

1. State one homeostatic role of the human skin.

- ***Thermoregulation, osmoregulation, regulation of salts.***

2. Name three structures of the skin essential for its homeostatic function.

- ***Sweat glands.***
- ***Hair.***
- ***Erector pili muscle.***
- ***Blood vessels/ arterioles..***
- ***Nerve endings.***

3. Explain why the amount of sweat increases with increase in temperature.

- ✓ **This is because of increase in latent heat of vaporization hence causing evaporation/ vaporization of sweat to cool the body.**

C. KIDNEY.

- It is used to excrete **urea, uric acid, excess water, salts.**
- It performs the following functions:

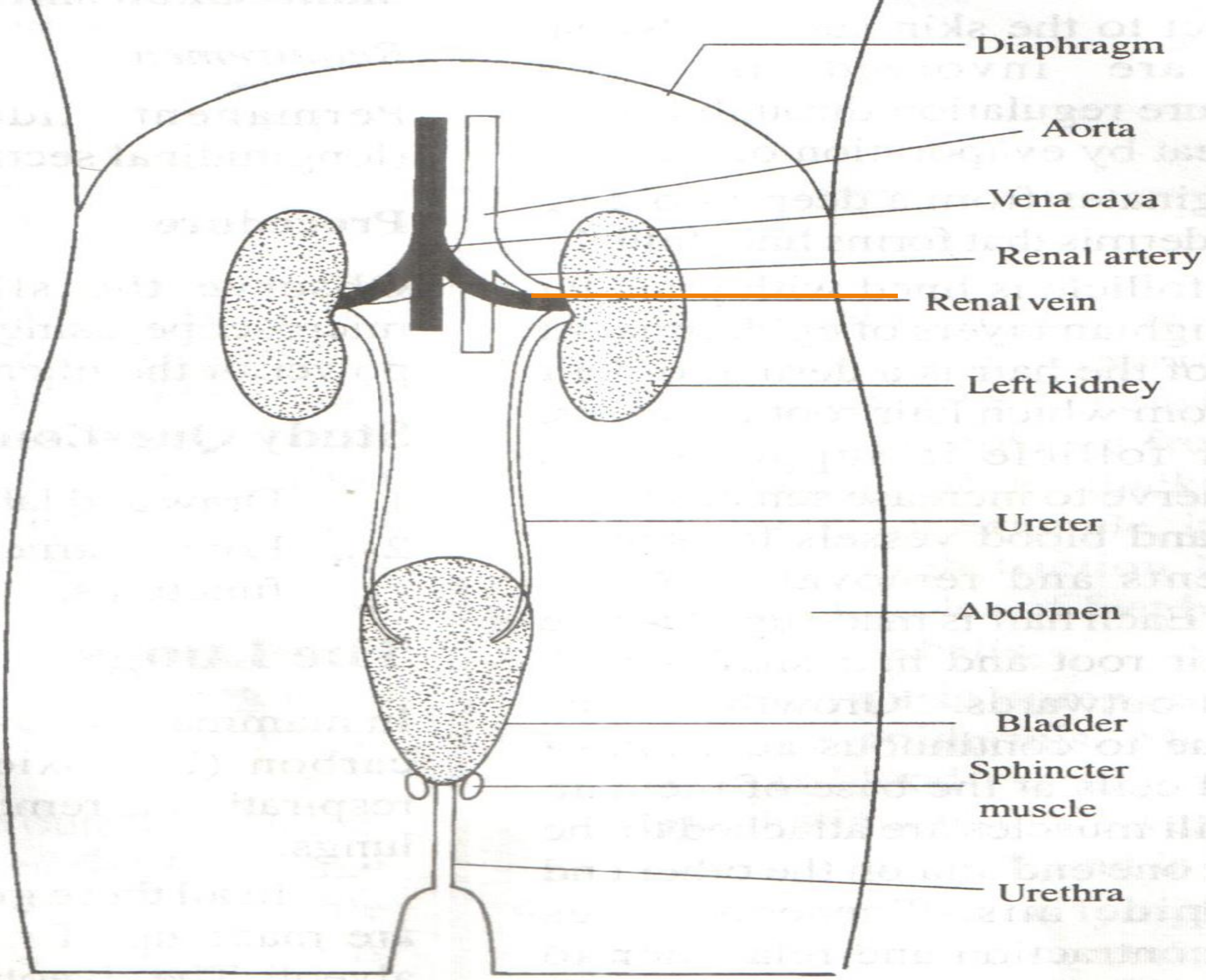
1. Excretion
2. Osmoregulation (regulation of water and ionic content in blood)
3. Regulation of pH of blood and tissue fluid.

- A mammal has a pair of kidneys located in the abdominal cavity. They are bean-shaped and red in colour.
- The **adrenal glands** are located above each kidney which secrete hormones.

Parts of a kidney.

1. **Hilum-** it is a depression located on the concave side of the kidney through which the **renal artery** enters to supply blood from the heart containing **oxygen, nutrients and urea** and **renal vein** which removes blood from kidney from the kidney to the heart containing **carbon (IV) oxide.**
2. **Cortex** – this is the outer part of the kidney and contains **glomeruli , Bowman's capsule and the convoluted tubules of the nephrons.**

3. **Medulla** – this is the inner part of the kidney. It is red in colour and contains **the loop of Henle and the collecting ducts.**
4. **Pyramids-** they are conical structures that extend from medulla.
5. **Pelvis-** this is a swollen cavity which is white in colour.
6. **Ureter**- it arises from the pelvis and directs urine to the **urinary bladder** for storage.
7. **Nephrons-** functional units of the kidney. Each kidney has about 5 million nephrons.



l urinary system of a mammal

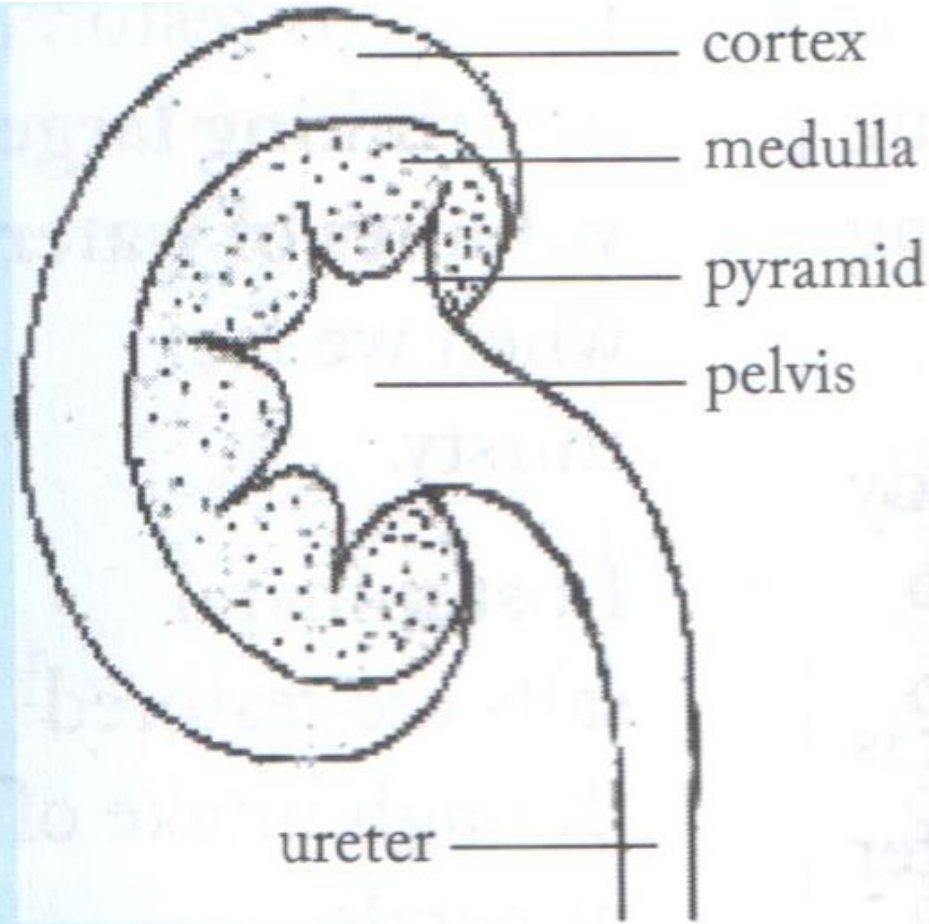
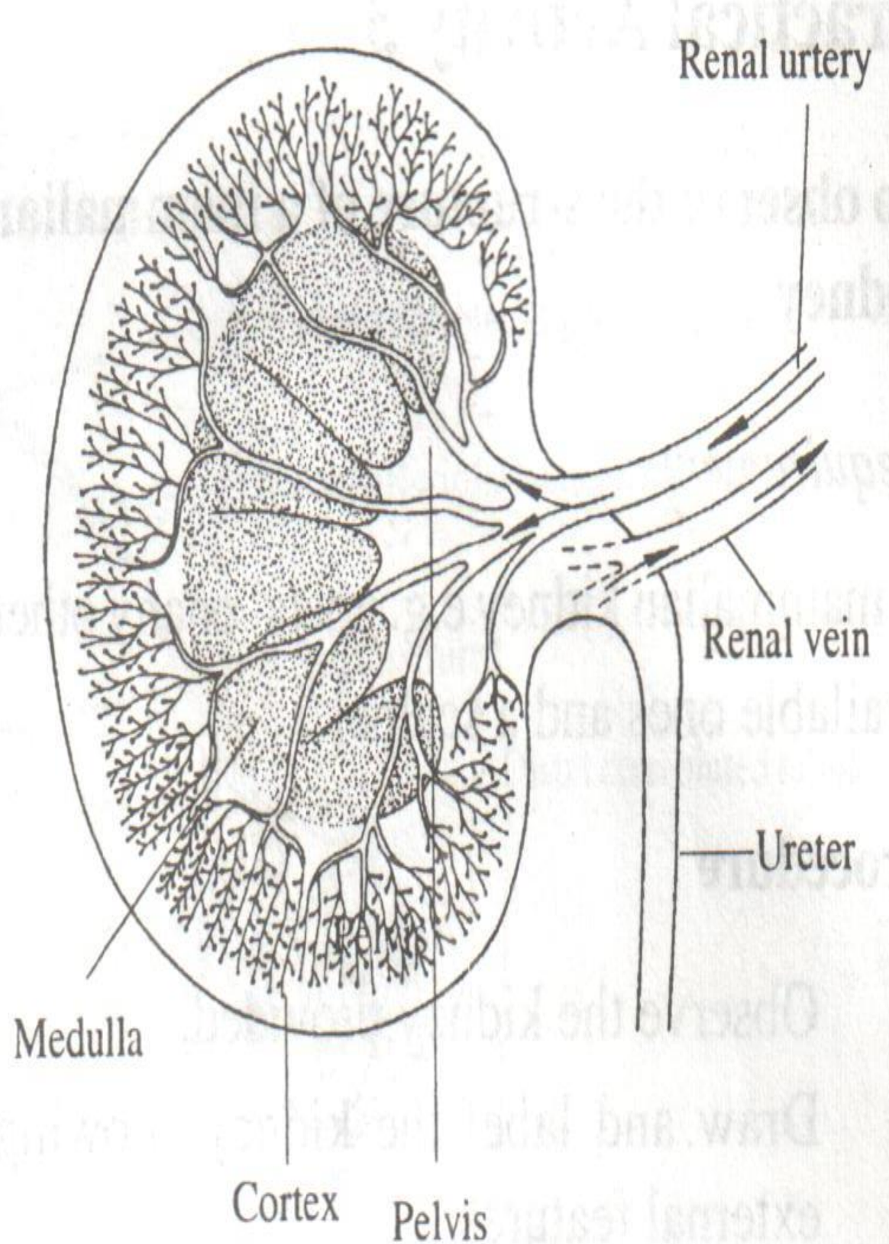
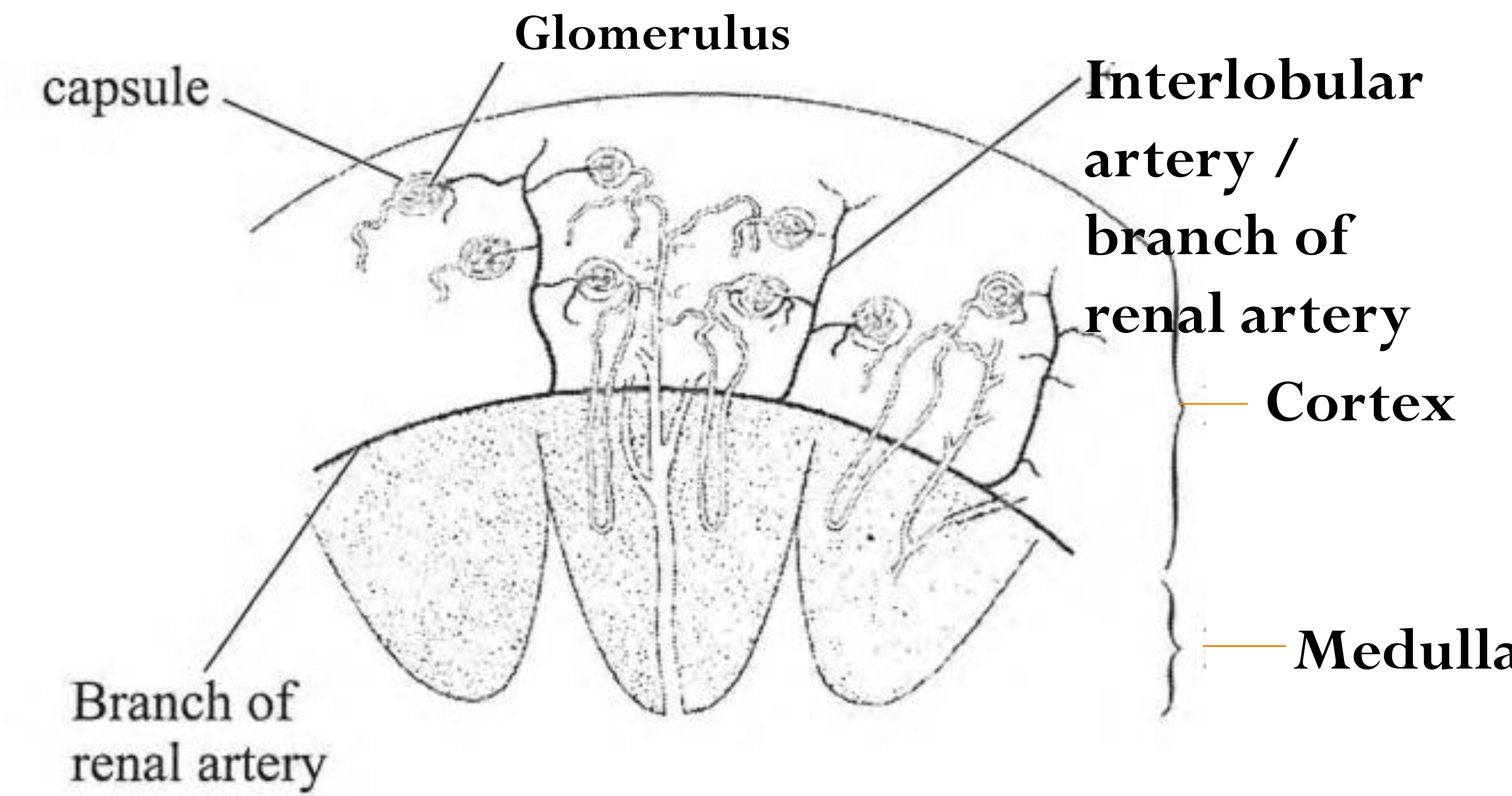


Fig 3.28: Parts of the kidney



Section through the cortex and medulla



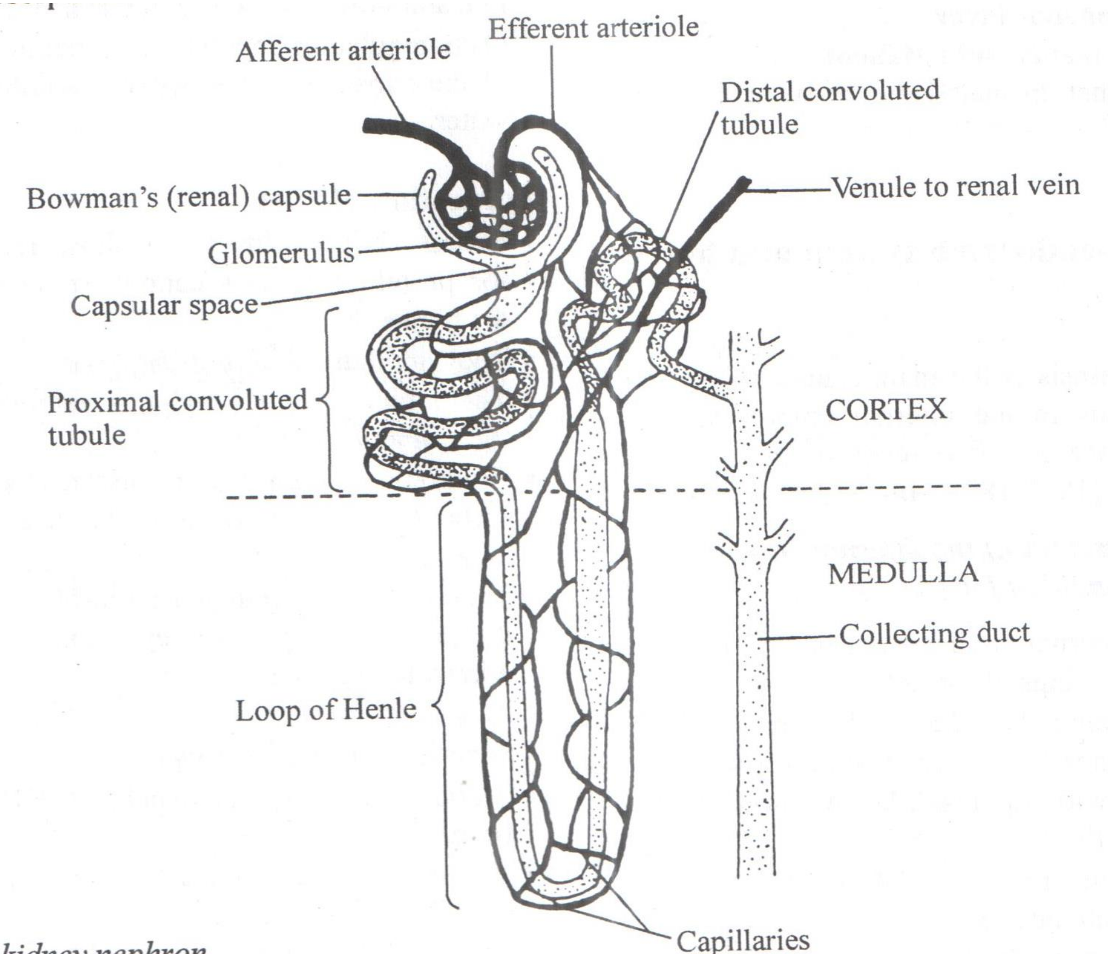
THE NEPHRON.

- This is the basic functional unit of the kidney.
- Each kidney contains about 5 million nephrons.

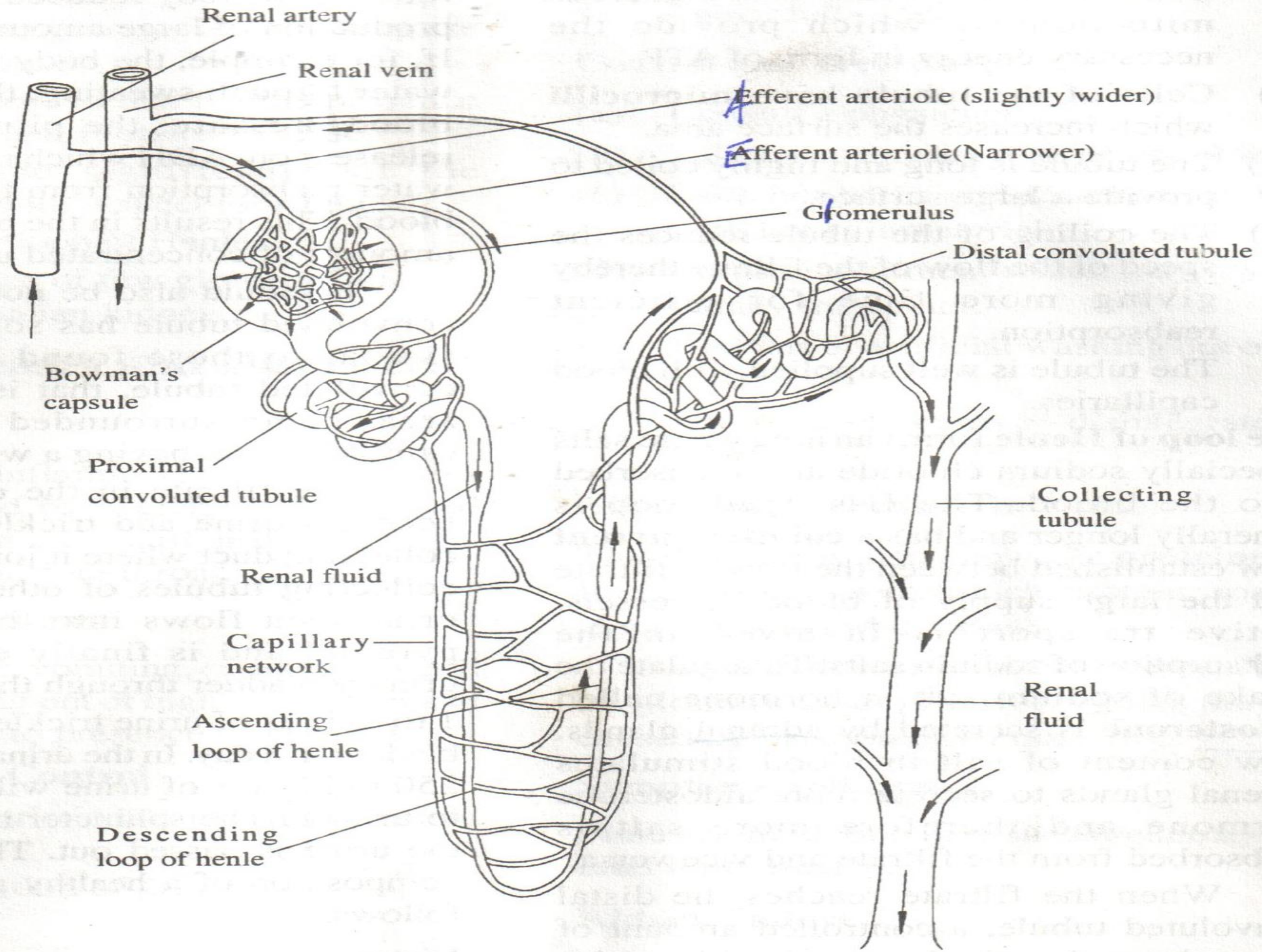
Parts of the nephron.

1. **Afferent arteriole-** brings blood to the nephron from the renal artery.
2. **Efferent arteriole** - takes blood away from the nephron to the renal vein.
3. **Bowman's capsule-** cavity which encloses the glomerulus.
4. **Glomerulus (Plural- glomeruli)** - a network of capillaries enclosed by bowman's capsule.
5. **Proximal convoluted tubule-** it is coiled and extends into Loop of Henle.
6. **Loop of Henle-** U- shaped part of the nephron.
7. **Distal convoluted tubule-** it is coiled and leads into a collecting duct/ tubule
8. **Collecting duct-** it receives urine from several nephrons and directs it to the pelvis and ureter.

The structure of kidney nephron.



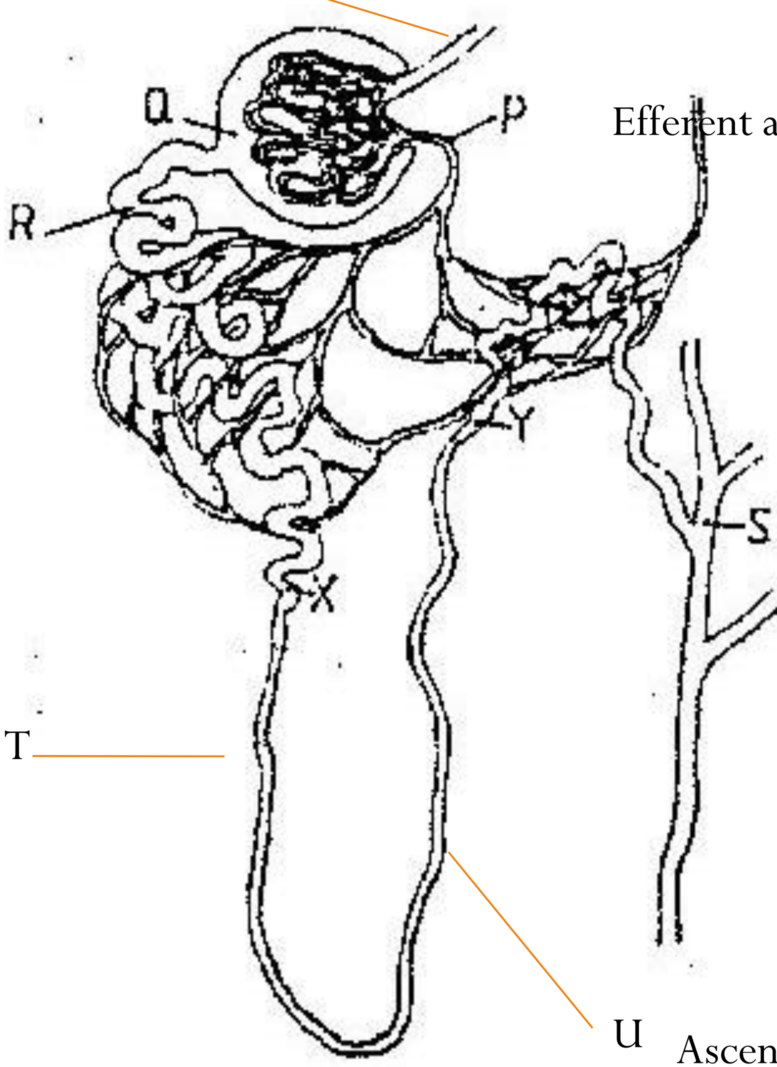
The kidney nephron



The structure of the kidney nephron

Afferent arteriole O

Bowman’s capsule



Efferent arteriole

Proximal
convoluted tubule

Collecting duct/tubule

Descending loop of
Henle

T

U

Ascending loop of Henle

ROLE OF THE KIDNEY IN EXCRETION/URINE FORMATION/HOW THE KIDNEY/ NEPHRON WORKS(FUNCTIONS)

- The kidney/ nephron receives blood from the **renal artery** through **afferent arteriole** into the **glomerulus.**
- Blood contains **urea, blood cells, dissolved food substances, water , hormones and blood proteins.**
- The afferent arteriole receives blood at a higher pressure from the renal artery. The afferent arteriole entering the glomerulus is wider that the efferent arteriole leaving it.
- The **higher blood pressure, narrower lumen of glomerulus and narrowness of the efferent arteriole than the afferent arteriole** causes resistance and high pressure in the glomerulus.
- Because of the high pressure, small sized substances **(water, urea, glucose, mineral salts, amino acids)** filter through the **glomerulus** into **Bowman's capsule/ capsular cavity/ space** in the process called **ultrafiltration.** The mixture is called **Glomerular filtrate.**

- **Ultrafiltration** is important to allow excretion/removal of metabolic/ nitrogenous waste/ urea.
- Large sized substances (**blood cells and blood proteins)** do not filter through, instead they flow to **efferent arteriole.** This is because of small pores of glomerulus and Bowman's capsule.
- The **glomerular filtrate** then flows to the **proximal convoluted tubules** where **selective reabsorption** takes place.
- **Amino acids, glucose, vitamins, and some water** are reabsorbed through **diffusion** and **active transport** and **water** through **osmosis.**
- **Selective reabsorption** is important to allow return/ reabsorption of useful substances back into the blood stream.
- The filtrate then flows to the **descending arm/ limb of loop of Henle** where **water** is selectively reabsorbed through **osmosis.**
- Water re-absorption is influenced by active uptake of sodium ions at the ascending loop of Henle which increases osmotic pressure of tissue fluid and **Anti-diuretic hormone (ADH)** secreted by **pituitary gland.**

- At the **ascending arm/ limb of Loop of Henle, sodium ions /salts / mineral salts/ ions** are selectively re-absorbed through **active transport.** Re-absorption of sodium chloride ions is controlled by **aldosterone** secreted by **adrenal glands**.
- The filtrate then **flows** to **distal convoluted tubule** where **water** is reabsorbed through **osmosis.** The water reabsorption is influenced by active uptake of sodium ions at the loop of Henle and Antidiuretic hormone.
- The filtrate/ urine then flows to collecting duct where **water** is reabsorbed through **osmosis**. Urine contains urea, excess salts, water, some ammonia, some uric acid.
- Urine flows to the ***pelvis*** and then to the ***urinary bladder*** through the ***ureter***. Urinary bladder stores the urine for some time before it is eliminated through the urethra (through urination).

ADAPTATIONS OF THE NEPHRON TO ITS FUNCTION.

1. **Afferent arteriole** has a **wider lumen** than **efferent arteriole** creating **high-pressure** that **enables ultra-filtration** to occur at the glomerulus.
2. The **glomeruli** (capillaries) have **tiny pores** to facilitate **ultra-filtration.**
3. The **proximal and distal convoluted tubules** have the following adaptations:

a) The lumen wall has villi and microvilli which increase the surface area for reabsorption.

b) The tubule is long and highly coiled to increase surface area and slow down movement of filtrate/ creating more time for efficient reabsorption.

c) It is one cell thick/has thin epithelium to reduce the distance travelled by substances hence faster reabsorption of materials.

d) The tubule is well vascularized/ well supplied with blood capillaries for transportation of reabsorbed materials/ create a steep concentration gradient for efficient transport of reabsorbed materials.

e) The cells lining the tubule have numerous mitochondria which provide energy for active transport/ reabsorption of substances.

5. The **<u>Loop of Henle</u>** has the following adaptations:

   a) It is long to increase the surface area for re-absorption of mineral salts and water.

   b) It has **a counter current flow** established between the filtrate flow and the large supply of blood in capillaries. This creates a large/steep diffusion gradient for efficient re-absorption.

Renal adaptations of a desert animal e.g. desert rat

1. Has a small **glomerulus** to reduce the amount of water filtered into the **glomerular filtrate** which helps in water retention.
2. Has a **long loop of Henle to** increase the surface area for water re-absorption conserving water/ causing less water to be lost in urine.

Renal adaptations of aquatic animal e.g. hippo.

1. Has a **large glomerulus** to increase the amount of water filtered into the **glomerular filtrate.**
2. Has a **short loop of Henle to** reduce water re-absorption.

Factors that promote re-absorption of water in the distal convoluted tubule.

1. The active uptake of mineral salts at the loop of Henle that raises the osmotic potential of blood.
2. Secretion of ***Antidiuretic hormone (ADH)*** from the pituitary gland which increases permeability of the tubules and blood capillaries to water.

Factors that determine the quantity and concentration of urine in animals.

1. Habitat e.g. whether terrestrial or aquatic.
2. Physiological adaptations.
3. Structural adaptations e.g. possession of a long ***loop*** of ***Henle***.
4. **Environmental temperature-** as temperature increases, the amount of urine produced decreases.

- ✓ This is because increase in temperature increases sweating which raises the osmotic pressure of blood.
- ✓ This causes more water to be reabsorbed into the bloodstream in the kidney tubules resulting in production of little but concentrated urine.

Role of the kidney in excretion/ purification of blood.

- Blood entering the kidney has a lot of water, salts and nitrogenous wastes e.g. urea, uric acid, ammonia and creatinine.
- In the glomerulus, these substances are forced out into the glomerulus by the process of ultrafiltration.
- They pass through the tubules without reabsorption and finally eliminated through urine and the blood leaving the kidney is purified.

Study question.

1. Explain why the nephron is long and coiled.

- ***To occupy less space in the kidney, to increase surface area for selective reabsorption and allow more time for selective reabsorption.***

ROLE OF THE KIDNEY IN HOMEOSTASIS

- When the osmotic pressure of the blood rises above normal (as a result of dehydration), the osmoreceptors in the **hypothalamus** are stimulated which stimulates the **pituitary gland** to secrete a hormone called **anti-diuretic hormone** (**ADH**) or **vasopressin** into the blood.
- On reaching the kidney, **Anti-diuretic hormone** (**ADH**) or **vasopressin** causes the kidney tubules to be more permeable to water. More water is reabsorbed into the blood stream lowering osmotic pressure of the blood producing a concentrated urine.

- When the osmotic pressure of the blood falls below normal, hypothalamus is less stimulated hence the **pituitary gland** is less stimulated, less **Anti-diuretic hormone** (**ADH**) or **vasopressin** is released into the blood stream.
- The kidney tubules become less permeable to water and less re-absorption of water into blood stream takes place hence osmotic pressure of blood rises and dilute urine is produced. Lack of **ADH/Vasopressin** leads to **Diabetes Inspidus**

- When the level of sodium ions is low in the blood, **adrenal glands** are stimulated to release **aldosterone** into the blood. Aldosterone stimulate loop of **Henle** of **kidney** to reabsorb sodium ion into the blood.
- If the sodium ions concentration in the blood rises above optimum level, **adrenal glands** produce less **aldosterone** into the blood and less amounts of sodium ions are absorbed.

Diabetes Inspidus.

- This is a condition in which in which a person excretes large amount of dilute urine.
- Occurs when the pituitary gland fails to produce ***anti-diuretic hormone*** or produces it in inadequate amount.
- The kidney tubules are less permeable to water producing large amount of dilute urine. This is called diuresis).
- The patient becomes dehydrated and has to compensate for the loss by drinking a lot water.

KIDNEY DISEASES.

A. **NEPHRITIS**

- This is the inflammation of the glomerulus of the kidney caused by bacterial associated infections e.g. small pox, measles, typhoid fever and sore throat.

Symptoms

1. Headache.
2. Oedema (swelling of jaw).
3. Vomiting.
4. Drowsiness.
5. Nausea.
6. Fever.
7. General weakness.
8. Passing of highly coloured urine due the presence of proteins.

Control and treatment.

1. Administration of drugs/ antibiotics.
2. Renal dialysis.
3. Controlled use of salts and proteins.
4. Bed rest.

B. **KIDNEY STONES.**

Causes

1. Improper diet and inadequate of water.
2. Chemical salts in water e.g. oxalates, phosphates, urates and uric acid.

- These chemicals undergo precipitation and form hard deposits or stones in the pelvis and ureter hence cause blockage of urine.

Control and treatment.

i. Sharp pain on the lower back
ii. Difficulty in passing out urine.
iii. Pain
iv. Chills
v. Fever.

Control.

1. Consult a physician.
2. Take balanced diet with plenty of water.
3. Take hot baths and massage the back with hot soft material.
4. Surgical treatment which may involve kidney transplant.
5. Dialysis or artificial washing out of the wastes.
6. Use of laser beams to disintegrate the stones.
7. Use of drugs to dissolve the stones.

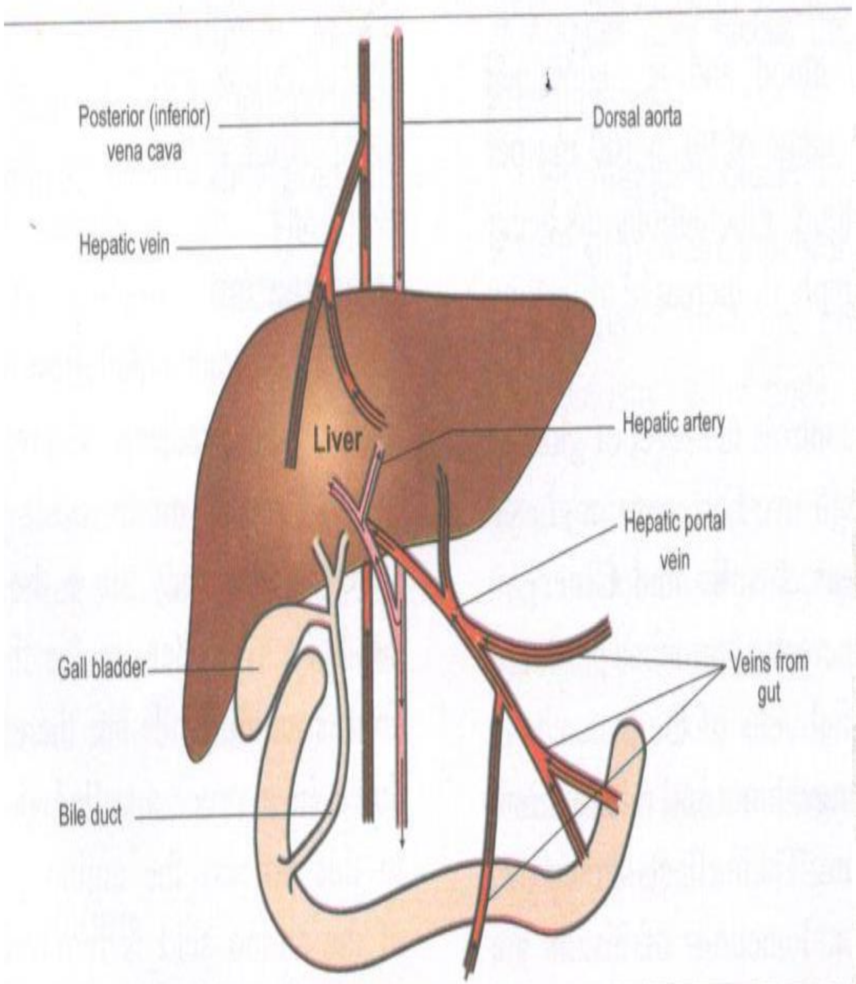
D.LIVER

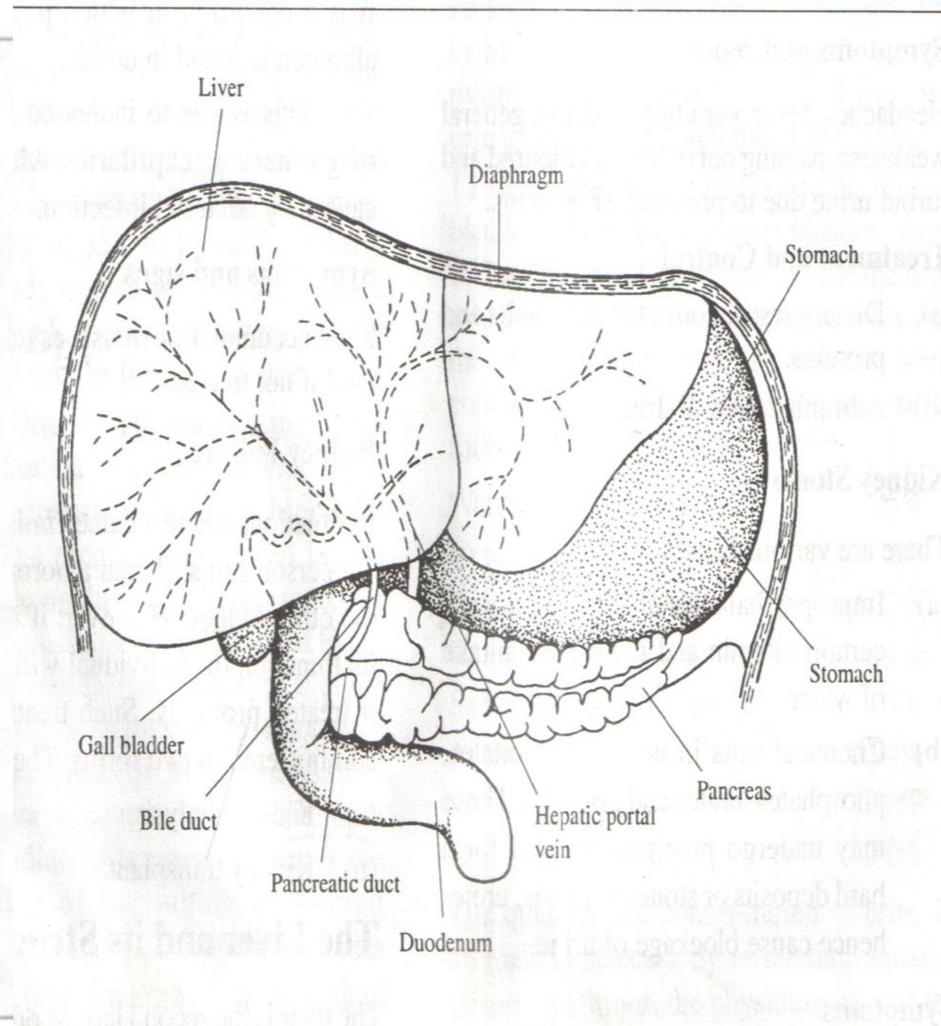
- It is located below the diaphragm and used to excrete the following products: **bile pigments and cholesterol.**
- It is connected to the following blood vessels:

1. **Hepatic artery-** which carries oxygenated blood rich in nutrients and oxygen from the heart to the **liver.**
2. **Hepatic vein –** which carries blood rich in carbon (IV) oxide and nitrogenous wastes from the **liver** to the heart.
3. **Hepatic portal vein –** which carries blood from the intestines and stomach to the liver to regulate the amount of blood sugar before it enters the general circulation.

Roles/ functions of the liver.

1. Regulation of blood sugar level.
2. Detoxication/ detoxification.
3. Deamination.
4. Thermoregulation.
5. Regulation of haemoglobin/ excretion of bile pigments.
6. Regulation of plasma proteins.
7. Manufacture of blood cells (during foetal stage)
8. Formation and elimination of excess cholesterol.
9. Regulation of fat metabolism.
10. Storage of blood.
11. Storage of vitamins B, C, E, K and minerals.


Posterior (inferior)
vena cava
Dorsal aorta
Hepatic vein
Liver
Hepatic artery
Hepatic portal
vein
Gall bladder
Veins from
gut
Bile duct


Liver
Diaphragm
Stomach
Stomach
Gall bladder
Bile duct
Pancreatic duct
Duodenum
Hepatic portal
vein
Pancreas

FUNCTIONS/ ROLE OF THE LIVER IN EXCRETION AND HOMEOSTASIS.

A. **ROLE OF THE LIVER IN HOMEOSTASIS.**

1. **Regulation of blood sugar/glucose-** When there is excess sugar/rises above normal, the hormone **insulin** is produced by interstitial cells of (**Beta (ß) Islets of Langerhans of)** the **pancreas**.

- Insulin stimulates liver cells to convert the excess **glucose** to **glycogen** or fats for storage, increase oxidation of glucose, inhibit conversion of glycogen to glucose lowering blood sugar level to normal/ optimum level.
- When the blood sugar level drops below normal, the hormone **glucagon** is produced by the interstitial cells (**Alpha(§) Islets of Langerhans of)** the pancreas.
- Glucagon stimulates the liver cells to convert **glycogen** and fats to **glucose** , reduce the breakdown of glucose thus raising blood sugar level to normal/ optimum level.

2. **Production of heat energy/ thermoregulation.**

- When the temperature is low, the hypothalamus sends impulse to the liver. The liver increases the rate of metabolic reactions producing heat energy which is distributed throughout the body thus increasing the body temperature.

B. **ROLE OF THE LIVER IN EXCRETION.**

1. **Deamination/ Regulation of amino acids levels-** Excess amino acids cannot be stored in the body because the body does not have mechanism for storage hence are eliminated through deamination. Deamination is the process by which **excess amino acids are broken down** in **the** liver to form urea which is excreted in urine.

Process of deamination.

- **Amino group** (NH2) is removed from the amino acid. Amino group combines with hydrogen atom to form **ammonia**.

- Ammonia is taken into ornithine cycle reacts/ combines with carbon (IV) oxide to form **urea**. Ornithine cycle is controlled by enzyme ***carbonic anhydrase*/ orginase.**
- The remaining organic compound is converted into glucose. Glucose is broken down to release energy or converted into glycogen/ fat for storage.

$$\underset{\text{Ammonia}}{2NH_3} + \underset{\text{Carbon (IV) oxide}}{CO_2} \xrightarrow[\text{Enzyme arginase /Carbonic anhydrase}]{\text{Ornithine cycle}} \underset{\text{Urea}}{CO(NH_2)_2} + \underset{\text{Water}}{H_2O}$$

2. **Detoxification/detoxication of toxic substances.**

- The liver converts toxic substances into harmless form and eliminates them.
- The toxic substances arise from metabolic activities of the liver, drugs, foods or drinks.
- For example, ***hydrogen peroxide*** produced by actively respiring cells is toxic.
- Enzyme catalase in the liver catalyzes/ speeds up the breakdown of hydrogen peroxide into water and oxygen which are harmless.
- Hydrogen peroxide $\longrightarrow$ Water + Oxygen

$$H_2O_2\,(l) \xrightarrow[\text{enzyme}]{\text{catalase}} H_2O\,(l) + O_2\,(g)$$

3. **<u>Excretion of bile pigments/ haemoglobin regulation.</u>**

- Bile pigments produced as a result of breakdown of red blood cells/haemoglobin are removed by the liver.
- Haemoglobin is broken down into haem group and globin. Globin is digested into amino acids while haen group is broken down into bilirubin and biliverdin and taken to the liver/ gall bladder.
- Bilirubin and biliverdin are released into the gut as bile and passed out through faeces (giving it brown colour).

N/B.

- Haemoglobin breakdown also relaeses pigment called **<u>urochrome</u>** which is eliminated in urine (giving it yellow tinge colour)

Diabetes Mellitus (Sugar Disease).

- It is due to a deficiency in **insulin** secretion from the **pancreas**. The malfunctioning of the pancreas leads to failure to release insulin or release inadequate amount.
- This leads to very high levels of sugar in the blood that cannot be utilized by cells hence glucose is eliminated by kidney.

Signs/ symptoms.

1. Passing large amounts of urine.
2. Excretion of glucose in urine.
3. Loss of body weight.
4. Feeling of thirst.
5. Passing urine frequently/polyuria.
6. Constant feeling of thirst/ Dehydration.
7. Excessive eating.
8. Poor resistance to diseases.
9. Excessive eating/polyphagia/hyperphagia

Control

1. Administration of regular injection of the insulin hormone to patients.
2. People suffering from diabetes should avoid food rich in sugars and excessive intake of alcohol.

Note

- Insulin is not administered orally because it is a protein and can be digested by ***proteases (protein-digesting enzymes)***.

Study question.

- **Describe how to test for the presence of glucose and protein in urine (describe how to test whether a patient is suffering from diabetes mellitus and proteinuria)**

1. **Testing for the presence of glucose (diabetes mellitus).**

i. Take 2ml of urine.

ii. Add equal amount of **Benedict's solution.**

iii. Heat to boil.

iv. If the colour changes from **blue-green-yellow-orange,** then glucose is present/ patient is suffering from diabetes mellitus.

2. **Testing for the presence of proteins in urine (proteinuria/albuminuria)**

i. Take a sample of urine.

ii. Add 2ml **sodium hydroxide.**

iii. Add 1 % **copper sulphate dropwise.**

iv. If **purple/violet** colour is observed then protein is present.

PRACTICAL ACTIVITY.

Aim

- To investigate the effect of enzyme catalase on hydrogen peroxide

Requirements

i. Fresh piece of liver/irish potato
ii. 20% hydrogen peroxide
iii. Boiling tube
iv. Glowing splint
v. Source of heat
vi. Scalpel
vii. Measuring cylinder.

Procedure.

i. Measure 2 cm^3 of the 20% hydrogen peroxide and put this in the boiling tube.
ii. Cut a small piece of liver/irish potato and put it into the boiling tube.
iii. Immediately test for the gas being produced using a glowing splint.

Observation.

- The gas produced relights the glowing splint.
- Bubbling/ effervescence.

Explanation.

- ***Catalase*** is an enzyme present in living tissues of plants and animals.
- It catalyzes/ speeds up the breakdown of toxic hydrogen peroxide **(H_2O_2)** produced during cellular respiration into water and oxygen which are less toxic.
- Hydrogen peroxide is a highly toxic chemical substance which should not be allowed to accumulate in the tissues.

$$H_2O_2\ (l) \xrightarrow[\text{enzyme}]{\text{catalase}} H_2O\ (l) + O_2\ (g)$$

Note

- If small pieces of liver/irish potato are used, the rate of gas production/bubbling would be high. This is because small pieces increase the surface area for the reaction.
- If boiled liver/irish potato is used, no gas is produced/no bubbling because boiling destroys/denatures enzyme.

LIVER DISEASES.

1. **LIVER CIRRHOSIS**

- This is the contraction and hardening of the liver due to death of liver cells.

Causes

i. Alcoholism.
ii. Hepatitis.
iii. Parasitic infections.
iv. Drug reactions.

Symptoms

i. Body weakness.
ii. Loss of weight.
iii. Indigestion.
iv. Poor appetite.
v. Pain in the upper quarter of the abdomen.
vi. Occasional vomiting of blood.
vii. Jaundice.

Control

i. Avoid excess alcohol intake.
ii. Avoid fatty diet.
iii. Take a balanced diet.
iv. Have bed rest.
v. Low salt intake.
vi. Treatment of bacterial and viral diseases.

2. **HEPATITIS.**

- This is the inflammation of the liver caused by a virus. It is of two types, namely: **Hepatitis A and B.**
- Hepatitis A is more common among children and young adults.
- It is transmitted from one person to another through:

i. Contact of body fluids

ii. Contaminated food, milk and water.

Symptoms of hepatitis A

i. Loss of appetite.

ii. Nausea.

iii. Fatigue.

iii. Jaundice/ (yellow skin)

iv. Abdominal pain.

- Hepatitis B is common in adults. It is transmitted through:

i. Contaminated instruments used for injections.

ii. Body fluids e.g. semen, blood and saliva.

Control.

i. Proper disposal of sewage.

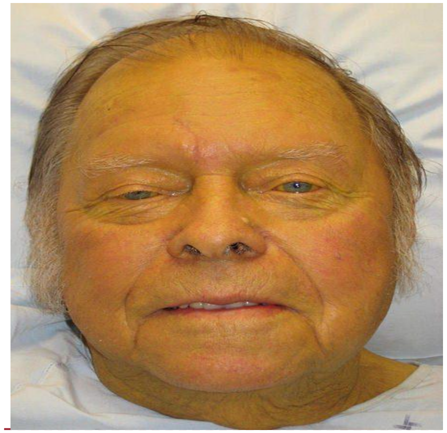
ii. Vaccination.

iii. Bed rest.

iv. Balanced diet.

3. **JAUNDICE.**

- It results from failure of the liver to excrete bile pigments from the breakdown of haemoglobin in red blood cells.
- The bile pigments accumulate in the blood leading to yellowing of the skin.



Causes of jaundice.

i. Blockage of bile duct.
ii. Destruction of the liver.
iii. Diseases e.g. liver cirrhosis and hepatitis B.
iv. Mass destruction of red blood cells e.g. in *Erythroblastosis foetalis.*

E. ROLE OF HYPOTHALAMUS IN HOMEOSTASIS

a) **Osmoregulation.**

- When the osmotic pressure of the blood rises above normal (as a result of dehydration), the osmoreceptors in the **hypothalamus** are stimulated which stimulates the **pituitary gland** to secrete a hormone called **anti-diuretic hormone** (**ADH**) or **vasopressin** into the blood.
- On reaching the kidney, **Anti-diuretic hormone** (**ADH**) or **vasopressin** causes the kidney tubules to be more permeable to water. More water is reabsorbed into the blood stream lowering osmotic pressure of the blood producing a concentrated urine.
- When the osmotic pressure of the blood falls below normal, hypothalamus is less stimulated hence the **pituitary gland** is less stimulated, less **Anti-diuretic hormone** (**ADH**) or **vasopressin** is released into the blood stream.
- The kidney tubules become less permeable to water and less re-absorption of water into blood stream takes place hence osmotic pressure of blood rises and dilute urine is produced.

b) **<u>Thermoregulation</u>**.

- When the body temperature rises above normal, the hypothalamus is stimulated which sends impulse to the skin.
- This causes the arterioles to dilate causing more blood flows near the skin surface hence more heat is lost.
- When it is cold/ when the body temperature falls below normal, the hypothalamus detects it and sends impulse to the skin.
- This causes the arterioles to constrict constrict/ vasoconstrict (vasoconstriction), less blood flows near the skin surface hence less heat is lost/ heat is conserved.
- When the temperature falls below the normal/ when it is cold, the hypothalamus sends impulse to the liver. The liver increases the rate of metabolic reactions producing heat energy which is distributed throughout the body thus increasing the body temperature.

c) **Blood sugar regulation.**

- When there is excess sugar/rises above normal, the hypothalamus is stimulated which stimulates the pancreas to secrete insulin hormone.
- Insulin stimulates liver cells to convert the excess **glucose** to **glycogen** or fats for storage, increase oxidation of glucose, inhibit conversion of glycogen to glucose lowering blood sugar level to normal/ optimum level.
- When the blood sugar level drops below normal, the hypothalamus is stimulated which stimulate the pancreas to secrete glucagon hormone.
- Glucagon stimulates the liver cells to convert **glycogen** and fats to **glucose** , reduce the breakdown of glucose thus raising blood sugar level to normal/ optimum level.

TEMPERATURE REGULATION (THERMOREGULATION) IN ANIMALS.

Importance/ significance of thermoregulation.

- Enzymes work best under a narrow range of temperature, very high temperature/ temperature above optimum denature/ destroy enzymes. Very low temperature/ temperature below optimum inactivate enzymes.

Categories of animals based on thermoregulation.

A. **Homoiotherms/e ndotherms/ homoithermic animals/ endothermic animals.**

- They maintain their body temperature constant despite changes in external /environmental temperature e.g. birds and mammals.

B. **Poikilotherms/ectotherms/poikilothermic animals/ectothermic animals.**

- Their body temperature changes with fluctuations/ changes in the environmental temperature e.g. **fish, amphibians e.g. frog, reptiles e.g. snake.**

Advantages of homoiotherms over poikilotherms.

1. Remain active throughout the day.
2. Can exploit/ live in a wide range of ecosystems.

Methods through which heat is lost and gained by animals.

1. Radiation.
2. Conduction.
3. Convection.
4. Evaporation.

WAYS IN WHICH ENDOTHERMS REGULATE THEIR BODY TEMPERATURE

A. **DURING HOT CONDITIONS.**

1. **Physiological mechanisms** - processes that go on inside the body that help to maintain constant body temperature.

- They include:

i. **Decreased metabolic activities** so that less heat is produced.

ii. **Vasodilation** of blood vessels/ arterioles, more blood flows near the skin surface hence more heat is lost.

iii. **Erector pili muscles relax** causing hairs lie flat on the skin surface trapping less air, hence more heat is lost.

iv. **More sweating,** sweat evaporates from the surface of the body cooling the body

2. **<u>Behavioral mechanisms- </u>**changes in behavior of an animal aimed at maintaining constant body temperature.

- They include:

i. **<u>Aestivation</u>** by small animals e.g. desert kangaroo rats spend most of their time in underground burrows.

- Aestivation is important to reduce metabolic activity hence low rate of respiration.

ii. Removal of excess clothes (for human beings) to allow more heat loss through the skin.

iii. Moving away from the heat in animals to avoid gaining of more heat (through radiation)/ Migration over long distances to avoid hot environmental conditions.

iv. **Panting** (e.g. in dogs) to allow evaporation of water vapour from the tongue and nose thus cooling the body.

- This is because sweat glands are located on the **pads of paws.**

Note:

- When it is hot, taking of iced water lowers the internal temperature. Activities to raise the body temperature set in leading to increase in skin temperature.

DURING COLD CONDITIONS.

A. **Physiological mechanisms.**

i. Increased metabolic activities of the body to produce heat.

ii. **Vasoconstriction** of blood vessels/ arterioles, hence less blood flows near the skin surface. Less heat is lost/ conserving heat.

iii. **Shivering-** involuntary contraction and relaxation of muscles to generate heat.

iv. **Erector pili muscles** contract causing hairs to stand erect, trapping more hair hence less heat is lost/ conserving heat.

v. The sweat glands secrete less sweat/ less sweating hence less heat is lost/ conserving heat.

B. Behavioral mechanisms.

i. **Hibernation** by small animals i.e. they go into deep sleep due to extreme conditions. This is important to reduce metabolic activities.

ii. Putting on warm clothes (for human beings) to conserve heat.

iii. Taking hot drinks to increase body temperature.

iv. Gathering together or clustering of organisms to gain heat/ conserve heat.

v. Basking to gain heat through radiation.

vi. Burrowing to reduce metabolic activities.

WAYS IN WHICH ECTOTHERMS REGULATE THEIR BODY TEMPERATURES.

A. During hot conditions.

i. They move into the shade/burrow in holes/stay under stone to prevent the body temperature from rising further.

iii. Crocodiles open their mouths to increase heat loss by evaporation/move into cool water.

iv. **Aestivation** (remaining inactive for the period when it is hot) to reduce metabolic rate hence producing less heat.

B. DURING COLD CONDITIONS.

i. They move to the warmer place/bask on the sun to gain heat from the surrounding.

ii. **Hibernation** during which animals go into a deep sleep and metabolic rate falls to save on stored food.

<u>RELATIONSHIP BETWEEN BODY SIZE AND HEAT LOSS.</u>

- **Very small animals** have a **large surface area to volume ratio** hence lose body heat faster hence have a high metabolic rate in order to produce heat to maintain their body temperature.
- **Large animals** have **a small surface area to volume ratio** hence retain more heat.

<u>Example</u>

- Elephants have large ears and are continually flapping them to encourage air movement hence loss of heat by radiation and convection.
- **Adult elephants flap their ears twice as much as their calves. This is because the adult elephants have smaller surface area to volume ratio hence retain more heat/ lose less heat/ lose heat slowly.**
- **The calves have a larger surface area to volume ratio hence lose heat faster.**

Study questions.

1. People in the tropics tend to be thin and tall compared to those in the arctic/ temperate regions who tend to be short and plump. Account for these observations in relation to body temperature regulation.

Answer.

- ***In the tropics, temperatures are generally high, therefore their body structures increase the surface area to volume ration to enable them lose heat faster. In the temperate regions, the temperatures are low, therefore the body structures reduce the surface area to volume ratio thus reducing the rate of heat loss. And the thick layer of fat insulates against heat loss.***

2. Desert kangaroo rats spend most of their time in underground furrows.

a) Name this type of behavioral activity.

- ***Aestivation.***

b) Explain the significance of this behavior to organisms.

Reduced metabolic activity hence low rate of respiration.

DIFFERENCES BETWEEN HOMOITHERMS AND POIKILOTHERMS

Homoitherms

i. Their body temperature does not depend on the environmental temperature.
ii. They are active even under cold conditions.
iii. They are not easy prey to predators.
iv. They require more food as they use it to maintain body temperature.

Poikilotherms

i. Their body temperature depends on the environmental temperature.
ii. They are inactive under cold conditions.
iii. They are easy prey to predators during hibernation and aestivation.
iv. They require less food as they get heat from the surrounding.