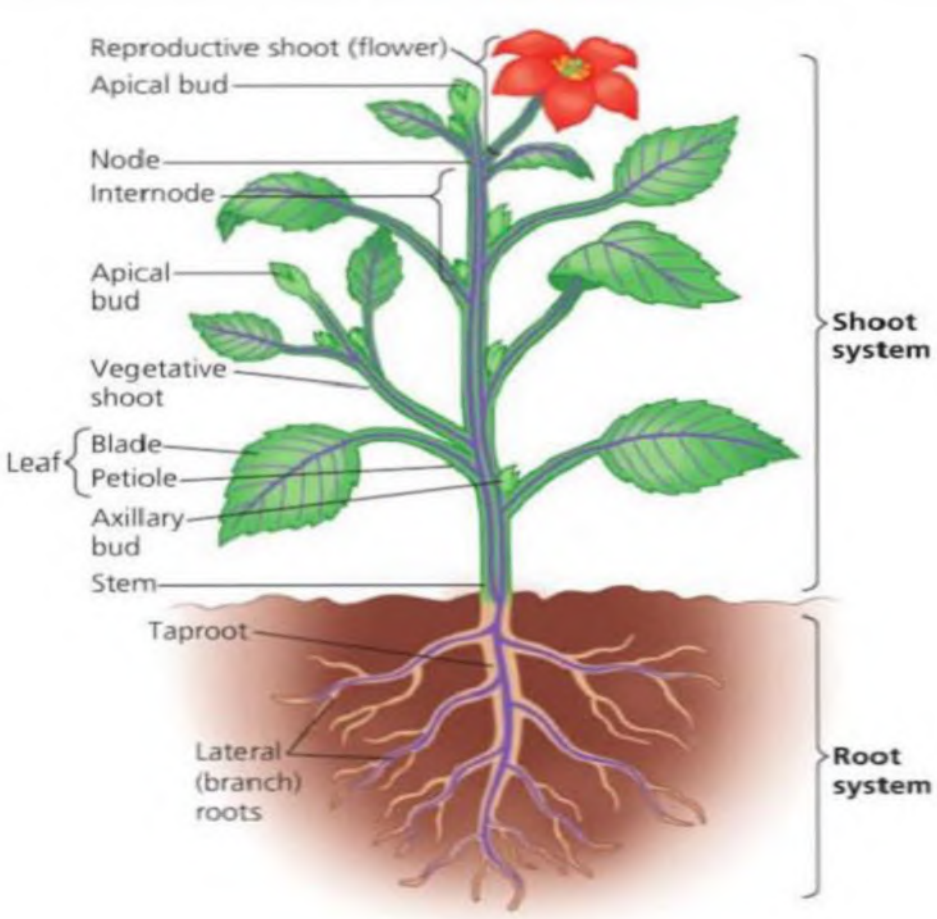


ROOTS

A root is a descending portion of the axis of the plant and develops from the radical of the embryo during germination.

KINDS OF ROOTS

There are 3 main kinds of roots;

1. Primary roots

These are the first roots to grow out of a seed as an extension of the radicle.

2. Secondary roots

These grow laterally from the primary roots

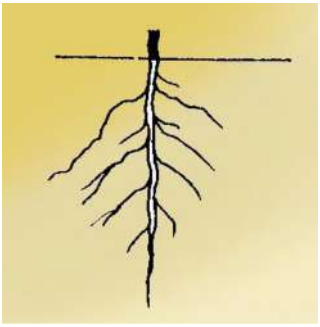
3. Adventitious roots

These are roots that grow from the stems or leaves and not as branches from either primary or secondary roots. They are almost of the same size.

TYPES OF ROOTS

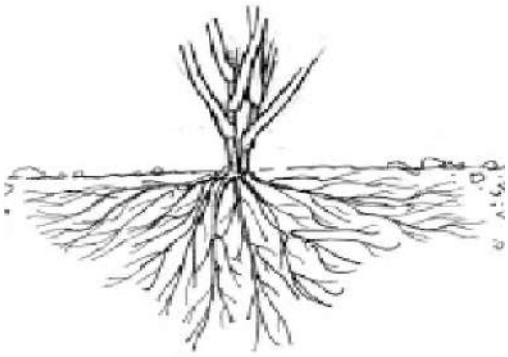
1. Tap root system

This consists of a main root growing straight down wards from the radicle. It gives rise to side roots called lateral roots. Tap root system is a characteristic of dicotyledonous plants.



2. Fibrous root system

This is the root system without a main root and all roots arise from the same point of the base of the stem. The roots are almost of the same size and a characteristic of monocotyledonous plants.



Functions of roots

i) They anchor the plant firmly in the soil.
ii) They absorb water and mineral salts from the ground to the plant.
iii) They conduct the absorbed water and mineral salts up to the stems and leaves.
iv) In some plants, roots are modified into root tubers which store food e.g. cassava.
v) Some roots are modified for breathing e.g. white mangrove.

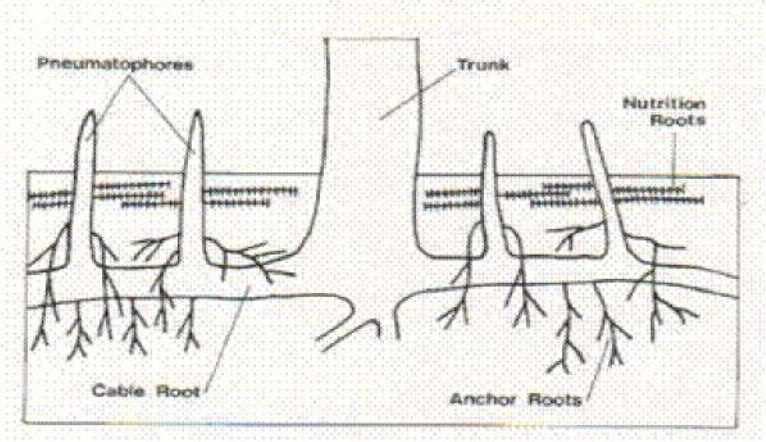
MODIFIED ROOTS

1. Storage roots

These are thick fleshly and succulent roots. ***They contain stored food like sugar and starch. The roots are modified as root tubers*** e.g. ***carrots, cassava and sweet potato roots.***

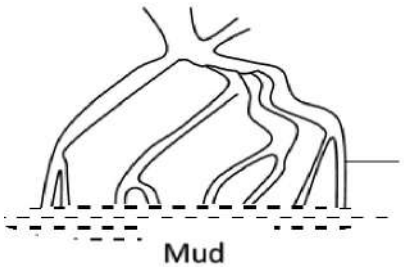
2. Breathing roots

These are found on some plants growing in swampy areas e.g. ***white mangrove***. Its roots grow up through the mud to the air. The root parts above the mud are spongy ***and absorb air from the atmosphere.*** The main root of such plants bears branch roots.



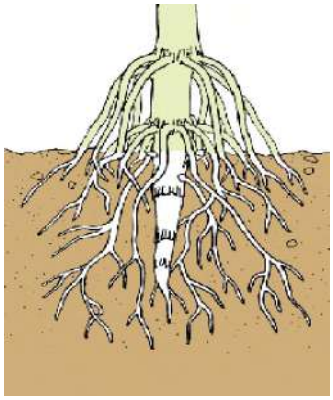
3. Stilt roots

These roots develop from the main stem in certain plants such as ***red mangrove*** which grow in muddy areas. ***Stilt roots provide additional support to the plant.***



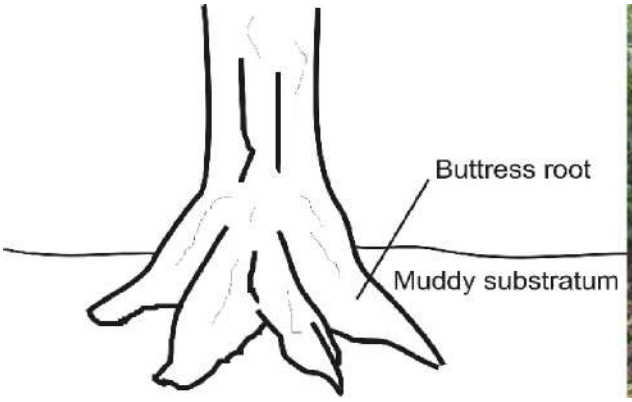
4. Prop roots

These are found growing on plants such as ***maize, sorghum and sugar canes***. They develop from the nodes of the stem close to the soil surface. ***They provide extra support by holding the plant firmly to the soil surface.***



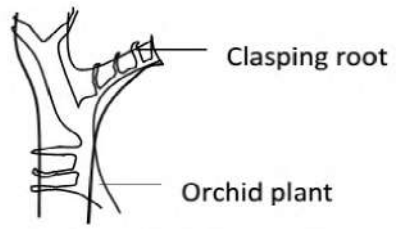
5. Buttress roots

These are large thick roots growing from the base of certain stems e.g. ***Mvule trees, silk cotton***, etc. ***They provide extra support to the plant by anchoring it firmly in the soil.***



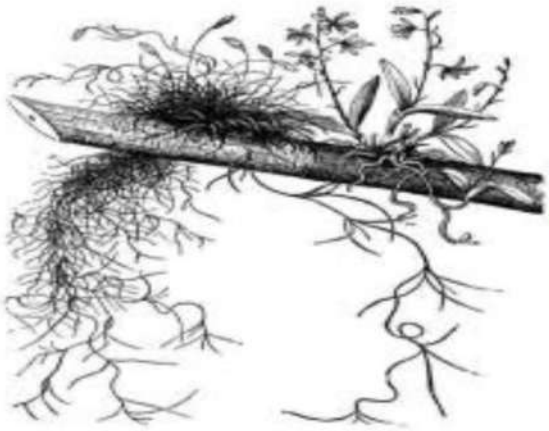
6. Clasping roots

These are roots growing from the nodes of climbing stems such as ***figs (mituba trees), vanilla and orchids.*** They secret a sticky substance which dries up in air. ***<u>This helps such plants to cling on to other plants for support.</u>***



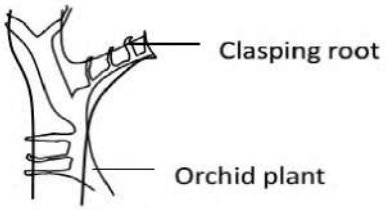
7. Epiphytic roots

These grow on certain plants called epiphytes. Epiphytes are plants which grow and get support from other plants. These roots hang freely in the atmosphere. ***They absorb moisture from the atmosphere.***

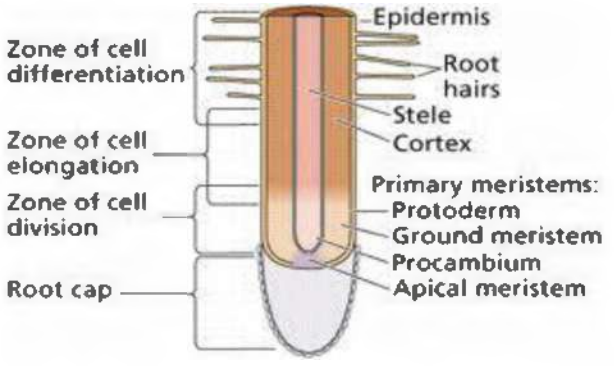


8. Sucking roots

These are roots found growing on certain parasitic plants e.g. ***figs (mituba)***. They grow from the stem and penetrate the host plant. ***These roots absorb water, mineral salts and organic food compounds from the host plant.***



INTERNAL STRUCTURE OF A ROOT (LONGITUDINAL SECTION)



In a longitudinal section through the growing end of a root, its parts are divided into 4 main zone or regions:

1) Root cap
2) Region of cell division (meristematic region)

3) Region of cell elongation
4) Region of cell differentiation (maturation)

1) Root cap

This is found at the tip of the root and is made up of loosely arranged cells. It protects the tender apex of a root from mechanical damage as it makes its way through the soil. It's absent in aquatic plants.

2) Region of cell division

This is the growing apex of the root lying just behind the root cap. The ***cells in this region undergo repeated divisions*** to form new root cap and new cells that increase the length of the root.

3) Region of cell elongation

This is the region lying just above the region of cell division. The cells in this region absorb water and develop vacuoles, the cells being elastic, elongated and enlarged. This causes an overall growth in the length of the root.

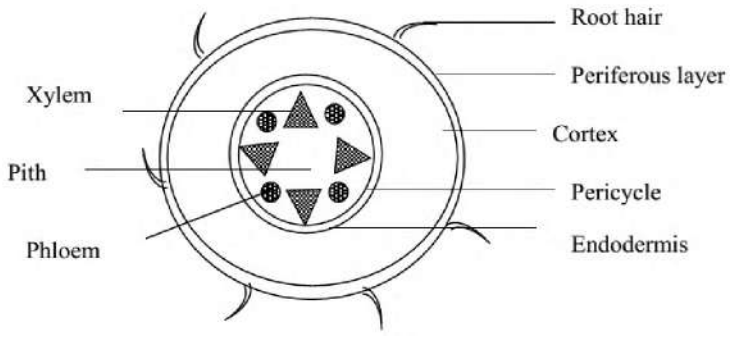
4) Region of cell differentiation

This is also called the region of absorption. The characteristic feature of this region is the development of root hairs; these are fine, delicate, unicellular hair like extensions of epidermal cells (periferous layer). They absorb soil water and dissolved mineral salts from the soil. The cells in this region acquire specific shapes and functions thus they are said to be differentiated or specialized.

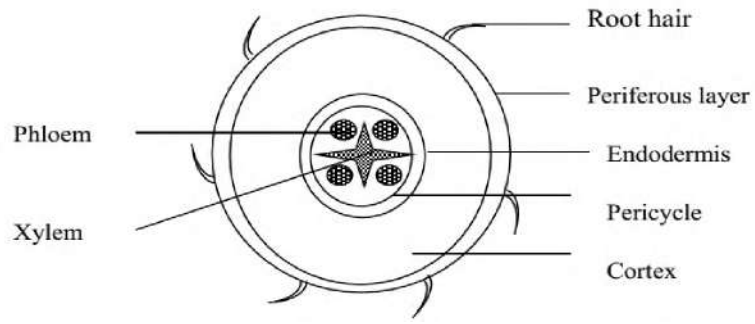
NB: the region behind the zone of differentiation is the oldest part of the root. It has permanent tissues and is covered by a layer of cork which prevents the evaporation of water from the roots.

Transverse section of a root

1. **Monocot root**



2. **Dicot root**



The transverse or cross section of most young roots has two regions

- The outer cylinder (cortex)
- The central cylinder (stele)

1) Cortex

This is the outer most layer of a root which is wide, composed of many smaller layers of thin walled cells called parenchyma (for strengthening the root).

It is surrounded by the outer layer within thin walled cells called periferous layer through which root hairs rise.

The periferous layer has no cuticle but the cells forming it have cellulose cell wall.

This allows water and mineral salts to be absorbed from the soil by root hairs.

As the root grows older, the cells die and periferous layer is replaced by cork cells which prevent water loss from the roots.

The inner most layer of the cortex is called endodermis. The endodermis is made of a layer of barrel shaped cells which are thickened so as to allow free movement of water. The endodermis is a ring around the central cylinder (stele).

2) Stele

This is made of a pericycle, vascular tissue and pith (in case of monocots).

The pericycle is the outermost layer of the stele. It's made up of thin walled cells. It surrounds the vascular tissues of the root and it produces lateral roots.

The vascular tissues are composed of xylem and phloem and may contain cambium and pith tissues.

Xylem *is the water conducting tissue through which water and mineral salts pass from the soil upwards to the stem and leaves.*

Phloem *is the food conducting tissue that carries manufactured food from the upper parts of the plant mainly leaves and distributes it to various parts of the root.*

Cambium: *causes secondary thickening of the root.* It adds all secondary xylem cells on its inner side and secondary phloem cells on its outer side by continuous cell division during growing season.

Pith: *is a small area in the centre of the monocot root. It is composed of parenchyma cells for strengthening the root*. It's normally absent in most roots because the centre is normally occupied by the xylem. It also stores food and water for the plant.

Differences between transverse section of monocot and dicot roots

Dicot root	Monocot
1. Has no pith.	Has pith.
2. Can form a ring of cambium.	Cannot form a ring of cambium.
3. The xylem is star-shaped occupying the central part.	The xylem and phloem alternates forming a ring.

STEMS

This is the ascending portion of the plant axis that develops from the plumule of the embryo. It has the following characteristic features;

i) It bears leaves at the nodes.
ii) It has nodes and internodes.
iii) It has buds in the axills called axillary buds.
iv) It has flowers or fruits.
v) Its terminal bud is located at the tip of the stem.

NB: the axill is the angle between the leaf and the stem.

Functions of stems

a) **Primary functions**

i) They hold leaves in the best position for receiving enough sun light needed in the process of photosynthesis.
ii) They conduct water and mineral salts from roots to leaves and manufactured food from leaves to other parts.

iii) They hold flowers and fruits in good position so that they can be easily pollinated or dispersed.
iv) When stems are young, they carry out photosynthesis thus making food for the plant.
v) Stems have lenticels (pores) that facilitate gaseous exchange.

b) Secondary functions

i) Some stems may specialize in storing food and water e.g. stem tubers like corms, Irish potatoes, rhizomes and sugar cane.
ii) Protect a plant against browsers by forming thorns, spines or prickles.
iii) Vegetative reproduction or propagation through the stem cuttings e.g. cassava and sweet potatoes.
iv) They support the plant by climbing stem tendrils e.g. *pasum* pea (wild pea).

TYPES OF STEMS

1) Erect stems

These can support themselves in an upright position. They may be woody or herbaceous.

Woody stems: These have a high content of lignin and are hard. They are found in shrubs and trees.

Herbaceous stems: These contain no or less woody materials e.g. tomatoes, rice. The herbs are shorter than grass.

2) Weak stems

These can't support themselves upright but either creep or climb for support.

3) Underground stems

These are modified stems which remain permanently underground. They are often swollen and serve as food storage organs.

NB:

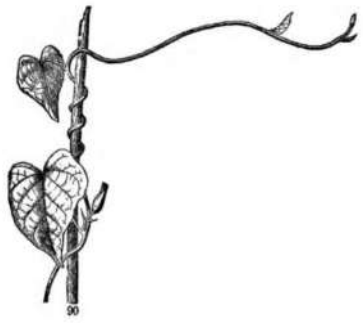
- Annual herbs only live for one year
- Bi – annual herbs live for two years
- Perennial herbs live for many years

MODIFICATION OF STEMS

Weak stems

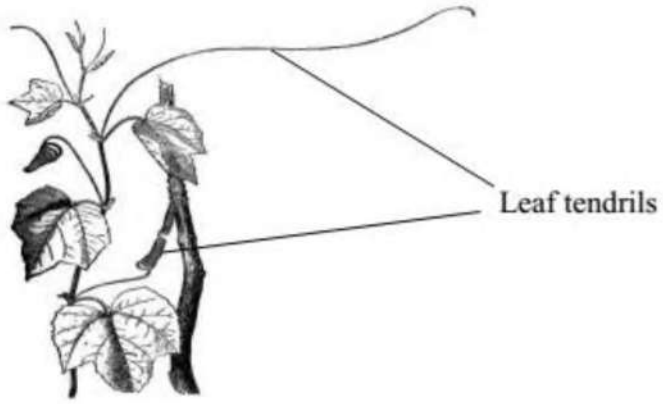
1. Twinning stems (twinners)

These are stems that grow ascending spirally around a support. They are usually long and slender e.g. Dutch man's pipe and lianas.



2. Climbing stems

These are stems that grow clinging to the support of other plants by means of tendrils. Tendrils are thin wire-like spirally coiled branches of certain stems. They may be modified at axillary buds e.g. in passion fruit plants or terminal buds.



3. Creeping stems (creepers)

These are long thin stems which grow along the surface of the ground, giving off roots at certain intervals of the nodes. Four types of creeping stems are;

a) **Runners**

This is a slender trailing stem lying flat on the ground possessing long internodes. A runner arises as an axillary bud and creeps some distance away from the mother plant and grow into another plant e.g. oxalis.

b) Offset stems

This is a horizontal thickened short stem. It originates from the axil of the leaf and grows flat on the ground. It produces many leaves above and a cluster of roots below e.g. water hyacinth and water lettuce.

4. Sucker

A sucker is a creeping stem that grows obliquely upwards, directly giving rise to a leafy shoot. E.g. banana, pineapple, sisal plant, etc.

Underground stems

There are four types of underground stems namely:

1) Rhizome
2) Corm
3) Stem tuber
4) Bulb

1. Rhizomes

This is a horizontal thick underground stem having adventitious roots growing from the lower side of the nodes. It has terminal buds which develop into aerial shoots. It bears buds in axils of the reduced brown leaves called scale leaves.

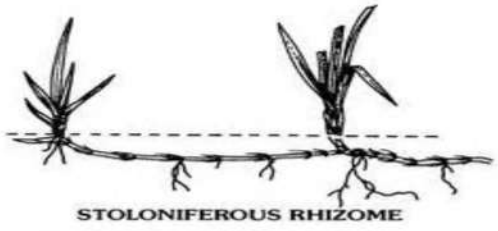
Rhizomes store a lot food for the plant. Some also act as organs for vegetative propagation e.g ginger, canalily, couch grass and Solomon's seal.

2. Stem tuber

This is a short, fleshy underground stem swollen with large amounts of stored food. It has scale leaves and axillary buds which form the "eyes" e.g Irish potato, yams.

3. Stolon

A stolon is a horizontally growing stem that roots at the nodes and develops buds that grow into new plants. E.g. straw berry.

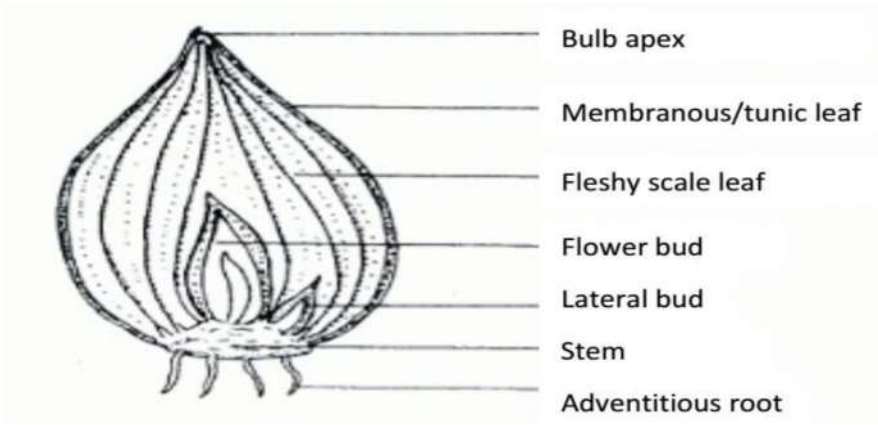


4. Bulb

A bulb is short conical-shaped underground stem comprising of thick fleshy leaves arranged in concentric circles. The thick fleshy leaves store food for the plant and are protected by outer dry brown leaves called scale leaves.

A terminal bud lies at the top of the stem and give rise to the aerial shoot. Axillary buds are situated between the leaf bases. Onions, garlic, tuberose, etc. are bulbs.

Structure of a bulb (onion)

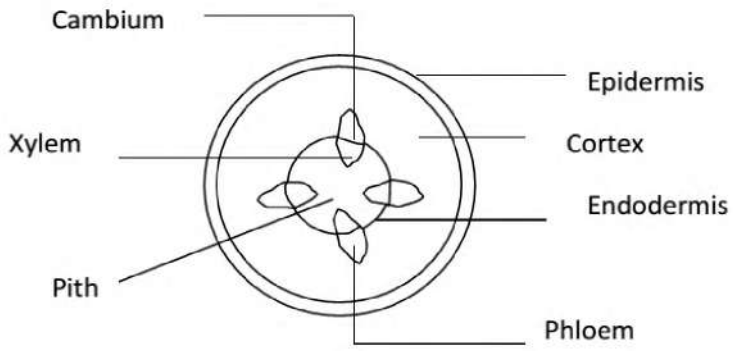


5. Corm

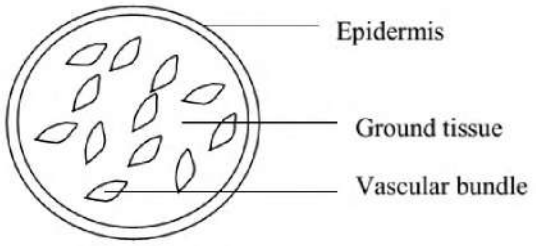
A corm is a swollen fleshy underground stem that grows in a vertical direction. It is round-shaped and somehow flattened from the top to bottom. It has a terminal bud lying at the top of the stem and has scale leaves a rising from the nodes. Its roots grow randomly from the stem. Examples of corms are cocoyams crocus and yams.

INTERNAL STRUCTURE OF STEMS

Transverse section of a dicot stem



Transverse section of a monocot stem



Internally stems have 3 main tissues;

1. Epidermis

It comprises of a single layer of cells which are brick-shaped. The outer wall of these cells is thickened by cutin, a waxy material which forms the outside skin of a stem called cuticle.

- ❖ It protects the stem against water loss.
- ❖ It also protects the inner tissues of the stem from mechanical injury.
- ❖ It prevents entry of bacteria and germs into stem.

2. Cortex

This is the part of the stem between the epidermis and the vascular bundles. It's made up of collenchyma, parenchyma and endodermis.

i) Collenchyma

This is the outer tissue of the cortex. It's 3 or more cells thick. The cells are small, tightly packed and thickened at their corners. They offer mechanical support, hence strengthening and giving rigidity to the stem.

ii) Parenchyma

This is made up of large thin walled cells. These cells have air spaces between them called intercellular spaces. The spaces provide passage for water vapour and gases in the stem. Parenchyma cells offer support to the stem when filled with water and store some food.

iii) Endodermis

This is a single layer of rectangular shaped cells. It contains starch usually, and its main function is storage of food.

3. Vascular bundles

These are conducting or transporting tissues of a plant. They consist of xylem and phloem. The phloem lies externally and the xylem lies internally in each bundle.

Phloem:

The phloem conducts and transports manufactured food. It is made up of three main cells:

i) Sieve tubes

These are cylindrical tubes arranged end to end in long rows. Their cross-walls have many fine pores forming a sieve plate. They conduct manufactured food in the stem.

ii) Companion cells

These are smaller than the sieve tubes. They are filled with a dense cytoplasm and have nucleus. They control the activities of the sieve tubes.

iii) Phloem parenchyma

It stores some food in the stem. They are the first to be formed in the vascular bundle.

Xylem:

Xylem is water and mineral salts conducting tissue. It comprises of 2 types of cells i.e. vessels and tracheids. These cells have their walls thickened with a substance called lignin.

The xylem also provides mechanical strength to the stem due to the presence of lignified dead cells.

The lignified dead cells formed between the endodermis and phloem is termed as sclerenchyma.

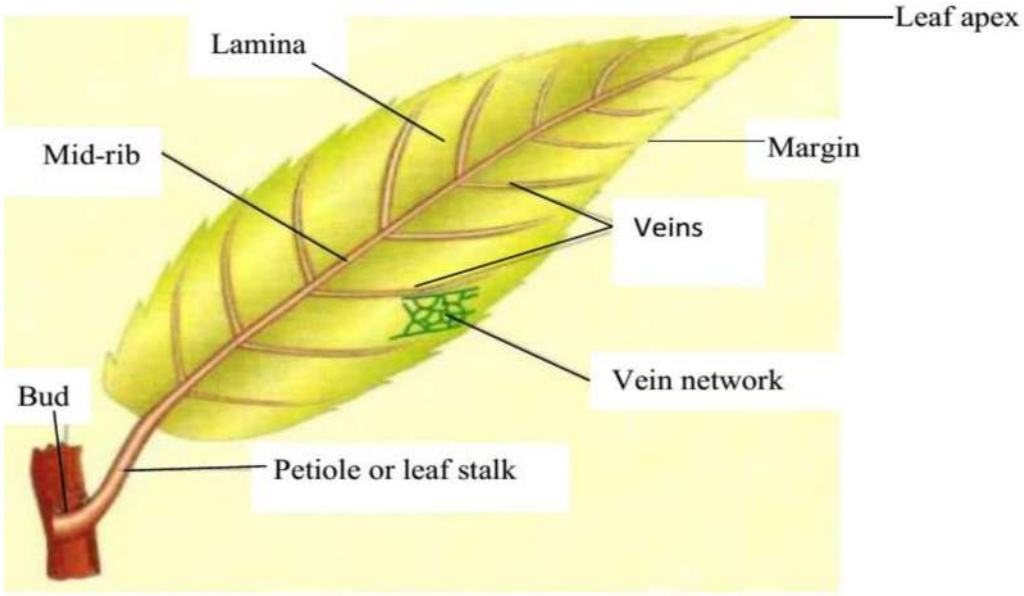
Differences between dicot and monocot stems

Monocot stem	Dicot stem
Lack cambium	Has cambium. The cambium is responsible for secondary growth or thickening of the stem.
The vascular bundles are scattered within the stem.	The vascular bundles are arranged in form of a ring.
Lack a distinct cortex and pith.	Has a distinct cortex and pith. The pith is wide.
Its cortex has several layers of parenchyma cells.	Its cortex has a few layers of parenchyma cells.

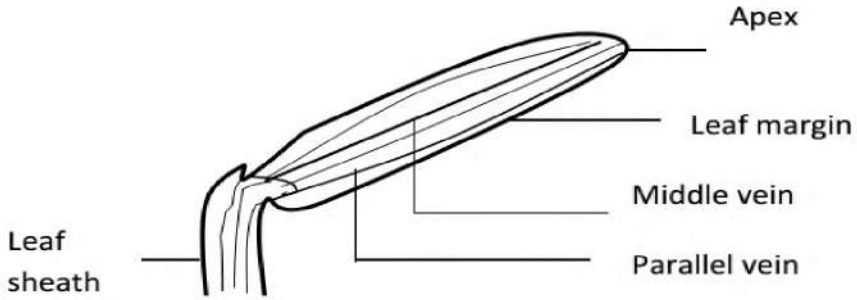
LEAVES

A leaf is a thin flattened structure which grows from the nodes of a stem or its branches and has a bud in its axil. Leaves are generally green although some are red or brown. The leaf is made up of 3 main parts;

External structure of a leaf



The monocot leaf



Leaf base; this is the part which attaches the leaf to the stem.

Petiole; this is the part which connects the leaf base to the leaf blade. Leaves with a petiole are called ***petiolate*** and those without are called ***sessile.***

The ***leaf stalk*** is a characteristic of dicots while a ***leaf sheath*** is found in monocots. The leaf stalk/sheath can be hairy or smooth.

Lamina; this is the expanded and flattened portion of the leaf consisting of veins and midrib.

Texture of lamina; the lamina may be hairy or smooth. It may be hard or soft.

VENATION

The arrangement of veins in the lamina of a leaf is called venation. Two broad types of venation are;

1. Network venation

In network venation, the veins in the lamina branch while intersecting to form a network. It's a characteristic of dicots.

2. Parallel venation

In this venation, the veins run side by side without branching. This is a characteristic of monocotyledonous plants.

LEAF COMPLEXITY

Leaves can be classified according to whether the leaf lamina is completely divided or not divided. Two broad types are:

- Simple leaves
- Compound leaves

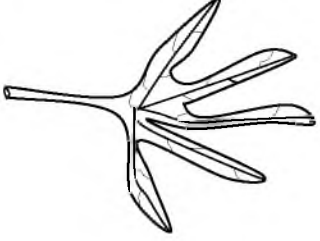
1. Simple leaves

A simple leaf has a single lamina which isn't divided up into leaflets e.g. Avocado, mango, orange, hibiscus, pawpaw, cassava, etc.

Cassava and pawpaw leaves are partly divided. The lobes are not considered to be leaflets because the divisions do not reach down the midrib. They are simple digitate i.e.

Simple leaf of a mango

Simple leaf of cassava



A swelling at the base of the leaf stalk is called ***pulvinus*** e.g. beans and cassava. Some leaves have it while others do not have it.

2. Compound leaves

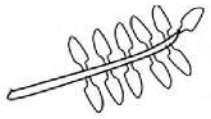
A compound leaf has a lamina which is completely divided into leaflets. They resemble leaves but are not leaves because the axillary buds are absent in the axis of leaflets e.g. beans, oxalis, cassia, etc.

Types of compound leaves

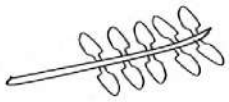
i) Compound pinnate leaves

These are compound leaves with leaflets arranged either in pairs opposite one another or alternately along the midrib called rachis of the leaf. If the terminal leaflet is present, the leaf is said to be ***imparipinnate*** and if the terminal leaflet is absent, the leaf is said to be ***paripinnate.***

Imparipinnate

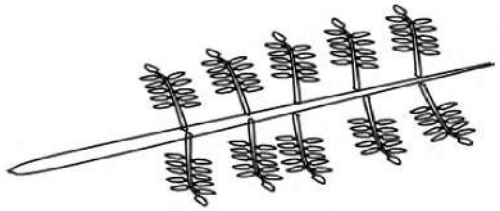


Paripinnate



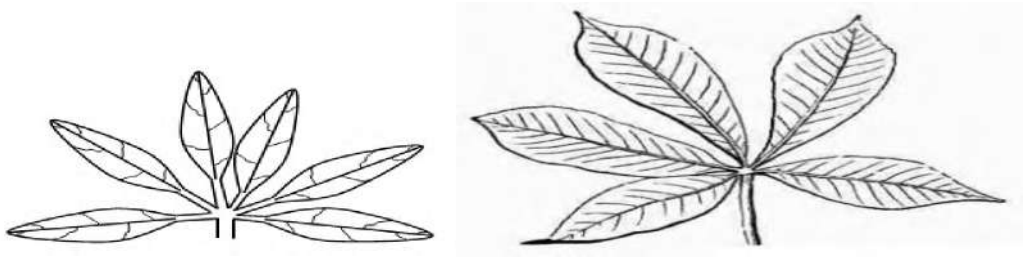
ii) Compound bipinnate leaves

These are compound leaves with 2 orders of leaflets. Leaflets are further divided up to form leaf-like structures called pinnules e.g. jacaranda.



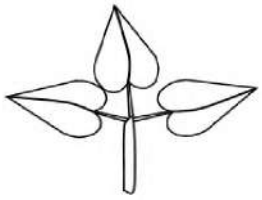
iii) Compound digitate leaves

These are compound leaves with leaflets radiating out from the end of the petiole-like fingers of the hand.



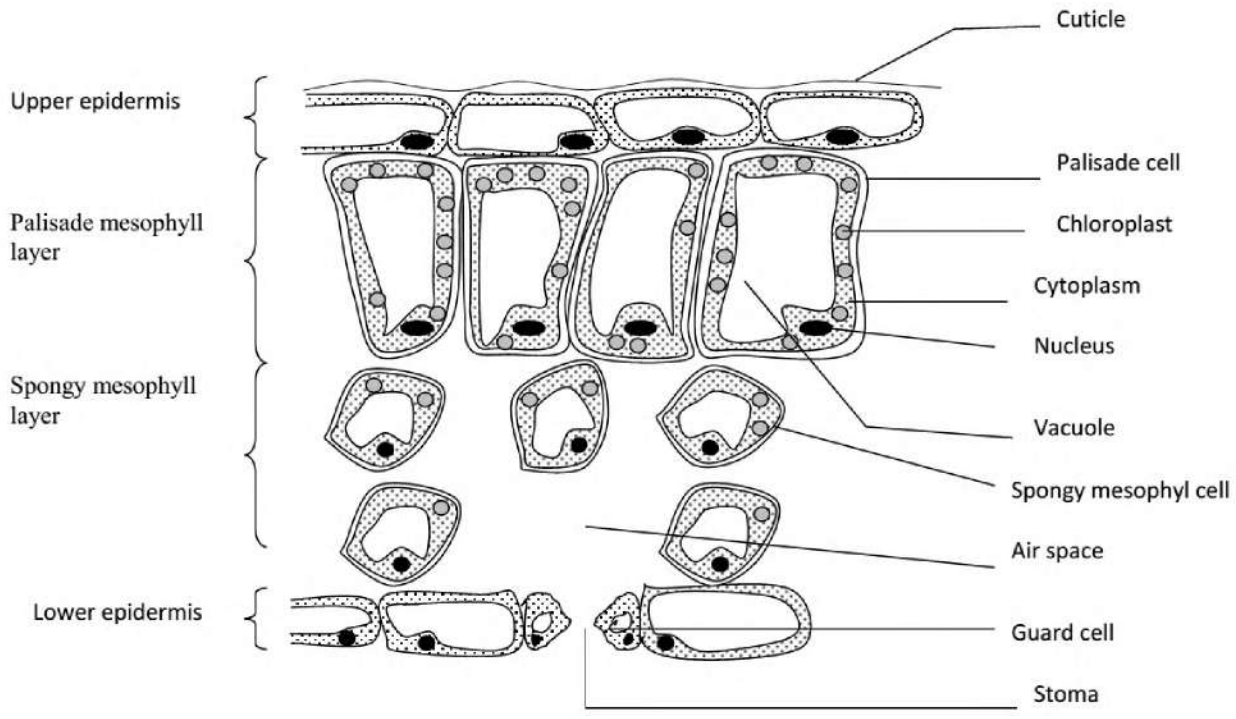
iv) Compound trifoliate leaves

These are compound leaves with only 3 leaflets. They include soya beans, oxalis and straw berry.



NB: stipules (foliar appendages) are attached to the leaf base or petiole e.g. in beans, hibiscus and cassia.

INTERNAL STRUCTURE OF A LEAF



1. Epidermis:

This is the outer most layer of a leaf. It acts as a skin covering the whole leaf surface. It's covered by a transparent water porous layer of cutin called cuticle.

This cuticle allows light penetration into the leaf and prevents excess water loss from the leaf surface.

The epidermal tissue is divided into 2 according to the location on a leaf i.e. upper and lower epidermis. The upper epidermis is a single layer of brick-shaped cells covered by a thick cutin in case of terrestrial plants or land plants.

In most plants, it does not possess stomata and if present are few. This is so as to control the amount of water loss during transpiration process.

The major function of this epidermis is to prevent evaporation of water from the leaf cells and protection of the inner cells.

The lower epidermis is usually made up of one layer of cells and contains numerous openings called stomata. These stomata are protected by 2 guard cells. In water plant e.g. water lily or hyacinths, stomata are few on this side of the leaf. Some chloroplasts are present in this layer of cells.

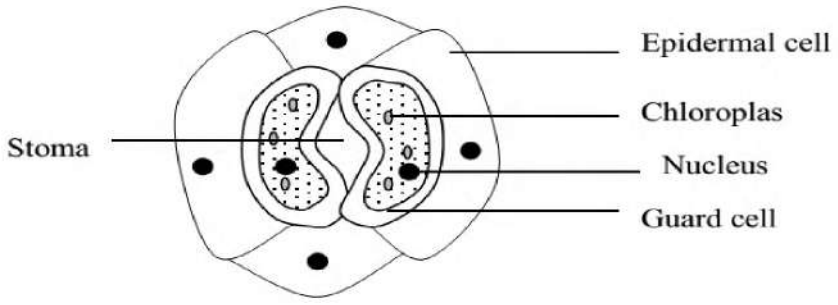
Stomata

These are small openings found in the epidermis of a leaf. They are surrounded by 2 guard cells. Plants growing on land have more stomata located in the lower epidermis than in the upper epidermis. (the reverse is true for aquatic plants)

The function of the stomata is to allow entry and exit of important gases like O_2 and CO_2 into the leaf.

The stomata also regulate the loss of water vapour from the plant i.e. they control transpiration.

Structure of the stomata



2. Mesophyll:

This is located between the upper and the lower epidermis. It's differentiated into two layers. i.e.

i) Palisade layer

It's found just below the upper epidermis. It's made up of cylindrical shaped cells. The cells are closely packed together without air spaces. The palisade cells contain many chloroplasts which are the major sites for photosynthesis.

Chloroplasts are small and made up of proteins. They contain chlorophyll which gives green plants their colour. The chlorophyll absorbs sun light energy that is used in the process of food manufacture (photosynthesis).

ii) Spongy mesophyll layer

It's found under the palisade layer. It consists of cell called spongy cells which are irregularly arranged. These cells are not closely arranged, and therefore have large intercellular air spaces between them. The air spaces are connected with each. There is also the sub-stomatal air chamber where the gases collect before moving out of a leaf. Spongy cells contain fewer chloroplasts than the palisade cells hence they manufacture food.

3. Vascular tissue

These are vascular bundles consisting of veins. Each vein has a phloem for transporting manufactured food and the xylem for conducting and distributing water and mineral salts. The veins also provide mechanical support to the leaf lamina.

ARRANGEMENT OF LEAVES ON A STEM

Arrangement is the insertion of leaves on the stem. Leaves develop at the nodes in the stem and are arranged in different ways.

1. Alternate

This is when one leaf only arises from each node and the nodes are at different levels and the successive nodes are at different nodes.

2. Opposite

This is when two leaves arise from nodes that are opposite each other and are at the same level.

3. **Whorls**

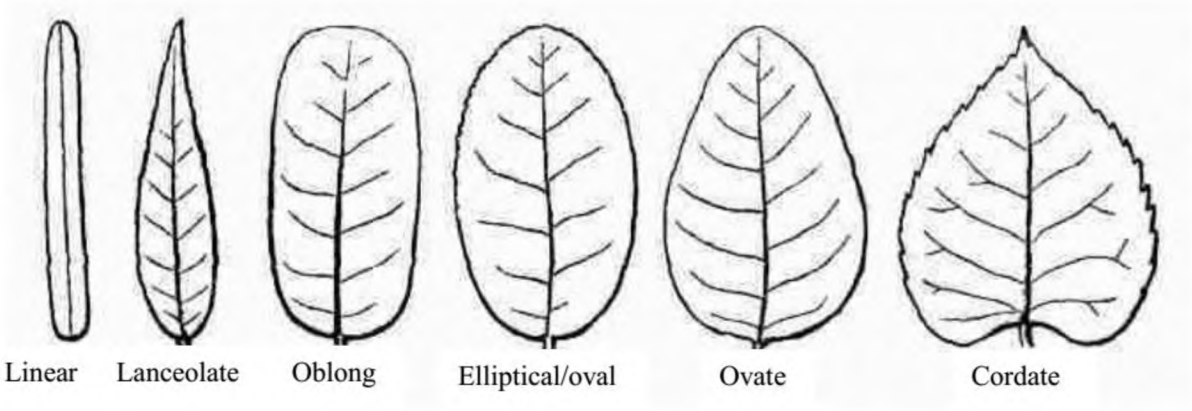
This is where more than 2 leaves arise from each node.

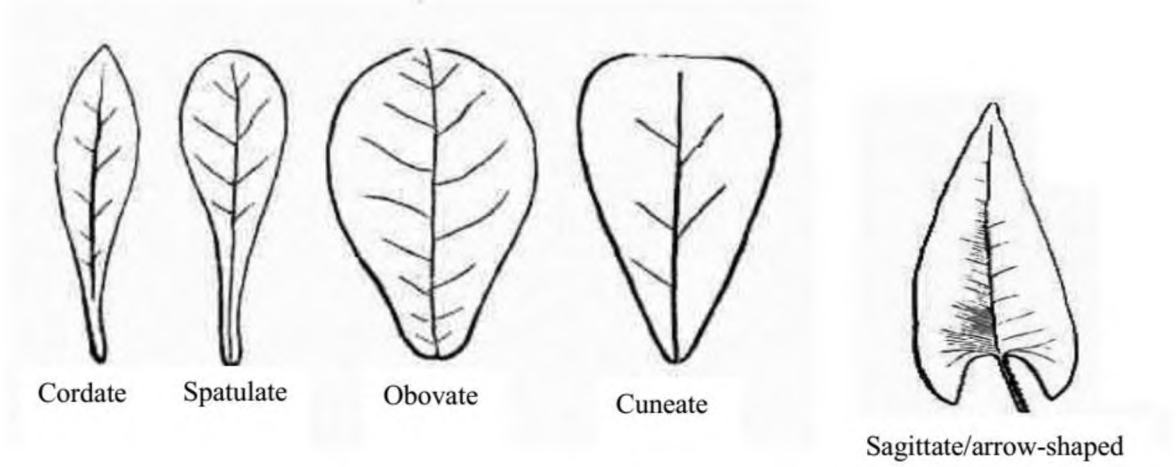
TYPES OF LEAF MARGINS

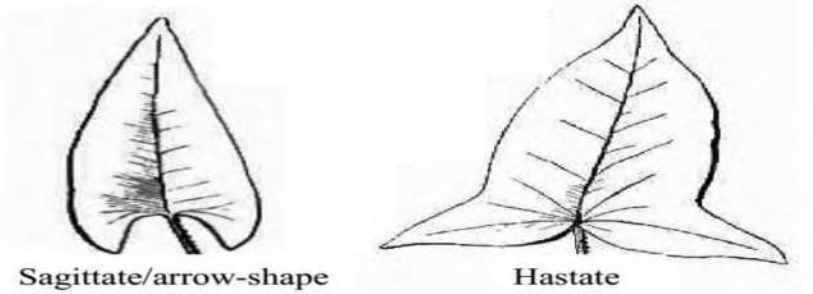
Leaves can be classified according to the leaf margins.

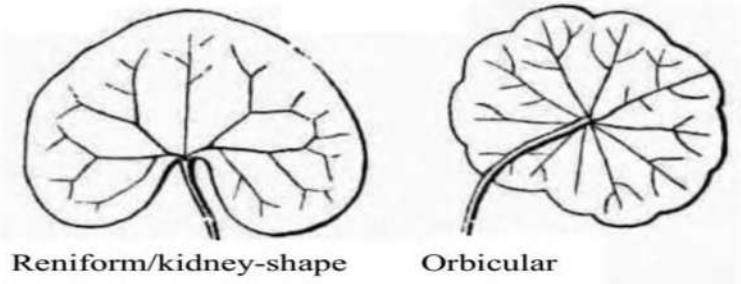
1. **Entire margin**
   The margin is smooth and without indentation of any kind. E.g. mango leaves.
2. **Serrate margin**
   The margin is with indentations pointing towards the apex.
3. **Dentate margin**
   The margin has indentations pointing towards the petiole.
4. **Crenate margin**
   The margin has round indentations.
5. **Lobed margin**
   The margin has relatively few and shallow indentations.

Types of leaf shapes









Functions of leaves to plants

a) Primary functions

- The major function is to manufacture food for the plant during photosynthesis.
- Leaves have stomata which allow exchange of gases i.e. O_2 and CO_2.

- Leaves facilitate transpiration which sometimes helps the removal of excess water within the plant.

b) Modified or secondary functions

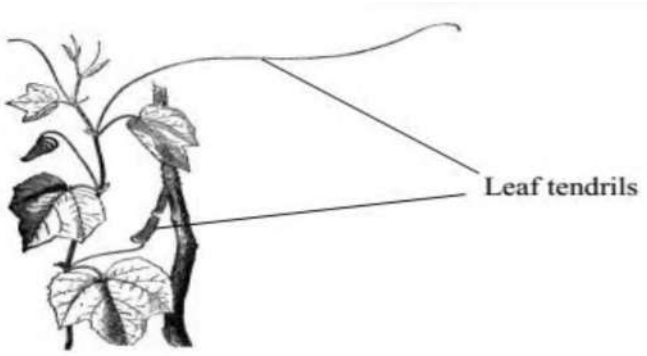
- They store food and water for the plant e.g. the thick fleshy leaves of onions.
- Some plant leaves are useful in vegetative reproduction e.g. bryophytes.

Modification of leaves

Leaves of some plants have become modified to perform other functions other than photosynthesis.

1. Leaf tendrils

These are slender wire like coil structures used as climbing organs in climbers for support. The leaf may be partly modified into a tendril.



2. Leaf spines

These are sharp pointed structures of certain plants modified for defense.

3. Scale leaves

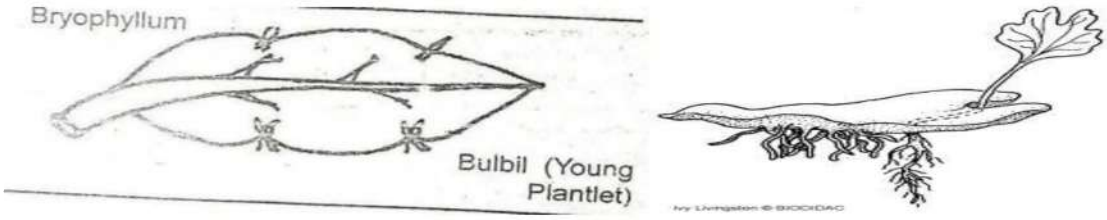
These are thin, dry membranous structures usually brown in colour and sometimes colourless. Their main function is to protect the axillary bud from mechanical injury and drying out. They are commonly found on underground stems. E.g. scale leaves of onions, rhizome and garlic.

4. Insectivorous leaves

These are modified leaves whose function is to capture and digest insects. Such plants are called insectivorous plants. Pitcher plants grow in soil with a deficiency of nitrogen/nitrates. They obtain nitrogen from insects. E.g. Venus fly trap, butter wort, sundew, bladder wort, nepenthes, and the pitcher.

5. Bryophyllum leaves

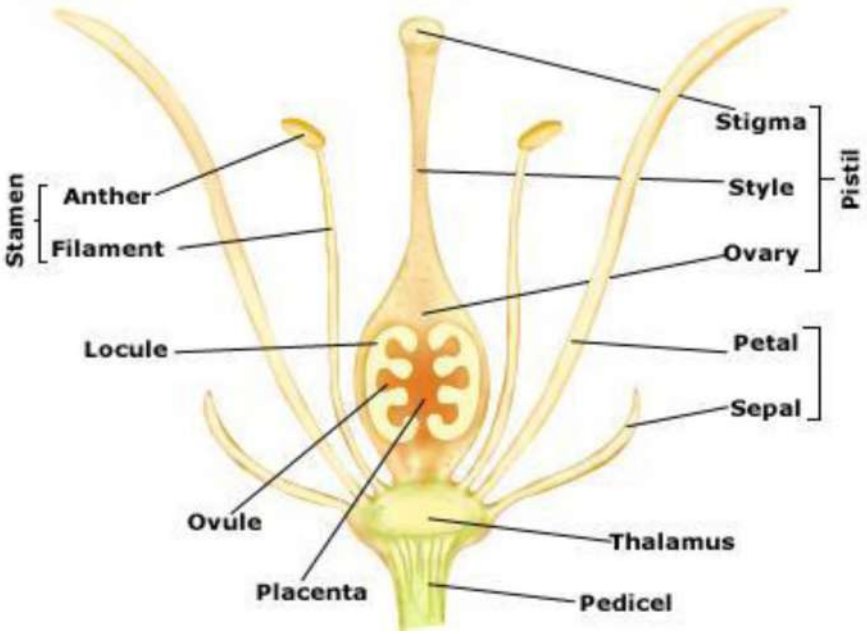
Leaves have series of buds at the end of vein. These buds grow into new plants (plantlet) when the leaf is mature.



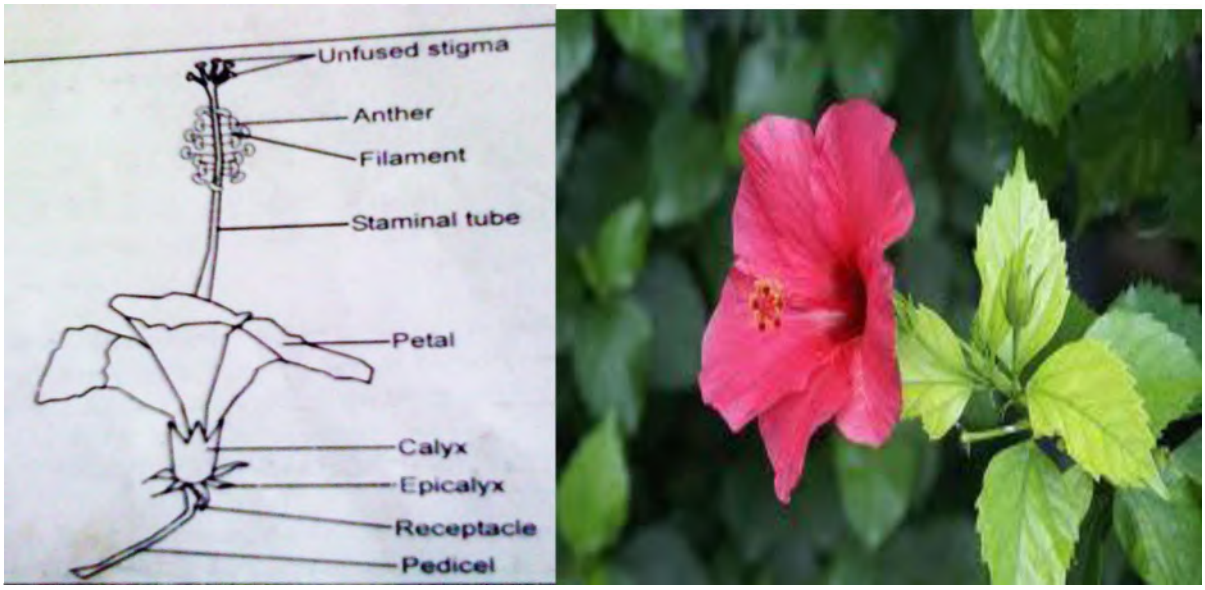
THE FLOWER

The flower is part of the shoot specialized for reproduction. Most flowers have male and female reproductive organs though some are of a single sex. A group of flowers is called an ***inflorescence*** e.g. maize flower.

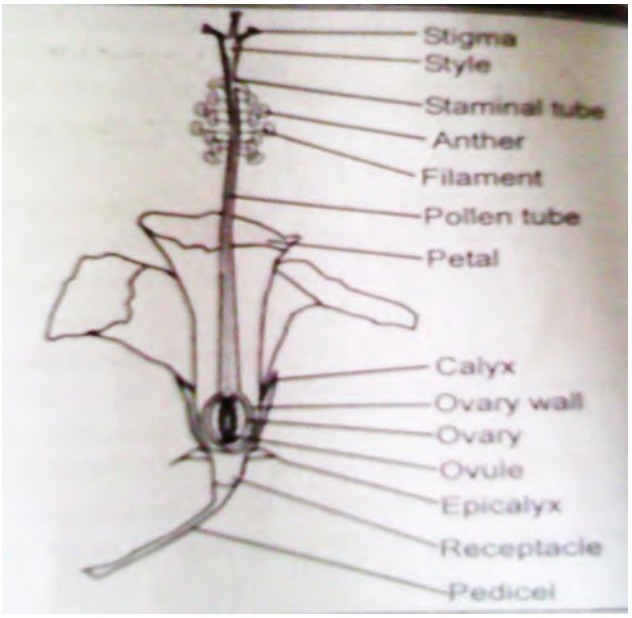
General structure of a flower



Structure of a hibiscus flower (external structure)

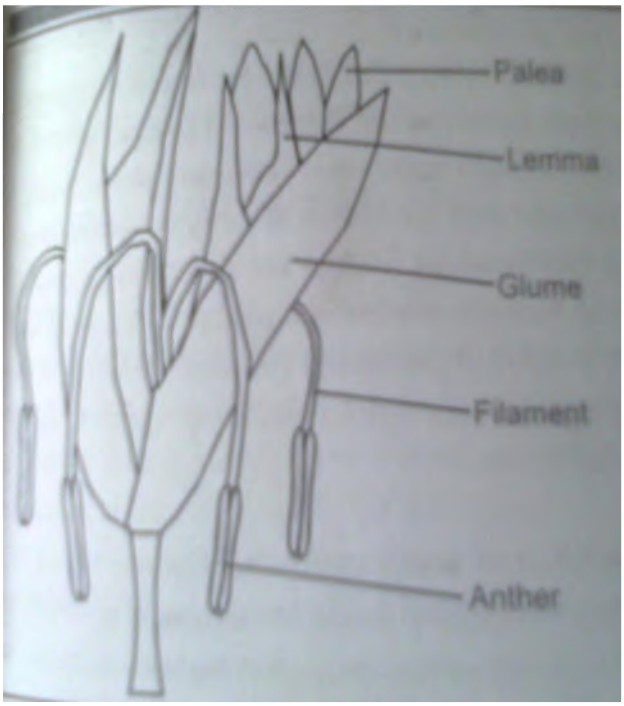


Internal structure of a hibiscus flower



When petals, calyx, epicalyx and the sheath of the staminal tube have been removed, this is shown in the diagram

Spikelet of the male maize flower



Single grass flower

Grass and male maize flowers grow in groups along the same axis. The flowers are in pairs and each pair is called a ***spikelet.*** The whole individual flower is called a ***floret.*** These flowers have no petals or sepals instead they have green leaf-like structures called ***bracts.*** The outer and larger bract is called ***lemma*** and the inner smaller one is called ***palea.*** At the base of each spikelet is a pair of modified leaves called ***glumes.***

Parts of a flower

The floral parts are arranged in rings, spirals or whorls with short internodes. The end of a flower stalk may be expanded to form a receptacle. The stalk of the flower where floral parts grow is called pedicel.

The four floral whorls are

- Calyx
- Corolla
- Gynoecium
- Androecium

The calyx is the outer most floral whorls of the flower made up of sepals. The calyx protects the inner whorls of a flower during the bad stage.

The corolla is the second floral whorl of a flower made up of petals. Most flowers have scented petals to attract insects for pollination e.g. hibiscus, crotalaria, coffee, morning glory, etc. the calyx and corolla are collectively known as Perianth.

Androecium is the male part of the flower consisting of stamen. Each stamen is made up of filament and head called anther. Anthers contain pollen grains which develop to form male reproductive cells called gametes.

N.B: an infertile or sterile stamen is called staminode.

Gynoecium (pistil) is made up of female reproductive parts called carpels. The pistil occupies a central position in the flower. Each carpel is made up of;

- ✓ Ovary which contains ovules or female gametes.
- ✓ Style which connects the ovary to the stigma
- ✓ Stigma which receives the pollen grains

The wall of the ovary develops into the pericarp of the fruit. Nectaries are swellings often at the base of the ovary or on the receptacle which produce a sugary solution called nectar.

Types of pistils

Three main types of pistils are:

1. Monocarpous

This is a pistil with only one carpel e.g. morning glory and cow pea.

2. **Syncarpous pistil**
   This is a pistil with carpels fused together e.g. hibiscus and isolanum.

3. **Apocarpous pistil**
   This is a pistil with several carpels which are not fused i.e. as distinct carpels e.g butter cap and Bryophyllum.

Types of ovaries

The two types of ovaries include the following

1. **Superior ovary**
   Is the one that arises above the other floral parts e.g. hibiscus, cassia, commelina, mimosa pudica, etc.
2. **Inferior ovary**
   Is the one which arises below the rest of the floral parts e.g. morning glory.

Hypogenous

The gynoecium is situated at the apex of the receptacle and other whorls arise below it. The sepals and petals are inserted independently below gynoecium. Hypogenous flower has superior ovary.

Terms used

Complete flower: A flower having all the four whorls or floral parts i.e. calyx, corolla, stamen and pistil.

Incomplete flower: A flower lacking one or more of the four floral parts.

Perfect flower: Is a flower with both male (stamen) and female (pistil) parts.

Imperfect flower: A flower lacking either stamen or pistil.

Unisexual flower: Has only one of the sexual parts i.e. staminate; when the flower has stamens only. Pistillate (carpellary) when it has carpels only.

Staminode: sterile stamen.

Bisexual (hermaphrodite) flower: is one that contains both male and female organs or parts.

Monoecious plant: Is one that has the pistillate and staminate that are born on the same plant but at different points on the plant e.g. maize and castor oil plants.

Dioecious plant: is one that bears either pistillate or staminate flower only e.g. pawpaw.

Dichogamy: Is a condition in which the male and female parts of a flower mature at different times. There are 2 types;

- **Protandry:** when the anthers mature before the stigma.
- **Protogyny:** where by the stigma matures before the anthers.

Regular (actinomorphic) flower: a flower which can be divided symmetrically (equally) in different planes.

Irregular (zygomorphic) flower: is one which can be divided into 2 similar halves in only one plane.

Polysepalous: is when the sepals are borne free or are separate and are distinct from each other.

Gamosepalous: is when the sepals are fused or joined together.

Petaloid: Sepals resembling petals and have the same colour.

Gamopetalous: Are petals which are wholly joined or fused together e.g. morning glory, sweet potatoes.

Sepaloid: They are petals which resemble sepals and are green in colour.

Septum: Is an internal dividing wall or partition with in a syncarpous ovary.

Locules: Is an internal compartment of an ovary of fruits.

Simple flowers may be borne on a common flower stalk called peduncle while individual flowers may be borne on a pedicel.

POLLINATION

Pollination is the transfer of pollen grains from the anther to the stigma of a flower. There are two types of pollination.

1. **Self-pollination**. This is the transfer of pollen grains from the anther to the stigma of the same flower or between two flowers on the same plant.
2. **Cross-pollination**. This is the transfer of pollen grains from the anthers of one flower to the stigma of another flower on a different plant but of the same species.

Agents of pollination

These are things that aid the process of pollination. The agents of pollination include.

Animals, Water, Wind and Artificial pollination

There are however two major agents that is wind and insects. Pollination can therefore be described as wind pollination and insect pollination.

Characteristics of insect pollinated flowers

i) They have brightly coloured petals to attract insects.
ii) They have a scent to attract insects
iii) They have large conspicuous petals, which act as landing sites for insects.
iv) They have sticky pollen grains, which stick to the insects body.
v) They have sticky stigmas, which hold pollen grains.
vi) They produce few sticky pollen grains.
vii) They produce heavy pollen grains.
viii) They produce nectar from nectarines to attract insects.

Characteristics of wind pollinated flowers.

i) They have dull coloured petals.
ii) They have small petals.
iii) They produce light pollen grains, which can easily be carried by wind.
iv) They do not produce nectar
v) They have feathery stigmas to trap pollen grains carried by wind.
vi) They produce a lot of pollen grains.
vii) They have no scent
viii) They have long stamens and pistils hanging outside the petals to release and receive respectively pollen grains easily.

Differences between insect and wind pollinated flowers.

Insect pollinated flower	Wind pollinated flower
Have brightly coloured petals	Have dull coloured petals
Have a scent	Have no scent
Produce nectar from nectarines	Produce no nectar
Have large petals	Have small petals
Produce few pollen grains	Produce a lot of pollen grains
Have sticky stigmas	Have feathery stigmas
Produce heavy pollen grains	Produce light pollen grains
Have short pistils	Have long pistils
Have short stamens	Have long stamens

Characteristics of flowers pollinated by nocturnal insects

Nocturnal insects are those insects, which are active at night. Flowers pollinated by such insects have the following characteristics.

1. They have light coloured petals mainly white and pink.
2. They produce a strong scent.
3. They open their petals at night and close them during daytime.

Modifications of flowers to prevent self-pollination

1. **Protandry**. This is a situation where stamens ripen before the stigma such that when pollination occurs, the pollen grains cannot germinate on the immature stigma.
2. **Protogyny.** This is a condition where the stigma ripens before the anthers.
3. **Dioecious condition**. This is a condition where a plant bears either pistilate or staminate flowers but not both.

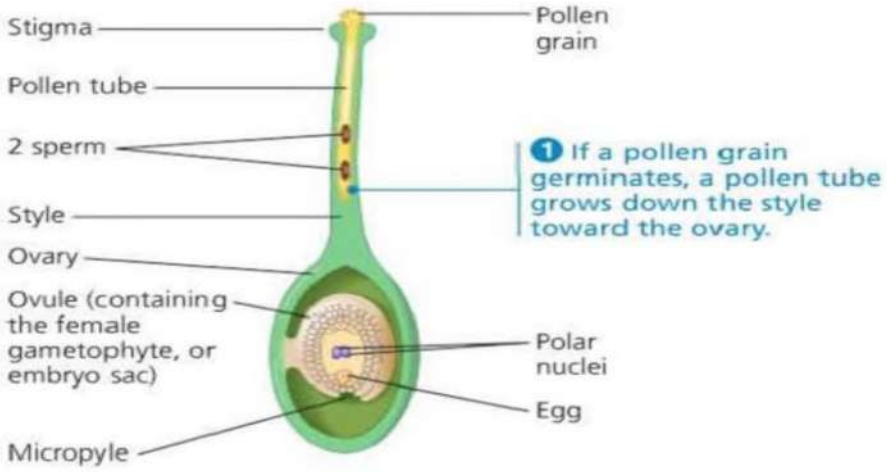
4. **Self-incompatibility**. This is where pollen grains from the same flower fail to fertilize the stigma of that flower.
5. **Structure of the flower**. Sometimes the carpel is taller than the stamens of the same flower and in some flowers the corolla covers the stamens preventing self-pollination.

FERTILIZATION IN PLANTS

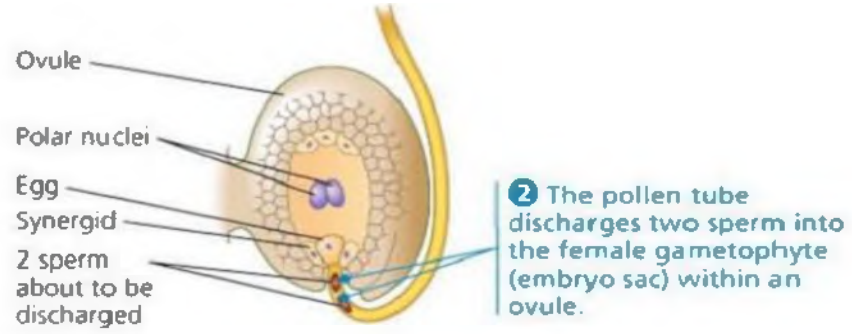
This is the fusion of male and female gamete to form a zygote. Fertilization in plants is internal taking place inside the ovary in the structure called embryosac.

The process of fertilization in plants:

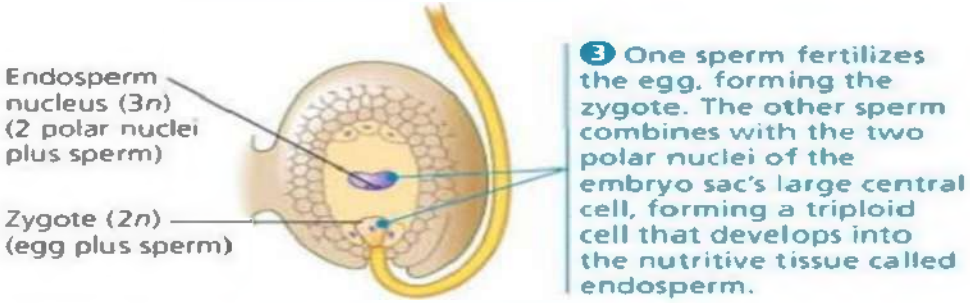
1. Pollen grain lands on the stigma of a flower of the same species.
2. On the stigma, pollen grain absorbs water, nutrients and then germinates to form a pollen tube which grows through the style under the control of the tube nucleus at the tip.
3. Pollen grain has two nuclei i.e. generative nucleus and pollen tube nucleus. The generative nucleus divides mitotically to form two male nuclei which lie behind the pollen tube nucleus.



4. The pollen tube enters the ovary and the tip of the pollen tube breaks. The pollen tube nucleus disappears.

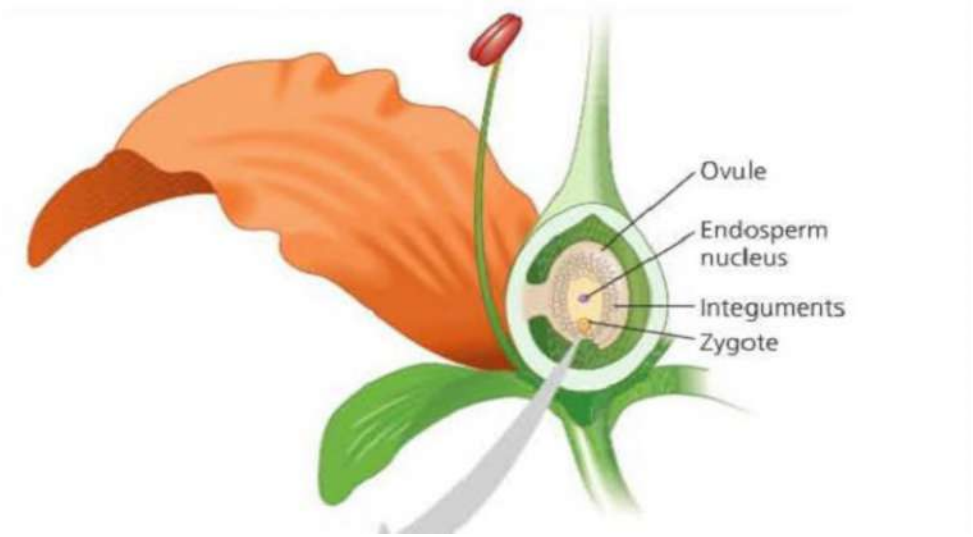


5. One of the male nucleus fuse with the egg nucleus to form a zygote which divides mitotically to form embryo.
6. The other male nucleus fuses with two polar nuclei to form a triploid endosperm which develops into endosperm. This is called double fertilization.



Events after fertilization

1. The zygote divides mitotically followed by growth and development resulting into an embryo.
2. The triploid endosperm divides mitotically to form good solid organs called endosperm.
3. The ovules develop into seeds.
4. The integuments become the seed coat.
5. The ovary develops into a fruit and ovary wall develops into a fruit wall which protects the seeds.
6. Petals, stigma, style and stamen wither and fall off while the calyx may wither and fall off or may remain in shriveled form.



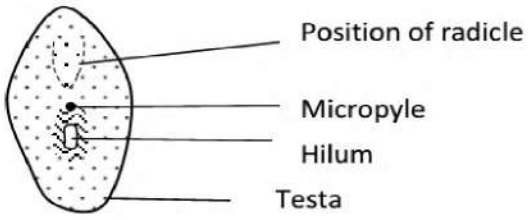
SEEDS

A seed is a fertilized mature ovule. It has one scar called hilium which is a spot where it was attached to the pod inside a fruit.

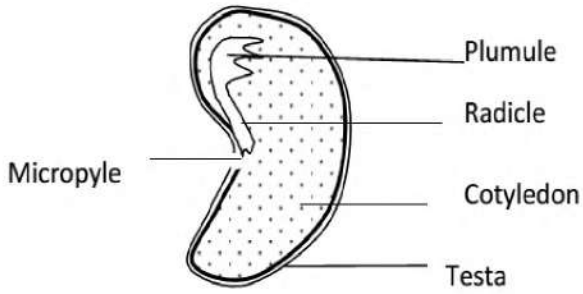
Types of seeds

1. **Monocotyledonous seeds:** These contain only one seed leaf or cotyledon. E.g. cereals like maize.
2. **Dicotyledonous seeds:** These contain 2 cotyledons e.g. legumes like beans, peas and G. nuts.

External structure of a seed (dicot seed)

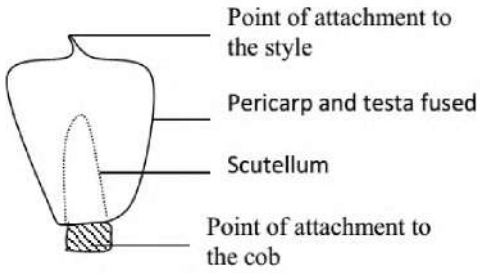


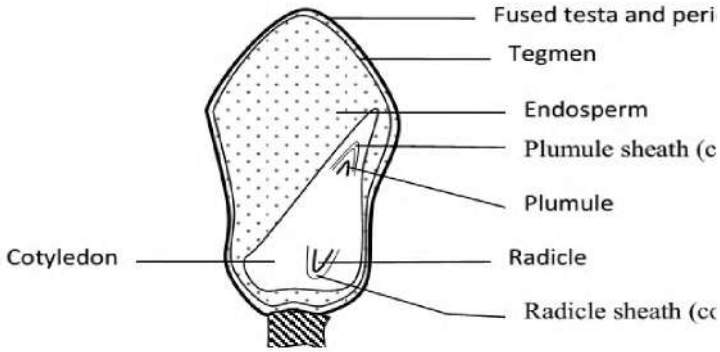
Internal structure of a dicot seed



External structure of a monocot seed

Internal structure of a maize seed





i) Testa

It is a protective -covering of the embryo of the seed formed from the integuments. It is usually hard and dry. It protects it from fungi, bacteria and insects.

ii) Tegmen

It is the inner membrane of the seed coat and its also used for protection.

iii) Micropyle

It is a narrow opening into the seed through which water, mineral salts and oxygen enter during germination.

iv) Radicle

It is a seed root (embryo root) which develops into primary root of the plant. A developing root has a root cap which bores through the soil particles and protects the newly formed cells at the root tip from mechanical damage.

v) Hilium

It's a scar of attachment left by the stalk of the ovule to the ovary wall.

vi) Endosperm

Stores food especially starch for the embryo.

vii) Scutellum or cotyledon

Digests and absorbs food stored in the endosperm. It provides food to the whole seed.

viii) Coleorhiza
It is the radicle sheath that offers protection to the radicle.

ix) Coleoptile
It is the plumule sheath that offers protection to the plumule.

x) Cotyledon
These contain stored food like starch, proteins and liquids for the initial growth of the embryo during germination.

FRUITS

A fruit is a fully grown fertilized ovary containing one or more seeds. A fruit has 2 scars, one where it was attached to the receptacle and the other, the remains of the style or stigma.

During a fruit formation, the wall of the ovary becomes a fruit wall called pericarp. In some fruits such as banana and pine apple, the fruits develop without fertilization. Such fruit are said to be ***parthenocarpic*** fruits. Therefore ***parthenocarpy is the development of fruits without fertilization.***

Classes of fruits

True fruits: develop only from the ovaries of a flower e.g. beans, tomatoes, etc.

False fruits: develop from the association of ovaries and other floral parts such as receptacle. Examples include; pineapples and apples.

Classification of fruits

There are 3 groups of fruits namely;

- ❖ Simple fruits
- ❖ Aggregate fruits
- ❖ Multiple fruits

Simple fruits

These are formed from one flower in which the pistil consists of either one carpel (monocarpic) or of several fused together (syncarpous) e.g. legumes, g, nuts, peas, tomatoes, mango, beans, etc.

Aggregate fruits

These are formed from one flower in which the pistil consists of several free carpels (apocarpous) e.g. apples and rose.

Multiple fruits

These are formed from several flowers and the ovaries become fused after fertilization e.g. jackfruit and pineapple.

SIMPLE FRUITS

There are either dry or succulent according to whether the pericarp becomes dry or juicy as the fruit ripens.

Types of simple fruits

Simple fruits are further divided into three categories.

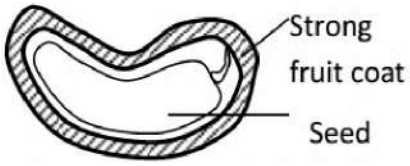
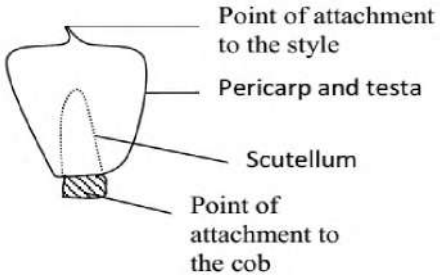
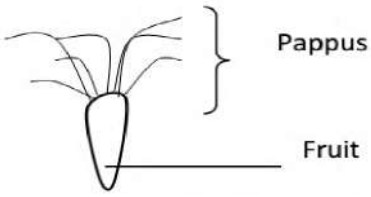
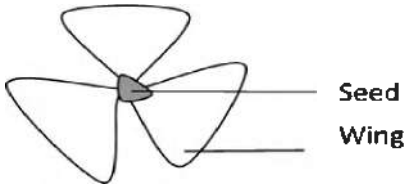
1. Dry indehiscent fruits
2. Dry dehiscent fruits
3. Succulent fruits.

Dry indehiscent fruits

These are fruits with a dry pericarp that does not split up (dehisce) to release seeds. This category contains five types of fruits. These are Achene, Nut, Caryopsis, Cypsela and Samara.

The table below shows the different types of dry indehiscent fruits.

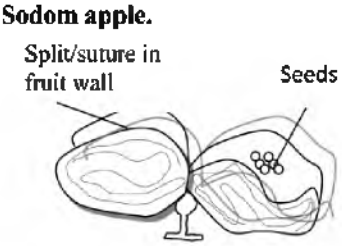
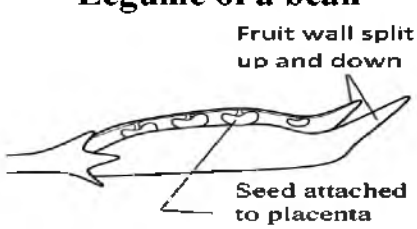
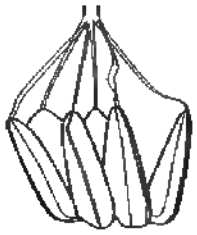
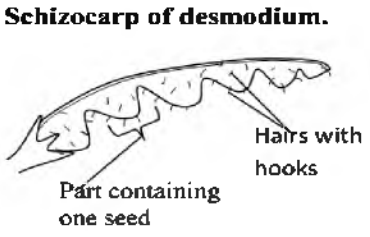
Type of dry indehiscent fruit	Description	Illustrative diagram

Achene	This is a one seeded fruit covered by a dry pericarp, which does not split open, e.g. sunflower. The achene is the simplest fruit.	**An achene of sunflower.** 
Nut.	This is similar to an achene but the pericarp is hard and tough, e.g. cashew nut. Note; coconuts and groundnuts are biologically not nuts.	**Section through a cashew nut** 
Caryopsis.	This is an achene-like fruit in which the testa and pericarp are fused. These are mainly found in grasses and maize.	**Caryopsis of maize.** 
Cypsela	This is a fruit similar to an achene in which the inferior ovary has a pappus of persistent calyx. It is common in composite fruits, e.g. tridax and *bidens pilosa*	**Cypsela of tridax.** 
Samara.	This is a fruit similar to an achene in which the pericarp is extended to form one or more wings, e.g. in jacaranda and African rose wood.	**Samara of jacaranda.** 

Dry dehiscent fruits

These are fruits with a dry pericarp that splits (dehisces) to release seeds. The fruits split at particular lines of weakness known as sutures. These fruits are categorized into the following different groups depending on the number of splits that occur on the pericarp. These fruits include, Follicles, Legume, Capsule and Schizocarp.

The table below shows the different types of dry dehiscent fruits

Type of dehiscent fruit	**Description**	**Illustrative diagram**
Follicle	This is a dry fruit with many seeds and splits open along one suture, e.g. Sodom apple	
Legume.	This is a dry fruit with many seeds and splits open along two sutures, e.g. beans, peas, flamboyant and Barbados pride.	
Capsule	This is a dry fruit with many seeds and splits open along many vertical slits. It is formed from an apocarpous flower, e.g. Dutchman's pipe, balsam, cotton, e.t.c.	
Schizocarp.	This is a dry several seeded fruit, which breaks up into separate parts each containing one seed, e.g. desmodium, sweet hearts	

	and some cassia.	

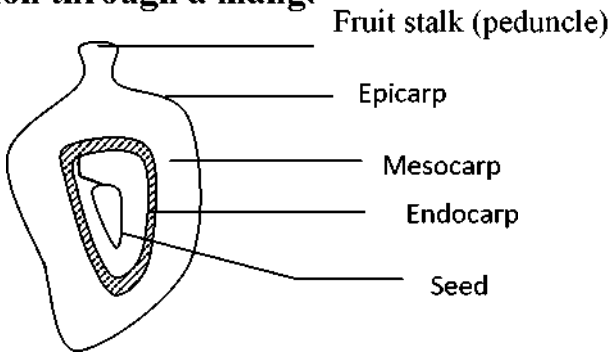
Succulent fruits

These are fleshy fruits. They are either entirely fleshy or have part of it fleshy. They are further divided into 2 types.

1. Drupes.

These are fruits with only one seed and only part of it fleshy (epicarp and mesocarp). The endocarp is fibrous and hard, e.g. mango and avocado.

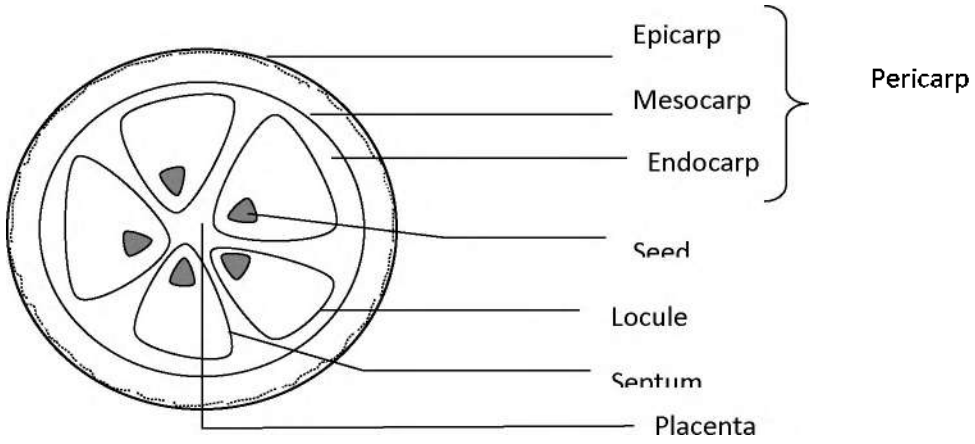
Longitudinal section through a mango



2. Berry.

This is a fruit with many seeds and the whole of it fleshy, e.g. tomatoes, guavas, oranges, bananas etc.

A berry of an orange (T.S).



3. Pome

This is a succulent fruit in which the outer fleshy (normally edible) part develops from the calyx and receptacle. The ovary forms a papery aore containing seeds e.g. apple and pears.

PLACENTATION

This is the distribution of the placentae in the ovary or the arrangement of the seeds on the placenta within the ovary.

There are five types of placentation as shown in the table below.

Type of Placentation	Description	Example
Marginal	Ovules are situated at or near the margin of the ovary	Beans, peas, cassia
Axile	Ovules centrally located in the ovary with ovary divided into many chambers.	Orange and tomato
Central	Ovary is one chambered and ovules centrally located	Soap wort,
Parietal	Placenta is found on the inner wall of the fruit and the ovules are attached on the inner wall	Passion fruits pawpaw, cocoa
Free central	Ovules located on the projection from the base of a one chambered fruit	Green pepper
Basal	Ovule found on a placenta that arises from the base of the ovary, fruit usually single seeded	Mango, avocado.

FRUIT/SEED DISPERSAL

This is the scattering or spreading/displacement of fruits and seeds from their parent plants. In some plants, only seeds are dispersed while in others, fruits are dispersed with seeds.

Importance of dispersal

i) It helps to prevent overcrowding among plants of the same species.
ii) It reduces competition between member plants of the same species.
iii) It helps to minimize the spread of epidemic diseases especially in seedlings if they are crowded.
iv) It helps plants to colonize new areas which may even be better for the species survival.
v) It enhances the chances of survival and continuity of the plant species.

Agents of dispersal

They include;

1) Water,
2) Wind
3) Animals
4) Self-dispersal/ explosive mechanism

Fruits and seeds possess specialized structure to aid their dispersal and are adopted to specific mode of dispersal.

Characteristics of fruits/seeds dispersed by wind

i) They are usually small, light and dry which enables them to easily be carried or flown by wind.
ii) Some fruits like elm and tecoma have wing like structures that increase their surface area. This helps in delaying the fall of seeds and fruits and increases chances of being blown away.
iii) Some fruits like tridax and clancletion have parachute-like hairs called pappus which enables them to fleet and fly by wind.
iv) Some seeds like silk cotton possess thread-like structures called floss which increase surface area enabling the seeds to float in air.
v)

Characteristics of fruits/seeds dispersed by water

i) They are usually light and contain air space inside which reduces their relative density and enable them float on water easily like the coconut.
ii)

Characteristics of fruits/seeds dispersed by animals

i) Some fruits such as tomatoes, oranges and mangoes are usually large and brightly coloured especially when ripe. This helps to attract animals.

ii) Some fruits when ripe are scented e.g. jack fruit. This helps to lure/attract animals.

iii) Some usually possess edible parts which are succulent / juicy and the only part of the fruit that is eaten and the rest containing the seeds is thrown away e.g. mango and avocado.

iv) In some fruits, such as guavas, tomatoes, pepper and pawpaw. The whole fruit is eaten and the seed passed out in the faeces because of their resistance to digesting i.e. are indigestible.

v) Some fruits e.g. Biden pilosa and desmodium possess hooks and sticks in the hair of passing animals. They stick in the fur of animals or on clothing of people.

Self-dispersal

a) explosive mechanism

This happens with dry dehiscent fruits. The pericarp splits open along the sutures to release the seeds. This is made possible due to the tension that is built during the process of dying. E.g. legumes, capsule or follicles

b) ribbon fruits

These are succulent, may drop freely from the parent plant. The pericarp then rots, bearing the seeds that are enclosed within a hard protective testa so that it can begin germinating.

SEED GERMINATION

This is the growth and development of an embryo of a seed into a seedling or a young plant under favorable conditions.

Types of germination

1. Epigeal germination

This is where the cotyledons appear above the ground due to the rapid elongation of the hypocotyl e.g. beans, cotton, sun flower, etc.

2. Hypogeal germination

Is where the cotyledons remain below the ground and the radicle emerges due to elongation of the epicotyl e.g. maize, mango and black jack.

NB: During germination, the seed absorbs water mainly through the micropyle which makes the cotyledon swell and split the testa. This process is called imbibition. The radicle comes out of the testa faster followed by the plumule.

Conditions necessary for germination to occur

a) Environmental or external factors

i) Water
ii) Oxygen
iii) Suitable temperature

b) Internal conditions

i) Viability of the seeds
ii) Amount of food in the seeds
iii) Enzymes
iv) Absence of germination inhibitors e.g. poison

1. Water

Water is needed for the following:

- It activates the enzymes within the seed to hydrolyze the stored food.
- It makes the seed swell, soft and the testa to bursts.
- It dissolves the stored food.
- It is a medium in which all the chemical and enzymatic reactions proceed.
- It is a medium of transport of the dissolved food substances to the developing shoot and root of the new plant.
- Water is needed for the development of cell vacuoles. Large cell vacuoles contribute to increase in size of cells.

2. Oxygen

Oxygen is necessary for the process of respiration, the oxidation of food to provide energy required for growth.

3. Warmth

Suitable temperature is important for the enzyme controlled reactions in the cotyledon of the germinating seed. At low temperatures, the enzymes are inactive and at high temperatures, they are denatured hence no germination. Germination will require an optimum temperature which varies from 10℃-50℃ for most tropical seeds.

EXPERIMENTS ON GERMINATION

An experiment to demonstrate the conditions necessary for germination

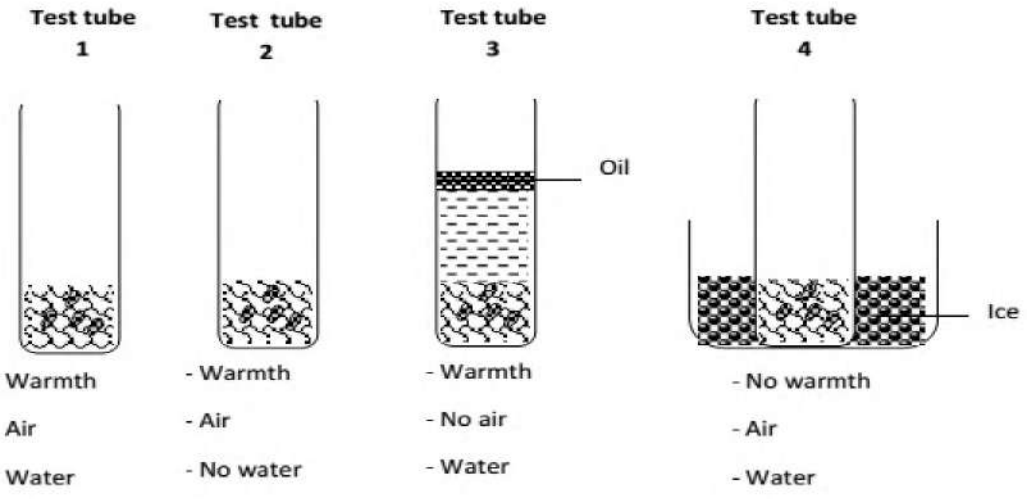
Apparatus:

4 test tubes, Cotton wool, Seeds, Oil and Water.

Procedure:

a) Arrange four test tubes labeled 1-4
b) To test tube 1 add moist cotton wool, seeds and leave test tube open.
c) To test tube 2 add dry cotton wool, seeds and leave test tube open.
d) To test tube 3 add seeds, boiled cooled water and a layer of oil.
e) To 4 add seeds, moist cotton wool, ice and leave test tube open. Leave all test tubes for 3 days.

Setup:



Observations

Seeds germinated in only test tube 1 and those in 2, 3 and 4 did not germinate.

Conclusion:

Air, water and warmth are necessary for germination.

Experiment to show that oxygen is necessary for germination

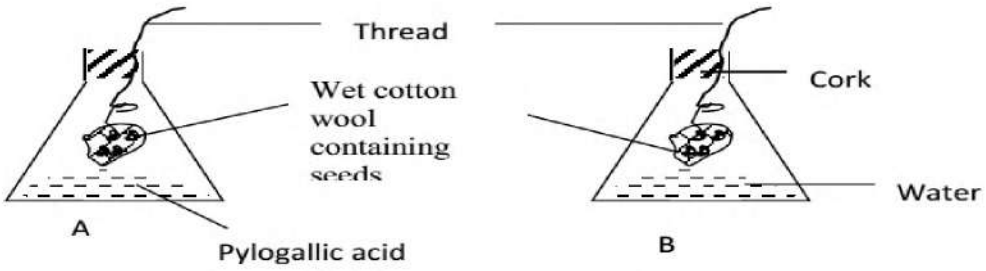
Apparatus:

2 conical flasks, 2 corks, Water, Cotton wool, Seeds and Pyrogallic acid.

Procedure:

- ✓ 1. Pour some water in one conical flask and some alkaline pyrogallol in another conical flask.
- ✓ Tie some seeds in wet cotton wool and suspend the cotton wool in the flasks using a thread.
- ✓ Fix the threads using a cork.
- ✓ Leave the set up for three days

Set up:



Observation:

After a few days the seeds in B germinated while those in A did not germinate.

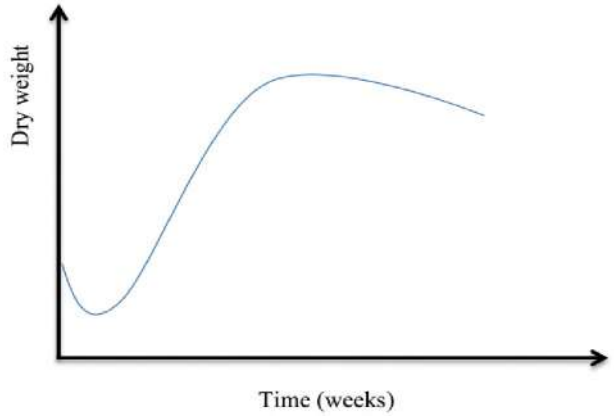
Conclusion:

Oxygen is necessary for germination.

Explanation:

Alkaline pyrogallol absorbs oxygen from air in flask A thereby preventing germination.

The graph showing the change in dry weight of a germinating seedling



This is called the **sigmoid curve** (S shape) which is true for most organisms.

Description: Briefly the graph slows down at first and then increases rapidly reaching the maximum when it becomes constant for some time after which it begins to decrease gradually/slowly.

Explanation:

The decrease in dry mass is due to hydrolyzed food being oxidized to produce energy required for growth.

The dry mass increased gradually because this period growth proceeds slowly because the number of dividing cells is small. Then the dry mass increased rapidly because during this time the first green leaves appear and therefore carries out photosynthesis. As more leaves appear the amount of food manufactured during photosynthesis increases hence a rapid increase in the dry mass of the bean seedling.

The dry mass then increases gradually after a plant approaches its full size of development because most of the cells becomes differentiated and lose their power of cell division. This decreases the number of cells formed and hence decrease in the rate of growth.

The rate of growth then remains constant because the numbers of cells added are equal to the number of cells which are dying off.

The dry mass decreases after some time because the plant is in senescence stage where the numbers of cells added are less than the numbers of cells dying off. This results into a gradual decrease in dry mass until when a plant dies.

SEED DORMANCY

Seed dormancy is the condition where by viable seeds fails to germinate under certain conditions or resting stage.

Causes of seed dormancy

1. Immature embryo of the seed

This may cause dormancy in seed germination since the embryo may undergo development before germination occurs.

2. Presence of germination inhibitors

Some chemical substances like acids do not promote germination of seeds when present. They destroy the enzymes.

3. Extreme temperatures

These greatly offect the function of enzymes in the seed. High temperatures denature enzymes while low temperatures inactivate them.

4. Presence of hard impermeable seed coat

Some seeds have a strong seed coat that does not allow water and gases to enter the seeds. Without water and gases, germination will not take place.

5. Dryness of soil and lack of sufficient oxygen enough for seeds.

If oxygen is absent, seed respire anaerobically and obtain less energy. This will not allow seeds to germinate.

Ways of breaking seed dormancy

1. Harvesting mature seeds. This involves allowing embryos in seeds to develop up to maturity for certain period called ***after-ripening period.*** This allows the seed to develop fully.
2. By providing growth promoters which deactivate germination inhibitors. These are chemical substances that can make inhibitors less acive. They contain nutrients or hormones for proper growth.
3. By exposing seeds to a cool period or chilling to initiate germination. This is common method of breaking seed dormancy in cereals.
4. By providing suitable conditions of oxygen, temperature and moisture which favour germination.
5. Removing the hard seed coat by:
   - Soaking seeds in water to soften it.
   - Action of fire to burn away the seed coat.
   - Passing seeds through animal gut.
   - Churning seed coat in concentrated acids.
   - Physical removal of the seed coat by using the hand or pricking or by action of bacteria in the soil.

Importance of seed dormancy

i) It prevents seed germination in unfavorable conditions e.g. seeds dispersed in winter remain dormant in summer.

ii) It improves the chances of seedling to grow to maturity during favourable conditions.

iii) Dormant seeds can be stored for a long time and the seed dormancy can be broken by giving artificial conditions. This helps in their transportation.

iv) It reduces the risk of seeds being frozen to death during unfavorable conditions.

THE SOIL

Soil is finely divided material covering the earth crust or surface. It consists of air, water, humus, living organisms, and weathered rocks.

Importance of soil

- Soil provides nutrients e.g. water and minerals to plants which are the chief producers of food in the environment.
- Soil is a habitat (home) for many organisms such as earth worms, termites, bacteria fungi and arthropods.
- Soil provides a medium through which man and all other animals dispose of their wastes.
- Soil is an important natural resource which provides construction materials, supports agriculture, craft and art materials.

SOIL FORMATION

soil is formed from parent rocks by the process of weathering. This occurs over several years. The process of weathering takes place in three ways;

1. Physical weathering:

This occurs in the following ways;

i) Alternate heating and cooling of the rocks on exposed mountain sides, causes expansion and contraction which cause the rock to crack and break up.
ii) By water; this is where rivers and streams wear away the rocks over which they flow by rolling pebbles and other hard particles on them.
iii) During sandstorm when wind blows sand against bare rocks
iv) Frosting: frost is weather condition where temperatures fall below 0^0C, water in cracks freezes and expand, causing the rock to break up.

2. Chemical weathering:

This is brought about mainly by the action of water especially rain water on the rocks. As it rains, rain dissolves carbon dioxide in the atmosphere to form weak solution of carbonic acid which when falls on soft rocks for example lime, it dissolves them, this results in the release of mineral elements like calcium, magnesium, Aluminium, etc. which are components of soil.

In hot damp conditions (tropics) the constituency of rocks especially those containing iron, oxidizes very quickly. The oxidized rocks disintegrate to form soil.

3. Biological weathering:

This is brought about by the action and presence of living organisms on rocks. Certain organisms such as lichens are able to grow on bare rock while other small flowering plants are able to grow between the rock fragments. When these die, they form humus which is a component of soil.

Man contributes to biological weathering through direct splitting of rocks during road and house construction and indirectly through cultivation.

FACTORS INFLUENCING SOIL FORMATION

There are 5 major factors influencing soil formation:

- Climate
- Living organisms
- Nature of soil parent material
- Topography of the area
- Time that the parent rock material is subjected to soil formation.

i) Climate

The main climatic factors involved in the soil formation are rainfall, temperature and wind.

Rainfall and temperature influence the chemical and physical break down of the parent rock e.g. rainfall promotes weathering of rocks into small particles by leaching of soluble constituent compound in the rock.

ii) Living organisms

These include the vegetation cover, living microorganisms (bacteria and fungi) and invertebrates e.g. earth worms. The vegetation cover influences the characteristics of the soil formed through the litter and roots remains which add to the soil.

The termites feed on dead vegetation there by decomposing it. The bi-products of decomposition are added into the soil.

iii) Parent rock

This influences physical properties and chemical constituents of the soil e.g. granite and sand stones which are rich in mineral content giving rise to sand soil while volcanic larva produces clay soils.

iv) Topography

It influences the movement of products of weathering which consist of soluble substances and solid soil particles.
Ti affects soil depth and vegetation thus on a steep or rolling topography there is a tendency for soil erosion to occur with a result that relatively shallow soils develop. Therefore it modifies the effects of soil climate and vegetation on soil formation.

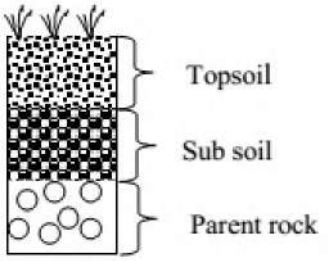
v) Time
The length of time over which soil forming processes have been in action affects the age of the soil. When soils forming have taken place for a long time, one tends to get deep mature soils, provided other factors are constant.

SOIL PROFILE

This is the vertical arrangement of the various soil layers called horizons. It represents the different layers at various stages of soil development. A soil with distinguished soil layers is known as mature and that without clear profile is immature or young. The profile consists of the following:

i) Top soil
ii) Sub soil
iii) Parent or underlying rock

Diagram to show the soil profile



1) Horizon A – Top soil
This is the upper most soil layer. It's usually about 20cm deep and is the most important horizon that supports the growth of plants. It has got the following characteristics:

- It's usually better aerated
- It has more active soil microorganisms
- It contains humus so it's usually dark in colour.
- It contains more plant root and usually litter.

2) Horizon B – Sub soil

This is a thicker light brown layer lying immediately below the top soil. It's composed of mainly rock fragments, clay and gravel. It has the following characteristics:

- It is less aerated than top soil.
- It contains only deep roots of plants and hardly any other organism.
- It contains very little or no humus
- It tends to contain a lot of mineral salts due to leaching and therefore referred to as the layer of accumulation.

3) Horizon C – Parent rock

This is a solid rock layer found below the sub soil. It represents the original parent material which is still intact and unweathered.

The common parent rocks in East Africa are granites, volcanic and sedimentary rocks. This horizon lack humus completely. It has low air content and mineral salts.

COMPONENTS OF SOIL

There are basically six components of soil. These are:

i) Inorganic particles,
ii) Humus,
iii) Water,
iv) Air,
v) Mineral salts, and
vi) Soil living organisms.

1. INORGANIC PARTICLES

These are produced during the process of weathering. Soil particle vary in size and their sizes are used to classify them. The different soil particles are clay, silt, fine sand, coarse sand and gravel.

Table showing sizes of soil of particles

Soil particle	Diameter (mm)
Gravel	> 2.0
Coarse	0.2– 2.0
Fine sand	0.02 – 0.2
Silt	0.002 – 0.02
Clay	< 0.002

Uses of soil particles

i) They provide a surface for anchoring plant roots hence providing support to the plants.
ii) Soil particles give a rigid frame work to the soil.
iii) They provide mineral elements to the soil which are the absorbed by plants using roots.

Experiment to show the soil texture of topsoil

Apparatus/materials:

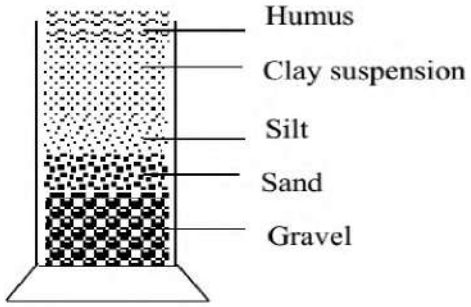
Measuring cylinder, Top soil, Stirrer, Beaker

Procedure:

Put water in a measuring cylinder half way. Pour soil ($20cm^3$) in water and stir thoroughly. Leave the experiment to stand for 3 minutes and observe.

Observation

When the soil particles settle down, the particles arrange themselves according to their particle size where the heaviest settle at the bottom and the small and lightest at the top as shown above.



Conclusion

Soil is made up of different particles, which have varying sizes and densities.

2. SOIL AIR

Soil air exists between the soil particles. Airspaces in the soil are important for growth of plant roots and health of soil organisms. It is mainly oxygen and nitrogen. (Carbon dioxide is usually in solution as carbonic acid). The depth to

which the roots can grow depends on how deep the air can penetrate through the soil

Importance of soil air

- It provides oxygen for respiration of soil organisms and plant roots.
- Oxygen is also needed for the decay that produces humus.
- It also provides nitrogen for fixation by the nitrogen-fixing bacteria in the soil. The nitrogen absorbed is needed in the formation of nitrates and proteins.
- Carbon dioxide present in the air helps in increasing soil acidity which favours proper growth of some plants.
- Carbon dioxide present in the air dissolves in water to form carbonic acid for weathering.

EXPERIMENT TO DETERMINE THE PERCENTAGE OF AIR IN THE SOIL

Apparatus

Measuring cylinders (2)
Dry soil sample
Water
Glass rode

Method

1. Measure about 50cc of dry soil in a measuring cylinder and tap the container to level out the soil.
2. Measure 50 cc of water in another measuring cylinder.
3. Add the two together (observe carefully as you pour the water onto the soil)
4. Allow the mixture to stand until no more bubbles appear. Read and record the final level of water plus soil in the measuring cylinder.
5. Calculate the air content in terms of percentage.

Example

Volume of soil = 50cc
Volume of water = 50cc
Final volume of water + soil after mixing = 85cc

Volume of air in soil (100-85)= 15cc

$$\text{Percentage of air in soil sample} = \frac{\text{vol of air in soil}}{\text{vol of soil used}} \times 100\%$$

3. WATER

Soil water comes from rain. Also some rise up from the ground water by capillary action to replace water lost by evaporation from the surface. It is found as a thin film surrounding the soil particles.

Soil water has the following functions

i) It moistens soil and keeps it humid/moist, making it favorable for survival of micro-organisms.
ii) It dissolves mineral salts making them available for plants to take.
iii) It dissolves carbon dioxide produced by living organisms to form carbonic acid which causes chemical weathering of rocks.
iv) It is a raw material for photosynthesis.
v) Water absorbed from the soil allows plant cells to be rigid (turgid), and this is very important for support of the plant, particularly herbaceous plants.

EXPERIMENT TO DETERMINE THE PERCENTAGE OF WATER IN A SOIL SAMPLE

Apparatus:

Evaporating dish or basin, fresh soil, weighing scale and oven or Bunsen burner.

Procedure:

a) Weigh a clean evaporating dish and record its weigh. (Let the weight be X g).
b) Fill the evaporating dish with soil and record the weight of the soil plus the evaporating dish. (Let the weight be Y g).
c) Dry the soil by heating it gently over a Bunsen burner flame for about 30 min.
d) Heating and weighing is repeated until a constant mass is achieved. (Take care not to burn the soil (no smoke))
e) Re-weigh the soil and the evaporating dish. (Let it be Z g).
f) Then calculate the water content in the soil sample as shown below;

Note:

You should cool in a desiccator before weighing. This ensures that no fresh vapour enters the soil.

Results:

Weight of the evaporating dish= X
Weight of soil + evaporating dish = Y
Weight of soil + evaporating dish after heating = Z

Weight of soil sample = Y-X
Weight of water in the soil sample = Y-Z

$$\%\text{age of water} = \frac{\text{weight of water}}{\text{Weight of soil}} \times 100$$

$$\text{Therefore percentage of water} = \frac{(Y-Z) \times 100}{Y-Z}$$

4. HUMUS

Humus is decaying plant and animal material- the dead bodies of animals, fallen leaves, dead plants and animal droppings. It is a dark brown, rather sticky material that gives soil its dark colour. For the decay process that form humus to work properly plenty of oxygen is needed.

Importance of humus

i) Because humus is dark-coloured, soil rich in humus absorbs more heat, and this warmth is useful for the germination of seeds and helps to speed up decomposition, making more humus.
ii) It has a high absorptive capacity for water.
iii) It forma\s a sticky coat around soil particles and binds several together to form soil clumps. The clumps structure greatly improves the drainage of the soil.
iv) Humus retains moisture and minerals in the top soil and so, greatly reduces the effects of drying and leaching (washing of minerals).
v) It is a source of nutrients used by plants after it is decomposed.
vi) It improves soil aeration.
vii) It improves soil structure by reducing the sticky properties of clay.
viii) It stabilizes soil pH.
ix) It leads to improvement of activities of soil organisms by providing them with food and shelter.
x) It insulates soil against extreme heat and cold temperatures changes.

EXPERIMENT TO DETERMINE THE PERCENTAGE OF HUMUS (ORGANIC MATTER) IN THE SOIL

Apparatus:

Crucible, soil sample, weighing scale, heat source, wire, tripod stand, pipe clay triangle

Procedure:

a) Weigh a clean empty crucible and record its weight (W g).
b) Half fill the crucible with soil and record the exact weight of soil plus crucible on weighing scale (X g).
c) Dry the soil by heating it in an oven at 105^0C to constant weight (Y g) (the loss in weight of soil at this temperature is due to the water driven out by evaporation)
d) Reweigh the soil and crucible and record the weight.
e) Heat the dried soil on a crucible to redness in an oven.
f) Weigh the soil after cooling and record its weight.
g) Repeat this till a constant weight is achieved (Z g).

Results:

Weight of crucible = W g

Weight of crucible + fresh soil = X g

Constant weight of soil + crucible after heating at 105^0C =Y g

Constant weight of soil + crucible after heating after heating to redness = Z g

Weight of soil = X - W

Weight of dry soil = Y-W

Weight of dry soil after burning off humus = Z - P

Weight of humus = Y - Z g

$$\text{Percentage of humus} = \frac{\text{weight of humus}}{\text{Weight of soil}} \times 100\%$$

$$\text{Percentage of humus} = \frac{(Y-Z) \times 100}{X - W}\%$$

Exercise

The following experiment was done to find out the percentage of humus in a given soil sample. The soil sample weighing 120g was heated in an oven kept at 100^o C. The dry soil weighed 112g. The soil was then heated slowly to burn away humus. The weight of soil after all humus had burnt was 106g

a) Why was the soil not heated properly at first?
b) What was the weight of humus in the soil?
c) Calculate the percentage of humus in the soil.
d) How many times was water more than humus?

Solution:

a) It was not because it will burn the humus containing water

b) Weight of soil after burning humus = 106g

Weight of dry soil = 112g

Weight of humus = (112 – 106)
= 6 g

c) Percentage of humus = $\frac{6 \times 100}{20}$
= 5%

5. MINERAL SALTS

These are chemical elements inform of ions, dissolved in the film of water, surrounding the soil particle.
Some of the mineral elements in soil are; Sulphur, phosphorous, nitrogen, silicon, magnesium, iron and Aluminium ions which results from weathering of rocks.

6. SOIL LIVING ORGANISMS

a) Micro organisms

They include bacteria and fungi. They play an important part in maintaining soil fertility through decomposition of plant and animal remains nitrifying bacteria convert nitrogen into nitrates thus making it available to plants.

b) Macro organisms.

They include roots of higher plants, earth worms, nematodes e.g. ascaris, hookworms, filarial worm, and soil arthropods.
Earth worms are common in moist soils rich in humus. They dislike dry or acidic soils. They tunnel into the soil by force, thus improving the soil aeration and drainage.

Importance of living organisms

i) They improve fertility of the soil through fixing atmospheric nitrogen by nitrogen fixing bacteria and decomposing litter and other wastes into humus carried out by termites and bacteria.
ii) Some living organisms like earth worms burrow in the soil and this improve soil aeration and drainage.
iii) Some living organisms in soil cause diseases to man and his plants.
iv) Wastes from soil living organisms add fertility to the soil.

EXPERIMENT TO INVESTIGATE THE PRESENCE OF LIVING ORGANISMS IN SOIL

Apparatus

Two test tubes
Muslin bag
Top soil
Two corks
Lime water/ bicarbonate indicator solution

Procedure

i) Collect a hand full of fresh top soil and divide it into 2 equal portions.
ii) Sterilize one portion of the soil sample by heating it strongly on a crucible for 30 minutes. Leave it to cool and place it in a muslin bag.
iii) Place the remaining portion of the fresh soil sample in another muslin bag.
iv) Add equal amounts of lime water or bicarbonate indicator in the test tubes and then suspend the muslin bags with soil in the test tubes as shown in the set up below.

Allow the test tubes to stand for about 2 days and observe the appearance of lime water or bicarbonate solution.

Observation

Lime water turns milky or the bicarbonate indicator solution turns yellow in test tube A but remains clear in test tube B.

Conclusion

Carbon dioxide was produced in test tube A during respiration indicating the presence of living organisms.

Lime water remained clear in test tube B because the living organisms in soil in test tube B were killed by heating

ALTERNATIVE EXPERIMENT

The experiment is set up as shown below;

The setup is left to stand for about 2 days and any changes in the water level in the U-tube are observed.

Observation

Water level in the u-tube increases in the left arm and decreases in the right arm. This is due to oxygen in the air inside conical flask A being absorbed by the living organisms in the soil causing reduced pressure in conical flask A hence the raised pressure of the remaining gases in conical flask B causing water to raise in the left arm of the u-tube.

TYPES OF SOIL

Soil is grouped basing on size and nature of soil particles. On this basis, there are 3 main types of soil namely:

Clay soil

Loam soil

Sand soil

1. **Sandy soils;**
   - Sandy soils contain large space between the particles and these spaces allow water to drain off very quickly.

- They have a gritty feel when wet and felt between the thumb and figure.
- They contain only very small quantities of water and they may be deficient in calcium and magnesium
- They are described as light soils because they are relatively easy to work with.

2. Clay soil:

- They have small fine particles i.e. fine texture.
- The soil particles in clay are closely parked together leaving very small spaces between them. This causes clay soils to have poor water drainage and also become water logged.
- They are difficult to work with and therefore described as heavy soils.
- They have a sticky feel when wet.

3. Loam soil:

This is a mixture of sand (about40%), silt (about40%), clay (15%), organic matter (1-4%) it has stable crumb structure and is the best for crop production.

Differences between clay and sand soil

Clay soil	Sand soil
1. Very small air spaces between particles	Large air spaces between particles
2. Rich in dissolved salts	Poorly dissolved salts
3. Has high water retention capacity	Has only very low water retaining capacity
4. Poor drainage i.e. low permeability	Very easy drainage i.e. high permeability
5. Water can rise to high level by capillarity	Water cannot rise to high level by capillarity
6. More than 30% clay and less than 40% sand	More than 70% sand and less than 20% clay

PHYSICAL PROPERTIES OF SOIL

1. Porosity:

Sandy soil possess large spaces between the soil particles and so more porous.

Clay soils possess very small spaces between the soil particles thus less porous.

Loam soil is moderately porous.

2. Air content:

Sand contains a lot of air so it is well aerated. This is because it has large spaces existing between the particles.
Clay soil contains little air so it is poorly aerated due to presence of small spaces between the particles.
Loam soil has varying amounts of air.

3. Drainage of water:
Sand has good water drainage so it allows water to pass through it very quickly.
Clay soil has poor drainage of water and this makes clay water logged. This can be improved by adding humus to it.
Loam drains water moderately.

4. Water retention capacity:
This refers to the amount of water soil can hold. Sand soil holds little water so it has a poor water retention capacity. It can be improved by adding humus to it. Humus sticks sand particles together.
Clay soil tends to become water logged i.e. it holds a lot of water so has a high water retention capacity.
Loam soil holds water moderately but not becoming water logged.

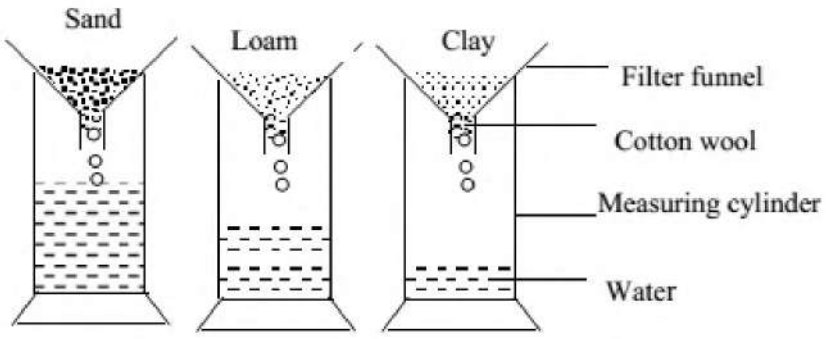
EXPERIMENT TO COMPARE THE DRAINAGE AND RETENTION OF WATER IN SAND AND CLAY SOILS

Apparatus
2 filter funnels,
2 measuring cylinders,
2 filter papers
Equal volumes of samples of dry sand and dry clay soils,
Water and
Beakers

Procedure
a) Measure an equal volume of each soil sample.
b) Fold filter papers properly and put one in each funnel.
c) Then place clay soil in the filter paper in one funnel and the sand in the other funnel.

d) Place the funnels with their contents over measuring cylinders and at the same time pour an equal volume of water on each of the soil samples as shown in the diagrams.

Setup:



Observe which soil allows water to drain through quickly.
Allow the set up to stand for some time till water stops draining through the soils.

Observation
Water passes through sand soil faster than clay soil. So much water is collected in the cylinder with sand soil and less water is collected in the cylinder containing clay soil.

Conclusion
Clay soil holds more water than sand soil and sand soils drains water faster than clay.

Explanation
Sand soil has larger air spaces which enable water to drain through more rapidly and on the other hand clay soil retains more water than sand because it has many small particles which can hold more water.

5. Water capillarity through different soils:
Capillarity through soil means how well water can rise up in the soil and this depends on the size of air spaces between the soil particles.

Sand soil has the lowest capillarity of water while clay soil has the highest water capillarity and loam soil has medium water capillarity.

EXPERIMENT TO DEMONSTRATE AND COMPARE WATER CAPILLARITY THROUGH SAND, CLAY AND LOAM SOIL

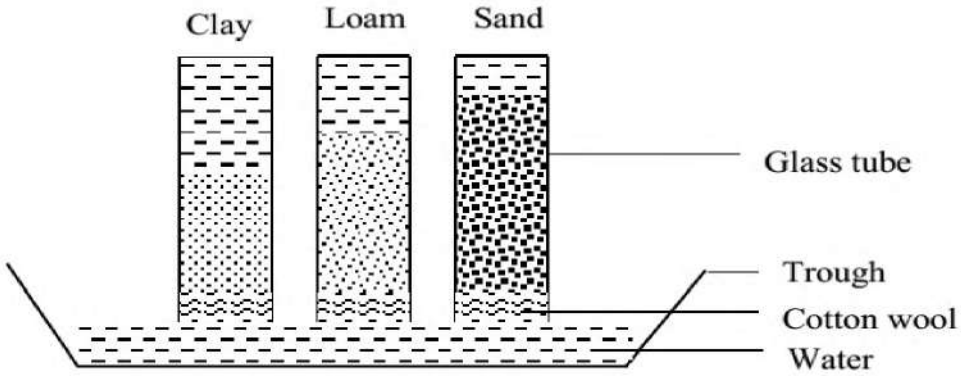
Materials

3 long glass tubes
Glass troughs
Muslin bags and threads
3 retort stands and clamps
3 samples of dry sand, clay and loam soils.

Procedure

a) Tie a muslin sheath tightly at the end of the glass tubes.
b) Fill one glass tube with dry sample of sand soil and pack it well ensuring that there are no spaces in the soil.
c) Repeat this with clay and loam soils.
d) The glass tubes are stood vertically with the ends tied with muslin sheath immersed in a glass trough containing enough water.
e) The glass tubes are supported upright with retort stands and clamps as shown in the diagram below.

Setup



Observation

Water rises faster for a short distance in sand soil while in clay soil water rises slowly but to higher distances. In loam soil, water rises moderately to a moderate distance.

Conclusion

Clay soil has the highest capillarity of water.

Sand soil has the lowest capillarity while loam has moderate water capillarity.

Explanation

Water rises to the greatest height at the nearest stages of the experiment in sand soil because sand has large spaces that enable water to rise more rapidly in the first hours.

Clay soil shows the highest rise of water hence the highest water capillarity because it is composed of tiny soil particles which present the large surface area over which water molecules cling.

Water rises at a slow rate in clay soil because clay has small air spaces between its particles.

CHEMICAL PROPERTIES OF SOIL

1. Soil colour

This determines the amount of heat that can be trapped in a soil sample. Dark soils retain heat more than light soils.

2. Soil pH

This is the degree of acidity or alkalinity of the soil. Most soils in the tropics are acidic but some are alkaline. Soil pH affects the rate at which mineral salts e.g. nitrogen, phosphorous, iron are absorbed by plant roots. Most plants grow best in slightly acidic or neutral soil.

EXPERIMENT TO DETERMINE THE SOIL PH

Materials

Soil
Petri dish
Universal indicator
Indicator chart

Procedure

a) Place about 3g of soil on a Petri dish and soak it with universal indicator. Leave for 2-3 minutes.
b) Tilt the Petri dish so that the indicator drains out of the soil.
c) Compare the indicator color with the indicator chart.

Alternatively:

a) Soak the soil sample with distilled water.

b) Drain off/ filter off and test with universal indicator solution or universal indicator papers.

SOIL EROSION

This is the removal or washing a way of top soil by animals, wind or running water. The extent of soil erosion is dependent upon the intensity with which the rain falls and not the amount of water.

Types of soil erosion

Sheet erosion

This is where thin uniform layers of soil are eroded over the whole slope.

Rill erosion

This is where water cuts shallow channels called rills. The channels deepen as volume of water run off increases.

Gulley erosion

This results from rill erosion when the channels deepen and form galleys. Here a lot of soil is carried a way over greater distances. It is facilitated by careless ploughing (up& down the slope). It may follow tracks made by vehicles and from animals.

Splash erosion or raindrop erosion

This occurs when intense raindrops displace soil.

Wind erosion

In dry conditions, herds of farm animals trample and compact the soil, causing a layer of dust on top. When wind comes, it can blow away the dust.

CAUSES OF SOIL EROSION

1) Slopes of land

The deeper the slope the greater the erosion and this is coupled with the intensity of rain.

2) Over grazing

This is caused by the keeping of many grazing animals on a small area. They finish the grass, i.e. remove the grass cover and open it to water erosion. They trample the soil and make it dusty, thus erosion can take place.

3) Deforestation

Foliage of trees reduces intensity at which raindrops reach the ground. Extensive falling of trees in an area removes this cover thus facilitating erosion on slopes.

4) Bush burning

Uncontrolled burning of bushes in dry seasons removes the grass top cover, thus leaving the soil bars for erosion.

5) Poor farming methods:

Ploughing: It lessens the soil and destroys its natural structure. Failure to replace humus after successive crops reduces water holding properties, so soil dries easily and can easily be blown away.

Ploughing up and down a slope accelerates water erosion.

Over cropping; over use of soil depletes fertility, thus causing loss of plant cover. This leaves the soil bare and so susceptible to erosion.

Methods of reducing (preventing) soil erosion

a) Contour ploughing

Ploughing a long contours i.e. across a slope and not up and down. It allows furrows to trap water rather than to channel it a way.

b) Strip cropping

This consists of alternate bands of cultivated and uncultivated soil, following contours. Un tilled soil is covered with grass.

By alternating the grass and crops each year, the soil is allowed to rebuild its structure while under grass.

c) Terracing

This is cultivation a long contours in horizontal strips supported by stones or walls, so breaking up the step down water rush of the surface run-off. The steeper the slope, the closer the terraces must be.

d) Correct crop for soil

Steep slopes which should not be ploughed are covered with pasture crops, their roots hold the soil

e) Afforestation

This is the Planting large areas of land with trees. They act as wind brakes, hold the soil together, and prevent raindrops from hitting the soil directly

They conserve water and control flooding.

f) Mulching

covering of top soil with plant material e.g. banana leaves, maize stems after harvest, cut grass etc. it protects the top soil and conserves the water in the soil.

Effects of soil erosion (to farmers)

- Nutrients and soil organisms are carried a way in the top soil.
- The soil left behind is unproductive.
- Fields may be cut into irregular pieces by rill and gulley erosion
- Floods carry a way or submerge and suffocate crops and soil organisms.

SOIL FERTILITY AND CONSERVATION

SOIL FERTILITY

Soil fertility refers to the amount of nutrients in the soil that can support the growth of plants. Soil can lose its fertility through the following ways.

1. **Soil erosion**.
2. **Leaching**; this is the washing down of soluble minerals from topsoil layers to bottom layers where they cannot be accessed by plants.
3. **Soil exhaustion**; this is the depletion/reduction in soil nutrients as a result of monoculture, over cropping, etc.
4. **Soil compaction**; this is the hardening of soil on the surface due to action of heavy machinery, movement of animals and man on soil, etc. Soil compaction prevents water from penetrating into the soil.

SOIL CONSERVATION

This is the protection and careful management of soil to maintain its fertility. It includes methods of controlling erosion and others such as:

Intercropping

Here, plants are alternately planted in a systematic or even random manner e.g. coffee, beans, and banana can be intercropped.

Fallowing

Land is left to rest and grow back to bush.

Crop rotation

The farmer carefully rotates his crops season after season, so that the plants make different demands on the soil.

Deep rooted crops like cassava are rotated with shallow rooted ones e.g. g. nuts

Application of manure (organic manure)

1) Green manure;

These are green plants, mostly legumes which can be dug back into the soil. However, any available green plants can do.

2) Farm yard manure;

This is from wastes of farm animals like urine and faeces when left become manure. This improves the process of nitrification (addition of nitrates to the soil) e.g. poultry dropping, goats, pigs, cows etc.

3) Compost manure;

This is made by collecting all available organic materials like chicken waste, weeds, fresh leaves into a pit with alternating layers of soil, and leaving them to rot. Water is added periodically to keep it moist for bacteria and fungi in the soil speed up the process. When well decayed, the compost is spread over the garden. Organic manure adds humus to the soil and maintains the crumb

Structure

4) Artificial fertilizers;

These are added directly. The most common element lacking in highly cultivated soils are nitrogen, phosphorus and potassium. They are supplied in form of $K2SO_4$, $(NH4)_2SO_4$ and calcium phosphate which lead to high yield.

THE NITROGEN CYCLE

Nitrogen is one of the elements that make up proteins. Nitrogen makes up to 80% of air but it is un reactive so cannot be used by plants and animals in its elemental form. It becomes part of the bodies of organisms in a process called the nitrogen cycle. The changing of nitrogen into more reactive forms is called nitrogen fixation.

Nitrogen fixation takes place during lightening, in the manufacture of artificial fertilizers and in the metabolism of the nitrifying and nitrogen fixing bacteria.

Plants absorb nitrogen as ammonium salts or nitrates.

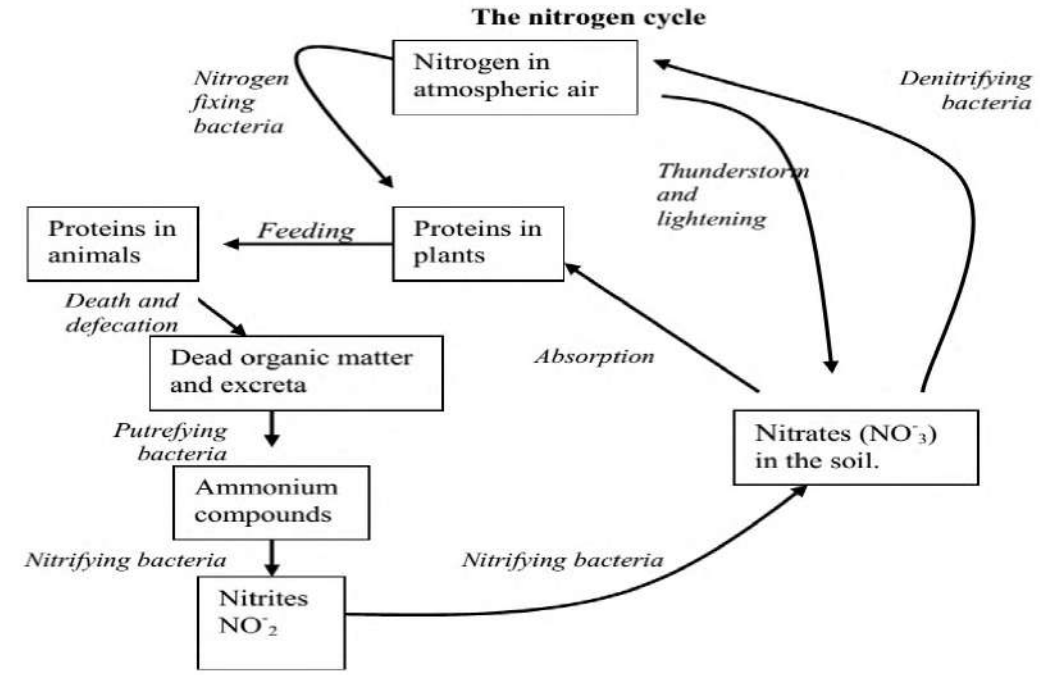
Animals obtain nitrogen they need by eating plants or other animals that have eater plants

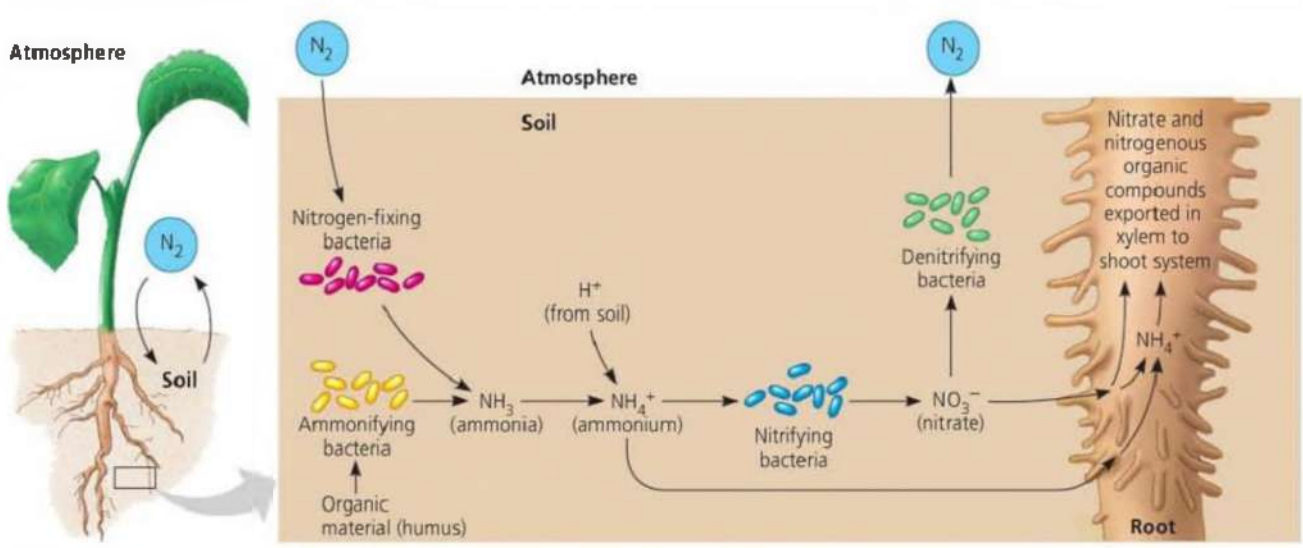
At death or by leaf fall, egestion, excretion (urine), the nitrogen of plants and animals is returned to the soil

Nitrogen is in constant circulation between autotrophs, heterotrophs, and the soil in atmosphere

Plants absorb nitrogen inform of nitrates and ammonium salts, for manufacture /build up of proteins they require.

At death or by leaf fall, egestion, excretion (urine), the nitrogen of plants and animals is returned to the soil.





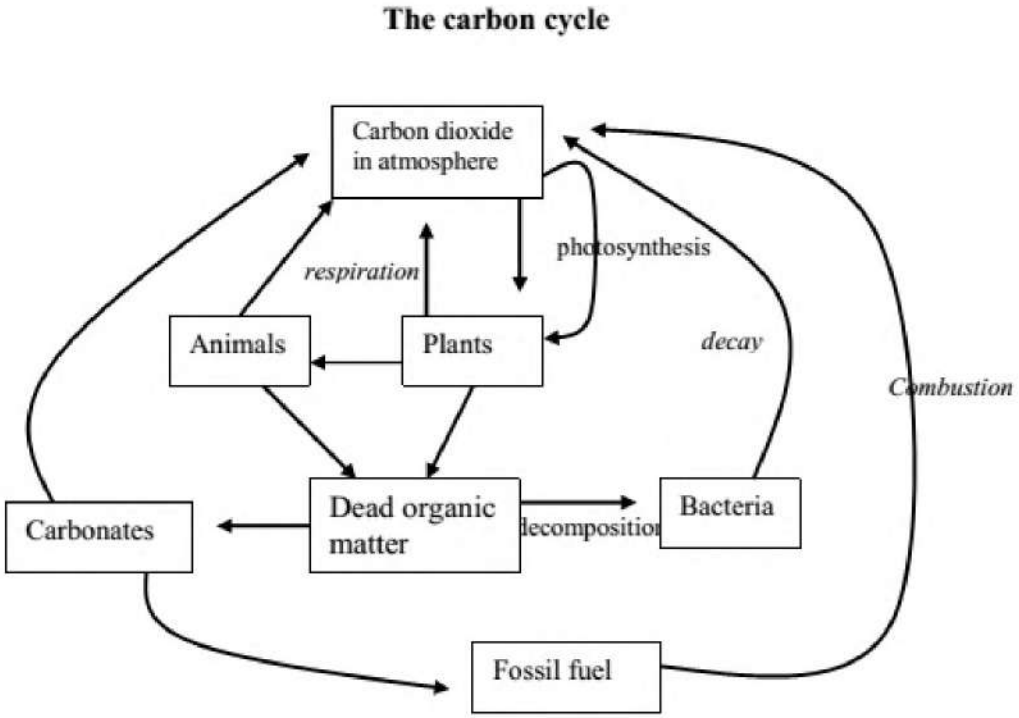
▲ Figure 37.9 The roles of soil bacteria in the nitrogen nutrition of plants. Ammonium is made available to plants by two types of soil bacteria: those that fix atmospheric N_2 (nitrogen-fixing bacteria) and those that decompose organic material (ammonifying bacteria). Although plants absorb some ammonium from the soil, they absorb mainly nitrate, which is produced from ammonium by nitrifying bacteria. Plants reduce nitrate back to ammonium before incorporating the nitrogen into organic compounds.

THE CARBON CYCLE

Carbon is an element which occur in all elements that make up a living organism. Carbon is therefore a major component of all organic matter. Plants get carbon from the atmosphere in the air during the process of photosynthesis. Plants use carbon to make food like starch. Starch is eaten by animals to get energy.

When animals die, they decay and release the carbon and other nutrients in the soil. The circulation of carbon in nature from the atmosphere into the living organisms and back into the atmosphere forms the carbon cycle.

The cycle



Removal of CO_2 from the atmosphere:

Green plants remove CO_2 into the atmosphere during the process of photosynthesis.

Some of the CO_2 in the atmosphere dissolves in rain water to form carbonic acid. This acid reacts with soil mineral salts to form carbonates.

Addition of CO_2 in the atmosphere:

a) Combustion (burning)

When carbon containing fuels e.g. petroleum, coal, natural gas, fire wood are burnt, CO_2 is released into the atmosphere. Formation of such fuels over millions of years is referred to as fossilation.

b) Respiration in animals and plants.

c) Decomposition of organic matter by bacteria and fungi. During this process, CO_2 is released into the atmosphere.

NUTRITION

Nutrition refers to the process by which living organisms obtain, consume and use food substances to maintain their life processes (metabolic processes).
These food substances are called nutrients.
These nutrients in green plants include; water, mineral salts, carbon dioxide and in animals include; carbohydrates, proteins, lipids, etc.

Modes of nutrition

Nutrition is broadly classified into two groups namely;
14. Heterotrophic nutrition (nourishment on others).
15. Autotrophic nutrition (self-nourishment).

1. AUTOTROPHIC NUTRITION

This is a mode of nutrition where by an organism is able to synthesize its own food from inorganic nutrients using some external source of energy. Such organisms are called Autotrophs.
Since the nutrition of all other organisms depends either directly or indirectly on these Autotrophs, they are referred to as producers.
Autotrophic nutrition can be divided into two depending on the external source of energy used to drive there processes;

i. Photosynthesis:

This is the type of nutrition where organisms make food with the help of sunlight energy. Examples include; green plants, algae, photosynthetic bacteria.

ii. Chemosynthesis:

This is where organisms make their own food with the help of energy from specific chemical reactions (oxidation of various inorganic compounds). Examples include; chemosynthetic bacteria.

2. HETEROTROPHISM / HETEROTROPHIC NUTRITION

This is the mode of nutrition where by organisms obtain their food by feeding on already manufactured organic (food) compounds.
Heterotrophs are incapable of making their own food.
They include; all animals, fungi, insectivorous plants and most bacteria.

Heterotrophic nutrition is of 5 major types, which include:

1. **Parasitism**

This is an association between two living organisms of different species in which one organism (parasite) obtains food and shelter from the other organism (host) which instead suffers injury and harm. For examples;

- A tape worm in the gut of man
- A cow and a tick.
- A bedbug and a man.

2. Phagocytosis:

This is the process of nutrition where simple cells or unicellular organisms engulf solid food particles. For examples;

- Amoeba.
- White blood cells.

3. Saprophytic/saprotrophic nutrition:

Saprotrophic nutrition is a mode of heterotrophic nutrition where an organism feeds on dead decaying matter where by they absorb solutions from this dead decaying matter.

Saprotrophs lack chlorophyll and thus cannot make their own food. Examples include; Mushrooms, mucor, common bread mould.

4. Symbiosis / Mutualism;

This is a nutritional relationship between two organisms of different species where both organisms benefit. However, only one organism benefits nutritionally.

Examples include;

- Fungi and algae (lichen).
- Root nodules
- Leguminous plants and rhizobium bacteria.
- Protozoa and ruminants.
- Egret white bird and a cow.
- Bacteria and man in the small intestine.

5. Holozoic nutrition;

This is the mode of nutrition where by food nutrients are taken into the body and broken down into smaller soluble molecules which can be absorbed and assimilated (utilized) by the body.

This mode of nutrition is normally found in mainly free living organisms which have a specialized digestive tract.

Holozoic nutrition is characterized by the following:

i) Ingestion:

This is the taking in complex organic food into the body.

ii) Digestion:

This is the breakdown of complex organic food into smaller diffusible molecules.

iii) Absorption:

This is the taking up of soluble molecules from the digestive region across a membrane into the body tissues.

iv) Assimilation:

This refers to utilization of absorbed food molecules by the body to provide either energy or building up of body tissues.

v) Egestion:

This is the elimination of undigested food materials from the body.

Animals which undergo holozoic nutrition can be classified into three groups;

- ❖ Carnivores
- ❖ Omnivores
- ❖ Herbivores.

Herbivores; These live entirely on plant vegetation.

Carnivores; These feed on flesh e.g. lion, cat, dog.

Omnivores; These feed on both plants and animals e.g. man and a pig.

FOOD

Food is any substance which can be digested and absorbed by the body to maintain the body's life processes (Metabolic process).

Food is required by organisms for:

i. Growth so as to build new cells.
ii. Respiration to produce energy
iii. Repair of worn out cells or tissues
iv. Protection of the body against diseases e.g. vitamins, proteins.

CLASSES OF FOOD

There are three classes of food, namely:-

a) Energy giving foods (fats and oils).
b) Body building foods (growth foods) e.g. proteins.
c) Protective foods, these protect the body against infections and diseases e.g. vitamins and minerals.

TYPES OF FOOD/NUTRIENT COMPOUNDS

There are six different nutrient compounds namely:-

1. Carbohydrates
2. Proteins
3. Vitamins
4. Mineral salts
5. Roughages and water
6. Fats and oils (lipids)

CARBOHYDRATES

These are made up of carbon, hydrogen and oxygen.

They are either sugars or starches.

Carbohydrates are grouped into 3 categories which include monosaccharides, disaccharides and polysaccharides depending on number of sugar molecules they are composed of.

i) Monosaccharides

Monosaccharides (mono=one, saccharide= sugar) are substances consisting of one molecule of sugar. They are also known as simple sugars.

Properties of monosaccharides

- They have a sweet taste
- They dissolve in water
- They form crystals
- Can pass through a selectively permeable membrane.
- They change the colour of benedict's solution from blue to orange when boiled with the solution thus they are known as ***reducing sugars.***

Monosaccharides include the following:

1. Glucose (present in grapes)
2. Fructose (present in many edible fruits)
3. Galactose (present in milk)

ii) Disaccharides

Disaccharides (di=two, saccharide= sugars) are carbohydrates molecules made up two simple sugars joined together. When the two monosaccharides combine, it results in the loss of one molecule of water and this reaction is called a condensation reaction.

Glucose + Glucose = maltose + water

Glucose + Galactose = lactose + water

Glucose + Fructose = sucrose + water

The disaccharides have the following properties:

i) They are sweeter than monosaccharides
ii) They can be crystallized
iii) They are soluble in water
iv) Do not change the colour of Benedict's solution when heated with it (apart from maltose)- they are known as non-reducing sugars
v) Can be broken down into simple sugars by dilute mineral acids and enzymes

Examples of disaccharides include:

1) Sucrose (present in sugar cane)

2) Maltose (present in germinating seeds)
3) Lactose (present in milk)

iii) Polysaccharides

Polysaccharides (poly = many, saccharide = sugar) are complex carbohydrates made up of many units of simple sugars.

Properties of polysaccharides include:

- ✓ Are not sweet
- ✓ Do not dissolve in water
- ✓ Cannot be crystallized
- ✓ Do not change the colour of Benedict's solution

Examples include:

1) Starch
2) Glycogen
3) Cellulose.

Functions of carbohydrates

i) They provide energy in the body when oxidized during respiration.
ii) They are the cheap sources of energy for living things
iii) They act as food reserves which are stored within organisms e.g. many plants store food as starch and animals as glycogen.
iv) They are important components of body structures e.g. cellulose is a component cell walls, chitin forms exoskeleton of arthropods, and heparin is anticoagulant in mammalian blood.
v) They are important for commercial values as they provide raw materials for manufacture of various products such as cellulose provides raw materials for manufacture of paper and textiles.

Deficiency of carbohydrates results in a deficiency disease called marasmus.

Symptoms of marasmus

i) High appetite.
ii) Dehydration of the body
iii) Growth retardation
iv) Wastage of muscles
v) Misery and shrunken appearance

FOOD TESTS ON CARBOHYDRATES

1. Test for reducing sugars

The reagent used is Benedict's solution (blue) or Fehling's solution (blue). Boiling is required.

Procedure	Observation	Conclusion
To 1 cm^3 of food solution,	Colourless or turbid	Little or

add 1 cm^3 of Benedict's solution and boil.	solution turned to a blue solution, then to a green solution, to a yellow precipitate, to orange precipitate and to a brown precipitate on boiling.	Moderate or Much or Too much; reducing sugars present.
	Colourless or turbid solution turned to a blue solution which persists on boiling.	Reducing sugars absent.

If Fehling's solution is used, the change is from blue solution to orange precipitate if reducing sugars are present. It remains a blue solution if they are absent.

Examples of reducing sugars include:

1) Glucose (present in grapes)
2) Fructose (present in many edible fruits)
3) Galactose (present in milk)
4) Maltose (present in germinating seeds)

The conclusions based on colour changes are according to the following observations:

Blue ***solution***- no sugars

Green ***solution***- little sugars present

Yellow ***precipitate***- moderate sugars present

2. Test for non-reducing sugars

procedure	**Observation**	**conclusion**
To 1 cm^3 of food solution add 1 cm^3 of dilute hydrochloric acid and	Colourless or turbid solution turned to a blue solution, then to a green	Little or Moderate or Much or

boil, cool under water then add 1 cm^3 of sodium hydroxide solution, followed by 1 cm^3 of Benedict's solution and boil.	solution, to a yellow precipitate and to a brown precipitate on boiling.	Too much; non-reducing sugars present.
	Colourless or turbid solution turned to a blue solution which persists on boiling.	Non-reducing sugars absent.

Note:

i) When boiled with dilute HCl, the non- reducing sugars breaks down into the reducing sugars.

ii) Sodium hydroxide solution or sodium hydrogen carbonate powder is added to neutralize the acid so that Benedict's solution can work.

Examples of non-reducing sugars include:

i. Sucrose (present in sugar cane)

ii. Lactose (present in milk)

3. Test for starch:

The reagent used is iodine which is a brown or yellow solution).

Procedure	**Observation**	**Conclusion**
To 1 cm^3 of food solution, add 3 drops of iodine solution.	Colourless or turbid solution turned to a black or blue-black or blue solution or brown solution with black specks.	Much or moderate or little starch present.
	Colourless or turbid solution turned to a yellow or brown solution.	Starch absent.

PROTEINS

These are food nutrients containing carbon, hydrogen, oxygen and nitrogen and sometimes sulphur or phosphorus. The smallest and building unit of proteins are called Amino acids. The amino acid molecule can condense to form dipeptide; further condensation gives rise to polypeptide molecule (protein).

The **amino acids** can be differentiated into essential and non-essential amino acids. There are a total of twenty (20) amino acids present thus allowing the formation of a variety of proteins.

Types of amino acids:

i) Essential amino acids

These are amino acids which cannot be synthesized in the body. This means they can only be got from the diet.

ii) Non-essential amino acids

These are amino acids that can be synthesized by the body so they are not essential in the diet.

Sources of proteins:

Food substances rich in proteins are eggs, lean meat, beans, Soya, milk and its products, fish and groundnuts.

Properties of proteins

i) Most dissolve in water to form colloidal or sticky suspensions.
ii) They are denatured by high temperatures-there structure is completely changed.
iii) They have both acidic and alkaline properties

The main functions of proteins

i) Body building which brings about growth i.e. from structures like in cell membrane, certain as in horns, fingernails, hooves etc.
ii) Repair and regenerate tissues that are damaged or worn out.
iii) Synthesis of body chemicals like enzymes, hormones, hemoglobin etc.
iv) Provision of energy in times of starvation.

Note: Protein deficiency results in poor health especially in children where it causes ***kwashiorkor.***

Symptoms of kwashiorkor

i) Loss of appetite
ii) Diarrhea
iii) The hair becomes soft and can easily be plucked out accompanied by loss of its colour.
iv) Growth retardation
v) Pot belly i.e. swollen lower abdomen
vi) Swollen legs and joints i.e. Oedema.
vii) Wasted muscles

TEST FOR PROTEINS

There are two food tests for proteins: the ***biuret*** test and ***Millon's*** test. Due to toxic nature of Millon's reagent, it not commonly used any more.

The biuret test is more commonly used.

The Biuret test:

Procedure	Observation	Conclusion
To 1 cm^3 of food solution, add 1 cm^3 of sodium hydroxide solution, then add 3 drops of Copper II sulphate solution and shake.	Turbid solution turned to a colourless solution then to a violet or purple solution.	Proteins present.
	Turbid or colourless solution turned to a blue solution.	Proteins absent.

Millon's test:

Procedure	Observation	Conclusion
To 1 $cm^3$of food solution, add 3 drops of Millon's reagent and boil.	A pink coagulated mass is formed.	Proteins present
	Turbid or colourless solution remained turbid or colourless.	Proteins absent.

LIPIDS (FATS AND OILS)

Lipids also contain carbon, hydrogen and oxygen but with higher proportions of hydrogen and less oxygen than carbohydrates. Because of this, they are able to yield more energy than carbohydrates or proteins weight for weight when oxidized.

Fats differ from oils in that they are solids at room temperature whereas oils are liquids at room temperature (25^0C).

Fats are mainly found in animal tissues while oils are obtained from plant tissues.

Examples of fats include; kimbo, cow boy, tamu, margarine, etc.

Examples of oils include; fortune buto, sun seed cooking oil, ufuta cooking oil, etc.

Lipids are made up **fatty acids and glycerol.**

Food sources:

Ground nuts

Eggs

Sun flower

Palm oil
Castor oil, etc.

Properties of lipids

i) Fats and oils are distinguished from other nutrients in that they make a permanent translucent mark or spot on papers. This property also provides a simple test for fats and oils.
ii) They also don't dissolve in water

Functions of lipids

i) Energy production during respiration
ii) Insulate the body to prevent excessive heat loss; this has been of major adaptations in some small animals and those animals living in cold regions where the sub- cutaneous fats are largely deposited under the dermis of the skin.
iii) Prevent water loss and entry in cells and tissues
iv) They are also constituents of waxy cuticle of animals and plants and the cell membrane.
v) In some areas of animals they act as shock absorbers
vi) They can be used as a source of water in desert animals such as camels- when stored fat is broken down in the body, much water is produced.

TESTS FOR LIPIDS

They are tested for using the emulsion test or the grease spot (translucent spot) test.

a) The emulsion test:

The reagents used are ethanol and water.

Procedure	**Observation**	**Deduction**
To 1 cm^3 of food solution, add 1 cm^3 of ethanol and shake. Then add 5 drops of water and shake.	A turbid solution turns to a cream emulsion	Lipids present.
	Turbid or colourless solution remains a turbid or colourless solution.	Lipids absent.

b) Translucent spot test:

Procedure	**Observation**	**Conclusion**
Add 2 drops of test solution on a piece of filter paper.	A translucent spot or patch is left on the paper.	Lipids present

Allow to dry and observe under light.	No translucent spot is formed on the paper.	Lipids absent.

VITAMINS

These are organic compounds required in small amounts in the diet for the normal functioning of the body. They are designated with alphabetical letters and are classified into two:

i) Water soluble vitamins
ii) Fat soluble vitamins

Water soluble vitamins are those which dissolve in water. They include vitamins B and C.

Fat soluble vitamins dissolve in fats but not in water. They include vitamins A, D, E, and K.

A table showing vitamins and their deficiency diseases

Vitamin	Common food source	Functions	Symptom of deficiency
A (Retinol)	Green vegetables, liver, butter, margarine, egg yolk and carrots	Growth in children, resistance to diseases of eye (night blindness) and respiratory tract. good night(Dim light) vision	Night blindness(poor dark adaptation), frequent cold, sore eyes and wealthy skin
B_1(Thiamine)	Yeast, beans, lean meat, egg yolk, bread and rice husks	Tissue respiration, keeps the heart, nerves and digestive organs healthy	Tiredness(fatigue), retarded growth in children and poor appetite, constipation**(beriberi)**
B_2(Riboflavin)	Yeast, milk ,liver, cheese, leafy vegetables.	Tissue respiration, growth and health of skin. Keeps mucus membrane healthy	Retarded growth especially in children, cracks on lips, poor vision and skin disorders
B_3 (Nicotinic	Cereal grains,	Same as B_2	Disorders of central

acid /Niacin)	milk and its products, liver and yeast		nervous system(CNS) like memory loss & depression(pellagra)
B_{12}(cobamine)	Beef, kidney, liver, yeast	Forms red blood cells	Low blood count(Anemia)
C (Ascorbic acid)	Fresh fruits and row vegetables	Development of teeth and bones, normal growth and sticks together the cells lining parts of the body	Scurvy- Sore gums, poor healing of sores in the gum
D(calciferol)	liver, fish, egg yolk, formed beneath skin of man in sunlight	Building strong and hard bones and teeth, promotes absorption of phosphorus and calcium in the gut	Weak bones and teeth, rickets in children and dental caries
E(tocopherol)	All foods	Anti-oxidant to prevent excess energy production. Promotes fertility in animals e.g. rats	Sterility(infertility) in some animals like rats
K(phyllaquinone)	Cabbage, spinach	Normal clotting of blood	Prolonged bleeding.

TEST FOR VITAMIN C:

The reagent used is DCPIP (Dichloro Phenol Indole Phenol). It is a deep blue solution. The sources of vitamin C are fresh fruits e.g. oranges, mangoes, lemon, etc.

Procedure	**Observation**	**Conclusion**
To 1 cm^3 of DCPIP solution in the test tube, add the food solution drop wise.	The blue DCPIP solution is decolourised or turned to a colourless solution.	Vitamin C present
	The blue DCPIP solution remained blue.	Vitamin C absent

MINERAL ELEMENTS AND SALTS

These are inorganic food constituents required in small amounts but whose deficiency affects the normal functioning of the body leading to deficiency diseases.

Mineral salts can be divided into;

(i) Essential mineral elements (macro elements)

These are mineral elements required in relatively large amounts. They are sodium, potassium, phosphorous, calcium iron.

(ii) Non-essential or Trace mineral elements (micro- elements)

These are mineral elements required in relatively very small amounts. However, their presence in the diet is of at most importance. They are Zinc, Molybdenum, cobalt Manganese.

A table showing some elements and their deficiency diseases

MINERAL ELEMENTS	SOURCE	IMPORTANCE	DEFFICIENCY
Fe Iron	- Beef, liver, kidney, G.nuts, beans, eggs, green vegetables.	- It is a constituent of Haemoglobin.	**Anaemia** - Reduced red blood cell account. - Reduction in oxygen transportation rate.
Ca Calcium	Vegetables, fish, milk, bread, eggs.	- In blood clotting - hardening of bones and teeth.	**Rickets in children** - Delay in blood clotting - Soft bone, poor skeletal growth.
P Phosphorus	- Most foods	- Constituent of cell membrane. - Formation of teeth & bones.	- It is not likely for one to be deficient of phosphorus since it is found in most foods.
I Iodine	- Iodised salts - Marine fish	- It is a constituent of a haemone **Thyroxin**	**Goitre** - Swelling of the Thyroid gland. - Muscle cramp (sharp pains in muscles).
	Drinking water	It is constituent of	Weak teeth in children.

F Fluorine	(National water and sewage co-operation	bones and teeth.	
K Potassium	Fish, beef, liver, mushroom and some tubers	Transmission of nerve impulse along neurons	Muscular cramp
Na sodium	Common salt(NaCl) and cheese	Transmission of nerve impulse along neurons	

WATER AND ROUGHAGES/DIETARY FIBRES

WATER

This compound is made of two elements namely Oxygen and Hydrogen. In living things, water forms about 60% of weight

Importance of water

- ✓ It's a universal solvent in which absorbed foods, wastes and hormones are transported around the body in blood.
- ✓ The plasma of blood is made up of water.
- ✓ It participates in many metabolic reactions or processes as a raw materials e.g respiration, photosynthesis, gaseous exchange, digestion, and removal of wastes.
- ✓ Plays a role in temperature regulation ie cooling the body on hot days and plants through transpiration.
- ✓ Offers turgidity thus acts as a hydrostatic skeleton- hence supporting organisms.
- ✓ It softens food.
- ✓ It is used in seed dispersal.
- ✓ It is a habitat (home).
- ✓ It acts as a Lubricant e.g. salvia lubricant the mouth, tears lubricate eyes, synovial fluids lubricate the joints.

ROUGHAGES / DIETARY FIBRE

They are indigestible materials in food and consist mostly of cellulose, pectin, and lignin.

The major sources of roughages include: vegetables, such as cabbages, dodo, fruits, etc.

Functions of roughages

- ✓ They stimulate muscular movements called peristalsis which move food (propel) through the alimentary canal.
- ✓ Some delay food in the intestines whereas others enable food pass through the intestines very fast.
- ✓ The deficiency or lack of roughages causes constipation.

Balanced Diet:

A balanced diet is a meal containing all food nutrients in their right proportions.
If a person depends on a poor diet (unbalanced diet) i.e. containing inappropriate quantities of nutrients, then the person suffers from Mal nutrition.

Mal-Nutrition:

This simply refers to an unhealthy state of the body resulting from a long term deficiency or excess of one or more of the essential nutrients.
Malnutrition is normally detected by the onset of some deficiency diseases like kwashiorkor, marasmus, obesity, etc.

ENZYMES

Enzymes are organic compounds protein in nature that speed up the rate of biochemical reactions in the body of an organism and remains unchanged at the end of the reaction.

Importance of enzymes

The rate at which some reactions occur in the body without enzymes is too slow to sustain life. Enzymes therefore ***speed up the rate of the reaction without changing the product formed and the nature of reaction*** i.e. an enzyme cannot make a reaction that would not occur to take place and it cannot make an endothermic reaction exothermic but only ensures that products are formed in the shortest time possible.
They also control metabolic processes hence promoting normal body functions.

Classification of enzymes

Enzymes are classified depending on the type of reaction they catalyze. The following are some of the classes of enzymes.

1) **Isomerase;** these catalyze reactions involving isomerism
2) **Phosphorylases**; these catalyze reactions involving addition of a phosphate
3) **Hydrogenases;** these catalyze reactions involving addition of hydrogen.
4) **Dehydrogenase;** these catalyze reactions involving removal of hydrogen.
5) **Kinases;** these catalyze reactions involving movement of molecules from one area to another.

6) **Carboxylases;** these catalyze reactions involving addition of Carbon dioxide.

Enzyme can also be described as being intracellular or extracellular. Intracellular enzymes are those which catalyze reactions inside the cells producing them, e.g. all respiratory enzyme are intracellular. Extracellular enzymes are those produced by a cell to catalyze reactions outside that cell. All digestive enzymes in man are extracellular.

Nomenclature of enzymes

Enzymes are named by adding a suffix "ase" to their substrates. A substrate is a substance, which the enzyme acts upon, or simply it is the raw material for the enzyme.

Examples of enzymes and their substrates

Enzyme	Substrate
Peptidase	Peptides
Lipase	Lipids
Maltase	Maltose
Sucrase	Sucrose
Lactase	Lactose
Cellulase	Cellulose

Some enzymes however retained their names they had before this convention. Such enzymes include pepsin and trypsin.
Sometimes the enzymes digesting carbohydrates are generally called carbohydrases and those digesting proteins as proteases.

PROPERTIES OF ENZYMES

1) They are all protein in nature.
2) They are specific in their action i.e. they catalyze specific food i.e. Maltase on Maltose.
3) They speed up the rate of chemical reactions (they are catalysts).
4) They are effective even in small amounts.
5) They remain unchanged at the end of the reaction.
6) They are denatured by high temperatures since they are protein in nature and are inactivated by low temperatures.
7) They are inactivated by inhibitor chemicals (poisons e.g. cyanide).
8) They work at a specific PH. (either acidic or alkaline).
9) Their reactions are reversible.

10) Their activity can be enhanced by enzyme activators e.g. chloride ions activate amylase.

FACTORS AFFECTING ENZYME ACTIVITIES

To investigate the effects of a given factor on the rate of enzyme controlled reactions, all other factors should be kept constant and at optimum levels so as to obtain accurate results.

The factors are:

i) Temperature
ii) Concentration of the substrate
iii) PH of the medium
iv) Presence of activators
v) Presence of inhibitors
vi) Concentration of the enzyme

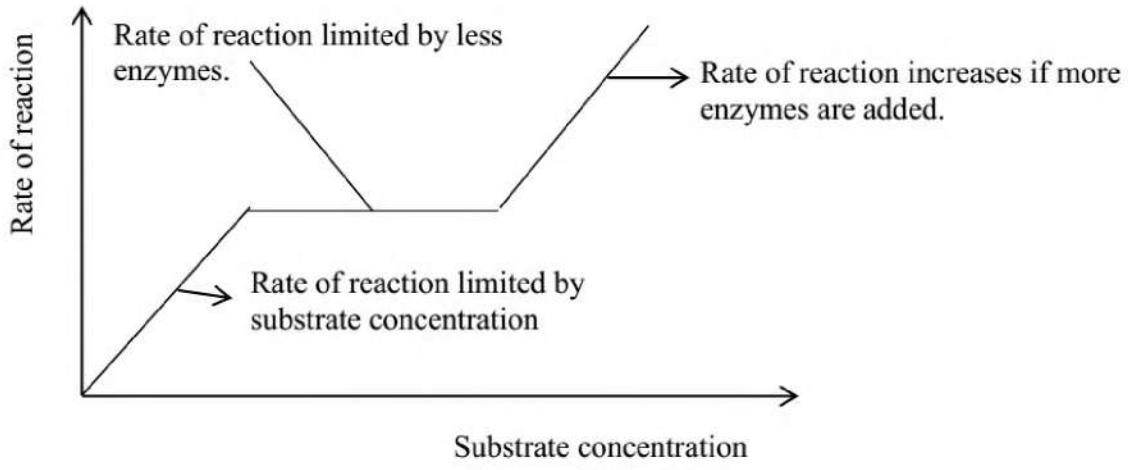
1. Concentration of substrate:

A substrate is a substance (food) acted upon by the enzyme to form simpler products.

The rate of enzyme reaction increases with increase in substrate concentration and enzymes work slower when the substrate concentrations low.

However, further increase in substrate concentration will not increase enzyme reaction rate since all its active sites are fully saturated with food.

A graph showing how the rate of reaction varies with substrate concentration

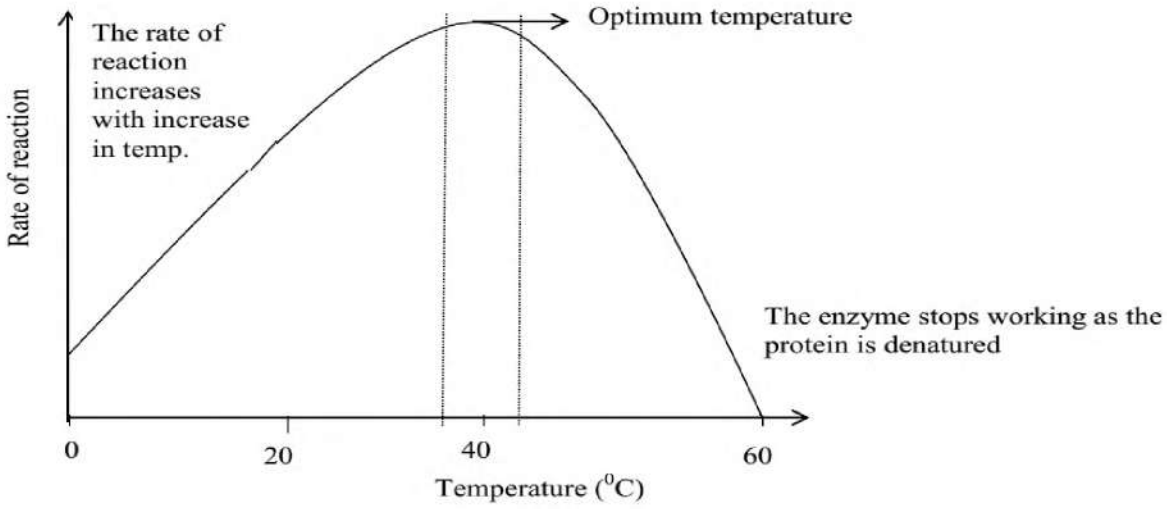


2. Temperature:

Enzymes work best at optional temperatures of (approximately 37^0 C). At very low temperatures, the rate of enzyme reaction is very slow because the enzyme is inactive at such low temperatures.

As the temperatures increase, the rate of reaction also increases gradually until it attains a peak where it has maximum activity and this always correspond at optimal temperatures. An optimal temperature is which promotes maximum enzyme activity. However with further increase in temperature, the rate of reaction decreases exponentially, sharply, steeply since at high temperatures, the enzyme is denatured ie the active site of the enzyme which is (protein in nature) is a altered (changed) or completely destroyed.

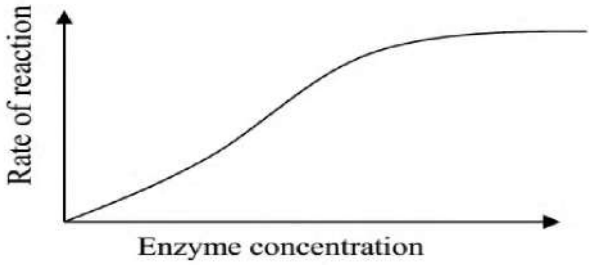
A graph showing the variation of enzyme activity with temperature



3. Enzyme concentration:

As the concentration of the enzymes increases, the rate of reaction also increases until all the substrates are being acted upon when the rate finally becomes constant.

A graph showing variation of enzyme activity with enzyme concentration

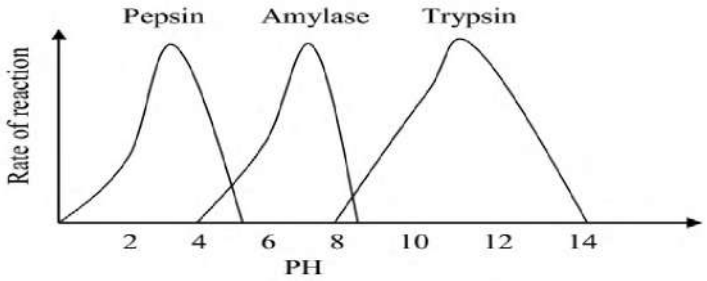


4. The PH of the medium.

Enzyme reactivity is reduced or stopped completely if placed in a medium whose PH is different from that in which it works best (optimum PH).

PH varies slightly above or below an enzyme's optimum PH resulting in a marked fall in the enzyme efficiency. E.g. pepsin enzyme in the human stomach has a maximum activity with in acidic pH of 1.5 and 2.5 while the enzymes in the duodenum e.g. trypsin work at maximum with in alkaline pH of 8.5 to 9.5.

A graph showing variation of different enzyme activity with PH



5. Presence of enzyme inhibitors

Enzyme activities decrease in presence of enzyme inhibitors and increase in their absence.

6. Presence of activators

Enzyme activators increase with presence of enzyme activators and decrease with absence of enzyme activators.

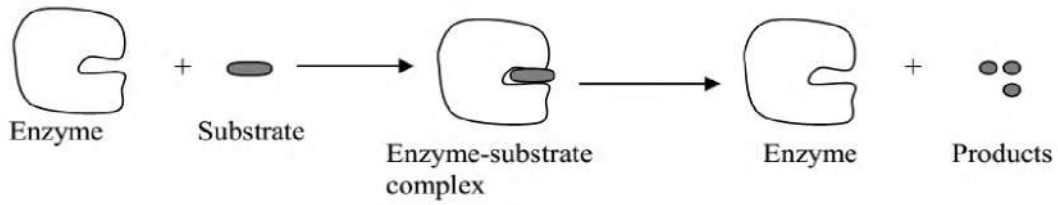
Mechanism of enzyme action

The widely accepted mechanism by which enzymes are known to work is the "**key and lock" hypothesis**.

The hypothesis suggests that the enzyme has a specific region known as the active site where the substrate fits like a key fits in a lock. The substrate must have a complementally shape to the active site of the enzyme. In this hypothesis the key is analogous to the substrate and the lock to the enz combines with the enzyme, an enzyme- substrate complex is formed. This breaks down to release the products and the enzyme, which can pick other substrates.

A graph showing variation of different enzyme activity with PH.

Illustration



MAMMALIAN TEETH

Mammals have different types and shapes of teeth and they are thus termed **Heterodonts.** Those which have teeth of the same size and shapes are termed as **Homodonts**.

Teeth are embedded in the upper and lower jaws. In mammals teeth consist of an exposed portion known as **a crown** and a portion that is firmly fixed or anchored in a jaw bone called a **root.**

Types of teeth in mammals

There are 4 types of teeth in mammals and these include;

1) Incisors

These are the front teeth in both the upper and lower jaws in man. The crowns are chisel shaped (sharp flat edge) and have only one rot. ***Incisors are used for cutting food***

Structure of an Incisor

2) Canines

These are found next to the incisors and they are normally long and pointed. They are poorly developed in herbivores and very prominent in carnivores where they are used for holding and piercing food. They have a conical shaped crown which is sharp and pointed. They have one root. ***They are used for tearing flesh.***

Structure of canine

3) Premolars

These lie behind the canines on both jaws.

These have flat broad surfaces which are used for grinding food.

Premolars possess two or more **cusps** and **ridges** and have two roots.

Premolars are used for grinding and chewing food.

Structure of premolar

4) Molars

They are absent in young mammals.

These have wider crowns with more ridges and cusps compared to premolars.

They may have three or more roots.

Molars are used for grinding and crashing food.

Structure of a molar

Note:

- Elephant tusks are **incisors.**
- Carnivores have a special type of teeth called the **carnassial** teeth which are adopted for cracking bones and scrapping (removing) of meat from bones.

Internal structure of mammalian tooth

Each tooth consists externally of a crown, Neck and root.

1) Crown

This is a region of the tooth which projects above the gum; it is used for breaking down food.

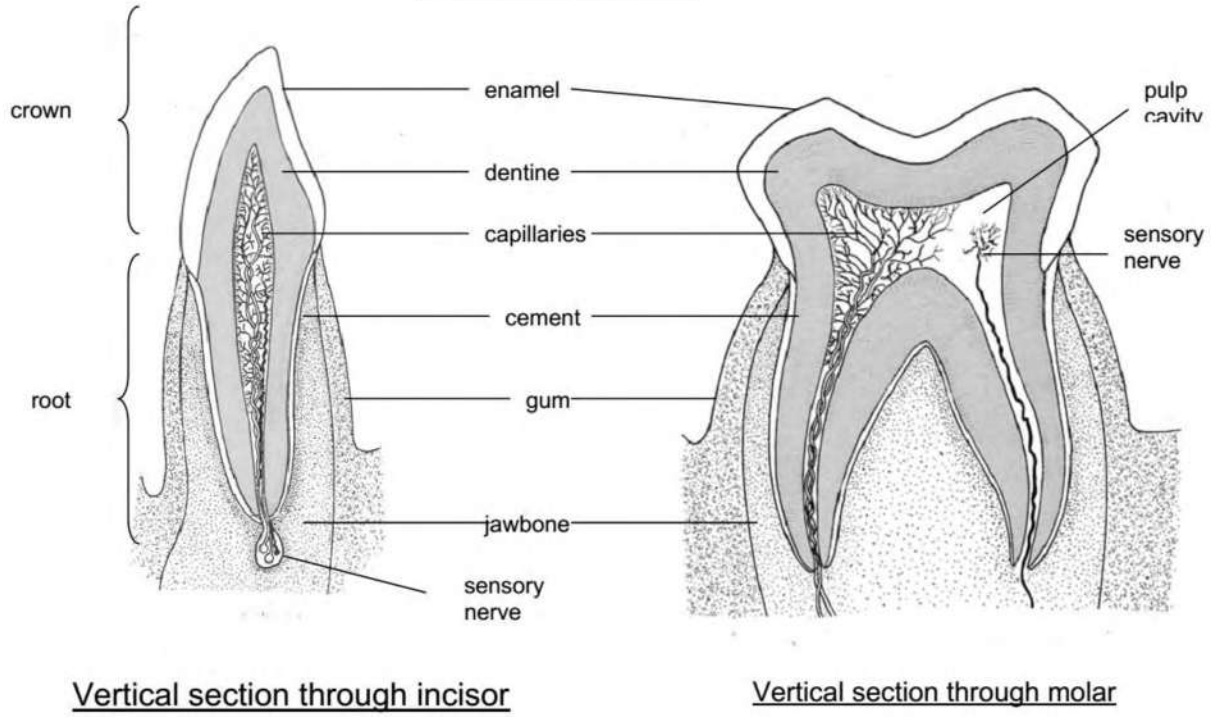
2) Neck

This is the junction between the crown and the root.

3) Root

This is the region which lies embedded in the jaw bone. It cannot be seen and it anchors / fixes firmly the root into the jaw bone.

Tooth structure



Vertical section through incisor

Vertical section through molar

Functions of the parts of the tooth

1) **Crown**; this break down food into small particles during chewing, grinding and cutting.
2) **Enamel**; this strengthens the tooth to enable it grind and cut. It protects the dentine and pulp cavity. It is the hardest material in the body. It is white in colour and made up of ***calcium phosphate salts.***
3) **Root**; this fixes the tooth into the jaw.
4) **Dentine**; this strengthens the tooth.
5) **Pulp cavity**; this contains nerves that provide sensitivity to the tooth and blood vessels that transport food and oxygen to the tooth.
6) **Gum**; this is fibrous which fixes or anchors the teeth firmly in the jaw. It is also called the gingiva.
7) **Cement**; this is a thin layer of bone-like material that fixes the tooth in the jawbone.

DENTITION

This refers to the number, arrangement and shape of teeth in an animal.

In mammals, two sets of teeth occur in one's life time i.e. the milk teeth and permanent teeth. The first set is called the ***milk teeth*** which arises when the animal is young and lasts for relatively a short time. Milk teeth in man are 20 in number and normally get replaced by ***permanent teeth*** at the age of usually 7 to 11 years.

DENTAL FORMULA

This is a formula indicating the number of each type of teeth in half the upper jaw and half the lower jaw. The dental formula gives evidence that the dentition of an animal is closely related to its diet. The number of teeth in the upper jaw is written above that of the lower jaw. The different types of teeth are represented by letters i.e.

Incisors (i)

Canines (c)

Molars (m)

Premolars (pm)

Dental formulae of some animals

Mammal	**Dental formulae**	**Total number of teeth**
Man	$\frac{I2}{2}\ \frac{C1}{1}\ \frac{PM2}{2}\ \frac{M3}{3}$	32
Dog	$I\ \frac{3}{3}; C\ \frac{1}{1}; p\,m\ \frac{4}{4}, M\ \frac{2}{3}$	42
Rat	$\frac{I1}{1}\ \frac{C0}{0}\ \frac{PM0}{0}\ \frac{M3}{3}$	16
Cow	$\frac{I0}{3}\ \frac{C0}{1}\ \frac{PM3}{3}\ \frac{M3}{3}$	32

E.g. the dental formula of an adult human is written as below:

$I\ \frac{2}{2}; C\ \frac{1}{1}; p\,m\ \frac{2}{2}, M\ \frac{3}{3} = 32$

This means that man has 2 incisors on each half on the top and lower jaws, one canine on each half of the top and lower jaws, 2 premolars on each half of the top and lower jaws. Therefore man has 8 teeth on each half on the jaws which adds up a total of 32 teeth.

Dental care in man

Although hard teeth are delicate and need proper care if their life is to be sustained. Common problems that may arise if teeth are not cared for include:-

i) Tooth decay or dental caries.

This is caused by lodging (when food gets stuck) of food particles especially sugars between the teeth. This food is then attacked by micro-organisms (bacteria) which ferment this food producing an acid which reacts chemically with the

enamel and removes calcium from it making it soft. During chewing, the soft part of the enamel begins wearing away forming a hole which gets larger and larger as more food gets stuck in the now bigger hole and fermentation process continues. Tooth ache commences into the dentine, the pulp cavity with nerves and blood vessels get affected and a lot of pain is felt.

ii) Periodental diseases.

These are diseases which make the gum soft and flabby so that they do not support the tooth well. Sometimes these diseases may lead to bleeding of the gum and passing out of pus. The 2 periodental diseases known are;

- Pyorrhea
- Gingivitis

They are characterized by reddening of the gums, bleeding and presences of pus in the gums.

Prevention of dental decay and proper care of teeth

- Visit a dentist regularly for checkup.
- Proper cleaning of teeth (brushing after meals)
- Avoid sweet sugary foods like sweets which encourage bacterial growth.
- Avoid opening bottles using teeth carrying desks.
- Avoid eating very hot and very cold foods especially at a go since they result into alternate expansion and contraction since it leads to cracking or chipping of the enamel.
- Eating foods rich in calcium, phosphates and vitamins A, D, and C
- Exercising your teeth by eating hard fibrous foods like sugar canes, carrots, etc. This stimulates the flow of saliva which neutralizes acids formed bacterial fermentation.

CARNIVORE DENTITION

Carnivorous animals such as dogs, cats and lions are adapted for feeding on other animals.

Their teeth are adapted for capturing and killing other animals and tearing their flesh.

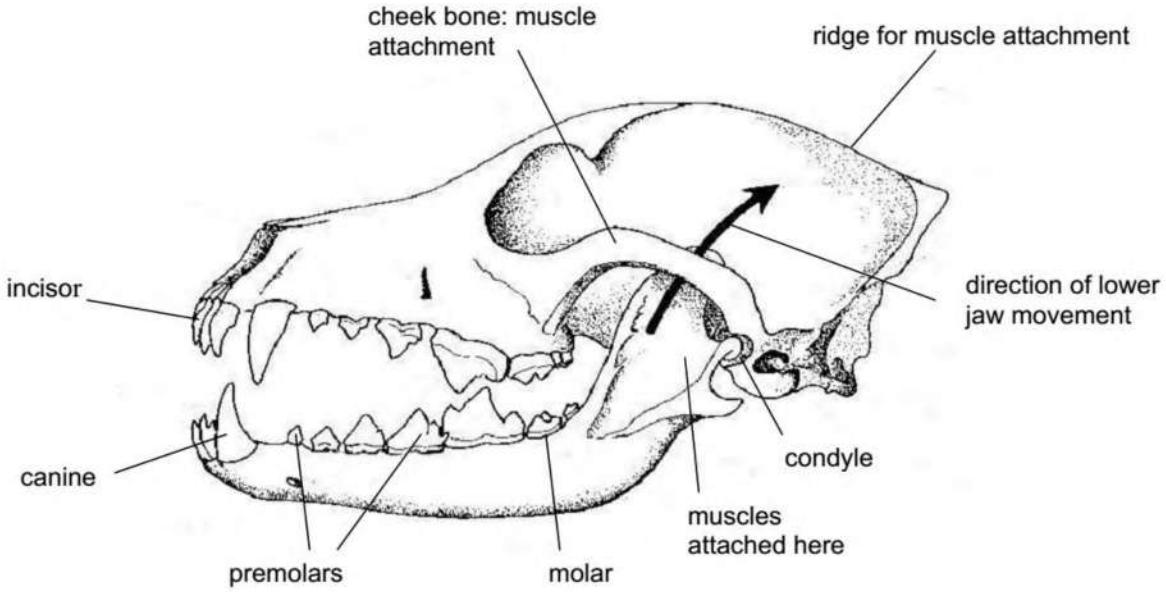
Their incisors are chisel shaped and enable them to grip and strip off pieces of flesh from bones.

Their canines are long, curved and pointed used for piercing the prey and preventing it from escaping.

The upper fourth premolar and the first lower molar are large and powerful. They are called ***carnassial teeth***. They overlap like blades of scissors and are used for tearing and slicing flesh.

The other premolars and molars have jagged edges that fit perfectly together making them ideal for cracking bones.

Diagram showing dentition in the carnivore e.g. a dog



HERBIVORE DENTITION

Herbivorous animals e.g. cows, goats and elephants eat plant foods such as grass, leaves and small stems.

Their teeth are adapted for crushing and grinding vegetables.

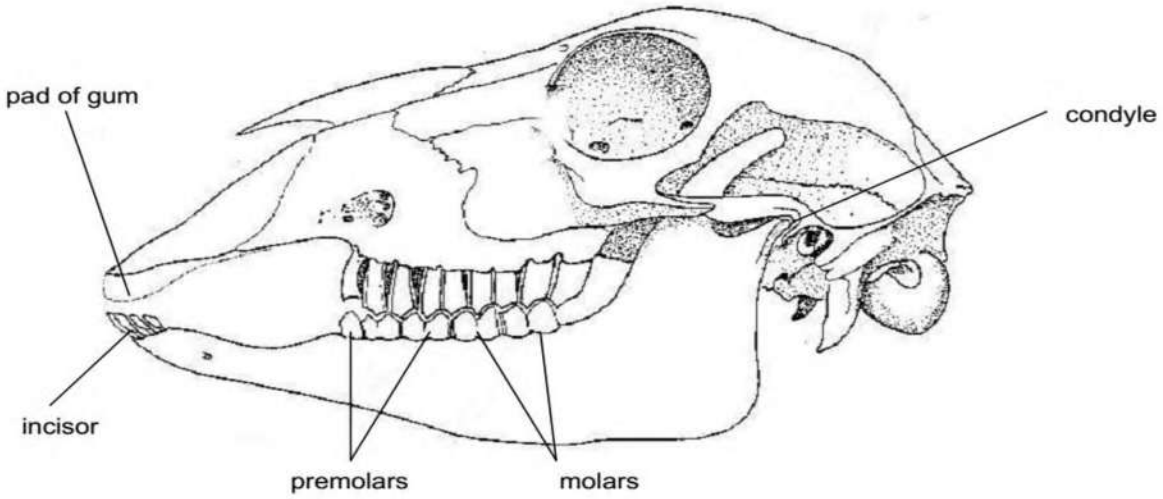
Their incisors and canines are chisel shaped and only found in the lower jaw.

In the upper jaw, the incisors and canines are replaced by a thick horny pad.

Grass and other vegetation are gripped between the incisors and canines on the lower jaw and the horny pad.

Between the front teeth and the cheek teeth is a large gap called ***diastema***. It provides space for the tongue to manipulate vegetation in such a way that the material being chewed is kept away from that which is freshly gathered.

Dentition of a sheep



DIGESTION IN MAN

Digestion is the process by which complex food substances are broken down into simpler soluble compounds that can be absorbed and assimilated (utilized) by the body.

Digestion can be divided into; physical or mechanical digestion and chemical digestion.

Physical digestion:

This is the breakdown of food due to the mechanical action of teeth, muscular contractions and bile juice.

Chemical digestion: This is the breakdown of food due to enzyme action or enzymatic action.

Extracellular digestion:

When digestion occurs or takes place outside the body or cells, it is called extracellular digestion. This may not necessarily be outside the body but it may occur inside the body but not inside cells. E.g. in fungi, man etc.

Intracellular digestion: This is a type of digestion which take place inside the body cells eg Amoeba, Paramecium.

Note: digestion in man is extracellular digestion because the enzymes are released in the gut cavity where digestion occurs.

Steps involved in digestion of food

Ingestion ⟶ Digestion ⟶ Egestion

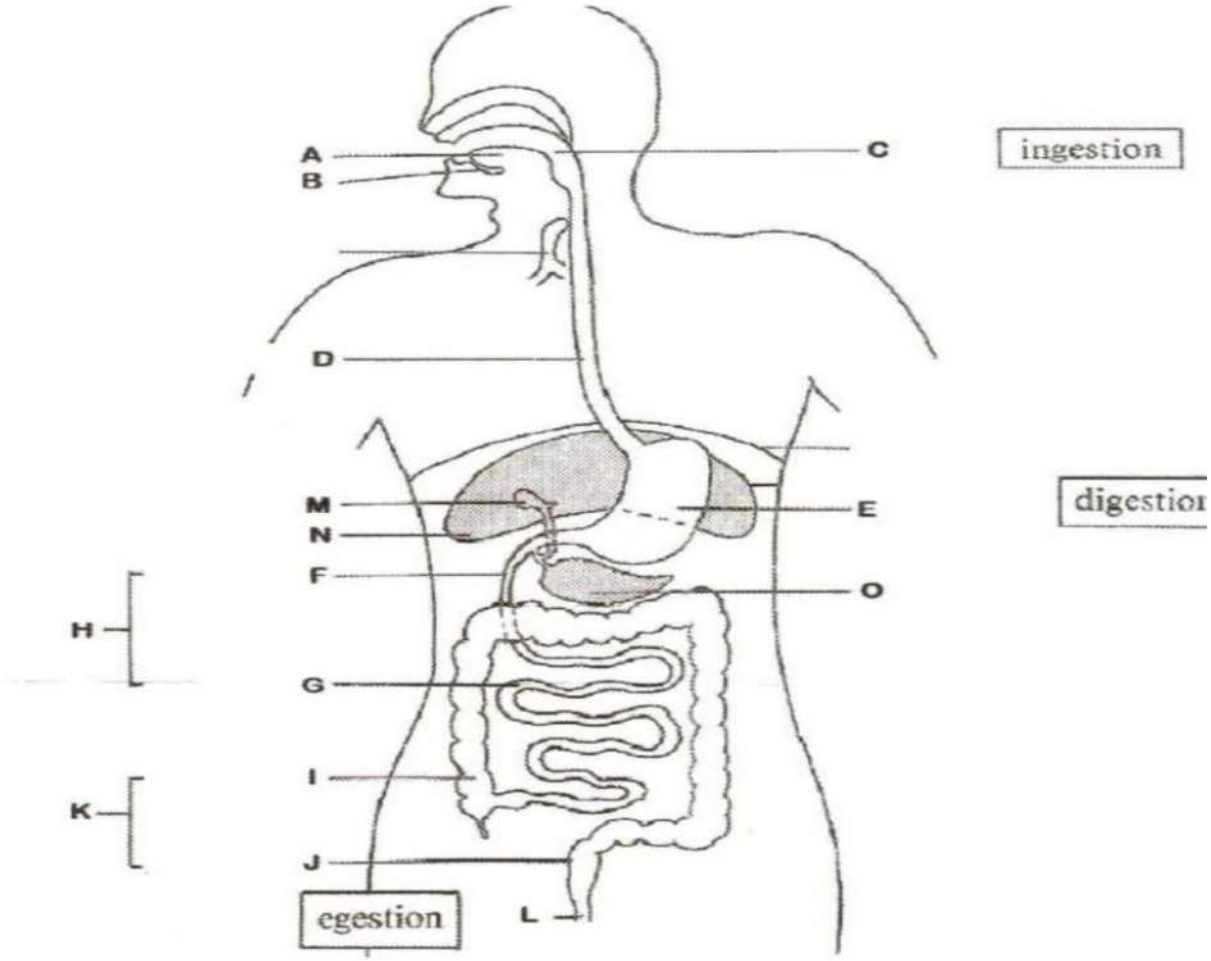
Ingestion

Is the taking in of food into the body

Egestion

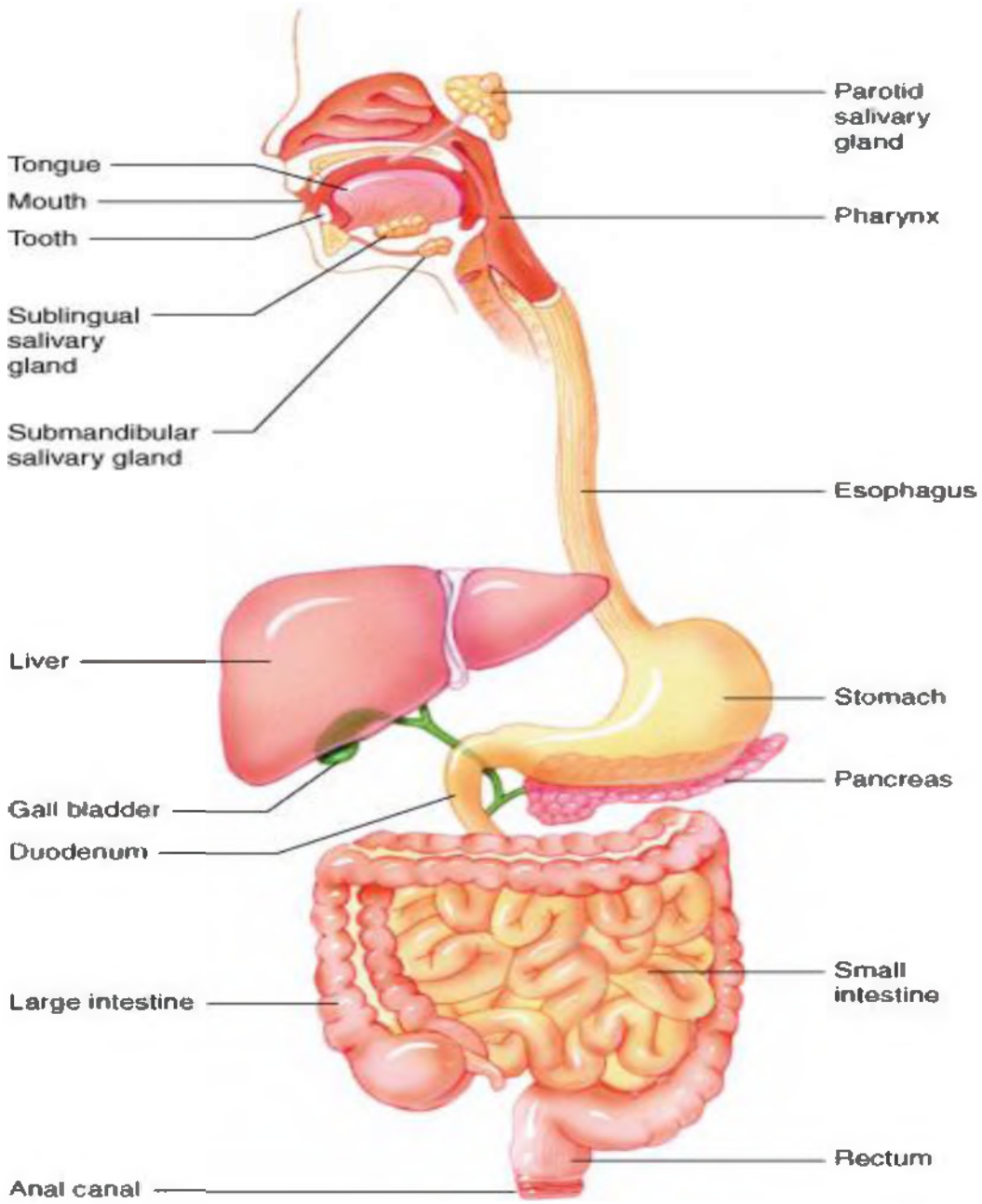
This is the process by which insoluble undigested compounds of food are discharged or expelled from the body as faeces.

The human alimentary canal



A) Tongue.
B) Salivary gland.
C) Buccal cavity
D) Oesophagus/gullet.
E) Stomach.
F) Duodenum.
G) Ileum.
H) Small intestine.
I) Colon;
- Ascending colon.
- Transverse colon.
- Descending colon.

J) Rectum.
K) Large intestine.
L) Anus.
M) Gall bladder.
N) Liver.
O) Pancreas.



Parts of the alimentary canal

iii. The mouth

The mouth has the teeth and salivary glands. The mouth opens to the large space called buccal cavity. The mouth is roofed by the plate of bone called hard plate which is continuous with the soft palate (pharynx).

Once food is in the buccal cavity, the teeth break down food particles into smaller particles providing a large surface area for the enzyme action. On the floor of the

cavity is the long muscular organ, the tongue which is covered by the taste buds. The tongue moves food around the mouth for chewing to occur and mixing with saliva secreted by salivary glands. Saliva contains enzymes and mucus which moistens, softens and lubricates food as well as sticking food particles together into boluses for easy swallowing. The enzyme in the saliva is called ***salivary amylase (ptyalin).***

iv. Oesophagus

This is a straight tube that passes from the mouth through the thorax and diaphragm into the abdomen.

When the food is fully chewed, the tongue rolls it into bolus pushes it against the soft palate at the back of the mouth (pharynx). This initiates the process of swallowing the food into the oesophagus. The tube adjacent to the oesophagus is the trachea which leads to the lungs. During swallowing, the flap of the tissue called epiglottis above the trachea prevents food from entering into the trachea.

v. **The stomach**

The gullet opens to the stomach which has a cardiac sphincter muscle at the entrance and pyloric sphincter muscle at the exit. (Sphincter is a circular band of muscle).

4) The small intestine

The small intestine is long and coiled with length of about 6-7metres in man. ***It is made up of two parts; ileum and duodenum.***

5) The duodenum

This is the first part of the small intestine. It is short and wider than ileum. It bends into a loop to accommodate the pancreas.

The ducts passages open into duodenum are;

- ❖ The bile duct from the liver and gall bladder,
- ❖ The pancreatic duct from the pancreas.

Functions of bile

i) It contains high % of water and adds it to the food coming from the stomach called chime.

ii) It's alkaline and neutralizes the HCl of the chime to stop the action of the stomach enzymes and allow enzymes in the pancreatic juice to begin working.

iii) It reduces the surface tension of fats and breaks them into minute droplets i.e. emulsifies fat.

6) The ileum

This is the second part of small intestines. It is long and coiled with length of about 6-7metres in man. It involves digestion and absorption.

Its lining has numerous tiny finger-like structures called villi (singular; villus) which increase surface area for absorption.

7) The large intestines

In man it consists of colon, appendix and rectum which open at the anus.

Note: in rabbits, the large intestine consists of the caecum which is very large and ends in the blind appendix and small colon leading to the rectum.

DIGESTION IN THE MOUTH

Digestion in the mouth is both physical and chemical.

a) Physical digestion

Physical digestion in the mouth is carried out by the action of teeth or is the act of Mastication / chewing.

Mastication is important in that;

i) Increase the surface area of food for efficient Enzyme action.
ii) It helps to mix the food with saliva and in so doing; it softens the food, mixes it with the enzymes and lubricates it with the mucus in the saliva.
iii) With the help of the tongue , the food is rolled into a Bolus (a small ball) for easy swallowing and movement in the gut.(alimentary canal)
iv) Chewing stimulates enzyme secretion because the secretion of saliva is a reflex action stimulated by the presence of food in the mouth.

NOTE: The secretion of saliva can also be stimulated by sight, smell and sought of food.

b) Chemical digestion in the mouth.

Chemical digestion is carried out by the enzyme Salivary amylase

Saliva is an alkaline watery solution and it provides the optimal PH for the action of amylase i.e a high PH.

Salivary amylase acts only on cooked starch breaking it down to disaccharide called Maltose.

Cooked starch $\xrightarrow[\text{(Ptyalin)}]{\text{Salivary amylase}}$ Maltose.

The act of swallowing:

Swallowing is a reflex action. Here, food is rolled into a Bolus which is then transferred into the Oesophagus (gullet).
During the act of swallowing, breathing momentarily stops and the epiglottis closes the Entrance into the trachea preventing food from entering into the trachea.
At the same time, the soft palate also closes the entrance into the nose cavity preventing the food from escaping or passing through the nose.
Once the bolus is in the oesophagus, the food moves by a wave of muscular contractions called ***Peristalsis.***

DIGESTION IN THE STOMACH

Most of the digestion in the stomach is chemical. Food is allowed into the stomach from the oesophagus by a ring of muscle called the ***Cardiac Sphincter.***

In the stomach, there is only protein digestion.

Gastric juice is secreted and it contains two enzymes, (pepsin and renin), hydrochloric acid, mucus and water.

Pepsin acts upon proteins/ breaking them down into polypeptides.

Pepsin is initially secreted in an inactive form called Pepsinogen which is activated into active pepsin by hydrochloric acid. This is the safe guard mechanism because if pepsin was stored in its active form, it would destroy the gut walls or stomach walls since they are protein in nature (self-digestion).

Pepsin works at low PH i.e. acidic conditions provided by the presence of Hydrochloric acid (HCl).

Renin coagulates milk. (Makes it insoluble) i.e. it converts the soluble milk protein caseinogen to an insoluble curd, casein which is then acted upon by pepsin breaking it down to polypeptide.

Rennin is an important enzyme especially in young mammals since they feed on milk.

Caseinogen $\xrightarrow{\text{Renin}}$ Casein
(Soluble protein) (Insoluble protein)

Proteins $\xrightarrow{\text{pepsin}}$ polypeptides

Functions of HCl in the stomach

i) It kills some bacteria in ingested food.
ii) It activates pepsin and renin and provides ideal medium for their activity.
iii) It stops the action of salivary amylase and ensures protein digestion only.
iv) It prevents fermentation of food in the stomach by bacteria.

Mucus:

Mucus forms a barrier between stomach walls and Gastric juice thus protecting the stomach walls from the action of hydrochloric acid (which can give rise to stomach ulcers due to its corrosive action) and also stops the action of pepsin which can digest the stomach walls also giving rise to ulcers.

DIGESTION IN THE DUODENUM

The chime from the stomach enters the duodenum in small quantities at a time regulated by the ***pyloric sphincter.*** There are access organs which provide secretions. They secret bile from the gall bladder and pancreatic juice from the pancrease

The arrival of food in the duodenum stimulates the production of a hormone called ***secretin*** from the pancrease and another hormone called ***cholecystokinin*** which stimulates secretion of bile from the gall bladder. The secretions are alkaline thus stopping the action of pepsin and provides an ideal medium for enzymes in pancreatic juice to work. Pancreatic juice contains a number of enzymes which are called the *pancreatic enzymes.*

Enzymes	**Food acted upon**	**Products**
Trypsin	Proteins	Peptides and Amino acids
Pancreatic amylase	Starch	Maltose
Pancreatic lipase	Lipids	Fatty acids and glycerol

Trypsin is also secreted in an **inactive** form, **trypsinogen** to prevent it from digesting the duodenum walls.

Both trypsin and pancreatic amylase act upon proteins and starch that were not broken down in the stomach and mouth respectively.

DIGESTION IN THE ILEUM

This is where final digestion takes place.

Food moves down from the duodenum into the ileum by peristalsis.

The presence of food in the ileum stimulates the secretion of the ***intestinal juice, succus entericus by walls of the ileum.***

Succus entericus contains several enzymes which complete the process of digestion forming a milky fluid substance called ***chyle*** (food after final digestion is called **chyle**).

Enzymes	**Food and Upon**	**Products**
Sucrase	Sucrose	Glucose and fructose

Maltase	Maltose	Glucose and glucose
Lactase	Lactose	Glucose and galactose
Peptidase	Polypeptides	Amino acids
Lipase	Lipids	Fatty acids and glycerol

The composition of chyle is a group of soluble end products of digestion namely; Glucose, Fructose, Amino acids, Glycerol, Vitamins and Mineral salts.

DIGESTION IN THE LARGE INTESTINES / COLON

In the colon, water and mineral salts are absorbed. The undigested and indigestible food substances pass down into the large intestines which are eventually removed from the body as faeces through the anus. ***There is no digestion in the large intestine.***

Accumulation of hard particles like stones, small sticks in the appendix results into a condition known as **appendicitis.** The appendix is thus removed surgically by a simple operation.

SAMPLE QUESTIONS:

Question 1: Describe the digestion process that occurs when a person consumes Posho (starch)?

Answer:

A piece of Posho is placed into the mouth, a process called ingestion.

In the mouth; The Posho is thoroughly chewed by teeth, breaking it into smaller particles. During this chewing, Posho is mixed with saliva to make it soft and easy to swallow.

Saliva contains salivary amylase which breaks down cooked starch in Posho into maltose under neutral conditions.

Food is then pushed down the Oesophagus by a process called peristalysis.

In the stomach; no digestion of starch occurs because of acidic conditions due to presence of hydrochloric acid which provide unfavourable pH for activity of salivary amylase.

In the duodenum; the pancreatic juice contains pancreatic amylase which speeds up the breakdown of undigested cooked starch to maltose.

In the ileum, intestinal juice contains maltase which speed up the breakdown of maltose to glucose molecules which are soluble hence easily absorbed by the body. This marks the end of the digestion for Posho.

Question 2:
Describe the process of digestion of proteins in man.

Answer:
In the mouth; Protein food is chewed by the teeth and swallowed into the stomach.
In the stomach; gastric juice is produced which contain pepsin that digests proteins to peptides and rennin coagulates protein milk in babies.
In the duodenum; presence of food stimulates pancreas to secrete pancreatic juice containing trypsin which digests undigested proteins to peptides.
In the ileum; intestinal juice is produced containing peptidase which break down peptides to amino acids which are later absorbed through the ileum walls.

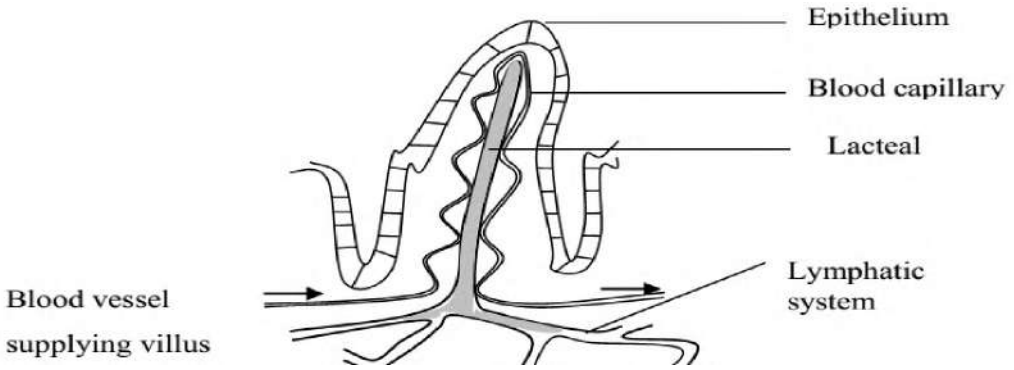
THE PROCESS OF ABSORPTION AND ASSIMILATION OF FOOD

ABSORPTION

Absorption is the process by which soluble products of digestion diffuse through the cellular lining of the villi into the blood stream.
The villi are located in the ileum (small intestine) and thus absorption takes place in the small intestine. Some nutrients like minerals and vitamins also enter the villi by active transport.
The ileum shows various adaptions to suit the process of absorption which includes:

i) It is highly coiled/folded and consequently long thus providing a large surface area for digestion and absorption of food. (It is six (6) meters long).
ii) Has a thin layer of cells to reduce the diffusion distance over which soluble food passes through.
iii) They are highly supplied with blood capillaries and lacteals which transport away absorbed food thus maintaining a diffusion gradient.
iv) Have figure-like projections called the villi which increase the surface area for absorption of soluble food.
v) The villi also have hair like extensions called the micro villi whichs ***further*** increase the surface area for absorption of soluble food products. The villi are the actual sites for absorption of soluble food products.

Diagram of Villus



Fatty acids and glycerol are absorbed into the lacteal of the villi. These lacteal later join up to form the lymphatic system carrying these food materials and distributing them to all parts of the body.

Glucose, Amino acids and Fructose pass into the blood capillaries of the villus which join up to form the Hepatic portal vein which transport these nutrients to the liver.

ASSIMILATION

This is the process by which absorbed food materials are built up into complex constituents of the organism.

Assimilation is also the incorporation/utilization of the products of digestion into the body's metabolism for life processes e.g. respiration, growth and repair and digestion.

Assimilation and metabolism for:

1) Carbohydrates: (Glucose)

Glucose is mainly broken down in the process of respiration to provide energy for the body's metabolic process.

Excess glucose is stored as **Glycogen** (animal starch); however, the liver has the ability to re-covert back the glycogen to Glucose in periods of starvation.

2) Proteins

Amino acids are used in the synthesis of new proteins especially regulators like enzymes, and hormones.

Some Amino acids are used in body growth and repair and in absence of Glucose and Fats, Amino acids can instead be used in the process of respiration to produce energy.

Excess Amino acids are not stored in the liver, they are instead **deaminated** by the liver (removal of the Amino group) to form urea which is then passed on to the kidneys and excreted in urine.

Deamination is the removal of the amino group from Amino acids to form urea (which is a toxic waste product).

3) Lipids (Fatty acids & Glycerol)

Fatty acids and glycerol in the absence of Glucose can be oxidized to release energy. Fats produce much more energy compared to glucose considering the same amount by mass.

Fats are used for body insulation i.e. they prevent heat loss from the body which is an important temperature regulatory mechanism.

Lipids are used in the formation of structures like the cell membrane.

Excess fats and Glycerol are stored under the skin in the **adipose tissue.**

THE LIVER

This is the largest organ in the body and it carries out several functions within the body. The liver is the body's metabolic center as it receives all nutrient supplies from the blood through the ***hepatic portal vein.***

Functions of the Liver

i) Assimilation and metabolism of carbohydrates.
ii) Assimilation and metabolism of proteins.
iii) Assimilation and metabolism of lipids.
iv) Production of heat helps in temperature regulation. Since there are many metabolic reactions occurring in the liver, there is a lot of heat given off-and this heat is distributed throughout the body and it plays a great role in temperature regulation.
v) Manufacture of plasma proteins in clotting of blood. The liver helps to manufacture proteins like Albumin, Globulin and fibrinogen which are important in body process like clotting of blood (stopping bleeding).
vi) Production of bile which emulsification lipids. The liver produces bile which is important in the process of digestion i.e. in the emulsification of lipids.
vii) Storage of iron and other minerals. The liver destroys worn out blood cells and removes the ion group from them which it stores for future formation of other blood cells.
viii) Formation of red blood cells with the iron yet from the above process, coupled with vitamin B_{12}. New red blood cells can formed in the bone narrow using these raw materials.

ix) Storage of blood. Blood vessels in the liver can expand and contract to great extents such that the amount of blood in the liver can vary from $300cm^3$ – $1500cm^3$ an increase of five times thus the liver can be a blood reservoir.
x) Detoxification. The liver converts toxic substances to harmless substances by altering their chemical structure and later sends them to the excretory organs for expulsion e.g. it converts Ammonia to urea which is then expelled by the kidneys.
xi) Elimination of sex hormones. Testosterone and oestrogen are sent to the kidneys by the liver for excretion.

DIGESTION IN HERBIVORES

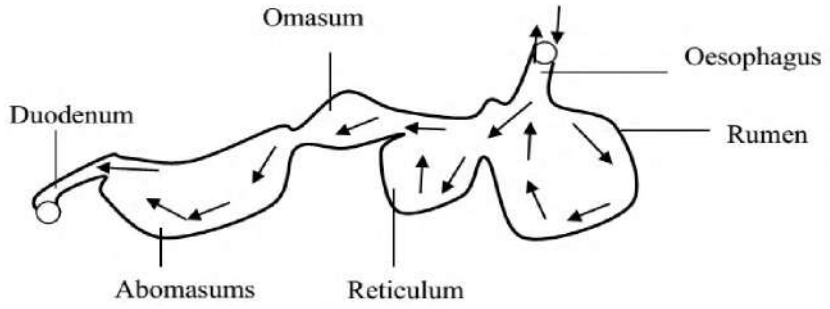
Animals that depend on plant materials (herbivores) like leaves, wood, grass are faced with a problem of digesting the cellulose that make up the plant walls.
It is necessary to break through the cellulose to release the inside cell nutrients which are required by the herbivores.
These herbivores cannot secret the enzyme which digests cellulose because they cannot produce **cellulase.** However, some protozoans and bacteria can produce the enzyme cellulase.
Fortunately, some of these micro-organisms can live in the guts of herbivores in a harmless beneficial nutritional association called ***symbiosis.***

Digestion of cellulose in ruminants

Ruminants are mammals which chew cud.
Cud is imperfectly / incompletely chewed grass or plant materials that are taken into the stomach (rumen) and later returned back to the mouth for further chewing through a process called ***regurgitation.***

Ruminants have a complicated stomach made up of four chambers namely;
i) Rumen
ii) Reticulum
iii) Omasum
iv) Abomasum

Diagram showing the stomach of a ruminant and the flow of food through it



In the mouth, the saliva does not contain any enzyme. So only mastication (chewing) and softening of food takes place.

The food moves through the oesophagus by peristalsis (wave like motion).

1. Rumen:

This is the largest component (chamber) of the stomach. It is used for storing food as the animal feeds. Fermentation and digestion of cellulose by bacteria and protozoa occurs in the rumen.

Fermentation is the breakdown of food by bacteria in the absence of oxygen. During fermentation, there is a release of a weak acid called ***lactic acid.***

Food then moves from the rumen to the reticulum and from the reticulum back to the rumen where regurgitation takes place (This is where food is returned to the mouth bit by bit for further chewing and that completes the first cycle.

2. Reticulum:

Bacterial action continues here and also food is sieved where finely ground food materials are separated from the coarse materials which are then retained. These coarse materials may include small stories, small pieces of wood, etc.

3. Omasum:

This consists of parallel leaf like compartment with rough surfaces.

Food is ground finely here and water absorption also takes place.

4. Abomasum (True stomach)

Here, enzymatic digestion of proteins takes place like in human and digestion beyond this point also proceeds like in humans and that is why we refer it as a true stomach, you can continue in the same line in humans e.g. colon.

Digestion of cellulose in termites

Termites eat wood, dry leaves and other plant materials which contain cellulose. The digestion of cellulose also takes place in the gut (stomach) with the help of protozoans which lives symbiotically in the termite's gut.

These protozoa have the ability to produce the enzyme cellulase which digests cellulose.

COMPARISION BETWEEN RUMINANT AND NON RUMINANT DIGESTION

Similarities:

i) In both, young animals have a single stomach where digestion takes place.
ii) The final digestion of proteins and carbohydrates takes place in the small intestines.

Differences:

Ruminant	Non-Ruminant
1. Chew cud.	Do not chew cud.
2. Have a four chambered stomach.	Have a single stomach.
3. Ptyalin (salivary amylase is absent in saliva.	Ptyalin is present in saliva.
4. Most digestion and absorption takes place in the stomach.	Most digestion and absorption takes place in the ileum.
5. Water absorption takes place in the stomach.	Water absorption takes place in the colon.

NUTRITION IN PLANTS

Nutrition in plants is by a process called photosynthesis.
The process of photosynthesis is divided into two stages;

i) Light stage
ii) Dark stage

Photosynthesis is the process by which living plants manufacture their own food in form of carbohydrates (starch) from raw materials i.e. carbon dioxide and water using sunlight energy trapped by chlorophyll and give off oxygen as a bi-product.

In summary photosynthesis is a natural process that;
(i) requires two raw materials (carbon dioxide and water)
(ii)requires two conditions (i.e. chlorophyll and sunlight energy)
(iii) and forms two products namely (starch or carbohydrates & oxygen)

The process of photosynthesis occurs in all green plants in organs called **chloroplast** most of which are found in leaves.
Chloroplast contains chlorophyll which traps sunlight energy.
The process of photosynthesis is very complicated but it can be summarized by the equations below.

Carbon dioxide + water $\xrightarrow[\text{Chlorophyll}]{\text{Sunlight energy}}$ starch (Glucose) + oxygen

$$6CO_{2(g)} + H_2O_{(l)} \xrightarrow[\text{Sunlight energy}]{\text{Chlorophyll}} C_6H_{12}O_{6(s)} + 6O_{2(g)}$$

The insoluble starch (storage carbohydrates) is them converted to soluble glucose which is then transported by the phloem to different parts of the plant body especially storage organs like the roots (in cassava and sweat potatoes) stems (in sugarcanes and Irish potato) or transported to actively metabolizing parts of the plants e.g. the growing regions, and the respiring parts.
On reaching these storage organs, the soluble glucose is then reconverted back to insoluble starch for storage.

CONDITIONS NECESSARY FOR PHOTOSYNTHESIS TO TAKE PLACE

1) Chlorophyll:
Chlorophyll is a green pigment that absorbs light energy from the sun. The amount of chlorophyll present in a leaf is directly related to the rate of photosynthesis.

2) Carbon dioxide:
It is absorbed from the atmosphere by terrestrial plants through their stomata. For aquatic plants like algae, they absorb the carbon dioxide as hydrogen carbonates which diffuse directly from the water in plant tissues. The use of carbon dioxide is to combine or react with hydrogen atoms to form carbohydrates. Thus CO_2 is used as a raw material.

3) Light:
This is the source of energy necessary for the process of photosynthesis to take place. The rate of photosynthesis increases in light intensity, up to a maximum when it levels off. The energy of light is used for the following purposes:

i) Used to split water molecules into hydrogen atoms and oxygen. The oxygen is given off by the photosynthesizing plants. The hydrogen atoms combine with CO_2 to form carbohydrates.
$H_2O \xrightarrow{\text{split by light energy}} 2H^+ + O_2$

ii) Provides energy for photosynthesis. The process by which light energy splits water into H^+ and oxygen is called photolysis of water.

4) Temperature:
Temperature influences the rate of chemical reactions which are controlled by enzymes which are protein in nature.

The rate of photosynthesis doubles for every ten degrees centigrade (10^0C) rise in temperature up to about 400C where the rate of photosynthesis drops drastically because the enzymes are denatured

5) Water:

Water is a raw material for the process of photosynthesis. It is absorbed by the root hairs from the soil and transported up the rot by the xylem vessels.

A decrease in the concentration of water lowers the rate of photosynthesis.

6) Oxygen:

Oxygen is not necessary for the process of photosynthesis i.e. it is a bi-product of thus its accumulation instead lowers the rate of photosynthesis.

Adaptation of leaves to carry out photosynthesis

The leaf is the major organ of photosynthesis in a plant.

The leaf is adapted to carry out the photosynthesis process in a number of ways namely

External adaptations

Leaves are broad and flat:

This provides a large surface area for trapping sunlight and taking in of Carbon dioxide.

Numerous leaves:

This helps to increase the total surface area exposed to the sun thus increasing the rate of photosynthesis.

Thinness:

Most leaves are just a few cells thick thus providing a small diffusion distance for penetration of carbon dioxide and sunlight.

Leaf arrangement / leaf mosaic:

Leaves are usually arranged in such a way that they rarely shade or block each other thus ensuring that each leaf obtains maximum sunlight for photosynthesis. This is termed as a leaf mosaic.

Internal adaptation of a leaf

Palisade mesophyll layer

The layer **contains numerous chloroplasts** especially the palisade thus it is the best position to receive sunlight.

Their elongated shapes minimize the number of cross wall which would minimize light penetration by absorbing some of it.

The spongy mesophyll layer

This layer has mainly **air spaces** thus allowing many gases to easily diffuse into all the photosynthesizing cells.

Network of veins (vascular tissues)

The vascular tissues include the xylem and phloem where by xylem transports water and mineral salts up to the stem while the phloem transports food (starch) up to the stem.

The network contains the phloem and the xylem where by the phloem conducts food made by the leaf and the xylem conducts dissolved mineral salts up to the stem.

Presence of stoma:

This controls passage of gases and water vapour between air and the leaf.

There are more stomata on the lower side of the leaf compared to the upper side to reduce water loss by transpiration.

The cuticle

This is a water tight layer and so it helps to prevent desiccation (water loss) by the photosynthesizing tissues.

Numerous chloroplasts

These ensure that enough sunlight is trapped by the chlorophyll.

EXPERIMENTS ON PHOTOSYNTHESIS

Experiment 1

AN EXPERIMENT TO TEST LEAF FOR STARCH

The presence of starch is evidence that photosynthesis has been taking place.

Apparatus:

- A green leaf,
- water bath,
- Iodine solution,
- Water
- absolute alcohol (99%-OH),
- beaker,
- white surface or tile

Procedure:

1) A leaf from a health plant which has been receiving sunlight is removed and placed in boiling water (water bath) for about 5 minutes. This softens the leaf cell wall protoplasm and makes it permeable to Iodine.
2) The leaf is then placed in a beaker containing 99% alcohol and boiled using a water bath until all the chlorophyll is dissolved out. This decolorizes the leaf and makes detection of any colour changes possible and easier.
3) The leaf is then washed in hot water which softens it.
4) The leaf is now spread on a white surface tile and drops of iodine added on it.

Observation:

A blue black colour shows that starch is present.

NOTE: If the brown colour of iodine persists/ remains this shows that the leaf lacks starch or the starch is absent.

Conclusion:

The presence of starch in a leaf shows that photosynthesis was taking place.

Experiment 2:

AN EXPERIEMENT TO SHOW THAT OXYGEN IS GIVEN OFF DURING PHOTOSYNTHESIS

Apparatus:

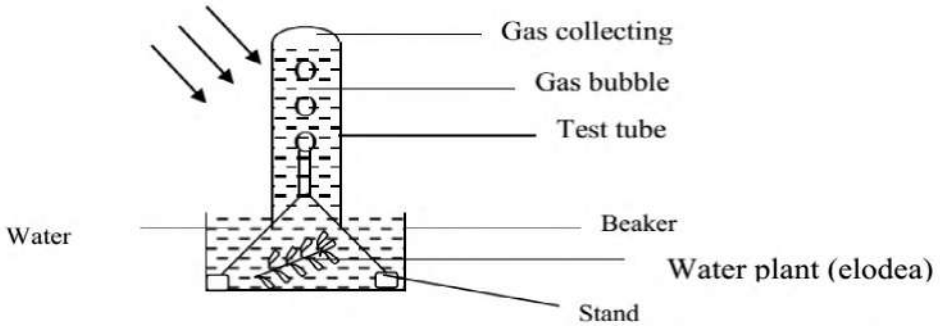
- Afresh water weed.
- Funnel and wooden blocks.
- Test tube,
- beaker
- Water.
- Sodium hydrogen carbonate.

Procedure:

a) The funnel is inverted in the beaker over the plant.
b) Sodium hydrogen carbonate is added to the water to provide CO_2
c) The funnel is raised slightly above the bottom of the beaker using small wooden blocks to allow water to circulate freely under it.
d) The apparatus is then placed in the bright sunlight.
e) Another similar set up is made and placed in darkness. This acts as the control experiment.

The apparatus is arranged as shown below:

Experimental setup



Observation:

Gas bubbles are evolved and sufficient gas is collected at the top of the test tube.

In the control experiment, no bubbles are involved.

Conclusion:

The gas collected relights the glowing split proving that it is oxygen.

The evolution of oxygen by the water plant in the presence of sunlight is an indication that photosynthesis is taking place.

NOTE: This experiment can also be carried out to estimate the rate of photosynthesis (speed) by counting the number of bubbles produced per unit time.

Experiment 3:

AN EXPERIMENT TO SHOW THAT LIGHT IS NECESSARY FOR PHOTOSYNTHESIS

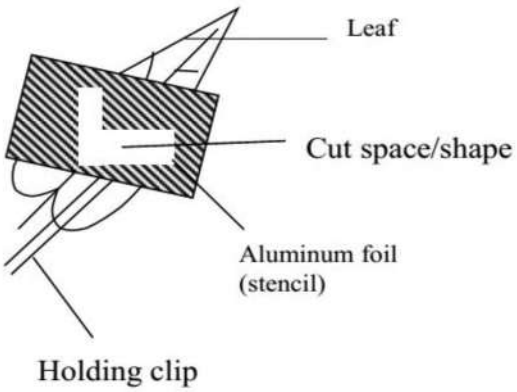
Apparatus/materials:

- ❖ Potted plant
- ❖ Aluminum foil
- ❖ Water
- ❖ Ethanol
- ❖ White tile
- ❖ Source of heat
- ❖ Wire gauze
- ❖ Dropper
- ❖ Boiling tube
- ❖ Razor blade.

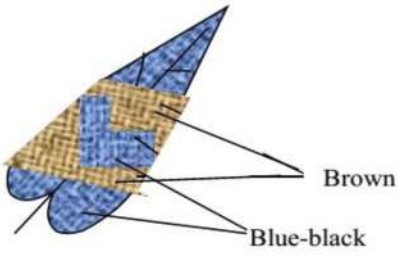
Procedure:

1) Get a potted plant and place it in darkness for 24 hours to destarch it.
2) Make a shape in an aluminum foil and make a stencil
3) Place the stencil around the leaf with the cut shape facing upwards where light strikes.
4) Place the plant in sunlight for 3 hours.
5) Remove the leaf with a stencil from the plant using a razor blade
6) Remove the stencil and carry out the test for starch.

Before testing for starch



After testing for starch



Observation:

The parts, which were covered by the stencil, turned brown while the parts exposed to light turned blue-black.

Conclusion:

Light is necessary for photosynthesis to take place.

Explanation:

Putting the leaf in darkness removes starch in the leaf by all the starch being converted into simple sugars. Putting the plant in light is to allow photosynthesis to take place. Covering the leaf with a stencil is to prevent light from reaching certain parts of the leaf. During exposure to light, the parts covered do not access sunlight and do not photosynthesize while the un-covered parts access sunlight and photosynthesize. Testing for starch helps to find out whether photosynthesis took place or not.

Experiment 4:

AN EXPERIMENT TO SHOW THAT CARBONDIOXIDE IS NECESSARY FOR THE PROCESS OF PHOTOSYNTHESIS

Apparatus:

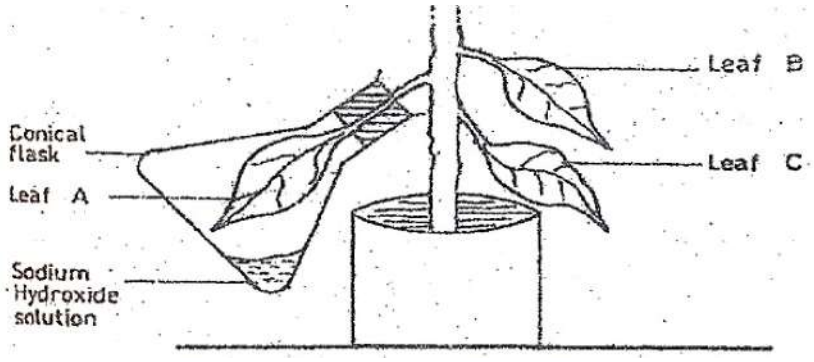
- Sodium hydroxide (NaOH) / Potassium Hydroxide (KOH),
- Conical flasks fitted with corks with a hole,
- well watered destarched plants,
- Iodine,
- (99% alcohol)
- water beaker,
- white tile
- Test tubes.

Procedure:

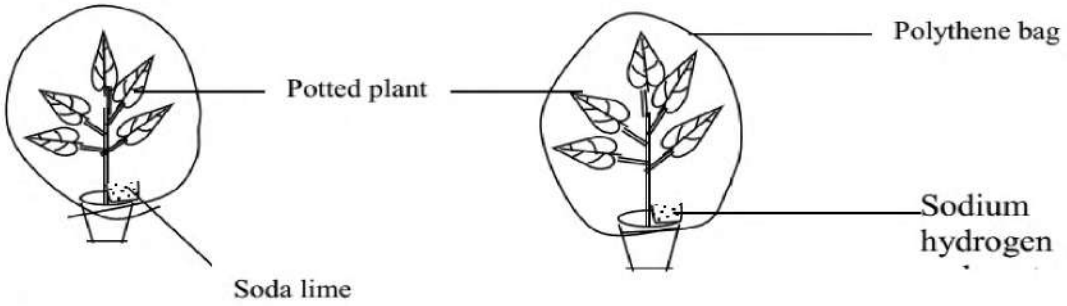
a) The leaves of a potted plant are destarched by keeping the plant in darkness for two days.
b) The petiole of the leaf (stalk) is passed through the hole in the cork so that the leaf is completely enclosed in a flask containing Sodium Hydroxide.
c) The Sodium Hydroxide absorbs all Carbon dioxide enclosed in the flask.
d) The flask is then made air tight by smearing Vaseline at the neck of the flask to prevent any air from entering.
e) A control experiment is also set up, however here the flask contains water which does not absorb Carbon dioxide.
f) The plant and the flasks are then placed in sunlight for 6 hours.

g) The enclosed leaves are then removed from the plant and then tested for starch using Iodine solution.

Experimental set up.



Alternatively



Observation:

The leaf in the flask containing Sodium Hydroxide solution remains brown (the colour of Iodine persisted) when tested for starch while that (the flask containing water / control experiment) turned blue black.

Conclusion:

The leaf in the flask containing Sodium Hydroxide didn't contain starch since it lacked Carbon dioxide which was absorbed from the flask by the Sodium Hydroxide solution thus Carbon dioxide is necessary for photosynthesis.

Experiment 5:

AN EXPERIMENT TO SHOW THAT CHLOROPHYLL IS NECESSARY FOR PHOTOSYNTHESIS

Apparatus:

- A beaker,
- Alcohol,
- white tile
- Iodine,
- test tube, and

- Plant with variegated leaves.

A variegated leaf *is one which has chlorophyll in some parts of the leaf lamina and not in other parts of the same leaf. It has green and yellow parches on the same leaf.*

Procedure:

a) After a period of destarching (removing starch) by placing a plant in a dark cupboard for two days, the variegated plant is then exposed to sunlight for about two (2) hours.
b) The parts of the leaf that are not green are used as the control experiment.
c) At the end of the two hours, the leaf is removed and then tested for starch.

Observation:

The parts that were green are stained blue black with iodine solution while the yellow patches stained brown with iodine (brown is the colour of iodine).

Conclusion:

The green parts of leaf contained starch because they contained chlorophyll and thus turned blue black while the yellow patches (non-green parts) did not contain starch because they lacked chlorophyll.

Chlorophyll is thus necessary for photosynthesis.

GASEOUS EXCHANGE AND COMPESATION POINT

Both respiration and photosynthesis take place in a green plant.

Photosynthesis equation:

$$6CO_2 + 6H_2O \xrightarrow{\text{chlorophyll, light}} C_6H_{12}O_6 \text{ (Starch)} + 6\ O_2$$

In darkness, Green plants do not photosynthesize however they continue to respire. Here oxygen is used up (through respiration) and carbon dioxide given off and there is an overall net consumption of sugars and starch during respiration.

At low light intensity, some photosynthesis occurs and some carbon dioxide produced in respiration by plants is used up in photosynthesis. However, there is a net loss of Carbon dioxide.

As the light intensity increases, the rate of photosynthesis also increases until a point is reached when all the Carbon dioxide produced during the process of respiration is reused in the process of photosynthesis. This point is called the **compensation point**.

The compensation point *is that point of light intensity at which the rate of Carbon dioxide produced by respiration is equal to the amount of Carbon dioxide consumed during photosynthesis.*

At the compensation point, the rate of photosynthesis is equal to the rate of respiration ie the rate at which food (starch) is manufactured is equal to the rate at

which it is used up in the process of respiration and this means that there is no net gain or loss in the mass of the plant.

IMPORTANCE OF PHOTOSYNTHESIS

Photosynthesis is the method by which food is made from simple inorganic materials.

(i) Photosynthesis helps to purify the environment by removing excess Carbon dioxide from the atmosphere which is a pollutant.
(ii) During the photosynthesis process, oxygen is released back into the atmosphere and it is very vital in the respiration process of most organisms.
(iii) It provides energy. This energy is mainly organic in nature in form of fuels like coal, petroleum, firewood, all of which are products of photosynthesis.

Factors that affect the rate of photosynthesis

The rate of photosynthesis can be determined by considering how much oxygen is evolved by the plant or the amount of oxygen given off by the plant or increase in the weight of the plant due to accumulation of starch. Some of the factors include the following:

1) Amount of chlorophyll

The more chlorophyll, the more the light energy absorbed leading to increased rate of photosynthesis. The less the chlorophyll, the less light energy absorbed leading to decreased rate of photosynthesis

2) Amount of CO_2 in the atmosphere

It is required as a raw material for photosynthesis thus the rate of photosynthesis increases in CO_2 concentration and it decreases with the lowering of CO_2 concentration.

3) Light intensity

The rate of photosynthesis increases with increase in light intensity. And it lowers with decrease in light intensity.

4) Temperature

It is required for the activity of enzymes that control the rate of photosynthesis. Thus the rate of photosynthesis increases with increase in temperature till the optimum temperature for enzyme action. Beyond which the enzymes are denatured leading to decrease rate of photosynthesis.

5) Number of stomata

The more the stomata, the more the gaseous exchange. This avails more CO_2 to the plant leading to high rate of photosynthesis.

6) Surface area for photosynthesis