# NUTRITION

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

## Modes of nutrition

Nutrition is broadly classified into two groups namely;
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.
Since the nutrition of all other organisms depends either directly or indirectly on these Autotrophs, they are referred to as producers.
Autotrophic nutrition can be divided into two depending on the external source of energy used to drive there processes;

#### i. Photosynthesis:

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

#### ii. Chemosynthesis:

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

### 2. HETEROTROPHISM / HETEROTROPHIC NUTRITION

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

# FOOD

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

### Food is required by organisms for:

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

## CLASSES OF FOOD

There are three classes of food, namely:-

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

## TYPES OF FOOD/NUTRIENT COMPOUNDS

There are six different nutrient compounds namely:-

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

## CARBOHYDRATES

These are made up of carbon, hydrogen and oxygen.

They are either sugars or starches.

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

### i) Monosaccharides

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

### Properties of monosaccharides

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

*Monosaccharides include the following:*

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

### ii) Disaccharides

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

Glucose + Glucose = maltose + water
Glucose + Galactose = lactose + water
Glucose + Fructose = sucrose + water

**The disaccharides have the following properties:**

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

**Examples of disaccharides include:**

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

### iii) Polysaccharides

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

**Properties of polysaccharides include:**

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

**Examples include:**

1) Starch
2) Glycogen
3) Cellulose.

**Functions of carbohydrates**

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

***Deficiency of carbohydrates results in a deficiency disease called marasmus.***

**Symptoms of marasmus**

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

# FOOD TESTS ON CARBOHYDRATES

## 1. Test for reducing sugars

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

| Procedure | Observation | Conclusion |
|---|---|---|
| To 1 $cm^3$ of food solution, 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 or<br>Moderate or<br>Much or<br>Too much; reducing sugars present. |
| | Colourless or turbid solution turned to a blue solution which persists on boiling. | Reducing sugars absent. |

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

### Examples of reducing sugars include:

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

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

Blue ***solution*** - no sugars

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

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

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 | 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 or<br>Moderate or<br>Much or<br>Too much; non-reducing sugars present. |
| | Colourless or turbid | Non-reducing sugars |

| | | |
|---|---|---|
| boil. | solution turned to a blue solution which persists on boiling. | absent. |

**Note:**

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

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

**Examples of non-reducing sugars include:**

1) Sucrose (present in sugar cane)
2) Lactose (present in milk)

3. **Test for starch:**

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

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

## PROTEINS

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

The **amino acids** can be differentiated into essential and non-essential amino acids.

There are a total of twenty (20) amino acids present thus allowing the formation of a variety of proteins.

**Types of amino acids:**

i) **Essential amino acids**

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

ii) **Non-essential amino acids**

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

**Sources of proteins:**

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

## Properties of proteins

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

## The main functions of proteins

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

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

## Symptoms of kwashiorkor

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

## TEST FOR PROTEINS

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

**The Biuret test:**

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

**Millon's test:**

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

## LIPIDS (FATS AND OILS)

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

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

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

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

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

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

**Food sources:**

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

### Properties of lipids

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

### Functions of lipids

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

### TESTS FOR LIPIDS

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

**a) The emulsion test:**

The reagents used are ethanol and water.

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

| | | |
|---|---|---|
| shake. | or colourless solution. | |

b) Translucent spot test:

| Procedure | Observation | Conclusion |
|---|---|---|
| Add 2 drops of test solution on a piece of filter paper.<br>Allow to dry and observe under light. | A translucent spot or patch 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:

i) Water soluble vitamins
ii) Fat soluble vitamins

Water soluble vitamins are those which dissolve in water. They include vitamins B and C. Fat soluble vitamins dissolve in fats but not in water. They include vitamins A, D, E, and K.

**A table showing vitamins and their deficiency diseases**

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

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

## TEST FOR VITAMIN C:

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

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

## MINERAL ELEMENTS AND SALTS

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

**Mineral salts can be divided into;**

**(i) Essential mineral elements (macro elements)**

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

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

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

A table showing some elements and their deficiency diseases

| MINERAL ELEMENTS | SOURCE | IMPORTANCE | DEFFICIENCY |
|---|---|---|---|
| **Fe**<br>Iron | - Beef, liver, kidney, G.nuts, beans, eggs, green vegetables. | - It is a constituent of Haemoglobin. | **Anaemia**<br>- Reduced red blood cell account.<br>- Reduction in oxygen transportation rate. |
| **Ca**<br>Calcium | Vegetables, fish, milk, bread, eggs. | - In blood clotting<br>- hardening of bones and teeth. | **Rickets in children**<br>- Delay in blood clotting<br>- Soft bone, poor skeletal growth. |
| **P**<br>Phosphorus | - Most foods | - Constituent of cell membrane.<br>- Formation of teeth & bones. | - It is not likely for one to be deficient of phosphorus since it is found in most foods. |
| **I**<br>Iodine | - Iodized salts<br>- Marine fish | - It is a constituent of a haemone **Thyroxin** | **Goitre**<br>- Swelling of the Thyroid gland.<br>- Muscle cramp (sharp pains in muscles). |
| **F**<br>Fluorine | Drinking water (National water and sewage co-operation | It is constituent of bones and teeth. | Weak teeth in children. |
| **K**<br>Potassium | Fish, beef, liver, mushroom and some tubers | Transmission of nerve impulse along neurons | Muscular cramp |
| **Na**<br>sodium | Common salt(NaCl) and cheese | Transmission of nerve impulse along neurons | |

## WATER AND ROUGHAGES/DIETARY FIBRES

### WATER

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

#### Importance of water

- ✔ It's a universal solvent in which absorbed foods, wastes and hormones are transported around the body in blood.
- ✔ The plasma of blood is made up of water.
- ✔ It participates in many metabolic reactions or processes as a raw materials e.g respiration, photosynthesis, gaseous exchange, digestion, and removal of wastes.
- ✔ Plays a role in temperature regulation ie cooling the body on hot days and plants

through transpiration.
- ✔ Offers turgidity thus acts as a hydrostatic skeleton- hence supporting organisms.
- ✔ It softens food.
- ✔ It is used in seed dispersal.
- ✔ It is a habitat (home).
- ✔ It acts as a Lubricant e.g. salvia lubricant the mouth, tears lubricate eyes, synovial fluids lubricate the joints.

## ROUGHAGES / DIETARY FIBRE

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

### Functions of roughages

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

### Balanced Diet:

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

### Mal-Nutrition:

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

## ENZYMES

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

### Importance of enzymes

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

## Classification of enzymes

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

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

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

## Nomenclature of enzymes

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

**Examples of enzymes and their substrates**

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

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

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

## PROPERTIES OF ENZYMES

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

8) They work at a specific PH. (either acidic or alkaline).
9) Their reactions are reversible.
10) Their activity can be enhanced by enzyme activators e.g. chloride ions activate amylase.

## FACTORS AFFECTING ENZYME ACTIVITIES

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

The factors are:

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

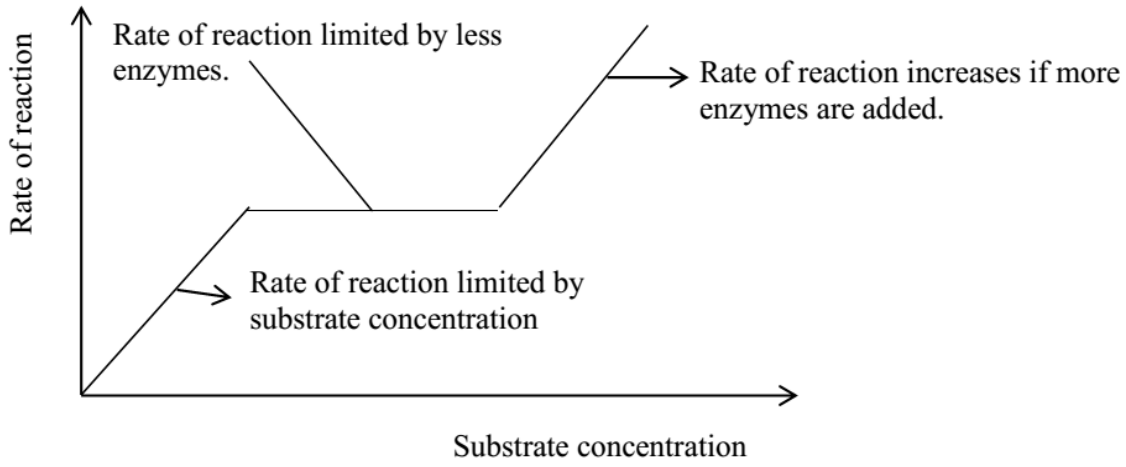
### 1. Concentration of substrate:

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

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

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

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



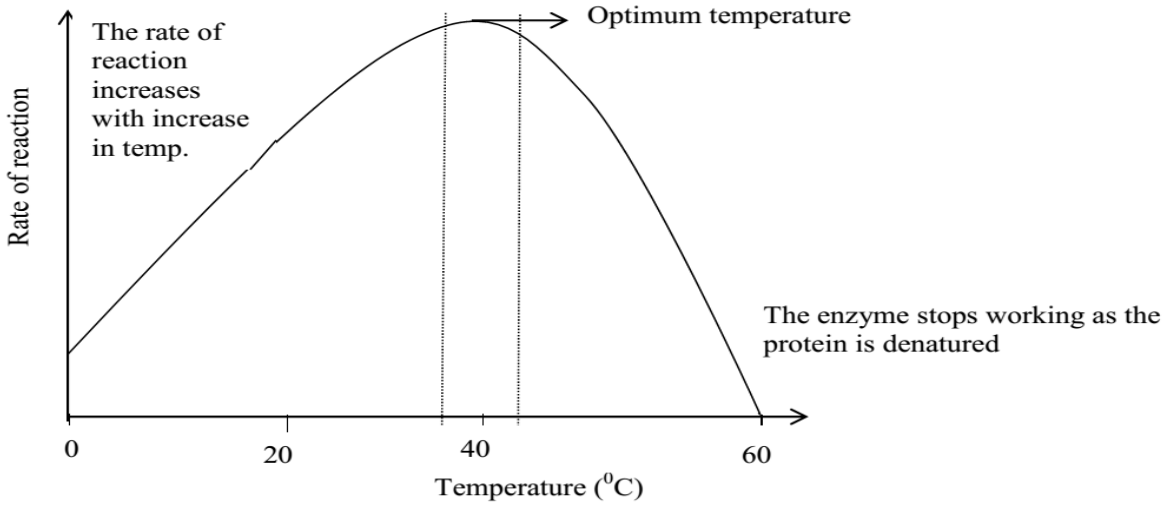

### 2. Temperature:

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

As the temperatures increases, the rate of reaction also increases rapidly by doubling

for every increase in temperature by $10^{o}c$ this because increase in temperature increases the kinetic energy of both the substrate and enzyme molecules hence their speed also increases and this increases the chance of them bumping into each other hence increase in the rate of reaction until it attains a peak where it has maximum activity and this always correspond at optimum temperatures. An optimum temperature is one which promotes maximum enzyme activity. However with further increase in temperature, the rate of reaction decreases exponentially, sharply, steeply since at high temperatures, the enzyme is denatured i.e. the active site of the enzyme which is (protein in nature) is altered (changed) or completely destroyed.

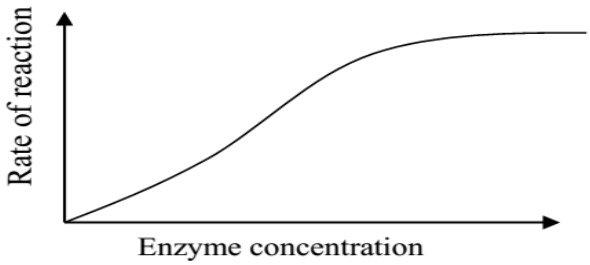
A graph showing the variation of enzyme activity with temperature




### 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.

A graph showing variation of enzyme activity with enzyme concentration



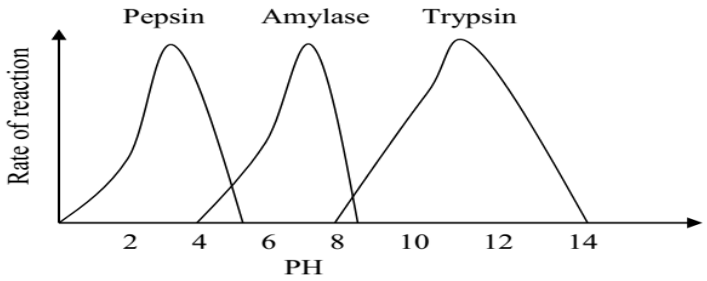

### 4. The PH of the medium.

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

PH varies slightly above or below an enzyme's optimum PH resulting in a marked fall in

the enzyme efficiency. E.g. pepsin enzyme in the human stomach has a maximum activity with in acidic pH of 1.5 and 2.5 while the enzymes in the duodenum e.g. trypsin work at maximum with in alkaline pH of 8.5 to 9.5.

A graph showing variation of different enzyme activity with PH




5. Presence of enzyme inhibitors

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

6. Presence of activators

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

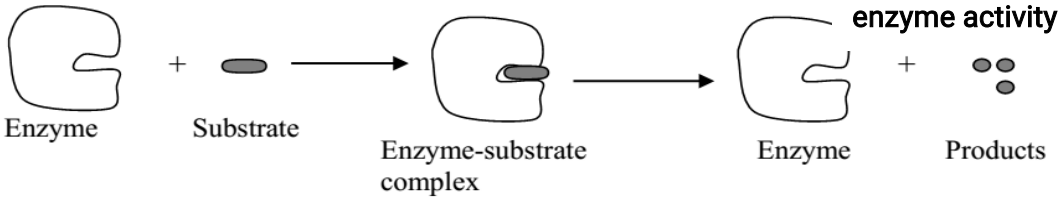
## Mechanism of enzyme action

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

The hypothesis suggests that the enzyme has a specific region known as the active site where the substrate fits like a key fits in a lock. The substrate must have a complementary 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

A graph showing variation of different enzyme activity with PH.




## 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 **Homodont**.

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

Types of teeth in mammals

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

1) Incisors

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

Structure of an Incisor

2) Canines

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

Structure of canine

3) Premolars

These lie behind the canines on both jaws.
These have flat broad surfaces which are used for grinding food.
Premolars possess two or more **cusps** and **ridges** and have two roots.
*Premolars are used for grinding and chewing food.*

Structure of premolar

4) Molars

They are absent in young mammals.
These have wider crowns with more ridges and cusps compared to premolars.
They may have three or more roots.
*Molars are used for grinding and crashing food.*

Structure of a molar

Note:

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

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

1) **Crown**

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

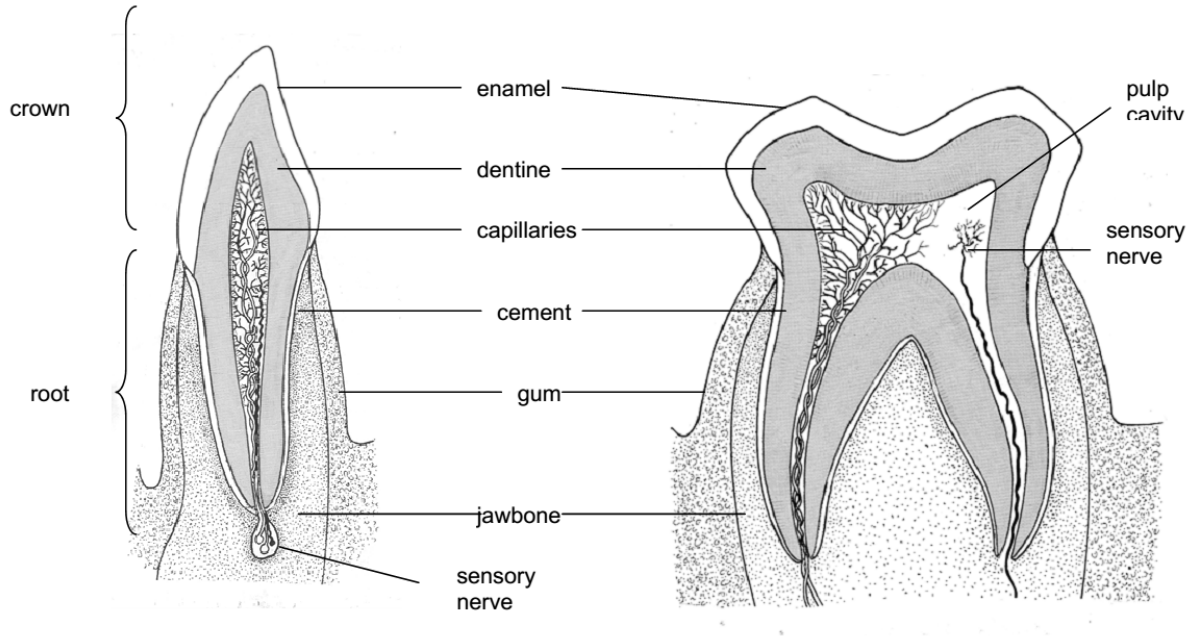
2) **Neck**

This is the junction between the crown and the root.

3) **Root**

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

## Tooth structure




Vertical section through incisor

Vertical section through molar

### Functions of the parts of the tooth

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

jawbone.

## DENTITION

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

## DENTAL FORMULA

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

**Dental formulae of some animals**

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

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

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

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

## Dental care in man

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

### i) Tooth decay or dental caries.

This is caused by lodging (when food gets stuck) of food particles especially sugars between the teeth. This food is then attacked by micro-organisms (bacteria) which ferment this food producing an acid which reacts chemically with the enamel and removes calcium from it making it soft. During chewing, the soft part of the enamel begins wearing away forming a hole which gets larger and larger as more food gets stuck in the now bigger hole and fermentation process continues. Tooth ache commences into the dentine, the pulp cavity with nerves and blood vessels get affected and a lot of pain is felt.

### ii) Periodental diseases.

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

- Pyorrhea
- Gingivitis

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

### Prevention of dental decay and proper care of teeth

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

## CARNIVORE DENTITION

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

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

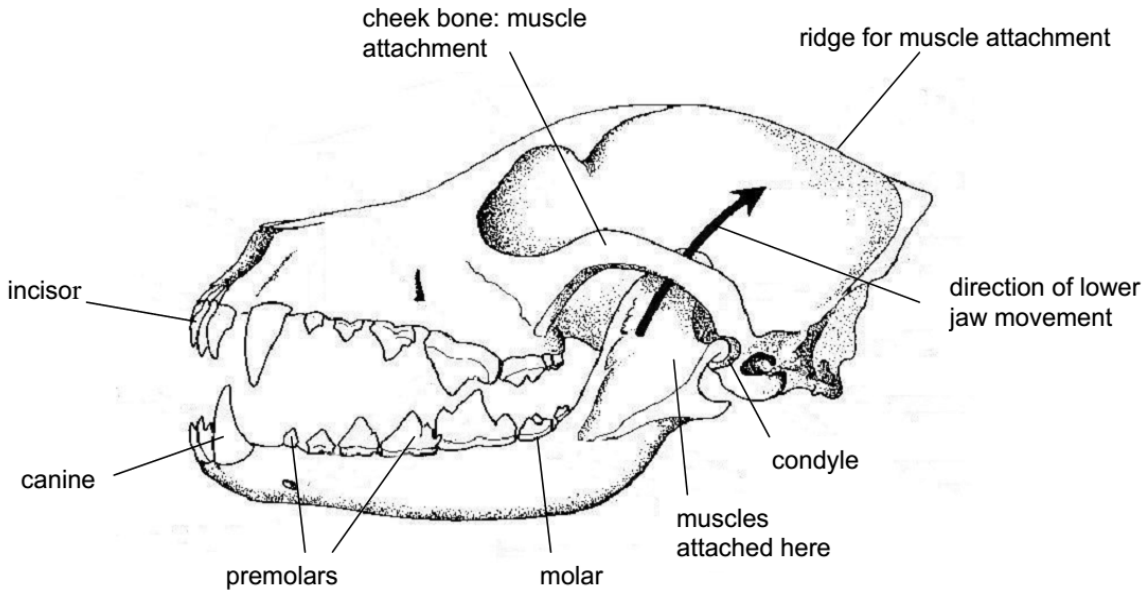
Their incisors are chisel shaped and enable them to grip and strip off pieces of flesh from bones.

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

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

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

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




HERBIVORE DENTITION

***Holozoic nutrition***;

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

This mode of nutrition is normally found in mainly free living organisms which have a specialized digestive tract.
Holozoic nutrition is characterized by the following:
i) Ingestion:
This is the taking in complex organic food into the body.
ii) Digestion:
This is the breakdown of complex organic food into smaller diffusible molecules.
iii) Absorption:
This is the taking up of soluble molecules from the digestive region across a membrane into the body tissues.
iv) Assimilation:
This refers to utilization of absorbed food molecules by the body to provide either energy or building up of body tissues.
v) Egestion:
This is the elimination of undigested food materials from the body.

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

- Carnivores
- Omnivores
- Herbivores.

Herbivores; These live entirely on plant vegetation.
Carnivores; These feed on flesh e.g. lion, cat, dog.
Omnivores; These feed on both plants and animals e.g. man and a pig.

## DIGESTION IN MAN

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

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

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

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

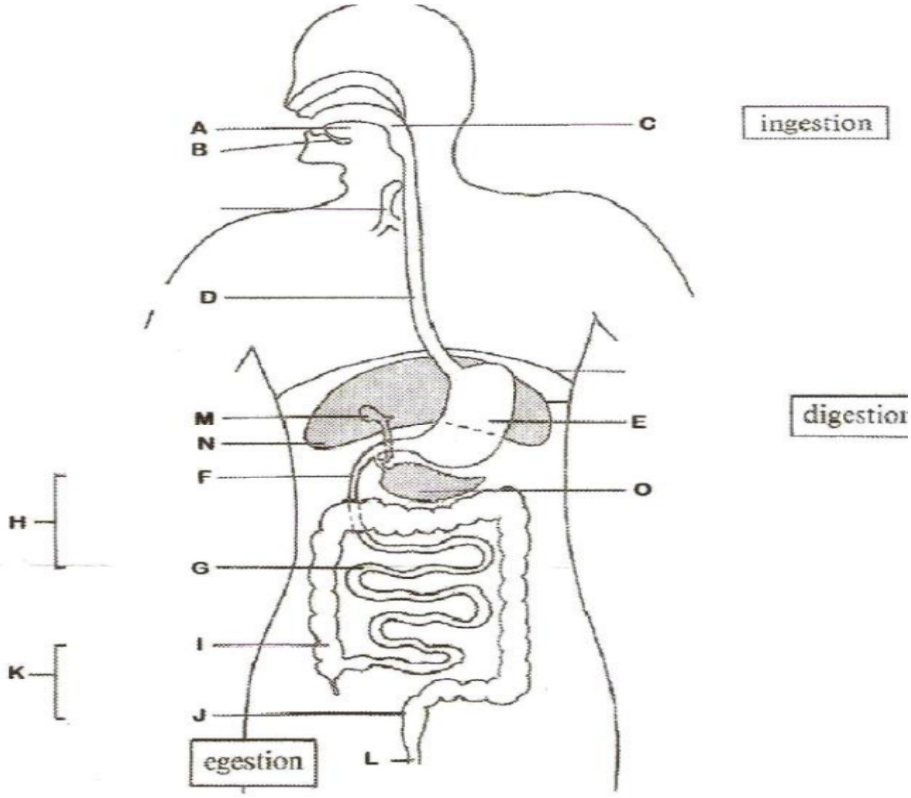
**Extracellular digestion:**
When digestion occurs or takes place outside the body or cells, it is called extracellular digestion. This may not necessarily be outside the body but it may occur inside the body but not inside cells. E.g. in fungi, man etc.

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

Note: digestion in man is extracellular digestion because the enzymes are released in

the gut cavity where digestion occurs.

**The human alimentary canal**




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

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

## Parts of the alimentary canal

1) **The mouth**

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

Once food is in the buccal cavity, the teeth break down food particles into smaller

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

2) **Oesophagus**

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

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

3) **The stomach**

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

F**unctions of the stomach**

- Stores food temporarily after meals
- It carries out mechanical digestion by its churning action
- It has a protective outer membrane which protects it from self-digestion by pepsin

**4) The small intestine**

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

- **The duodenum**

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

The ducts passages open into duodenum are;

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

**Functions of bile**

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

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

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

emulsifies fat.

- **The ileum**

This is the second part of small intestines. It is long and coiled with length of about 6-7metres in man. It involves digestion and absorption.
Its lining has numerous tiny finger-like structures called villi (singular; villus) which increase surface area for absorption.

**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) 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 thought of food.

**b) Chemical digestion in the mouth.**

Chemical digestion is carried out by the enzyme salivary amylase
Saliva is an alkaline watery solution and it provides the optimal PH for the action of amylase i.e. a high PH.
Salivary amylase acts only on cooked starch breaking it down to disaccharide called Maltose.

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

**The act of swallowing:**

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

Once the bolus is in the oesophagus, the food moves by a wave of muscular contractions called ***Peristalsis.***

## DIGESTION IN THE STOMACH

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

***In the stomach, there is only protein digestion.***

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

*Pepsin acts upon proteins/ breaking them down into polypeptides.*

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

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

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

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

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

Proteins ——pepsin——> polypeptides

### Functions of HCl in the stomach

i) It kills some bacteria in ingested food.
ii) It activates pepsin and renin
iii) Provides ideal medium for their activity of proteins (low PH).
iv) It stops the action of salivary amylase and ensures protein digestion only.
v) It prevents fermentation of food in the stomach by bacteria.
vi) Denatures proteins making them easy to digest sine they unfold.

### 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 pancrease

The arrival of food in the duodenum stimulates the production of a hormone called ***secretin*** from the pancrease and another hormone called ***cholecystokinin (cck)*** which stimulates secretion of bile from the gall bladder and pancreatic juice form the

pancreas
Secretin also stimulates production of hydrogen carbonate ions which neutralize the acid.
CCK stimulates synthesis of digestive enzymes.
The secretions are alkaline thus stopping the action of pepsin and provides an ideal medium for enzymes in pancreatic juice to work. Pancreatic juice contains a number of enzymes which are called the *pancreatic enzymes.*

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

Trypsin is also secreted in an **inactive** form, **trypsinogen** to prevent it from digesting the duodenum walls.
*Both trypsin and pancreatic amylase act upon proteins and starch that were not broken down in the stomach and mouth respectively.*

## DIGESTION IN THE ILEUM

This is where final digestion takes place.
Food moves down from the duodenum into the ileum by peristalsis.
The presence of food in the ileum stimulates the secretion of the ***intestinal juice, succus entericus by walls of the ileum***.
Succus entericus contains several enzymes which complete the process of digestion forming a milky fluid substance called ***chyle*** (food after final digestion is called **chyle**).

| Enzymes | Food and Upon | Products |
|---|---|---|
| Sucrase | Sucrose | Glucose and fructose |
| Maltase | Maltose | Glucose and glucose |
| Lactase | Lactose | Glucose and galactose |
| Peptidase | Polypeptides | Amino acids |
| Lipase | Lipids | Fatty acids and glycerol |

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

## DIGESTION IN THE LARGE INTESTINES / COLON

In the colon, water and mineral salts are absorbed. The undigested and indigestible food substances pass down into the large intestines which are eventually removed from the body as faeces through the anus. ***There is no digestion in the large intestine.***
Accumulation of hard particles like stones, small sticks in the appendix results into a condition known as **appendicitis.** The appendix is thus removed surgically by a simple

operation.

SAMPLE QUESTIONS:

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

Answer:

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

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

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

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

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

Only slight mechanical digestion occur due to the churning action of the stomach.

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

***In the ileum***, intestinal juice contains maltase which speed up the breakdown of maltose to glucose molecules which are soluble hence easily absorbed by the body.

This marks the end of the digestion for Posho.

**Question 2:**

Describe the process of digestion of proteins in man.

Answer:

***In the mouth;*** Protein food is chewed by the teeth and swallowed into the stomach.

***In the stomach;*** gastric juice is produced which contain pepsin that digests proteins to peptides and rennin coagulates protein milk in babies.

***In the duodenum;*** presence of food stimulates pancreas to secrete pancreatic juice containing trypsin which digests undigested proteins to peptides.

***In the ileum;*** intestinal juice is produced containing peptidase which break down peptides to amino acids which are later absorbed through the ileum walls.

## THE PROCESS OF ABSORPTION AND ASSIMILATION OF FOOD

### ABSORPTION

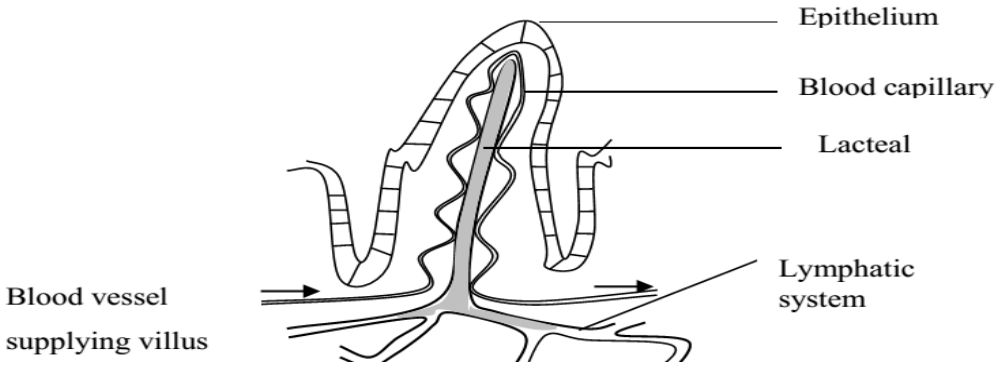
***Absorption is the process by which soluble products of digestion diffuse through the cellular lining of the villi into the blood stream.***

The villi are located in the ileum (small intestine) and thus absorption takes place in the small intestine. Some nutrients like minerals and vitamins also enter the villi by active transport.

**The ileum shows various adaptions to suit the process of absorption which includes:**

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

Diagram of Villus




***Fatty acids and glycerol are absorbed into the lacteal of the villi.*** These lacteal later join up to form the lymphatic system carrying these food materials and distributing them to all parts of the body.
Glucose, Amino acids and Fructose pass into the blood capillaries of the villus which join up to form the Hepatic portal vein which transport these nutrients to the liver.

## ASSIMILATION

***This is the process by which absorbed food materials are built up into complex constituents of the organism.***
***Assimilation is also the incorporation/utilization of the products of digestion into the body's metabolism for life processes e.g. respiration, growth and repair and digestion.***
***After the food has been absorbed by the ileum into the blood stream it moves to the liver through the hepatic portal vein.***

### Assimilation and metabolism for:

1) Carbohydrates: (Glucose)

Glucose is mainly broken down in the process of respiration to provide energy for the body's metabolic process.
Excess glucose is stored as **Glycogen** (animal starch); however, the liver has the ability to re-covert back the glycogen to Glucose in periods of starvation.

## 2) Proteins

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

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

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

**Deamination** is the removal of the amino group from Amino acids to form urea (which is a toxic waste product) and the remaining portion is used to produce energy

## 3) Lipids (Fatty acids & Glycerol)

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

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

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

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

## THE LIVER

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

### Functions of the Liver

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

raw materials.

ix) Storage of blood. Blood vessels in the liver can expand and contract to great extents such that the amount of blood in the liver can vary from $300cm^3$ – $1500cm^3$ an increase of five times thus the liver can be a blood reservoir.

x) Detoxification. The liver converts toxic substances to harmless substances by altering their chemical structure and later sends them to the excretory organs for expulsion e.g. it converts Ammonia to urea which is then expelled by the kidneys.

xi) Elimination of sex hormones. Testosterone and oestrogen are sent to the kidneys by the liver for excretion.

## DIGESTION IN HERBIVORES

Animals that depend on plant materials (herbivores) like leaves, wood, grass are faced with a problem of digesting the cellulose that make up the plant walls.

It is necessary to break through the cellulose to release the inside cell nutrients which are required by the herbivores.

These herbivores cannot secret the enzyme which digests cellulose because they cannot produce **cellulase.** However, some protozoans and bacteria can produce the enzyme cellulase.

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

### Digestion of cellulose in ruminants

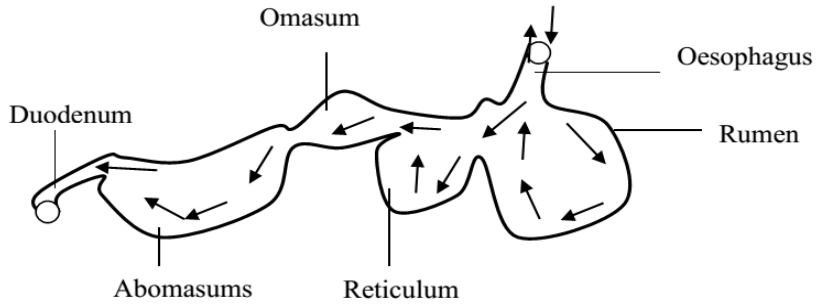
Ruminants are mammals which chew cud.

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

Ruminants have a complicated stomach made up of four chambers namely;

i) Rumen
ii) Reticulum
iii) Omasum
iv) Abomasum

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




In the mouth, the saliva does not contain any enzyme. So only mastication (chewing) and softening of food takes place.
The food moves through the oesophagus by peristalsis (wave like motion).

1. Rumen:

This is the largest component (chamber) of the stomach. It is used for storing food as the animal feeds. Fermentation and digestion of cellulose by bacteria and protozoa occurs in the rumen.
Fermentation is the breakdown of food by bacteria in the absence of oxygen. During fermentation, there is a release of a weak acid called ***lactic acid.***
Food then moves from the rumen to the reticulum and from the reticulum back to the rumen where regurgitation takes place (This is where food is returned to the mouth bit by bit for further chewing and that completes the first cycle.

2. Reticulum:

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

3. Omasum:

This consists of parallel leaf like compartment with rough surfaces.
Food is ground finely here and water absorption also takes place.

4. Abomasum (True stomach)

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

## Digestion of cellulose in termites

Termites eat wood, dry leaves and other plant materials which contain cellulose. The digestion of cellulose also takes place in the gut (stomach) with the help of protozoans which lives symbiotically in the termite's gut.
These protozoa have the ability to produce the enzyme cellulase which digests cellulose.

## COMPARISION BETWEEN RUMINANT AND NON RUMINANT DIGESTION

### Similarities:

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

Differences:

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

## FEEDING RELATIONSHIPS BETWEEN ORGANISMS

### SYMBIOSIS

This is the relationship between two organisms of different species .
Examples

### MUTUALISM

This is the feeding reiationshi in which two oirganisms of different secies are involved and both benefit.

1. In the stomach of cattle and sheep there are bacteria. These bacteria help to digest cellulose, which is used by the cow. The bacteria benefits by getting food and shelter from the cow.
2. The nitrogen-fixing bacteria in root nodules of leguminous plants. The bacteria provide nitrates to the plant by converting nitrogen to nitrates and the bacteria are protected in the root nodules. The bacteria may also use sugars produced by the plant during photosynthesis
3. The lichen is composed of a fungus and filament of algae. The fungus provides water and mineral salts to the algae and the fungus benefits by using the sugars produced by the algae

### COMMENSALISM

This is the relationship between the organisms of different species in which only one organism (commensal) benefits but the other organism neither benefits nor loses.
Examples.

1. The shark and the ramora. The ramora is a small fish that lives as a commensal attached to the shark by its sucker. When the shark feeds, the ramora feeds on left overs of the shark. The shark neither benefits nor loses.
2. The cattle/buffalos and the egret. The egret gets food in form of insects forced to fly by grazing animals. The cattle do not gain and do not lose.

### PARASITISM

This is the association between two organisms in which one (the parasite) is nutritionally dependent on the other (host). The host is harmed in the process.
Parasites are divided into two categories:
1. Endo-parasites; these are parasites that live inside the body of the host, e.g. plasmodium and HIV
2. Ectoparasites; these are parasites which live outside the body of the host, e.g. ticks, lice and flea.

Parasites can also be described as:

Obligate parasites; these are parasites which cannot live without their hosts. Examples of obligate parasites are plasmodium and HIV.

Facultative parasites; these are parasites that can spend some time outside the bodies of their hosts. E.g. Ticks.

Incidental parasites; these are organisms that are not usually parasite but may become parasitic due to factors like lack of their normal food, increase in their numbers, etc. an example is Entamoeba gingivalis.

Problems faced by parasites
i) Finding the host may be difficult since most hosts keep on moving from one place to another.
ii) Deficiency of food in case the host has similar deficiency.
iii) They may be killed by the hosts' immune reactions.
iv) Death of parasites incase the host dies due to starvation.
v) Inabilities to live in a wide range of environment since most of them have low power of locomotion i.e. they are not able to live freely.
To overcome some of these problems, the parasites have a number of adaptations so as to cope up with their mode of life.
ADAPTATIONS OF PARASITES TO THEIR MODE OF LIFE
Structural
- Some have boring devices to enter the host
- Have attachment organs like suckers and hooks to attach to the host internally e.g. the tapeworm
- Highly specialized mouth arts like in fluid feeders e.g. aphids
- Absence of feeding and locomotory organs in order for the parasite to occupy the smallest space possible
- Have cuticle to prevent digestion by the hosts enzyme

Physiological
They produce enzymes that digests the external tissue of the host
The have the ability to respire anaerobically though they can also respire aerobically

Ability to tolerant high PH

Reproductive

Some are hermaphrodites and can reproduce since they have both reproductive organs

Have numerous reproductive bodies e.g. eggs ,cysts and sores

Use of secondary vectors

The reproductive bodies are resistant to the external environment.

Types of hosts

1. Intermediate host:

This is the host in which the larvae stage of parasites develops from (secondary host).

2. Primary host (infinite host):

This is the host in which sexual reproduction of a parasite occurs from.

EXAMPLES OF PARASITES

1. PLASMODIUM SPP

Control of malaria

Spraying the walls of dwelling places with insecticides. The insecticide may also be sprayed directly on the mosquito vector.

Draining all stagnant water to prevent mosquitoes from breeding there.

Removing broken bottles, old tins, old car tyres, e.t.c in which water collects. This also prevents breeding of mosquitoes.

Sleeping under mosquito nets

Treating the infected people using anti-malarial drugs.

2. THE TAPEWORM

These are flatworms belonging to phylum platyhelminthes. There are two common species known.

i) Taenia sagnata (beef tape worm)

ii) Taenia solium (pork tape worm)

They live in the small intestine of humans attached to the wall of the small intestine by hooks and suckers. They absorb nutrients from the digested food.

Life cycle of a tapeworm

Within the infected human being, the segments containing fertilized eggs break off and pass out in feaces.

These eggs then tend to become attached to leaf blades of vegetation.

When the eggs are eaten by the pig or cow depending on the species of the tapeworm, they develop into embryos.

The released embryos burrow through the intestinal walls into the blood, which transports them to the muscles.

Within the muscles they develop into bladder worms.

If uncooked or partially cocked, meat from an infected cow or pig is eaten, the bladder worms are released in the intestines where they develop into tapeworms.

Control

1. Avoid eating raw or half cooked meat.
2. By regular de-worming of infected individuals
3. By proper disposal of wastes
4. Inspection of meat before it is considered fit for human consumption.

Adaptations of tapeworms to parasitic life

i) They have lost the alimentally canal hence absorb already digested food over the entire body surface by diffusion.
ii) They have a thick cuticle to prevent attack by digestive enzymes of the host.
iii) They produce substances that inactivate the enzymes of the host.
iv) Each mature proglotids of the tapeworm contains both male and female reproductive organs (hermaphrodites) hence fertilizes itself.
v) They produce large numbers of eggs to ensure their survival.
vi) They have suckers for attachment to intestinal walls. This prevents the tape worm from being dislodged by host peristaltic movements
vii) They have resistant stages in their lifecycles with secondary and intermediate hosts to ensure survival during adverse conditions.
viii) There is loss of unwanted organs like locomotally organs, eyes, etc. to ensure that they occupy as little space as possible within the host.
ix) They have the ability to respire anaerobically and can survive in an oxygen free environment.

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

## NUTRITION IN PLANTS

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

i) Light stage
ii) Dark stage

Photosynthesis is the process by which living plants manufacture their own food in form of carbohydrates (starch) from raw materials i.e. carbon dioxide and water using

sunlight energy trapped by chlorophyll and give off oxygen as a bi-product.

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

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

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

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

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

## CONDITIONS NECESSARY FOR PHOTOSYNTHESIS TO TAKE PLACE

### 1) Chlorophyll:

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

### 2) Carbon dioxide:

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

### 3) Light:

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

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

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

**4) Temperature:**

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

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

**5) Water:**

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

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

**6) Oxygen:**

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

## Adaptation of leaves to carry out photosynthesis

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

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

## External adaptations

**Leaves are broad and flat:**

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

**Numerous leaves:**

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

**Thinness:**

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

**Leaf arrangement / leaf mosaic:**

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

## Internal adaptation of a leaf

**Palisade mesophyll layer**

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

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

**The spongy mesophyll layer**

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

**Network of veins (vascular tissues)**

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

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

**Presence of stoma:**

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

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

**The cuticle**

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

**Numerous chloroplasts**

These ensure that enough sunlight is trapped by the chlorophyll.

## EXPERIMENTS ON PHOTOSYNTHESIS

**Experiment 1**

### AN EXPERIMENT TO TEST LEAF FOR STARCH

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

**Apparatus:**

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

**Procedure:**

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

**Observation:**

A blue black colour shows that starch is present.

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

**Conclusion:**

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

**Experiment 2:**

## AN EXPERIEMENT TO SHOW THAT OXYGEN IS GIVEN OFF DURING PHOTOSYNTHESIS

**Apparatus:**

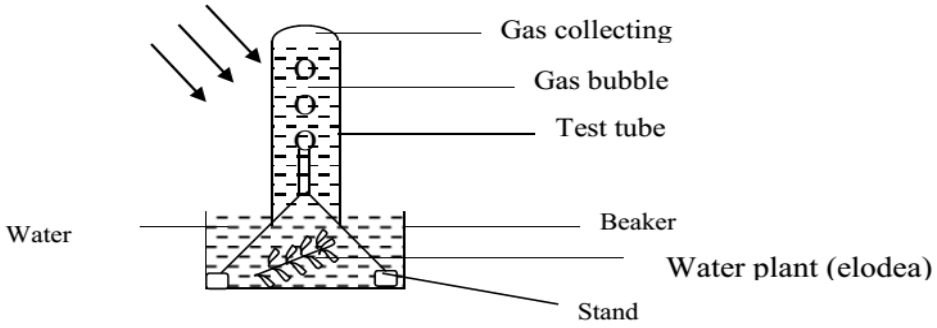
- Afresh water weed.
- Funnel and wooden blocks.
- Test tube,
- beaker
- Water.
- Sodium hydrogen carbonate.

**Procedure:**

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

The apparatus is arranged as shown below:

**Experimental setup**




**Observation:**

Gas bubbles are evolved and sufficient gas is collected at the top of the test tube.
In the control experiment, no bubbles are involved.

**Conclusion:**

The gas collected relights the glowing split proving that it is oxygen.
The evolution of oxygen by the water plant in the presence of sunlight is an indication that photosynthesis is taking place.

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

**Experiment 3:**

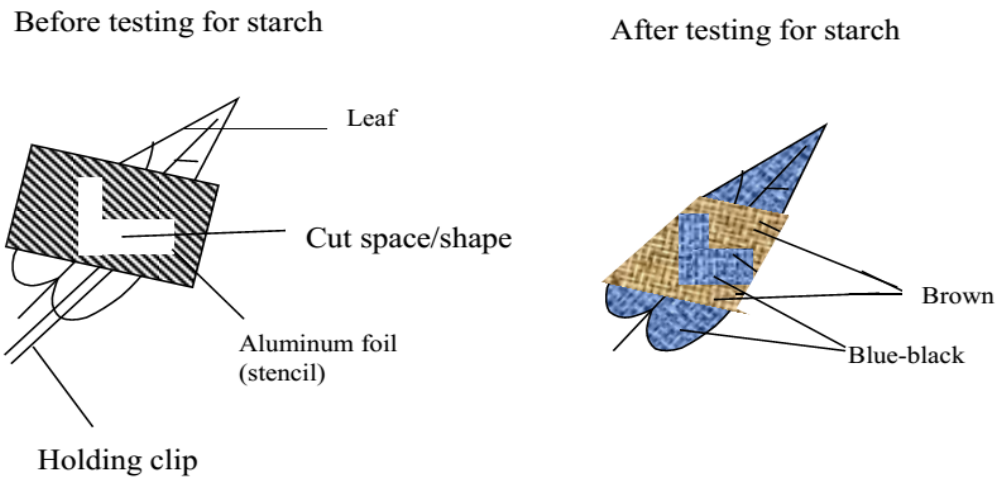
## AN EXPERIMENT TO SHOW THAT LIGHT IS NECESSARY FOR PHOTOSYNTHESIS

**Apparatus/materials:**

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

**Procedure:**

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




**Observation:**

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

**Conclusion:**

Light is necessary for photosynthesis to take place.

**Explanation:**

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

Experiment 4:

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

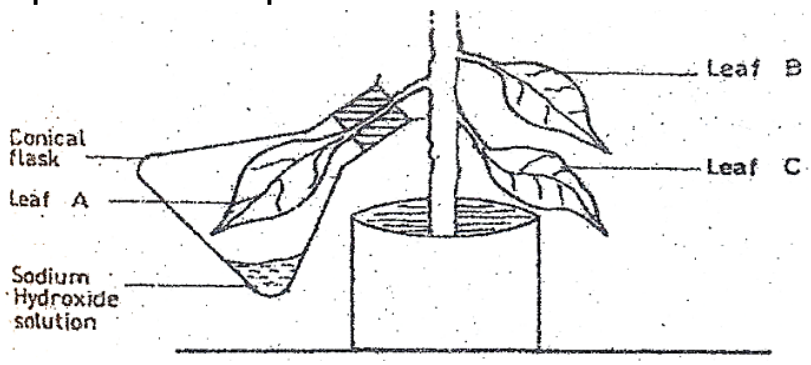
Apparatus:

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

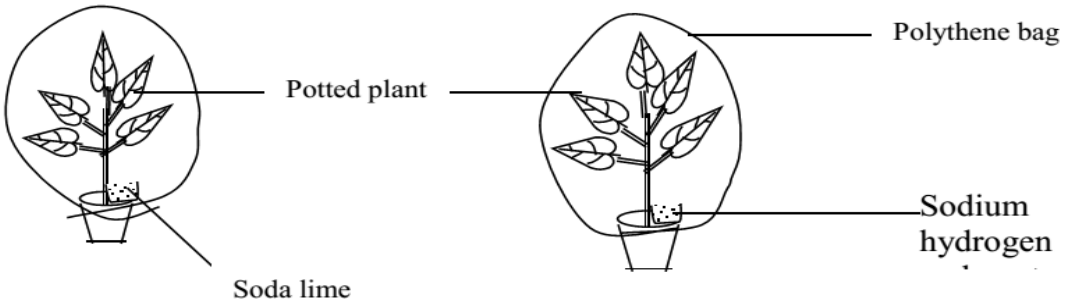
Procedure:

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

Experimental set up.




Alternatively




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

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

**Experiment 5:**

## AN EXPERIMENT TO SHOW THAT CHLOROPHYLL IS NECESSARY FOR PHOTOSYNTHESIS

**Apparatus:**

- A beaker,
- Alcohol,
- white tile
- 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**.

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

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

## IMPORTANCE OF PHOTOSYNTHESIS

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

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

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

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

## Factors that affect the rate of photosynthesis

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

### 1) Amount of chlorophyll

The more chlorophyll, the more the light energy absorbed leading to increased rate of

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

2) Amount of $CO_2$ in the atmosphere

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

3) Light intensity

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

4) Temperature

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

5) Number of stomata

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

6) Surface area for photosynthesis

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

7) Amount of oxygen

The rate photosynthesis decreases with increase in oxygen concentration and it increases with the lowering of oxygen concentration.

8) Availability of water

## 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.

**Elements, their functions and effects of their deficiency**

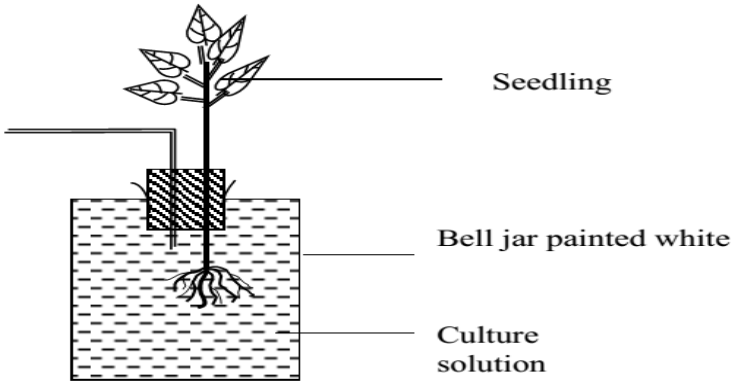
| Mineral | Form taken into plant | Function | Deficiency symptoms |
|---|---|---|---|
| Nitrogen | - Nitrates ($NO_3^-$)<br>- Ammonium ion ($NH_4^-$) | - Synthesis of amino acids, proteins and nucleotides<br>- Forms part of chlorophyll | Stunted growth, yellow under developed leaves |
| Potassium | $K^+$ | -Formation of cell membrane and proteins<br>- Opening of stomata | -Yellow and brown edges of leaves<br>-Premature death |
| Calcium | $Ca^{2+}$ | - Development of cell wall<br>- Activates some enzymes. Neutralizes certain acids in the soil. | - Poor root growth<br>-Stunted growth |
| Phosphorus | $PO_4^{3-}$ | - Formation of ATP<br>- Synthesis of nucleic acids.<br>- Formation of proteins. | -Red leaves |
| Magnesium | $Mg^{2+}$ | -Part of chlorophyll molecule<br>- Activates enzymes. | -Poor root and development of fruits.<br>- Stunted growth. |
| Iron | $Fe^{2+}$ or $Fe^{3+}$ | -Synthesis of chlorophyll<br>- Activates enzymes. | -Stunted growth<br>-Yellow leaves and veins remain green |
| Sulphur | $SO_4^{2-}$ | -Amino acid and Protein synthesis | -Yellow leaves<br>-Stems become weak and slender. |
| Manganese | $Mn^{2+}$ | -Activation of enzymes<br>-Formation of chloroplast membranes. | -Premature death of shoots |
| Zinc | $Zn^{2+}$ | -Activation of enzymes<br>-Forms plant growth substances. | -Poor leaf and stem formation |
| Boron | Borate | -Uptake of calcium<br>-Cell differentiation. | -Gray colouration<br>-Death of stem. |
| Carbon | $CO_2$ | Carbohydrate synthesis | Not common |
| Hydrogen | $H_2O$ | Carbohydrate synthesis | Not common |
| Silicon | | Cell wall formation in grasses | -Decrease in weight in cereals |
| Aluminum | | Decrease in cell division | -Stunted growth |

| | | | |
|---|---|---|---|
| Copper | | Important in reactions of photosynthesis | -Inhibits respiration and photosynthesis |

## 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.

### 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.<br>- Consistent of chlorophyll and respiratory pigments. | - Stunted growth.<br>- Yellowing of leaves (chlorosis) |
| Phosphorus | Phosphate, $PO^{3-}_4$ | - Form part of the nuclear acid.<br>- Necessary in nuclear division. | - Poor root growth.<br>- Poor fruit development.<br>- Stunted growth. |

| | | | |
|---|---|---|---|
| | | - Acts as a buffer in the cell sap. | - Premature leaf fall. |
| Calcium | Calcium ions $Ca^{2+}$ | - Activates enzymes<br>- 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.<br>- It is an enzyme activator. | - Chlorosi of the margins and tips of leaves.<br>- Stunted growth. |
| Sulphur | Sulphate ions $SO^{2-}_{4}$ | - forms part of proteins.<br>- it is a constituent of enzymes. | - cholorosis<br>- weak and slender stems |
| Iron | Iron(II)-$Fe^{2+}$ (green)<br>Iron(III)-$Fe^{3+}$ (brown) | - Formation of chlorophyll.<br>- 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.<br>-It is important in the formation of growth hormones. | -Interveinal chlorosis.<br>- Stunted growth |