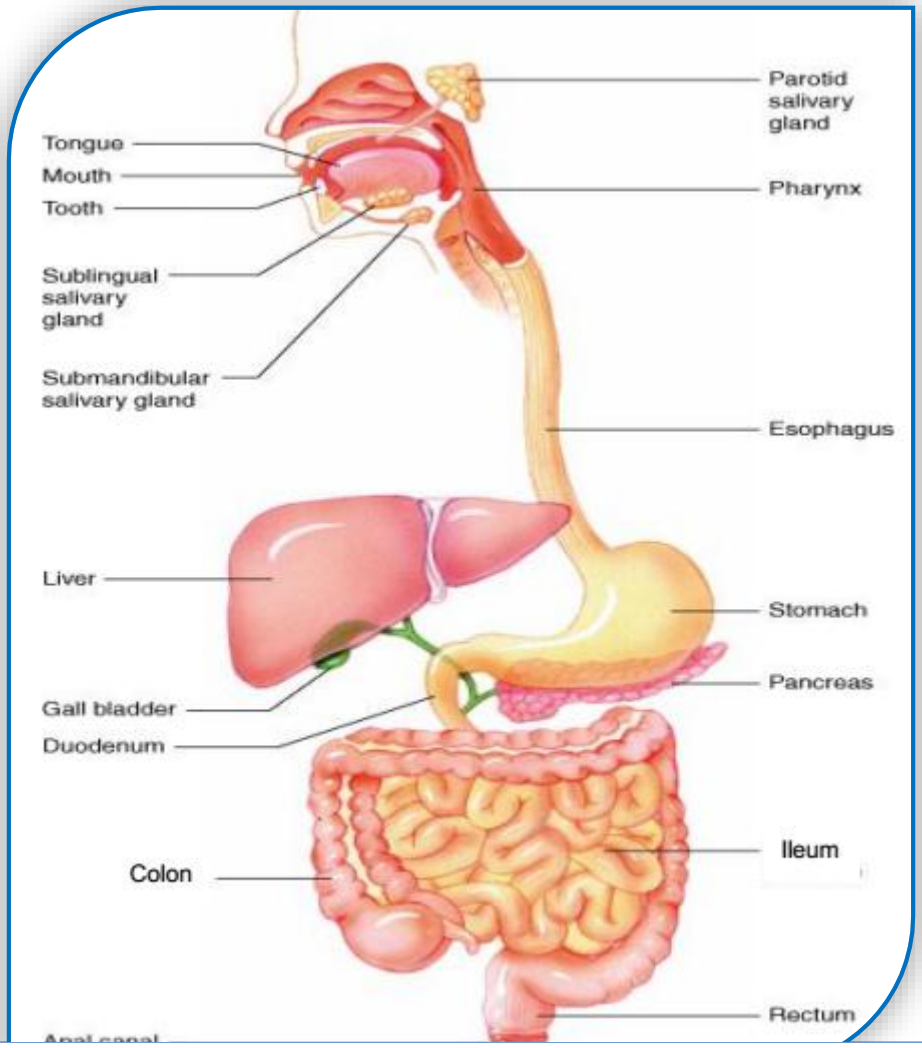
S.2 BIOLOGY CLASS NOTES

By Kugonza Arthur H

2017



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

It 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.

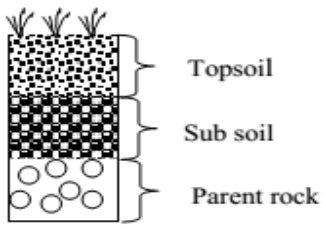
Man contributes to biological weathering through direct splitting of rocks during road and house construction and indirectly through cultivation.

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



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.

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

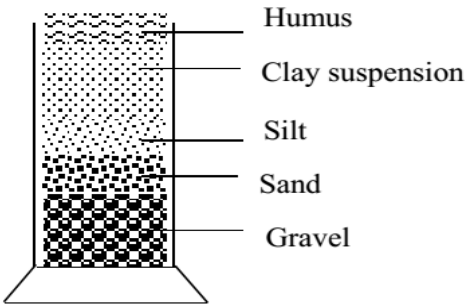
i) They provide a surface for anchoring plant roots hence providing support to the plants.
ii) Soil particles give a rigid frame work to the soil.
iii) They provide mineral elements to the soil which are the absorbed by plants using roots.

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 in the air increases 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, and glass rod.

Method

1. Measure about 50 cm^3 of dry soil in a measuring cylinder and tap the container to level out the soil.
2. Measure 50 cm^3 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. Calculate the air content in terms of percentage.

Example

Volume of soil = $50cm^3$

Volume of water = $50cm^3$

Final volume of water + soil after mixing = $85cm^3$

Volume of air in soil (100 - 85) = $15cm^3$

Percentage of air = $\frac{volume\ of\ air}{volume\ of\ soil\ used}\ x\ 100\%$

Percentage of air = $\frac{15}{50}\ x\ 100\%$

Percentage of air = 30%

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.

Importance of soil water

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, 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 minutes.
d) Heating and weighing is repeated until a constant mass is achieved. *(Take care not to burn the soil to produce 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

Percentage of water = $\frac{amount\ of\ water}{amount\ of\ fresh\ soil}\ x\ 100\%$

Percentage of air = $\frac{Y-Z}{Y-X}\ x\ 100\%$

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 leads to improvement of activities of soil organisms by providing them with food and shelter.
viii) 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) Fill the crucible with soil halfway and record the weight of soil plus crucible on weighing scale *(X g).*
c) Dry the soil by heating it in an oven at ***105^{0}C*** 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, then weigh the soil after cooling and record its weight. 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^{0}C =*Y* g
Constant weight of soil + crucible after heating to redness = *Z* g
Weight of fresh soil = *X - W*
Weight of dry soil = *Y - W*
Weight of dry soil after burning off humus = *Z - W*
Weight of humus = *Y - Z* g

Percentage of humus = $\frac{amount\ of\ humus}{amount\ of\ dry\ soil}\ x\ 100\%$

Percentage of humus = $\frac{Y-Z}{Y-W}\ x\ 100\%$

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° 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) Because burning the soil strongly 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 = $\frac{amount\ of\ humus}{amount\ of\ dry\ soil}\ x\ 100\%$
Percentage of humus = $\frac{6}{112}\ x\ 100\%$
= 5.36%
d) Weight of water = 120 – 112 = 8 g
Therefore water is more than humus 2 times (8g – 6g)

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

Set up

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.

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 and 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.

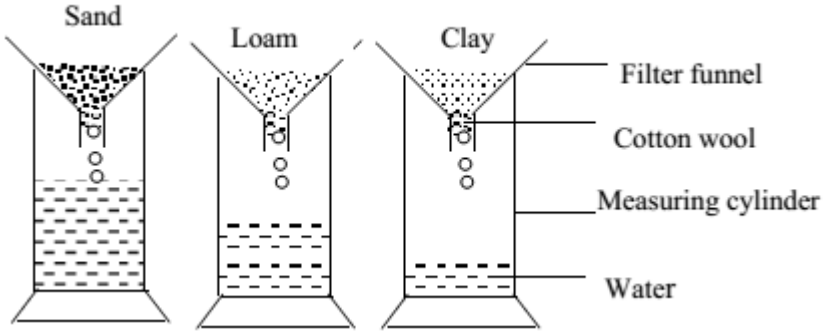
Experiment to compare the drainage and retention of water in sand and clay soils

Apparatus

- filter funnels,
- measuring cylinders,
- filter papers
- Equal volumes 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.



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.

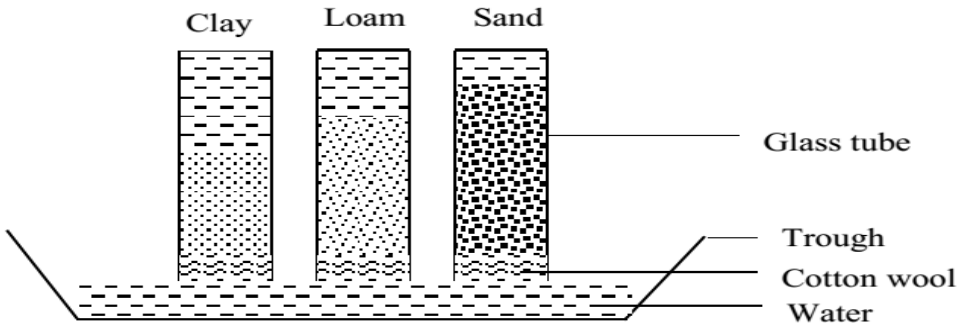
Observation:
Water passes through sand soil faster than clay soil. So much water is collected in the cylinder with sand soil and less water is collected in the cylinder containing clay soil.
Conclusion:
Clay soil holds more water than sand soil and sand soils drains water faster than clay.
Explanation:
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. 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.



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.

An experiment to determine the soil pH

Apparatus: Fresh soil sample, Distilled water, Universal solution and Indicator chart.

Procedure:

i) Place about 3g of soil on petri dish and soak it with universal indicator. Leave it for about 2 minutes.

ii) Tilt the petri dish so that the indicator drains out of the soil and then compare the indicator colour with the indicator chat.

Alternatively:

Soak the soil sample with distilled water. Drain off/filter off the water and test it with the universal indicator solution or universal indicator papers.

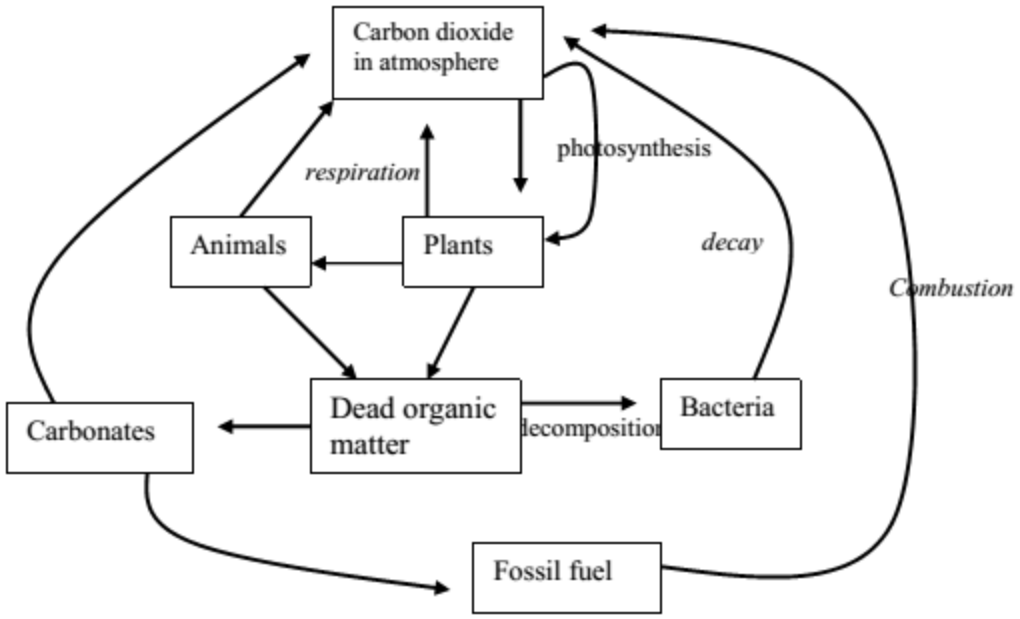
SOIL EROSION

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

1. **Sheet erosion:** This is where thin uniform layers of soil are eroded over the whole slope.
2. **Rill erosion:** This is where water cuts shallow channels called rills. The channels deepen as volume of water run off increases.
3. **Gulley erosion:**

The carbon 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:

i) 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 fossilization.

ii) Respiration in animals and plants.

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

NUTRITION IN LIVING ORGANISMS

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;

1. Heterotrophic nutrition (nourishment on others).
2. 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.

Autotrophic nutrition can be divided into two depending on the external source of energy used to drive there processes;

Photosynthesis:

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

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. 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 example amoeba and the 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.

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.

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

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. Carbohydrates are grouped into 3 categories; disaccharides, monosaccharides 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 are: Starch**,** Glycogen and 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, add 1 cm^3 of Benedict's solution and boil.	Colourless or turbid 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.	Little/Moderate/Much/Too much; ***reducing sugars present.***
	Colourless or turbid solution turned to a blue solution which persists on boiling.	Reducing sugars 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*

*Orange **precipitate-** much sugars present*

*Brown **precipitate-** too much reducing 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 boil, cool under water then add 1 cm^3 of sodium hydroxide solution, followed by 1 cm^3 of Benedict's solution and boil.	Colourless or turbid solution turned to a blue solution, then to a green solution, to a yellow precipitate and to a brown precipitate on boiling.	Little/Moderate/Much/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 are sucrose (present in sugar cane) **and** 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/moderate/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.

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

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.

Food sources are, Ground nuts**,** Eggs**,** Sun flower**,** Palm oil**,** Castor oil, etc.

Properties of lipids

i) They make a permanent translucent mark or spot on papers.
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.
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, allow to dry and observe under light.	A translucent spot is left on the paper.	Lipids present
	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: Water soluble vitamins and 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 and good night(Dim light) vision	Night blindness, frequent cold sore eyes and unhealthy 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, 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 acid/Niacin	Cereal grains, milk and its products, liver and yeast	Same as B_2	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 and normal growth.	**Scurvy** - Sore gums, poor healing of sores in the gum
D Calciferol	Liver, fish, egg yolk. It is also 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 decay.
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 decolorized 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;

Essential mineral elements (macro elements): These are mineral elements required in relatively large amounts. They are sodium, potassium, phosphorous, calcium, iron, etc.

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, etc.

A table showing some elements and their deficiency diseases

MINERAL ELEMENT	SOURCE	IMPORTANCE	DEFFICIENCY
Fe Iron	Beef, liver, kidney, G.nuts, beans, eggs, green vegetables.	- It is a constituent of Haemoglobin.	**Anemia** - 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	Formation of teeth & bones.	It is not likely for one to be deficient of phosphorus since it is found in most foods.
I Iodine	- Iodized salts - Marine fish	It is a constituent of the growth hormone	**Goiter:** Swelling of the Thyroid gland. Muscle cramp (sharp pains in muscles).
F Fluorine	Drinking water	Strong bones and teeth.	Weak teeth in children.
K Potassium	Fish, beef, liver, mushrooms	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

- ✓ The plasma of blood is made up of water.
- ✓ It's a universal solvent in which absorbed foods, wastes and hormones are transported around the body in blood.
- ✓ 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 an agent of 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

- They *speed up the rate of the reaction without changing the product formed and the nature of reaction*.
- *They also control metabolic processes hence promoting normal body functions.*

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	Peptidase	lipase	Maltase	Sucrose	Lactase	Cellulase
Substrate	Peptides	Lipids	Maltose	Sucrose	Lactose	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

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 concentration is low.

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

2) Temperature:

Enzymes work best at optimum temperatures of (approximately 37^0C). 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 to optimum temperatures. *An optimum temperature is which promotes maximum enzyme activity*. However with further increase in temperature, the rate of reaction decreases exponentially/sharply since at high temperatures, the enzyme is denatured i.e. the active site of the enzyme which is (protein in nature) is 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.

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.

5) Presence of enzyme inhibitors

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

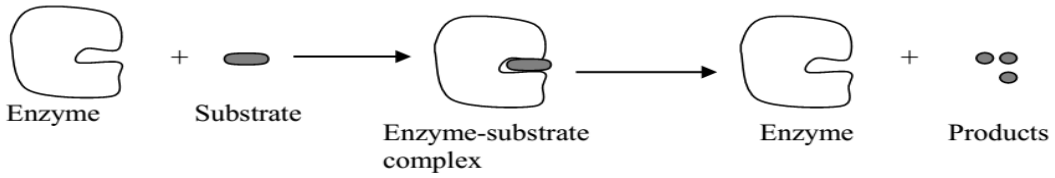
6) Presence of activators

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 enzyme. When the substrate 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.



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**.

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. They have a conical shaped crown which is sharp and pointed. They have one root. ***They are used for tearing flesh.***	**structure of a 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 a 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

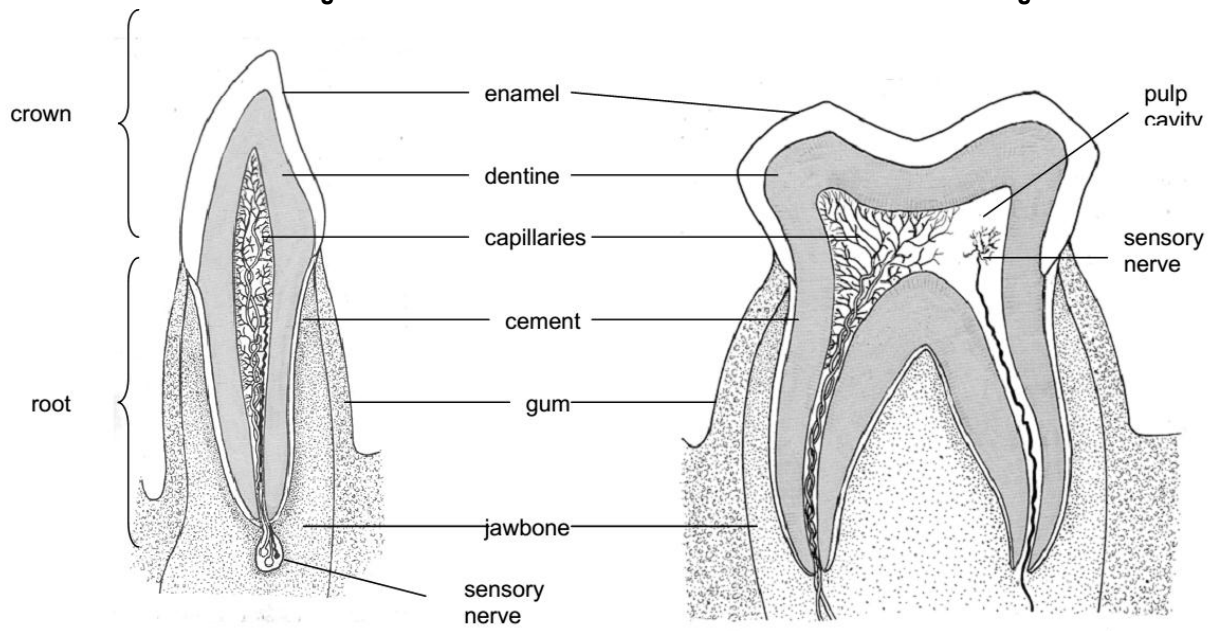
Each tooth consists of a crown, Neck and root.

i) **Crown:** This is a region of the tooth which projects above the gum; it is used for breaking down food.

ii) **Neck:** This is the junction between the crown and the root.

iii) **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.

Vertical section through an incisor **Vertical section through molar**



Functions of the parts of the tooth

i) **Crown**; this break down food into small particles during chewing, grinding and cutting.

ii) **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.***

iii) **Root**; this fixes the tooth into the jaw.

iv) **Dentine**; this strengthens the tooth.

v) **Pulp cavity**; this contains nerves that provide sensitivity to the tooth and blood vessels that transport food and oxygen to the tooth.

vi) **Gum**; this is fibrous which fixes or anchors the teeth firmly in the jaw. It is also called the gingiva.

vii) **Cement**; this is a thin layer of bone-like material that fixes the tooth in the jawbone.

Dental formula

This is a formula indicating the number of each type of teeth in half 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**

The dental formula of an adult human is written as below:

$$\mathbf{I}\frac{2}{2};\ \mathbf{C}\frac{1}{1};\ \mathbf{PM}\frac{2}{2},\ \mathbf{M}\ \frac{3}{3} = 32$$

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 formulae of some animals

Mammal	Dental formulae	Total number of teeth
Man		32
Dog	I $\frac{3}{3}$; C $\frac{1}{1}$; PM $\frac{4}{4}$, M $\frac{2}{3}$	42
Rat	I $\frac{1}{1}$; C $\frac{0}{0}$; PM $\frac{0}{0}$, M $\frac{3}{3}$	16
Cow	I $\frac{0}{3}$; C $\frac{0}{1}$; PM $\frac{3}{3}$, M $\frac{3}{3}$	32

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) Periodontal 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 periodontal diseases known are; Pyorrhea and Gingivitis.

They are characterized by reddening of the gums, bleeding and presence 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.
- 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 by 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.

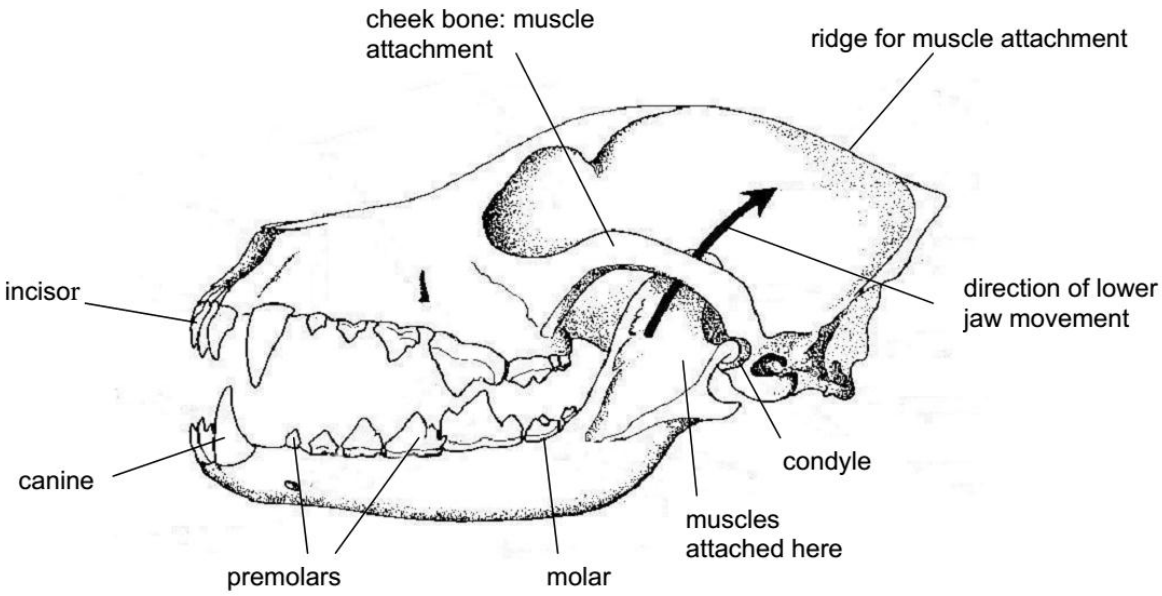
Their incisors are chisel shaped and enable them to grip and strip off pieces of flesh from bones.

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.

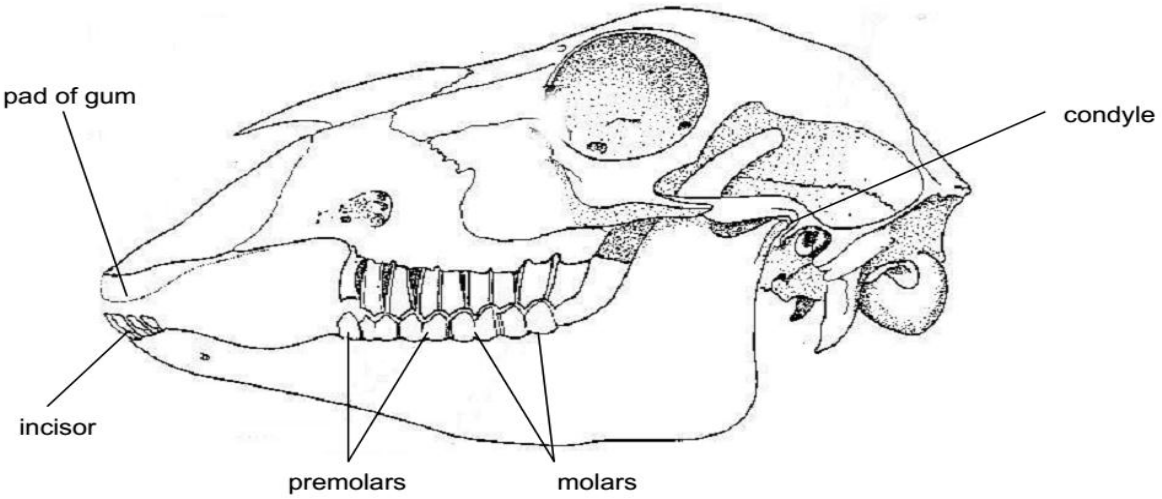
Diagram showing dentition in the carnivore e.g. a dog



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 vegetables 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 (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.

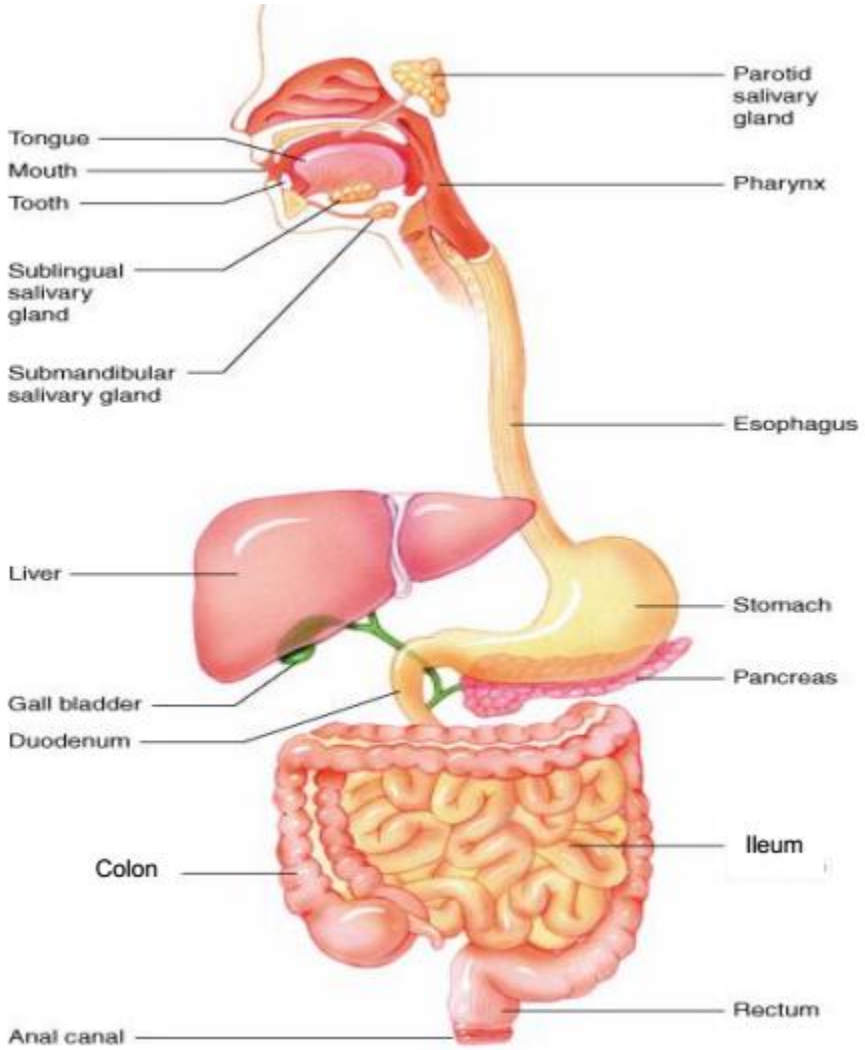
Steps involved in digestion of food

Ingestion ⟶ Digestion ⟶ Egestion

Ingestion: This 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



Digestion in the mouth

Digestion in the mouth is both physical and chemical.

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.

Chemical digestion in the mouth:

Chemical digestion is carried out by the enzyme salivary amylase (ptyalin)

Saliva is an alkaline watery solution (high PH) and it provides the optimal PH for the action of amylase.

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

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

The act of swallowing:

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 protein in baby mammals from soluble milk protein caseinogen to an insoluble curd, casein which is then acted upon by pepsin breaking it down to polypeptide.

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 chyme 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 pancreas

Functions of bile

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

The arrival of food in the duodenum stimulates the production of a hormone called ***secretin*** from the pancreas 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.

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

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 peristalsis.

In the stomach; no digestion of starch occurs because of acidic conditions due to presence of hydrochloric acid which provide un favourable 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.

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

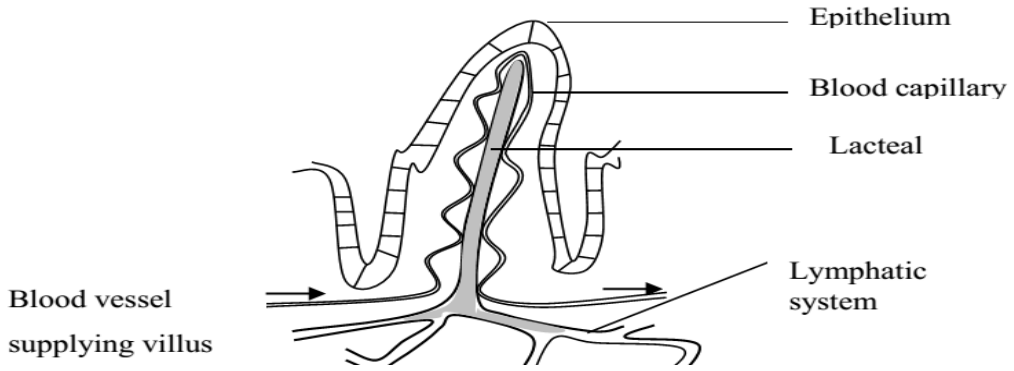
Absorption is the process by which soluble products of digestion diffuse through the cellular lining of the villi into the blood stream.

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 finger-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 which ***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.

Question:

Describe the fate of the absorbed food materials in the human body? Or

Describe what happens to the absorbed food materials in the human body after they are absorbed?

Solution:

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, proteins and lipids.
ii) 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.
iii) 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).
iv) 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.
v) 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.
vi) 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.
vii) 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.
viii) Detoxification. The liver convert 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.
ix) 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.

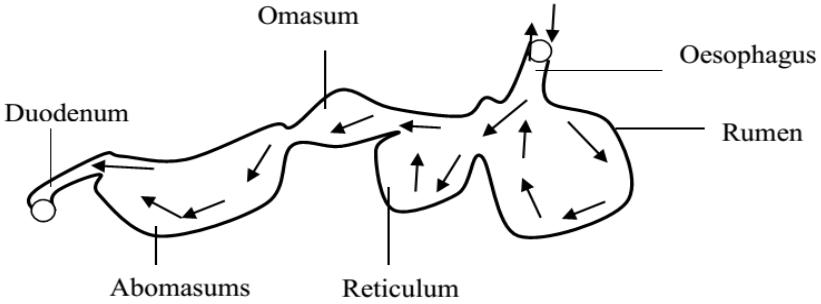
Fortunately, some of these micro-organisms can live in the guts of herbivores in a harmless beneficial nutritional association called ***symbiosis.***

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; Rumen, Reticulum, Omasum and 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).

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.

Comparisons 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
Chew cud.	Do not chew cud.
Have a four chambered stomach.	Have a single stomach.
Ptyalin (salivary amylase is absent in saliva.	Ptyalin is present in saliva.
Most digestion and absorption takes place in the stomach.	Most digestion and absorption takes place in the ileum.
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 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.

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

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

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:

i) **Leaves are broad and flat:** This provides a large surface area for trapping sunlight and taking in of Carbon dioxide.

ii) **Numerous leaves:** This helps to increase the total surface area exposed to the sun thus increasing the rate of photosynthesis.

iii) **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.

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

Internal adaptation of a leaf:

v) **Palisade mesophyll layer contains numerous chloroplasts** especially the palisade thus it is the best position to receive sunlight.

vi) **The spongy mesophyll** layer has mainly **air spaces** thus allowing many gases to easily diffuse into all the photosynthesizing cells.

vii) **Network of veins (vascular tissues) which** 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.

viii) **Presence of stoma which** 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.

ix) **Has cuticle** which is a water proof layer and so it helps to prevent desiccation (water loss) by the photosynthesizing tissues.

x) **Numerous chloroplasts** ensure that enough sunlight is trapped by the chlorophyll.

Factors that affect the rate of photosynthesis

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

The larger the area for photosynthesis (more leaves) the more light energy is absorbed which causes increased rate of photosynthesis.

7) Availability of water

Importance of photosynthesis

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.

AN EXPERIMENT TO TEST A 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 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.

AN EXPERIEMENT TO SHOW THAT OXYGEN IS GIVEN OFF DURING PHOTOSYNTHESIS

Apparatus:

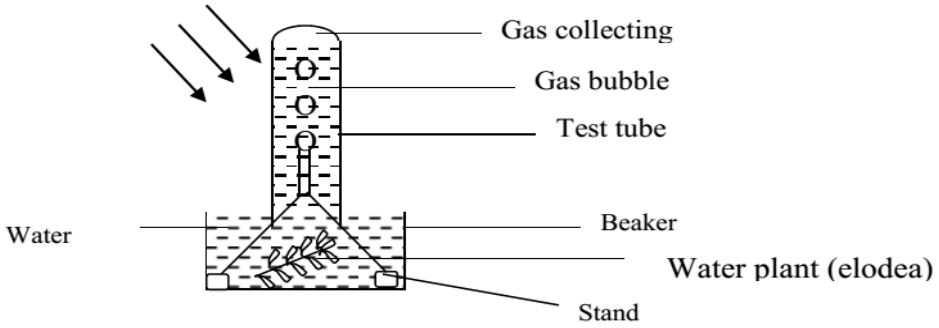
- Afresh water weed.
- Funnel and wooden blocks.
- Test tube,
- beaker
- Water.
- Sodium hydrogen carbonate.

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 evolved.

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.

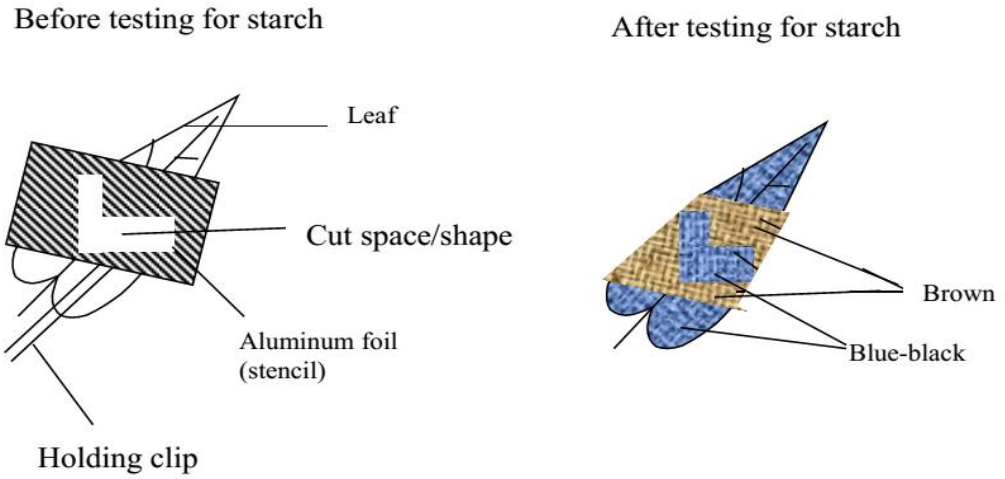
AN EXPERIMENT TO SHOW THAT LIGHT IS NECESSARY FOR PHOTOSYNTHESIS

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 de-starch 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.



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.

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

Apparatus:

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

Procedure:

a) The leaves of a potted plant are de-starched by keeping the plant in darkness for two days.

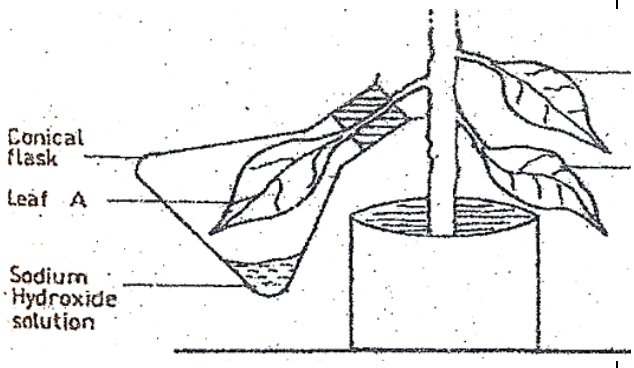
b) The petiole of the leaf (stalk) is passed through the hole in the cork so that the leaf is completely enclosed in a flask containing Sodium Hydroxide (The Sodium Hydroxide absorbs all Carbon dioxide enclosed in the flask.)

c) The flask is then made air tight by smearing Vaseline at the neck of the flask to prevent any air from entering.

d) A control experiment is also set up, however here the flask contains water which does not absorb Carbon dioxide.

e) The plant and the flasks are then placed in sunlight for 6 hours.

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



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.

AN EXPERIMENT TO SHOW THAT CHLOROPHYLL IS NECESSARY FOR PHOTOSYNTHESIS

Apparatus:
- A beaker,
- Alcohol,
- white tile
- Plant with variegated leaves.
- Iodine,
- test tube, and

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 de-starching (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 compensation point

Both respiration and photosynthesis take place in a green plant. In darkness, Green plants do not photosynthesize, however they continue to respire. Here oxygen is used up (through respiration) and carbon dioxide is given off and there is an overall net consumption of sugars and glucose 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 (glucose) 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.

MINERAL NUTRITION IN PLANTS

Pants need mineral elements for proper growth. Mineral elements are divided into two categories depending on the relative amounts of element needed.

i) **Essential elements:** These are elements needed in large quantities for proper plant growth, e.g. nitrogen, phosphorus, magnesium, potassium, calcium, sulphur, carbon, hydrogen, oxygen, etc.

ii) **Trace elements:** These are elements need in small quantities for proper plant growth they include manganese zinc boron silicon aluminum copper, molybdenum, and iron.

Plants obtain minerals from mineral salts present in the soil; Mineral salts are absorbed in form of soluble salts e.g. nitrogen as nitrate, phosphorus as phosphates, sulphur as sulphate. When a particular element is missing in the soil, a plant shows deficiency signs.

TRANSPORT OF MATERIALS IN ORGANISMS

This refers to the movement of materials from one part of the organism to another.

Requirements of transport system

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

Materials to be transported:

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

The medium of transport:

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

The channels of transport:

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

Energy:

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

MOVEMENT OF MATERIALS IN AND OUT OF CELLS

Substances like nutrients and excretions move in and out of the cell by:

1. Active transport
2. Phagocytosis
3. Pinocytosis
4. Diffusion
5. Osmosis

Movement of substances depends on the permeability of the cell membrane or cell wall.

Pinocytosis

This is the process by which animal cells take in liquid materials into their bodies. Thus it is said to be cell-drinking.

Phagocytosis

This is the process by which animal cells take in solid materials. The cell engulfs/invaginates or takes in solid materials and form a food vacuole where the food is digested.

Importance of phagocytosis

1) Used by amoeba during feeding
2) White blood cells destroy pathogens by phagocytosis
3) Unicellular animals egest undigested material by phagocytosis

Active transport

This is the *movement of molecules from the region of* ***low concentration*** *to the region of* ***higher concentration*** **against concentration gradient using energy**.

Examples of active transport

1) Up take of mineral salts from soil by plant roots
2) Absorption of some food molecules e.g. glucose
3) Selective re absorption of molecules e.g. glucose

Importance of active transport

1) Used by plant roots or root hairs to absorb minerals from the soil.
2) Used in the absorption of food materials from the ileum into the blood stream
3) Used in the reabsorption of minerals in the kidney during urine formation
4) Used in the secretion and active uptake of ions in the fish gills from fresh water

DIFFUSION

This is the ***movement of molecules of gases and liquids from a region of high concentration to a region of low concentration***. Diffusion occurs because small molecules are in constant random motion. Molecules of gases and liquids by random motion tend to distribute themselves evenly, throughout the available space, unlike in solids where molecules are closely packed together and have no freedom of movement. Diffusion only takes place where there is a difference in concentration i.e. where there is a concentration gradient and continues until there is even distribution of molecules.

Experiment to demonstrate diffusion in gases

Apparatus

- Wet red litmus paper,
- cotton wool,
- glass tube,
- ammonium solution,
- glass rod

Method

Some strips of wet red litmus papers are stuck on the walls of a glass tube as indicated below.

The glass tube is corked as one end and a piece of cotton wool is soaked in ammonium solution and is introduced at the other end which is also plugged.

Procedure

Squares of wet red litmus paper were pushed with a glass rod or wire into a wide glass tube so that they stick to the side and are evenly spaced out. The glass tube is corked at one end the other end is closed with a cork carrying a plug of cotton wool, soaked in ammonia

Observation

The alkaline ammonia gas, diffused along the glass tube, turning the litmus papers blue in succession from 1to 5, showing that the ammonia gas was diffusing from one end to the other.

NB: If the experiment is repeated using more dilute solution of ammonia, the rate of diffusion would be seen to be slower.

Experiment to demonstrate diffusion in liquids

Materials

- Glass beaker
- Potassium permanganate crystals
- Water
- spatula

Procedure

Fill a glass beaker with about 50cc of water

Place a few crystals of potassium permanganate at the base of the beaker in the water.

Leave the set up for about 30 minutes.

Observation

After 30-40 minutes, the potassium permanganate color will have spread first at the bottom and later upward to color all the water in the beaker.

Conclusion

Diffusion occurs in liquids.

Factors affecting the rate of diffusion

1) Concentration gradient

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

2) Temperature

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

3) Size/density of molecules

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

4) Distance over which diffusion occurs

The shorter the distance between the two regions of different concentration, the greater is the rate of diffusion like the alveoli of lungs or the epithelial linings of the ileum are thin to provide a short distance for diffusion thus increasing the rate of diffusion.

5) Surface area over which diffusion occurs

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

Types of diffusion

Simple diffusion

This is the type of diffusion where molecules or ions move freely across the cell membrane without being aided.

Facilitated diffusion

This is where molecules or ions move across the cell membrane by being aided by protein carriers using energy.

Significance of diffusion to organisms

i) It helps substances to move in and out of cells.
ii) Plant root hairs take up some salts by diffusion
iii) Unicellular microorganisms like amoeba, take in oxygen and pass out carbon dioxide through the cell membrane by diffusion.
iv) Digested food e.g. simple sugars, amino acids, enter the blood from the gut by diffusion.
v) Once dissolved in blood, the food substances diffuse out of the blood into the cells where they are needed.
vi) Oxygen diffuses into blood and CO_2 out of blood in the lungs of mammals and gills of fish by diffusion.
vii) Waste products of metabolisms e.g. nitrogen containing substances like urea, diffuse out of the animal cells into blood.

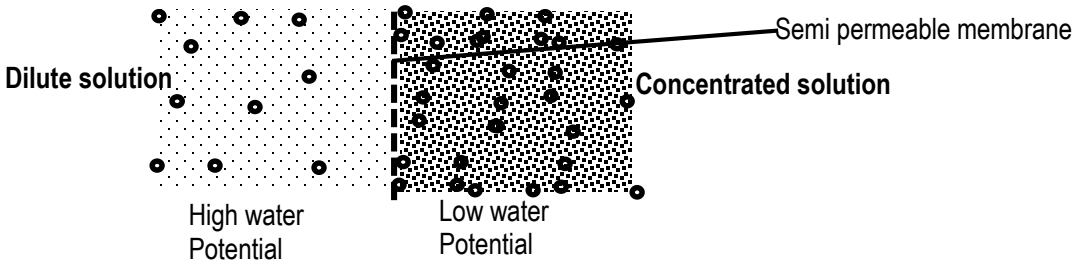
OSMOSIS

This is the ***movement of water/solvent molecules from a dilute solution to a concentrated solution across a semi permeable membrane.***

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

A semi/partially/selectively permeable membrane is one which can allow the passage of some materials to occur and prevent other materials from passing across it.

Diagram showing details of osmosis



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

Experiment to demonstrate osmosis in an artificial membrane

Materials

- ✓ Cellophane /visking tube,
- ✓ Capillary tube,
- ✓ Beaker,
- ✓ Syrup or sugar solution,
- ✓ Thread,
- ✓ Clamp

Procedure	**setup**
i) Tie one end of the visking tube using a thread.	
ii) Make a sugar solution and pour it into the tube	
iii) Tie the open end of the tubing to the capillary tube using a thread.	
iv) Pour some water in the beaker half way full.	
v) Insert the capillary tube with the visking tube into water in the beaker.	
vi) Note the level of the solution in the capillary tube and that of water in the beaker.	
vii) Clamp the capillary tube on a retort stand and leave the set up for 30 minutes.	

Observation

In a few minutes, the level of the solution is seen to rise up the capillary tube

Interpretation

- Water molecules are passed through the cellophane tubing into the sugar solution by osmosis, thus increasing its volume and forcing it up the capillary tube.
- Water acts as a dilute solution
- Sugar solution acts as a concentrated solution
- Membrane of the visking tubing acts as the semi permeable membrane.

Experiment to demonstrate osmosis in a living tissue

Apparatus

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

Procedure

a) 3 fresh Irish potatoes are peeled and their ends sliced flat. The interiors are scooped out to form a 'cup' with walls of uniform thickness. The potato cups are labelled ***A***, ***B*** and ***C*** respectively.

b) In ***A***, some grains of sugar are placed in the cup, while the other potato ***B*** is left empty as a control.
c) The third potato 'cup' ***C*** is boiled to kill or destroy the tissues and also some sugar grains are put in it.
d) All the potato cups are placed in water in Petri dishes. The experiment is let to run for 2-6 hours.

End of experiment (2-6 hours)

The liquid in the cup potato ***A*** had risen to form a sugar solution and in the Petri dish, the level water had fallen.

In potato ***B*** and in the boiled potato, the cups were still empty and the water level in the Petri dishes remained the same.

Conclusion

Osmosis takes place in living tissues and does not take place in boiled tissues. This is because, by boiling, the tissues are destroyed and loose semi permeability

Explanation

Living tissues have cell membrane or cell walls acting as semi permeable membrane and allow water to move through by osmosis while boiling a living tissue makes it impermeable.

Terms used in osmosis

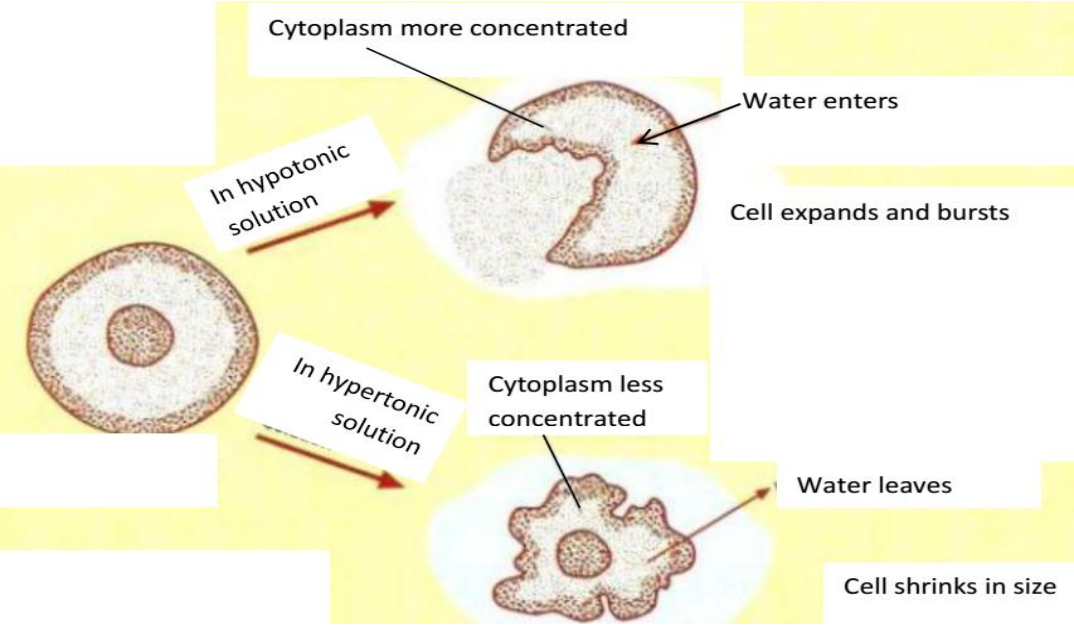
1) **Osmotic potential:**
   This is the capacity of a solution to allow in water molecules by osmosis. Therefore a concentrated solution has a higher osmotic potential than a dilute one.
2) **Osmotic pressure:**
   This is the force that must be applied to stop water molecules from entering that solution,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

Osmosis in red blood cells

Unlike plant cells, animal cells like red blood cells lack a cell wall and only have a cell membrane which is weak and non-resistant to high internal pressure.

When red blood cells are placed in a dilute solution (hypotonic solution) i.e. distilled water, the cells swell up and eventually ***burst (haemolyse***). This is because water moves from the surrounding solution (distilled water) via the semi permeable cell membrane into cells.

Hemolysis in red blood cells



When the red blood cells are placed in a more concentrated solution (hypotonic solution) e.g. a strong sugar solution, water moves out of the cells to the surrounding solution by osmosis. As a result, the cells shrink, the process called crenation.

However, when red blood cells are placed in isotonic solution they neither gain nor lose water.

Osmosis in plant cells

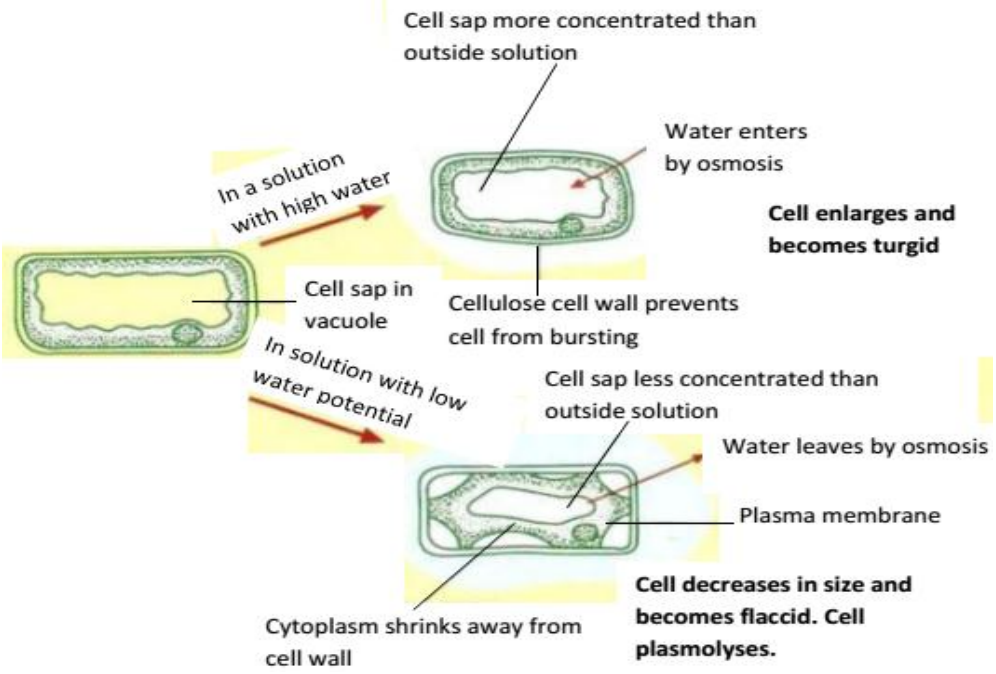
Plant cells possess a rigid cell wall which prevents the cell from bursting.

When a plant cell is placed in a dilute solution (water) than the cell sap, water enters by osmosis through the semi permeable cell wall and cell membrane into the cell sap. The volume of cell sap increases and it makes the sap vacuole expand. This causes the cytoplasm move towards the cell wall thus gaining ***turgidity***. Time comes when all the cytoplasm is pressing against the cell wall and no more water can be absorbed. At this state, the cell is said to have gained ***full turgidity*** and the force on the cell wall is called ***turgor pressure***.

A condition when water is lost from the cell to the surrounding causing the vacuole to shrink and the cytoplasm to lose contact with the cell wall is called ***plasmolysis.*** When the cell is in this condition, it is said to be ***flaccid or plasmolysed***. Therefore a flaccid cell is one whose cytoplasm has lost contact with the cell wall due to loss of water from the cell sap of the vacuole.

When the cell is placed in a more concentrated solution than the cell sap, water moves from the cell sap through the cytoplasm then the cell wall, to the surrounding solution. This causes the vacuole to shrink and the cytoplasm to lose contact with the cell wall and the cell is said to be flaccid or plasmolysed.

Diagram showing a plasmolysed plant cell



Experiment to demonstrate turgor and plasmolysis

Materials

- ✓ Cock borer
- ✓ Four beakers
- ✓ Water
- ✓ Irish potato
- ✓ Razor blade
- ✓ Sugar crystal.

Procedure

i) Get four beakers and pour ¾ of water in 3 of them and leave one empty.

ii) Mix the sugar in one beaker to make 5% solution.

iii) Mix sugar in another beaker to make 50% solution.

iv) Leave one beaker with pure water.

v) Leave the forth beaker empty.

vi) Using a cock borer, make 4 potato cylinders of the same length e.g. 3.0 cm. Name this the initial length.

vii) Deep the potato cylinders in each beaker.

viii) Leave the setup for one hour and observe.

Remove the cylinder from each beaker and measure each length. Also feel the texture. Tabulate your results in the table below.

Beaker	Initial length/cm	Final length/cm	Change in length/cm	% change in length	Texture (soft/tough)
Pure water	3.0	3.3	+0.3	+10.0%	Tough
5% sugar solution	3.0	3.0	0	0	Tough
50% sugar solution	3.0	2.8	-0.2	-0.67%	Soft/flaccid
Empty beaker	3.0	2.9	-0.1	-0.33%	Soft

Observation:

The cylinder in water had increased in length and became tougher.

The cylinder in 5% sucrose solution didn't have any change in length and the texture remained the same

The cylinder in 50% sucrose solution had decreased in length and become soft, flaccid and curved.

The potato in the empty beaker decreased in length.

Conclusion: Turgor and plasmolysis occur in plant cells.

Explanation

- The cylinder in water increased in length because water molecules moved into it from the surrounding water by osmosis because the cell sap had a higher concentration than the surrounding water.
- There was no change in length for the cylinder in 5% sucrose solution because the solution had the same concentration as the cell sap of a potato cylinder hence no net osmosis.
- There was a decrease in length for the cylinder in 50% sucrose solution because water molecules moved out of the cylinder which had a lower concentration by osmosis.
- There was a decrease in length for the cylinder in the empty beaker because water was lost to the surrounding through evaporation.

Significance of osmosis in plants

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

Significance of osmosis in animals

i) Movement of water in to unicellular animals
ii) Movement of water from tissue fluid to the cell
iii) It enables reabsorption of water into the blood stream via the kidney tubules.

TRANSPORT IN PLANTS

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

THE XYLEM

This Consists of xylem vessels and tracheids. Xylem vessels develop from cylindrical cells, arranged end to end, in which the cytoplasm die and cross- walls disappear leaving a dead empty tube. Through this:
Water, mineral salts, move from roots, stems, up to leaves.
Xylem vessels are strengthened by lignin in their walls. This strength gives support to the soft tissue of roots, stems, and leaves: it also prevents collapse of the vessels under tension as sap pressure changes.

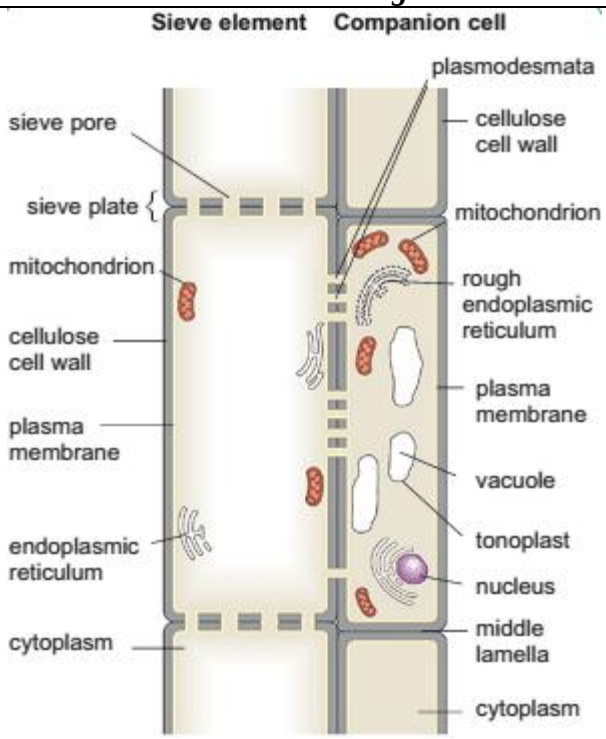
Characteristics of xylem tubes

a) Consist of dead cells
b) They are hollow
c) Its walls are lignified
d) Has no protein filaments
e) Has no cytoplasm
f) Transports water and salts

Structure of xylem

PHLOEM TISSUE

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



Characteristics of phloem tissue/tube

- Consist of living cells
- Have a thin cytoplasm
- Associated with companion cells
- Consist of sieve cross walls
- Consist of protein filaments
- Transport food materials

Structured comparison between xylem and phloem

Similarities:

- Both are perforated, i.e. xylem is bordered with pits and phloem has sieve pores in the sieve plates
- Both tissues are surrounded by parenchyma cells as packing tissues.

Differences:

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

TRANSPORT OF WATER FROM SOIL TO THE LEAVES

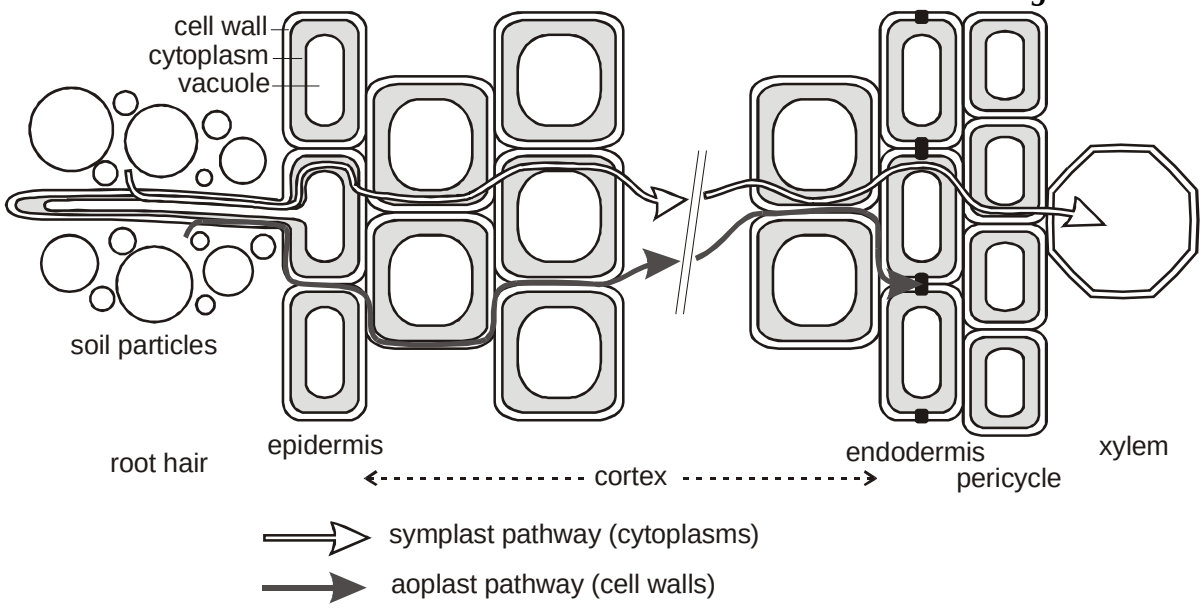
Water absorption by the root hairs to the xylem

Up take of water also called absorption is a continuous stream through the plant. Root hairs in the soil are surrounded by a film of water containing mineral salts/ soil solution.

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

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

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



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

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

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

The water rises up the xylem by the following forces:

Capillarity:

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

Cohesion – tension forces:

This is a force of attraction between the molecules of the same substance. Cohesion between water molecules allows water in a continuous column without breaking. This occurs because as water is lost by transpiration from the leaves, the water potential at the top of xylem vessels falls below that at the bottom of the xylem in the root. Water is now pulled by this potential difference because of the cohesion of the water molecules.

Adhesion:

This is the force of attraction between molecules of different substances. Adhesion forces between walls of xylem and water molecules support a considerable weight of water within the xylem tissue and prevent the water in the xylem vessels from collapsing.

Root pressure:

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

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

The root pressure theory has been suggested as a result of a common observation that water tends to exude from the cut stem indicating that some pressure in a root is actually pushing the water up. However, like capillary, root pressure is not sufficient on its own to push water to the leaves of the plant at the top of the tree and can slowly cause guttation in transpiring herbaceous plants.

Transpiration pull:

This is the pulling force generated by the evaporation of water from the leaves. This is caused when the cells of the spongy mesophyll layer in the leaf lose water by evaporation into the air spaces causing their cell sap to become more concentrated and as a result they draw the water from the surrounding cells by osmosis. These cells in turn get water from the xylem in the veins and then water from the xylem moves to replace the lost water by evaporation. This evaporation sets up the passing action on water in the xylem called transpiration pull.

Adaptations of the root hair to water absorption

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

Importance of water to the plant

- Raw material for photosynthesis
- Solvent for mineral salts and oxygen that enable them to diffuse into the roots.
- It is a constituent of the cytoplasm and all sap of the growing plants
- Provides turgidity which provides support in non woody plants
- Cools the leaves of the plants during transpiration

Absorption of mineral salts by the root hairs

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

TRANSPORT OF THE PRODUCTS OF PHOTOSYNTHESIS

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

The process of translocation process

The process of photosynthesis leads to accumulation of food substances in leaves. This causes a high turgor pressure within the leaves.

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

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

Evidence to show that food made in leaves is translocated by the phloem

1) The Ring Experiment:

Remove a ring of the bark from the stem at a point between the ground and the upper leaves. Leave another plant with the ring on. The plants are left to stand for one week after which the observation is made.

Observation

The upper part of the stem of the ring plant swells immediately above the ring while the lower part of the stem remains unswollen. The unringed plant remains unchanged.

Conclusion: The phloem transports manufactured food.

Explanation

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

2) Feeding Aphids:

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

3) Radio Active Tracers:

If a plant is exposed to CO_2 labeled with radioactive C-14, the C-14 becomes incorporated into the end products of photosynthesis which are subsequently detected in the stem. That these substances are confined to the phloem and can be shown by cutting sections of the stem, placing the sections in contact with photographic film and making auto radiographing it is found that the sites of radioactivity correspond precisely to the positions of the phloem.

TRANSPIRATION

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

Types of transpiration

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

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

An experiment to show that water is lost mainly from leaves during transpiration

Apparatus:

Potted plant, Polythene paper, String and Cobalt (II) chloride paper or anhydrous copper (II) sulphate.

Procedure

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

Observation

A vapour forms inside the polythene and turns into drops / liquid which turn anhydrous copper (ii) sulphate from white to blue or blue cobalt (ii) chloride paper to pink.

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

Conclusion: Transpiration occurs from the leaves

Note: A control experiment may also be a covered pot where the plant shoot has been cut off.

Experiment to compare transpiration rates on both surfaces of a leaf

Apparatus

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

Procedure

a) Fix pieces of Cobalt (ii) chloride paper on the upper and lower surfaces of a leaf still to the plant with glass slides.
b) Tie the slides using the rubber bands
c) Note the time taken for the Cobalt (ii) chloride paper on each slide to turn / change colour from blue to pink.

Observation

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

Conclusion

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

Factors that affect the rate of transpiration

1) **Temperature:** Increase in temperature increases the rate of transpiration. This is because high temperatures provide latent heat of vaporization which increases the evaporation of the water leading to more water to be lost. Temperatures also increases the kinetic energy of the air molecules around the leaf which causes them to move further apart and this increases rate of diffusion from the leaf
2) **Relative humidity:** Humidity is the amount of water vapour in the atmosphere. As humidity increases, the rate of transpiration decreases. This is because the environment becomes saturated with the water vapour. The water then can be absorbed from the plant decrease which reduces the rate of transpiration.
3) **Wind:** Rate of transpiration is higher in windy air than in still air. This is because wind helps / assists to remove water vapour in the air around the leaf and creates more spaces that can take up more water vapour.

4) **Light intensity:** Rate of transpiration is high in the presence of light and low in the dark. This is because high light intensity result in high rate of photosynthesis which increase the sugar concentration in the guard cells which lead to wide opening of the stomata leading to more evaporation from the plant (also light provide heat which increase evaporation from the leaf stomata.
5) **Atmospheric pressure:** Humidity decreases with decrease in atmospheric pressure. Hence decrease in atmospheric pressure greatly increases the rate of transpiration due to decreased humidity.

Non environmental factors

6) **Distribution of stomata:** The rate of transpiration is low when more stomata are on the lower side and is higher when more stomata are on the upper side of the leaf.
7) **Number of stomata:** The greater the number of stomata, the higher the rate of transpiration because more water vapour is lost through the stomata.
8) **Surface area for transpiration:** Plants with wide/broad leaves have a larger surface for transpiration thus they experience a higher rate of transpiration.
9) **Thickness of the plant cuticle:** The rate of transpiration decreases with increase in thickness of the cuticle. For that reason, plants found in deserts have extremely thick cuticle than those in tropical regions.

Experiments to measure the rate of transpiration

1. The weighing method:

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

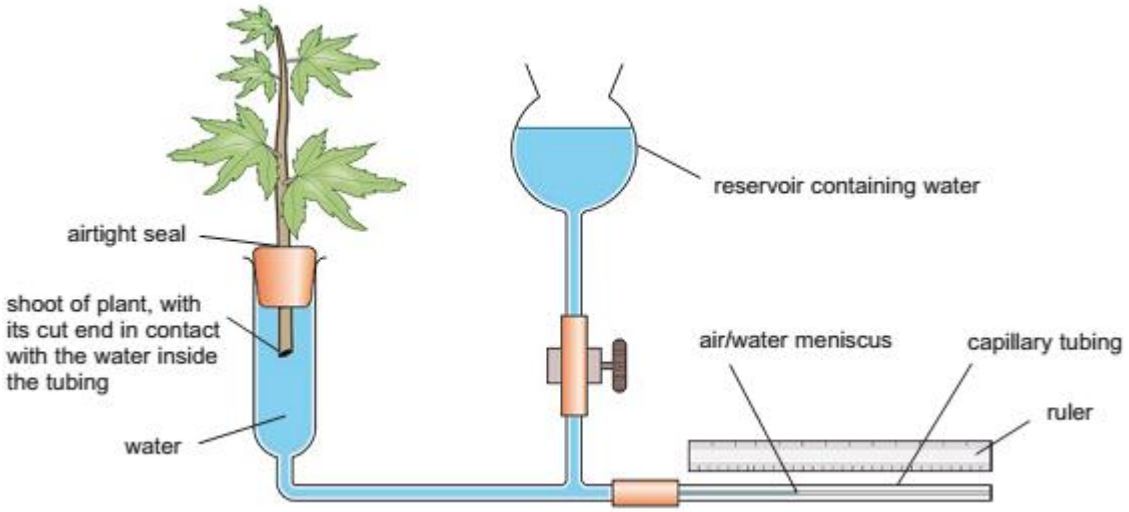
2. Potometer method:

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

Therefore the potometer:

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

Set up of a potometer



Procedure:

i) A leafy shoot of a plant is cut under water to prevent air bubbles from entering as these would block the xylem vessels.
ii) The potometer is filled with water.

iii) The leafy shoot is fixed into the cork and then fitted into the mouth of the potometer vessel.
iv) Vaseline is smeared at the interface of the shoot and the cock to prevent entry of air into the apparatus.
v) A single air bubble is introduced at the open end of the capillary tube by touching the open end briefly under water and then release.
vi) At a given mark V_1, reached by the air bubble, a clock is started and after a given time t, the new position of the air bubble V_2, is noted and recorded.

Rate of transpiration $= \frac{distance\ moved\ by\ the\ air\ bubble}{time\ taken}$

$= \frac{V2-V1}{t}$

vii) In any given set of environmental conditions, about 3 experiments can be performed, resetting the air bubble after each experiment by opening the tap and then close.
viii) Average rate is then calculated and taken as the rate of transpiration in that environment.
ix) The set up can be moved to different environmental conditions and rate of transpiration determined in the same way.

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

- A leafy shoot should be used to ensure significant water loss.
- The shoot must be cut under water to prevent air from entering and blocking the xylem vessels.
- The whole apparatus must be full of water.
- A single air bubble must be present in the capillary tube fir each experiment.
- Air bubble must be reset to zero mark before each experiment
- A graduated capillary tube must be used in order to clearly read results.
- Air bubble should not cross the T- function at the reservoir

Adaptations of plants to reduce transpiration rate

i) Shedding off of leaves in deciduous plants to reduce transpirations since most of it occur from the leaves
ii) Reducing the number, size and distribution of the stomata and only on lower epidermis
iii) Structural adjustments in stomata i.e. some plants have sunken stomata and others have hairy stomata which reduces evaporation from them.
iv) Reduction in leaf structure i.e. some plant leaf are reduced to narrow or thorny / spines structures that reduce surface area over which transpiration occurs.
v) Rolling of leaves to create a humid atmosphere around the stomata in order to reduce water loss.
vi) Possession to thick cuticle of the leaves to prevent water loss through it.
vii) Thick leaves that store water
viii) Changes in the rhythm of stomata opening i.e. they close during day and open at night when temperatures are very low.
ix) They shed off their leaves in extremely hot environment to cut down water loss.
x) Reversed opening and closing of stomata. Stomata open at night and close during the day when its rate of transpiration is likely to be higher.

Importance of transpiration (functions / advantages)

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

Disadvantages / dangers of transpiration

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

TRANSPORT OF MATERIALS IN ANIMALS

Smaller organisms (protozoa) that have large surface area to volume ratio carry out transport by simple diffusion.
Transport system is important in large organisms (multicellular) because the increased size of the organisms and the great distance over which materials are supposed to move makes diffusion rate slow which in turn make it inadequate for the distribution of these materials.
To overcome the physical limitation on size placed by diffusion, multicellular animals have the major adaptations. They have organs that provide a large surface area for absorption of nutrients such as small intestines and exchange of gases such as lungs/ gills, without a great increase in total body volume. They have a transport (circular) system within the body, so that substances can be carried to cells that need them and waste products removed more quickly than in diffusion.

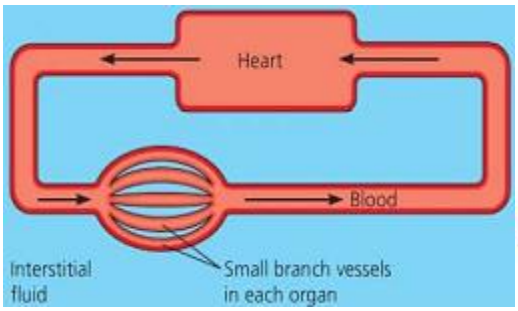
Plants do not need a circulatory system because:

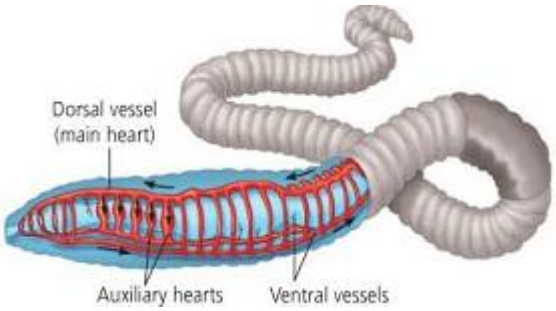
- The oxygen requirement of the plant is very low as compared to mammals.
- Plants have a continuous series of airspaces throughout the body opening to the atmosphere by the stomata and ventricles.
- In plants oxygen from the air diffuses through the stomata opening in to the airspaces and from the air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

CIRCULATORY SYSTEMS IN ANIMALS

1. Closed circulatory system:

Closed circulatory system e.g. in earthworm, fish and mammals have blood enclosed in tubes. Here blood is pumped by the heart to tissues through the arteries and return to the heart through the veins. The arteries and veins are connected by capillaries which are thin walled.
The body cells do not come in to direct contact with blood but are bathed in the tissue fluids. Substances diffuse out of the blood which is confined to blood vessels into the tissue fluid and then across to cell membrane into the cell.





Advantages of closed circulatory system

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

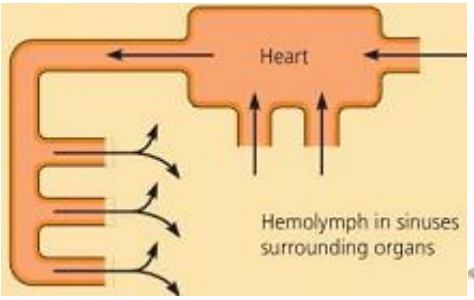
Demerits of closed circulatory system

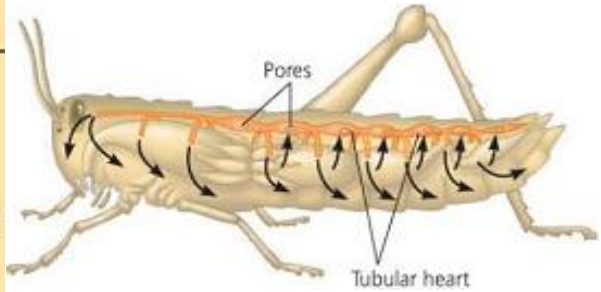
- ✓ It requires a special heart whose pumping action provides pressure for movement of blood.
- ✓ Blood movement meets a high resistance within vessels.

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

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

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





Advantages of open circulatory system

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

Disadvantages of open circulatory system

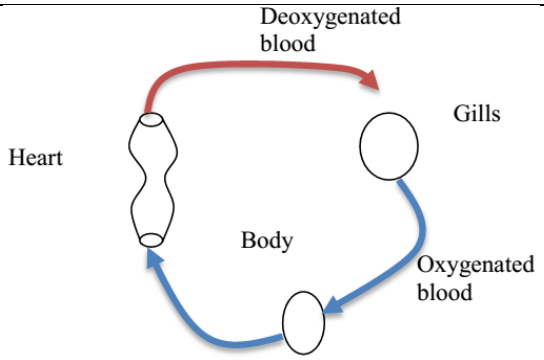
- ✓ Blood flows sluggishly/slowly leading to slow supply of materials.
- ✓ Blood flows at a low pressure.
- ✓ There is little control over distribution of materials or blood.

TYPES OF CLOSED CIRCULATORY SYSTEM

1. Single circulatory system:

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

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



2. Double circulatory system

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

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

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

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

Double circulation is further divided into 2;

- Incomplete double circulation
- Complete double circulation

Incomplete double circulation: This is a system in which blood flows through the heart twice for every complete cycle through a three-chambered heart. The heart has one ventricle through which both oxygenated and deoxygenated blood from the two atria flow.

Mixing of oxygenated and deoxygenated bloody is prevented by ridges present in the ventricle. This system of blood circulation is found in amphibians like frogs.

Diagram of incomplete double circulation

Complete double circulation

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

Diagram showing complete double circulation

Advantages of double circulatory system

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

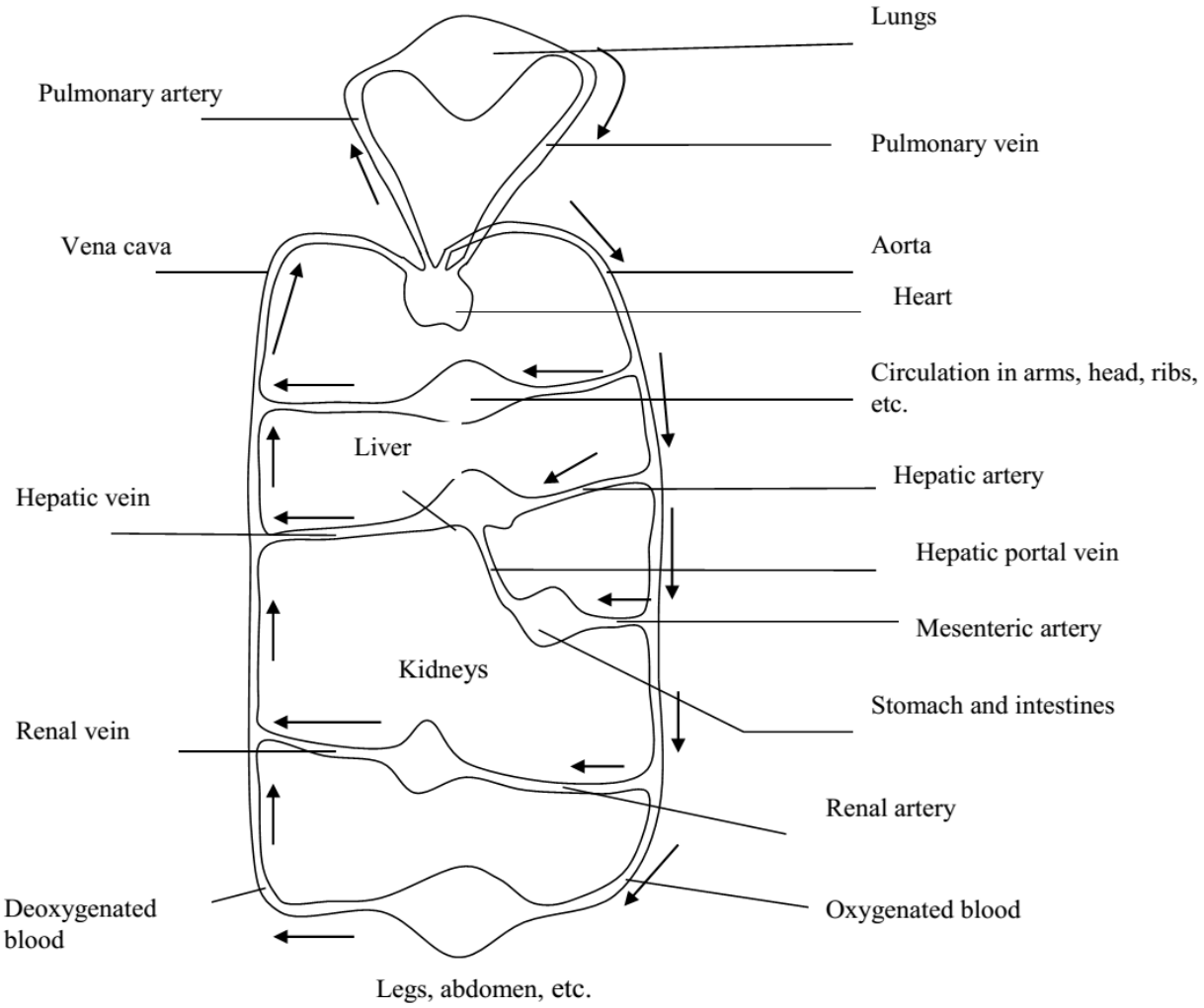
Note: The amount of blood flowing to a certain organ can be regulated by changing the diameter of the blood vessel.

THE MAMMALIAN CIRCULATORY SYSTEM

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

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

Structure showing the flow of blood in a mammal



BLOOD VESSELS

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

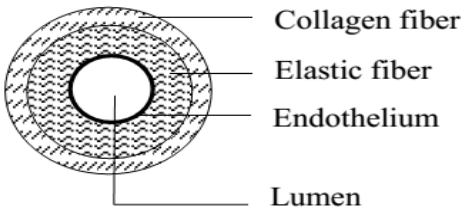
Arteries and veins both have three layers in their walls but the layer of the muscles (elastic tissue).is much greater in arteries than in the veins.

1. ARTERIES:

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

Characteristics of arteries

- Has three layered wall. These are strong to withstand the higher pressure as resulting from the pumping action of the heart.
- They have fibrous outer wall so as to withstand high pressure
- They are found deeply in the body.
- Their walls are elastic to allow stretching due to high blood pressure.
- They have no valves except at the base of the pulmonary artery and aorta.
- They have narrow lumen than veins which maintains blood flow at high pressure.
- They carry oxygenated blood except the pulmonary artery and umbilical artery.
- They all carry blood from the heart to other parts of the body.



2. CAPILLARIES

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

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

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

Blood pressure reduces in them as a result of their resistance, and blood flows in them slowly without pulse. The capillaries network is so dense and the capillaries unite to form large vessels called venules which join to form veins.

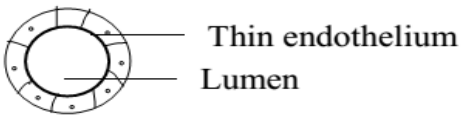
Adaptations of capillaries to its functions

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

Characteristics of capillaries

i) They carry both deoxygenated and oxygenated blood.
ii) They have a small lumen.
iii) They have permeable thin walls to allow diffusion of materials.
iv) They have no valves.
v) Blood flows slowly.
vi) There is a decrease in pressure.

Cross-section through a capillary



3. VEINS

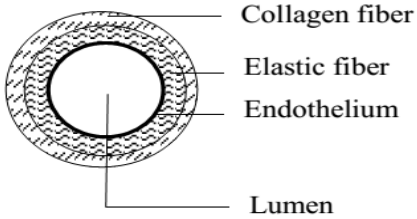
These carry blood from tissues to the heart. The pressure in them is steady and less than in arteries. All veins carry de-oxygenated blood except pulmonary vein. Blood in the veins flows slowly after losing pressure in the capillaries; however the sluggish flow of blood is maintained by:

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

Characteristics of veins / Adaptations

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

Cross section through a vein



Differences between arteries, veins and capillaries

Structural:

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

Functional

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

THE MAMMALIAN HEART

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

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

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

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

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

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

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

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

The ventricle walls are more muscular (have thicker walls) than those or the auricles because the auricle pump blood to shorter distance i.e. to the ventricle while the ventricles pump blood longer distances i.e. to body and lungs.

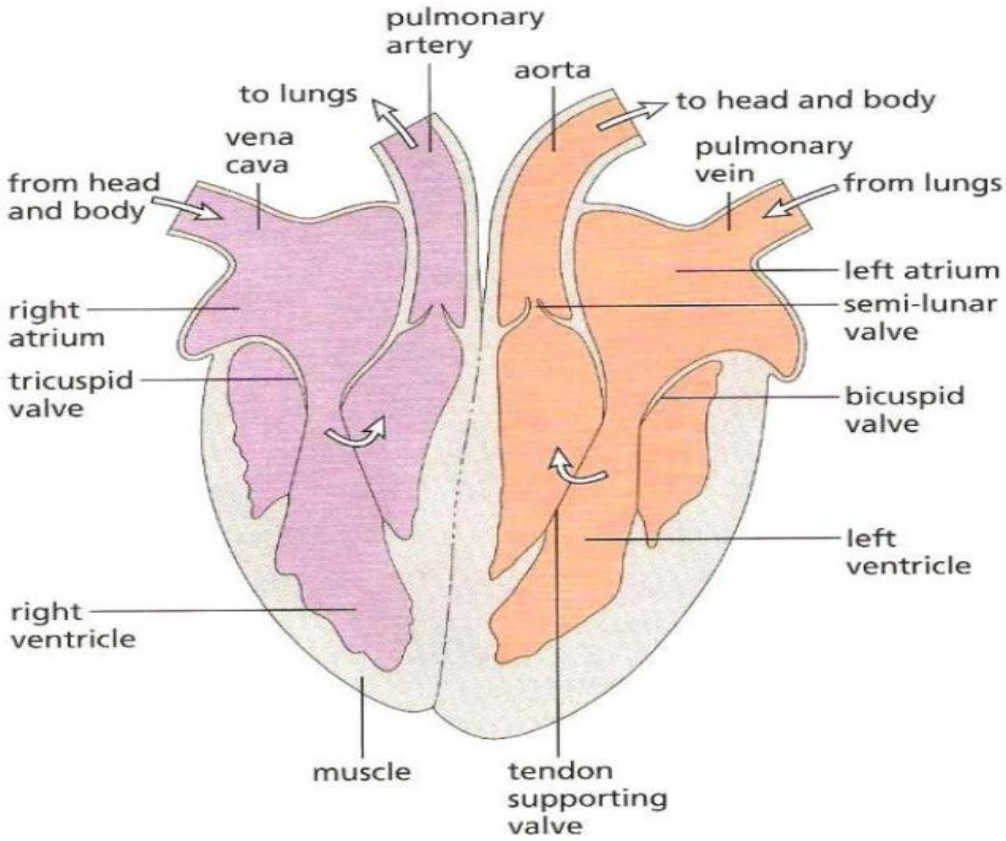
The walls of the left ventricle that pump blood in to the systemic circulation are thicker than those of the right ventricle which pump blood to pulmonary circulation.

Flow of blood through the heart:

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

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

Longitudinal section of the heart



THE CARDIAC CYCLE

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

- Re-filling of the heart with blood
- Pumping of blood

The pumping action of the heart consists of alternate contraction and relaxation of cardiac muscles in the walls of the heart. Contraction of cardiac muscles is called ***systole*** while relaxation is called ***diastole***.

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

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

After expelling blood, ventricles relax and their pressure lowers compared to aorta and pulmonary artery pressure. This would cause back flow of blood to the heart but is prevented by sudden closure of the semi lunar valves. The closure of the semi lunar valves causes a second heart sound called '***dub'.***

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

Initiation and control of the heart beat

Contraction of the heart is initiated by heart, heart muscles/cardiac muscles themselves. Therefore the heart muscles are myogenic i.e. the rhythmic contraction a rise from within the tissue itself.

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

Factors affecting the heart beat rate

- Exercise.
- Lack of hormones in the body e.g. adrenaline
- State of health and diseases e.g. malaria
- Age i.e. it's faster in infants than adults.
- Body size i.e. it is faster in small organisms than large
- Sex i.e. faster in female than in male.

NB: In normal adults at rest, heart contracts about 70 to 72 times per minute.

Blood pressure

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

BLOOD

Blood is a connective tissue made up of cells suspended in a fluid matrix called ***plasma.*** There are two types of cells in blood i.e. **White blood cells (leucocytes) and red blood cells (erythrocytes)**. The **platelets (thrombocytes)** are **fragments of cells.**

In an adult human being, there are five to six liters of blood with blood making up approximately 10% of the body weight.

Main components of blood

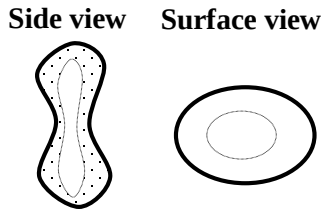
i) Red blood cells/erythrocytes
ii) White blood cells/leucocytes
iii) Platelets/thrombocytes
iv) Plasma

General importance of blood in the bodies of animals

i) It transports oxygen from the lungs to all parts of the body.
ii) It transports digested food from the ileum to other parts of the body for use.
iii) It transports Carbon dioxide from the tissues to the lungs.
iv) It transports nitrogenous wastes from the liver to the kidney where they are excreted.
v) It transports hormones from their site of production to where they perform their functions.
vi) It distributes heat and aids in temperature control.
vii) It prevents infection by transportation of white blood cells.

THE RED BLOOD CELLS (ERYTHROCYTES)

Characteristics of Red Blood Cells



- They have hemoglobin molecules which carry oxygen from the lungs to the tissues.
- They lack nuclei
- They have thin cell membranes which thinness reduces the diffusion distance for gases.
- They are manufactured from the red bone marrow.
- On average, red blood cells last for four month after which they are destroyed by the liver to form bile pigment and the iron in haemoglobin is stored in the liver
- They have a biconcave disk shape
- They are approximately 5 million/mm^3 of blood.

Importance of Red Blood Cells

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

Adaptation of Red Blood Cells to carry out their function

- They are biconcave in shape so as to avail a large surface area to volume ratio for absorption of oxygen.
- They have hemoglobin molecules that bind to oxygen and transport it from the lungs to the tissues.
- They have a thin membrane which reduces the diffusion distance for the respiratory gases in and out of the cells.
- They lack nuclei which provides enough space for packaging of haemoglobin
- They lack mitochondria and generate their ATP exclusively by anaerobic respiration to prevent them from using the oxygen they are carrying.
- They are numerous per mm^3 to increase surface area for transportation of oxygen
- They have flexible membranes which make them able to squeeze through capillary networks as they exchange materials they transport with the surrounding tissues.

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

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

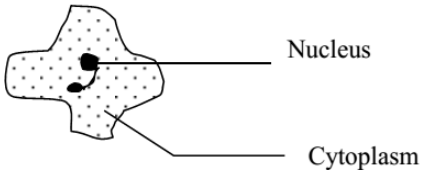
THE WHITE BLOOD CELLS (LEUCOCYTES)

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

Characteristics of white blood cells

i) They have no definite shape (they are amoeboid)
ii) They have a nucleus even at maturity.
iii) They are relatively few in blood but their number increases when the body is attached by an infection.
iv) They lack haemoglobin.
v) They feed on foreign particles by Phagocytes

Structure of a white blood cell



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

Phagocytes: These are white blood cells with a lobed nucleus. They ingest and destroy germs by phagocytes.

Lymphocytes: These are white blood cells, which defend the body by producing antibodies.

Production of red and white blood cells

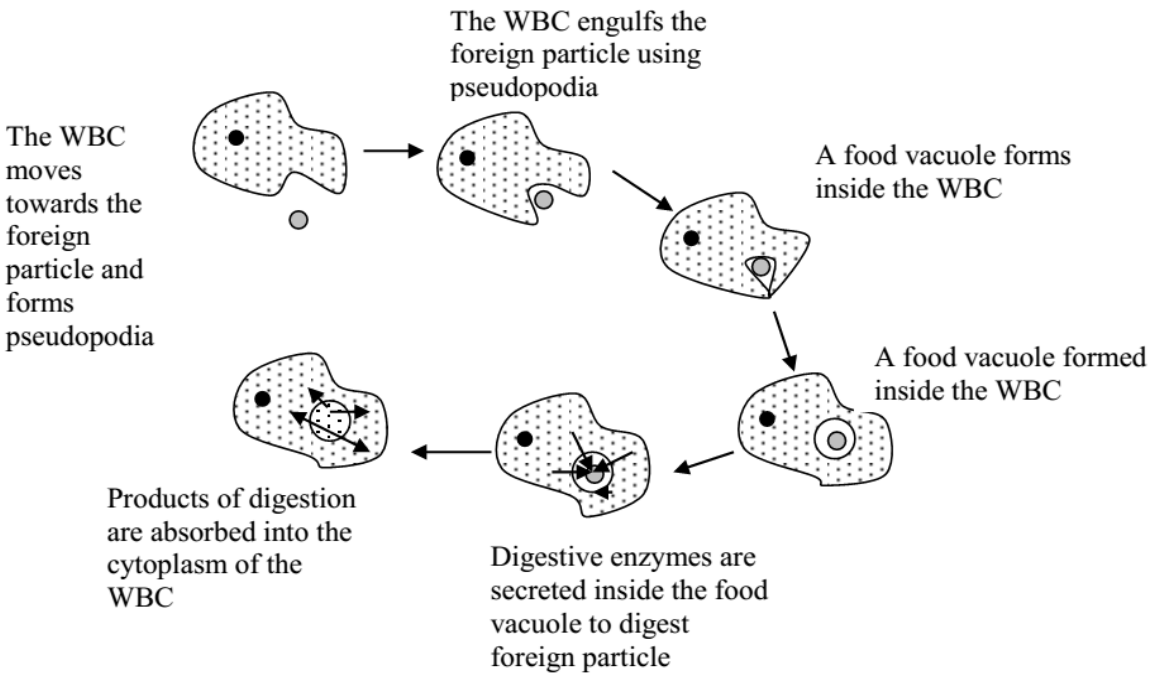
The red blood cells are manufactured form the red bone marrows in adults. Old red blood cells are taken to the liver for destruction.

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

Action of white blood cells on the foreign particles

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

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



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

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

THE PLATELETS (THROMBOCYTES)

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

Characteristics of platelets

- They are cell fragments.
- They are spherical in shape.
- They do not have a nucleus.
- They do not have haemoglobin.

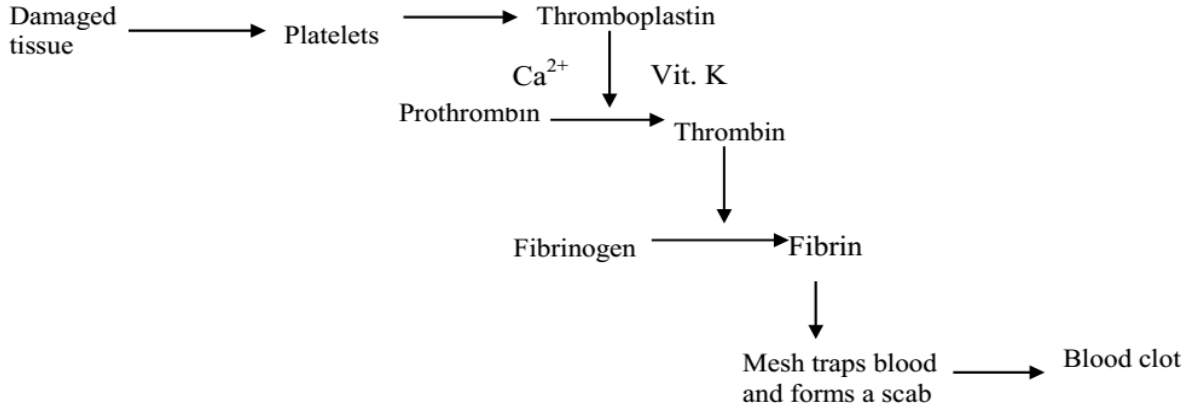
Functions

They play a role in blood clotting which protects the body against excessive loss of blood and entry of pathogens through the injured part. ***Blood clotting is the process by which blood stops oozing out of a cut or wound***. It is important because of the following reasons.

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

The Process of Blood Clotting:

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



BLOOD PLASMA

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

i) A soluble protein called **fibrinogen** that plays a role in blood clotting.
ii) Serum, a watery fluid containing a variety of substances transported from one part of the body to another e.g. hormones, lipids, enzymes, urea, carbon dioxide, plasma, proteins, amino acids etc.

Functions of blood plasma

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

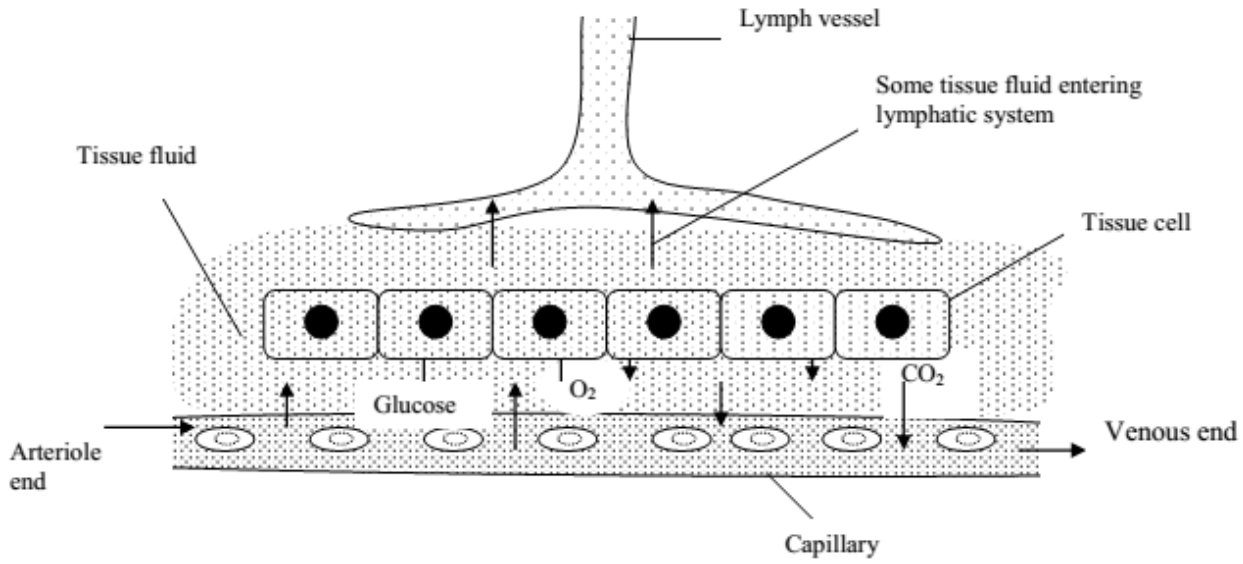
Capillary exchange, formation of tissue fluid and later lymph.

As blood flows from arterioles into blood capillaries. Pressure builds up in the capillaries forcing small molecules like food materials and the fluid part of blood to leave the capillaries and enter the intercellular spaces, leaving behind large molecules like proteins in plasma and cells.

Once the fluid is in the intercellular spaces of tissues, it is no longer called blood but tissue fluid.

Once formed, the tissue fluid surrounds the cells. Body cells then get their requirements e.g. glucose, oxygen, etc. from the tissue fluid and they add excretory materials to the fluid.

Some of the fluid returns in to the capillaries and the other is drained in to a system of narrow channels called lymph vessels. The fluid in these vessels is now called lymph. Lymph is therefore, tissue fluid in the lymph vessels.



THE LYMPHATIC SYSTEM

This is part of the vascular system. It forms the second type of circulation. Most of the tissue fluid as explained above goes back into the blood capillaries and the remainder enters the lymphatic system and becomes lymph fluid. The lymph fluid is transported through lymph vessels. The lymph vessels are similar to veins but they have more valves than the veins. The movement of the lymph fluid through the lymph vessels is due to the contractions of the surrounding muscles. As they contract and relax, they squeeze the lymph vessels to gain the force by which lymph moves. The walls of the lymphatic vessels have pores, which allow the entry of cell, wastes and bacteria. Before reaching the blood, lymph passes through the lymph nodes where the wastes and bacteria are removed.

Functions of the lymphatic system

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