NUTRITION

Nutrition refers to the process by which living organisms obtain, consume and use **nutrients** to maintain their life processes (metabolic processes).

These nutrients in green plants include; water, mineral salts, carbon dioxide and in animals include; carbohydrates, proteins, lipids, etc.

Nutrients are either organic or inorganic. Organic substances are those that contain carbon e.g. carbohydrates, proteins, vitamins, nucleic acids and fats. Inorganic substances include water, mineral ions.

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 an external source of energy. Such organisms are called Autotrophs.

Since the nutrition of all other organisms depends either directly or indirectly on these Autotrophs, they are referred to as **producers**.

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

i. Photosynthesis:

This is the type of nutrition where organisms make organic food products from inorganic materials using sunlight energy. Examples include; green plants, algae, photosynthetic bacteria.

ii. Chemosynthesis:

This is the type of nutrition where organisms make organic food products from inorganic materials using energy from specific chemical reactions for example chemosynthetic bacteria which obtain energy from oxidation of hydrogen sulphide.

2. HETEROTROPHISM / HETEROTROPHIC NUTRITION

This is the mode of nutrition where by organisms obtain their food by feeding on already manufactured organic (food) compounds.

Heterotrophs are incapable of making their own food.

They include; all animals, fungi, insectivorous plants and most bacteria.

Heterotrophic nutrition is of 5 major types, which include:

1. Parasitism

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

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

2. Phagocytosis:

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

- ❖ Amoeba.
- ❖ White blood cells.

3. Saprophytic/saprotrophic nutrition:

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

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

4. Symbiosis / Mutualism;

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

Examples include;

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

5. Holozoic nutrition;

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

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

Holozoic nutrition is characterized by the following:

i) Ingestion:

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

ii) Digestion:

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

iii) Absorption:

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

iv) Assimilation:

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

v) Egestion:

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

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

- ❖ Carnivores
- ❖ Herbivores.
- ❖ Omnivores

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 with nutritional value 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 (lipids and carbohydrates).
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 which include *monosaccharides, disaccharides* and *polysaccharides* depending on number of sugar molecules they are composed of.

i) Monosaccharides

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

Properties of monosaccharides

- They have a sweet taste
- They dissolve in water
- They form crystals
- Can pass through a selectively permeable membrane.
- They are reducing.

Test for monosaccharides: To a given volume of test solution, add an equal volume of Benedict's solution and boil.

Observation: colour of solution changes from blue to green solution to yellow precipitate to orange precipitate to red precipitate in presence of monosaccharides.

Monosaccharides are said to reduce Benedict's solution and are thus called <u>reducing sugars.</u>

Monosaccharides include the following:

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

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.	Solution turns to a blue solution, then to a green solution, to a yellow precipitate, to orange precipitate and to a brown precipitate on boiling.	Little or Moderate or Much reducing sugars present.
	Solution turns to a blue solution which persists on boiling.	Reducing sugars absent.

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

NB: *though not a monosaccharide**,** Maltose present in germinating seeds is a reducing sugar*

ii) Disaccharides

Disaccharides (di=two, saccharide= sugars) are carbohydrates molecules made up two monosaccharides 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:

ii) They are sweet
iii) They can be crystallized
iv) They are soluble in water
v) They are non-reducing sugars **except** maltose

Examples of disaccharides include:

1) Sucrose (present in sugar cane)
2) Maltose (present in germinating seeds)
3) Lactose (present in milk)

1. 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.	Solution turned to a blue solution, then to a green solution, to a yellow precipitate and to a brown precipitate on boiling.	Little or Moderate or 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 break 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.

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
- ✓ Insoluble in water
- ✓ Non crystallisable
- ✓ Are non-reducing

Examples include:

1) Starch
2) Glycogen
3) Cellulose.

- **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.	Solution turned to a black or blue-black or blue solution or brown solution with black specks.	Much moderate little starch present.
	Solution turned to a yellow or brown solution.	Starch absent.

Functions of carbohydrates

i) They provide energy in the body when oxidized during respiration.
ii) They function as food reserves for storage within organisms e.g. many plants store food as starch and animals as glycogen.
iii) 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.
iv) 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.
v) Used in the fermentation process to form alcohol
vi) Disaccharides like sucrose are used for preservation of food substances for a short period of time

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

PROTEINS

These are food nutrients containing carbon, hydrogen, oxygen and nitrogen and sometimes sulphur or phosphorus. The 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 functional molecules that control metabolism like enzymes and hormones.
iv) Provision of energy in times of starvation.
v) Used in formation of pigments that transport respiratory gases e.g. haemoglobin

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 test solution, add 1 cm^3 of sodium hydroxide solution, then add 3 drops of Copper (II) sulphate solution	Solution turns to a colourless solution then to a violet or purple solution.	Proteins present.
	Solution turned to a blue solution.	Proteins absent.

Millon's test:

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

LIPIDS (FATS AND OILS)

Lipids also contain carbon, hydrogen and oxygen but with higher proportions of hydrogen and less oxygen than carbohydrates. Because of this, they are able to yield more energy than carbohydrates or proteins of an equivalent mass when oxidized.
Fats differ from oils in that they are solids at room temperature whereas oils are liquids at room temperature (25^0C).

Fats are mainly found in animal tissues while oils are obtained from plant tissues.
Examples of lipids include; margarine, castor oil, waxes
Lipids are made up of **fatty acids and glycerol.**

Sources of lipids:

- Ground nuts
- Eggs
- Sun flower
- Palm oil
- Castor oil, etc.

Properties of lipids

i) Fats and oils are distinguished from other nutrients in that they make a permanent translucent mark or spot on papers. This property also provides a simple test for fats and oils.
ii) They are insoluble in water
iii) They are less dense than water

Functions of lipids

i) Energy production during respiration
ii) Insulate the body to prevent excessive heat loss; this has been of major adaptations in some small animals and those animals living in cold regions where the sub- cutaneous fats are largely deposited under the dermis of the skin.
iii) Prevent water loss for example waxes
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.	Solution turns to a cream emulsion	Lipids present.
	Solution remains turbid or colourless solution.	Lipids absent.

b) Translucent spot test:

Procedure	Observation	Conclusion
Add 2 drops of test solution on a piece of filter paper.	A translucent spot or patch is left on the paper.	Lipids present
Allow to dry and observe under light.	No translucent spot is formed on the paper.	Lipids absent.

VITAMINS

These are organic compounds required in small amounts in the diet for the normal functioning of the body.

Types of lipids

i) Water soluble vitamins ii) Fat soluble vitamins

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

- ❖ Vitamin B
- ❖ Vitamin C.

Fat soluble vitamins dissolve in fats but not in water. They include

- ❖ Vitamin A,
- ❖ Vitamin E,
- ❖ Vitamin D,
- ❖ Vitamin K.

A table showing vitamins and their deficiency diseases

Vitamin	Common food source	Functions	Symptom of deficiency
A (Retinol)	Green vegetables, liver, butter, margarine, egg yolk and carrots	Growth in children, resistance to diseases of eye (night blindness) and respiratory tract. good night(Dim light) vision	Night blindness(poor dark adaptation), frequent cold, sore eyes and wealthy skin
B_1(Thiamine)	Yeast, beans, lean meat, egg yolk, bread and rice husks	Tissue respiration, keeps the heart, nerves and digestive organs healthy	Tiredness(fatigue), retarded growth in children and poor appetite, constipation**(beriberi)**
B_2(Riboflavin)	Yeast, milk, liver, cheese, leafy vegetables.	Tissue respiration, growth and health of skin. Keeps mucus membrane healthy	Retarded growth especially in children, cracks on lips, poor vision and skin disorders
B_3 (Nicotinic acid /Niacin)	Cereal grains, milk and its products, liver and yeast	Same as B_2	Disorders of central nervous system(CNS) like memory loss & depression(pellagra)
B_5 (pantothenic acid)	Meats, dairy products, most foods	For metabolism	Fatigue, numbness, tingling sensation
B_9 (Folic acid)	Green vegetables, oranges, nuts, legumes, whole grains	Required for metabolism of amino acids	Anaemia, birth defects
B_{12}(cobalamine)	Beef, kidney, liver, yeast	Forms red blood cells	Low blood count(Anemia)
C (Ascorbic acid)	Fresh fruits and row vegetables	Development of teeth and bones, normal growth and sticks together the cells lining	Scurvy- Sore gums, poor healing of sores in the gum

		parts of the body	
D(calciferol)	liver, fish, egg yolk, formed beneath skin of man in sunlight	Building strong and hard bones and teeth, promotes absorption of phosphorus and calcium in the gut	Weak bones and teeth, rickets in children and dental caries
E(tocopherols)	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 (Dichlorophenol Indophenol). It is a deep blue solution. The sources of vitamin C are fresh fruits e.g. oranges, mangoes, lemon, etc.

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

MINERAL ELEMENTS AND SALTS

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

Mineral salts can be divided into;

(i) Macro elements

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

(ii) 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, copper, iodine, Molybdenum, cobalt, Manganese, fluorine.

A table showing some elements and their deficiency diseases

MINERAL ELEMENTS	SOURCE	IMPORTANCE	DEFFICIENCY
Fe Iron	- Beef, liver, kidney, Groundnuts, beans, eggs, green vegetables.	- It is a constituent of Haemoglobin.	**Anaemia** - Reduced red blood cell account. - Reduction in oxygen transportation rate.
Ca Calcium	Vegetables, fish, milk, bread, eggs.	In blood clotting Hardening of bones and teeth. Muscle functioning Nerve functioning	**Rickets in children** - Delay in blood clotting - Soft bone, poor skeletal growth.
P Phosphorus	- dairy products, grains, meat	Constituent of cell membrane. Formation of teeth & bones. Synthesis of DNA	- It is not likely for one to be deficient of phosphorus since it is found in most foods.
I Iodine	Iodised salts Marine fish Dairy products	It is a constituent of a hormone **Thyroxin**	**Goitre** - Swelling of the Thyroid gland. - Muscle cramp (sharp pains in muscles).
F Fluorine	Drinking water Sea food	It is constituent of bones and teeth.	Weak teeth in children. Weak bones
K Potassium	Fish, beef, liver, mushroom and some tubers	Transmission of nerve impulse along neurons	Muscular cramp
Na sodium	Common salt(NaCl) and cheese	Transmission of nerve impulse along neurons	
Zn zinc	Meat, sea food grains	Component of certain digestive enzymes	Slow growth

WATER AND ROUGHAGES/DIETARY FIBRES

WATER

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

Importance of water

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

- ✓ It participates in many metabolic reactions or processes as a raw materials e.g. respiration, photosynthesis, gaseous exchange, digestion, and removal of wastes.
- ✓ Plays a role in temperature regulation i.e. cooling the body on hot days and plants through transpiration.
- ✓ Offers turgidity thus acts as a hydrostatic skeleton- hence supporting organisms.
- ✓ It softens food.
- ✓ It is used in seed dispersal.
- ✓ It is a habitat (home).
- ✓ It acts as a Lubricant e.g. salvia lubricant the mouth, tears lubricate eyes, synovial fluids lubricate the joints.

ROUGHAGES / DIETARY FIBRE

They are indigestible materials in food and consist mostly of cellulose, pectin, and lignin.
The major sources of roughages include: vegetables, such as cabbages, dodo, fruits, etc.

Functions of roughages

- ✓ They stimulate muscular movements called peristalsis which move food (propel) through the alimentary canal.
- ✓ Add bulk to food enable food nutrients pass through the intestines very fast.
    - ❖ ***Deficiency or lack of roughages causes constipation.***

Balanced Diet:

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

Mal-Nutrition:

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

ENZYMES

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

Importance of enzymes

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

Examples of enzymes and their substrates

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

Some enzymes however retained their names they had before this convention. Such enzymes include pepsin and trypsin.

Sometimes the enzymes digesting carbohydrates are generally called carbohydrases and those digesting proteins as proteases.

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

PROPERTIES OF ENZYMES

1) They are 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 required in small amounts to catalyze reactions.
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)

FACTORS AFFECTING ENZYME ACTIVITIES

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

The factors are:

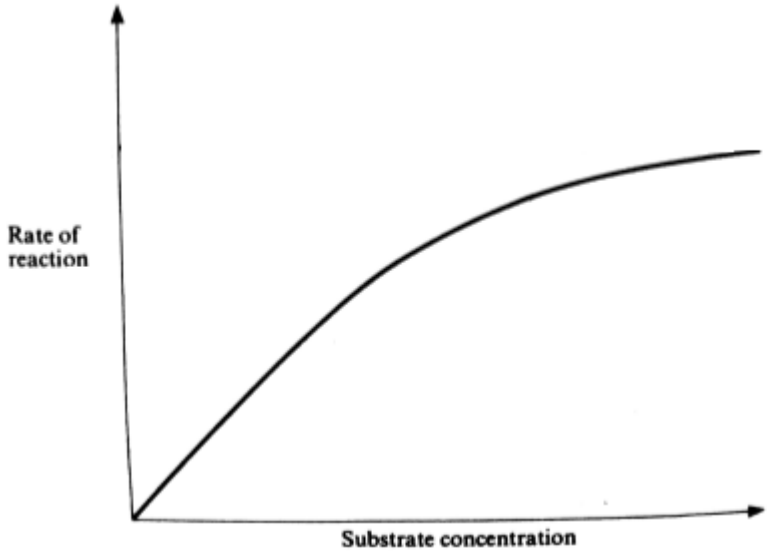
i) Temperature
ii) Concentration of the substrate
iii) P^{H} of the medium
iv) Presence of activators
v) Presence of inhibitors
vi) Concentration of the enzyme

1. Concentration of substrate:

The rate of enzyme reaction increases with increase in substrate concentration, this is due to increased tendency of enzyme molecules to collide with substrate molecule forming products. The rate of enzyme activity is low at low substrate concentration. This is due to few enzyme-substrate collisions.

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

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

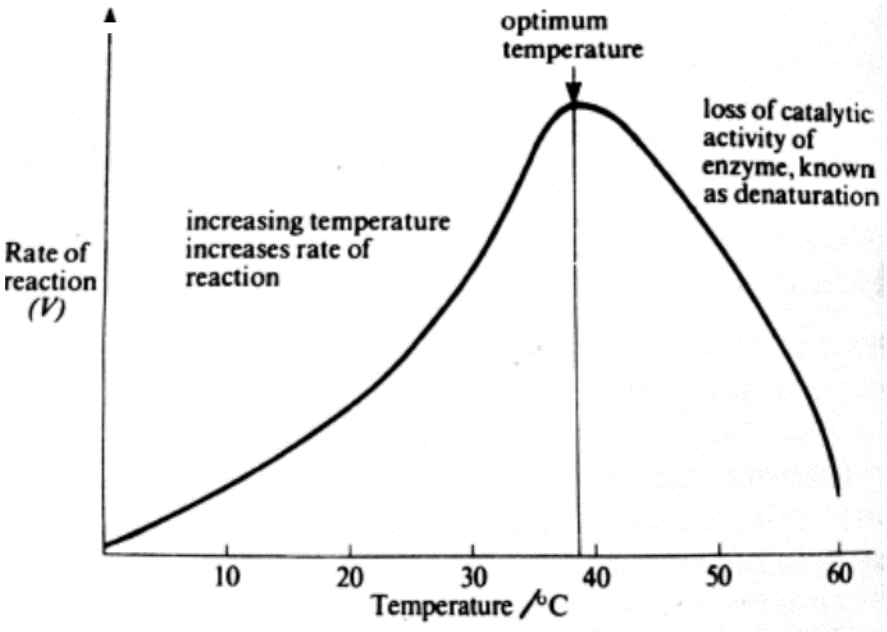


2. Temperature:

Enzymes work best at optimum temperatures. At very low temperatures, the rate of enzyme reaction is very slow because of low kinetic energy leading to few collisions.

As the temperatures increases, the rate of reaction also increases due increasing kinetic energy resulting into an increase in effective collisions between enzymes and substrate molecules. However, further increase in temperature reduces the rate of reaction since enzymes are denatured i.e. the shape of active site of the enzyme is changed.

A graph showing the variation of enzyme activity with temperature

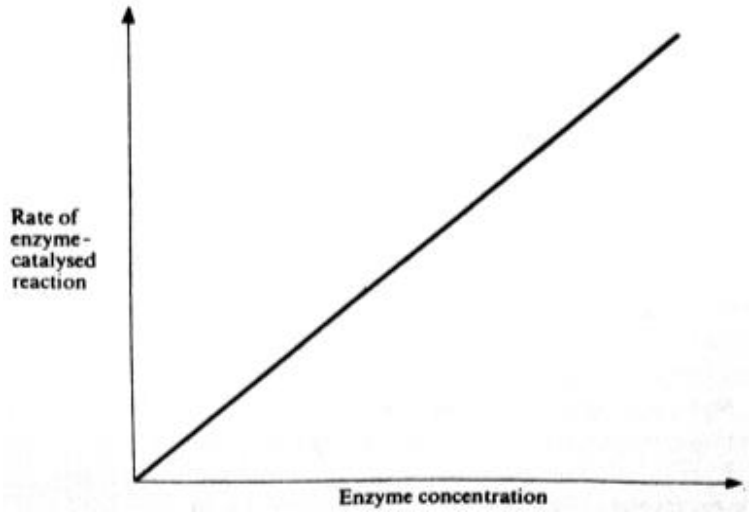


3. Enzyme concentration:

At low enzyme concentration, the rate of reaction is low since few active sites are available for substrate molecules to be acted upon. As the concentration of the enzymes increases, the rate of

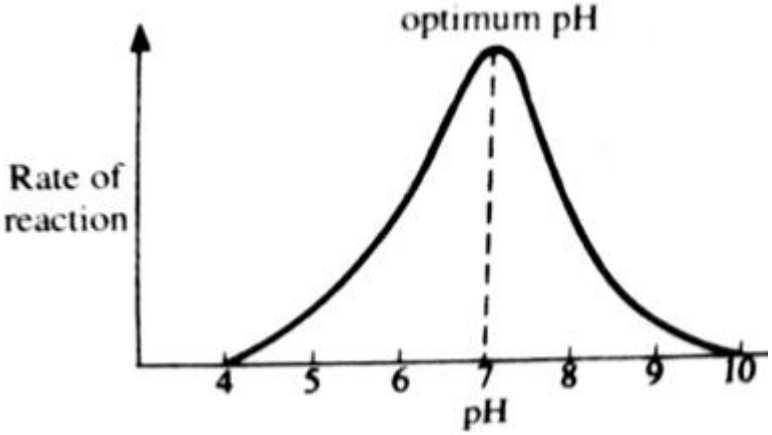
reaction also increases since more active sites are available for more substrate molecules to be catalyzed per unit time.

A graph showing variation of enzyme activity with enzyme concentration



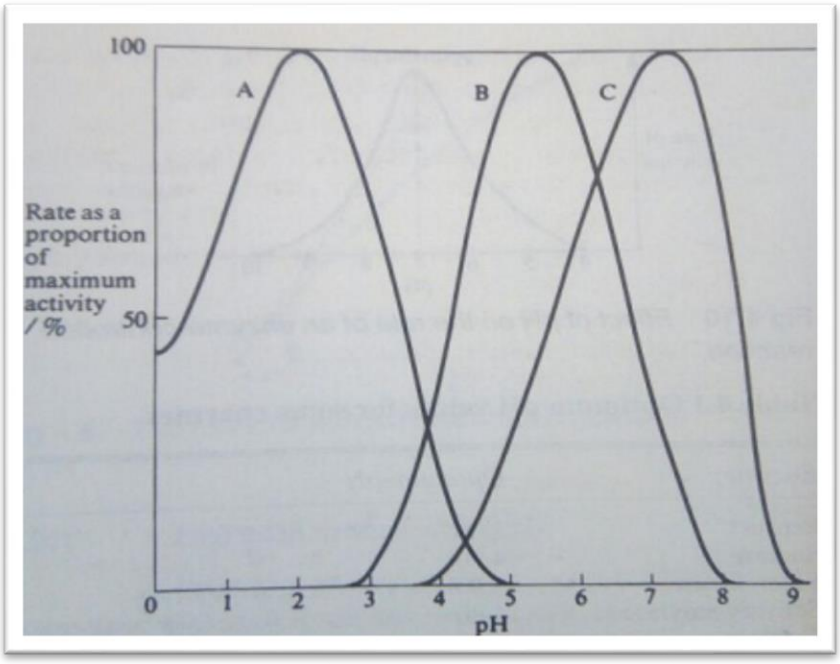
4. The pH of the medium.

Enzymes work best in optimum p^H. P^H below or above the optimum p^H results into reduction in enzyme activity, as shown for the enzyme amylase below



ENZYME	P^H	substrate	products
Pepsin	2	proteins	Short chain polypeptides
Salivary amylase	7.4 to 7.7	starch	maltose
Pancreatic trypsin	8	Short chain polypeptides	peptides
catalase	8	Hydrogen peroxide	Water & oxygen
lipase	8 to 9	fats	Fatty acids & glycerol

A graph showing variation of different enzyme activity with pH



5. Presence of enzyme inhibitors

Enzyme activity decreases in presence of enzyme inhibitors and increase in their absence.

6. Presence of activators

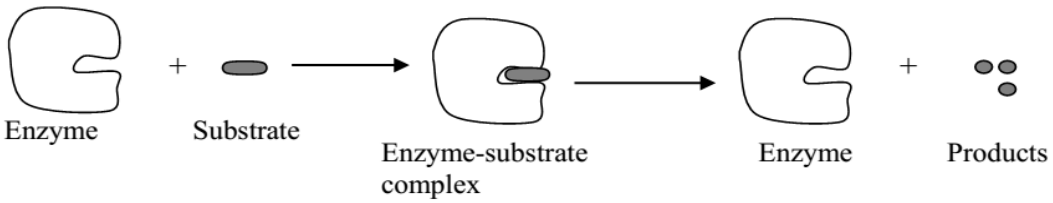
Enzyme activity increases with presence of enzyme activators and decrease with absence of enzyme activators.

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.

Illustration



MAMMALIAN TEETH

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

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

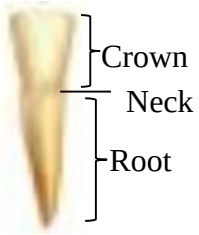
Types of teeth in mammals

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

1) Incisors

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

Structure of an Incisor



2) Canines

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

Structure of canine

3) Premolars

These lie behind the canines on both jaws.

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

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

Premolars are used for grinding and chewing food.

Structure of premolar

4) Molars

They are absent in young mammals.

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

They may have three or more roots.

Molars are used for grinding and crashing food.

Structure of a molar

Note:

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

External structure of mammalian tooth

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

1) Crown

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

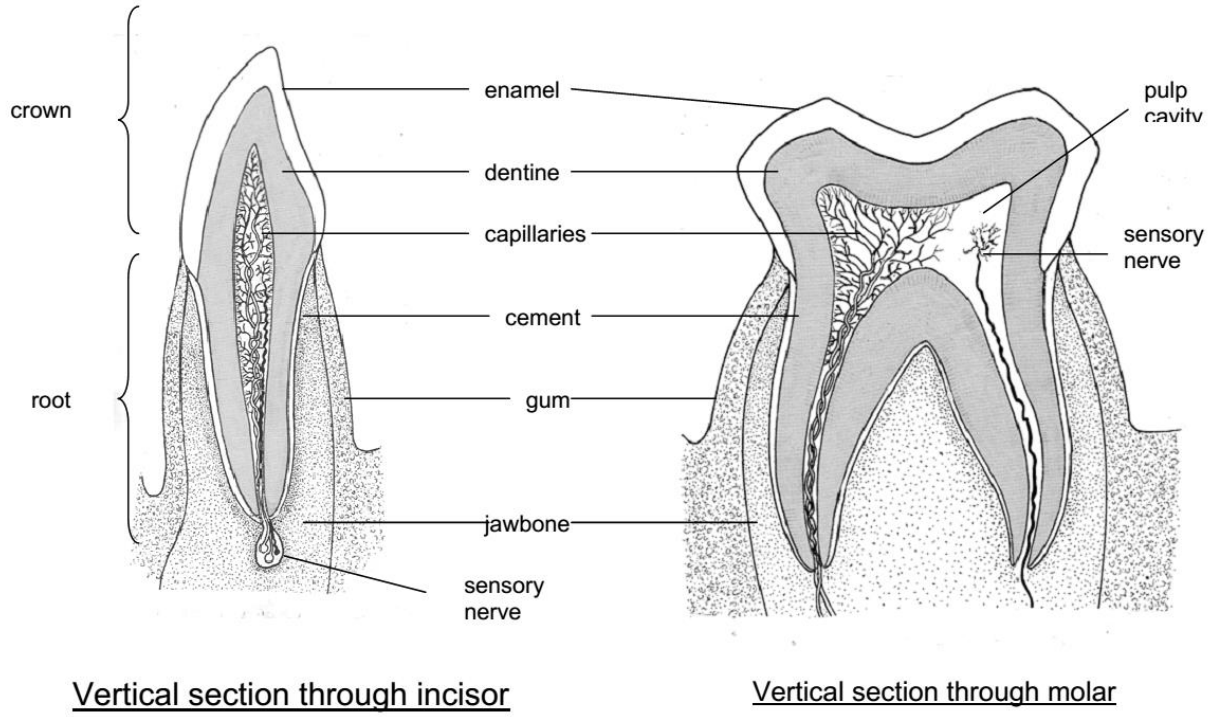
2) Neck

This is the junction between the crown and the root.

3) Root

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

Tooth structure



Vertical section through incisor

Vertical section through molar

Functions of the parts of the tooth

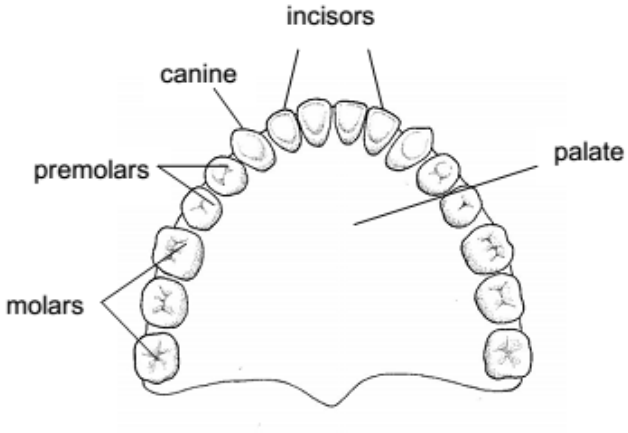
1) **Crown**; this break down food into small particles during chewing, grinding and cutting.
2) **Enamel**; this strengthens the tooth to enable it grind and cut. It protects the dentine and pulp cavity. It is the hardest material in the body. It is white in colour and made up of ***calcium phosphate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

DENTITION

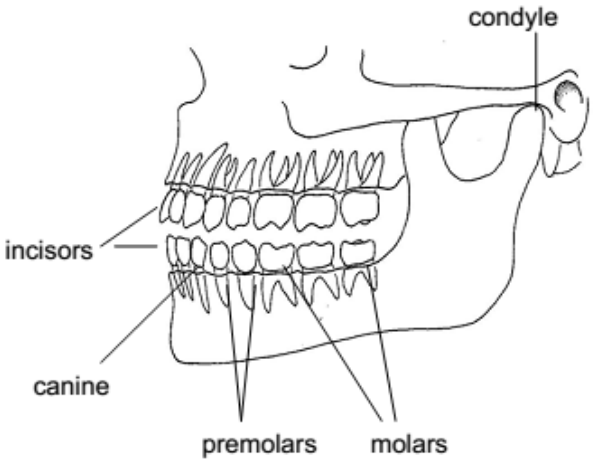
This refers to the number, arrangement and shape of teeth in an animal.

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

Dentition in human



Upper jaw seen from below



Position of teeth in jaws - side view

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)

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

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

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	$\frac{\text{I2}}{2}\ \frac{\text{C1}}{1}\ \frac{\text{PM2}}{2}\ \frac{\text{M3}}{3}$	32
Dog	$\text{I}\ \frac{3}{3};\ \text{C}\ \frac{1}{1};\ \text{p m}\ \frac{4}{4},\ \text{M}\ \frac{2}{3}$	42
Rat	$\frac{\text{I1}}{1}\ \frac{\text{C0}}{0}\ \frac{\text{PM0}}{0}\ \frac{\text{M3}}{3}$	16
Cow	$\frac{\text{I0}}{3}\ \frac{\text{C0}}{1}\ \frac{\text{PM3}}{3}\ \frac{\text{M3}}{3}$	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
- Gingivitis

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

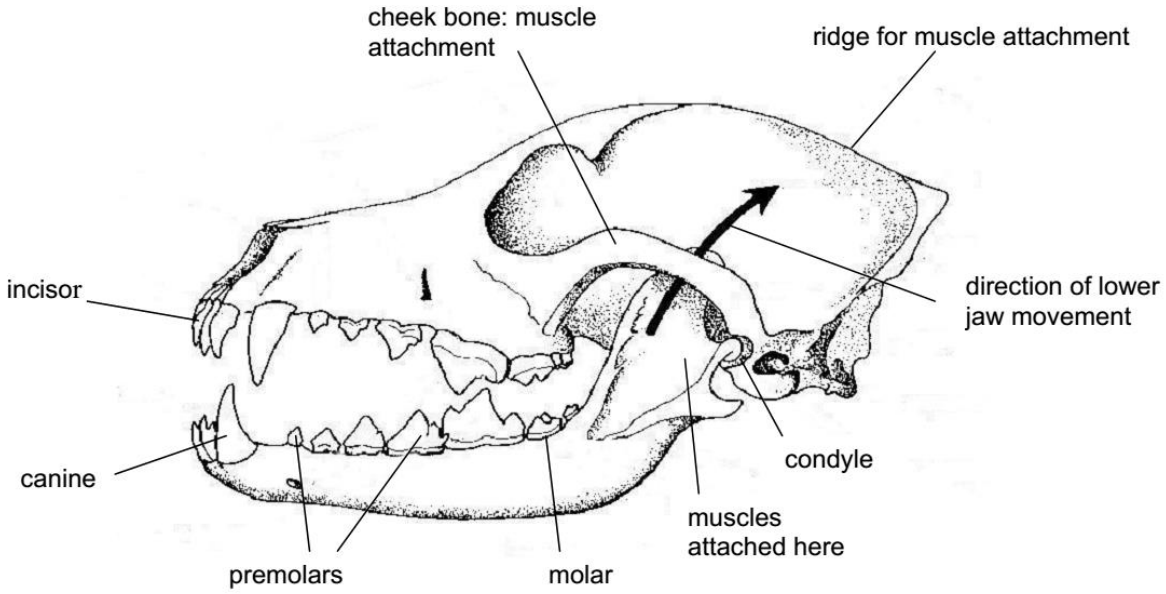
Prevention of dental decay and proper care of teeth

- 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 flesh 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.

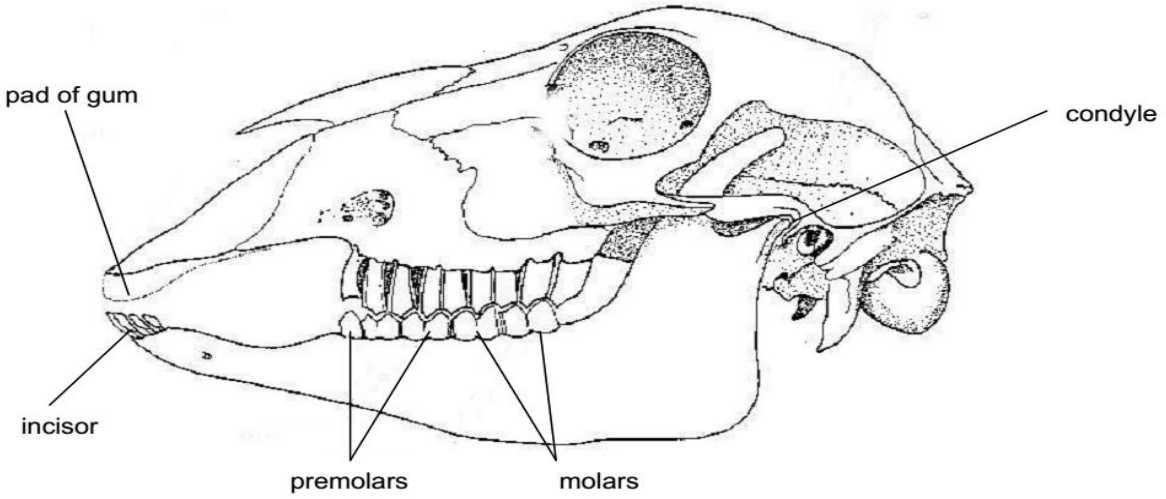
Their incisors and canines are chisel shaped and only found in the lower jaw.

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.

Jaw structure to show 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 types; **physical** or **mechanical digestion** and **chemical digestion**.

Physical digestion:

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

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

In organisms however, digestion can be classified basing on whether or not is occurs in cells as described below;

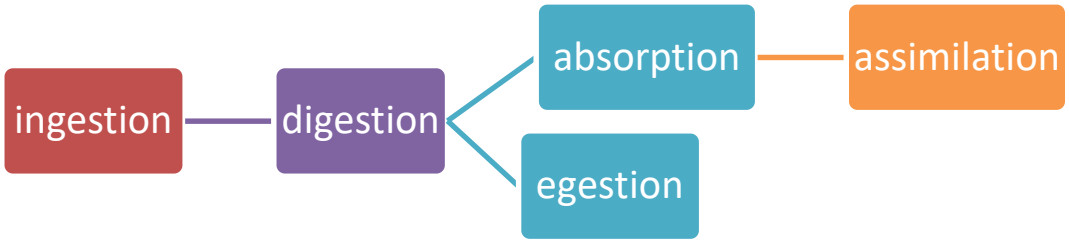
Extracellular digestion:

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

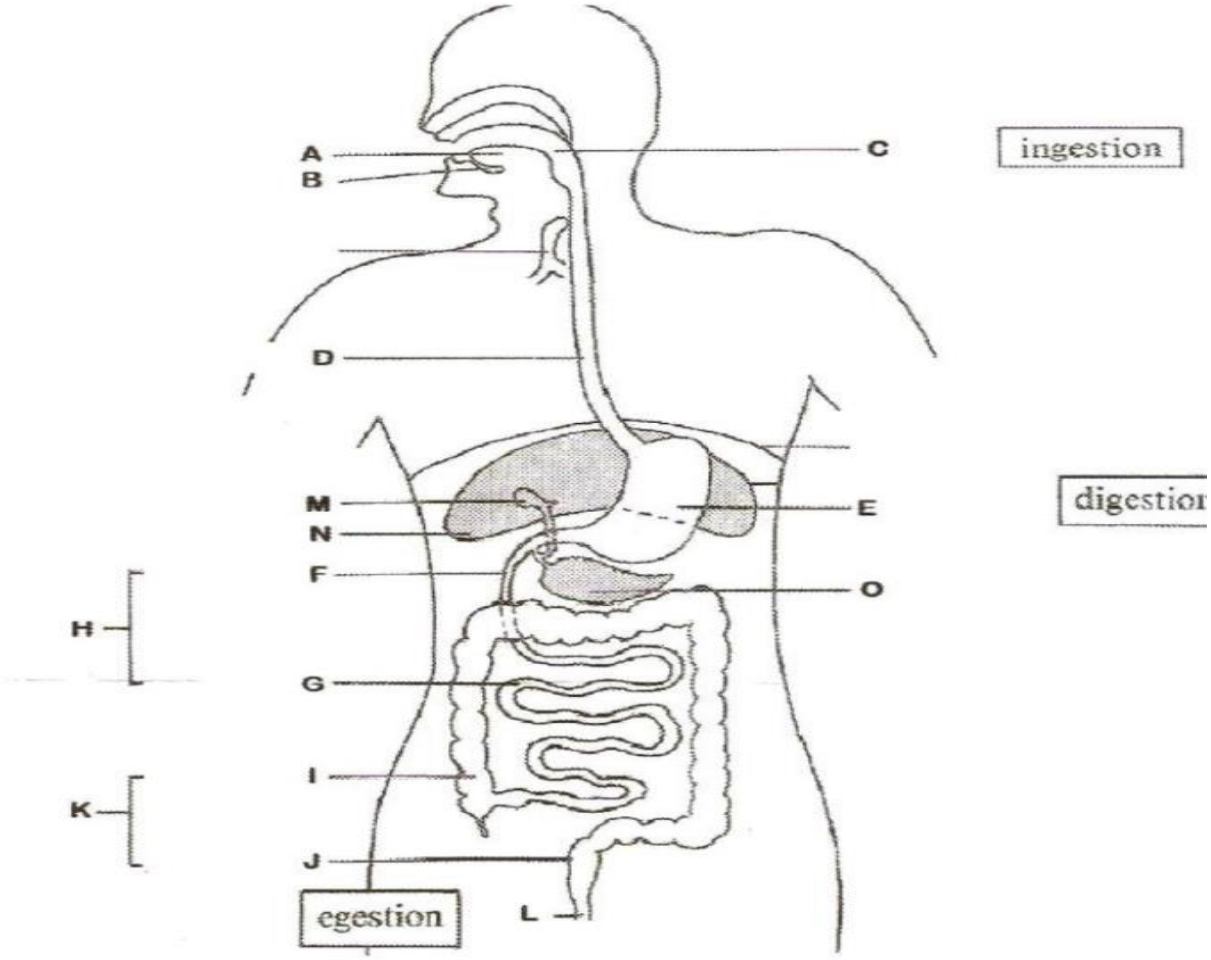
Intracellular digestion: This is a type of digestion which take place inside the body cells e.g. Amoeba, Paramecium.

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

As noted earlier, the following steps are important during the nutrition in mammals to obtain necessary nutrients. Each process will be discussed in detail to clearly understand the cycle below.

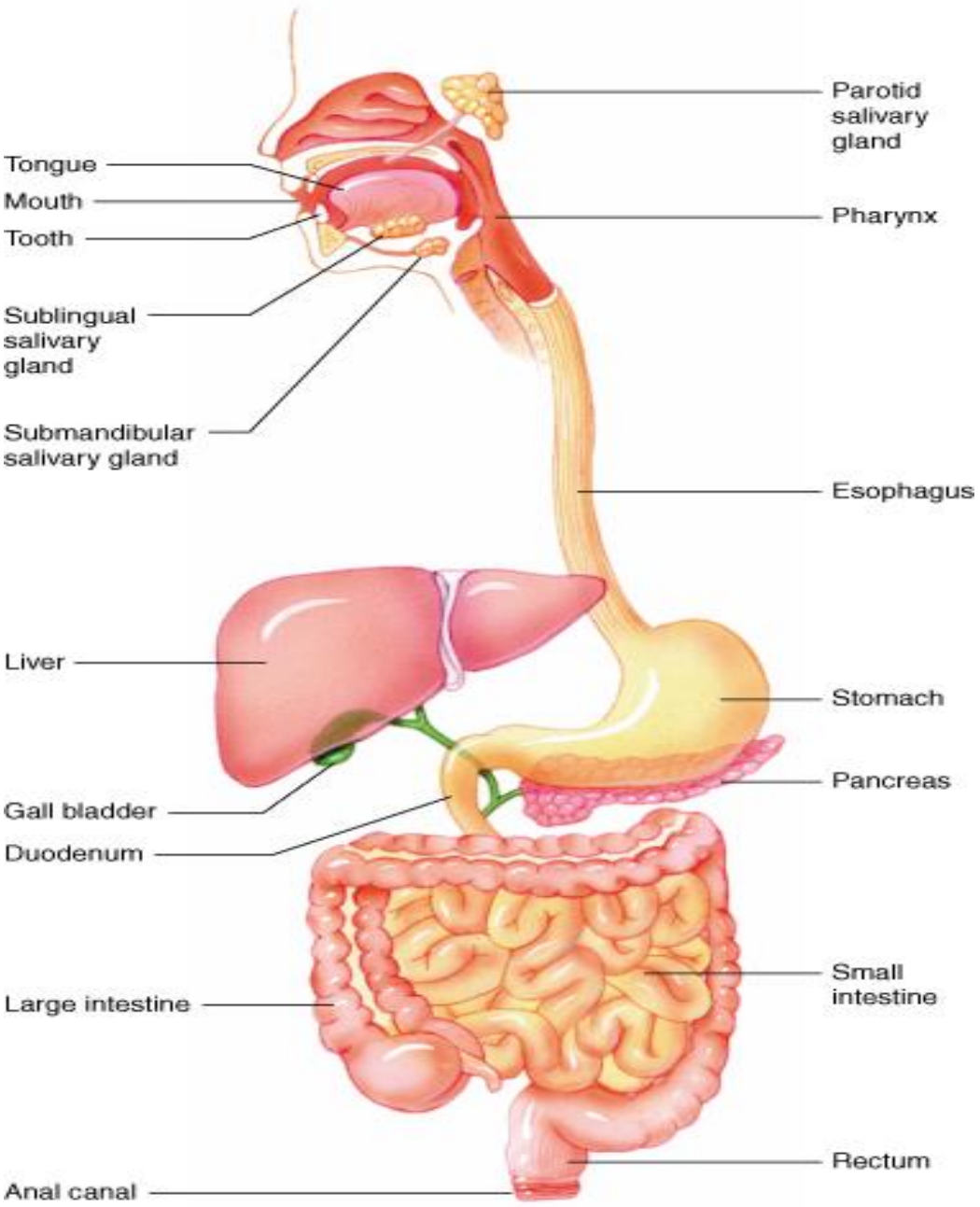


The human alimentary canal



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

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


Parotid salivary gland
Tongue
Mouth
Tooth
Pharynx
Sublingual salivary gland
Submandibular salivary gland
Esophagus
Liver
Stomach
Pancreas
Gall bladder
Duodenum
Small intestine
Large intestine
Rectum
Anal canal

PARTS OF THE ALIMENTARY CANAL

1. The mouth

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

Once food is in the buccal cavity, the teeth break down large food particles into smaller particles providing a large surface area for the enzyme action. On the floor of the cavity is the long muscular organ, the **tongue** which is covered by taste buds. The tongue moves food around the mouth for chewing to occur and mixing with saliva secreted by salivary glands. Saliva contains enzyme ***salivary amylase (ptyalin)*** which catalyses the breakdown of starch into maltose and mucus which moistens, softens and lubricates food as well as sticking food particles together into boluses for easy swallowing. The enzyme in the saliva is called

2. Oesophagus/gullet

This is a tube that passes from the mouth cavity through the thorax and diaphragm into the abdominal cavity.

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

3. The stomach

The gullet leads food substances to the stomach. The substances are momentarily released into stomach by cardiac sphincter. This contracts thus preventing flow of food backwards to the gullet.

- Peristaltic movement aid in further physical digestion by thick stomach walls
- Gastric juice is released into the stomach from gastric glands. Contains HCL, mucus, renin, pepsinogen, mucus, water.
- Gastric juice contains hydrochloric acid which has the following functions
    - Activates pepsinogen to enzyme pepsin
    - Creates adequate pH medium for action of pepsin
    - Kills microorganisms that escape into stomach
    - Stops action of ptyalin (salivary amylase)

Note; pepsinogen is an inactive form of pepsin. Releasing it in an inactive state prevents it from digesting the stomach wall.

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.

4. The small intestine

The small intestine is long and coiled in man. ***It is made up of two parts; ileum and duodenum.***

i. The duodenum

This is the first part of the small intestine. It is short and wider than ileum.

The duodenum receives digestive juices from the pancreas and gall bladder through ducts;

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

Final digestion of most food substances occurs here

ii. The ileum

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

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

5. The large intestines

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

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

DIGESTION IN THE MOUTH

Digestion in the mouth is both physical and chemical.

a) Physical digestion

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

Mastication is important in that;

i) Increase the surface area of food for efficient Enzyme action.
ii) It helps to mix the food with saliva and in so doing; it softens the food, mixes it with the enzymes and lubricates it with the mucus in the saliva.
iii) Stimulates enzyme secretion because the secretion of saliva is a reflex action stimulated by the presence of food in the mouth.

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

b) Chemical digestion in the mouth.

Chemical digestion is carried out by the enzyme salivary amylase

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

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

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

The act of swallowing:

Swallowing is a reflex action. Here, food is rolled into a bolus by action of the tongue which is then transferred into the Oesophagus (gullet).

- During the act of swallowing, breathing momentarily stops and the epiglottis closes the glottis.
- 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.
- The tongue presses the bolus at soft palate at the back of the mouth such that it passes into the oesophagus.
- Once the bolus is in the oesophagus, the food moves by a wave of muscular contractions called ***Peristalsis.***

DIGESTION IN THE STOMACH

Digestion in stomach is mainly chemical. ***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 works at low pH i.e. acidic conditions provided by the presence of Hydrochloric acid (HCl).
Renin coagulates milk. (Makes it insoluble) i.e. it converts the soluble milk protein **caseinogen** to an insoluble curd, **casein** which is then acted upon by pepsin breaking it down to polypeptide.
Rennin is an important enzyme especially in young mammals since they feed on only milk.

Caseinogen ——Renin——→ Casein
(Soluble protein) (Insoluble protein)

Proteins ——pepsin——→ polypeptides

Physical digestion in stomach is due peristaltic movements of thick stomach wall against food. The peristaltic movements mix food with gastric juice to form ***acidic chyme***

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 accessory organs which release digestive juices into duodenum; pancreas releasing pancreatic juice and gall bladder releasing bile

Functions of bile

i) It's alkaline and neutralizes the HCl in chyme to stop the action of the stomach enzymes and allow enzymes in the pancreatic juice to begin working.
ii) It reduces the surface tension of fats and breaks them into minute droplets i.e. emulsifies fat.
iii) Provides suitable pH for action of pancreatic enzymes

The arrival of food in the duodenum stimulates the production of a hormone called ***secretin*** to the pancreas and stimulates secretion of pancreatic juice. It contains a number of enzymes which are called the *pancreatic enzymes* as shown in the table below.

Enzymes	Food acted upon	Products
Trypsin	Proteins/polypeptides	Peptides
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.

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.

Adaptations of ileum for digestion

- ✓ Contains enzymes secreted from the wall of ileum to catalyze digestion of food substances
- ✓ Is long to increase surface area for digestion of food substances

ACTIVITIES 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.***

However, there are microbes in the colon mainly mutualistic bacteria that form vitamin K

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

SAMPLE QUESTIONS:

Question 1: Describe the digestion process that occurs when a person consumes cassava

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

THE PROCESS OF ABSORPTION AND ASSIMILATION OF FOOD

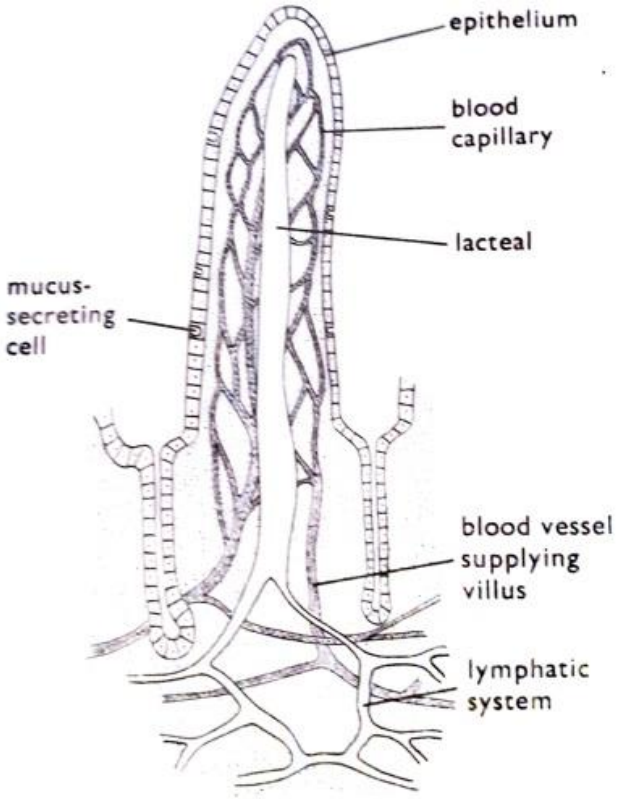
ABSORPTION

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

Adaptations of ileum for absorption

- ✓ Long to increase surface area over which absorption can take place
- ✓ Is coiled to reduce distance of movement of food substances, increasing time for absorption
- ✓ Has villi, which are finger like projections that increase surface area for absorption of nutrients
- ✓ The villi also have hair like extensions called the micro villi which ***further*** increase the surface area for absorption of soluble food products.
- ✓ Supplied with adequate blood by numerous blood capillaries which transport away absorbed nutrients.
- ✓ Lacteals into which fatty acids and glycerol is absorbed
- ✓ Thin wall to reduce diffusion distance for absorption of food nutrients.

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 used to form complex components of cells of organism as well as incorporation in tissues of an organism.

THE FATE OF ABSORBED FOOD NUTRIENTS IN THE BODY

1) 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 enzymes e.g. pepsin.

Amino acids are used in the synthesis of hormones e.g. insulin.

Amino acids are used in the synthesis of antibodies.

Some Amino acids are used in body growth and repair.

Amino acids can instead be used in the process of respiration to produce energy during starvation.

Excess Amino acids are **deaminated** by the liver to form urea and carbohydrate residue. The urea is deaminated while the carbohydrate residue is respired.

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 may be stored in adipose tissue. The fat tissue formed insulates the body against heat loss and also protects vital body organs like the liver and intestines from mechanical damage.
- Lipids are used in the formation of structures like the cell membrane.

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 for regulation of absorbed nutrients and it receives all nutrient supplies from the blood through the ***hepatic portal vein.***

Functions of the Liver

i) Conversion of excess glucose to form glycogen which is stored in the body.
ii) Deamination of excess amino acids.
iii) Conversion of excess fat into adipose tissue.

iv) Production of heat helps in temperature regulation. Since there are many metabolic reactions occurring in the liver, there is a lot of heat given off-and this heat is distributed throughout the body and it plays a great role in temperature regulation.
v) Manufacture of plasma proteins in clotting of blood. The liver helps to manufacture proteins like Albumin, Globulin and fibrinogen which are important in body process like clotting of blood (stopping bleeding).
vi) Production of bile which emulsification lipids. The liver produces bile which is important in the process of digestion i.e. in the emulsification of lipids.
vii) Storage of iron and other minerals. The liver destroys worn out blood cells and removes the ion group from them which it stores for future formation of other blood cells.
viii) Formation of red blood cells with the iron yet from the above process, coupled with vitamin B_{12}. New red blood cells can formed in the bone narrow using these raw materials.
ix) Storage of blood. Blood vessels in the liver can expand and contract to great extents such that the amount of blood in the liver can vary from $300cm^3$ – $1500cm^3$ an increase of five times thus the liver can be a blood reservoir.
x) Detoxification. The liver 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.
xi) Elimination of sex hormones. Testosterone and oestrogen are sent to the kidneys by the liver for excretion.

DIGESTION IN HERBIVORES

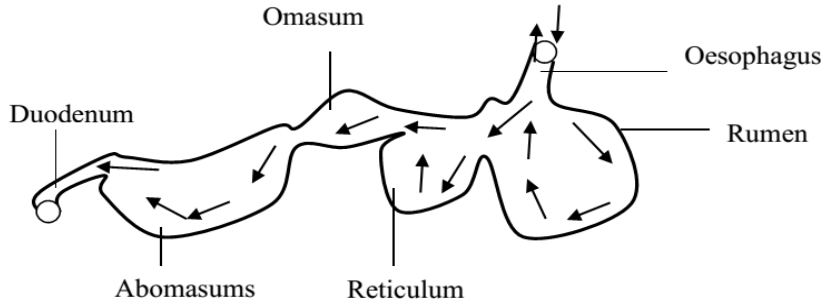
These are animals that depend on plant materials like leaves, wood, grass. They are faced with a problem of digesting the cellulose found plant cell walls.
Cellulose is a hard substance which requires special enzymes for breakdown.
These herbivores cannot secrete the enzyme which digests cellulose because they cannot produce **cellulase enzyme.** 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 incompletely chewed grass or plant materials that are taken into the stomach (rumen) and later returned back to the mouth for further chewing through a process called ***regurgitation.***

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

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



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

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

1. Rumen:

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

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

Food then moves from the rumen to the reticulum.

2. Reticulum:

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

Food is then sent back to the mouth to be chewed; chewing cud to make it softer.

3. Omasum:

This consists of parallel leaf like compartment with rough surfaces.

Water absorption also takes place.

4. Abomasum (True stomach)

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

NOTE: ***the action of microbes in the rumen and reticulum also results into formation of vitamin K and fatty acids required by the ruminant***

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 where mutualistic bacteria and protists (microbes) secrete cellulase enzyme to catalyse the breakdown of cellulose

COMPARISION BETWEEN RUMINANT AND NON RUMINANT DIGESTION

Similarities:

i) In both, young animals have a single stomach where digestion takes place.

ii) The final digestion of proteins and carbohydrates takes place in the small intestines.

Differences:

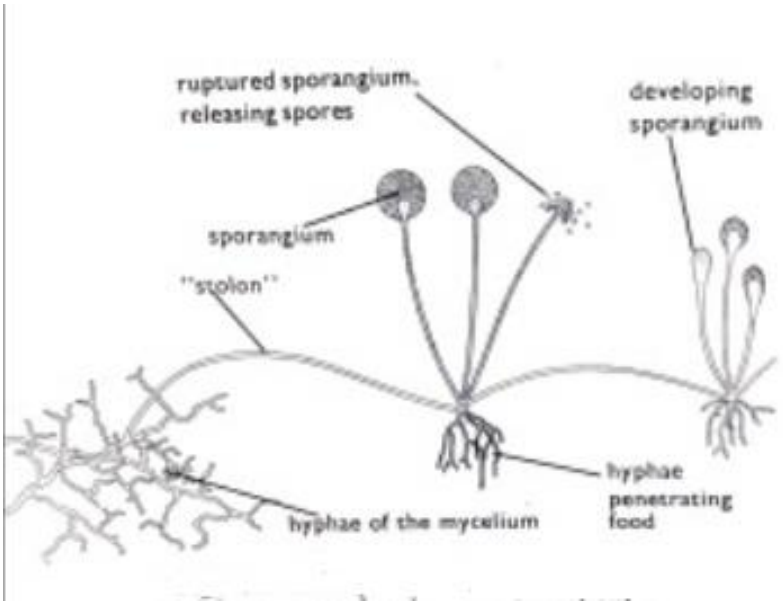
Ruminant	Non-Ruminant
6. Chew cud.	Do not chew cud.
7. Have a four chambered stomach.	Have a single stomach.
8. Ptyalin (salivary amylase is absent in saliva.	Ptyalin is present in saliva.
9. Most digestion and absorption takes place in the stomach.	Most digestion and absorption takes place in the ileum.
10. Water absorption takes place in the stomach.	Water absorption takes place in the colon.

NUTRITION IN A MOULD

Mould are fungi in the genus *Rhizopus.* They cannot make their own organic food materials from simple inorganic substances like water and carbon dioxide. Instead, they depend on already manufactured food substances.

Fungi may be parasitic or saprotrophic. Moulds however are ***saprotrophic/ saprophytic***

STRUCTURE OF A MOULD (RHIZOPUS)



SAPROPHYTIC NUTRITION IN A MOULD

The mode of nutrition in a mould is ***Saprophytism.***

Here, the functional unit of a mould called hypha is extended such that numerous hyphae spread all over the organic food substrate.

At the tip of the hypha, digestive enzymes which break down the cell walls and externally break down the organic food substances. This is called external digestion since it occurs outside the cells of the organism.

Nutrients are formed from the external digestion process and the nutrients are absorbed into the protoplasm through the chitin cell wall of the hypha.

Question: state two similarities and two differences between internal digestion and external digestion

NUTRITION IN PLANTS

Nutrition in plants is by a process called photosynthesis.

Photosynthesis is the process by which plants manufacture their own food in form of carbohydrates from carbon dioxide and water using sunlight energy.

In summary photosynthesis is a natural process that;

(i) requires two raw materials (carbon dioxide and water)

(ii) requires two conditions (i.e. optimum temperature and sunlight energy)

(iii)and forms two products namely (starch or carbohydrates & oxygen)

The process of photosynthesis occurs in all green plants in organs called **chloroplast** most of which are found in leaves.

Chloroplast contains chlorophyll which traps sunlight energy.

The process of photosynthesis is complicated but it can be summarized by the equations below.

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

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

From the equations above, there are two main products of photosynthesis;

a) Sugars, mainly glucose which can be converted to other organic compounds like sucrose, starch, amino acids, and proteins.

b) Oxygen gas.

Importance of products of photosynthesis

Sugars manufactured are then transported through the phloem to;

i) Actively matabolising parts of the plant where they are respired to give energy for growth such as growing regions (meristems)

ii) Actively matabolising cells where energy from the respired sugars is also used to drive other activities such as formation of plant hormones.

iii) Storage organs such as the roots (cassava, carrots and sweet potatoes), stems e.g. sugarcanes and Irish potatoes, fruits e.g. mango fruit, jack fruit etc.

NB: Sugars are mainly stored as starch for example in cassava tubers.

Oxygen given off is used;

i) By the plant for aerobic respiration

ii) Given off to the ecosystem where it is used by other animals for respiration.

RAW MATERIALS REQUIRED FOR PHOTOSYNTHESIS TO TAKE PLACE

1) 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. Carbon dioxide is the source of carbon found in organic plant materials.

2) Water:

Water is absorbed by the root hairs from the soil and transported up the root by the xylem vessels. Water is the source of hydrogen found in sugars.

CONDITIONS NECESSARY FOR PHOTOSYNTHESIS TO TAKE PLACE

1) Presence of chlorophyll:

Chlorophyll is a green pigment that absorbs light energy from the sun which drives the process of photosynthesis.

2) Light:

This is the source of energy necessary for the process of photosynthesis to take place. The energy from light is used to drive photosynthesis, giving oxygen as a bi-product.

3) Temperature:

For photosynthesis to take place, there must be favourable temperature to ensure enzyme activity.

Factors that affect the rate of photosynthesis

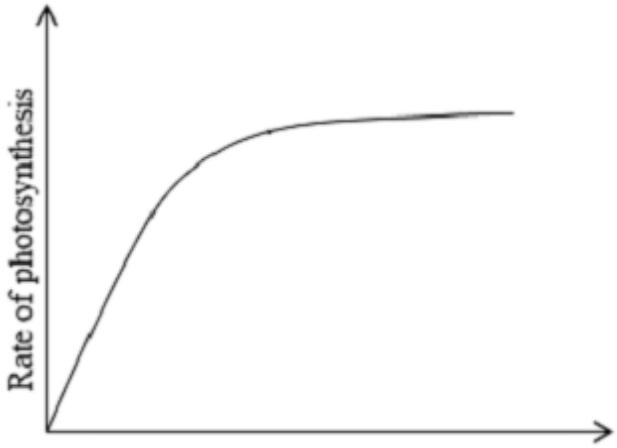
The rate of photosynthesis can be determined by considering how much oxygen is evolved by the plant or the amount of oxygen given off by the plant or increase in the weight of the plant due to accumulation of starch. Some of the factors include the following:

1) Amount of chlorophyll

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

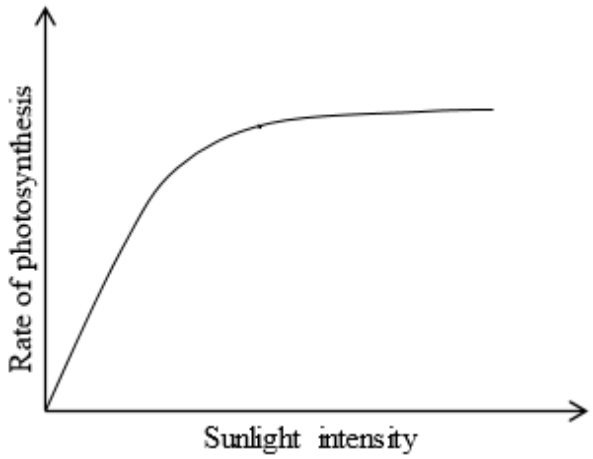
2) Amount of CO_2 in the atmosphere

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



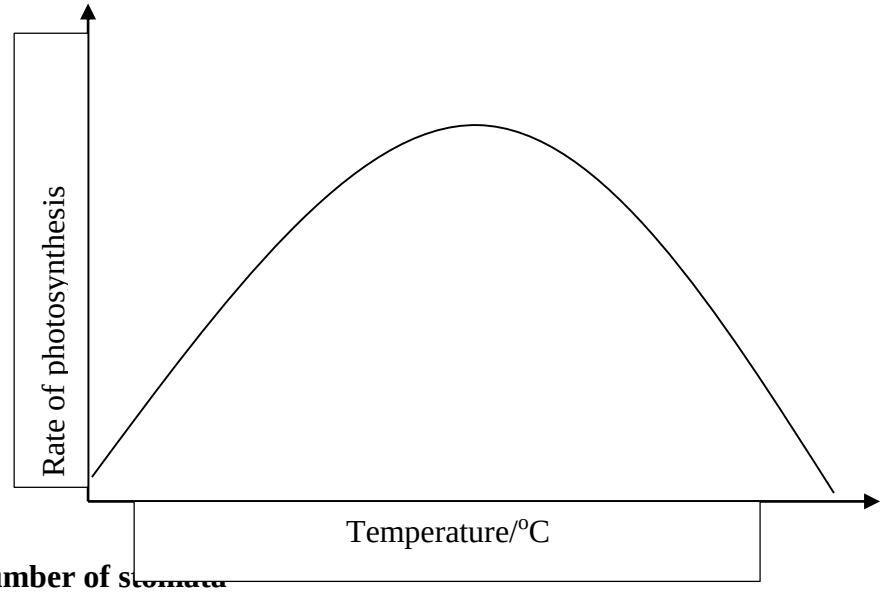
3) Light intensity

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



4) Temperature

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



5) Number of stomata

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

6) Surface area for photosynthesis

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

7) Availability of water

Increase in water concentration results into an increase in the rate of photosynthesis since water is a raw material required for photosynthesis.

ADAPTATION OF LEAVES TO CARRY OUT PHOTOSYNTHESIS

External adaptations

- Some leaves are broad provides a large surface area for trapping sunlight and taking in of Carbon dioxide.
- Numerous leaves which increase the total surface area exposed for sun light absorption thus increasing the rate of photosynthesis.
- Thinness and flatness of leaves providing a short distance for penetration of sunlight and diffusion of carbon dioxide.
- Leaf arrangement /mosaic; Leaves are arranged to ensure minimum shading of one leaf by another from light in such a way that each leaf obtains maximum sunlight for photosynthesis. This is minimum shading of one leaf by another to ensure maximum light absorption is called **leaf mosaic.**

Internal adaptation of a leaf

- Presence of numerous chloroplasts in the palisade mesophyll layer, to absorb maximum light for photosynthesis
- Presence of a spongy mesophyll layer with **air spaces** to allow easy diffusion and exchange of gases during photosynthesis.
- Presence of xylem vessels which transport water a raw material for photosynthesis from stems to the leaves where it's required.
- Presence of phloem which conduct away manufactured food to storage organs thus maintaining a concentration gradient for manufacture of more organic materials.
- Presence of numerous stomata to allow carbon dioxide to diffuse into the leaf for photosynthesis.
- Presence of a cuticle, a water tight layer which prevent desiccation (water loss) by the photosynthesizing tissues.
- Transparent cuticle to allow light penetration
- Numerous chloroplasts providing a large surface area for photosynthesis to take place.
- Numerous chlorophyll molecules in chloroplasts to absorb maximum sunlight energy for photosynthesis.
- Has closely packed palisade cells with numerous chloroplasts to increase surface area for maximum light absorption.

EXPERIMENTS ON PHOTOSYNTHESIS

Experiment 1: AN EXPERIMENT TO TEST LEAF FOR STARCH

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

Apparatus:

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

Procedure:

1) A leaf is removed from a healthy plant previously in sunlight
2) The leaf is placed in boiling water (water bath) for about 5 minutes to kill the protoplasm
3) The leaf is then placed in a beaker containing 99% alcohol and boiled using a water bath until all the chlorophyll is dissolved out, to decolorize the leaf, making detection of any colour changes easy
4) The leaf is then washed in hot water which softens it.
5) The leaf is now spread on a white surface and drops of iodine added on it.

Observation: Leaf turns to blue-black colour.

Conclusion: starch present therefore photosynthesis was taking place.

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

Experiment 2:

AN EXPERIEMENT TO SHOW THAT OXYGEN IS GIVEN OFF DURING PHOTOSYNTHESIS

Apparatus:

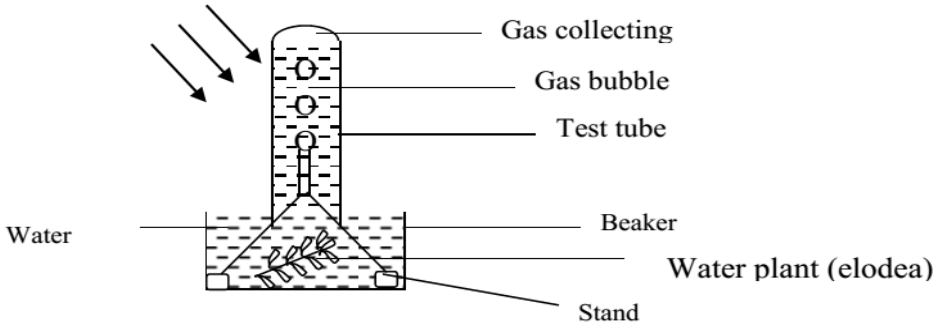
- Afresh water weed.
- Funnel and wooden blocks.
- Test tube,
- beaker
- Water.
- Sodium hydrogen carbonate.

Procedure:

a) The funnel is inverted in the beaker over the fresh water 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 supporting it 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.

NB: The evolution of oxygen by the water plant in the presence of sunlight is an indication that photosynthesis is taking place and that oxygen is given off during the process.

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

Experiment 3:

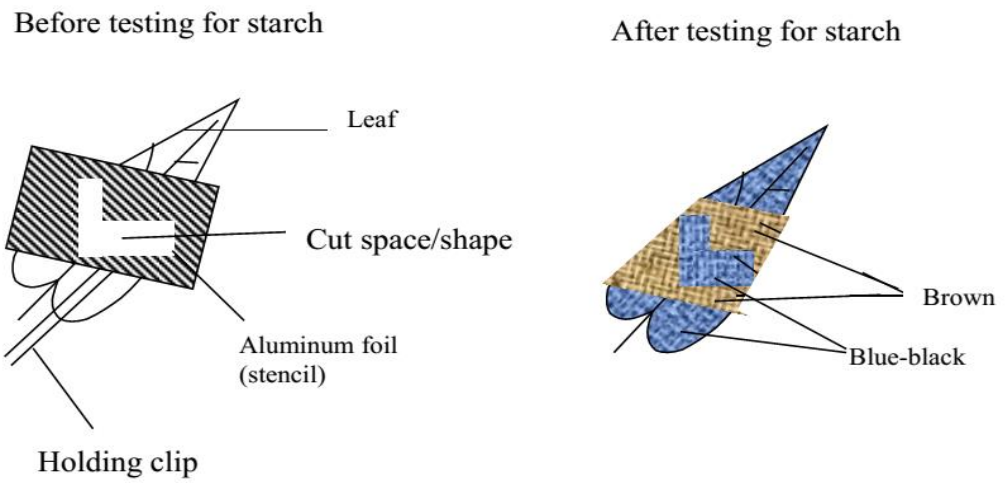
AN EXPERIMENT TO SHOW THAT LIGHT IS NECESSARY FOR PHOTOSYNTHESIS

Apparatus/materials:

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

Procedure:

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



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

Conclusion:

Light is necessary for photosynthesis to take place.

Explanation:

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

Experiment 4:

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

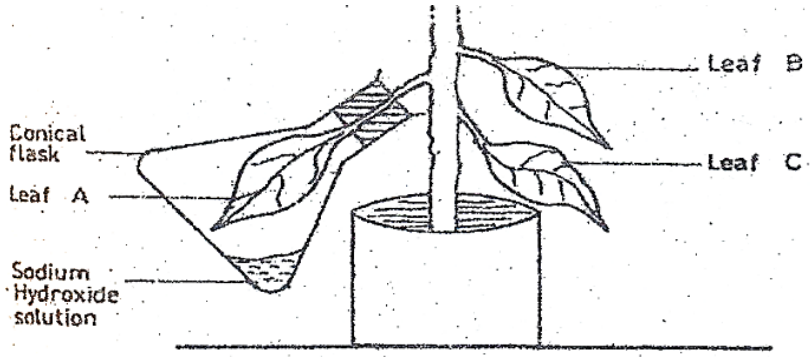
Apparatus:

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

Procedure:

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

Experimental set up.



Observation:

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

Conclusion:

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

Experiment 5:

AN EXPERIMENT TO SHOW THAT CHLOROPHYLL IS NECESSARY FOR PHOTOSYNTHESIS

Apparatus:

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

Observation:

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

Conclusion:

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

Chlorophyll is thus necessary for photosynthesis.

GASEOUS EXCHANGE AND COMPESATION POINT

Both respiration and photosynthesis take place in a green plant.

Photosynthesis equation:

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

In darkness, Green plants do not photosynthesize however they continue to respire.

Here oxygen is used up (through respiration) and carbon dioxide given off and there is an overall net consumption of sugars and starch during respiration.

At low light intensity, some photosynthesis occurs and some carbon dioxide produced in respiration by plants is used up in photosynthesis. However, there is a net loss of Carbon dioxide. As the light intensity increases, the rate of photosynthesis also increases until a point is reached when all the Carbon dioxide produced during the process of respiration is reused in the process of photosynthesis. This point is called the **compensation point**.

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

At compensation point, the carbon dioxide produced during respiration is directly used for photosynthesis

At the compensation point, the rate of photosynthesis is equal to the rate of respiration ie the rate at which food (starch) is manufactured is equal to the rate at which it is used up in the process of respiration and this means that there is no net gain or loss in the mass of the plant.

IMPORTANCE OF PHOTOSYNTHESIS

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

(i) Photosynthesis helps to purify the environment by removing excess Carbon dioxide from the atmosphere which is a pollutant.

(ii) During the photosynthesis process, oxygen is released back into the atmosphere and it is very vital in the respiration process of most organisms.

(iii) It provides energy. This energy is mainly organic in nature in form of fuels like coal, petroleum, firewood, all of which are products of photosynthesis.

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.

1. Essential macro (elements)
2. Trace micro (elements)

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.

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 in the surroundings, a plant shows deficiency signs.

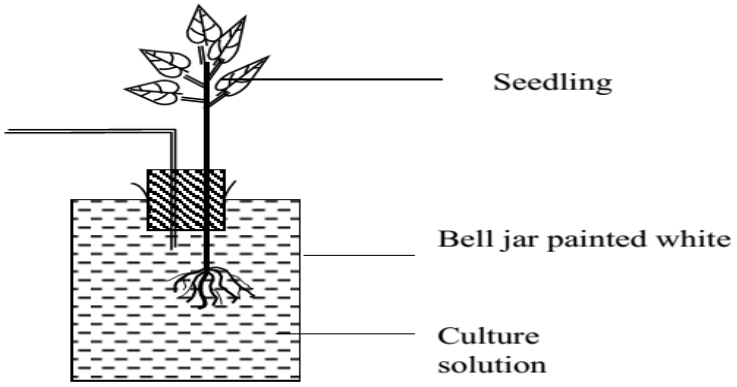
A table showing various elements and their deficiency elements

ELEMENTS	ABSORBED AS:	FUNCTION	DEFICIENCY
Nitrogen	Nitrates, NO^-_3, Ammonium ions NH^+_4	- Synthesis of proteins, Protoplasm and nuclear acids. - Consistent of chlorophyll and respiratory pigments.	- Stunted growth. - Yellowing of leaves (chlorosis)
Phosphorus	Phosphate, PO^{3-}_4	- Form part of the nuclear acid. - Necessary in nuclear division. - Acts as a buffer in the cell sap.	- Poor root growth. - Poor fruit development. - Stunted growth. - Premature leaf fall.
Calcium	Calcium ions Ca^{2+}	- Activates enzymes - Forms part of the cell wall.	- Poor root growth.
Magnesium	Magnesium ions Mg^{2+}	- Formation of chlorophyll of leaves.	- Yellowing of leaves or chlorosis.
Potassium	Potassium ions K^+	- Opening of the stomata. - It is an enzyme activator.	- Chlorosi of the margins and tips of leaves. - Stunted growth.
Sulphur	Sulphate ions SO^{2-}_4	- forms part of proteins. - it is a constituent of enzymes.	- cholorosis - weak and slender stems
Iron	Iron(II)-Fe^{2+} (green) Iron(III)-Fe^{3+} (brown)	- Formation of chlorophyll. - Activates enzymes	- Chlorosis.
Manganese	Manganese ions Mn^{2+}	- It is an activator of enzymes	- Chlorosis between veins
Chlorine	Chloride ions, Cl^-	- Activates enzymes.	- Chlorosis stunted root growth.
Molybdenum	Molybdate ions $(MnO_4)^{2+}$	Important in Nitrogen fixation as an enzyme activator.	- Chlorosis of lower leaves.
Copper	Copper ions, Cu^{2+}	- It is a constituent of enzymes	- Wilting of leaves
Zinc	Zinc ions, Zn^{2+}	- Activates enzymes. -It is important in the formation of growth hormones.	-Inter-veinal chlorosis. - Stunted growth

CULTURE SOLUTIONS

These are solutions with a balanced concentration of mineral salts. Such solutions are used to investigate the effect of a missing mineral element on plant life. This is done by dissolving all other minerals in water except one whose effect is being investigated.

Experimental apparatus for culture of seedlings



Precautions taken:

1) Walls of the jar should be painted white to keep light away from the culture in order to prevent the growth of unicellular algae which can bring about shortage of the minerals
2) The underside of bung should be kept dry otherwise the stem of the seedling may rote.
3) Air must be blown in through the right angled tube every day to provide oxygen for the roots
4) The solution should be renewed at the end of every two weeks.