3 TRANSPORTATION

Chapter coverage

3.1 *Introduction of Transportation*
3.2 *Transportation in plants*
3.3 *Transportation in animals*

3.1 INTRODUCTION OF TRANSPORTATION

Throught an organism's life, materials are constantly being moved to and from all parts of the body. Materials that need to be transported include; food, oxygen, carbondioxide, water, hormones, antibodies and metabolic wastes. All these materials are essential for the organism to survive. Unlike higher complex organisms which require **transport systems** for transportation of materials, in many smaller animals, however, internal transport system is by **diffusion** only. The movement of materials between the body cells and external environment in a living organism is called **transportation**.

Significance of transportation in animals

The transportation process is very important to animals due to the following reasons:

- It aids in the distribution of **nutrients** to all over the body for utilization and storage.
- It aids in the distribution of **hormones** from the secretory cells to the target organs such as transportation of thyroid stimulating hormone from the anterior pituitary gland to the thyroid gland.
- It aids in the distribution of **metabolic waste products** from the centre of production to the excretory organs such as transportation of urea from the liver to the kidney.
- It aids in the distribution of **antibodies** to the site of infection.
- It aids in the distribution of respiratory gases such carbondioxide and oxygen between the tissues and external environment.

Significance of transportation in higher plants

Like animals, transportation process is also very important to plants due to the following reasons:

- It aids in the distribution of **nutrients** from the photosynthetic area such as leaves to non-photosynthetic area such as roots.
- It aids in the distribution of **plant hormones** such as auxins.

- It aids in the transportation of **water** and **dissolved minerals** from the soil to the leaves for photosynthesis.

SAQ 3.1

NECTA 2007

- With reference to flowering plants and mammal, give an account on the importance of transport giving specific examples.

Methods of transportation

Transportation of materials in living organisms employs two (2) main mechanism namely – **active transport** and **passive transport**.

Active transport

Active transport is the movement of materials (molecules or ions) against the concentration gradient by using ATP energy; Figure 3.1.

Properties of active transport

1. **Active transport** requires energy. The energy for active transport comes from respiration. Anything that inhibits the synthesis of ATP stops active transport. ***Cyanide***, for example, prevents ATP being synthesized and therefore inhibits active transport.
2. **Active transport** often moves molecules or ions against the concentration gradient that is from low concentration region to high concentration region.
3. **Active transport** involves the use of carrier proteins coupled with a source of energy (ATP).
4. **Active transport** is the one way system, so that substances are only moved in the direction required by the cell.
5. **Active transport** occurs rapidly, thus, it occurs in the body parts in which quickly and effective movement is required such as in the nerve cells during the conduction of the nerve impulse.

Examples of active transport include:

- **Active transport** in the intestine for the absorption of the end products of digestion.
- **Active transport** in the nerve cells for the transportation of the nerve impulse, i.e. ***Na – K pump***.
- **Active transport** in the kidney for the selective reabsorption of useful materials into the blood.
- **Active transport** in plant roots for reabsorption of mineral salts from the soil.

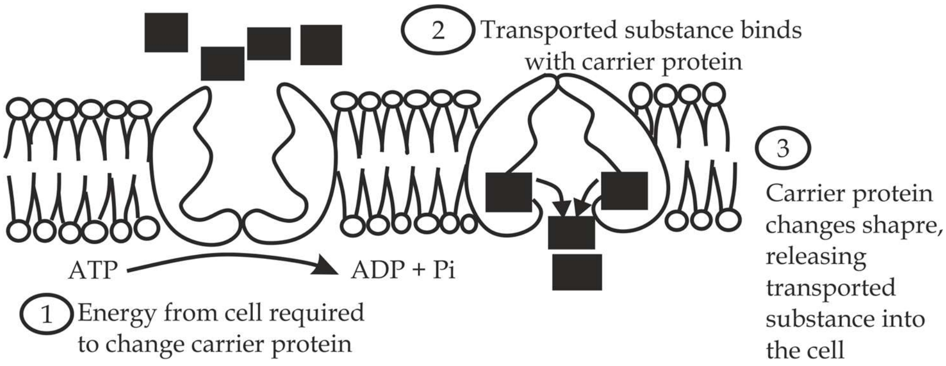


***Figure 3.1** active transport*

Advantages of active transport

- It ensures that even if the soluble food molecules are in concentration lower than those already present in the blood, they will still flow into the blood.
- It is more efficient and effective since it ensures that no any material is left.

SAQ 3.2

NECTA 1998

- Explain why it is important that, active transport is employed in the absorption of end product of digestion.

Passive transport

Passive transport is the movement of materials (molecules or ions) along the concentration gradient without the expenditure of ATP energy.

Properties of passive transport

- **Passive transport** often moves molecules or ions along the concentration gradient that is from high concentration region to low concentration region.
- **Passive transport** does not require transport protein except facilitated diffusion which only involves *channel protein.*
- **Passive transport** is the two ways system, substances move in both directions across the membrane.
- **Passive transport** occurs slowly, thus in the body parts which requires high rate of transportation such as alveolus of the lungs it must increase its surface area for maximum rate of diffusion.

- **Passive transport** does not require ATP energy for the transportation of molecules or ions.

Types of passive transport

Passive mode of transport is divided into three types, which includes; **simple diffusion, facilitated diffusion** and **osmosis**.

a. Simple diffusion

Simple diffusion is the movement of materials *(molecules only)* along the concentration gradient through the phospholipid bilayer of the cell surface membrane; Figure 3.2.

Examples of simple diffusion include:

- **Simple diffusion** in the alveolus of the lungs for the transportation of respiratory gases such as oxygen gas and carbon dioxide gas.
- **Simple diffusion** in the intestine for the absorption of lipid soluble food such as fatty acids, glycerol and lipid soluble vitamins such as vitamin A, D, E and K.

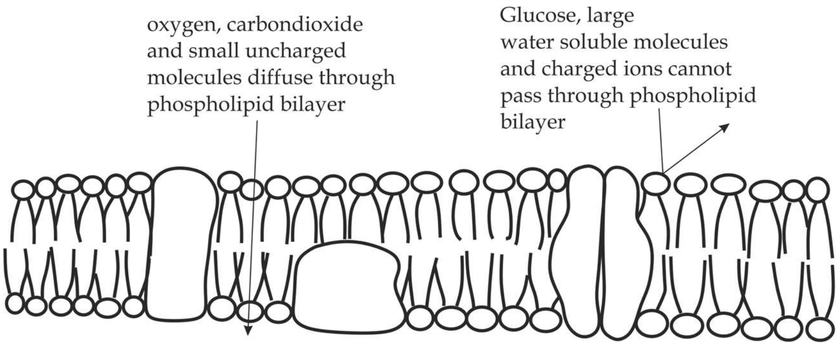


Figure 3.2 *simple diffusion*

Factors affecting the rate of diffusion

The rate of diffusion across the cell membrane is affected by the following factors:

1. **Surface area to volume ratio**
   The larger the surface area to volume ratio of the substance, the greater the rate of diffusion.

2. **Concentration gradient**
   The greater the concentration gradient difference between two regions of a substance, the greater the rate of diffusion.

3. **The nature of diffusing molecules**
   Fat soluble molecules diffuse faster than water soluble molecules.

4. **The diffusion distance**
   The shorter the distance between regions of different concentration, the greater the rate of diffusion.

5. **The size of diffusing molecules**
   Smaller molecules diffuse faster than the larger molecules.

The main factors affecting the rate of diffusion across a membrane are summarized in **Fick's Law** which states that**:**
" the rate of diffusion is directly proportional to the concentration difference and surface area, and inversely proportional to the diffusion distance"

$$\text{Rate of diffusion } \boldsymbol{\alpha} \quad \frac{\textit{Surface area x concentration difference}}{\textit{Membrane thickness}}$$

SAQ 3.3

NECTA 2012

- Briefly explain **five (5)** factors affecting the rate of diffusion across the membrane.

b. Faccilitated diffusion

Facillitated diffusion is the passive movement of molecules or ions along the concentration gradient by using channel proteins.As with simple diffusion, the movement occurs down a concentration gradient and does not require metabolic energy; Figure 3.3

Examples of facillitated diffusion include:

- **Faccilitated diffusion** in the small intestine which involves the absorption of polar molecules such as ions, Na^{+} and Cl^{-} absorption of larger molecules such as glucose and aminoacids which can not pass by simple diffusion across the membrane.
- **Facillitated diffusion** in the placenta which facillitate the passage of ions, glucose, aminoacids and vitamins from the mother to the fetus for proper growth and development of the fetus during pregnacy.
- **Faccilitated diffusion** in the renal tubule of nephron for selective reabsorption of ultrafiltrate.

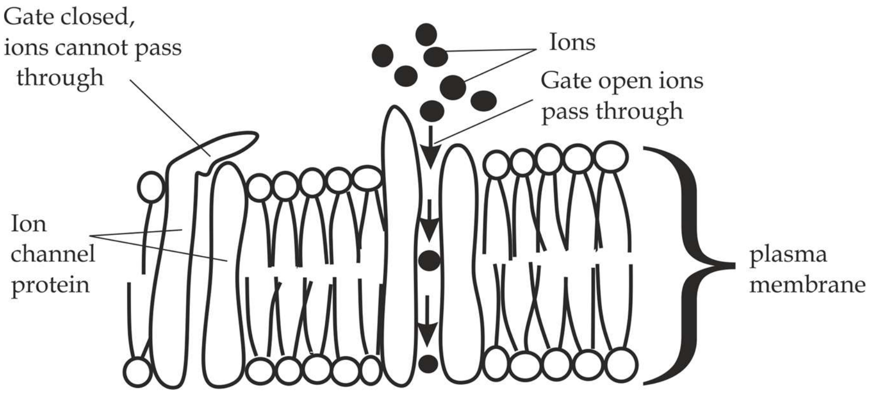


Figure 3.3 *faccilitated diffusion*

c. Osmosis

Osmosis is the movement of water molecules from the region of high water potential ***(less negative water potential)*** to the region of low water potential (***more negative water potential****)* through the partially *(semi)* permiable membrane; Figure 3.4.

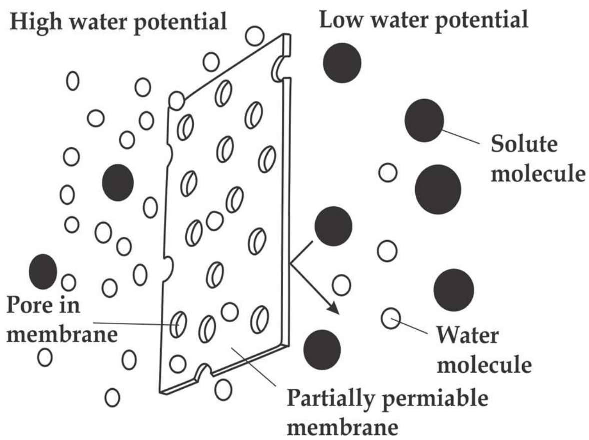


Figure 3.4 *illustration of Osmosis*

The concept of water potential

Water potential is the term given to the tendency of a sysytem to loose water by osmosis. A solution always has a negative water potential due to the presence of solutes.Pure water has the highest water potential, which is given as a water potential of zero.

- The symbol used for the water potential in cells is ψ *(Greek letter Psi).*
- The Si unit of water potential is customary to expressed in Kpa.

Components of water potential

Two important factors that determine the water potential of solution in and around the living cells are the presence of dissolved solutes (giving rise to a (**solute potential)** and mechanical pressure acting on water (**pressure potential*).***

Solute potential

Solute potential is a measure of water potential of the system in a dissolved solute molecules.Solute potential is always **negative**.Solute potential was previously reffered to as " **osmotic pressure**" or " **osmotic potential**". If you go on adding solute, the water potential gets lower and lower,i.e more and more negative, this reducing the number of water molecules that can diffuse out of it *(remember water potential is the capacity of a system to loose water)*,Solute potential is represented by the symbol of ψ_S.

Pressure potential

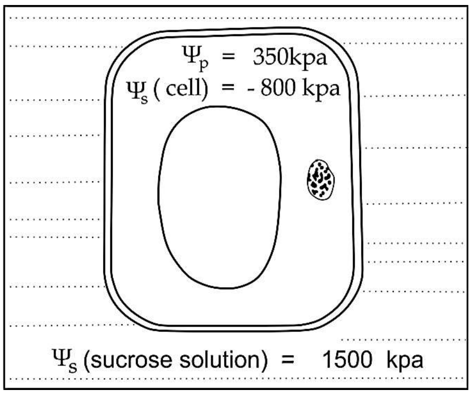
Pressure potential is the hydrostatic pressure exerts on water molecules by the cell wall. i.e, Pressure potential is always **positive**.The pressure potential was previously known as " **Turgor pressure**",Pressure potential is represented by the symbol of ψ_P.

We can summarize the water potential (ψ) relations of a plant cell by this equation:

Water potential = solute potential + pressure potential
(Usually negative) (Always negative) (Usually positive)

SAQ 3.4: Dar – Mock 2018

The diagram below shows a plant cell immersed in a sucrose solution.



i. Calculate the water potential of the cell.

ii. State whether water will move into or out of the cell. Explain your answer

Answer:

i. Water potential = solute potential + Pressure potential

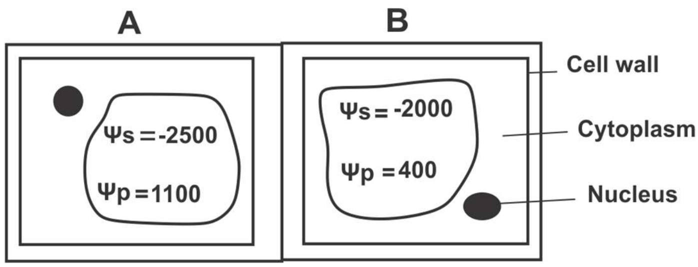
$\psi = \psi_s + \psi_p$

$\psi = {}^-800$ Kpa + 350 Kpa = $^-$ **450 Kpa**

ii. Water will move outside of the cell to sucrose solution because the cell has higher water potential ($^-$ **450 Kpa**) than the sucrose solution ($^-$ **1500Kpa**) and water normally moves from the region of high water potential to a region of low water potential by osmosis.

SAQ 3.5: Possible question:

- The diagram below shows the two adjacent plant cells **A** and **B.**The values of their pressure potential (ψ_p) and solute potential(ψ_s) are given in kPa.



Cell A **Cell B**

i. In which direction will water molecules flow when the two cells are in contact with one another?

ii. What will happen to the cytoplasm in both cells if plasmolysis occurs in both of them?

Answer:

i. To arrive at the answer to this question we have to calculate the water potential of each cell from the relationship $\psi = \psi_s + \psi_p$

For cell A: $\psi = -2500 + 1100$

$\Psi = -1400$kPa

For cell B: $\psi = -2000 + 400$

$\Psi = -1600$kPa

Therefore water will flow from **cell A** of high water potential($^-$**1400kpa)** to **cell B** which has low water potential **(**$^-$**1600**).

ii. When the cells are plasmolysed, water is lost from the cytoplasm and the vacuole.The protoplast(the living contents of the cell) surrounded by the cell walls will shrink and eventually get detached from the cell wall.

SAQ 3.6:
Observe the **figure 2** below and answer the following questions:

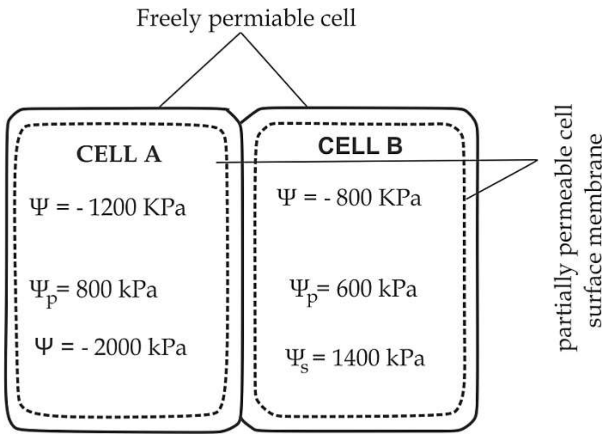


Figure 2

i. Which cell has the higher water potential?
ii. In which direction will water move by osmosis?
iii. Assuming that solute potential does not change significantly. What would be pressure potential at equilibrium in cell A and cell B?

Answer

i. Cell B
ii. From **Cell B** to **A**
iii. First, determine the water potential of **cell A** and **B** at equilibrium. This will be the average of the two.

Data given:
Ψ (water potential for cell A) = - 1200kpa
Ψ (water potential for cell B) = - 800 Kpa

$$\text{Average} = \frac{\psi_A + \psi_B}{2}$$

$$= \frac{(-1200 + -800)}{2} \text{ kpa}$$

$$= -1000 \text{ kpa}$$

Then; Pressure potentials (ψ_P) at equilibrium in cell A and B, will be as follows:

- Cell A at equilibrium: $\psi_p = \psi - \psi_s$
  $= -1000kpa - {}^{-}2000kpa$
  $= 1000$ kpa
- Cell B at equilibrium : $\psi_p = \psi - \psi_s$
  $= -1000$ kpa $- {}^{-}800kpa$
  $= 400$ kpa

Table 3.1 Differences between passive transport and active transport:

Active transport	Passive transport
It occurs against the concentration gradient of the membrane.	It occurs along the concentration gradient of the membrane.
It requires the expenditure of ATP energy during the transportation of materials.	It does not require the expenditure of energy.
It is a rapid process	It is a slow process.
It is more efficient	It is less efficient.
It occurs in only one direction	It occurs in both directions.

SAQ 3.4

TAHOSSA EASTERN ZONE 2017

- Differentiate between active transport and passive transport.

3.1 TRANSPORTATION IN PLANTS

The major transportation systerm in plants is the **vascular system** which consists of the vascular tissues or vascular bundle.

3.1.1 VASCULAR TISSUES

Vascular tissues are specialized tissues which conduct materials in plants.The primary components of vascular tissues are **xylem** and **phloem tissues**.

Xylem tissues

Xylem is a type of vascular tissue which conducts water and minerals salts in plants; it also provide mechanical strength and support to the plant.Xylem is made up of four different types of cells which include:*tracheids, vessel elements, xylem parenchyma* and *xylem fibres.*The tracheids and vessel elements are non living components which are desribed as essential elements since they are directly involved in the conduction of water and mineral salts.Xylem fibres and xylem parenchyma are described as associated elements, since they are only supporting elements.

a. Vessel elements

These are specialized cells for the conduction of water and mineral salts in angiosperms; Figure 3.5.A vessel is formed of a large number of cells.

Characteristic features of tracheids

- These are long and cylindrical tubular cells; a vessel is usual several centrimetres in length.
- They are perforated at both ends; hence more efficient in water and mineral conduction.
- They are less secondary thickened with wide lumen.
- They have small pits which are larger in number.
- They are present in angiosperms.

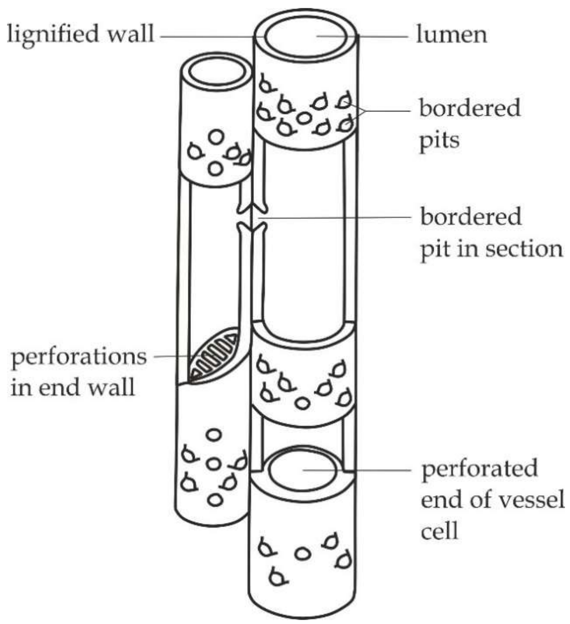


Figure 3.5 *Diagram showing the Vessel elements*

Roles of vessel elements

- They conduct water and dissolved minerals in angiosperms.
- They provide structural and mecxhanical support to the plant.

b. Tracheids

These are specialized cells for the transportation of water and dissolved minerals in all vascular plants.Conifers and ferns do not contain vessels; their role is taken by tracheids.

Characteristic features of tracheids

- They are elongated with tapering ends; Figure 3.6 . A tracheid is less than one centimetre.
- They are not perforated at both ends; thus less efficient in conduction of water.
- They are more secondary thicked with narrow lumen.
- They have large pits which are less in number.
- They are present in all vascular plants; but they are major conductive elements in ferns and conifers such as pine.

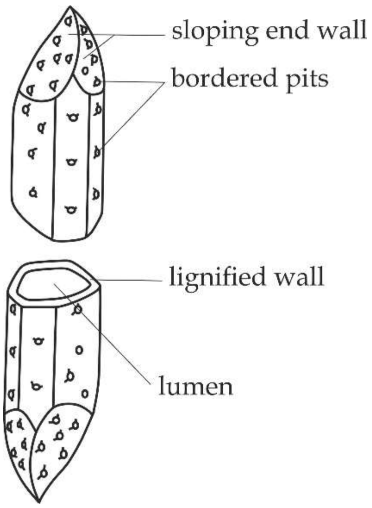


Figure 3.6 *diagram of a tracheid showing the tapered ends and pits*

Roles of tracheids

- They conduct water and dissolved minerals in ferns and conifers.
- They provide mechanical strength and support to the plant.

c. Xylem parenchyma

Xylem parencyma are living cells, with relatively thin walls containing cellulose and pectin. The xylem parenchyma is prersent in both primary and secondary xylem.They have structural similar to the plant cells except that, they do not have chloroplast.

Roles of xylem parenchyma

- They serve as storage devices for starch.
- They provide structural and mechanical support to the plant.
- They participitate in lateral conduction of water.

d. Xylem fibres

These are long, slender and non conducting cells which mainly provide mechanical strength and support to the plants.

Adaptations of xylem to its function

The xylem is capable of transporting water and dissolved minerals from the roots to the shoot due to the folllowing adaptative features:

- Both vessel elements and tracheids have narrow lumen that allow water to raise up the stem by the capillary action.
- Both vessel elements and tracheids are joined end to end to ensure flow of water in a continous column.
- They have narrow pits that allow lateral movement of water.
- They have lignified walls that provide mechanical strength and support against high pressure created by the moving water.
- They are dead at maturity which enable them to transport large amount of water and dissolved minerals.
- Vessel elements are perforated at their ends to allow upward movement of water and dissolved minerals.

SAQ 3.7

JECAS 2016

- Describe xylem structure to its role of water transport.

Evidences to show that xylem transport water and dissolved mineral salts

There are pieces of evidences to show that the xylem tissue transports water and mineral salts in plants.Such evidences are supported by the following explanations:

1. If a leafy shoot is cut and placed in water containing a dye such as **red eosin**, it takes up the dye.When the shoot is removed from the dye and cut at various parts and examined, only the xylem tissue is stained by the dye.This indicating that; xylem transporting water.

2. The removal of a ring of tissues outside a woody stem does not affect the flow of water.This is because only the phloem is removed.However, if the xylem is removed, upward transport of water stops and the leaves wilt.

3. Metabolic poisons, such as **cyanide**, do not impede water flow through the xylem; Xylem vessel elements arnd tracheids are dead.

4. If the lumen of the vessel elements and tracheids are artificially blocked by fats, the uptake and transportation of water cease and the palnt wilt.

Phloem tissues

Phloem is a type of vascular tissue which translocate manufactured food in plants; It consists four types of cells, namely: *sieve elements*, *companion cells*, *phloem parenchyma* and *phloem fibres*.

a. Sieve elements

These are specialized cells for transporting manufactured food. They are also called sieve members.Each sieve element is associated with one or more companion cells.

Characteristic features of sieve elements

- They are dead at maturity, thus receive energy for active transport from the connected nucleated companion cells.
- They have sieve plates to prevent back flow of translocated food.
- They have sieve pores that allow the passage of food from one cell to another.
- They have sieve proteins which replace the worn out tissues.
- They have secondary thickened walls which provide mechanical strength and support to the phloem.

Role of sieve elements

- They translocate manufactured foood in plants.
- They provide mechanical strength and support to the phloem due to the presence of thickened cell walls.

b. Companion cells

These are small living active cells which regulate the activities of the sieve elements;they are arise from the same meristematic cells as sieve elements; after cell division one cell became large with no nucleus called sieve element and the other cell became small with nucleus called companion cell as shown in Figure 3.7; but they are still connected by strands of cytoplasm called plasmodesmata.

Characteristic features of companion cells

- They have dense cytoplasm and prominent nucleus, thus remain living even at maturity.
- They have large number of mitochondria which provide energy to the sieve elements for active transport.
- They have large number of ribosomes which are responsible for the active and constant production of respiratory enzymes.

Role of companion cells

- They produce energy needed for the active transport.

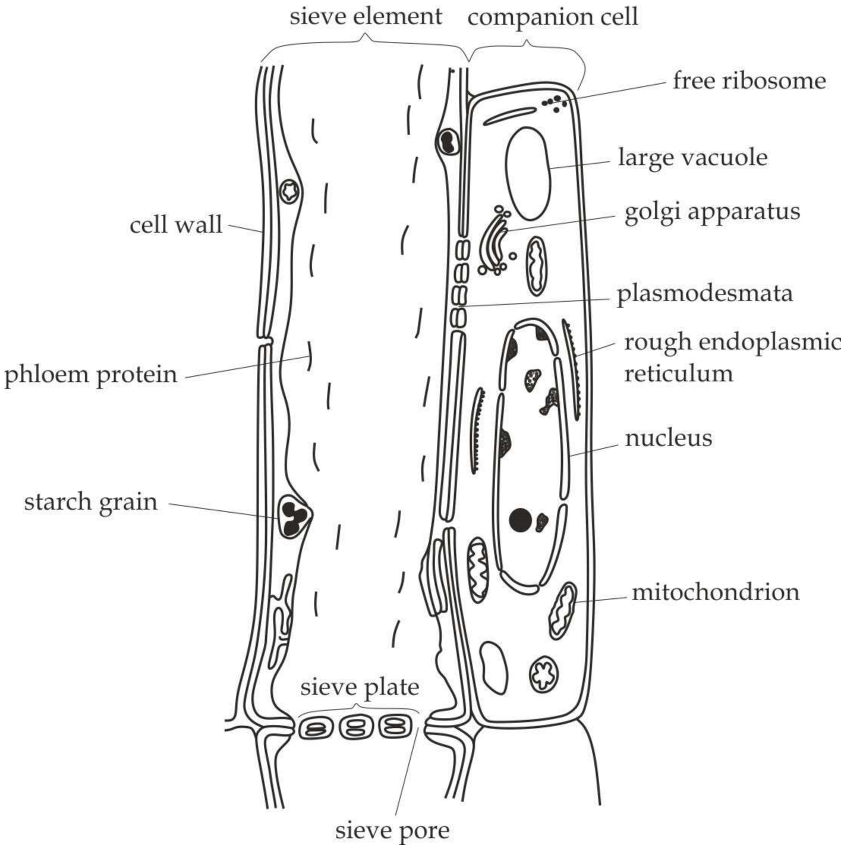


Figure 3.7 *Alongitudinal section of sieve element and companion cell*

c. Phloem parenchyma

These are elongated living cells with thin cell wall made up with cellulose.

Roles of phloem parenchyma

- They act as storage devices and consist of stored carbohydartes and accumulated tannis and resins.
- They provide mechanical support to the plant.

d. Phloem fibres

These are slender, flexible and elongated non living cells.They are found in the inner bark of the stem.

Role of phloem fibres

- They provide support to the mature plant cells.

Adaptations of phloem to its function

Phloem is capable of transporting food substances from the photosynthetic areas to non photosynthetic areas due to the following adaptive features:

- The sieve elements are joined end to end to ensure the flow of food in a continous column.
- The sieve elements have sieve plates to prevent back flow of food.
- The sieve elements have sieve pores that allow the passage of food from cell to cell.
- The sive elements have sieve proteins which replaces the worn out cells.
- Presence of companion cells with large number of mitochondria to produce energy needed for active transport of food.
- Presence of parenchyma cells for storage of food.
- Presence of phloem fibres to provide mechanical strength and sopport to the phloem.

SAQ 3.8

NECTA 2003

- Identify and describe the vascular tissues in plants and explain how they are adapted to their functions.

Evidences to show that phloem translocating manufactured food

There are pieces of evidences that show organic materials formed during photosynthesis are carried in the phloem tissues.Such evidences are supported by the following explanations:

1. **Analysis of sugar concentration in plants**

   The diurnal variations of sucrose concentration in the leaf and after a time lag there are reflected in the phloem sieve tubes.During the day when photosynthesis is taking place, the concentration of sugars in the phloem is higher compared to the c concentration in the dark when there is no photosynthesis.

2. **Using carbon – 14 isotope**

   If a photosynthesizing plant is subjected to the carbondioxide from a radioactive isotope of ^{14}C as photosynthetic substrate, The end products of photosynthesis if traced later in the phloem will be found to contain ^{14}C.

3. **Ringing experiment**

   When a ring of the phloem is removed from around the stem but leaves xylem intact.movement of food materials downward become interfered and food accumulate above the ring, this indicating that phloem translocated food Figure 3.8.

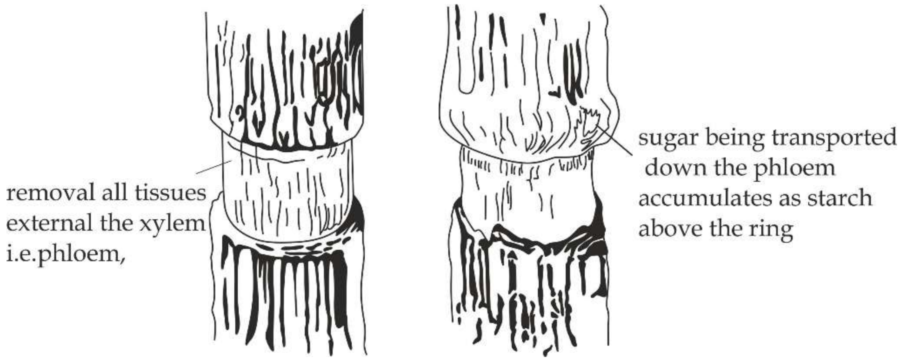


Figure 3.8 *Ringing experiment*

4. **Using mouth parts of a feeding aphid**
   Aphids are insects that feed on the contents of the sieve tubes of a living plant by using its needle shaped mouth parts.Removal of anaesthetized aphid, leaving its mouth parts inserted like a pippetes in the phloem; contents oozes containing sugars and amino acids that are products of photosynthesis as shown in Figure 3.9.

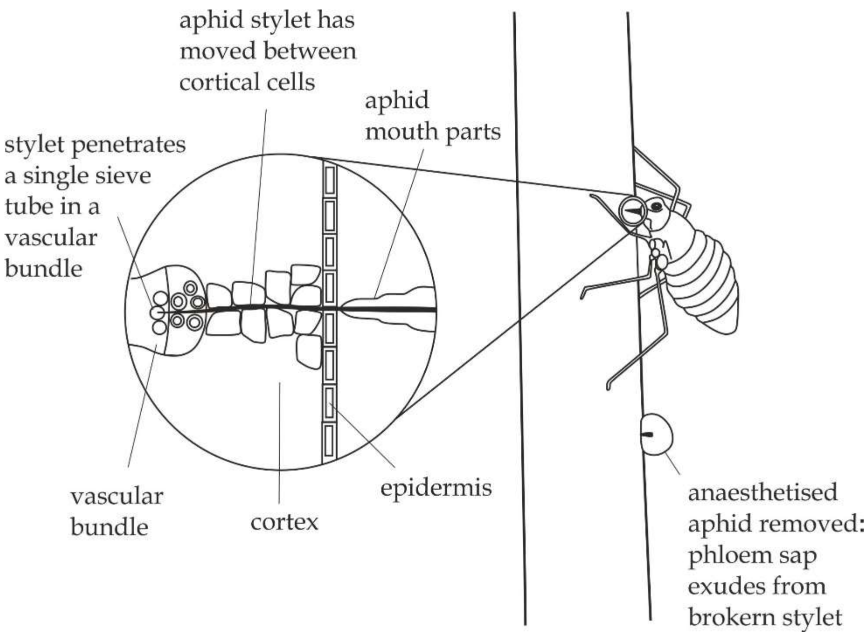


Figure 3.9 *Using an aphid to collect phloem sap*

SAQ 3.9

NECTA 2004

- Outline the evidences for the transport of organic materials in the phloem.

3.1.2 MOVEMENT OF WATER AND MINERALS ACROSS THE ROOTS

The movement of water and mineral salts across the roots to the xylem is mainly absorbed by the root hair cells.This movement of water and mineral salts is by osmosis which can be created by four main features of the root hair cells:

- They have lower water potential than the surrounding soil, thus water can enter the roots by osmosis.
- They have hair like extensions that increase the surface area to volume ratio for reabsorption.
- They have permiable membranes to allow the movement of water from the soil into the root hair cells.
- They lack photosyntheic pigments to provide enough room for water reabsorption.

SAQ 3.10

MTWARA AND LINDI MOCK 2022

- Describe the structure of a root hair cell and state the ways in which its structure relates to its function.

The passage of water into the roots is through the thin walls of the root hair and the epidermal cells of the root tips.From the epidermal cells, the water passes laterally through thin – walled cortical cells and then through the endodermal cells.From the endodermis, the water moves into the xylem tissues where the direction of movement is upward.There are three (3) main pathways in which water move in roots.These pathways are apoplast, symplast and vacuolar pathway as indicated in Figure 3.10.

The apoplast pathway

This is the movement of water across the cell wall through intercellular space.The highest percentage of water movement in plants goes though the apoplast pathway.The movement of water in this pathway occurs exclusively through the cell wall and intercellular space.This movement of water through the cell walls in the apoplast is prevented by wax – like material known as suberin, which is deposited in the cell wall to form **casparian strip** in the endodermis.In this movement, water is thereby forced to enter the living protoplast of the endodermal cell, as the only avilable route to the xylem.

Key point

Casparian strip is a band of suberin material which deposited on the endodermis of the roots to prevent apoplast pathway.

Roles of casparian strips

- They increase the chance of water moving into the xylem
- They maintain root pressure.
- They regulate the amount of water and mineral salts from soil to the xylem, since they cause active secretion of ions and salts into the xylem.
- They provide mechanical strength and support to the plant.
- They prevent the entry of toxic chemicals and pathogens into the xylem.

SAQ 3.11

COAST REGION – 2021

- Give four (4) roles of casparian strip.
- Describe the Munch mass flow hypothesis model.
- Explain the application of munchs model to the living plant.

The symplast pathway

This is the movement of water from cell to cell through the cytoplasm .The water molecules passes through the cell walls along tiny openings called plasmodesmata.Each plasmodesmata (singular) is filled with a thin strand of cytoplasm.Therefore there is continous column of cytoplasm extending from the root – hair cell to the xylem at the centre of the root. The movement in the symplast pathway are aided by cytoplasmic streaming.In the endodermis, plasmodesmata help to allow the passage of water into pericycle from where it enters the xylem.

The vacuolar pathway

This is the movement of water from one cell to another by osmosis through the cell vacuoles.However, the water molecules encounter high resistance; as a result, little flow usually occurs making this pathway insignificant.

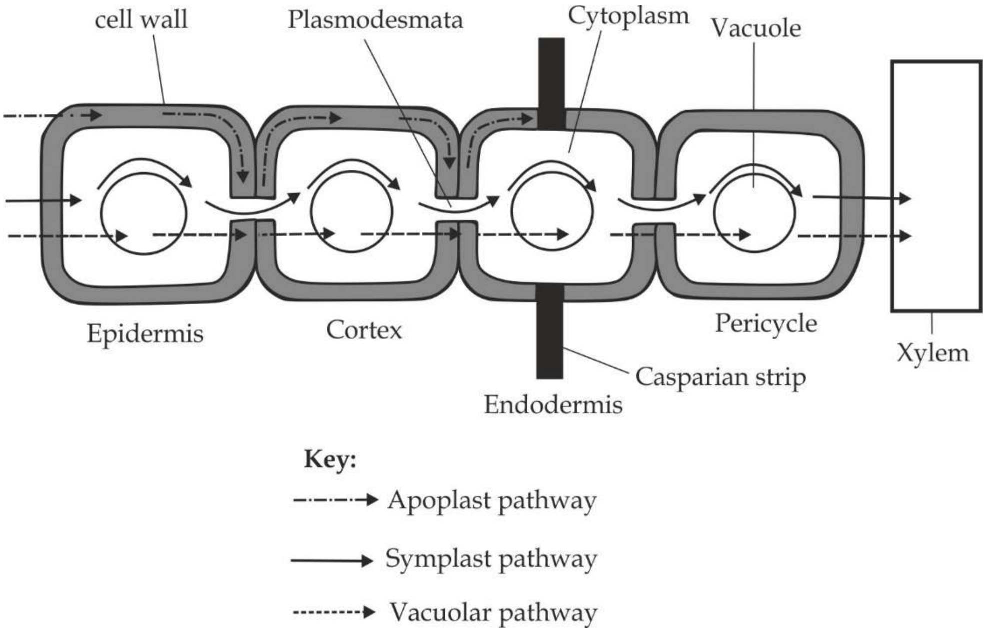


Figure 3.10 *Apoplast, symplast and vacuolar pathways in plants*

SAQ 3.12

DAR MOCK 2019

- Describe the paths of water and mineral salts across the root.

3.1.3 UPWARD MOVEMENT OF WATER AND MINERAL SALTS

The upward movement of water and dissolved minerals is caused by four (4) passive processes – **root pressure**, **cappilarity**, **cohensive – tension theory** and **transpiration pull**.

Root pressure

Root pressure is the hydrostatic pressure with which the water is pushed to the xylem from the roots.The pressure generated is about 100 – 200Kpa.Root pressure is created by the active secretion of solutes into the water in the xylem vessels from the endodermis of the roots.The presence of solutes lower the water potential of the solution in the xylem, thus drawing in water from the surrounding root cellsby osmosis.This influx of water increases the water pressure at the base of the xylem vessel that forces water up the xylem of the stem.The root pressure is responsible for transporting water to the leaves of herbaceous plants and grasses.However, in tall trees such as redwood whose height may sometimes exceeds 100m, root pressure is not sufficient to transport the water up the leaves.

Capillarity

Capillarity is the tendency of water molecules to rise in narrow tubes or tubes with very small diameter.This force is created by the narrownes of the xylem vessels which cause upward movement of water through the xylem of the stem.

The cohesive – tension theory

Cohesive – tension is the force of attraction between molecules of the same substances.This force is caused by the attraction forces between the water molecules which cause upward movement of water in a continous column along the xylem of the stem.

Transpiration pull

This is the force which is created by the evaporation of water that takes place in the leaves. When water is lost from the leaves during transpiration, the water potential of the leaves decreases, this creates a water potential gradient with neighbouring cells, which forces water to be replaced in the leaves due to high water potential gradient difference and transpiration pull. It is important to note that, transpiration pull is sufficiently enough to move water upward to the leaves of the plant of any height such as giant redwood trees found in *California* as shown in Figure 3.11.The giant redwood tree regularly raises water to over 30 m.

Figure 3.11 *Transpiration pull is sufficient to transport water up plants such this giant redwood tree, which is over 80m tall.*

SAQ 3.13

TAI QUESTION

- Describe the forces governing the upward movement of water and mineral salts in plants.

3.1.4 TRANSPIRATION AND GUTTATION

Transpiration

Transpiration is the process by which a plant loses excess water in the form of vapour.It is essentially evaporation of water from aerial plant leaves.

Types of transpiration

Generally, there are three types of transpiration namely – stomatal, cuticular and lenticular.

a. **Stomatal transpiration**
   This is a type of transpiration in which water vapour is lost through the stomata.It contributes about 90% of the whole process; because stomata is not the major barrier against uncontrolled loss of excess water through the leaves.

b. **Cuticular transpiration**
   This is the type of transpiration in which water vapour is lost through the cuticle.It contibutes about 10% of the whole process of transpiration. Since the stomata pores close during the night, then the only way the plants can lose water by transpiration is through the cuticle.

c. **Lenticular transpiration**
   This is the type of transpiration in which water vapour is lost through the lenticells.These are small slits in the stem and bark of the tree for gaseous exchange.However, the amount of water that is lost through these slits is almost negligible.

Effects of transpiration in plants

Transpiration has been described as " *a necessary evil* " because it is unavidable but with a number of negative effects.
Transpiration is "necessary" event because of the following beneficial effects gained by the plants:

- It creates transpiration pull result into availability of water and mineral salts in various parts of plants.
- It cools the plant leaf during evaporation to avoid excess temperatures, which could affect the rate of photosynthesis.
- It removes excess water from the plant because the plant requires a very little amount of water to perfom its function.
- It aids in the distribution of mineral ions, sugars and hormones as they moved around dissolved in water.
- It adds water in the atmosphere in the form of vapour, this inturn condenses and then falls as rain to make water available in the soil.

Transpiration is an evil event because of the following hazard effects to the plants:

- It reduces water necessary for various physiological processes in plants such as photosynthesis.
- It reduces water content of a plant which can result into wilting and if this process lasts for a long time, can lead to the death of the plant.
- It interferes with the process of gaseous exchange through the stomata pores, This is because the stomata have to open to take in carbondioxide as a raw material for photosynthesis.However, the opening of stomata allows water to be lost to the atmosphere.
- It also reduces the water content of the soil.

SAQ 3.14

COAST MOCK 2020

- Transpiration is said to be a necessary evil; Discuss.

Factors affecting the rate of transpiration

The factors which influence the rate of transpiration are of two types, namely: external and interanal factors.

A. External factors

These are environmental factors that influence the rate of transpiration include the following:

Light: Light affect transpiration because stomata usually open in the light and close in darkness.It follows that an increase in the light intensity increase the rate of transpiration and vice versa.

Temperature: temperature provides the kinetic energy which favours the evaporation of water from the mesophyll cell. It follows that increase in temperature increase the rate of transpiration and vice versa.

Humidity and water vapour: The lower the humidity and water vapour around the plant, the greater the transpiration rate and vice versa.

Air movement (wind): The moving air sweeps away the water vapour around the leaf surface.This creates a water potential gradien between the leaf and atmosphere consequently increase the arte of transpiration.

Water availability: The rate of transpiration is higher if the amount of soil water available is greater and vice versa.

B. Internal factors

The internal factors that affect transpiration include morpholigal features of the plants which include the following:

Surface area of the leaf: The larger the surface area to volume ratio of a leaf, the greater the rate of transpiration and vice versa.The reduction of the leaf surface is achieved when leaves are modified to needles as in pine plant or to spines as in cacti.

Cuticle: The thinner the cuticle the higher the rate of transpiration and vice versa.

Stomata: The greater the number of stomatal pores the higher the rate of stomatal transpiration and vice vesa.The rate of transpiration also depend on the distribution of stomata.The rate of transpiration is greater if a large number of stomata are on the upper surface of leaves because stomata in the upper suface face light directly such as in most dicotyledonous plants.

SAQ 3.14

TAI QUESTION

- Explain the internal and external factors that affect the rate of transpiration.

Guttation

Guttation is a process whereby a plant loss excess water in form of liquid.It mainly occurs in the members of the grasses through specialized structures called hydathodes which are found on the leaf margin or surface.Guttation is caused by root pressure and capillary action.

Table 3.1 Differences between transpiration and guttation

Transpiration	Guttation
It involves loss of water from plants in the form of of vapour	It involves loss of water from plants in the form of liquid
It is caused by transpiration pull	It is caused by root pressure
It occurs through the stomata that are founde on the lower side of a leaf	It occurs through the hydathodes that are found at the leaf margin
It takes place during the day	It takes palce during the night
It is favoured by high light intensity	It is favoured by low light intensity
It maintains the temperature of the plants	It has no direct relationship with the maintanance of temperature
It occurs in higher terrestrial plants	It occurs in herbaceous plants

SAQ 3.15

TAI QUESTION

- Distinguish between transpiration and guttation.

3.1.5 THE CONCEPT OF STOMATA

Stomata are specialzed sites for gaseous exchange in plants.They are largely located in the leaf epidermis.They are more distributed in the lower surface of the leaf compared to the upper surface.It is through these pores that gases diffuse in and out of the leaves.

Structure of the stomata

Each stoma is surrounded by a pair of specialized cells called **guard cells**. The inner wall of the guard cell is thick and inextensible wherebt the outer wall is thin and extensible.Like other plant cells, the guard cells contain cell vacuole, chloroplast,mitochondria and have cytoplasm with a nucleus as shown in Figure 3.12.

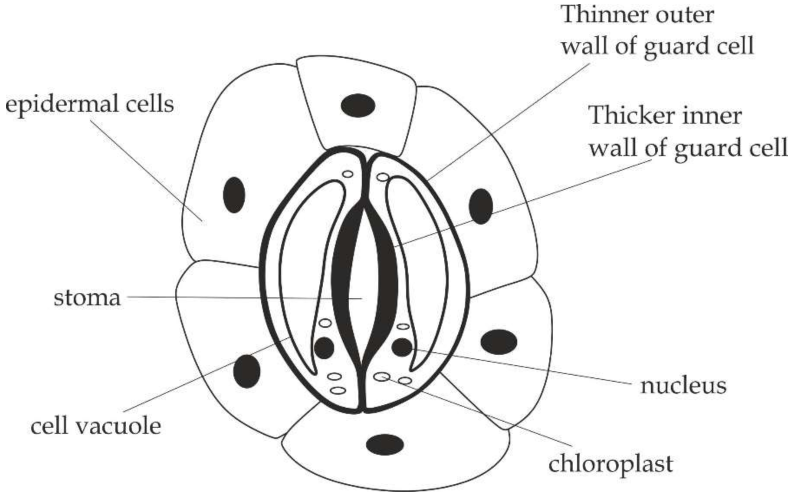


***Figure 3.12** The cross section of a stoma*

The mechanism of opening and closing of stomata

Changes in turgidity of the guard cells control the size as well as the closure and the opening of the stomatal pore.There are two main hypotheses which explain the mechanism of opening and closing of the stomata which include the following:

- *Starch- sugar hypothesis*
- *Potassium ions hypothesis*

A. Starch – sugar hypothesis

The starch sugar hypothesis suggests that *starch – sugar interconvervesion* is responsible for the opening and closing of stomata.

Opening of the stomata

- During the day, carbondioxide is used up in the photosynthesis which decreases carbonic acid, as the result of this, pH value rises in the guard cells, under such high pH value, and certain enzymes working under basic conditions convert starch into sugars.
- The accumulation of sugars in the guard cells increase the osmotic pressure which lead to the osmotic movement of water from the epidermal cells into the guard cells.
- The guard cells become more turgid as the result the outer walls expand more than the inner walls which result into the opening of the stomata pore.

Closing of the stomata

- During the night, carbondioxide is released by the respiration which increase carbonic acid, as the result of this, pH value drops in the guard cells, under such low pH value, and certain enzymes working in acidic conditions convert sugars into starch.
- The accumulation of starch in the guard cells decrease the osmotic pressure which lead to the osmotic movement of water from the guard cells into the epidermal cells.
- The guard cells become less turgidy and stomata pore closes.

Drawn back of the starch – sugar hypothesis

The starch – sugar hypothesis on the mechanism of the opening and closing of the stomata faces a number of challenges include:

1. The sugars that accumulate in the guard cells during photosynthesis are not sufficient to increase the osmotic potential required for an osmotic movement of water from epidermal cells into the guard cells.

2. The hypothesis also fails to explain the role of the rise in pH on the basis of carbondioxide concentration.

3. Sugars have never been noticed in the cell sap of the some guard cells during the opening of the stomata; yet they work just as well as those of other plants.

4. The starch – sugar interconvertional is very slow to the extent that it cannot affect quick movement of water through stomata.

B. Potassium ions hypothesis

It has been proved that potassium ions are responsible for the changes in the turgidity of the guard cells, thus opening and closing of stomata.

Opening of the stomata

- During the day, presence of sunlight activates the ATPase enzyme which catalyses the decomposition of ATP into ADP, free phosphate and energy that pump potassium ions from the epidermal cells into the guard cells.
- The accumulation of potassium ions in the guard cells increase the osmotic potential which lead to the osmotic movement of water from the epidermal cells into the guard cells.
- The guard cells become more turgid as the result the outer walls expand more than the inner walls which result into the opening of the stomata pore as shown in Figure 3.13.

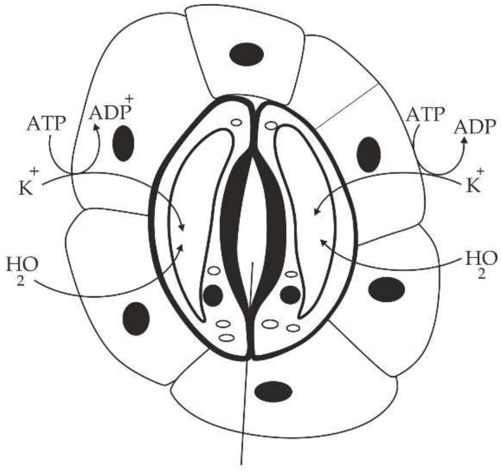


***Figure 3.13** the mechanism of stomatal opening*

Closing of the stomata

- During the night, absence of light inactivate the ATPase enzyme which fail to release energy requred to pump potassium ions into the guard cells.
- The potassium ions accumulated into the epidermal cells which inturn increase the osmotic potential of the epidermal cells as the result water is withdrawn into epidermal cells by osmosis.

- The guard cells become less turgid and stomata pores close as shown in Figure 3.14..

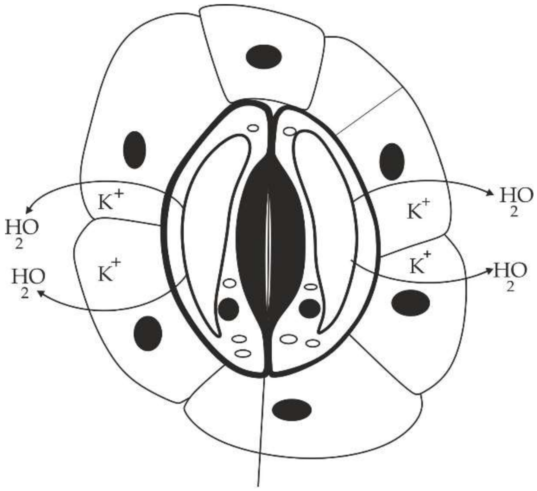


Figure 3.14 *The mechanism of stomata closing*

SAQ 3.16

NECTA 2005

- Explain the mechanism involved in stomatal opening and closing

3.1.6 TRANSLOCATION OF MANUFACTURED FOOD

Translocation is the transfer of manufactured food from the photosynthetic areas to non photosynthetic areas of the plant through the phloe. The areas where food is made is called source and the area where food is taken for use and storage is called sink. Therefore transportation in plants occurs in the direction of the source to the sink.Examples of the source are leaves and the sink are roots and stem.

The mechanism of phloem translocation

Several hypotheses have been developed to describe the movement of food materials in the plants,However, one common model is the mass flow or the pressure fow model, which was suggested by Münch in 1930. According to this model; **Mass flow** is the bulk transportation of food materials from one point to another as a result of difference in pressure.

Explanation of Münchs mass flow hypothesis

- In his experiment, Münch prepared a model as shown in Figure 3.15 with two containers A and B each of which contained a sugar solution The two containers were connected by a tube labelled C.
- The solution in container A was more concentrated than that in container B.Each container had a semi – permiable membrane.
- After being placed in water. The two solutions initially took up the water by osmosis.However, the tendency of water molecules uptake was higher in container A .
- The hydrosttic pressure built up in the closed system A –C – B tube, which in turn forced water out of container B.Consequently, the mass flow of solution occurred through tube C along the generated pressure gradient.
- The flow continued to dilute the contents of container A and solutes accumulated at container B, then the sytem came into equilibrium.

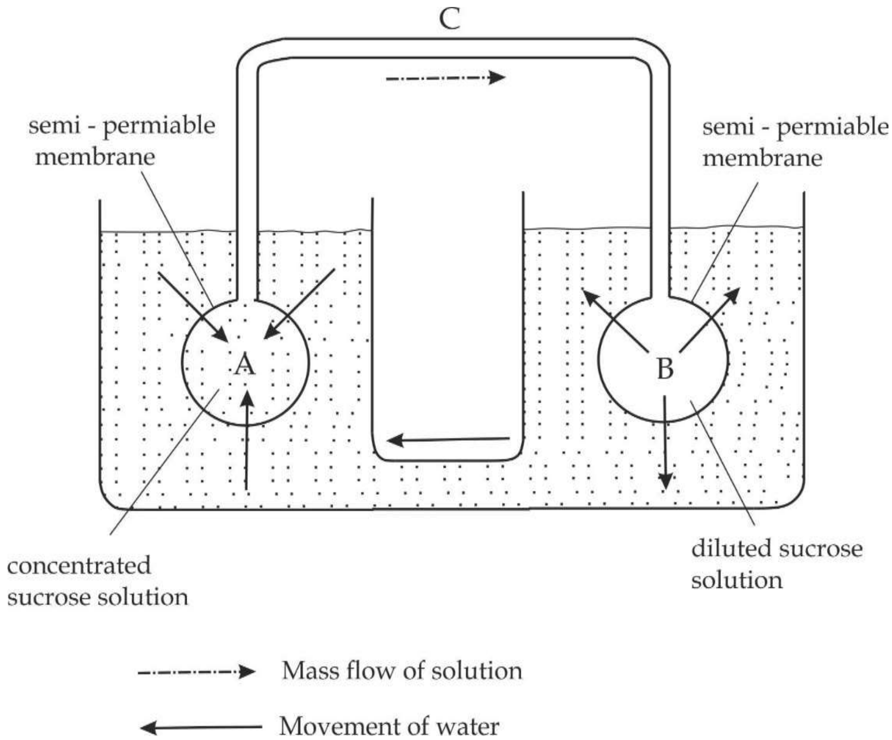


Figure 3.15 *illustration of Münch's mass flow hypothesis*

Application of mass flow hypothesis in the living plant

The model can be used to expalin the flow of sugar molecules from the leaves to the roots.**Container A** can represent the leaves, which are the **source** of sugars manufactured during photosynthesis process as indicated in Figure 3.

16.Water then leakes out continously in the mesophyll cells in the leaves making the solute potential of the leaf cells more negative.This cause the awter to be brought to the leaf from xylem by osmosis.The process results in raising the pressure potential.**Container B** can represent the **sink**, which is the area where sugar is used up or stored in an insoluble form.In this case, it is the root, young shoot or fruits.The hydrostatic pressure in the leaves increases and the pressure gradient is created between the leaves (**source**) and the roots (**sink**) resulting in the mass flow of solutes along the gradient through phloem which can be represented as **tube (C).**In plants, solutes are constantly being used up at the **sink (B)** and produced at the **source (A),** and therefore, the equilibrium state is not reached.

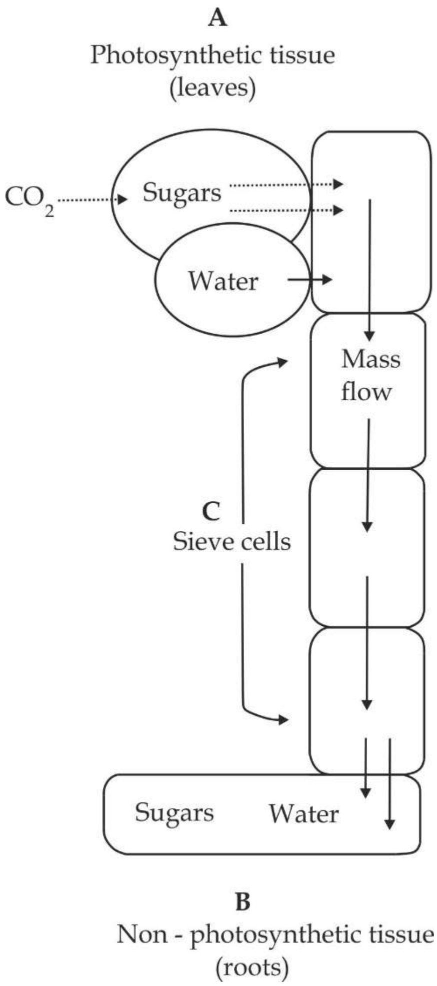


***Figure 3.16** Diagram showing phloem translocation of manufactured food*

Evidences of mass flow hypothesis

- When phloem is cut, sap oozes out apparently by mass flow
- The prolonged exudation of sucrose solution from aphid style indicate the evidence of the hydrostatic pressure in sieve tubes.
- Certain viruses move in the phloem translocation stream indicating mass flow rather than diffusion since the virus is in capable of locomotion.

Weaknesses of mass flow hypothesis

- It is purely physical explanation and does not expalin why sieve tubes must be living and metabolically active.
- It suggests that all organic substances are transported in the phloem tubes at the same speed, however, experiments show that amino acids and sugars are transported at different rates.
- It does not expalin about the biderectional movement of solutes in the translocation process; because sometimes in the roots(sink) there is high concentration of sugar than in the leaves (source).
- It ignores the membrane barriers such as sive plates as well as the factors that affect translocation such as temperature and metabolic inhibitors.
- It does not show the role of metabolism in phloem translocation.For example. The active mechanisms of loading sucrose to the sieve elements at the source and the unloading of sucrose from the sieve elements at the sinks are not explained.

SAQ 3.17

TAHOSSA DAR 2012

- Briefly describe the mass flow model (Münch 1930) of phloem translocation and relate it to the plant body.
- Give explanation on the evidence of mass flow hypothesis.
- Give the weaknesses of the mass flow hypothesis.

Factors affecting the rate of translocation

i. **The distance traveled**
The rate of translocation increases as the length of the plant decreases and vice versa.

ii. **The amount of phloem**
The greater the number of phloem in plant, the higher the rate of translocation and vice versa.

iii. **The diameter of sieve tube**
The smaller the diameter of the tube the greater the resistance the lower the translocation and vice versa.

iv. Rate of plant metabolism
The rate of translocation increases as the rate of plant metabolism increases and vice versa.

SAQ 3.18

NECTA 2009
- Explain the factors that affect the rate of translocation.

3.3 TRANSPORTATION IN ANIMALS

Transport of materials in animals such as vertebrtaes occur mainly through the blood circulatory system because tissues are distant from each other and from the environment thus make diffusion imposible; the smaller animals such as hydra and platyhelminthes do not contain blood circulatory system whereby the transport of substances occur by cell to cell diffusion.

SAQ 3.19

DAR MOCK 2018
- What is the alternative means of substance transport in animals without circulatory system? Why is blood important for larger animals?

3.3.1 THE CIRCULATORY BLOOD SYSTEM

The vascular (circulatory) blood system has three (3) major components**:**
- It has a circulatory fluid in which transported materials are dissolved called **blood** or **haemolymph**.
- It has a pumping device to pump blood around the body called **heart**.
- It has tubes or blood spaces through which blood can circulates called **blood vessels.**

SAQ 3.20

DAR MOCK 2014
- Any blood system posses three distinct characteristics; what are they.

Types of blood circulatory system
There are two main (2) types of blood circulatory systems namely:
- open circulatory system
- closed circulatory system

Open circulatrory system

This is a circulatory system in which blood mixes with the interstitial fluid (blood tissues).The " *blood*" in these organisms is called **haemolymph** that is an intermediate mixture of blood and interstitial fluid.This type of circulatory system is found in most arthropods and molluscs.

Mechanism of open circulatory system

The heart pumps blood at relatively low pressure through the artery into the open blood filled spaces, collectively called **haemocoel** , blood from these spaces gradually returns to the heart through a few open ended veins.This pattern of blood flow is called an **open circulatory system** and is summarized in Figure 3.17.

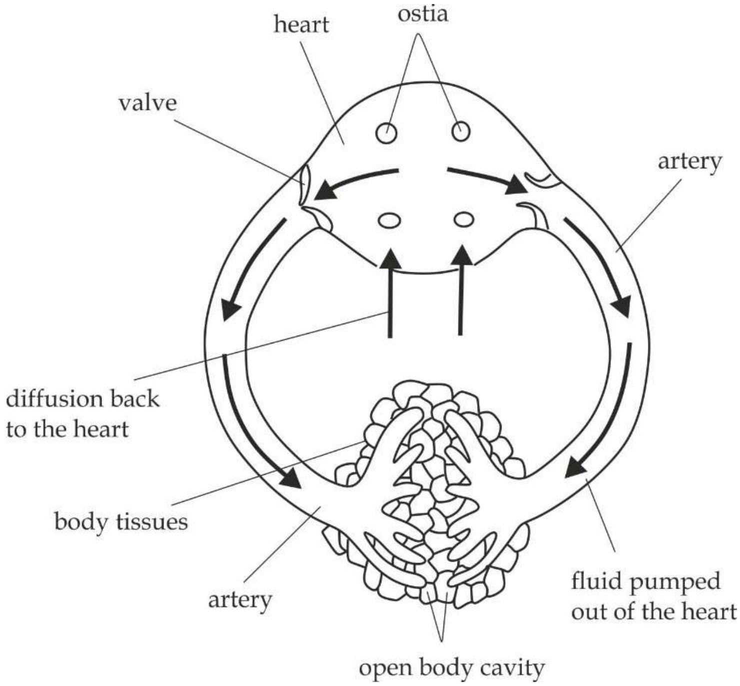


Figure 3.17 *open circulatory system*

Closed circulatory system

This is a type of circulatory system in which blood flows within a complex a cmplex continous network of tubes or blood vessels.The bood never mix up with the body tissues.This type of circulatory system is found in vertebrates ans a few invertebrates such as annelids.

Mechanism of closed circulatory system

The heart pumps blood under high pressure through the artery to the organs throught the body, unlike in the open circulatory system, in the closed circulatory system, organs are not in direct contact with the blood.They are rather bathed by the fluid leaking out of capillaries that are narrow, thin walled parts of the syste.This fluid, the **tissue fluid** , is the medium which exchange takes place in between blood and body tissues, before it returns to the blood vessels.This pattern of blood flow is called **closed circulatory system** is summarized in Figure 3.18.

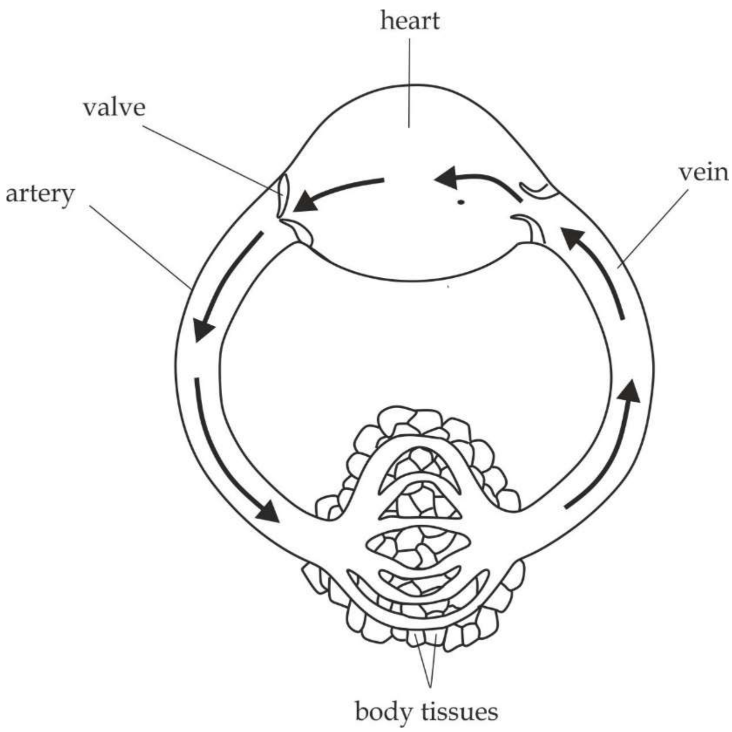


Figure 3.18 *closed circulatory circulation*

Advantages of closed circulatory system

- It is more efficient in transportation since blood circulates only inside blood vessels.
- Blood flows under high pressure as a result can travel greater distance to the organs.
- It has high circulatory speed to ensure sufficient supply of oxygen and nutrients.
- The distribution of blood is well controlled and adjusted due to the contraction and dilatation of vessels.

Disadvantages of closed circulatory system

- It is a complex blood system.
- There is a diffusion barrier between the blood and body tissues.
- It requires much ATP energy for blood distribution since tissues are distant to each other.

SAQ 3.21

MOROGORO MOCK 2006

- State three advantages and three disadvantages of a closed circulatory system.

Table 3.2 Differences between open and closed circulatory systems

Open circulatory system	Closed circulatory system
The blood is not confined to vessels	The blood is confined to vessels
The organs are in contact with the body fluids	The organs are not in contact with the body fluids
There are blood spaces known as haemocoel	There are no blood spaces
The blood circulates slowly around the body due to low pressure	The blood circulates rapidly around the body due to high pressure
The rate of flow can not be regulated	The rate of flow can be regulated
The exchange of materials takes place between blood and sinuses	The exchange of materials between blood and tissues takes place through capillaries

SAQ 3.22

NECTA 2001

- Differentiate between open blood system and a closed blood system; Give one example for each.

Types of closed circulatory system

There are two types of closed circulatory systems depending on whether the blood passes through the heart once or twice in each complete circulation; which include – **single** and **double circulatory systems.**

Single circulatory system

This is the blood circulation in which blood passes the heart once in a single complete circulatory turn. Fish is an example of organisms that have a single circulatory system. The blood flows is slow because the body organs are arranged in series. These causes blood pressure to fall from one organ to another, as a result the blood faces resistance when passing through the blood capillaries.

Mechanism of single circulatory system

The blood in fish is pumped from the heart to the gills, where oxygen is absorbed and carbondioxide is released. The oxygenated blood then flows through the artery from the gills to the rest of the body parts before returning to the heart. The deoxygenated blood from various parts is brought by the veins into the heart, then the heart pumps this deoxygenated blood towards the gills as shown in Figure 3.19.

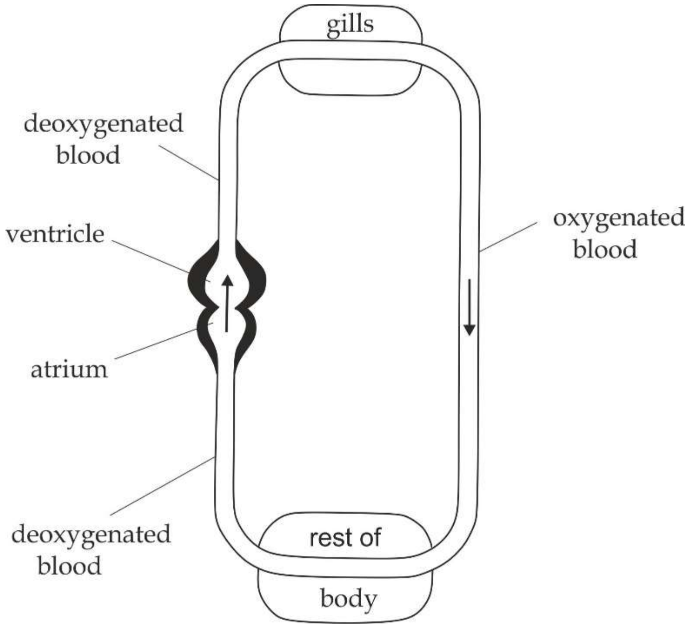


Figure 3.19 single circulatory system in fish

Double circulatory system

This is the blood circulation in which blood passes the heart twice in a single complete circulatory turn.In animals with double circulation, the body organs are arranged in parallel form as shown in Figure 3.20 . Examples of animals with double circulation are mammals, reptiles and birds

Mechanism of double circulation

The mechanism of double circulatory system is divided into three (3) main components namely – **pulmonary, systemic** and **coronary circulation**.

Pulmonary circulation

Pulmonary circulation is the flow of the blood between the lungs and the heart.In this route; a pulmonary artery carriers deoxygenated blood from the right ventricle to the lungs.The oxygenated blood from the lungs to the heart is conveyed to the left atrium by a pulmonary vein.

Systemic circulation

Systemic circulation is the flow of blood between the heart and all other parts of the body except the lungs.In this case, oxygenated blood leaves the left ventricle to various parts of the body through the aorta.The vena cava returns the deoxygenated blood from various parts of the body to the heart.

Coronary circulation

Coronary circulation is the circulation of blood within the heart chambers .The oxygenated blood enters the muscles through the coronary arteries and the deoxygenated blood is brought back to the heart chambers by coronary veins.

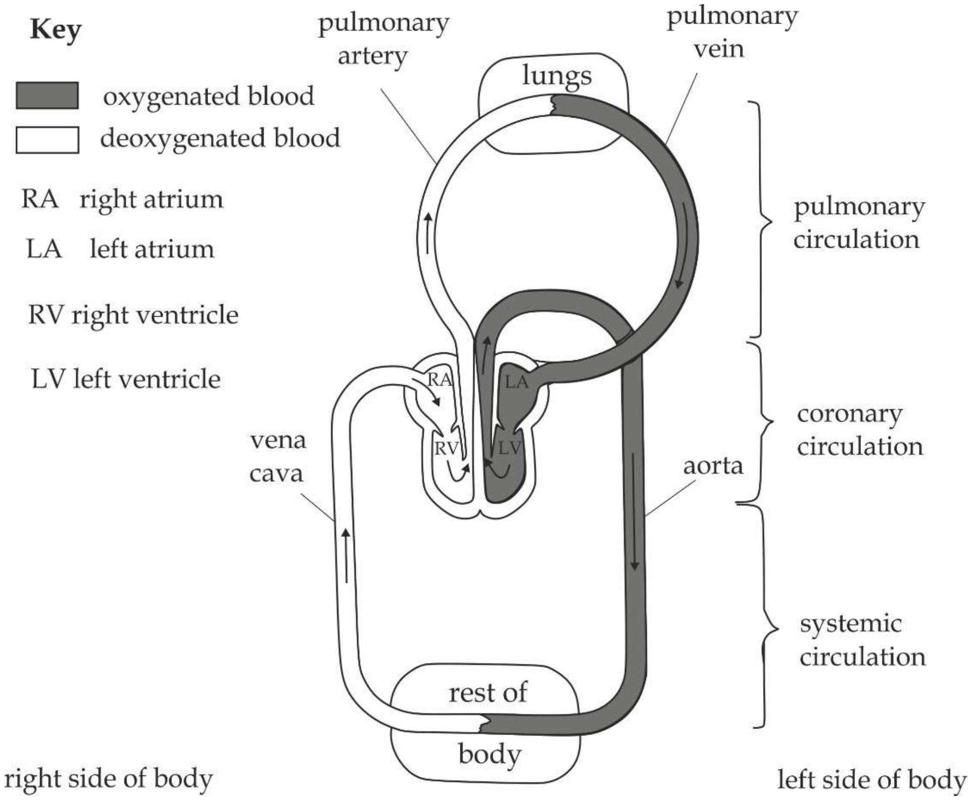


Figure 3.20 *double circulatory system*

SAQ 3.23

MOROGORO MOCK 2020

- Analyze the components of double circulation in animals.

Table 3.3 differences between single and double circulation

Single circulation	Double circulation
Blood passses through the heart only once per circuit	Blood passes the heart twice per circuit
Blood flows under low pressure	Blood flows under high pressure
The heart has two chambers	The heart has four chambers
Only deoxygenated blood passes through the heart	Both oxygenated and deoxygenated blood pass through the heart
Occurs only in fish	Occurs in mammals, reptiles and birds

SAQ 3.24

NECTA 2014

- Distinguish between single and double circulation.

3.3.2 CARDIAC MUSCLES

Cardiac muscles are the muscles that make up the walls of the heart. The role of cardiac muscles is to pump blood away from the heart to the body parts. The heart beats powerfully and continuously throught the entire life without any rest, this is because the cardiac muscles have incredibly high contractile strength and stamina.

Structure of cardiac muscles

The cardiac muscle is composed of muscle fibres interconnected by cross connection called branching fibres as shown in Figure 3.21. The muscle fibres are made up of many myofibrils that contain actin and myosin filaments. These proteins interact to bring about a contraction of the cardiac muscles. The muscles appears with striations due to the presence of the actin and myosin filaments. Each muscle fibre is made up with many cells separated with each other by the dark bands called intercalated disc.Each cell contains central nucleus, large number of mitochondria and well supplied blood capillaries to ensure sufficient supply of oxygen and nutrients. Another feature that is unique to the cardiac muscle tissue is autorhymicity or myogenicity.The cardiac muscle tissue is able to set its own contraction rhythm due to the presence of pacemaker cells or Sino – atrial node (SAN), which stimulates the other cardiac muscles cells. Thus, the excitation of one cell causes an action potential to spread to other cell quickly such that the whole mass of fibres behaves as one unit.

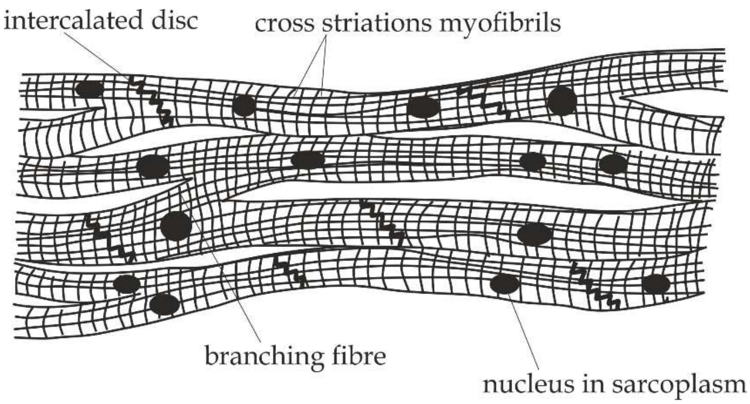


***Figure 3.21** the structure of cardiac muscle*

Adaptations of cardiac muscles to their functions

- They have many striations to provide mechanical strength and support, to withstand the pumping activity of the heart.
- They have numerous mitochondria which provide energy needed for pumping activity of the heart.
- They contain contractile elements such as actin and myosin which assist contraction.
- They have pacemaker (SAN) which generates signals during contraction.
- They have branching system for uniform distribution of signals.
- They have ability to oxidize lactic acid and slow contraction to prevent muscle fatigue.
- They are well supplied with blood capillaries to ensure sufficient supply of oxygen and nutrients,
- They have numerous nuclei to control the high metabolic activities in muscle fibres.
- They have ability of self – stimulation without the assistance of neurone for cardiac stroke to be self – generated within the heart itself.

SAQ 3.35

NECTA 2011

- Draw a well labelled diagram of the cardiac muscles.
- Identify the features and adaptations of cardiac muscles to the role it performs.

3.3.3 THE FOETAL BLOOD CIRCULATION

The foetal circulation works differently from that of an adult mammal, mainly because the foetal lungs are not in use. The foetus, therefore, obtains oxygen and nutrients from the mother across the placenta by diffusion.

Explanation of foetal blood circulation

Oxygenated blood returning to the foetus via the umbilical vein by passes the liver in the vessel called **ductus venosus**. The ducts shunts blood into the inferior venacava and passes it to the atrium. Some blood from the umbilical vein flows directly to the liver and into the inferior vena cava, thus blood entering the right atrium contains a mixture of oxygenated and deoxygenated blood. Most of the blood by passing the lungs flows through the **foramen ovale;** the hole which connects the right and left atria and **ductus arteriosus**; a vessel linking the pulmonary artery with the aorta. From here, the blood flows into the left ventricle from which it is pumped through the aorta into the body and finally deoxygenated blood is carried to the placenta by the umbilical arteries as shown in Figure 3.22.

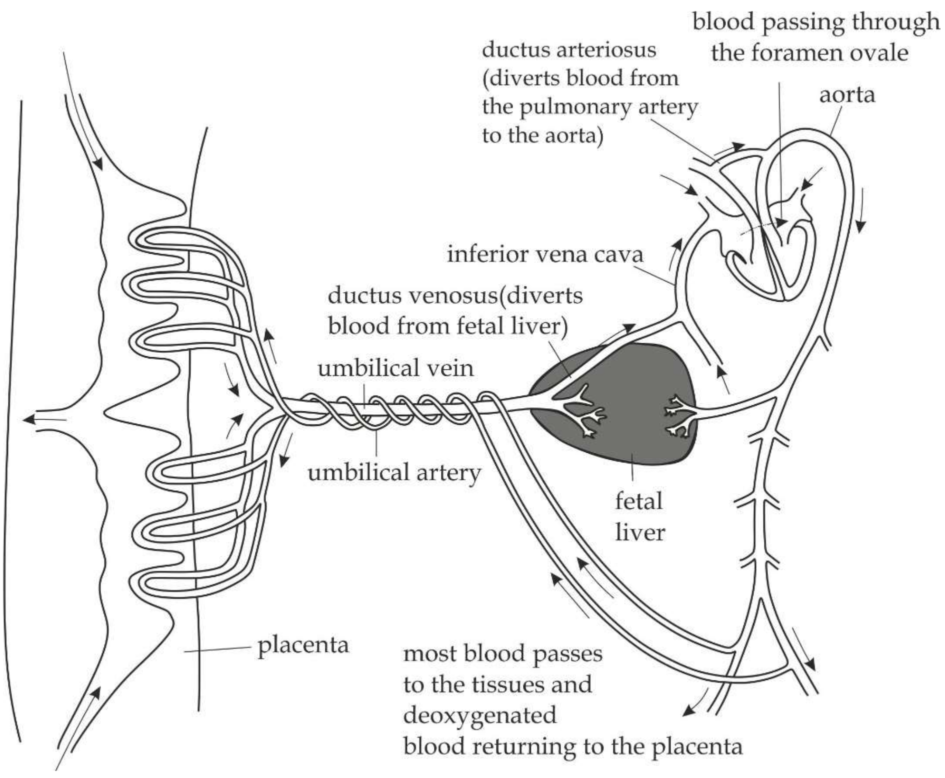


Figure 3.22 *Foetal blood circulation*

Special features of foetal circulation

There are five (5) main features which present on foetal circulation system:

Presence of umbilical vein

Umbilical vein is a blood vessel in the umbilical cord which connects placenta to the foetal ductus venosus. It performs the following functions:

- It carriers oxygenated blood from the placenta to the foetus.
- It carriers nutrients from the placenta to the foetus.
- It carriers antibodies from the placenta to the foetus.

Presence of umbilical arteries

Umbilical arteries are blood vessels which connect the foetal aorta to the placenta. It performs the following functions:

- It carriers the deoxygenated blood from the foetus to the placenta.
- It carriers metabolic waste products such as urea from the foetus to the placenta.

Presence of foramen ovale

Foramen ovale is the opening in the heart which allows the passage of blood from the right atrium to the left atrium. It prevents the flow of blood to the foetal lungs.

Presence of ductus arteriosus

Ductus arteriosus is the short blood vessel which connects the pulmonary artery to the aorta. It prevents the flow of blood to the foetal lungs until after birth.

Presence of ductus venosus

Ductus venosus is the short blood vessel which connects the umbilical vein to the inferior vena cava. It prevents the flow of blood to the foetal liver. This is because the liver has no much vital function as they are being performed by the placenta.

SAQ 3.36

MOROGORO MOCK 2020

- In five points, explain the features of foetal blood circulation.

Changes that occur in foetal blood circulation at birth

1. As soon as the baby is born, pressure in the pulmonary artery is reduced and blood flows to the pulmonary capillaries, this causes the sudden inflation of first breath into the lungs at birth and lungs start to function.

2. In few hours after birth, the concentration of oxygen in the blood increase which causes the ductus arteriosus and ductus venosus to close off whereby allowing hepatic portal vein to function and hence the liver to function.

3. Tying of umbilical cord prevents the flow of blood to the placenta thus causes sudden increase in the blood pressure in the aorta, left atrium and ventricle; result into closure of the foramen ovale in few days after birth.

Key point

If the valve guarding the foramen ovale does not close within a few month after birth, the baby is left with a hole in the heart.

SAQ 3.37

DAR MOCK 2021

- Explain the changes that take place in foetal circulation soon after birth.

Table 3.4 Differences between foetal and adult circulation

Foetal circulation	Adult circulation
Blood is oxygenated at the placenta	Blood is oxygenated at the lungs
Oxygenated blood from placenta is carried by umbilical vein	Oxygenated blood from lungs is carried by pulmonary vein
Both oxygenated and deoxygenated blood mix into the heart	Both oxygenated and deoxygenated blood can never mix into the heart
Right and left atria are connected by foramen ovale	Right and left atria are separated by septum
Blood bypasses the liver through and gut ductus venosus	Blood pass through the liver and gut by blood vessel called hepatic artery
Blood flows under low pressure	Blood flows under high pressure

SAQ 3.38

TAI QUESTION

- Describe the foetal blood system as compared to maternal blood system.