# CYTOLOGY

## THE CONCEPT OF CYTOLOGY.

Cytology is the study of cells, their structures, functions, characteristics and adaptations.

## THE CELL THEORY

The bodies of all living things are made up of cells.

Robert Hooke (1665) was the first person to discover a cell from a plant cork. The cells looked like boxes. Other people who studied the structure of cells are Lamark (1809), Detrochet (1824) and Turpin (1826).

Schleiden (1838) studied the plant cells and emphasized that the cells are organisms and entire animals and plants are aggregations of these organisms arranged according to the definite laws.

In 1839 Schwann, a German botanist stated that " we have seen that all organisms are composed of essentially like parts namely of cells".

## IMPORTANCE OF CYTOLOGY

Cytology has been very important discipline in the research diagnosis and treatment of human diseases. Most of health problems people encounter involve the cell disturbances.

The study examines cell interaction. Studying how cells interact or relate to other cells or environments the cytologists can predict problems or examine the dangers to the cell and identity type of infections.

## THE MAIN IDEAS OF THE CELL THEORY

1. All organisms are made up of cells.

2. The new cells are derived from the pre-existing cells by the process of cell division (mitotic and meiotic division).

3. All chemical reactions/metabolic activities in the bodies of the organisms take place within the cells.

4. The cells contain hereditary materials which are passed from one generation to another.

5. Given a suitable condition, a cell is capable of independent existence.

## CHALLENGES OF THE CELL THEORY

- Hereditary materials are also found in viruses, mitochondria and chloroplasts, all of which are not viruses.

**STRUCTURE OF CELLS AND FUNCTIONS**

The five structures are also known as ultra structure and are obtained by two techniques.

- Physiological or metabolic activities take place within a cell. Viruses though are not cells, have life within their hosts.
- The new cells arise from pre-existing cells by cell division. In this postulate the theory does not specify about the origin of the first cell.
- All living things must have cells. This postulate is challenged by the existence of viruses, where when they are inside the body of their host, viruses act as living things even though they don't have cellular organization.
- Electronic microscope.
- Cell fractionation.

A cell is usually a tiny, three dimensional sac of many organelles which are suspended within an aqueous medium (the cytoplasm) containing or contained (bounded) by a cell membrane.

In the case of plants, a cell wall is bounded by a cellulose cell wall.

The bulk of these structures (organelles) of the cells is referred to as a cytoplasm.

**Cytocil** is the fluid part of the cytoplasm.

**PROKARYOTIC CELLS.**

They are extremely small for example bacteria all range from 0.5 – 10 micrometers.

They appeared about 350 million years ago.

Cells of prokaryotes lack the true nuclei that are their genetic material (DNA) are not enclosed by the nuclear membrane and lies freely in the cytoplasm.

**EUKARYOTIC CELLS**

The cells of eukaryotic have three basic parts

1. The plasma membrane.

2. The cytoplasm.

3. The nucleus.

**Plasma membrane.**

This is also called the cell surface membrane as plasma membrane or plasma lemma which separates the contents of the cells from the external environment, controlling the exchange of materials.

In animal cells it is an outermost layer where as in plant cells it is beneath the cell wall. E.g. neurillema in neurons.

Muscle cells – sacrolemma.

**STRUCTURE OF THE CELL MEMBRANE**

There are two models suggested by different scientist to try to describe the cell membranes.

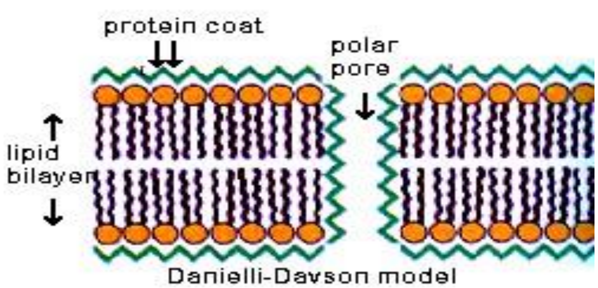
These are;

i. Daniel-Davson model (1935)

ii. Fluid mosaic model (1972)

**Daniel-Davson model**

**Diagram**




According to Daniel and Davson, the membrane is structurally composed of two chemical substances that form their own layer.

1. Protein layer made up of molecules. The layer is continuous and lacks pores.

2. Phospholipids (at least two layers of phospholipids) oriented with their polar (hydrophilic ends near the surface and their non polar (hydrophobic) hydrocarbon chains in the interior of the membrane as far as possible from the

surrounding water.

According to the model, the membrane is structurally rigid static and non dynamic.

**Strength of the model.**

1. The model suggests that the membrane is composed of proteins and lipids.

2. Ampliphetic (double) nature of phospholipids such as phospholipids molecule has a polar head (hydrophilic) and a non polar tail (hydrophobic).

**WEAKNESS OF THE MODEL**

1. The model suggests that the protein layer is continuous. Researches done by scientists show that the protein layer is in-continuous.

2. The membrane is static is a wrong concept since the membrane is a dynamic ever changing structure.

3. Lack of pores in protein layers.

The protein molecules in a membrane have pores for passage of materials.

4. The model does not indicate the presence of a carbohydrate.

**THE FLUID MOSAIC MODEL.**

The model was put forward by singer and Nicolson 1972 in order to modify the Daniel and Davson model.

According to the fluid mosaic model, the membrane is an ever-changing structure in which the mosaic protein floats on the lipid bilayer acting as a fluid.

Proteins in this model do not form a continuous layer covering both sides of the membrane as proposed by Daniel and Davson model.

According to this model, the membrane has 3 constituents.

- Lipids (45%)
- Proteins (45%)
- Carbohydrates (10%)

**1. Lipids.**

There are two types of lipids.

**a. Glycolipids**;

These are lipids associated with short carbohydrates chain.

**ROLES OF GLYCOLIPIDS**

Cell to cell recognition.

Act as receptors for chemical stimuli.

**b. Phospholipids;**

These are lipids associated with phosphates. They form 2 layers i.e. phospholipids bilayer. Each phospholipid consists of a polar head (hydrophilic) and a non polar tail (hydrophobic).
Act as a fluid and move about rapidly in their own layer. Since phospholipids are constantly in motion, the membrane is described as being fluidly.

**ROLES OF PHOSPHOLIPIDS**

1. Form the basic structure of the membrane.

2. Determine the fluidity of the membrane.

3. Allow the passage of fat soluble substances.

NB: cholesterol is a type of steroid located in between phospholipids keeping them fluidly.

**ROLES OF CHOLESTEROL**

1. Disturb the close package of phospholipids keeping them fluids.

2. Increase the flexibility of the membranes by allowing relative movements of the bilayers without actual displacement because it acts as an unsaturated fatty acid lubricating bilayer.

**2. PROTEINS**

These exist as globular in the membrane, i.e. they never form a continuous layer.

Within protein molecules or between adjacent there are poles. These may either be hydrophobic or hydrophilic.

Since the phospholipids are always in constant motion (fluid) proteins float in it forming a fluid mosaic model. The proteins are organized in a particular pattern known as mosaic.

There are protein molecules that extend/ transverse both layers of membranes. Other proteins are partially embedded in the membrane. These are called **intrinsic proteins**.

Some proteins float freely inside the membrane, hence they are called peripheral or extrinsic proteins.

**TYPES AND ROLES OF PROTEINS.**

**1. Carrier proteins or channel proteins**.

These are involved in the selective transportation of polar molecules. i.e. ions across the membrane

e.g. movement of glucose to the cell, chlorine ions. ($Cl^-$)

**2. Enzymes**

Catalyze different metabolic reactions.

**3. Receptor molecule.**

Some act as receptors for chemical stimuli example hormones.

**4. Antigen.**

Identity markers. These are glycoprotein. They have different shapes in every kind of a cell. They have specific side chains thus are recognized by other cells and behave in an organized manner.

5. **Energy transfer.**

In some physiological processes such as photosynthesis and respiration, some proteins are involved in energy transfer (special form of membrane found in chloroplasts and mitochondria).

**3. CARBOHYDRATES**

These branches to the outside of the membrane as an antennae or feelers.

There are two types;

1. Glycoprotein ( carbohydrate chain – plus protein)
2. Glycolipids ( carbohydrate chain plus lipid)

They form a layer of glycocalyx

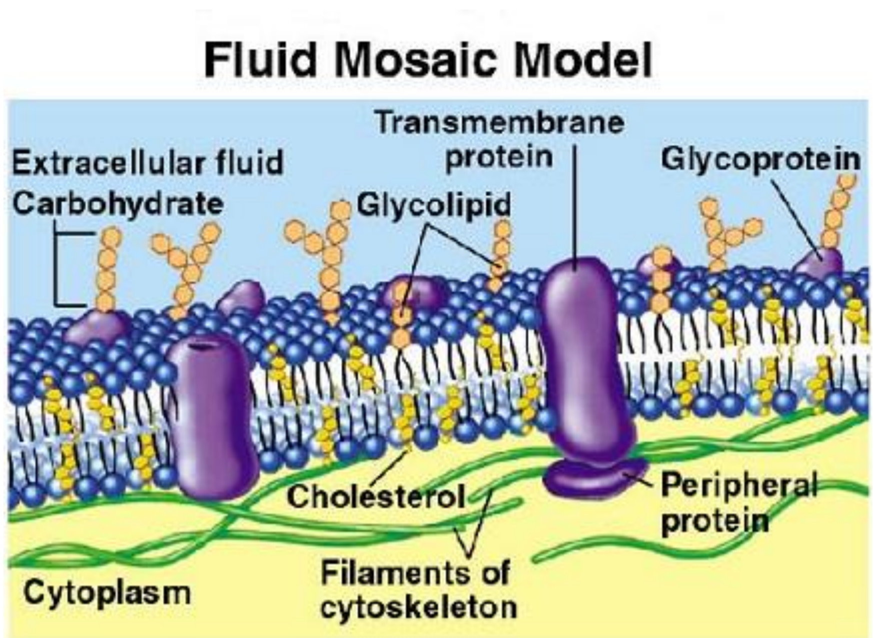
**ROLES**

1. Cell to cell recognition (in making tissues since same cells combine so similar cells will have similar glycolipids/ glycoprotein).
2. To receive chemical stimuli.

**STRENGTH OF FLUID MOSAIC MODEL.**

1. It realizes the presence of phospholipids bilayer and protein layer.
2. The presence of polar head (hydrophilic) and non polar tail (hydrophobic) in the phospholipids.
3. It shows that the membrane is not static.
4. It shows the presence of carbohydrates.
5. It shows that the protein layer is not continuous.
6. It indicates the presence of pores in the membrane passage of materials.

**Diagram**




**FUNCTIONS OF CELL MEMBRANES.**

1. It protects the cytoplasm contents of the cells.
2. It allows passage of materials in and out of the cells since it has pores.
3. In some membranes e.g. those of the intestine cells, there are microvilli which increase the surface area for absorption of materials.
4. Acts as receptor sites for chemical stimuli such as hormones.

5. In nerve cells, the membrane is over lined with a fatty sheath (myelin sheath) which prevents the spreading of local currents to other neurons.
6. It aids cell to cell recognition when membranes of two cells come together.

## VARIOUS WAYS BY WHICH MATERIALS PASS THROUGH THE MEMBRANES.

1. **Permeability**

   The plasma membrane is a thin elastic membrane around the cell which usually allows the movement of small ions and molecules of various substances through it. This nature of plasma membrane is termed as permeability.

2. **Osmosis**

   The plasma membrane is permeable to water molecules. To and fro movement of water molecules through the plasma membrane occurs due to the difference in concentration of the solutes on its either side. The process by which the water molecules pass through a membrane from region of higher water concentration to a region of lower water concentration is termed as osmosis.

3. **Diffusion or passive transport**.

   The diffusion of a certain solute or substance takes place through the plasma membrane depends on the concentration and electrochemical gradient.

4. **Active transport.**

   When molecules or ions move through the plasma membrane from low concentration to higher concentration, they require energy for such movement.

   The energy is provided by ATP which is produced by the mitochondria.

   Through the pores of plasma membrane some chemicals such as urea and glycerol could pass. It has been shown that large molecules of certain proteins also penetrate the cell.

5. **Endocytosis and exocytosis.**

   The plasma membrane particles actively in the ingestion of certain large sized foreign or food substances.

   The process by which the foreign substances are taken and digested is known as endocytosis.

In the process of exocytosis, the cells which have secretory functions such as pancreatic cells pass out their enzyme secretions outside the cell.

According to the nature of the food of foreign substance, endocytosis may be classified into two types;

1. **Pinocytosis**

When the ingestion of food materials in bulk takes place by the cell through the process known as pinocytosis.

2. **Phagocytosis**

Sometimes the large sized solid food or foreign particles are taken in by the cell through the plasma membrane. The process of ingestion of large sized solid substances by the cell is known as phagocytosis.

**Question:** what is the significance of a fluid mosaic model in the plasma membrane?

**Ans:**

- It explains easily the known physical and chemical properties of the membrane.
- It is the starting point to understanding the fix of the cell.
    - All membranes of the cell plus the tonoplast and those of the organelles have the fluid mosaic construction.

      NB: this point provides the clues about the distribution of cell membrane in the cell and its organelles.

**NOTE:**

$$R \,\alpha\, \frac{A \Delta C}{\Delta L}$$

Where

$\Delta$C=Different in concentration between two points

$\Delta$L=Distance between two points of the membrane (thickness of Material)

R = rate of transport of material.

A = cross section surface area.

**CYTOPLASM**

This is the part of a cell, which is filled with fluid in the protoplasm. This part of the cell is the ground substance of the cell known as the hyaloplasm, where the cell organelles are suspended. **Cytosil** is the soluble part of the cytoplasm.

Cytoplasm is distinguished into the following structures

1. **Cytoplasm matrix**

The space between plasma membrane and nucleus is followed by a morphous, translucent, homogenous liquid known as cytoplasm matrix and hyaloplasm.

The cytoplasm matrix consists of various inorganic compounds e.g. carbohydrates, lipids, proteins, nucleon proteins, nucleic acids (RNA and DNA) and variety of enzymes.

The peripheral layer of a cytoplasm matrix is relatively non-glandular viscous and known as endoplasm.

2. **Cytoplasm inclusion**

The cytoplasm matrix contains many refractive granules of various sizes; these granules in the animal cells are known as cytoplasm inclusion.

The cytoplasm inclusion includes oil drops, yolk granules, pigments, secretory granules and glycogen granules.

Such granules in plant cells are known as plastids. The most common plastids are the chloroplasts (containing pigment chlorophyll), the leucoplastids (white color plastids) ,omyplastids ( the plastids that store starch) and lipoplastids ( which contain fats).

NB: plastids like cytoplasmic inclusion having only storage functions but also perform various important synthesis and metabolic activities such as the production of food materials due to the presence of chloroplasts.

**ANIMAL CELL STRUCTURES**

Diagram of the animal cells under light and electron microscope.

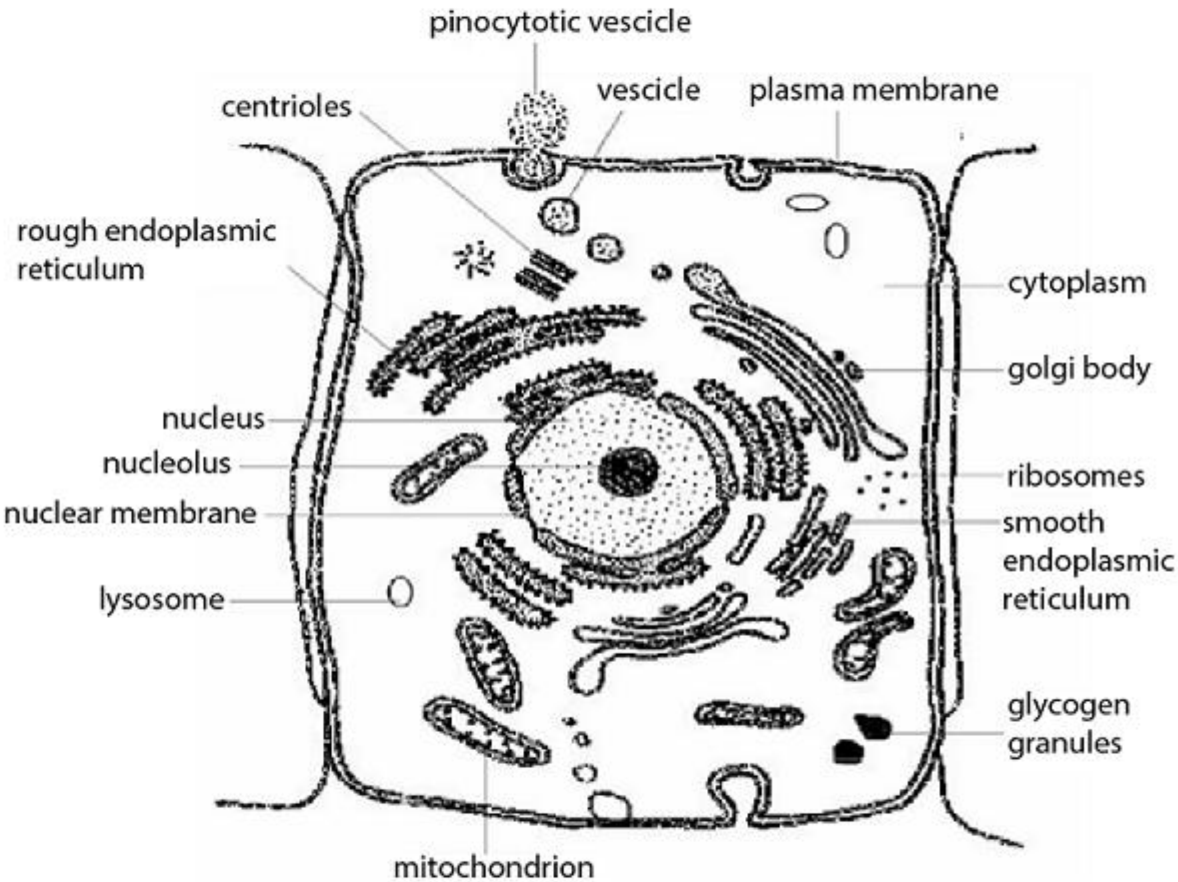
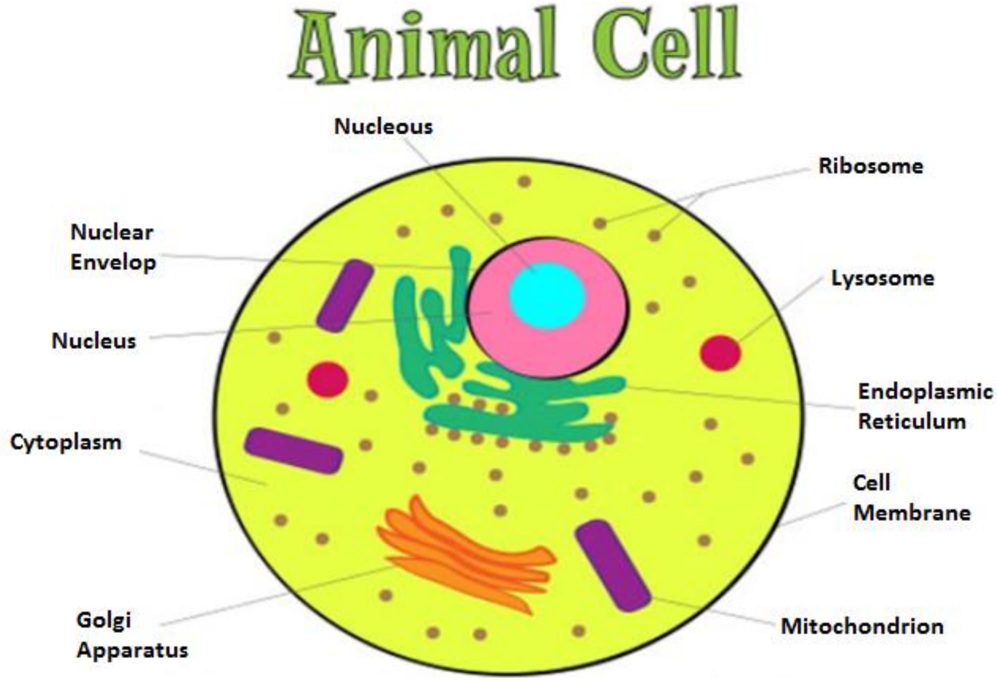

pinocytotic vescicle
centrioles
vescicle
plasma membrane
rough endoplasmic reticulum
cytoplasm
golgi body
nucleus
nucleolus
nuclear membrane
ribosomes
smooth endoplasmic reticulum
lysosome
glycogen granules
mitochondrion

**DIAGRAM OF ANIMAL CELL UNDER ELECTRON MICROSCOPE**




## ANIMAL CELL STRUCTURES

Characteristics;

1. Have irregular shape.
2. Have centrioles.
3. Have lysosomes.
4. Lack cell walls.
5. Lack plastids.
6. Store carbohydrates in the form of glycogen e.g. phagocytotic vacuoles, pinocytotic vacuoles, autophagic vacuoles and etc.
7. Cytokinesis occurs by furrowing i.e. periphery – centres direction of constriction of cell membrane.

## STRUCTURE OF THE PLANT CELL

A plant cell is incased in a tough and rigid cellulose cell wall.

Beneath the cell wall is the cell surface membrane which surrounds the cytoplasm.

The latter contains organelles; the prominent being vacuole plastids e.g. chloroplasts and nucleus.

-Since a greater part of the cell is occupied by the vacuole, then the cytoplasm and nucleus are squeezed by the vacuole to the periphery.

-When viewed under light microscope; only a few structures are seen under high magnification power, even finer details are seen.

**Diagram**

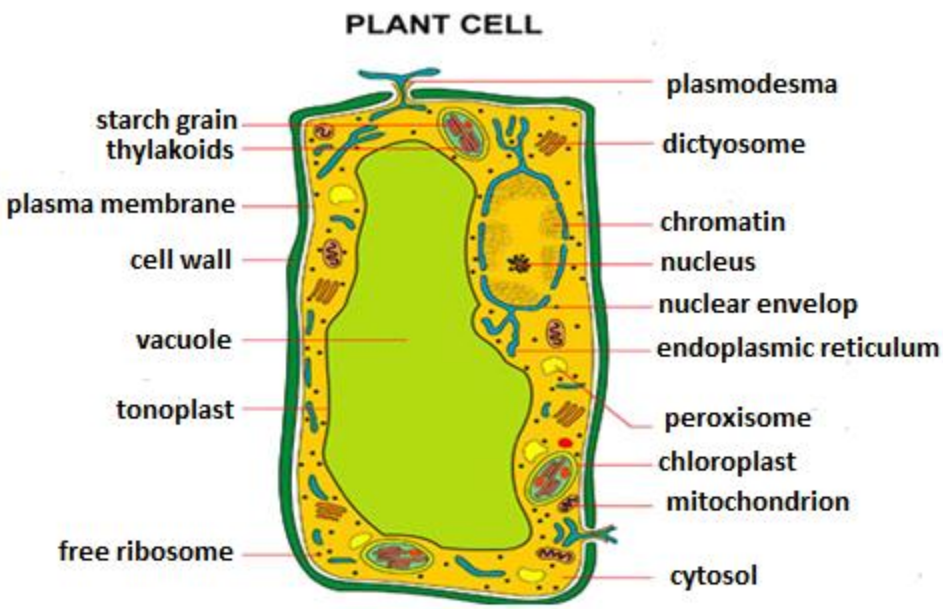
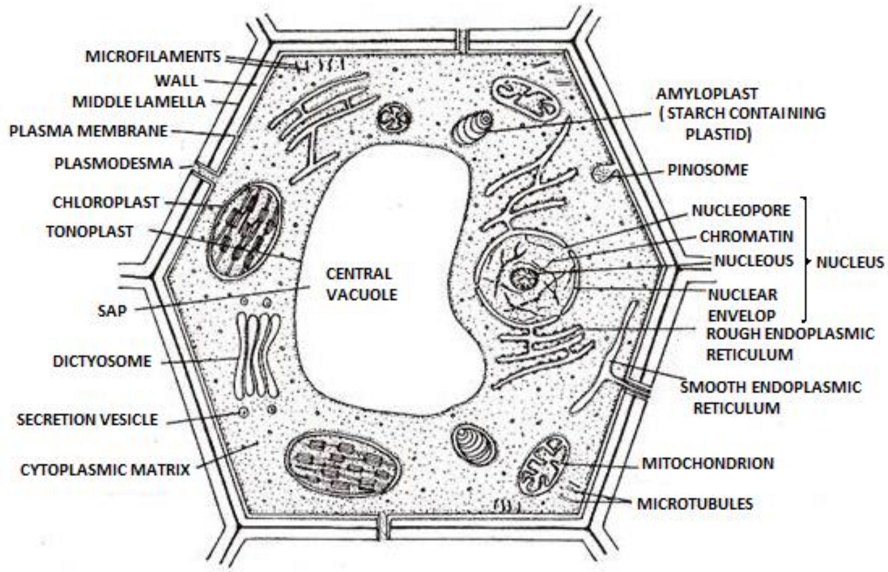


**Diagram of a plant cell under light microscope**




A generalized ultrastructure of eukaryotic cell with cell wall (plant cell)

**CHARACTERISTICS OF PLANT CELLS**

1. It has a fixed shape.
2. It has a cell wall made up of cellulose.
3. It has large permanent vacuole,
4. It has plastids; chloroplasts, chromoplast and leucoplasts.
5. Stores carbohydrates in the form of starch.
6. Lack lysosomes.
7. Lack centrioles.
8. Cell division; cytokinesis follows cento-periphery direction.

**Similarities between a plant and an animal cell:**

Both Have;

1. Plasma membrane
2. Distinct nucleus
3. Ribosome
4. Endoplasmic reticulum
5. Cytoplasm
6. Golgi apparatus
7. **Qn** What is an organelle?

**An organelle** is a distinct part of a cell which has a particular structure and function e.g. Mitochondria, chloroplast, ER etc.

CELL WALL

Cell wall is the structure that occurs externally to the cell.

Organisms with cell wall include.

8. Bacteria - have cell wall made up of murein and peptidoglycogen.
9. Fungi – has cell wall made up of chitin.
10. Algae and plant have cell wall made up of cellulose.

**Plant cells cell walls.**

It is the structure external to the cell; it isn't an organelle although it is a product of various cell organelle e.g. microtubules and Golgi apparatus.

**CHEMICAL COMPOSITION.**

It is made up of cellulose (mainly fibres) forming amorphous matrix of the cellulose that surrounds the entire cell.

Such fibre is made up of several hundred microfibrils which form the network of cell wall.

In addition to cellulose plant cell wall consists of pectron and hemicellulose which contribute to mechanical strength of the organism.

**Pectron**

These are polysaccharides of galactose and galactronic acid. Pectron may combine with $Ca^{2+}$ or $Mg^{2+}$ to form calcium pectate or magnesium pectrate, which are important components of the first layer of cell wall to be laid down on middle lamella.

**Hemicellulose**

Hemicellulose is the mixture of many compounds, but the chief ones are sugar e.g. glucose and sugar acid residue.

Hemicelluloses which form hydrogen bounds with cellulose fibres in the cell matrix. The cell wall is usually modified by deposition of other substances such as alginic acid and calcium carbonate in the case of algae.

**Functions of cell wall.**

1. Mechanical support and skeletal support of individual cell and plants as well. This is through lignifications.
2. To prevent cell from bursting in hypotonic solution.
3. Control cell growth and shape. Orientation of cellulose microfibrils limits and helps to control cell growth and shape because of the cells ability to stretch is determined by their arrangements.
4. Movement of water and material salts.

   The system of interconnected cell walls (apoplast) is a major pathway of the movement of water and dissolved mineral salts.

   The cell walls are held together by middle lamellae, they also posses minute pores through which structures called plasmodesmata form living connections between cells and allows the protoplast to be linked in a system called symplast.

5. Reduction of water loss and reduced risk of infection (due to its waxy cuticle).
6. Transportation of materials. The walls of xylem vessels and sieve tubes are adopted for long transportation of materials through the cells.
7. Barrier to water movement.

   The cell walls of root endodermal cells are impregnated with suberin that forms a barrier to water movement.

8. Some cell walls are modified as food reserves as in the storage hemicelluloses in some seeds.
9. Transport of materials by active transport.

   The cell wall of transfer cells develops an increased surface area and this increases the efficiency and transfer materials by active transport.

**CELL ORGANELLES OR ORGANOIDS.**

Besides the cellular inclusion and plastids, the cytoplasm matrix contains many large sized structures known as cell organelles or organoids which perform various important synthesis, transportation, support and

reproduction.

These organelles are the endoplasmic reticulum, ribosome, Golgi complex, liposomes, mitochondria, plastids, centrioles, cilia etc.

**Functions of cytoplasm**

1. It provides medium for chemical reaction to take place like protein synthesis, lipids synthesis and etc.
2. It stores useful materials such as amino acids, proteins, starch, carbohydrates, lipids, $O_2$ etc.
3. It stores waste materials such as $C0_2$ and nitrogen waste etc.
4. It controls the absorption of materials across the membrane due to its concentration gradient.

**CELL ORGANELLES**

1. **ENDOPLASMIC RETICULUM**

   Is the cytoplasm matrix, is transverse by a vast reticulum or network at interconnecting tubules and vesicles which is known as endoplasmic reticulum or ER.

   The endoplasmic is having a single vast and interconnected cavity which remains bounded by a single membrane. The membrane of endoplasmic reticulum is supposed to be originated in pushings of plasma membrane

   in the hyloplasm (matrix) because chemically it consists of a lipoproteinous structure like plasma membrane.

   The membrane of the endoplasmic reticulum may be either smooth when they do not have attached ribosome and rough when they have the attached ribosome.

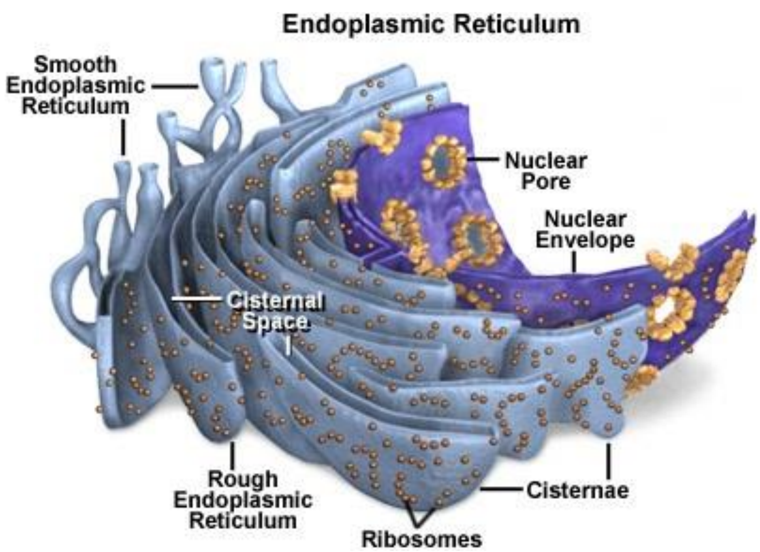
   The membranes of endoplasmic reticulum are found to be continuous with the nuclear membrane and plasma membrane.

   **FUNCTIONS OF ENDOPLASMIC RETICULUM**

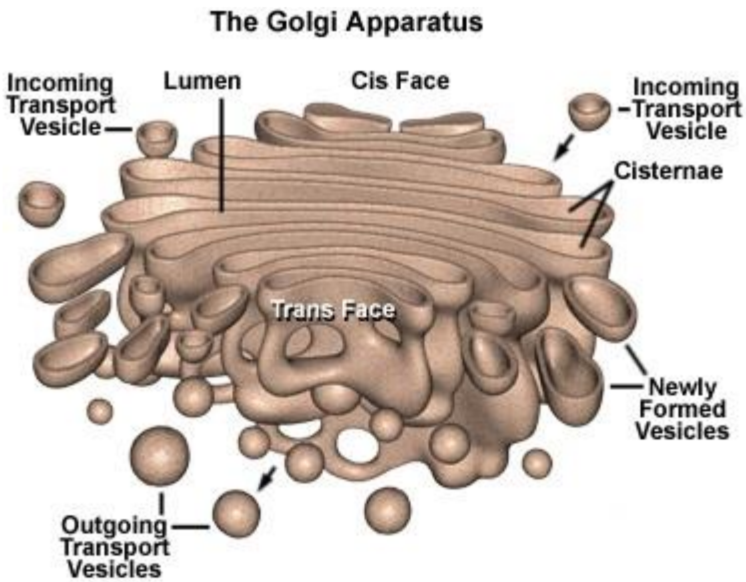
1. Transport of materials from exterior to the nucleus or to cytoplasm organelles such as Golgi complex.
2. It provides mechanical support to the cytoplasm matrix.
3. Functions as a cytoplasm framework.

   Surfaces for some of the biological activities of the cell catalyst its complex folding provide an enormous surface for such activities.

4. Synthesis and transfer of lipids.( smooth endoplasmic reticulum)
5. In the liver the smooth endoplasmic reticulum detoxifies many poisons and drugs.
6. The rough endoplasmic reticulum transports proteins synthesized in the ribosome of the rough endoplasmic reticulum.
7. Formation of Golgi bodies as they are modified endoplasmic reticulum.
8. Routes for movement of materials from the nucleus to the cytoplasm.




**2. GOLGI APPARATUS/ DICTYLOSOMES** This cell organelle is also known as the Golgi body, Golgi complex or sityasome.




It is the apparatus which consists of membranous sacs called cisternae and a system of small vesicle (called Golgi vesicles or dictysome vesicles) and vacuoles of various sizes.

The membranes of Golgi complex are of lipoproteins and these are supposed to be originated from the membrane of endoplasmic reticulum.

**FUNCTIONS**

1. Produce secretions

   There are many Golgi apparatus in;

- Cells of salivary gland
- Cells of root cap
- Cells of endocrine glands i.e. pancreas

2. Modification of materials.

The combination of carbohydrates and proteins to form glycoprotein takes place in them. Many materials such as mucin are glycoprotein. It takes place in the cistern.

Carbohydrate chain + lipids = glycolipids

3. Production of carbohydrates example cellulose produced in plants after division. Thus this separates one cell from another.

4. Transport of lipids (storage and transport of proteins and lipids) after digestion, the fatty acids and glycerol are formed. In the endoplasmic reticulum fatty acids and glycerol unite to form lipids (triglycerides). The latter are passed to the Golgi apparatus where it transports them to the plasma membrane as lymphatic system and going to the lymphatic system.

5. Formation of lysosomes.

6. Synthesis of various types of carbohydrates from simple sugars.

7. It activates the mitochondria to produce ATP.

8. It forms the acrosome of the sperms.

**3. LYSOSOMES.**

These are spherical single membrane bound organelles containing digestive enzymes.

-lipase

-carbohydrases

- Nucleases

The enzymes are synthesized in ribosome RER transported to the Golgi apparatus for modification. The Golgi vesicles are detached from the Golgi apparatus and remain in the cytoplasm as lysosomes because they contain digestive enzymes.

**FUNCTIONS**

1. Functions as storage vesicle for many powerful digestive (hydrocytic) enzymes.

2. Acts as digestive system of the cell enabling it to process some of the bulk materials taken in by phagocytosis or pinocytosis. Digests parts of the cell such as worn out organelles and also to digest the stored food contents of chloroplast A and B in extracellular digestion.

3. Play role in some developmental process e.g. remolding of bones and fractures.

NB: in plant cells, the large contrast vacuole may act as lysosomes although bodies similar to lysosomes of an animal cell sometimes seen in the cytoplasm of a plant cell.

**4. RIBOSOMES.**

Structurally it has two sub-units, i.e. small subunit and large subunit.

Each of the two subunits is composed of rRNA (ribosomal RNA) and proteins.

It is present in both eukaryotic and prokaryotic cells. The sizes can be determined by the sedimentation when centrifuging showing the 80's and 70's ribosome.

-80's ribosome are present in R.E (rough endoplasmic) reticulum of eukaryotic cells.

-70's ribosomes are present in prokaryotes as well as mitochondria and chloroplasts of eukaryotic cells.

**FUNCTIONS OF RIBOSOMES**

1. They provide large surface area for protein synthesis.

2. They are binding sites of the RNA.

**ADAPTATIONS OF RIBOSOMES.**

The ribosomes are the sites for protein synthesis. it has the following characteristics.

1. Presence of enzymes capable of catalyzing the synthesis of peptide bonds.
2. Presence of ribosomal RNA (rRNA) that attract other types of RNA i.e. mRNA and tRNA towards the ribosome's.

**5. VACUOLES**

1. A vacuole is a fluid filled sac which is bound by a single membrane.

   In animal cells, there are relatively small and temporary vacuoles such as phagocytotic, pinocytotic, autophagic vacuoles in plant cells; the vacuole is large and occupies a greater proportion of the cytoplasm.

   The membrane bounding the vacuole is the tonoplast and the fluid inside is the cell sap or vacuole sap.

The cell sap is a mixture of many substances; concentrates solutions of sugar, salt, organic acids, gases such as $C0_2$ and oxygen, pigments and waste products of metabolism.

It also contains enzymes similar to those of lysosomes.

**ROLES OF CELL VACUOLES**

1. They are involved in primary plant growth. It is a result of turgor pressure generated inside the vacuoles as a result of entry of water. This causes cell expansion as the tonoplast is pressed against the cell wall.

2. The pigment contained in the cell sap is responsible for flower color and therefore play a key role to pollination.

3. They contain enzymes similar to those of lysosomes when plant cell dies. The tonoplast looses the differential permeability and enzymes escape causing autolysis.

4. Vacuole acts as a temporary store of waste products such as crystals of waste calcium oxalate, toxins and metabolic waste products of plants.

5. The vacuoles sometimes functions as food reserves e.g. sucrose mineral salts and insulin are stored in vacuoles.

6. In prokaryotes it serves for buoyancy.

**6. MITOCHONDRIA**

**Structure of mitochondria**

It is a sausage shaped or an oval shaped organelle surrounded by a double membrane (mitochondrial envelope). The envelope consists of the outer and inner membrane.

Between the two membranes there is a space, the intermembranal space.

The outer membrane is smooth while the inner membrane is coiled to form t=surface area for attachment of membranes.

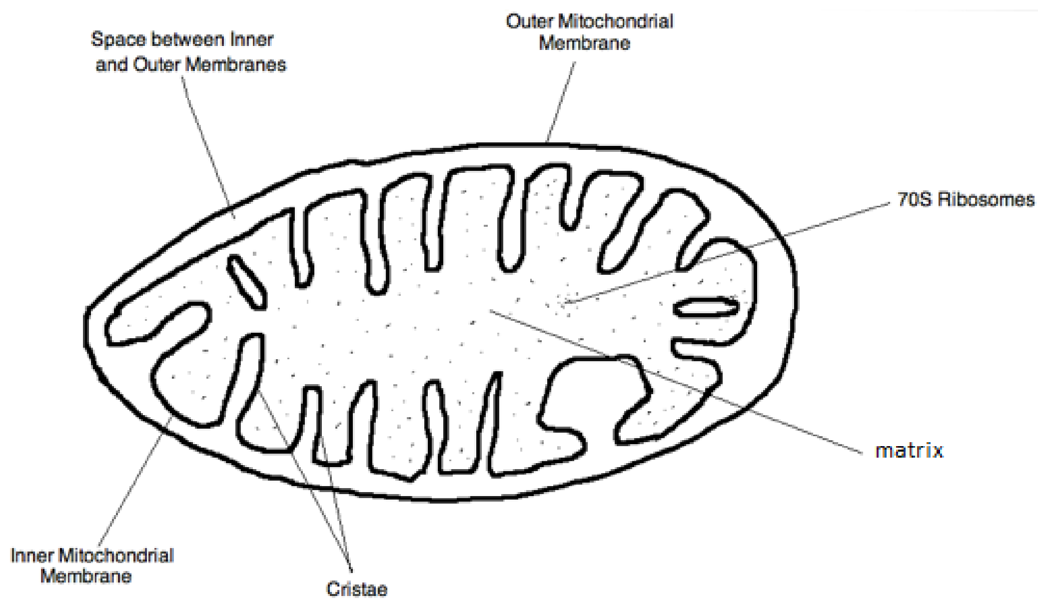
The ground substance of the mitochondrion is called matrix. This contains

1. Several enzymes responsible for Krebs cycle.
2. Circular DNA that resembles that of prokaryotic cells. It is for self replication of mitochondria.

3. 70s ribosome like those of prokaryotic cells. These are for protein synthesis e.g. enzymes

Phosphate granules ⟶ ATP synthesis
ADP + P ⟶ ATP (a product of respiration)

**Diagram of mitochondrion**




**Functions of mitochondrion**

The main function of mitochondrion is to yield energy during respiration.

About 98% of energy is synthesized e.g. one molecules of glucose yield 38 ATP. Out of 38ATP 36 is synthesized in the mitochondrion by the reactions of Krebs cycle and electron transport chain. Thus it is called power house or POWER station or power plant of the cell.

**Adaptations of the mitochondrion to energy productio**

1. Presence of outer membrane and inner membrane to allow entry and exit of materials.
2. The inner membrane is coiled to increase the surface area for attachment of enzymes responsible for electron transfer.
3. Presence of matrix which is as granular and gives enough space for reaction to take place (Krebs cycle reaction) also matrix contains Krebs cycle enzymes.

4. Presence of circular DNA for replication of the mitochondrion.
5. Have 70s ribosome's for synthesis of proteins.
6. Presence of phosphate for production of ATP.
7. Presence of Oxysome and water accompany aerobic respiration.

NB: the inner folded to form partitions called cristae which enables different types of metabolic activities to take place. This phenomenon is called compartmentalization hence enables multi-enzymes systems to operate.

**ENDOSYMBIOTIC THEORY**

**(Evolution of mitochondria)**

The mitochondria were originally independent prokaryotic bacteria like organisms which entered hosts cells and develop mutual relationship (symbiosis).

**MITOCHONDRIA AS PROKARYOTIC CELL**

1. Posses its own DNA and is able of self replication / reproduction.
2. Have a circular like bacteria DNA.
3. It is sensitive to different antibiotics such as chlorophyll and streptomycin which inhibit mitochondrial activities.
4. It contains ribosomes similar to those of bacteria.

**7. PLASTIDS**

These are organelles with double membrane, located in plant cells and algae

Types

1. Chromoplasts
2. Leucoplasts
3. Chloroplasts

1. **CHROMOPLASTS**

   (Chromo – color / pigment)

   These are types of plastids bearing pigments i.e. yellow, red, orange, purple pigments.

   Found in

1. Flowers
2. Fruits
3. Seeds
4. Leaves
5. Roots of carrots.

2. **LEUCOPLAST (embryos and germ cells)**

Leuco- colour / white.

These are colour plastids found mainly in storage organs. There are various types of leucoplasts;

1. Amyloplasts- contain starch
2. Lipoplasts – stores lipids
3. Proteoplasts- stores proteins

**Structure of chloroplasts**

**The chloroplast**

-the chloroplast is an oval shaped green in color due to presence of chlorophyll.

- It has two membranes an outer and an inner membrane which constitutes the double membrane or chloroplast envelope.

-Between the membranes there is the inter membrane space.

- The ground substance of the chloroplast is the stroma.

- The latter has a system of parallel running membranes called **thylakoids.**

-the interval between one grannum and the other is called intergranal lamellae.

- The stroma contains circular DNA and fewer small 70’s ribosomes and starch granules.

**Functions of chloroplasts**

1. It is the site of photosynthesis.

   This is the process whereby green plants manufacture food from $CO_2$ and water in the presence of light energy, it stores starch temporarily.

2. The thylakoids have chlorophyll pigment for trapping sunlight energy.
3. It has grana and thylakoids to hold the chlorophyll in proper position for maximum absorption of light energy.
4. Stroma contains enzymes for dark reactions of photosynthesis.
5. Presence of phosphate which acts as a source of phosphate during phosphorylation.
6. Ribosomes and circular DNA for synthesis of proteins such as enzymes

**Endosymbiotic nature of chloroplasts and mitochondria.**

The chloroplast and the mitochondria are endosymbiotic structures within a cell. They are capable of leading life within a cell because;

1. They have double membrane which allows passage of materials in and out of their inside.
2. They have their own hereditary materials i.e. circular DNA. They are capable of self replicating.
3. They have ribosomes (70's) thus synthesize proteins. E.g. enzymes.
4. Have matrix or stroma, the ground substance where various reactions take place.

STROMA; various photosynthetic membrane are found where light reactions take place and dark reactions in the aqueous part.

MATRIX: Krebs cycle of respiration.

5. They have their own enzyme system.

Therefore chloroplasts and mitochondria are said to be cells within cells.

The endosymbiotic nature of chloroplasts and mitochondria can be described as serial endosymbiotic theory (SET).

**SERIAL ENDOSYMBIOTIC THEORY.**

This theory accounts for the evolution of eukaryotic cells from prokaryotic cells.

Evidence / similarities of organelle and prokaryotic cells

- Double membrane as cell membrane.
- Circular DNA.
- 70's ribosomes.
- System of enzymes.

**SERIAL ENDOSYMBIOTIC THEORY.**

It was suggested that mitochondrion, chloroplasts are descendants of ancient prokaryotic organisms.

-Eukaryotic cells arose from invasion of one large cell by other prokaryotic cells.

The SET states that;

“All eukaryotic cells contain genetic material (DNA) ribosomes that resemble those of prokaryotic cells’’.

-It suggests that prokaryotic heterotropes ingested other mitochondrion like prokaryotic and roughly at the same time began forming an organized nucleus.

Subsequently, non motile cells established a symbiotic relationship with yet another prokaryote in the form of spirochetes or spiroplasma bacterium, attached to the outside of the cell. Such as bacterium has a function like flagellum.

Eventually a photosynthetic prokaryote engulfed by this regardless as a primitive plant cell.

**QNS**

1. Chloroplasts, mitochondria and bacteria have features in common. Enumerate the features to reveal the truth of this statement.
2. Where in the body would you expect to find large number of mitochondria? Give reasons.
3. If mitochondria were to perform the function of the function of the chloroplast, what modification would it require.

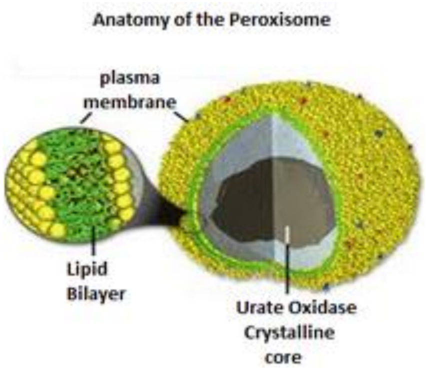
**8. MICROBODIES OR PEROXISOMES**

These are small spherical bodies with 0.5 – 1.5 micrometers in diameter. The ground substance of a micro body contains important enzymes especially catalyze or peroxidase.

These enzymes catalyse the hydrolysis of hydrogen peroxide in water and oxygen.

These peroxisomes are found in liver, potatoes, pea seeds and bean seeds.

**Diagram**




**FUNCTIONS OF PEROXISOMES**

1. To break down the poisonous hydrogen peroxide to water and oxygen in the presence of peroxidase enzyme/ catalase.

2. In plants special peroxisomes called glycoxisomes are centre's for glycoxylate cycle i.e. conversion of fats into carbohydrates especially during germination.

3.The leaf of peroxisomes are centers of photorespiration, especially in $C_3$ plants e.g. beach plants, potato plant, tomato, coffee in cold areas.

**CYTOSKELETON**

This is a complex network of fibrous protein structure that exists in cytoplasm of eukaryotic cell and anchor proteins or organelles such as nucleus to their fixed location.

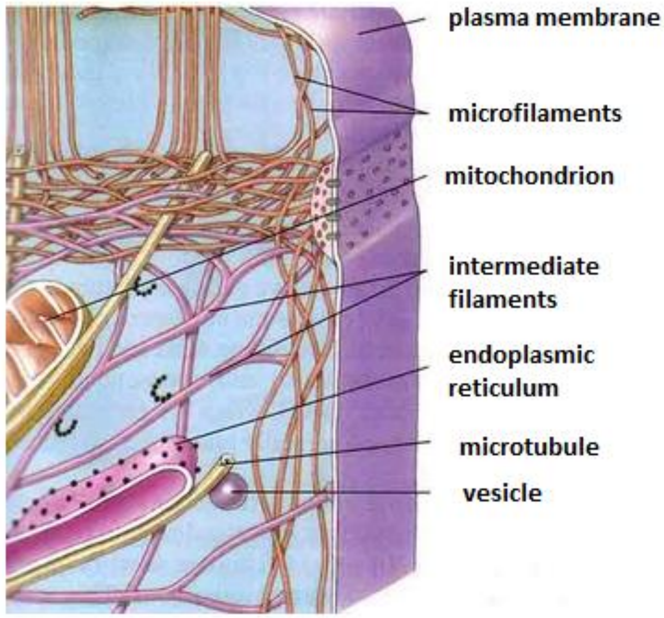
The structures which constitute cytoskeleton include;

1. Microfilament( actin filaments)
2. Intermediate filaments
3. Microtubules

1. **MICROFILAMENTS(ACTIN FILAMENTS)**

   These are thread like structures arranged in sheets or bundles first beneath the cell surface membrane.

**Diagram**




-Chemically they contain actin and myosin.

-Each fibre is composed of two chains of protein loosely twisted about one another in helical manner. These proteins molecules can be assembled and dis-assembled.

**FUNCTIONS**

- Interactions of these fibres with myosin help in muscle contraction.
- Determine the shape of cell's skeleton.
- Responsible for movement of materials within the cells.
- Cleavage of animal cells is brought about by the constriction of a ring of microfilaments after nuclear division, cytokinesis.

2. **INTERMEDIATE FILAMENTS.**

These are structures intermediate between microtubule and microfilament (rope like microtubule of polypeptides)

Skin cells for example form intermediate filaments from proteins called KERATIN. When the skin dies the intermediate filament of the cytoskeleton persists.

Hair and nails are formed this way.

**FUNCTION**

1. Provide cells shape
2. Act as intercellular tendons preventing excessive stretching of cells.
3. **MICROTUBULES**

Microtubules are tubular structures made up of helizelly arranged globular subunit called tubulin.

-They are about 25 nm in diameter. Each has a chain of proteins wrapped round and round in a tight spiral. Large microtubules are found in cilia, flagella, centrioles (formation of spindle-fibres microtubules).

**Functions**

1. They bring about movement of chromosomes during metaphase in nuclear division.
2. Since they are tubular, they transport materials from one part of the cytoplasm to another, i.e. they are cytoconductors.
3. In cilia and flagella, they help in rhythmical beating up movement.
4. They determine the shape of the cell. (Skeletal support).

**9. CILLIA AND FLAGELLA.**

The cells of many unicellular organisms and ciliated epithelium of multi-cellular organisms consists of some hair like cytoplasm projections outside the surface of the cell.

-These are known as cilia or flagella and they help in locomotion of the cells. The cilia and flagella are made up of proteins adenosine triphosphate (ATP).

-In prokaryotic cells, cilia and flagella (If they have structure lacking 9+2 arrangement of microtubules and arise from basal bodies).

-In eukaryotic cilia and flagella are complex. They have the 9+2 arrangement of microtubule and arise from basal bodies.

**10. CENTRIOLES.**

Centrioles are present in animal cells only.

-They are two placed at right angle to each other.

-A number of rays called ultra rays usually surround the centrosomes.

Each centriole is composed of nine paired thin threads and is in the form of cylinder.

They aid in cell division.

**11. PINOCYTOTIC VESSICLE**

These are organelle formed as a result of in folding of plasma membranes as it takes large particles of food from outside the cell.

The process is called pinocytosis.

Eventually pinch off and form very small vacuole (vesicle).

**FUNCTIONS**

Transport large particles into the cell.

**12. NUCLEUS.**

-Nucleus is the functional unit of a cell.

It contains materials which control different activities within the cell; the **genetic materials**.

**STRUCTURE OF THE NUCLEUS.**

The nucleus has a membrane called nuclear membrane envelope.

Then nuclear membrane has some pores which allow some materials to pass in and out of nucleoplasm to allow communication on with cytoplasm called nuclear pores.

-Nuclear pores are made up of non-membrane materials forming nuclear pores.

-Nuclear envelope is semi permeable membrane allowing some materials to pass and others not to pass.

-The space inside the nucleus is filled by fluid materials which are called nucleoplasm. These are semisolid granules ground substance or matrix.

Within the nucleoplasm there are two components;

1. Nucleolus
2. Chromatin
3. Matrix (aqueous)

**Chromatin threads**

Chromatin threads are grainy network of strands that undergo cooling into rod-like structures called chromatin.

Chemically chromatin and therefore chromosomes contains DNA (deoxyribose nucleic acids) and much protein and some RNA (ribonucleic acids) and few minerals.

**Nucleolus**

These are small dark regions where different RNA type examples ribosomal RNA is produced and RNA joins the protein to form the subunit of ribosomes.

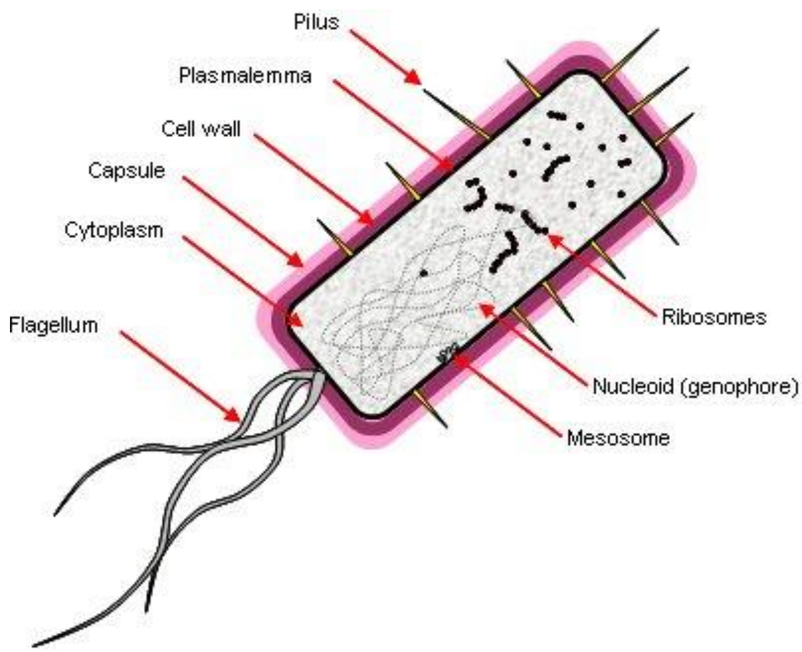
-It synthesizes the ribosomes protein and is used in controlling the cell division.

**Functions of nucleolus**

1. Controls all metabolic activities of the cells
2. It regulates cell division.
3. Concerned with transmission of hereditary traits from parent to offspring.
4. Synthesizes and stores proteins.

**PROKARYOTIC CELL**

1. **A WELL LABELLED DIAGRAM OF A BACTERIAL CELL.**




| **PROKARYOTIC CELL e.g. bacteria, cyano bacteria.** | **EUKARYOTIC CELL e.g. protoctista, green plants, animal and fungi.** |
|---|---|
| 1. Usually extremely small cells. | Usually large cells about 10-100 micrometer |
| 2. Nucleus absent, naked circular DNA | Distinct nuclear region DNA helical shaped enclosed in a protein coat. |
| 3. No nucleus. | Nucleus present |
| 4. Few organelles and non are surrounded by an envelope (double membrane). | Many organelles envelope(bound) organelles ( i.e. double membrane bound organelles) |
| 5. Internal membrane if present usually associated with respiration or photosynthesis. | Great diversity of internal membrane organelle e.g. Golgi apparatus, lysosomes, ER. |
| 6.Flagella are simple lacking arrangement of microtubule. | Complex flagella with ( 9+2) arrangement of microtubule. |
| 7. Have mesosome for respiration. | Use mitochondria for respiration |
| 8. Some are nitrogen fixing. | No ability to fix nitrogen. |
| 9. 70’s ribosomes. | 80’s ribosomes |

Similarities between prokaryotic and eukaryotic cells.

Both have;

1. Structure for movement (cilia and flagella)
2. Cell wall.
3. Cell membrane.
4. Ribosome's.
5. Genetic material.(DNA)
6. Storage of food organelles.

QUESTIONS

1. a. Give the principle constituent of the cell membrane.

   b. Draw a fully labeled diagram to illustrate the arrangement of these constituents and others in the fluid mosaic model of the cell wall membrane.

   c. why is the model described as being fluidy?

   d. Give two functions of the cell membrane.

2. Describe the role of the following membranous organelles; lysosomes, endoplasmatic reticulum, ribosome's and Golgi apparatus.

### CELL DIFFERENTIATION

This is the specialization of a cell in terms of both structure and functions. Ability of a cell to perform single function is called cell specialization. Cells work in interdependence with each other such that such that group of cells must be coordinated so that they carry out their activities efficiently such coordination is called integration.

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# CYTOLOGY 2

## BIOCHEMISTRY

### ORGANIC CONSTITUENT OF THE CELLS.

**Bio chemistry:** is the study of structures, properties and functions of chemical constituents of the cells.

-It is a great unifying theme in biology.

It finds applications in fields like;

1. Agriculture; in developing pesticides and herbicides.
2. Medicine; including all pharmaceuticals.
3. Fermentation; baking products, food products and breweries.
4. New development of biology eg genetic engineering.

**ELEMENTS FOUND IN LIVING ORGANISMS ARE**

1. Chief/ macro elements: hydrogen (H), carbon(C), nitrogen (N), oxygen (O), phosphorous (P), sulphur(S).
2. Ions – sodium($Na^+$) , magnesium ($Mg^{2+}$) , chlorine( $cl^-$) , calcium ($Ca^{2+}$) etc.
3. Trace elements – manganese(Mn) , iron(Fe) , cobalt(Co),copper (Cu) , molybdenum(Mo) and iodine(I).

**MACROMOLECULE(S)**

Macromolecule is a giant molecule made from many repeating units. The molecules built are polymers and the individual units are monomers.

-The units are joined together by a chemical process called CONDENSATION which means removal of water.

-The units can be broken down again by an opposite process known as **hydrolysis** which means adding of water.

- The most important macromolecules in biology are;

1. Polysaccharides( carbohydrates)
2. Protein
3. Lipids
4. Nucleic acids.

And their constituent monomers are; monosaccharide's, amino acids, glycerol, fatty acids and nucleotides respectively.

Others are;

- Adenosine triphosphate (ATP).

**ORGANIC SUBSTANCES ( CHEMICAL NATURE AND IMPORTANCE)**

**1. CARBOHYDRATES**

They are substances which contain carbon, hydrogen and oxygen with the general formula of $(CHO)_n$ where n is a real number.

**Characteristics of carbohydrates.**

1. They are either simple sugars or compound sugars.

   The compound sugars are formed by condensation of simple `sugar molecules.

2. They are hydrate of carbon from the proportion of hydrogen and oxygen in water.
3. The basic carbohydrate unit is thus a sugar which is the derivative of a poly hydrosol alcohol.

- Alcohol is the paraffin compound with hydrogen atom replaced by the univalent hydroxyl (OH) group.
- Paraffin is aliphatic or chain of compounds of carbon and hydrogen in which the carbon atoms are linked by single bonds to adjacent atoms. (see Example above).
- The simpler hydroxyls are the glycol and glycerol and the simplest of sugar is the glycerose (glycerin).

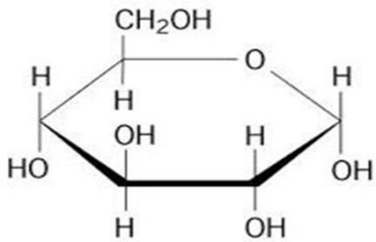
The carbohydrate contains several hydroxyl groups.

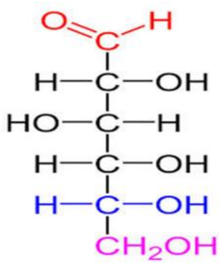
4. Some contain aldehyde (-CHO) group and others contain ketone group ( -CO-)

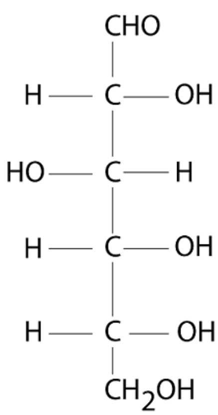
Examples;

1. Glucose: is a pentahydroxyl alcohol with the aldehyde group.

   **GLUCOSE**







2. Fructose: is the pent hydroxyl alcohol with ketone group.

Complex sugars are built from the basic sugar units called monosaccharides through the process of condensation polymerization.

Many sugars are reducing sugars and others are non-reducing sugars but give rise to reducing sugars on hydrolysis with enzymes or mineral acid (mostly dilute HCL)

NB:Carbohydrates are called reducing sugar because they act as reducing agents supplying electrons from their functional groups i.e. the aldehyde and ketone groups which can reduce the $cu^{2+}$ ions to $cu^{+}$ ions which appear orange or yellow ppt (precipitate).

The true carbohydrates are saccharides with a combination of sugar units. These are divided into three main classes

1. monosaccharides – with a single sugar unit
2. Disaccharides – with two sugar units.
3. Polysaccharides- with many sugar units.

**Classification of carbohydrates**

**Carbohydrate**

| Saccharides (Sugars) | Polysaccharides |
|---|---|
| Monosaccharides | .starch |
| Disaccharides | .cellulose |
| .lactose | .glycogen |
| .maltose | |
| .sucrose | |

**SUGAR**

Sugar which include mono and disaccharides are all soluble in water. They have a sweet taste.

They are crystalline and small molecules.

Those with a potentially active aldehyde or ketone group are the reducing sugars e.g. glucose.

| sugar | Natural occurrence |
|---|---|
| Glucose | Plant juice and grape sugar |
| Galactose | From fruits. |
| Fructose | From fruits |
| Maltose | From germinating seeds ( cereals) |
| Sacrose | From sugar cane ( in plants) |
| Lactose | From milk |

Sugars without potentially active reducing groups are known as non-reducing sugars e.g. Sucrose ($C_{12}H_{22}O_{11}$).

**Monosaccharides**

- Have general formula (CnH2nOn)
- All are reducing sugars
- They are classified according to the number of carbon atoms e.g.;

Trioses have 3 carbon atoms

Tetraoses have 4 carbon atoms

Pentoses have 5 carbon atoms

Hexoses have 6 carbon atoms

Heptoses have 7 carbon atoms

-Of code, hexoses and pentoses are most common and triose being the true sugar.

-Pentose sugars are never occurring but only in combination with other groups

Of compounds.

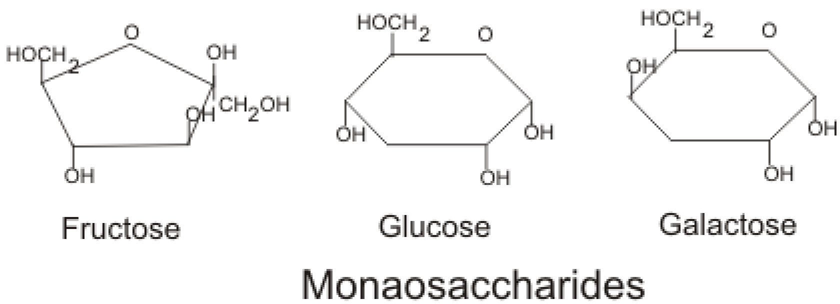
Riboses- this occurs in one kind of nucleic acid. A derivative of deoxyribose

Hexose. The most important free sugar.

D-glucose

D- Fructose these are the most common sugars.

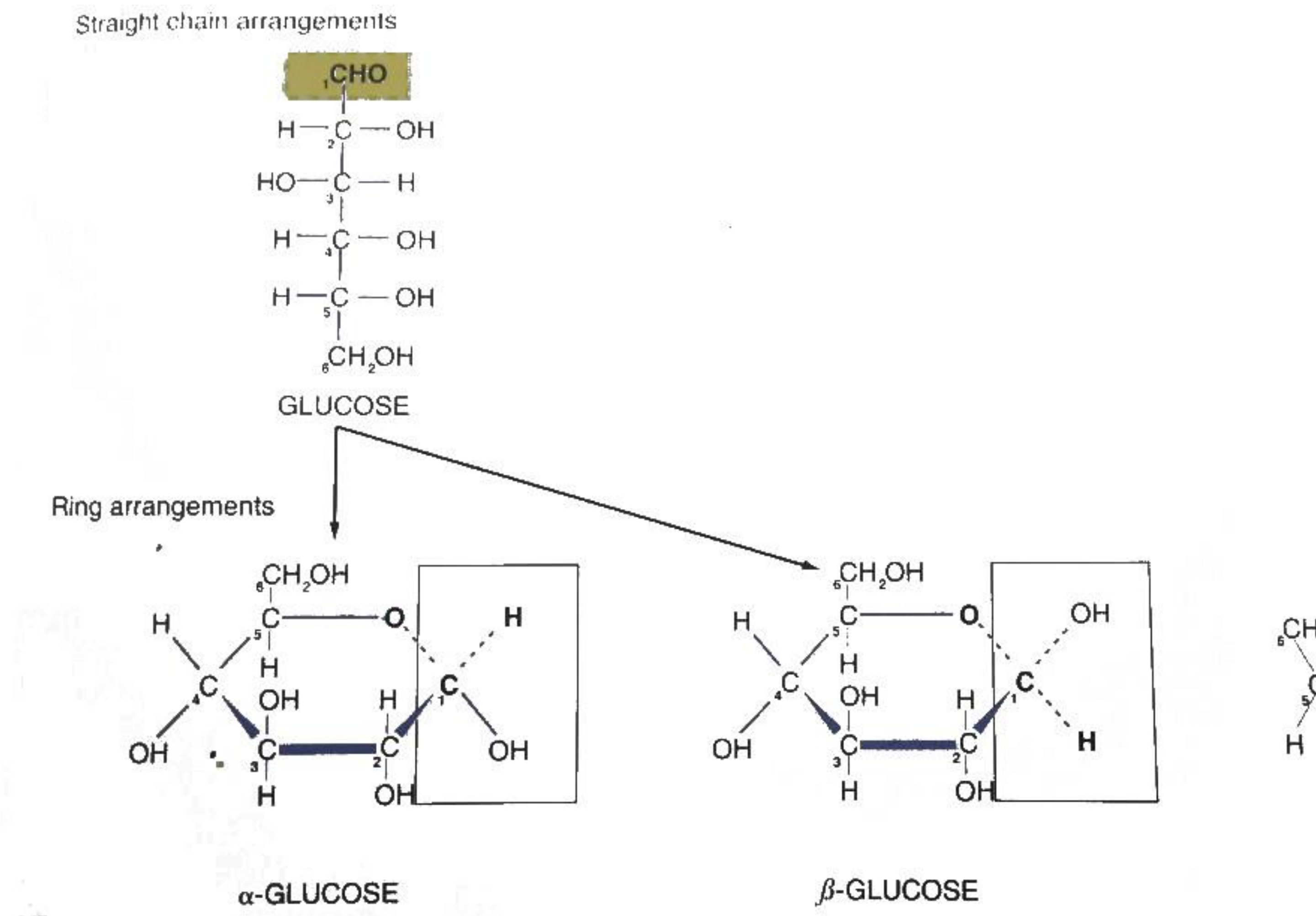
**Structure of Monosaccharides**




Glucose in common with other hexoses and pentoses easily forms stable ring structure. At any one time most molecules oxists as rings rather than
In case of glucose carbon atom number 1 may combine with the oxygen atom an carbon 5. This form a six -sided structure known as a <u>pyranose</u> ring
In case of fructose, carbon atom number 2 links with the oxygen an carbon atom number. This form a five sided structure known as furanose ring Both glucose and fructose can exist in beth
<u>pyranose</u> ring.

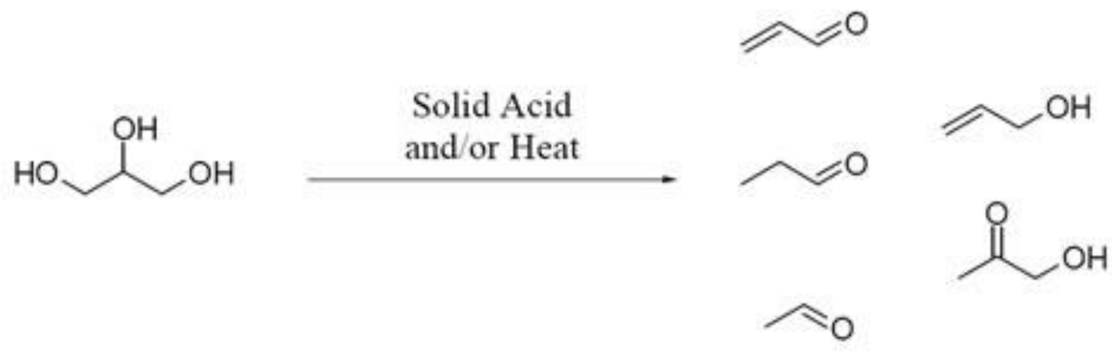
In case of fructose, carbon atom number 2 links with the oxygen on number 5. This form a five sides structure known as furanose ring Both glucose and fructose can exist in both pyranose and furanose and furanose ring form.

**<u>STRUCTURE PG 13 UB</u>**
Furanose




- Most carbohydrate in common glucose can exists as a numbee of isomers (they posses the same molecular formula but differ in the arrangement of this atoms). one type of isomer called <u>stereo isomerism</u>. occurs when the atom, or group, are joined together but differ in Their arrangement in space one form of stereoisomer is called <u>Optical Isomersm,</u> result in isomer which can rotate the plane of polarized light. If the substance rotates the plane of polarisation to the right it is said to be <u>dexTro-rotatory</u> (d) and if to the left is <u>laevo-rotatory</u> (L) Optical isomerism is a property of any compound which can exist in two forms whose structure are minor image. Like right and left handed gloves

<u>Example.</u>
Stady the structure of glycerin (ghycer aldehyde)




L-Form isomer mirror. D-form isomer

**Functions of monosaccharides.**

1. **PENTOSES ($C_5H_{10}O_5$ )** e.g. ribose, deoxyribose, ribulose.

1. Synthesis of nucleic acids e.g. Ribose is the chief constituent of the RNA.
2. Synthesis of co-enzymes e.g. ribose synthesis (NAD and NADP)

**HEXOSES (**$C_6H_{12}O_6$) e.g. fructose, glucose, galactose.

1. Sources of energy when oxidized by respiration.
2. Synthesis of disaccharides.
3. Synthesis of polysaccharides.

**TRIOSES** ($C_3H_6O_3$) e.g. glyceraldehydes, dihydroxyacetone.

1. Intermediate in respiration (glycolysis).
2. Photosynthesis (dark reaction) RUBP as an acceptor of $CO_2$
3. Carbohydrate metabolism.

-

<u>**Disaccharides**</u>

*Disaccharides are formed by the condensation or polymerlization of two monosaccharides.

The most common disaccharides are;

1. Maltose = glucose + glucose
2. Lactose = glucose + galactose
3. Sucrose = glucose + fructose.

In reducing sugars e.g. Lactose and maltose, one of the hexose residue retains its aldehyde or ketone groups as an intact unit as reducing sugar.

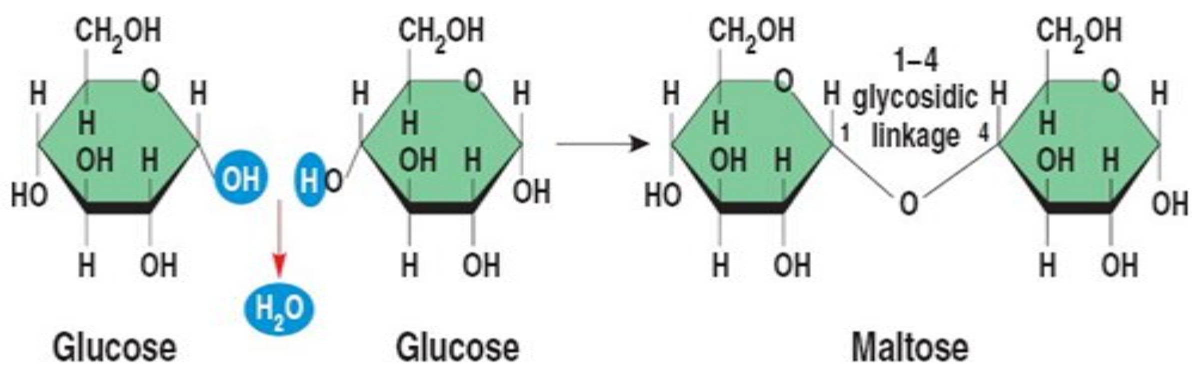
Maltose is a disaccharide produced upon incomplete hydrolysis of the polysaccharide starch.

-It is found in germinating seeds.

-It is also produced commercially for use in production of beer.

-Maltose is produced of two D-glucose units joined by a α-glycosidic bond between the anomeric carbon of one glucose unit and the number 4 carbon of the other glucose unit.

This specific bond formed an α-1,4-glycosidic bond also found in starch and glycogen.




NB: The numeric hydroxyl group of one of the glucose units participates in the glycosidic bond and

Therefore cannot be easily oxidized.

However the anumeric hydroxyl of the other glucose unit is not as occupied and this glucose unit exists in the equilibrium with free aldehyde solution.

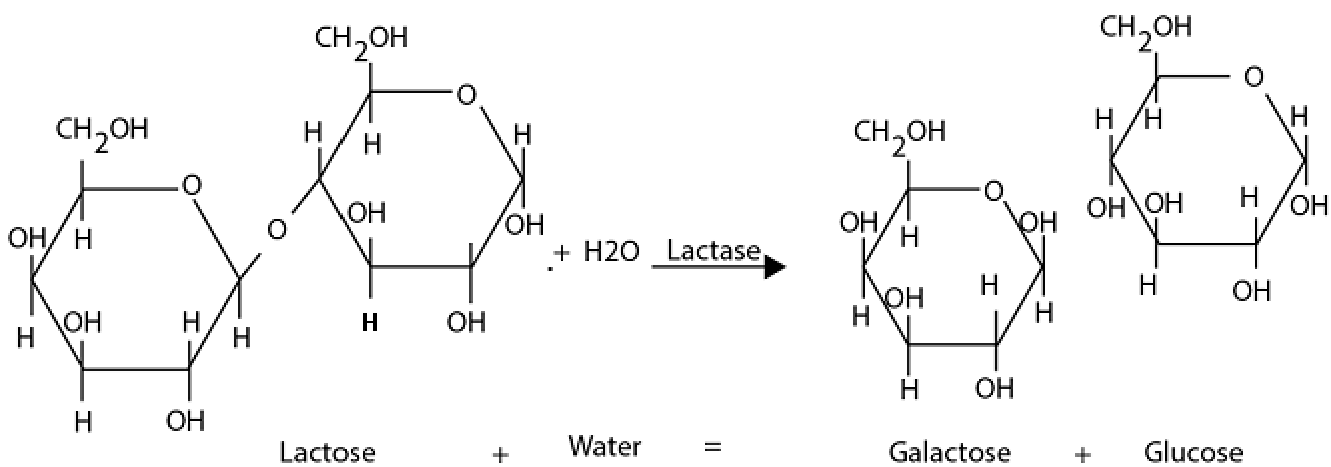
Thus maltose is oxidized by Fehling's solution, benedict's solution or any other suitable reagent.

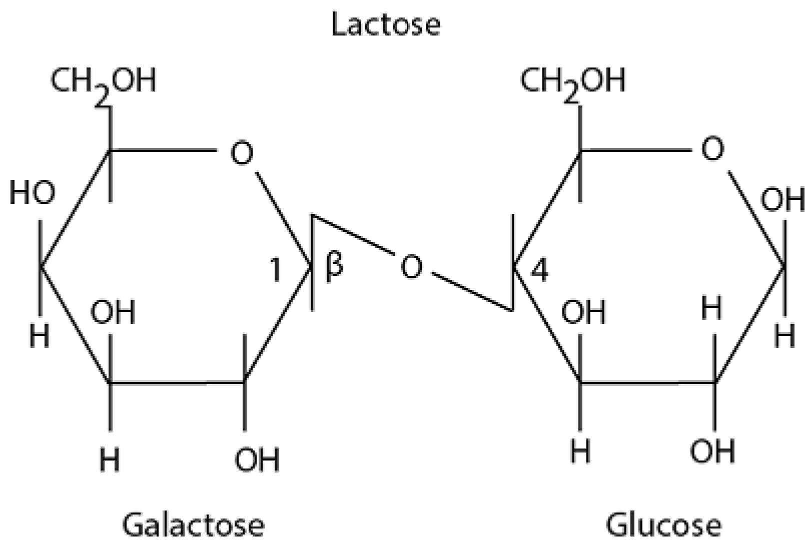
**Lactose**

Constitutes some 3% to 5% of the milk of animal including cows and humans.

This disaccharide is composed of one galactose unit and one glucose unit joined by a glycosidic bond between the anomer of galactose and the number 4 carbon of glucose. A β-1, 4 –glycosidic bond.

$$C_{12}H_{22}O_{11} + H_2O \longrightarrow C_6H_{12}O_6 + C_6H_{12}O_6$$






Glucose unit of the lactose still exists as an equilibrium mixture of α and β anomers and the free aldehyde in solution. Lactose is thus a reducing sugar.

**Sucrose**

-It is found in fruits and vegetables.

-Sugarcane and sugar beets are the commercial sources and used as table sugar.

-Sucrose is composed of one fructose unit joined by two glycosidic bonds.

Sucrose is not a reducing sugar since both anomeric carbons participates in the glycosidic bonds and thus no free aldehyde or ketone exists in solution.

NB: D is the hydroxyl group attached to the anomeric carbon atom (the anomeric hydroxyl group) is

drawn on the same side of the ring as the last -$CH_2OH$ group for the β-anomer and the opposite side

of the ring for the α-anomer.

The D-galactose only differs from the D-glucose only in the orientation of the groups bonded to

Carbon no. 4. Ingested D-glucose (from milk and some other complex polysaccharide) is normally

converted to D glucose in the human body.

The inability to perform this ionization (conversion of one isomer to another) results in a disease called galactosemis.

**POLYSACCHARIDES**

-Have high molecular weight formed by condensation of large number of monosaccharide units.

They include;

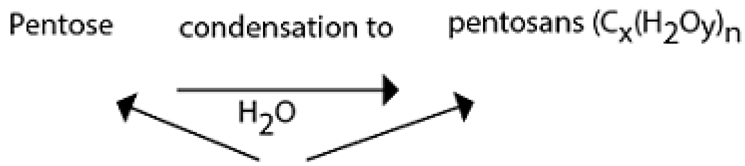
- Starch, glycogen, cellulose, chitin and insulin.

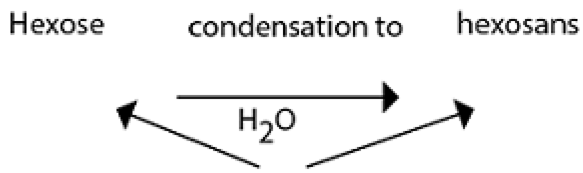
-All polysaccharides are insoluble in water forming colloidal solution.

-They are non –reducing sugars.

-They are Non- crystalline and as structural materials e.g. Cellulose.

-Represented by chemical formula ( $C_5H_{10}O_5$) n or ($C_6H_{10}O_5$)n where n is a whole number ranging from 300-400.




$$n(C_5H_{10}O_5) - n(H_2O) \underset{b}{\overset{a}{\rightleftharpoons}} (C_5H_8O_4)$$

a = condensation
b = hydrolysis

1. **Starch**

- Usually occur in a white powder-form at room temperature.

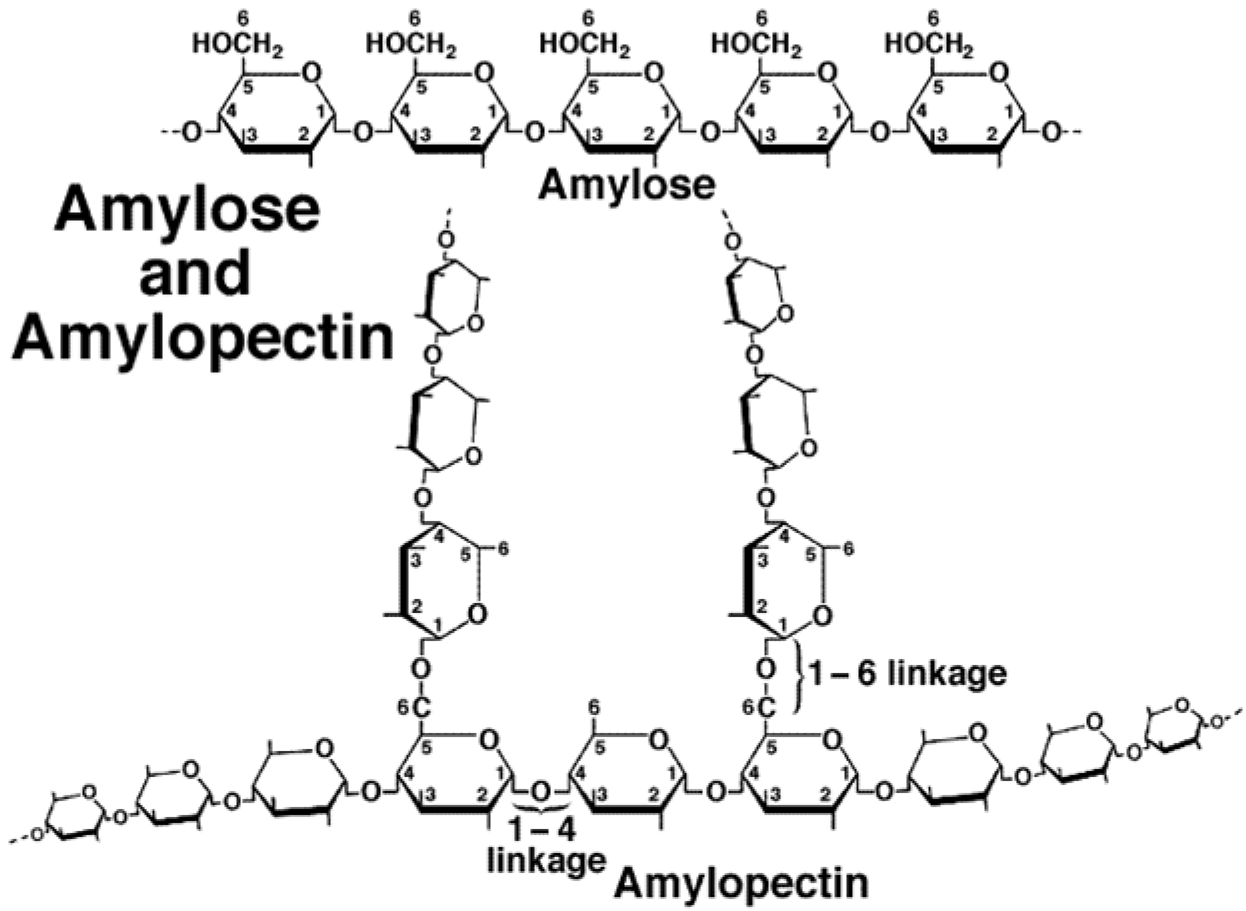
  It forms a solution with hot water and a gel on cooling.

- During digestion, it is converted to a mixture of detrins. Later from maltose to glucose units.
- It is largely stored in plants and it is a result of photosynthesis.
- In plants, starch is found in the storage parts such as roots and stem tubers, corn and some rhizomes.

A starch granule is composed of

- A core of amylase
- Amylopeptin
- Amyloplast membrane.

**Diagrams of amylase and amylopectin.**




**NB:** Amylase and amylopectin are two different forms of starch.

- Both have linear chains of glucose units joined by α-1, 4-glycosidic bond.

**Amylase** is linear polymer of α-1, 4-glucose unit and is insoluble in water.

**Amylopectin** is a branched polymer; the main chain of amylopectin is joined by α-1,4-glycosidic bond as in amylase. However about every 20-30 glucose units there are branches joined by α-1,6-glycosidic bond.

Amylopectin is not soluble in water.

When boiled to about $200^0$C starch is partially hydrolyzed to a mixture of dextrins. However, when heated with dilute mineral acids, starch is hydrolyzed via dextrin to glucose.

-In living things (tissues) the hydrolysis is of the following sequence.

$$\underset{\text{Starch}}{(C_6H_{10}O)\,n} \xrightarrow{\text{Diastase}} \underset{\text{destrins}}{(C_6H_{10}O_5)} \xrightarrow{\text{Diastase}} \underset{\text{Maltose}}{(C_{12}H_{22}O_{11})}$$

-A suspension of glucose gives a blue black coloration with iodine.

-Amylopectin is compact as it has many branches of 1, 6- glycosidic bonds.

**Biological importance**

1. Storage of food in seeds, example; cereals and legumes
2. Important for human food.

**GLYCOGEN**

-This is called animal starch formed by condensation polymerization of glucose on units.

-It is very similar to amylopectin in structure.

-It is a polymer of glucose units joined by α-1,4- bonds and with α-1,6- bonded branches . it is a white soluble powder and non reducing sugar.

**OCCURRENCE**

1. Mainly in vertebrates liver and muscles.
2. Also some maize seeds and fungi.

Glycogen differs from amylopectin because it is more highly branched than amylopectin with one branch point about every 8 and 12 glucose units.

**Biological advantage.**

- It is important food storage in muscle and liver of vertebrates and fungi.
- It provides energy and is an energy substance.

**CELLULOSE**

This is an important structural material in plants.

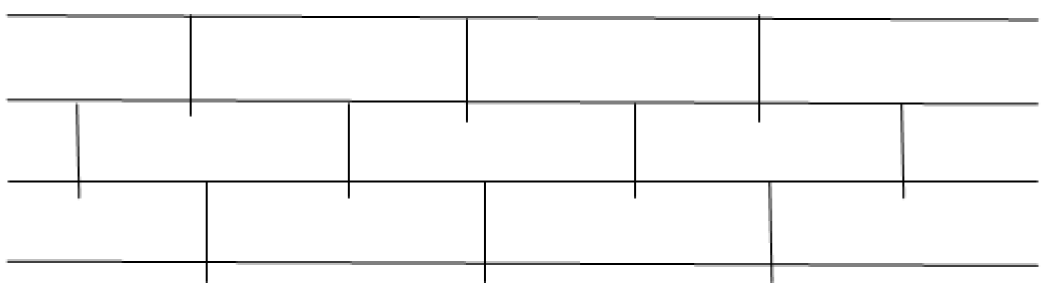
It largely constitutes the chemistry of the cell wall.

-Chemically cellulose is composed of several thousands of glucose units joined together by 1, 4- glycosidic bonds. The units are so arranged that the bonds alternate in appearance.

-This lead to the cross links of hydrogen bonds between the parallel running cellulose molecules.

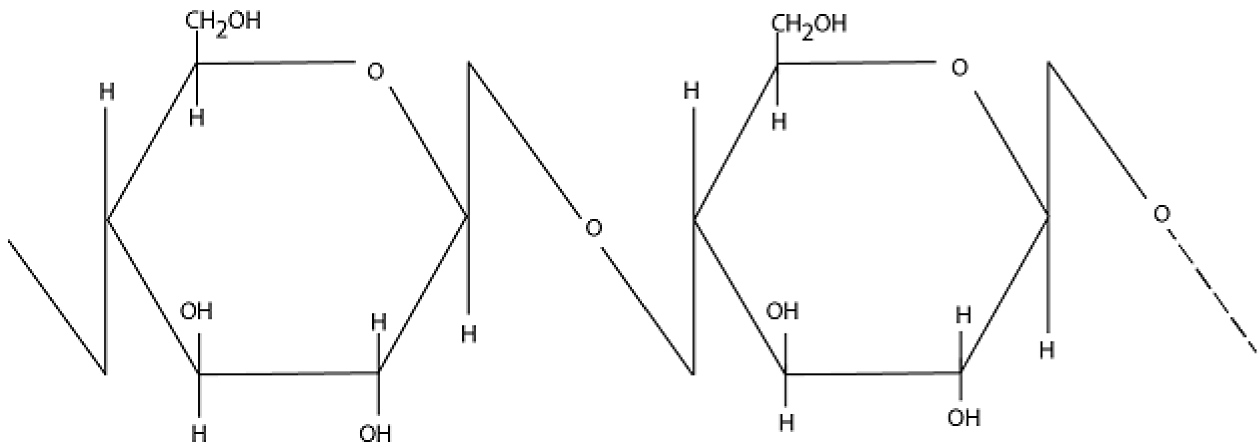
As a result of this, cellulose becomes tough with very high tensile strength.

The shape of a cellulose fibre is of the nature below.



Chemical structure of cellulose is presented as follows.

Cellulose




**Hydrolysis of cellulose.**

In the living tissues, hydrolysis of cellulose takes place in two stages;

$$\underset{\text{Cellulose}}{(C_6H_{10}O_5)} \underset{\text{Cellulase}}{\rightleftharpoons} C_{12}H_{22}O_{11} \underset{\text{cellulase}}{\rightleftharpoons} \underset{\beta\text{-glucose}}{2C_6H_{12}O_6}$$

**Commercial use of cellulose**

1. It is a raw material in the manufacture of many industrial products such as papers, rayon and plastics.
2. The rayon made from cellulose are used in the manufacture of industrial belts and tyre cords.
3. Cellulose derivatives such as cellulose nitrate are used in the manufacture of films.
4. Cotton, a pure form of cellulose is used in the manufacture of clothes.

**CHITIN**

This is closely related to cellulose in structure and function, being a structural polysaccharide.

-Structurally it is identical to cellulose except that the OH group at carbon 2 is replaced by – NH.CO. $NH_3$.

-This is a result of amino sugar (glucosamine) combine with acetyl group.

Chitin is therefore a polymer of N-acetylglucoamine.

**Inulin**

This is another storage carbohydrate which largely occurs of many plants.

It also occurs in small quantities in many monocots. Hydrolysis by dilute mineral acids or specific enzymes e.g. inulin produce fructose only.

It is a polymer of fructose molecule.

Inulin inulase fructose

**Summary roles of carbohydrates.**

1. They built up a cell plasma membrane. It is made up of carbohydrates and so they are used to build up the body of a living organism.
2. They are used as a substrate in respiration (to produce energy) as raw materials. Glucose is the base raw material in glycolysis.

   Are useful in pollination. Nectar which attracts pollinators is made up of sugars.

   Are useful in storage purpose for future metabolism eg starch, glycogen and laminarin.

   Used in the balance of osmotic pressure as they make solutes in the blood.

3. Are used in inheritance and control of the body activities as they make the genes e.g. deoxyribose of DNA and ribose of RNA are pentose sugars.

   *Other uses are from the above discussions.

**LIPIDS**

These are organic compound made up of elements carbon, hydrogen and oxygen in which its proportion of oxygen is smaller than that of hydrogen (i.e. not in the ratio of carbon dioxide of 2:1)

**Properties of lipids.**

The features that characterize the lipids include the following;

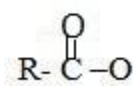
1. They are either liquids or non-crystalline solids at room temperatures.
2. They are higher than water ( less dense than water)
3. They are hydrolyzed by alkaline into their respective constituent compounds. This process is called saponification.
4. They contain either saturated or unsaturated hydrocarbon chains.
5. In the presence of water and alcohol they form an emulsion.

*They are esters of higher aliphatic alcohols.

*all lipids are insoluble in water but soluble in organic compounds or solvents e.g. ether, chloroform and hot alcohol.

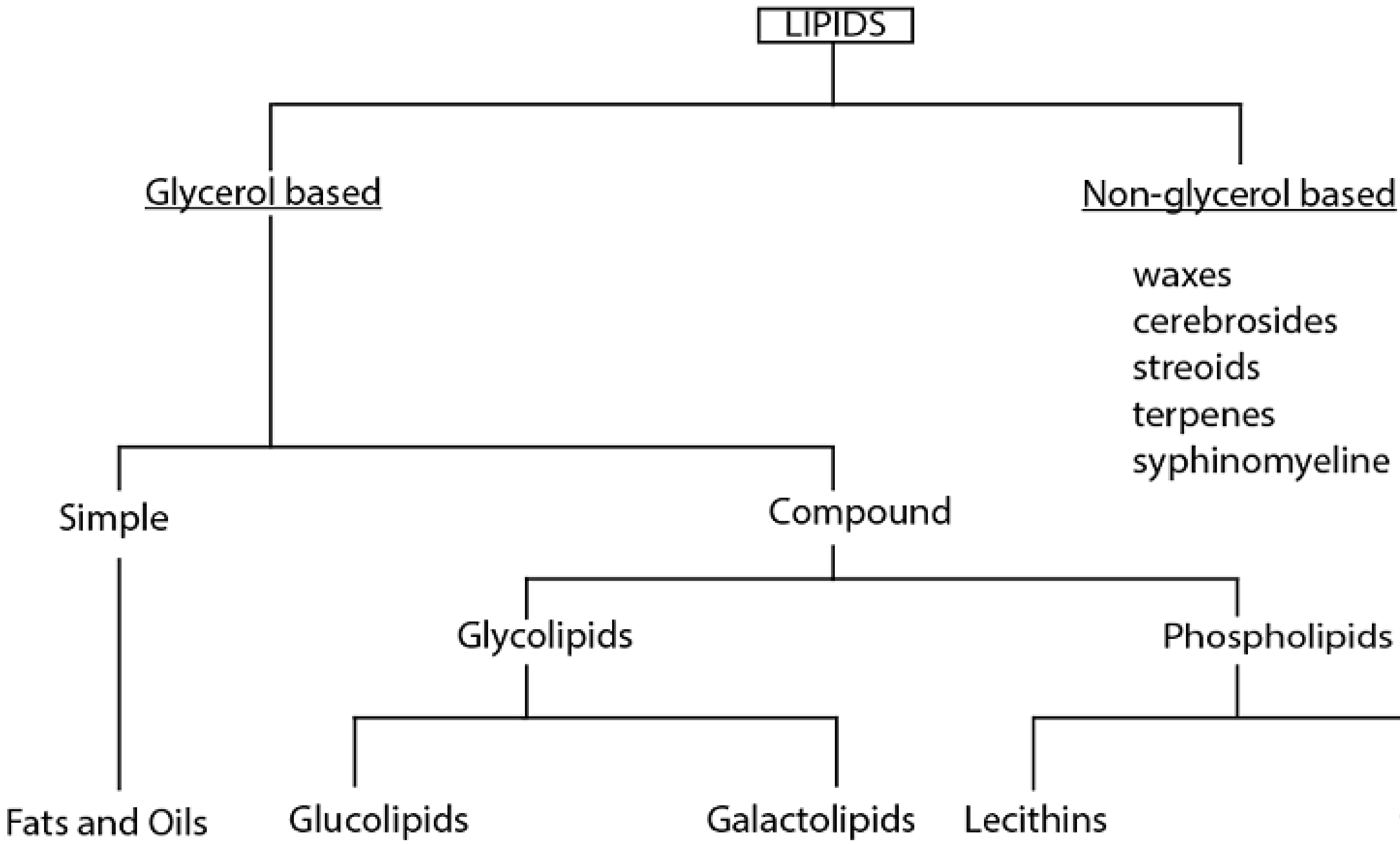
They occur in adipose tissues of animals and some are a component of the protoplasm of all living cells.

Lipids have ester linkage.

I.e. 

Because of unsaturated bonds which are easy to break, that are why they are liquid at room temperature, solids contain saturated bonds.

## Classification




**SIMPLE LIPIDS**

Simple lipids are oils and fats of which are esters of glycerol. (Higher alcohol). Than glycerol forms the ester called waxes.

-Oils and fats are formed by the combination of fatty acids and glycerol e.g. oleic acid which are widely distributed in many fats and oils.

-They are also known as triglycerides.

**Natural fats and oils.**

They are a mixture of glycerides (esters) of fatty acids and glycerol.

**Oils:** contain greater proportion of unsaturated fatty acids; they are liquid at $20^0$C.

**Fats:** contain a greater proportion of saturated fatty acids; they are solids at $20^0$C.

**BIOLOGICAL IMPORTANCE OF LIPIDS.**

1. They form an insulation material thus prevent heat loss in organisms and animals particularly.
2. Prevent water loss, form water proof in organisms, plants and insects.
3. Can be a stored form of energy in the body of an organism e.g. amoeba and seed like units.
4. Form the basic constituent of the cell membrane as well as the cell components.eg phospholipids
5. Enables large aquatic organisms like whales to have buoyancy.
6. Contains basic fat soluble vitamins A, B, D and K.
7. Forms the natural rubber.
8. It is a constituent of hormones like steroids e.g. oestrogen, progesterone, also acdysome hormone in insects and crustacea are made up of lipids.
9. Gives more energy in metabolism.
10. Used to make bile salts (sodium taurochlorate and sodium glycochorate) for emulsification in the duodenum.
11. Limits the linkage of small molecules across plasma membrane (cholesterol).
12. Constituent of myelin sheath; helps to prevent outward flow of ions which would short circuit the movement of ions along the nerve. Also enhance the salutatory condition.

**PROTEINS**

Proteins are nitrogenous compounds formed by condensation polymerization of larger number of amino acids.

-Proteins are thus polymer molecules of amino acids.

The monomers are;

$$\text{Amino acid + amino acid} \xrightarrow[\text{Hydrolysis}]{\text{condensation}} \text{proteins}$$

Element present in proteins are carbon, hydrogen, oxygen, nitrogen, sulphur acid and phosphorous and iron.

**THE AMINO ACIDS**

There are 20 amino acids which are polymerized to give many types of proteins.

**Physical properties.**

- They are colorless.
- They are Crystalline solid.
- Form colloidal solution.
- Coagulate on – heating

  - Strong acid or base

  - Presence of heavy metal

  - Organic detergent.

- They are specific in nature of action.

Substances which are protein in nature are;

1. Albumin – egg albumin and serum albumin.
2. Histone – make the chromosome of nucleus.
3. Globular- blood fibrinogen, prothrombine and antibodies.
4. Schleroproteins- keratin (of hair and feathers) also keratin of skin, collagen which makes tendon, bone, connective tissue myosin (muscles), silk (spiders web).

**GENERAL PROPERTIES OF PROTEINS**

1. They are polymers of amino acids.

   Many are large dimmers with many amino acid units. Eg serum globulin of human blood have 736 amino acids, myosin of muscle has 780 amino acids.

2. Colloidal in nature.
3. Amphoteric properties.
4. Every amino acid regardless of its side chain has an acidic carboxylic group and a basic amino group or it has acid-base properties i.e. is said to be amphoteric.

-In solid state the amino acid have base salt like properties because they have both a positive charge part and a negative charge part such substances are called **zwitterions**.

-Zwitterions are produced from the molecular form of the amino acid by internal-acid base reaction.

**NOTE**: in the reaction above, neither the molecular form nor the zwitterions form has a net electrical charge. In aqueous solution these two forms are in equilibrium but the equilibrium overwhelmingly favors the zwitterions at any pH.

At any pH, some of the alamine in solution exists in the positive ion form. Some of it in the negative ion form, some in the zwitterions form and some in molecular form.

- If the solution pH is very high that is ( $H_3O^+$) or ($H^+$) is very low, both of the equilibrium in the reaction is shifted to form the right and the negative ion form of alamine predomination.
- On the other hand, if the solution pH is very low that is ($H_3O^+$) 0r ($H^+$) is very high- both equillibria in reaction above are shifted to the left and the positive form of alamine predominates.
- At the pH of human cell and fluids ($pH_7$) alanine exists primarily as the zwitterions.

In solution that are predominantly basic (i.e. pH btn 8.5 to 10.5), no single form of alanine predominates. In this pH range, there are roughly comparable amount of zwitterions and the negative charged.

- Similarly in moderately acidic solution there are roughly comparable amount of the zwitterions and the positively charged form of alanine.
- The amount of positive or negative charge is affected by pH. Each molecule has a specific pH which the total positive charge is exactly equally to the total negative charge. It is electrically neutral and has no tendency to move to either the anode of cathodes of an electric field. This is known as isoelectric point.

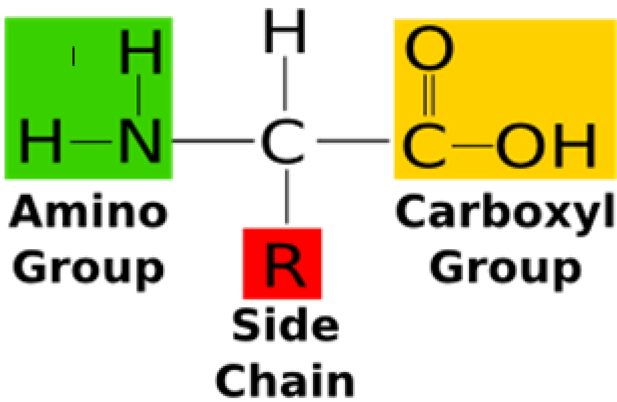
At higher pH protein and amino acid become more negative while at low pH they become more positively charged.

**Properties of isoelectric point.**

1. Solubility- have greater tendency to precipitate or coagulate.
2. Stability- as emulsion colloids.
3. Osmotic pressure- swelling by inhibition of water.
4. Viscosity and acid and base bonding properties.

5. They have large size molecule e.g. hemoglobin of mass 6000 and more. The enzyme urease nearly 500,000.
6. Denaturation – there are easily denatured by heat, ultraviolent reactor and chemicals. Denaturation alters the structure of proteins.

**Structure of amino acids.**

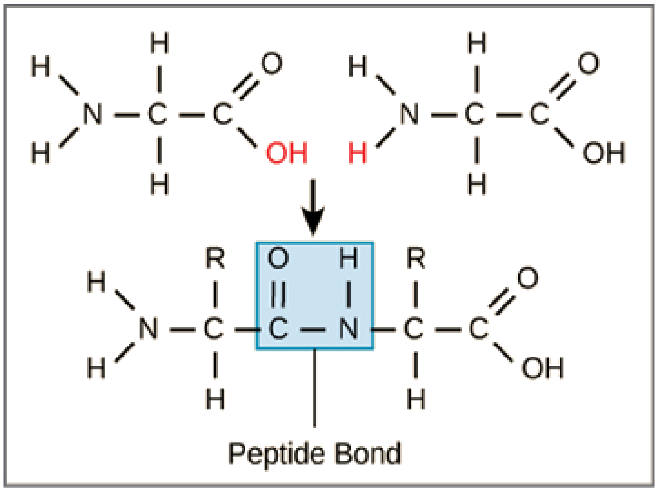



The amino acid consists of an α carbon surrounded by;

1. Hydrogen atom(H)
2. Amino group or amine group ($-NH_2$), giving the nature of amino acid.
3. The carboxyl ($-COOH$) giving the acidic nature of amino acid.
4. The R-group known as the side chain. It presents the hydrogen atom or any other group as alkyl group.

**How peptide bonds are formed.**

Proteins are polymers of amino acids joined together by peptide bond.




**OTHER BONDS FOUND IN PROTEINS.**

1. Ionic bonds: is an electrostatic attraction between positive and negative charge.
2. Hydrogen bond: this occurs between hydrogen atom and more electronegative atoms.
3. Disulphide bond: the bond between two crystalline molecules.
4. Van-de-Waal forces: these are weak non-attraction forces (hydrophobic interactions) created between $–CH_3$ groups which are non-polar.

**CLASSIFICATION OF PROTEINS.**

**CRITERIA**

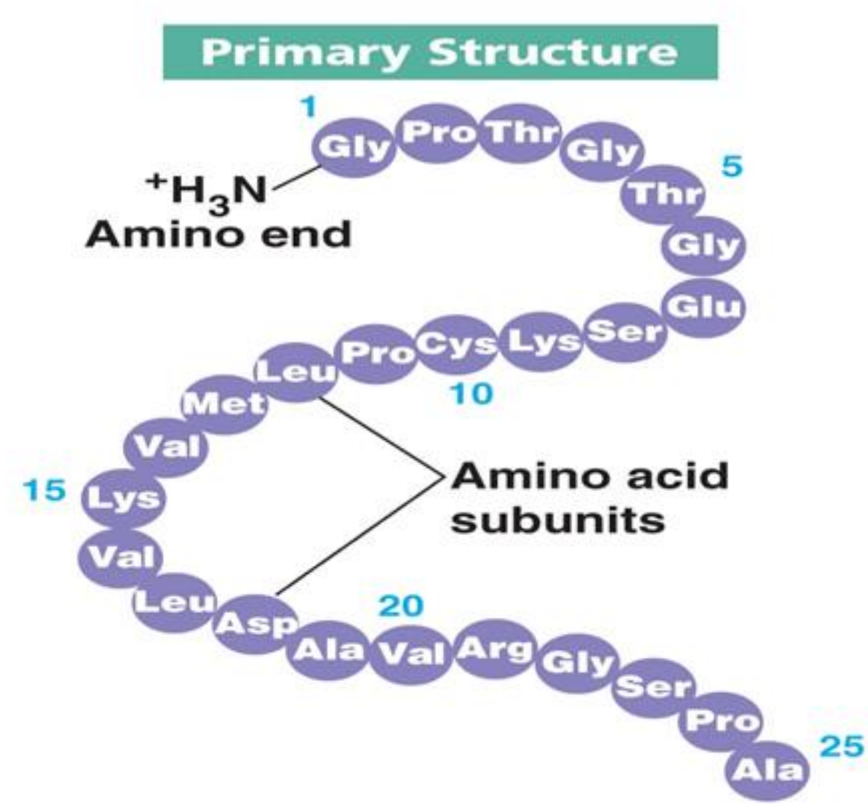
1. Level of organization.
2. According to function.
3. According to composition.
4. To whether they contain essential amino acids.
5. According to structure.

**ACCORDING TO LEVEL OR ORGANISATION.**

1. Primary structure.
2. Secondary structure.
3. Tertiary structure.
4. Quaternary structure.

1. **Primary structure.**

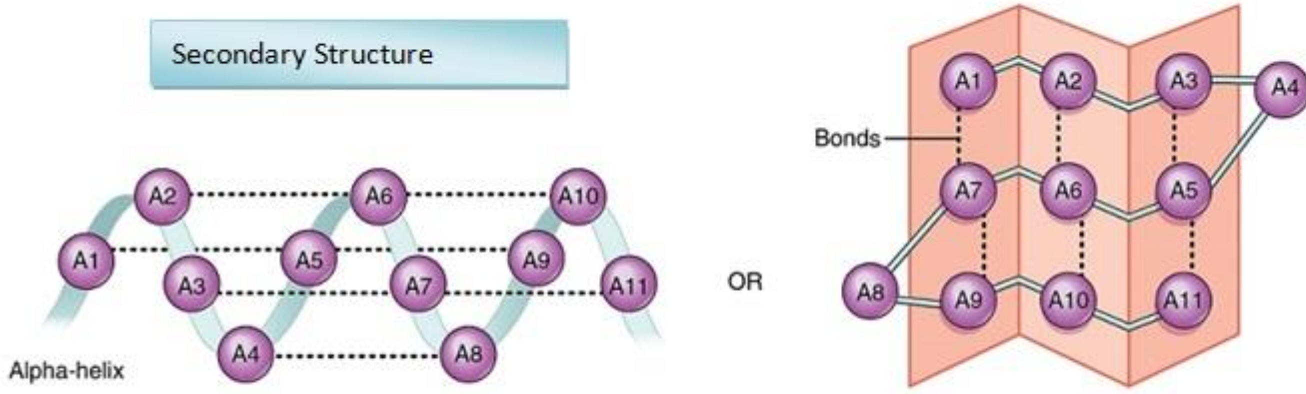
This is a linear sequence of amino acids joined together by peptide bonds. Also disulphide bond may be found.




2. **Secondary structure**

This is due to coiling or twisting of the polypeptide.

**Diagram**




**α helical**

This is due to attraction of various amino acids. This is a component of hair, claws, nails, as well as skin.

**β pleated sheets (zig zag structures)**

Collagen is a compound of tissues like bones and cartilage. Collagen is an example of β pleated sheet**s.**

3. **Tertiary structure.**

Tertiary structure is due to coiling and twisting of the polypeptide helix forming a globular or spherical shape.

Bonds present in the coiled structure are ionic bond, hydrogen bonds, hydrophobic interactions, disulphide bridges.

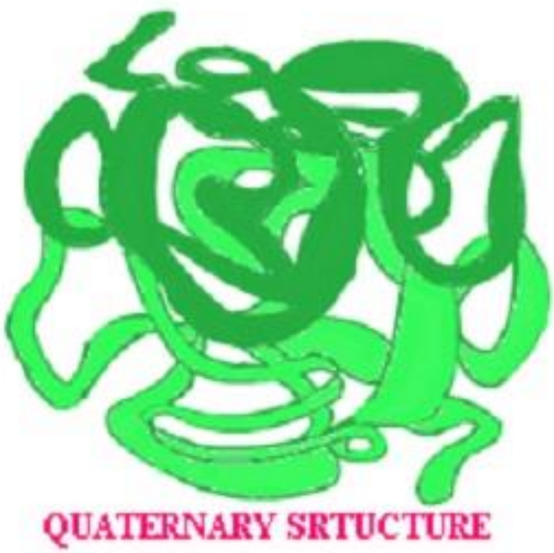
Examples of tertiary structures. (They are very soluble).


1. Immune globin( antibodies)
2. homornes
3. enzymes

4. **Quaternary structure.**

Quaternary structure is due to coiling and twisting of various polypeptide chains usually the structure is associated with non-protein parts called prosthetic groups e.g. hemoglobin.

Hemoglobin has four polypeptide chains, two α-chains and two β chains each surrounding an iron atom.

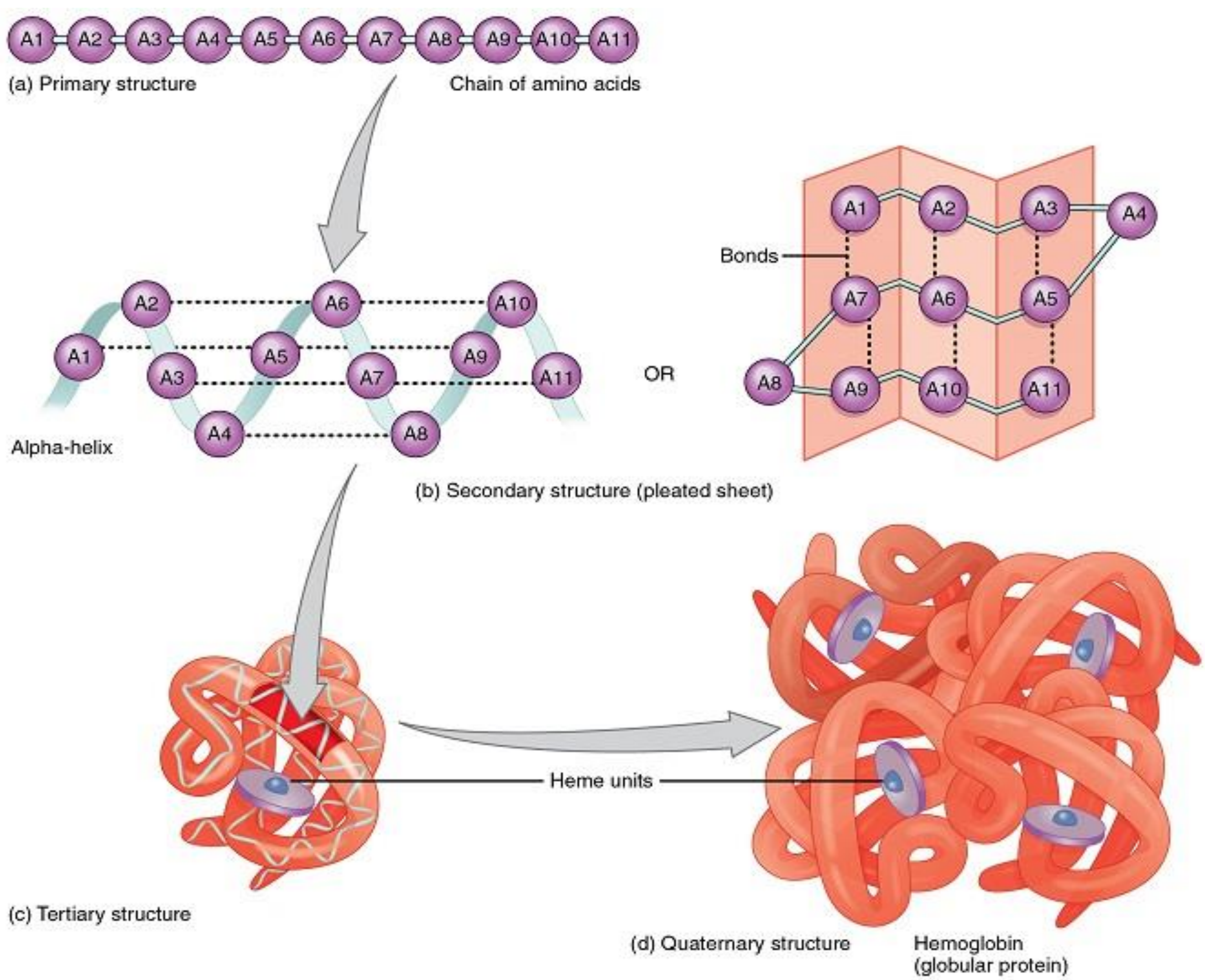



The hemoglobin consists of protein parts. The protein part consist of 4 polypeptide chains, of the four polypeptide chains, 2α chains and 2 β chains and is called globin.

The non protein parts is called HAEM consist of poiphyding surrounding an iron atom.

**THE FOUR LEVELS OF PROTEIN STRUCTURE**

1.




**ii. BASED ON WHETHER THEY CONTAIN ESSENTIAL OR NON ESSENTIAL AMINO ACIDS.**

**Essential amino acids Vs non essential amino acids**

**Essential amino acids** are those which cannot be synthesized by human cells but are obtained from food.

All of the 20 α amino acids are needed to make different proteins in the body of a human.

Twelve of these amino acids can be synthesized by the cells from other substances that are present in the body; these are called non-essential amino acids.

The other eight cannot be synthesized by the body and must be included in the persons diet are called essential amino acids.

**iii. BASED ON COMPOSITION.**

1. **Simple proteins**

   Simple proteins are made up of amino acids only.

   E.g. - Histones (nucleoprotein)

- Globulin( immunoglobulin)
- Schleroproteins ( e.g. Keratin)
- Albumins
- Pastamins

1. **Conjugated proteins.**

   Made up of amino acids; are globular proteins associated with non protein materials. E.g. haemoglobin glycoprotein (components of cell membrane), mucin (component of saliva), lipoproteins (components of cell membrane).

**iv. ACCORDING TO FUNCTION.**

NOTE:these are also functions proteins.

| | TYPE | EXAMPLE | OCCURRENCE/ FUNCTION. |
|---|---|---|---|
| 1. | Structural | - Collagen<br>- Keratin<br>-Elastin | - Components of the connective tissue, bone, tendon,cartilage, skin,hair,feather, nails and horns.<br>- Elastic connective tissues(ligaments 'wraps up' nucleic acid for virus. |

| | | | |
|---|---|---|---|
| | | -viral coat protein | |
| 2. | Enzymes | - Trypsin.<br><br>- Ribulose biphosphate carboxylase.<br><br>- Glutamine synthesase. | - Catalyze hydrolysis of proteins<br><br>- Catalyses carboxylation (oxidation)$CO_2$ of ribulase biphosphate in photosynthesis.<br><br>- Catalyze synthesis of amino acids, glutamine from glutamic acid and ammonia. |
| 3. | Hormones | -Insulin<br><br>- glucagon<br><br>Adrenaline corticotrophic hormone (ACTH). | - Helps to regulate glucose metabolism.<br><br>- Stimulates growth and activity of the adrenal cortex. |
| 4. | Respiratory pigment. | - Haemoglobin<br><br>- Myoglobin | - Transports oxygen in vertebrate's blood.<br><br>- Stores $O_2$ in muscles. |
| 5. | Transport | - Serum albumin | Transports fatty acids and lipids in the blood. |
| 6. | Protective | - Antibodies<br><br>- Fibrinogen<br><br>- Thrombin | - Form complexes with foreign proteins<br><br>- Form fibrin in blood clotting<br><br>- Involved in blood clotting mechanism. |
| 7. | Contractile | - Myosin<br><br>- Actin | - Moving filaments in myofibrils of muscles<br><br>- Stationary filaments in m myofibrils in muscles. |
| 8. | Storage | - Ovalbumin<br><br>- Casein | - Egg white protein<br><br>- Milk proteins |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| | | | |
|---|---|---|---|
| 9. | Toxins | - Snake venom<br>- Diphtheria toxin | - Enzymes<br>- Toxin made by diphtheria bacteria. |

**NEUTRAL AMINO ACIDS.**

This is because their side chains have no charge at the pH of body cell.

Thus are divided into;-

- Natural hydrophobic amino acids.
- Natural hydrophilic amino acids.

**Natural hydrophobic amino acids.**

Seven natural amino acids have side chains(R) that are non polar or hydrophobic. These hydrophobic are either alkyl or aromatic in nature.

- Alanine (ala).
- Valine (Val).
- Leusine (leu).
- Iso leusine.
- Proline
- Phenyl donine (phe)
- Tryptophan (trp).

**Neutral hydrophilic amino acids.**

Eight amino acids are classified as hydrophilic.

- In general these amino acids are more soluble than hydrophobic amino acids.
- The acid chain of glycine (gly) is just hydrogen. The other seven neutral hydrophilic amino acids have side chains that can form either strong or weak hydrogen bond with water.
- These have hydroxyl group in either side chain serine (ser) theorine (Thr) or tyrosine (try). Two contain an amino functional group, asparagines (asp) and glutamine (gln). The remaining two contain a sulphur atom cysterine (cys) and methionine (met).

**Others include**: tyrosine, asparagines, cysterine, glutamine, and methionine.

**ACIDIC AMINO ACIDS**

Acidic amino acids have side chains that contain a second carbonyl group.

At the pH of cells in the body, these carboxylic groups exist primarily as negative charged carboxylate ions and this interact strongly with water molecules.

Aspartic acid (asp)

Glutamic acid (glu)

**BASIC AMINO ACIDS.**

Three of the amino acids contain a side chain that act as a proton acceptor or base. They are thus classified as basic amino acids, these are lysine (lys), arginine (arg) and histamine.

**v. BASED ON STRUCTURE**

**a. fibrous protein.**

- Have a secondary structure and little or no tertiary structure.
- Insoluble in water.
- Physically tough.
- Form long polypeptide chain cross linked at intervals forming long fibres or sheets.

**Functions of fibrous proteins.**

Perform structural function in cell and organism e.g. collagen (tendon, bones, connective tissues) myosin in muscles, (silk) spider web, keratin (nail, hair, feathers).

**b. globular proteins.**

- Found mostly in tertiary structure.

- Polypeptide chain highly folded to form spherical shape.
- Easily soluble in water.

**Functions of globular proteins.**

Forms enzymes, antibodies and some hormone e.g. insulin.

**C. intermediate protein.**

Fibrous in nature but soluble in water e.g. fibrinogen.

**Function of intermediate protein.**

Fibrinogen forms insoluble fibrin when blood clots.

**NUCLEIC ACIDS.**

Like proteins, nucleic acids are largely polymers made up of small number of different building blocks called nucleotides.

Each nucleotide is in turn composed of 3 smaller parts.

- A phosphate group.

- Monosaccharide

- A nitrogen containing base.

The term nucleotide is used to refer to nitrogenous base bound to a monosaccharides.

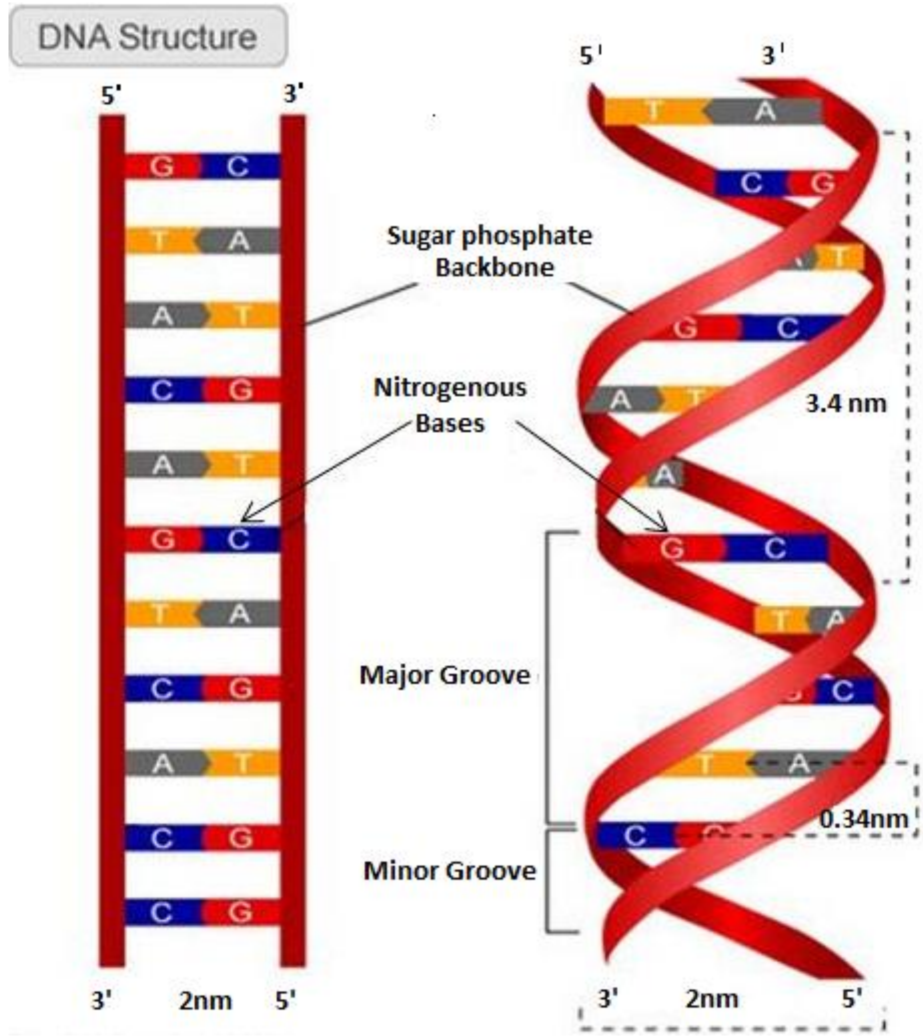
And the nucleotide is a nucleotide phosphate.

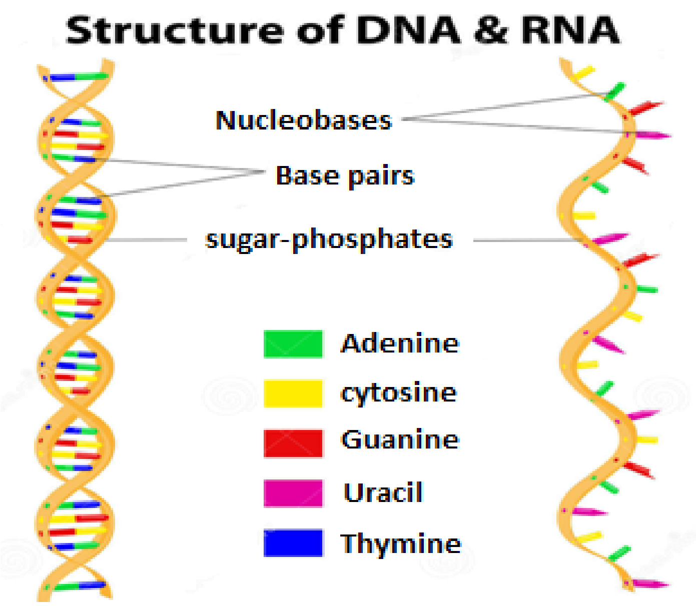
There are two major types of nucleic acids.

-i. deoxyribose nucleic acids (DNA).

-ii. ribonucleic acid (RNA).

**Diagrams**


DNA Structure
5'
3'
G C
T A
A T
C G
A T
G C
T A
C G
A T
C G
C G
3'
2nm
5'
Sugar phosphate
Backbone
Nitrogenous
Bases
Major Groove
Minor Groove
5'
3'
3.4 nm
0.34nm
3'
2nm
5'




There are two main differences between the deoxyribonucleotide components of DNA and the ribonucleotide component of RNA.

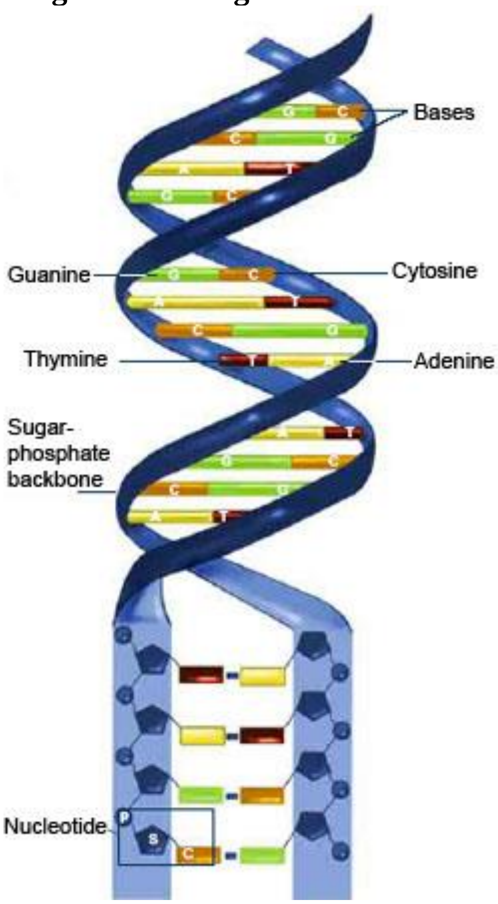
| criterion | DNA | RNA |
|---|---|---|
| 1. Sugar component | - Has its sugar D-ribose lacking hydroxyl group in carbon #2 of ribose; hence the prefix De-oxy is used to denote the absence of oxygen at that position. | - Has its sugar D-ribose having oxygen at carbon number 2. |
| 2. Organic bases. | - Have four possible organic bases, 3 of which are adenine, guamine and cytosine and the fourth is thymine which is lacking in RNA. | - Have four possible organic bases, 3 of which are adenine, guamine and cytosine and the fourth is uracil which is lacking in DNA. |

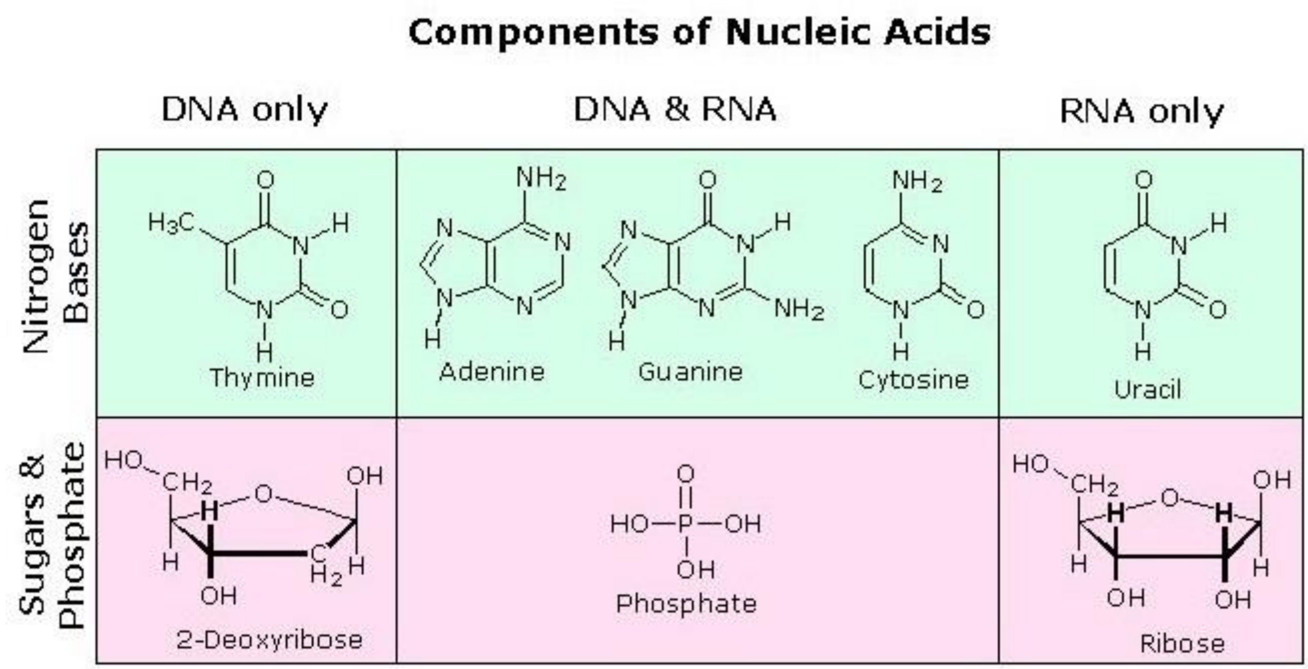
**JOINING THE NUCLEOTIDES TO FORM A POLYMER OF DNA OR RNA.**

The bond that holds these polymers together are ester linkage formed between the phosphate on the number 5 carbon of ribose in one nucleotide and the hydroxyl on the number 3 carbon of ribose in the next nucleotide (deoxyribose in the case of DNA)

Two nucleic acids are said to have $3^{l}5^{l}$- phosphate ester bridge/bond between their nucleotide components

**Diagram of a long nucleic acid.**





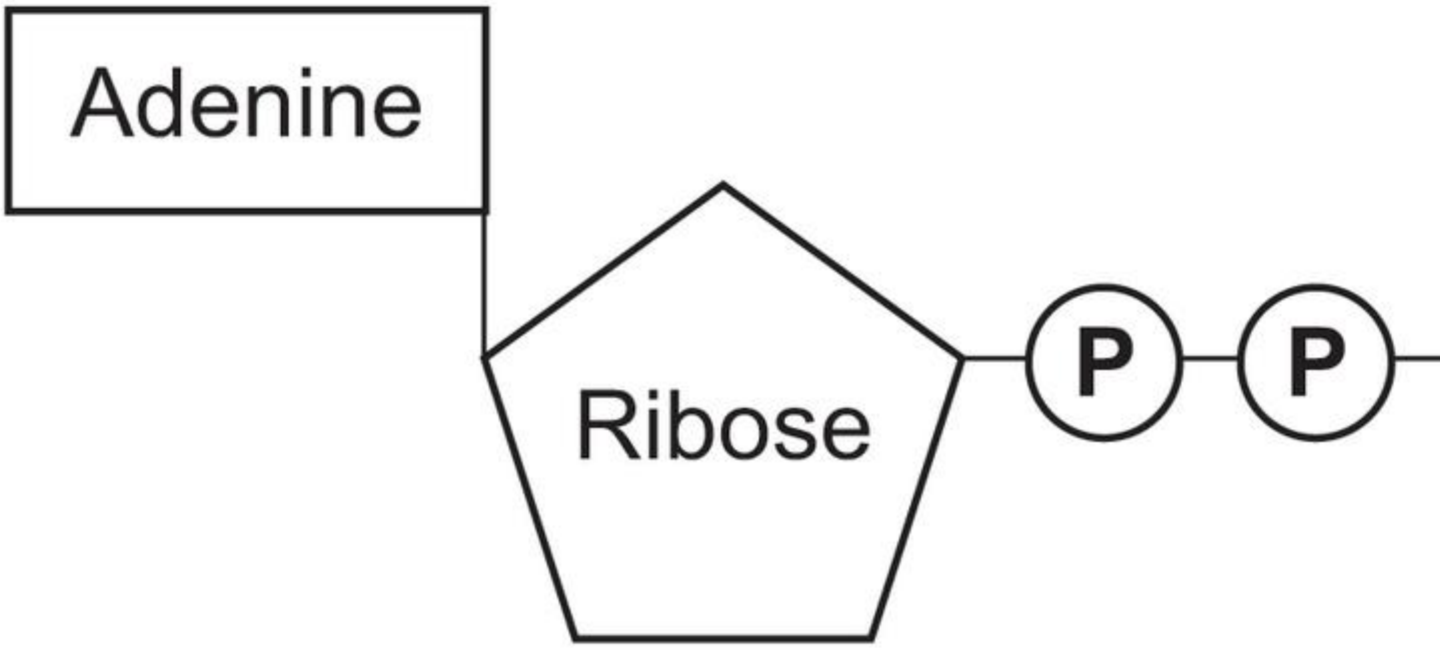

- The DNA consists of two long polynucleotide strands and the base components of each nucleotide on one strong can form hydrogen bonds with only one specific nucleotide base on the other strand.
- Guamine (G) can hydrogen bond only to cytosine in another DNA strands form a base pair.
- Adenine (A) can hydrogen bond with thymine (T).

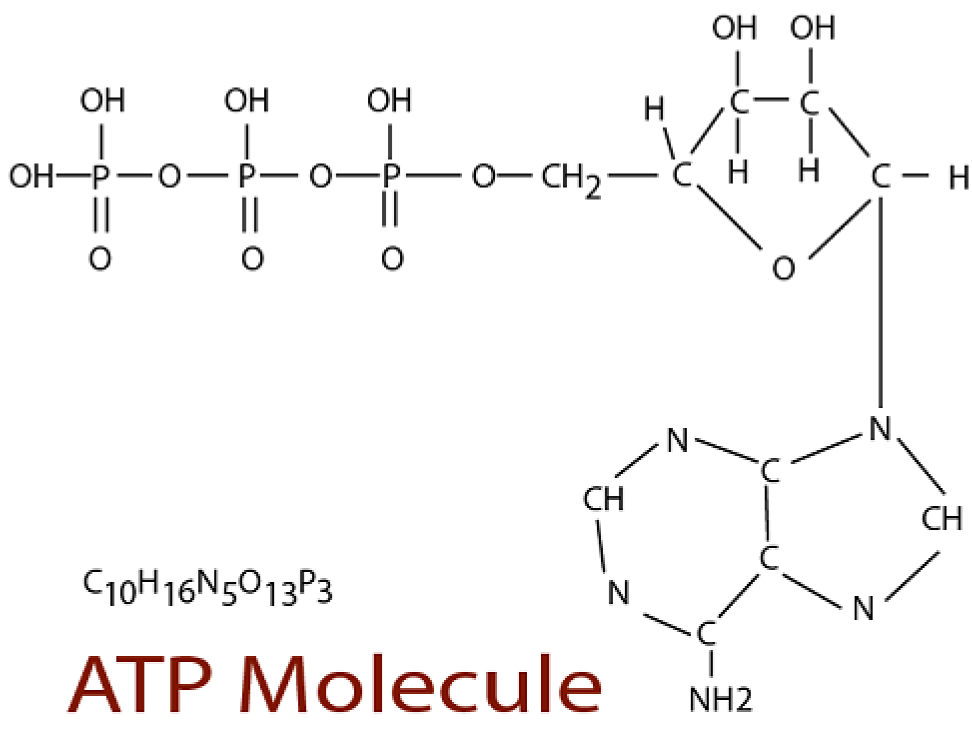
**ATP (ADENINE TRIPHOSPHATE)**

- ATP is formed from the nucleotide adenosine monophosphate by the addition of two further phosphate molecules.

Its structure:

**Diagram**




$C_{10}H_{16}N_5O_{13}P_3$

ATP Molecule

- ATP is an energy store, because the last branches are highly energetic on breaking.
- The hydrolysis of ATP to ADP is catalyzed by the enzyme ATPase and the removal of the terminal phosphate yield 30.6kj $mol^{-1}$ of free energy. So does the second one to from ADP and AMP respectively. AMP and ADP may be re-converted to ATP by the addition of phosphate molecule in a process called phosphorylation of which there two main forms.

1. **Photosynthetic phosphorylation**- occurring during photosynthesis in chlorophyll-containing cells.
2. **Oxidative phosphorylation** - occurring during cellular respiration in all aerobic cells.

**USES OF ATP.**

A metabolic active cell may require up to two million ATP molecules every second. ATP is the source of energy for;

1. Anabolic processes.

   It provides the energy needed to build up macromolecules from components units.

   Examples

- Polysaccharide synthesis from monosaccharide.
- Protein synthesize from amino acids.
- DNA replication.

2. Movement- it provides the energy for many forms of cellular movements, including;

-muscle contraction

- Cilliary actioning

- Spindle action in cell division.

3. Active transport – it provides the energy necessary to move materials against concentration gradient e.g. ion pumps.

4. Secretion – it is secreted to form the vesicle in the secretions of the cell product.

5. Activation of chemicals – it makes chemicals more enabling them in reacting (more readily) e.g. the phosphorylation of glucose at the start of glycolysis.

**ENZYMES**

- **Enzymes** are simple or compound organic proteins which are organic catalysts catalyzing reactions in living tissues.

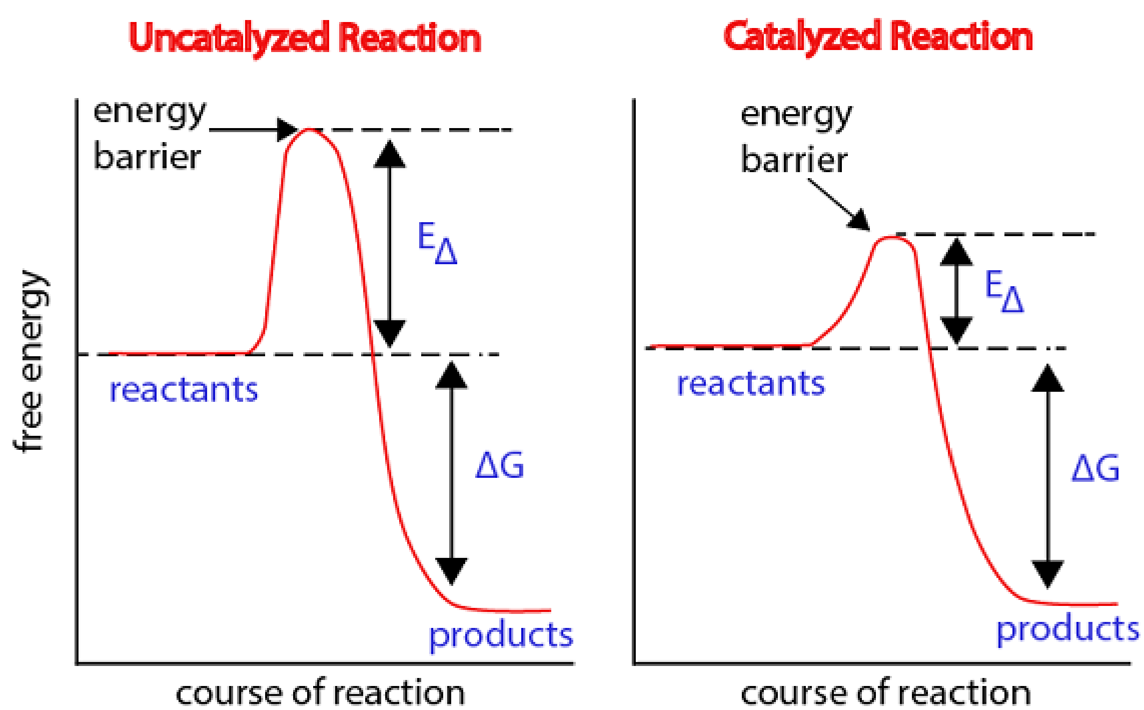
ENZYME: Greek word “en” means in and “zyme” means yeast cell.

They are bio catalysts found in living things.

- Catalysts accelerate chemical reactions although a catalyst is a participant in a reaction and undergoes physical change during the reaction. It reverts to its original state when the reaction is complete.
- Enzymes are protein catalysts for chemical reactions in biological systems. Most chemical reactions of living cells would occur very slowly, were it not for catalyzing enzymes as illustrated below.

**Energy diagram under catalyst action showing progress of the reaction.**

**Fig. reduction of necessary activation energy by enzymes.**




**NB**: as seen in the above graph, the activation energy (Ea) necessary to initiate the reaction is much less in the presence of the catalyst than in its absence.

- It is this lowering of activation energy barrier by enzyme catalysts that makes possible most of the chemical reactions in life.
- By contrast to non-protein catalyst (e.g. $H^+$, $OH^-$, or metal ions) each enzyme catalyze a small number of reactions, frequently only one and thus enzymes are reaction –specific catalysts.

- Most inorganic catalysts are relatively non specific for example platinum, often used to catalyze the formation of water from hydrogen gas and oxygen gas. Will catalyze almost any reaction in which $H_2$ is one of the reactants and the reaction of materials as well.

**Properties of enzymes.**

1. They generally work fast than inorganic catalysts and greatly lower the activation energy.
2. Enzymes are not consumed by the reaction they catalyze i.e. a given molecule of an enzyme can be used indefinitely if the conditions are kept suitable.
3. Enzymes can work in either direction i.e. catalyze reversible reactions. This is due to the fact that metabolic reactions are reversible and the direction of the reaction depends on the relative amount of substrates and products present.
4. Enzymes are denatured by excess heat (temperature) by the virtue of their proteineous nature.
5. Enzymes are sensitive to pH. Every enzyme has its own range of pH at which it functions effectively.
6. Enzymes are specific in the action they catalyze. Normally a given enzyme will catalyze only one reaction or one type of reaction.
7. Enzymes react in only small amount. A very small amount of catalyst will transfer in a very large amount of reactants.
8. They are colloidal in nature and thus provide large surface area for reaction to take place.
9. Enzyme activity can be accelerated or inhibited. The accelerators are called activators e.g. Cu, Zn, Co, Cl, Ca. while the inhibitors are for example DOT, Pb, and Hg etc.

**NATURE AND MODES OF ENZYME ACTIVITY.**

Hypothesis explains the nature and mode of enzyme activity.

1. The lock and key theory (hypothesis) by Fischer.

   In the model the three dimensional configuration of the enzyme represented the lock (the active title) into which particular substrate (key) will fit.

   The active site presumes to be rigid.

2. The induced fit model by Koshland.

   Originally little more than an attractive hypothesis, this model now has received considerable experiment support.

   An essential feature is the flexibility of the region of the active site. In this mode, the substrate induce the conformation change in an enzyme just like the shape of a glove is affected hand wearing.

**MOLECULAR STRUCTURE OF ENZYMES**.

Enzymes are either composed of;

1. Protein alone-simple enzymes.
2. Protein and other non-protein molecule( i.e. conjugated enzymes)

The protein part of an enzyme is called Apanzyme.

Non- protein part is called co-enzyme.

The protein part of an enzyme is made up of enzyme protein zymoprotein.

The two component (the apoenzyme and coenzymes) make up the active enzymes called holloenzymes.

Holoenzymes= coenzyme + apoenzyme.

Prosthetic groups are usually metallic ions such as Co, Mg, Ni, Cu, Zn (mineral salt). This is also a non-protein part, the well known co-enzyme are those which function as hydrogen carriers, in-oxidation-reduction in energy metabolism. For instance coenzyme NAD, NADP, Q, A. Coenzyme A is involved in transfer of an acetyl group.

These are substances which increase the activity of the halo enzymes. Their absence may retard the catalytic activity of the enzymes or preventing it from acting.

Activators are usually inorganic ions e.g. $Ca^{2+}$ for thrombo kinase, $Cl^{-}$ for ptyalin, $Mg^{2+}$ for phosphate.

Coenzymes and activators are needed by the enzymes for proper activities.

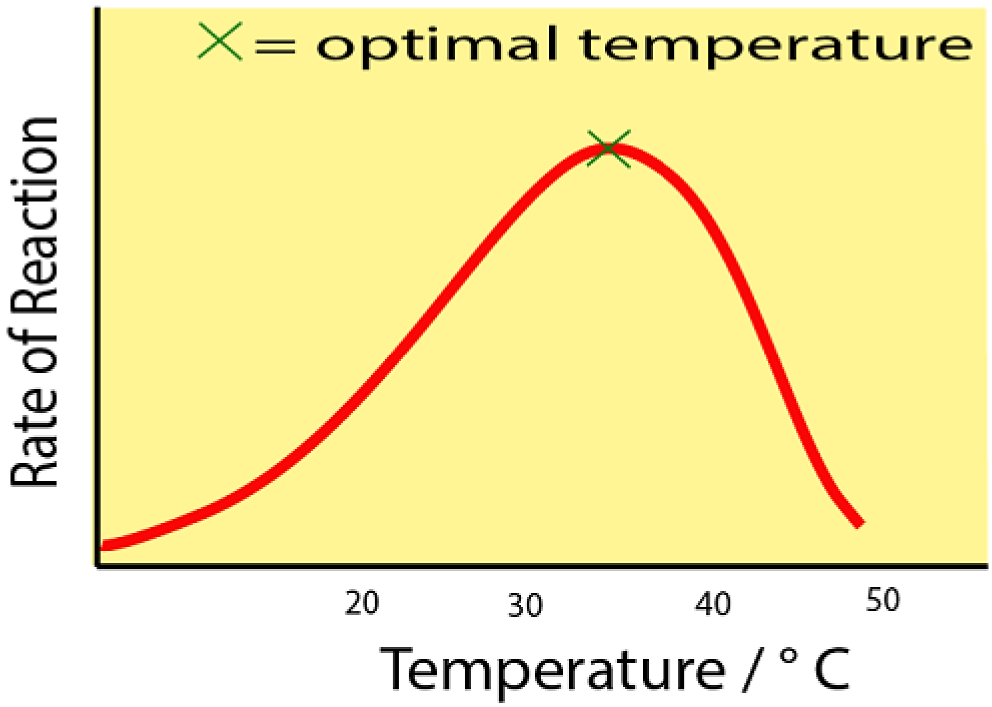
**FACTORS AFFECTING ENZYMATIC ACTIVITY.**

1. Over a limited range of temperature, the velocity of enzyme catalyzed reactions increase as the temperature rises. The exact ratio by which the velocity change for a $10^0$C temperature rise is the $Q_{10}$ or temperature coefficient.

   The velocity of many biological reactions roughly doubles with a $10^0$C rise in temperature ( $Q_{10} = 2$) and is halved if the temperature is decreased by $10^0$C. Many physiological processes e.g. the rate of contraction of an exercised heart- consequently exhibit $Q_{10}$ of about 2.

   When the rate of enzyme catalyzed reaction is measured at several temperature the result shows in the figure below is typical. There is an optimal temperature which the reaction is most rapid. Above this reaction the rate decrease sharply due to heat denaturation of the enzyme and below this the energy content of enzymes is too low to make them participate in their reaction.

   **Fig. enzymes activity as a function of temperature.**




2. Although temperature sensitivity varies somewhat from one enzyme to another the curve shown here may be taken as applying to an average enzyme.

   Its activity rises steadily with temperature (approximately) doubling for each $10^0$C increase until thermal denaturation cause a sudden sharp decline, beginning between $40^0$C and $45^0$C. The enzyme because completely ineffective/ inactive at temperature above $60^0$C presumably because its three dimensional configuration has been severely disrupted.

   Denaturation of a protein enzyme by heat is the loss of it biological activity. This can be done also by heat, acid or high salt concentration.

**2. pH.**

Moderate pH changes affect the ionic state of the enzyme and frequently that of the substrate also.

When enzyme activity is measured as several pH values optimal activity is generally observed between pH values of 5 and 9. However the few enzymes eg pepsin is active at pH values well outside this range. The shape of pH activity curves is determined by the following factors.

1. Enzyme denaturation.

At extremely high or low pH values.

Effect on the charged state of the enzyme or substrate.
For the enzyme, charge changes may affect the activity either by changing structure or by changing the charge on an amino acid residue functional in substrate binding or catalysis.
If a negatively charged enzyme ($E^-$) reacts with a positively charged substrate ($SH^+$).

$E^- + SH^+ \rightarrow ESH$

Thus at low pH values, $E^-$ will be protonated and lose its negative charge. i.e.

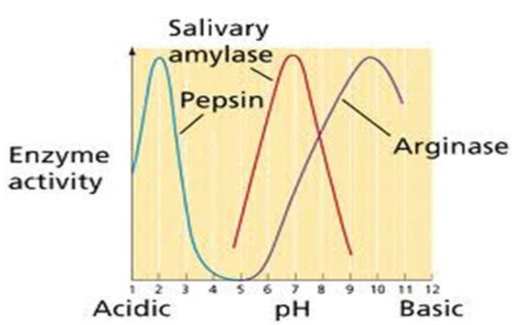
$E^- + H^+ \rightarrow E\text{-}H$

Similarly at very high pH values, SH will ionize and loose its positive charge.

$SH^+ \rightarrow S + H^+$

1. Since the only forms that will interact are $SH^+$ and $E^-$. Extreme pH values will lower the effective concentrations of $E^-$ and $SH^+$ thus lowering the reaction velocity as shown below.

**Diagram**



Only the crossed-hatched area of S and E in the appropriate ionic state and thermal concentration of E and S are correctly charged at X the result is a bell-shaped pH activity curve

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# PRINCIPLES OF CLASSIFICATION

There are few terms which come across when studying classification. These terms include systematic, taxonomy, classification and nomenclature.

To understand the principles used in classification these terminologies need to be clearly defined.

**SYSTEMATIC**

There are millions of living organisms in the world which exhibit great diversity and variations. Each one is different from the other in one way or another.

It is practically impossible to study and identify each and every organism. Biologists have designed a technique for identification, naming and grouping various organisms.

**Systematic** is a branch of biological science that deals with the study of the kinds of diversity of all organisms and their relationship.

The term systematic is derived from the Greek word 'systema' which simply means 'that which is put together'.

**Significance of systematic**

- Systematic gives the idea of organic diversity, its origin and evolution in the various kingdoms.
- It helps in identification of living organisms.
- It simplifies the study of biology.
- It makes biology communication easier e.g. nomenclature.
- It group together biology knowledge.
- It helps us to understand the relationship between the organisms and their environment.
- The subject is relevant to all sector of applied biology such as agriculture, forestry, medicine, fisheries and conservation of natural resources.

Systematic include taxonomy, identification, classification and nomenclature.

**TAXONOMY**

The word taxonomy is derived from the Greek words 'taxis' means arrangement and 'nomos' means law.

Taxonomy is a part of systematic which deals with the laws and principles on which classification is based.

Taxonomy can also be defined briefly as the study of classification.

It is a functional science concerned with identification, nomenclature and classification of different kinds of living organisms.

A taxonomist is the person who studies classification.

**IDENTIFICATION**

Identification refers to the determination that a particular organism is similar to some other known organism or individual.

**Or**

Identification is the part of taxonomy that assigns an organism to its correct taxon.

It involves describing an organism using evidence from other branches of biology e.g. cytology, biochemistry, anatomy, ecology or morphology.

**Example of identification**

Consider three animals such as a, b and c. all belonging to different species. Another animal d having resemblance with animal b. The recognition of animals which is identical or similar to the already known animal b is considered its identification.

**NB;** much evidence need to be collected in order to assign a particular organism in a certain group.

Identification is done by using identification key/ biological key.

**IDENTIFICATION KEY/ BIOLOGICAL KEY.**

This refers to a schedule of characteristics data which can be matched or correlated with observable characteristics of an organism so as to identify it.

**Or**

A set of observable characteristics that leads to the identification of an unknown organism

**Importance of the biological key**

- Provide a convenient method which enable biologists to identify an organism and allocate different organisms in their correct taxa or group or more useful in identification of unknown organisms.

**Types of biological key**

There are two types of key;

- Indented key.
- Bracketed key.

**Indented key;**This is the type of key which provides sequence of choices between two or more statements of characters of species. The use has to make a correct choice for identification

Example of indented key

Character

**Carpel.**

- Single-ovuled, fruit achene, leaves opposite, compound petals absent.
- Leaves with tendrils………………. Clematis.
- Petals present third or terminal leaf let modified into tendrils……….naravelia.
- Leaves alternate or radicle…………anemone

- Many - ovuled; fruit follicle, carpel united at base;
- Flowers regular……………………………..nigella
- Carpel free at base; flower irregular………..Aconitium

**Bracketed [dichotomous key]**

This type of key provides a choice between two contrasting statements which lead into accepting one statement and rejecting the other.

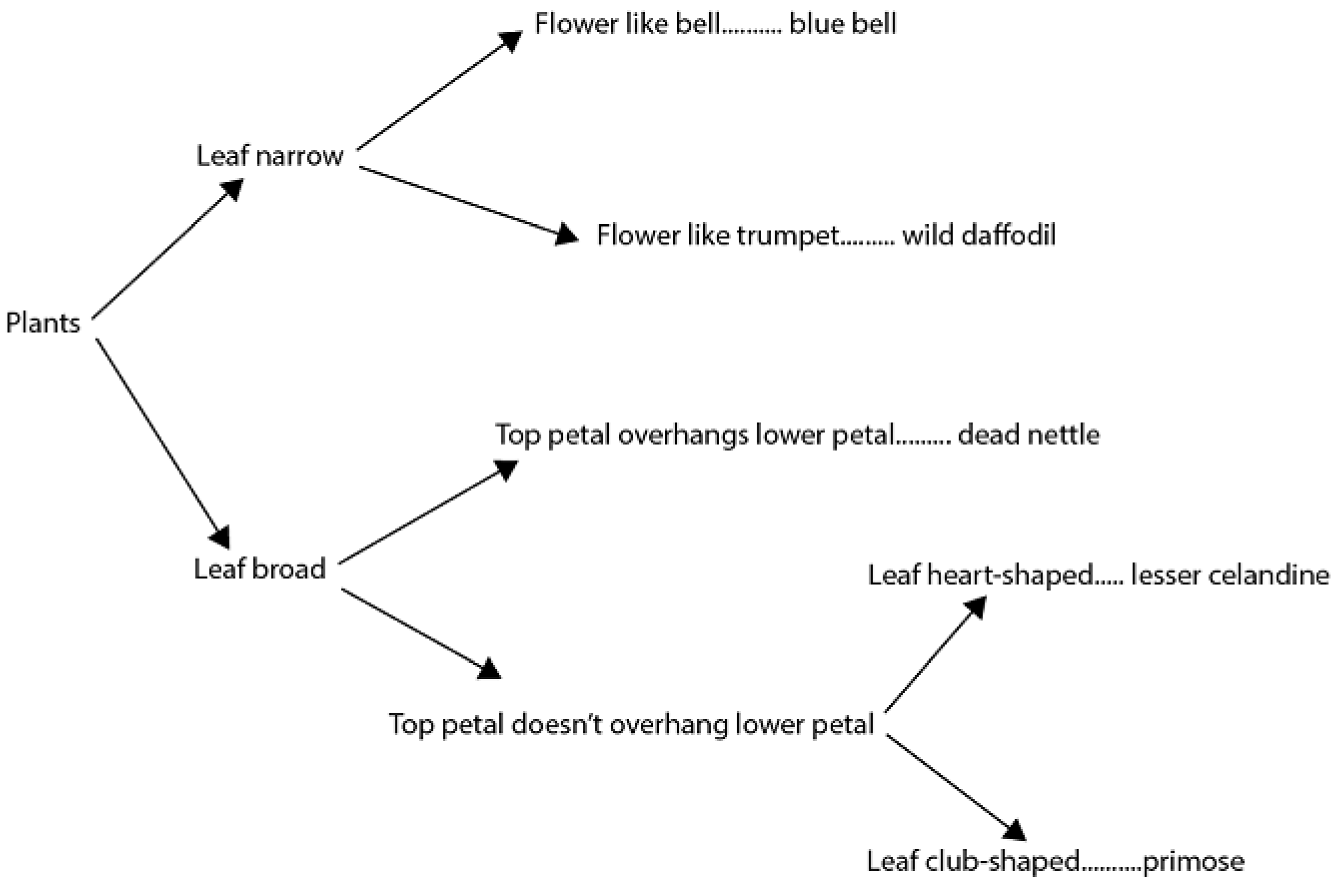
The word dichotomous means - separating or branching into two.

There are two types of dichotomous key.

A] **Branched [spider] key** –this is diagrammatically represented. The key form two branches at each stage. This means that one is confronted with two possibilities at each stage. The description which fits the member of each new group is put at the end of new branch.

The problem of branched key is that they take up much space particularly if many organisms are involved

Branched key (figure below)




**B) Numbered key**

This consists of pairs of statements which are numbered. Each pair of statements is called lead or couplet. Each lead deals with a particular observable characteristic. The leads are numbered 1,2,3,4 etc, the paired statements of each lead is marked A and B.

The biological key can be short i.e. having one or two pairs of statements [leads] or it may be long consisting of many leads.

By considering each lead at a time a large group of organisms may be broken down in progressively small groups until unknown organism is identified.

**NB**; the two statements should be contrasting and mutually exclusive ( on the same character but opposing statements).

**Rules used in constructing the dichotomous key.**

1. Use morphological characteristics (observable features) as many as possible.

2. Select characters that are in opposition to another so that the two statements of each lead comprise contradictory propositions of which one fit the situation and other not apply.

3. Select one character at a time and identify it by number e.g. 1,2,3,4, etc.

4. The statements should be put positivity particularly the first one.

5. Use identical first words for the two contrasting statement.

E.g. I. a) scented flower…………………

b) Non scented flower ………………..

6. Use macroscopic morphological characteristics as far as possible in separating groups.

7. Avoid generalization or overlapping variation i.e. be very specific in your description so that the two statement clearly represent different organisms e.g.

a) Plant 1 meter and above tall.

b) Plant 15cm to 60cm tall

**Steps in construction of the dichotomous key**

1. Study the morphological characters of the organisms provided and prepare a table of differences and similarities in characters.
2. Use the data you have tabulated to construct a dichotomizing tree of characteristics.

**Example**

Given the following organisms, construct the dichotomous key to identify them: grasshopper, Housefly, butterfly, beetle, wasps, and cockroaches.

**Morphological features**

One pair of wings, two pairs of wings

Scale on wings, none scaled wings

Hard outer wings, without hard outer wings

Constricted waist, non constricted waist

Numbered key

1. a) With two wings………………………………………. .Housefly

   b) With four wings………………………………………go to 2

2. a)Scale on wings ……………………………….……..Butterfly

   b) No scale on wings ……………………………..………go to 3

3. a) Insect with hard outer wings………………………… Beetle

   b) Insect without hard outer wings…………………...go to 4

4. a) Insect with constriction between abdomen and chest..….wasps.

   b) Insect without constriction between the abdomen and chest……Grasshopper

**Steps to follow on using a dichotomous key.**

1. Study the two couplets of the first lead and compare characters mentioned in the two couplets to the observable features of the organism in question.

2. Read from one lead to another until you come to the lead with one of its couplet matching with the observable features on the organism.

Given the organisms below use key provide to identify them; spider, butterfly, snail, mosquito, snake, millipede, housefly, butterfly.

1. a) Animal with wings………………………….…..2

   b) Animals without wings………………………...…3

2. a) Body with scale……………………….……..…..4

   b) Body without scale…………………….…….....5

3. a) Body with legs………………………………......6

   b) Body without legs ……………………………......7

4. a) Organism with clubbed antennae ……………...H

   b) Organism without clubbed antennae………..…G

5. a) Organism with thin abdomen ………………..…C

   b) Organism with broad abdomen ……………….F

6. a) Body elongated…………………………………E

   b)Body not elongated……………………………A

7. a) Animals withshell……………………………B

   b) Animal without a shell……………………….....D

1a, 2a, 3a, 4a, - H (Butterfly)

1a, 2a, 3a, 4b, 5a - C (mosquito)

1b, 2b, 3b, 7a - B (snail)

Characteristics used contraction dichotomous keys in plants.

Below are some characteristics used to identify flowering plants and to construct dichotomous keys.

1. Plant habitat i.e. being terrestrial or aquatic.
2. Plant morphology i.e. the plant herb, shrub or tree
3. Plant efflorescence e.g. are the flowers terminal or axial
4. Structure of the flower

a. Simple or compound (have one carpel or many fused)

b. Number of floral parts in each whole

c. Fusion of floral parts

5. The leaf

a) Type of leaf (simple or compound)

b) Types of venation (parallel or network)

c) Margin (smooth or serrate)

d) Arrangement on the stem i.e. alternate or opposite or whorled.

e) Texture e.g. hairy or smooth.

**Animals.**

Animals can be divided into vertebrates and invertebrates.

**Vertebrates**

Feature that can be used include.

1. Body covering i.e. scales, hairs or feathers
2. Structures used for locomotion i.e. fins, wings or legs

iii) Position of the eyes i.e. frontal or lateral.

**Invertebrates**

i) Body symmetry arrangement of other part of the body in relation to the axis of the organisms e.g. radial or bilateral or asymmetrical

ii) Body segmentation

iii) Body covering with shells, exoskeleton.

iv) Appendages whether present or absent, types and numbers e.g. tentacles, antennae, wings, legs etc.

**N.B**

Characteristics used in a key are mainly based on

1. Observable e.g. morphological features
2. Quantity e.g. number of hairs, legs, wings e.t.c
3. Qualitative e.g. shape of abdomen.

**NOMENCLATURE**

- ICB – international code of Botanical Nomenclature

  ICZN – international code of zoological Nomenclature

  ICVN – for virus Nomenclature

**Nomenclature** is defined as the system of naming the organisms. It is a branch of taxonomy which deals with giving or assigning biological name (scientific name) to the organism once it is identified.

**Significance of using scientific names**

1. A scientific name is universally used for a particular species or particular group of organisms. This help to avoid the confusion which may arise by use of local (or vernacular) names which differ in different parts of the world.
2. Scientific names give descriptive information about the species; the taxonomist can determine from the description exactly the kind of organism to which the name has been given.
3. The names used are uniformly binomial specifying the name of the genus and species of the organism hence organisms with similar evolutionary history are classified together.
4. The scientific name allows information about organisms to be organized and found easily
5. Help biologist to avoid errors in communication.
6. Rules followed in the procedure of scientific naming favors stability.

**BINOMIAL NOMENCLATURE.**

The system adopted international in assigning scientific name is the Binomial system of nomenclature. This is the standard system of nomenclature.

It is a system of naming where the organism is given two words name the first word standing for the genus (generic name) followed by the second word denoting species (the specific name)

The system was introduced by carolus Linnaeus (1707- 1778) a Swedish naturalist.

The term binomial come from two Latin words (bi=two; nomen = name)

**Rules of Binomial nomenclature.**

Scientific names are assigned based on rules framed and standardized by the international bodies of Biological nomenclature. For example there are international codes of Botanical nomenclature (ICBN), the international code of Botanical nomenclature (ICZN) e.t.c

These codes are useful in avoiding errors, duplication, confusion and ambiguity in scientific names.

A few commonly followed rules are given bellow;

1. Every organism can have only one scientific name.

2. A scientific name of each species is binomial name. This is made up of two parts, a specific (species) name and a generic (genus) name. For example scientific name of man is ***Homo sapiens***.

Homo – generic name, sapiens - specific names

3. The scientific name should be in italics if printed and underlined if hand written

4. The generic name should always begin with a capital letter but the specific name should not. For example the name of the mango plant is ***Mangifera indica***.

5. All scientific names should be in Latin or Latinized

6. The name of the author should be in most cases included at the end of the biological name. If the Author is well known e.g. Linnaeus only the first letter is written at the end e.g**. *Canis lupus (L), Homo sapiens .L or (Linn)*** where L or Linn is abbreviated form of Linnaeus

7. When several different names have been given to an organisms, the earlier name that published after Linnaeus system of classification is to be considered.

8. Within a kingdom, no two genera can have the same name and within a genus, no two species can the same name.

**Example of scientific names**

| Scientific names | common name |
|---|---|
| Homo sapiens | Human |
| Panthera tigris | Tiger |
| Canis familiars | Dog |

| | |
|---|---|
| Musca domestica | Housefly |
| Periplaneta americana | cockroach |
| Columba livia | pigeon |
| Mangifera indica | mango tree |
| Triticum aestivum | wheat |
| Ananas comosus | pineapple |
| Carica papaya | paw paw |
| ***Hibiscus rose*** | China rose |
| Citrus sinensis | orange |
| Lycopersion esculanta | Tomato |
| Persea Americana | Avocado |
| Zea mays | Maize |
| Pisum sativum | pea |

**Classification** refers to the method of identifying distinctions (distinguishing characters) among different organisms and placing them into groups that exhibit their most significant features and relationship. Or classification refers to the branch of taxonomy that deals with the study of grouping living organism into series according to their resemblance and differences.

**AIMS**

1. To identify the different kinds of the living organisms on earth
2. To arrange the different kinds of the living organisms into scheme that would show the true relationship among the organisms.
3. To recognize the difference and show similarities between organisms.

**The significance of classification**

1. It organizes the huge number of organisms into categories that could be named, remembered and studied. It is difficult to know everything about all living organisms. classifying them into groups according to their similarities make it easier to study their characteristics

2. Classification helps us to understand the kinds of diversity that occur in living organisms and their relationship.

**TAXONOMIC HIERARCHY**

In classification organisms are put into groups, categories or ranks based on their similarities and differences. The main objective of taxonomy is to put organisms in different groups which show their evolutionary relationship

The ranks or categories used in classification are known as taxa(in plural) (singular taxon)

The taxa or taxonomic groups are arranged in hierarchical order i.e. from the largest group to the smallest group (descending sequence)

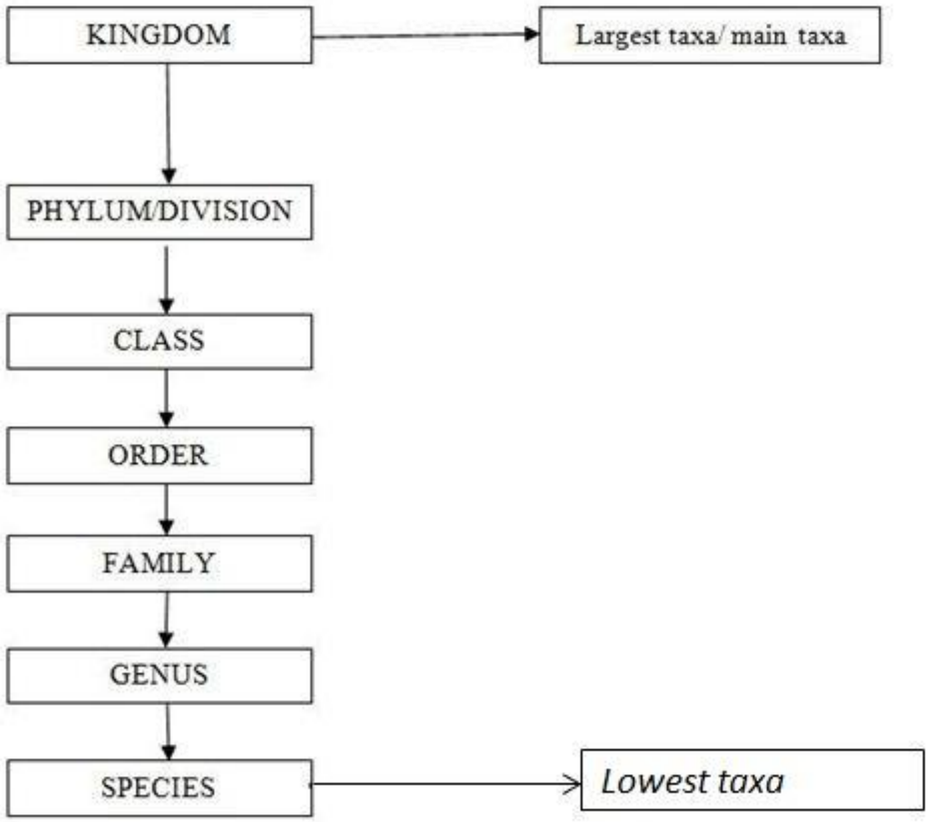
Taxonomic hierarchy refers to the sequential arrangement of the taxonomic group in definite order from higher to lower categories.

The taxonomic hierarchy consists of seven main categories or taxa. These are the kingdom, phylum, class, order, family, Genus and species. In plants however the division is used in categories in place of phylum while remaining categories are the same.

Linnaeus was the first taxonomist to establish a definite hierarchy of taxonomic ranks.

Sub – categories have been introduction to make a precise taxonomic position of the species. The prefix super is put for the category above the taxonomic category e.g. super class, super order etc. the prefix sub is added to make a lower category than the one existing e.g. sub order, sub family etc.

The figure below is an example of taxa or hierarchy of taxonomic ranks




**Characteristics of the taxonomic hierarchy**

- Members of a taxon show similar characteristics which are different from other taxa.
- As you go up the hierarchy organisms show much differences and few similarities. With that they evolved earlier from their ancestors.
- Down the hierarchy organisms show many similarities which these they show to have evolved recently from their ancestors
- As one descend along the hierarchy of ranks the size of the group decreases and vice versa

**Taxonomic categories**

- **The kingdom**

  This is the highest taxonomic category. it includes all organism that share a set of distinguishing common characters.

- **The phylum / Division**

The term phylum is used for animals and division for plants.

The phylum consists of closely related classes. A phylum can have one or more classes.

- **Class**

  Class is a group of closely related orders. For example class dicotyledonae of flowering plants include all dicots which are grouped into several orders such as Rosales, passiflorales, pelmoniales e.t.c.

- **order**

  Consists of a group of closely related family.

- **Family**

  Family is a group of closely related genus

- **Genus**

  Genus is a group of closely related species

- **Species**

  Specie is the lowest rank of classification or A species refers to a group of organisms which are similar and can freely interbreed to produce fertile offspring this means that the species is reproductively isolated from other species.

  **Fertile**– means capable of having offspring i.e. members of the same species can, if left alone in their natural environment, mate with one another to produce offspring which in turn, are also able to produce offspring.

  **Exception of the species definition.**

  If a male tiger mate with female lion production an offspring which is fertile (can reproduce)

- male lion and female tiger produce offspring (the liger )which is infertile
- male donkey and female horse produce infertile offspring (the mule)
- male horse and female donkey produce offspring the (hinny) infertile

**Example of taxonomic hierarchy**

**1. Domestic cat**

| | | |
|---|---|---|
| Kingdom | – | Animalia |
| Phylum | - | chordata |
| Class | - | mammalia |
| Order | - | carnvera |
| Family | – | Felidae |
| Genus | – | Felis |
| Species | – | Felis gatus |

**Human**

| | | |
|---|---|---|
| Kingdom | - | Animalia |
| Phylum | – | chordata |
| Class | - | mammalia |
| Order | – | primate |
| Family | – | Homonidae |
| Genus | – | Homo |
| Species | – | Homo sapiens |

**Mango**

| | | |
|---|---|---|
| Kingdom | - | plantae |
| Division | - | Angiospermaphyta |
| Class | - | Dicotyledoneae |
| Order | - | Sapindales |

- Family - Anacardiaciae
-

| | | |
|---|---|---|
| Genus | - | mangifera |

Species - Mangifera indica

**EXERCISE**

Illustrate the concept of taxonomic hierarchy for the following organisms.

Dog, maize, earth worm and Honey bee.

**TYPES OF CLASSIFICATION/CLASSIFICATION SYSTEM.**

There are two different types of classifications which have been proposed so far by different taxonomic

These are as follows:

- Artificial system of classification
- Natural system of classification

**1.Artificial system of classification**

- This system of classification / method of classifying organisms was based on one or two (few) superficial similarities or based on mere easy features of identification

Or

The system which was based on simple arbitrary chosen criterion instead of an evolution of totality of character.

For example Aristotle (384 – 322; BC) a Greek Biologist produced the first classified animals by looking the way they move e.g. bats, insects and birds were grouped together based on their ability to fly.

He classified plants based on the appearance and size e.g. he grouped plants into herbs, shrubs and trees.

Other criteria could be used for example utility where we have edible and non edible plants, medicinal and non medicinal plants etc.

An artificial system of classification is based on mere easy features of identification.

- **Advantages / Merits**

1. It is useful for quick reference and identification of organisms
2. Identification requires few characteristics which are not difficult to study and apply.
3. Organisms which are poorly known can be filled in the system very easily
4. It is a time saving since it is quick and easy to prepare.
5. It is very stable, does not subjected to changes.

**Disadvantages / Demerits**

1. The system did not reflect any natural relationship existing among the organisms
2. The system limit amount of information about members i.e. it rigid
3. It did not consider many important characteristics and could not explain the evolution significance
4. The system put unrelated organisms under one heading
5. It cannot not add any information about an organism.

**2. Natural system of classification**

- This is the system of classification based on characters of similarities which indicate natural relationship. The basis of a natural classification is similarities
- The system of classification based on the real nature of organism (s)
- In this system more numbers of characters rather than single character are used for determining similarities.For example phylogenetic and phenetic.

**Phylogenetic system of classification.**

This system of classification is based on evolution and generic relationship among organisms. This system enables us to find the ancestors or derivatives of any taxonomy. It reflects the true relationship among organisms. The system was proposed by two Germany botanists Adolf Eagler (1844- 1930) and Karl A.E prantl (1887- 1893)

- Relationship based on the evolutionary aspect of organisms. Darwin's concept; tells on regional relationship among organisms
- If relies on fossils records and is dynamic.
- They vary between zoologists and botanists as zoologists rely on structural aspect while Botanists don't.

**Phenetic classification**

- Type of phylogenetic classification which relies on similar and dissimilar features present in today's organism without including evolutionary and other reflected aspects.
- Cladistics.

The system is based on similarities of form known as phonetic. Phonetic system of classification emphasizes overall similarity. Phenetic reflect evolutionary relationship.

The character taken for identifying similarities are homologous not analogous structures.

**Homologous structure** – these are structural or biochemical features which are shared between organisms by virtue of common ancestry e.g. backbone, pentadyctyl limb plan of mammals, birds and reptiles.

**Analogous structure-** structural features which have the same function but basically different in structure e.g. wings of bats, birds and insects.

**Features studied in natural classification**

1. Various features of the organisms like external form (morphology ), internal structure (anatomy), cell structure (cytology) life process (physiology), biochemistry e.t.c
2. Homologous organs.

iii) Molecular similarities ( DNA, RNA and comparative proteins).

**Advantages of natural system of classification**

1. Closed related species are placed in the same group and hence reflect the evolutionary relationship
2. Many characteristics are considered in classifying organisms by so doing it is more accurate than artificial classification

- Like artificial system of classification, it is useful for reference identification of organisms.
- It is flexible hence can easily accommodate newly discovered organisms.
- It is based on biological important similarities of organisms.
- it offer information (knowledge ) about organisms
- The system brings out natural relationships among organisms.

**Disadvantages of natural system**

- It is time consuming since it takes more time and much effort also many attribute are taken into consideration.
- It is difficult as too much information is needed to group organisms.
- the system is not stable since it is liable to change with time increase of knowledge of living organisms
- Poorly known organisms are not easy to classify.
- It always need a skilled personnel hence it is expensive since identification use scientification and use of scientific instruments.

**The phylogenetic system of classification.**

This system of classification is based on evolution and genetic relationship among organisms.

This system enables us to find out the ancestors or derivatives of any taxon. It reflects the true relationship among the organism.

The system was first proposed by two German botanists Adolf Eagler (1844 – 1930) and Karl A. E prantl (1887 – 1893)

**Problems encountered in classifying living organisms**

1. The process is time consuming hence tiresome work

2. Some organisms may show living and non living properties hence difficult to place them in any group e.g. viruses

3. The process always need skilled personnel and instrument to place living organisms to their correct group therefore it is very expensive.

4. Sometimes evolutional information about an organism can be missing hence difficult to classify.

5. Classification is subject to change.

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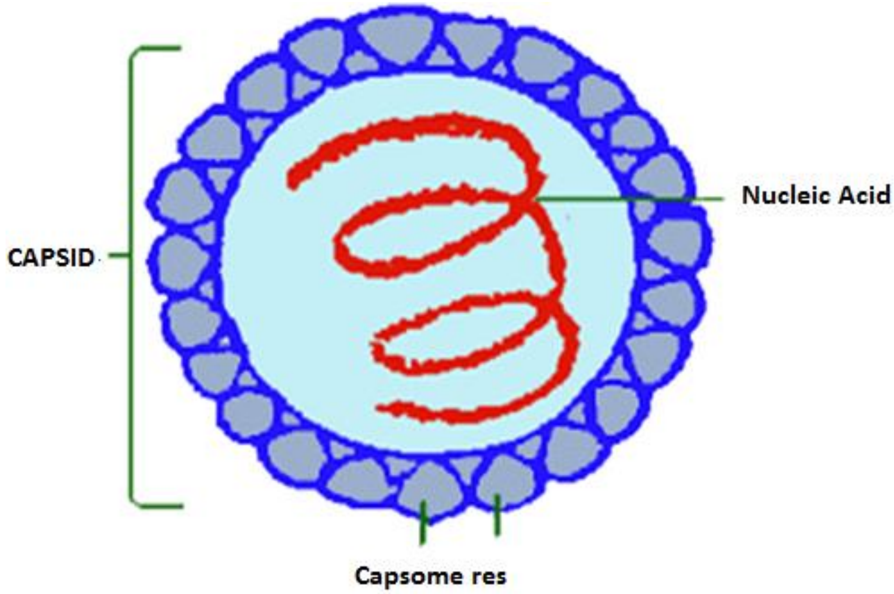
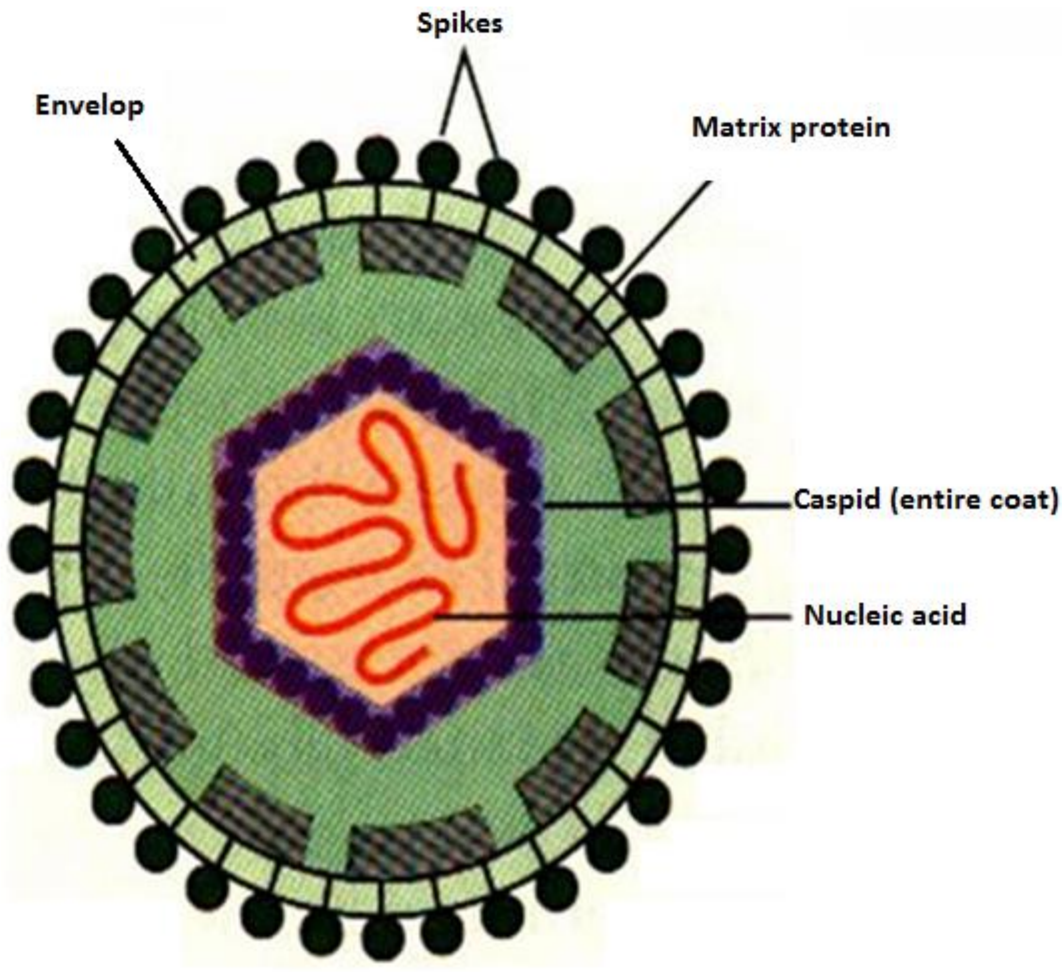
# COMPARATIVE STUDIES OF NATURAL GROUPS

***Viruses:*** -are simple structures with genetic material in the centre and surrounded by capsomere.

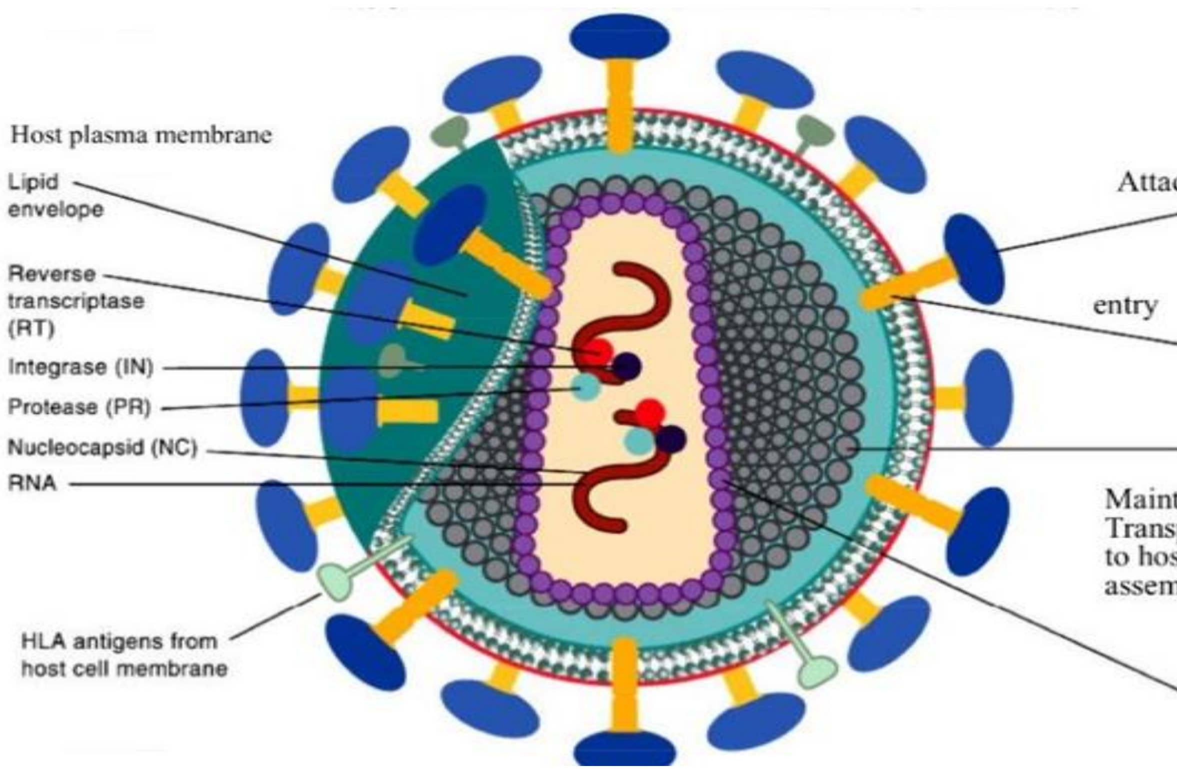
- Are obligate or compulsory parasites as they can only carry out metabolic activities inside organisms.
- Parasites are any organisms living in or on another organism deriving nutrients from the host and depending on the host for its life processes and retain only a few of them such as reproduction.
- Viruses are a cellular nucleic particles coated with a protein coat.

**Generalized section of a capsomere – processing virus.**




Envelope virus




- **STRUCTURE**

  They have very simple structure consisting of the following.

- CORE**:** the genetic material rather DNA or RNA maybe single structure or dabble stranded.
- CAPSID**:** a protective coat of protein surrounding the core
- **NUCLEOCAPSID:** the combined structure formed by the core and capsid.
- **ENVELOPE:** a few viruses such as HIV and influenza have an addition lipoprotein layer as around the capsid derived from the cell surface membrane of the host cell
- **CAPSOMERES:** capsids are often built up of identical repeating subunits called **capsomeres**.

**CHARACTERISTICS**.

1. They posses both living and non living characteristics therefore they are a border line case between living and non living.
2. Viruses are very small organisms ranging in size from 20-300nm. They cannot be seen by the light microscope and on the average they are about 50 times smaller than bacteria indicating that they pass though fitter which retain bacteria.
3. They are cellular i.e. they consist of nucleic acid either DNA or RNA surrounded by a protein coat called capsid. These fragments of genetic material are neither nucleus nor

cytoplasm it is only the DNA or RNA which form the central core. The fully assembled infected particle is called vision.

4. Viruses are obligate parasites / endo parasites and can only reproduce inside the living host.
5. They are highly specific to the host, sometimes to the host tissue, and to the cell. Virus will recognize and infect only a certain type of cells.
6. Viruses do not have a mechanism for producing energy for themselves and therefore all the enzymes for protein synthesis and the ribosome come from the host cells.
7. Viruses can be crystallized i.e. they show no life process when outside the cell; however the crystals retain the effective capacity as if they are in appropriate hosts.
8. Viruses rely on passive dispersal or a vector to move them from one host to another because they don't have any locomotive structures.
9. Viruses are metabolically / biologically inert. They cannot carry out any life process such as respiration, reproduction / protein synthesis
10. They either contain DNA or RNA but not both.
11. Viruses have to symmetries either helical or isometric.
12. Virus are classified as either

i) DNA viruses

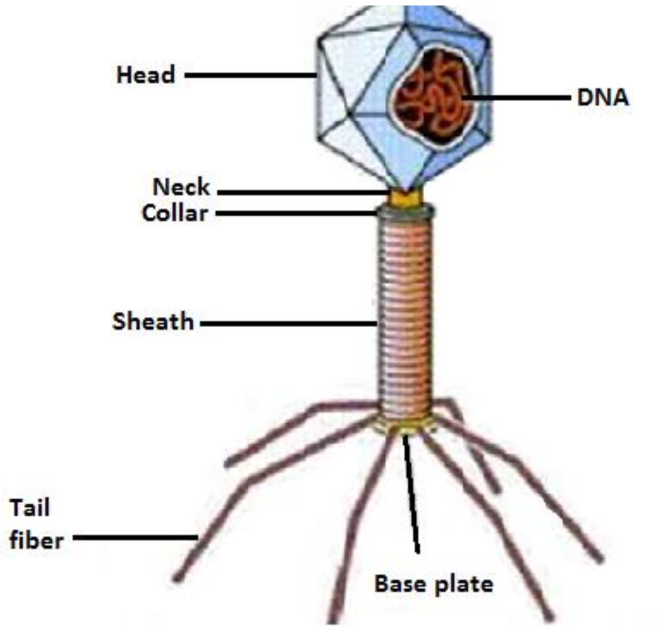
ii) RNA viruses (In core)

OR

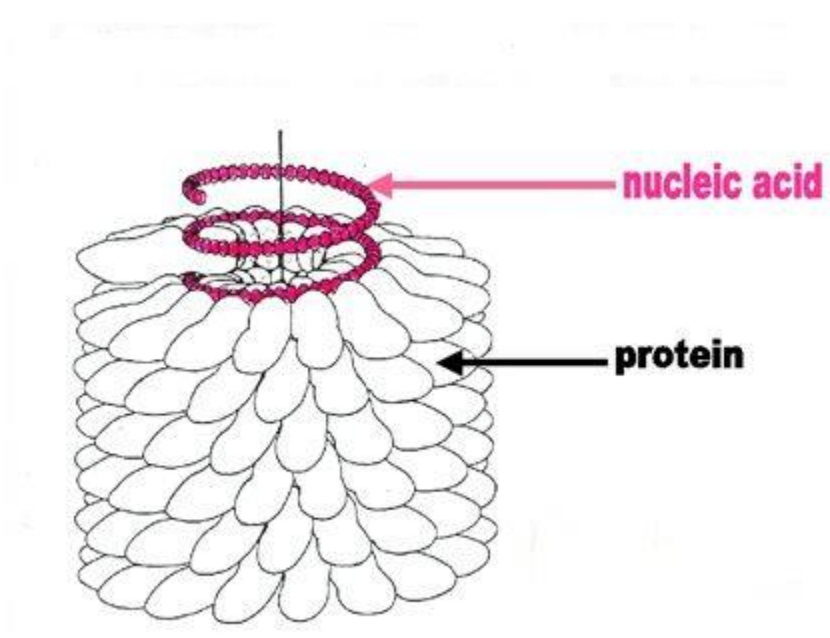
Can be classified according to the host e.g. bacteriophage only infect bacteria and animal virus only infect animals.

*Most of animal viruses are DNA viruses and plants viruses are RNA viruses.

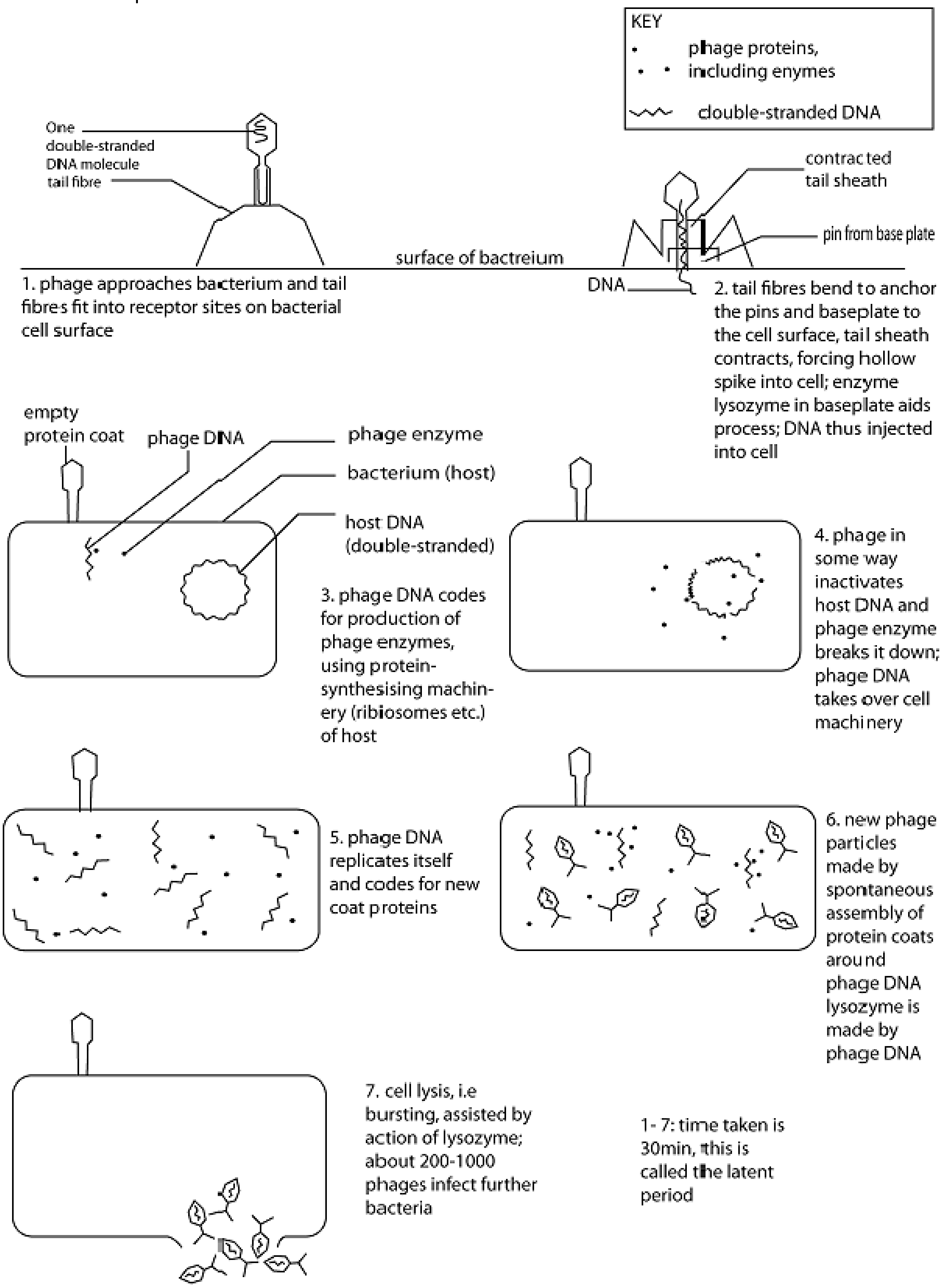
**STRUCTURE OF TO BACTERIOPHAGE**




**STRUCTURE OF A TOBACCO MOSAIC VIRUS**



Events of viral replication.



**Problem of classifying viruses**

- They are very simple in structure being compared of nuclei acid (DNA or RNA) and protein
- They seem to be more related to their host one another
- They usually undergo mutation.
- They are a border line case i.e. they posses both living and non living characteristics.

| LIVING CHARACTERISTICS | NON LIVING CHARACTERISTIC |
|---|---|
| - Have DNA or RNA but not both with exception of Retro virus.<br><br>- Viruses are capable of carrying out life processes while inside the organism or host e.g. they can replicate / reproduce, can mutate, protein synthesis.<br><br>- Viruses are highly specific to host organ and sometimes to the cells of a tissue i.e. they are capable of identifying their host cells and attack them and exercise metabolic control of the host nucleus influencing the cell mechanism.<br><br>- They can mutate (sudden change their DNA)<br><br>- Capable of entering and infecting hosts. | - They are a cellular i.e. they have no cell organelle cytoplasm and nucleus.<br><br>- They are not capable of carrying out life processes outside the organism e.g. Reproduction ATP generation.<br><br>- They can be crystallized and therefore can withstand extreme conditions e.g. very high temperature or very low temperature. |

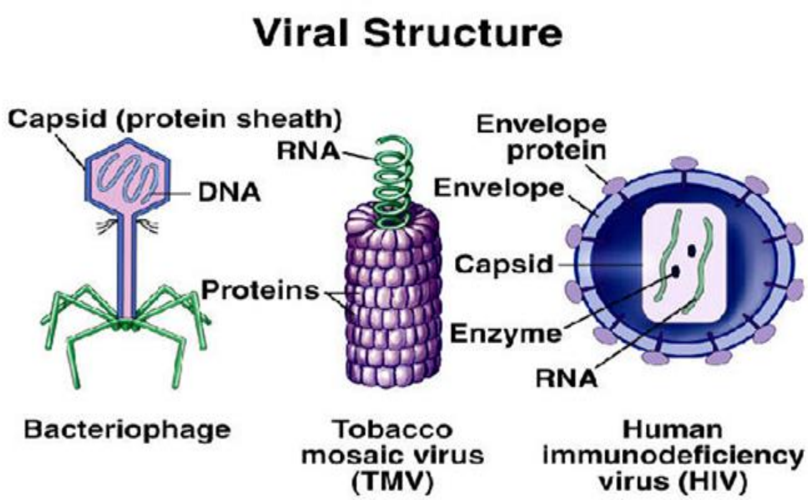
**ECONOMIC IMPORTANCES OF VIRUSES**

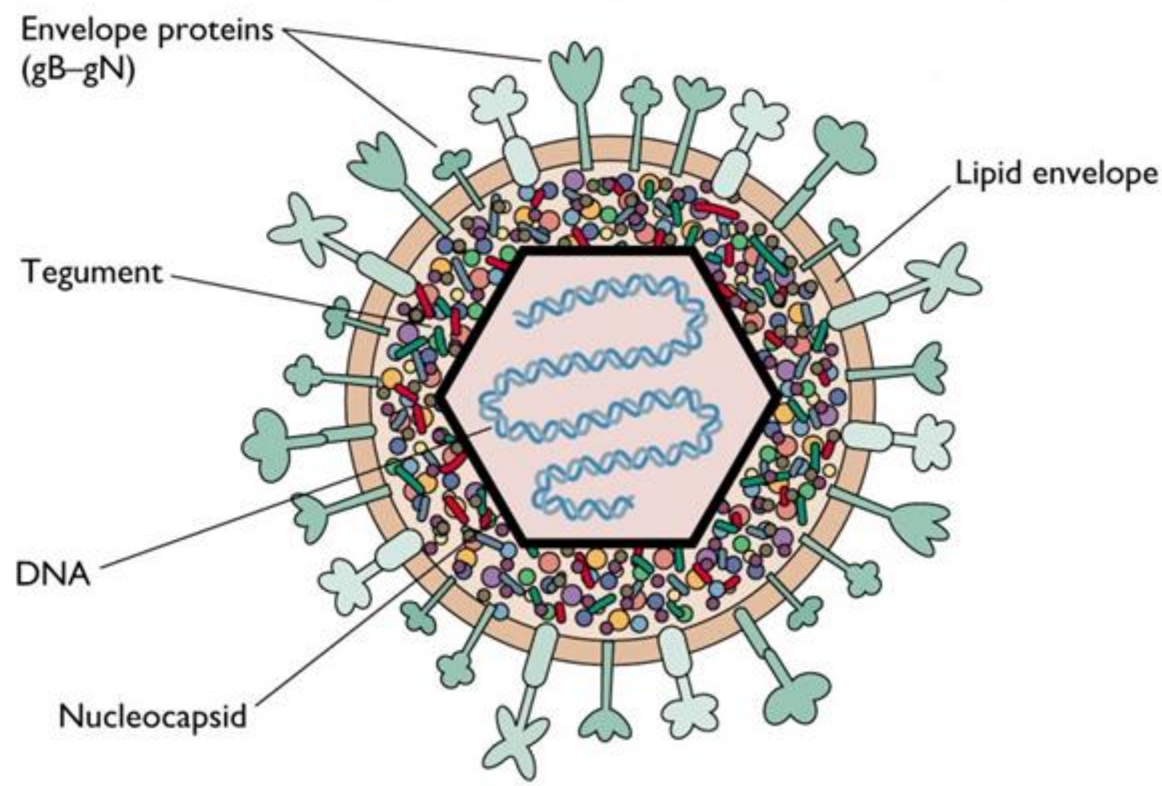
**Demerits of viruses**

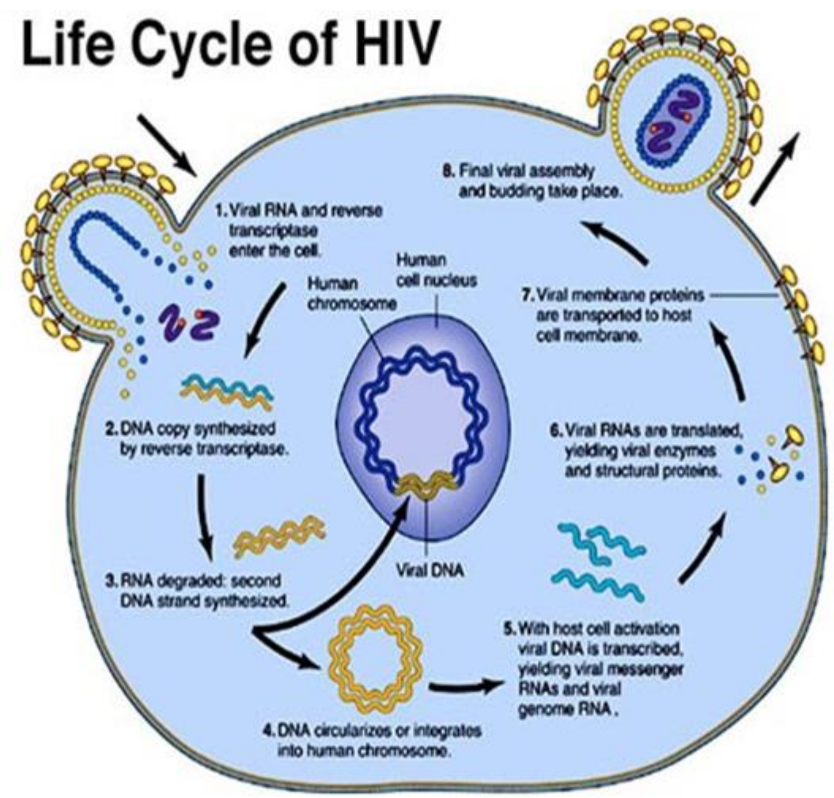
- Causes diseases to animals. Man incurs a great loss due to reproduction or death of animals e.g. foot and mouth disease in cattle, Rift valley in cattle new castle in poultry.
- Causes diseasesto plants leading to great losses for example maize strake, cassava mosaic, tobacco mosaic
- Cause disease to humans leading to depopulation and loss of man power eg HIV causes AIDS.
- Increases cost of living when you consider the cost of prevention or treatment of viral diseases.

**Merits of viruses**

- Used in research purposes this leads to development of drugs and research of the behavior or characteristics of other organisms.
- Useful in biological control of other pests like harmful which attack plants and animals.
- Some are used in developing vaccines which are useful in preventing diseases e.g. polio, measles.




Envelope proteins
(gB–gN)
Lipid envelope
Tegument
DNA
Nucleocapsid




- **LIFE CYCLE OF RETROVIRUS HIV**
- AIDS is caused by HIV or Human immunodeficiency viruses. If belongs to a group RNA viruses known a retroviruses.
- This name comes from the fact that these viruses can convert their RNA back into a DNA copy using an enzyme known as reverse transcriptase. Normally a section of DNA (gene) is copied to make RNA a process called transcription.
- Making DNA from RNA is therefore reverse transcription and the enzyme is called reverse transcriptase (this enzyme has proved extremely useful in genetic engineering )

**KINGDOM**

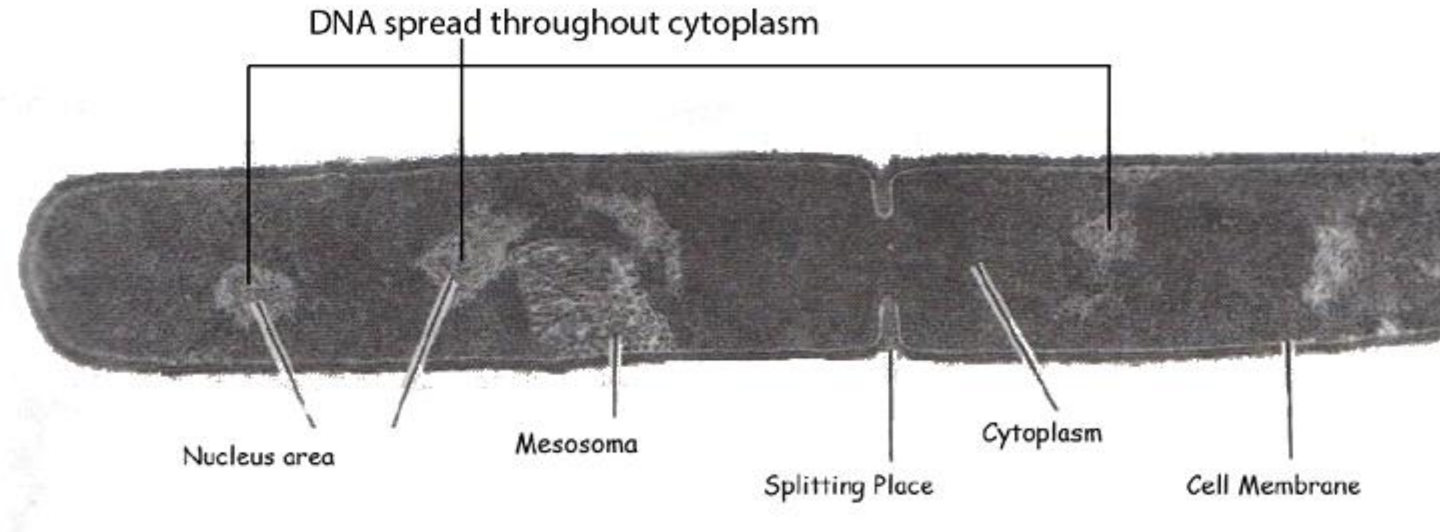
**PROKARYOTAE / MONERA**

**CHARACTERISTICS FEATURES.**

- They are unicellular, prokaryotic and microscopic organisms (can only be seen with a microscope).
- Their cell wall is made up of murein (proteins and polysaccharides)
- The genetic material i.e. circular DNA is not enclosed by nuclear membrane and lies freely in cytoplasm (Nucleoid) and therefore they are not true cells. They also do not have membrane bound organelles
- Their ribosome's are 70's and smaller in size.

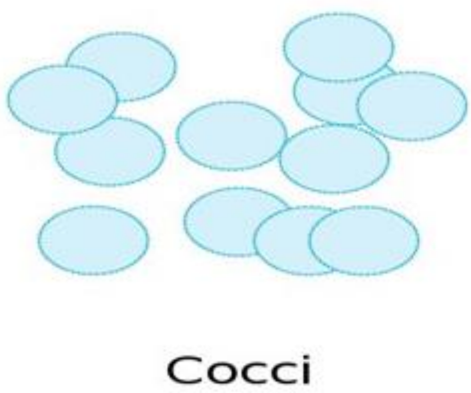
- There is no spindle formation during cell division and therefore reproduce mainly a sexually by binary fission and in some few species they reproduce by conjugation through Pilli.
- Some have ability to fix the atmospheric nitrogen to nitrides and nitrates which are then used by plants.
- Some can form spores in aqueous conditions and thus can survive extreme temperature and drought.
- They have mesosomes for respiration and associated with DNA which helps in cell division and helps in formation of new cells.

**Generalized Structure of Bacterium**



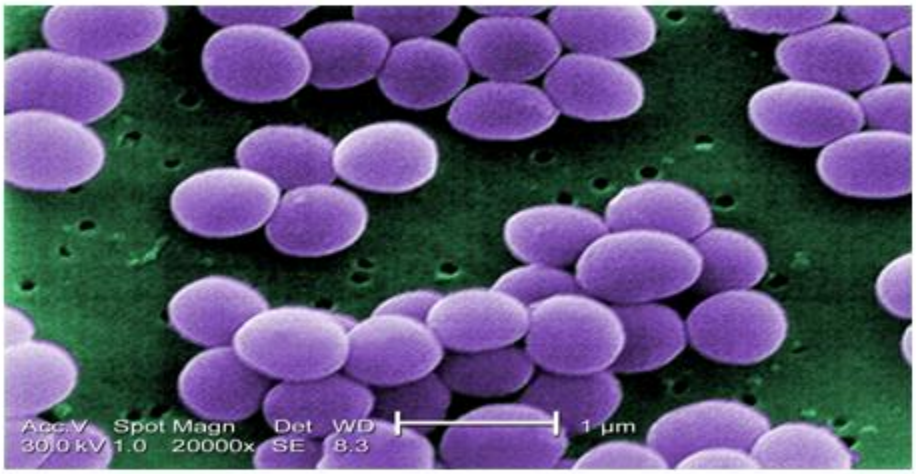

CLASSIFICATION OF BACTERIA ON BASIS OF MORPHOLOGY (SHAPE)

**1. COCCI (singular coccus)-they are spherical in shape**



**Staphylococci (like a bunch of grapes.)**

E.g. Staphylococcus aureus lives in nasal passages: different stains cause boils pneumonia food poisoning and other diseases.



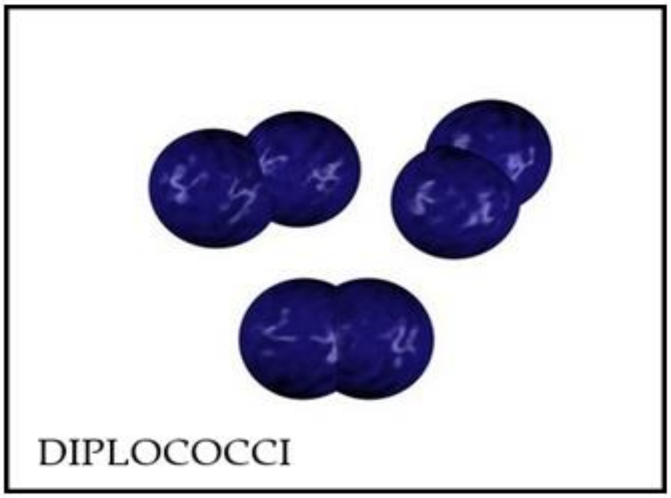

- E.g. Staphylococcus aureus lives in nasal passages: different stains cause boils pneumonia food poisoning and other diseases.

**Streptococci (chains)**

e.g. many streptococcus spp; same infect upper respiratory tract and cause disease e.g. s. pyogenes causes scarlet fever and sore throats; s. thermophilus gives yoghurt its creamy flavour ; s.lactis.

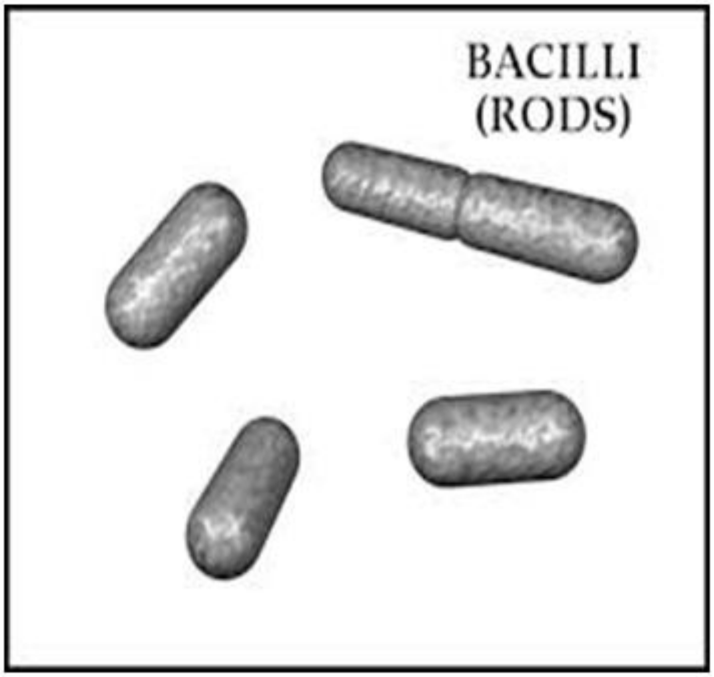
**Diplococci (pairs)**

The pneumococci (diplococcus pneumonia) are the only capsule members causing pneumonia.




**2. BACILLI (sing bacillus) rod shaped**.

**Single rods** e.g. Escherichia coli, common gut-living symbiont; lactobacillus, salmonella typhi causes typhoid fever.




**Rods in chains**

E.g. Azotobacter, a nitrogen fixing bacteria; bacillus anthracis cause anthrax.

- **bacilli with endospores (showing) various positions, shapes and sizes of spores)**

  Oval spore central not swollen e.g. bacillus anthracis, causes anthrax.

  Terminal swollen e.g. clostridium tetani, causes tetanus.

  Sub terminal swollen e.g. clostridium botulinum (spores may also be central) causes botulism.

**3. SPIRILLA (sing spirillum) spiral – shaped.**

Helical rod with single flagellum e.g. spirillum

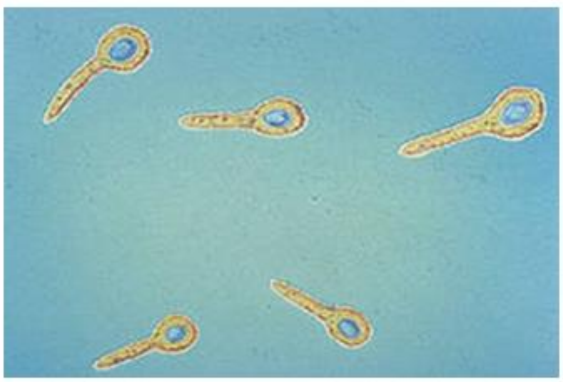
**NB;** body of spirochetes is similar in form but locomotion differs e.g. Treponema pallidum causes syphilis.

**4. VIBRIOS comma – shaped**

E.g. vibrio cholerae causes cholera, single flagellum.

**CLASSIFICATION OF BACTERIA ON BASIS OF STAINING PROPERTIES.**

Terminal swollen e.g. clostridium tetani. causes tetanus.



Sub terminal swollen e.g. clostridium botulinum (spores may also be central) causes botulism.

- Bacteria differ from each other in the nature of their cell walls. There are two types: gram positive and Gram negative and this is so basing on the staining properties.
- Gram positive have thick walls and murein is filled with polysaccharide and protein. They are most susceptible to antibiotics and lysozyme than gram negative ones.
- Lysozyme digest the polysaccharide of murein and puncture it causing osmotic sucking and bursting (anti – bacterial enzyme)
- Examples of gram positive bacteria are Lactobacillus.
- Gram negative bacteria have a rather thin cell wall and the murein is located on the outside with a thin, smooth, membrane like layer of lipids and polysaccharides.
- The layer protects them from lysozyme and the most of them are not very susceptible to antibiotics. Examples of gram negative bacteria are Escherichia coli.

**REPRODUCTION IN BACTERIA**

Bacteria reproduce asexually by binary fission, which is by division into two identical daughter cells. The cell division is there by replication of DNA and while this is being copied it may be attached to the new cross wall between the daughter cells wall material. The generation time for bacteria is very fast which may be on the average of 20 minutes.

## ECONOMIC IMPORTANCE OF BACTERIA

### Beneficial effects of Bacteria

- Bacteria are used in biotechnology.
- Biotechnology is the application of organisms biological system /biological processes to the manufacturing and servicing industries for benefit of humans.
- They are used in manufacturing processes e.g. leather; retting flex to make linen and making soap powder.
- They are source of antibiotics e.g. streptomycin from genus streptomyces, Gramicidin from bacillus breves'.
- They are used in food production e.g. manufacturing of yoghurt, cheese, vinegar, coffee and tea.
- Cheddar cheese is produced from lactobacillus species. Yoghurt is produced from streptococcus thermophilus.
- They are used in production of single cell protein (SCP) e.g. pruteen is used in animal feeds.

**Biological processes**

- They are used in sewage treatment most of them are saprophytic bacteria.
- They cause breakdown of plant and animal remains therefore they are decomposers thus bring about recycling of essential nutrients such as carbon, nitrogen, phosphorus and sculpture E.g. Azotobacter, Rhizobium.
- They are used in nutrient and biogeochemical cycle e.g. Nitrogen fixation. They are the only organisms which can fix nitrogen e.g. nitrosomonas and Nitrobacter.
- Their form symbiotic relationships with other orgasms e.g. cellulose digesting bacteria in the gut of herbivores.
- Are used in biological research and genetic engineering and this is important in development of vaccines and in synthesis of growth hormones e.g. somatotrophin to treat dwarfism production of insulin to treat diabetes.
- They are used in biological control of pests e.g. caterpillar.
- They can be used as biological weapons e.g. anthrax.

**Harmful effects of bacteria.**

- Bacteria are pathogens. Some are extra-cellular parasites while others are intra-cellular. Symptoms of the disease are often caused by the toxins they produce. Some infect plant e.g. Agro bacterium fumefaciens causing crown galls, fruit trees and erwinia amylovorum causing fire blight of apples and pears.

- Others infect animals and humans i.e. cholera caused by vibrio Cholerae, typhoid by salmonella typhi, tetanus caused by clostridium tetani.
- They cause decay of vegetables, food crops; fruits making storage are very expensive.
- The denitrifying bacterium (Thiobacillus) reduces soil fertility by converting nitrates and nitrides to atmospheric nitrogen which cannot be utilized by plants.

**KINGDOM PROTOCTISTA.**

-They are unicellular, eukaryotes and microscopic (a few)

-Their classification is based on the locomotary organ is present, and then the organ/organelle is used to classify the organism into smaller groups. E.g. flagella under the phylum flagellate pseudopodia under the phylum rhizopoda.

-They have different modes of nutrition some are photosynthetic i.e. algae, some are lutentrophic e.g. amoeba, and some are parasitic e.g. phylum oomycota phytophtera infestans.

-They can inhibit different environmental conditions e.g. some are terrestrial like slime moulds and oomyocta while some are aquatic e.g. algae (fresh water and marine).

-They form a link between eukaryotes and prokaryotes e.g. mitochondria and chloroplast contain DNA resembling that of prokaryotes.

**PHYLUM RHIZOPODA**.

E.g. Amoeba proteus, Entamoeba histolytica.

**Distinctive features.**

-Unicellular eukaryotes.

-The locomotary organelle is the pseudopodia.

**General features.**

-They exhibit both sexual reproduction by conjugation and asexual reproduction by binary fission and multiple fission speculation.

-Some secret slime coats, tests, shells, other posses no specific outer covering.

**Structure of entamoeba histolytica.**

- They have a defined /conspicuous cytoplasm – plasma gel in the plasmasol.
- Stored in cytoplasm are food vacuoles.

- There is an elaborate spherical nucleus with chromatin blocks and karysome this referring to the nature, the number, the type of chromosomes .chromatins are the chromosome in the stages of development.
- They exist in two body forms i.e. small and large. By some mechanism not known, the smaller form transforms into the larger form, which are similar in structure.
- The locomotary organelle is a single pseudopodium.
- The outer covering is all bound by a single plasma membrane/ cell membrane.
- Food vacuole of smaller one contains bacteria at different stages of digestion.
- The food vacuole of larger one contains the digested gut epithelial cells of red blood cells at different stages of digestion.

**Diagram of entamoeba histolytica (See chandy's Biology for class XI page 198 fig 5.6)**

**Adaptations of Entamoeba to its mode of life.**

-The adaptations can be divided into three major parts,

1) Structural adaptation.

2) Physiological adaptation/modification.

3) Reproductive adaptation.

**Structural adaptation.**

- There is only one pseudopodium since it does not need to move from place to place as the free living amoeba as it has most of the requirements in its environment.
- There is no contractile vacuole indicating that cytoplasmic contents of entamoeba are isotonic to the most environments.
- Isotonic-having a concentration such that it neither gains no loses water by osmosis.

**Physiology Adaptation**

- They can vary/change the diet from bacteria to animal cells and produce the necessary enzymes for digestion.
- They can live in conditions where oxygen content is very low, however when they puncture a capillary and ingest a red blood cell (as they live on epithelial), they can respire aerobically.
- They require little amount of energy as movement is limited

**Reproductive Adaptation**

- Like all parasites, entamoeba produces a larger number of off springs so that they survive the hazards of the environment as they move from one host to another.
- They reproduce asexually by binary fission and large numbers of cysts are produced each giving rise to 8 daughter amoebulae.
- The cysts are viable under variable environmental conditions and can survive in alternative hosts thus increasing the chance of survival.

  **NB**; Entamoeba histolytic causes amoeba dysentery which is characterized by adnominal pains, nausea, vomiting and fever.

Under severe attacks, ulceration develops and blood is released into the intestine and out of the body through frequent motion which contains blood and mucus.

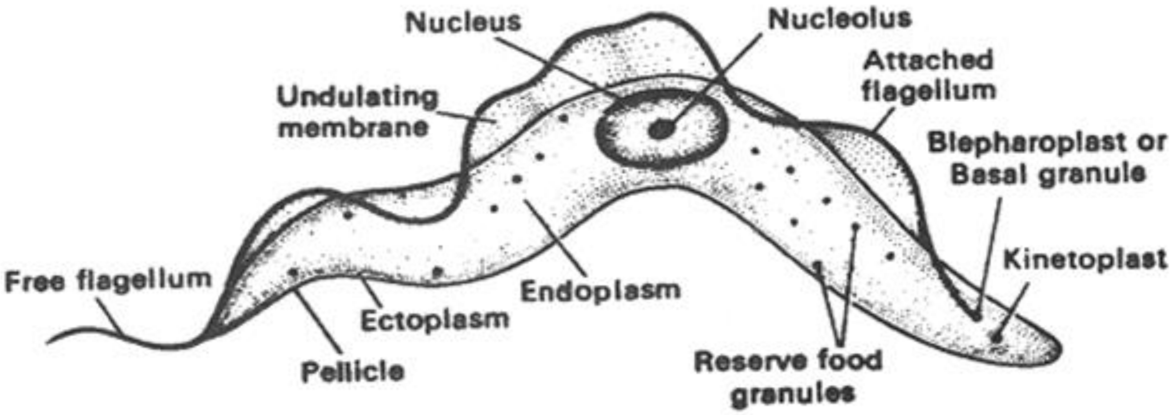
The parasite (i.e. Entamoeba) can affect the kidney, the liver and the brain.

**PHYLUM ZOOMASTIGINA**

E.g. trypanosome

**Characteristics features**

- They posses flagellum at some stages of their life cycle.
- They possess chromatophores (colored pigments)
- They have a definite shape and have pellicle which surrounds the body and maintains the shape.
- They reproduce asexually by binary fission
- They have variety modes of life




Trypanosoma gambiense

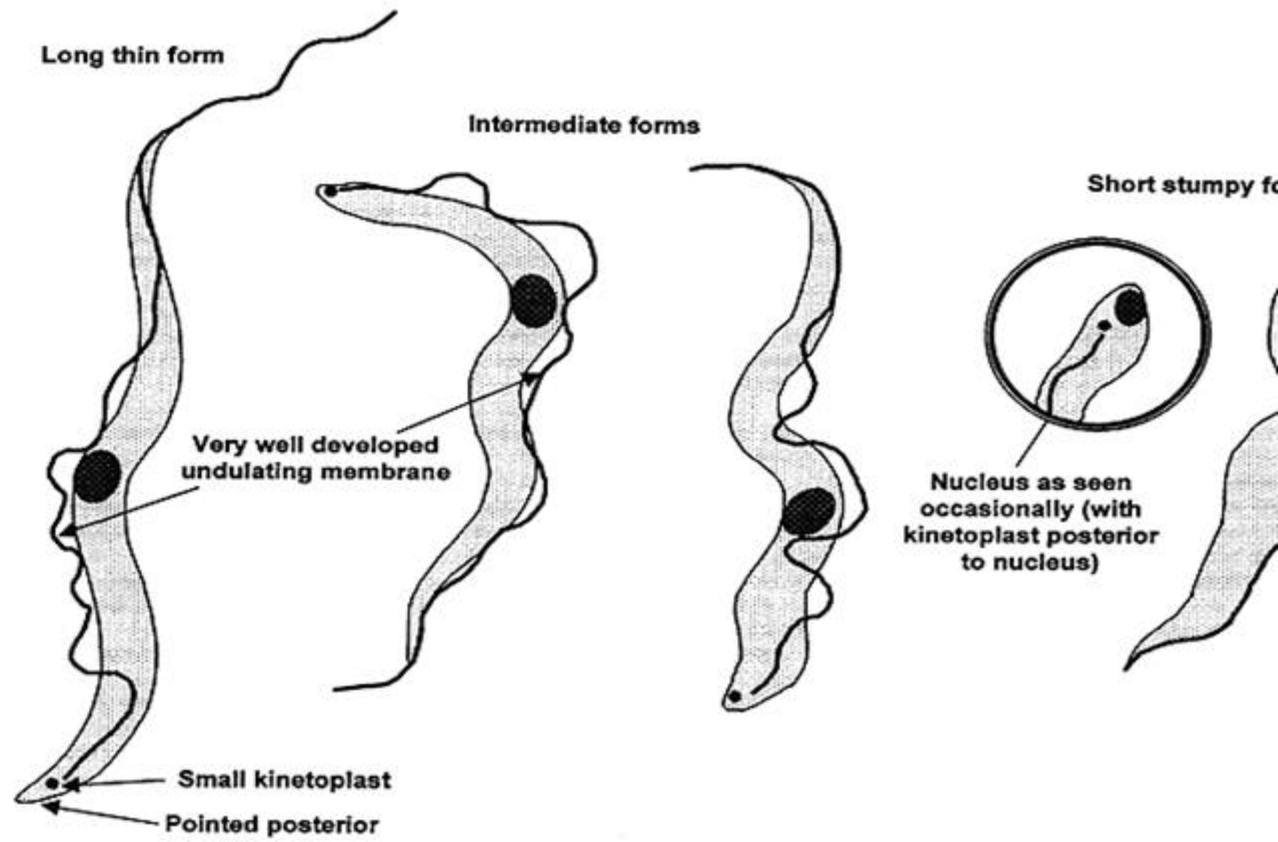



**Diagram of trpanosome**

**Adaptation to parasitic mode of life**

### Structural adaptations.

- They have no contractile vacuole and no gullet as they are living in constant internal environment i.e. the blood.
- The undulating membrane increases surface area to volume ratio for absorption (no gullet). In Some cases it is for locomotion incase of high viscosity.
- Being pointed at both ends, passage through the capillary is easier.
- There are small flagella as they are parasites and locomotion is limited.

### Physiological Adaptation

- The body fluids are isotonic to the blood plasma hence they do not need to regulate their mechanisms.
- Being parasites they require less thus have a few mitochondria for release of energy.
- Large surface area to volume ratio helps in excretion, nutrition and efficient gaseous exchange as all this is through diffusion.

### Reproductive Adaptation

- Binary fission occurs rapidly even under host high resistance mechanism
- The spleen and the lung cells contain the resting forms of the parasite. Leshmenia form of the parasite which can remain alive even when the parasites (slender form) in the general circulation are eliminated.
- The multiplication of the parasites up to infective stage in the tsetse fly serves as a good reservoir/storage.

Diagram of Trypanosome gambiense; slender form

## PHYLUM EUGLENOPHYTA.

**Characteristics**

- They are aquatic i.e. some are fresh water, some are marine and some species live in moist soil. Most members of the phylum have chloroplast and thus carry out autotrophic mode of nutrition though a few members are colorless and live in rectum of frogs.
- All members posses flagella as a locomotory organelle and there for are active swimmers.
- Member of the phylum have pellicle which maintains the shape of the body although they can change their shape as they move about i.e. Euglenoic movement.
- All have myonemes (sort of muscles) which are contractile.
- They store carbohydrate in form of paramylum. Paramylum gives a negative test with iodine.

- They possess vacuoles and gullet.
- They are sensitive to light i.e. they have photoreceptors stigmas.
- They chiefly respire aerobically and a few species living in the rectum of frogs can respire anaerobically.
- Under unfavorable condition they can form cyst which is tough and made of cellulose.

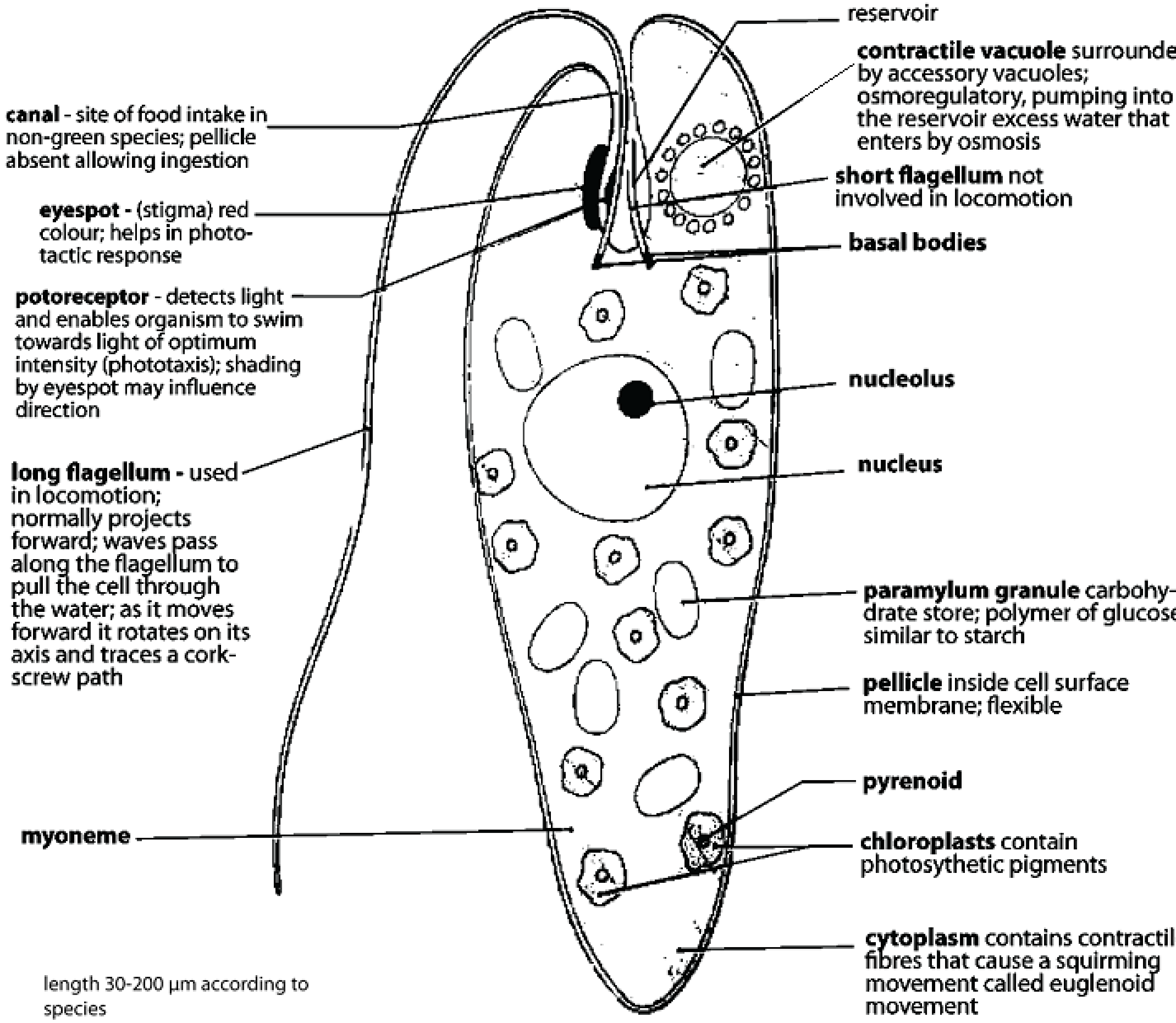
**Characteristics of euglena which makes it a plant.**

- They posses chloroplast with chlorophyll A and B therefore they are autotrophic.
- They have the ability to utilize nitrates and ammonia for nitrogen requirements i.e. use of nitrates to make their proteins.
- Possess paranoids which are the form of stored protein.
- Storage of carbohydrates in form of paramyium.
- Presence of contractile vacuole.

**Characteristics of euglena which makes it an animal.**

1. Presence for pellicles for support in the body.
2. Possess flagella which enable it to move actively (euglenoid movement).
3. They utilize amino acids and polypeptides as source of nitrogen.
4. Ability to form cysts during unfavorable conditions.
5. Possess myonemes which are contractile like muscles.
6. Possess gullets, sphincter.
7. Have a reservoir.
8. Possess eye spot and stigma as photoreceptor organelle.

Diagram of euglena




**Adaptations of euglena to its mode of life.**

- The body shape is elongated and oriented in such a way that allows them to be active swimmers.
- The fresh water species possess contractile vacuole which excrete excess water .The marine species do not have contractile vacuole.
- They possess chloroplast for photosynthesis i.e. autotrophic nutrition. But when the conditions are not favourable e.g. in the absence of light they feed saprophically.

- Possess flagella for locomotion.

**PHYLUM CHLOROPHYTA.**

**Characteristics.**

- They are mostly aquatic i.e. fresh water a few are marine and the other few are terrestrial.
- They contain / possess chlorophyll A and B and thus can photosynthesize (autotrophic nutrition).
- They have cell wall made of cellulose.
- They store carbohydrate in form of starch and posses vacuole.
- They have different body forms and range in size i.e. some are unicellular e.g. Clymadomonas, some are filamentous (spirogyra) and others live in groups.
- They reproduce asexually by fragmentation and sexually by conjugation.
- They are eukaryotes.

Structure of spirogyra.

**Adaptation to mode of life.**

- have chloroplast with chlorophyll A and B and thus can photosynthesize
- posses contractile vacuole for osmoregulation i.e. remove excess water
- Presence of mucilage covering for protection i.e. prevents growth of micro- organisms on the cells such as epiphytes. Epiphytes are plant parasites.
- They can undergo vegetative propagation and therefore have high rate of reproduction.

**PHYLUM OOMYCOTA**

**Characteristics**

- They are facultative parasites growing within plant tissues i.e. within the host; the mycelium is intercellular with the haustoria.
- The body is mycelium i.e. thread like structures with no septor (non septate).
- Have cell wall made of cellulose with deposits of fat substance, peptic materials and impregnated with chitin.
- They reproduce sexually and asexually and under unfavorable conditions conidia forms which develops into mycelium.

**Adaptations to mode of life.**

- Have extensively branching haustoria which penetrates into mesophyll cells or other tissues.
- They produce enzymes i.e. pectinases and cellulases which destroy the host cells.

- They are non septate with thin walls thus easy absorption of food materials into their bodies. (The walls are permeable).
- The sporangium hanging on the long sporangiophore makes it easy for the spores to be spread by water current/wind for other plants. By being on the lower part of the leaf they are easily protected from dehydration.
- They have high reproductive rate i.e. produce many spores asexually and rapidly also when conditions are not favorable they can still undergo asexual reproduction by formation of conidia.
- The spores can remain dormant for a long period (more than one year) thus increases it chances of survivals.
- The zoospores can penetrate through different parts of the plant like stomata in the leaves, lenticels in stem, epidermis or wounds.

Phytophthora infestans growing in a diseased potato leaf with sporangiophores emerging from the underside of the leaf.

**PHYLUM APICOMPLEXA**.

E.g. Plasmodium malariae.

**Characteristics**

- Most of them are obligate parasites and so most of them their life processes are taken up by the host e.g. they have no means of locomotion such as cilia, flagella and no excretory organelle.
- Reproduce asexually by spore formation.
- They have a definite shape maintained by presence of pellicle.

**Class: protozoa**

**Genus: plasmodium**

**Species: P. vivax, P. malariae, P. falciparum.**

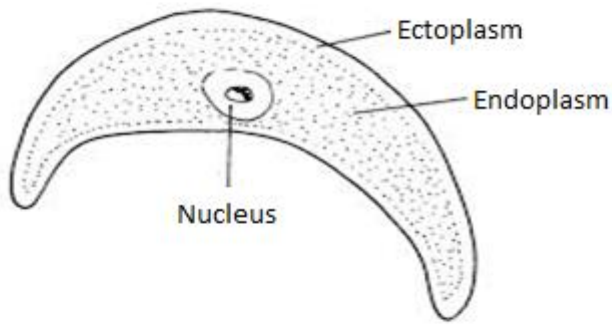
All the species cause malaria (meaning bad air in)

**Structure of plasmodium.**

- They are oval or spindle in shape or can even be called sickle with the small amount of cytoplasm with the nucleus occupying a large area in the center. The body shape is maintained by the presence of pellicle.

N.B; P.falciparum is most dangerous of all species that it attacks the liver.

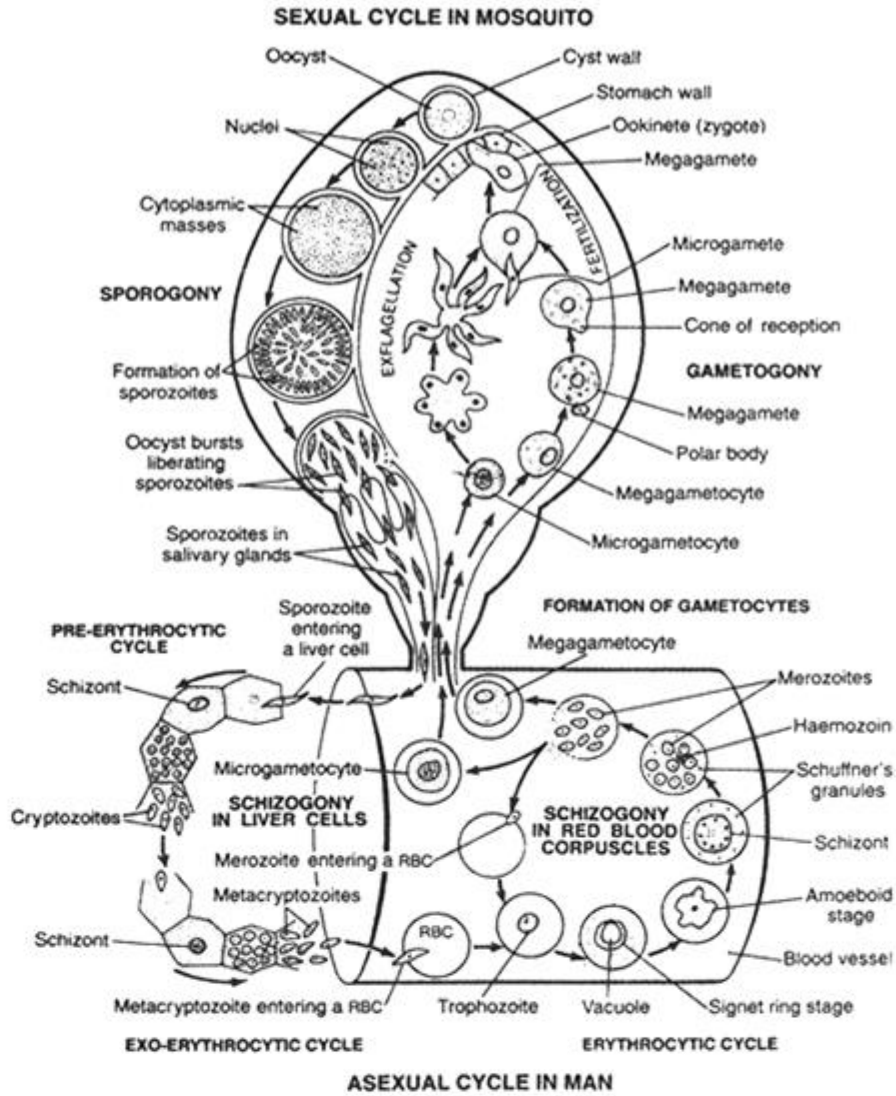
**LIFE CYCLE OF PLASMODIUM.**




- Sickle cell sporozoites 2um long enter the blood stream of man with saliva of female anopheles mosquito when it pierces the skin.
- They remain in the blood stream for an hour and then enter in the liver.
- They feed on liver cells (glucagon and fat) and form meront (schizont)
- They then divide mitotically and repeatedly to form nuclei which are surrounded in cytoplasm to form merozoites / schizozoites.
- Liver cells burst and release the merozoites/schizozoites.
- The merozoites enter the blood, others re-enter the liver cells (pre-erythrocytes cycle) which takes 8-10 days.
- Inside the RBC's the schizozoites feed and grow to become amoeboid in shape.
- A vacuole appears on the central region and pushes the nucleus to the sides forming ring structure (detected in blood when examined under microscope) growth and multiple division form the schizozoites, some excretory granules are formed from cytoplasm of RBC; as it bursts and open the schizozoites and excretory granules/ organelle are released to the plasma some schizozoites re- enter the RBC (erythrocytes cycles).

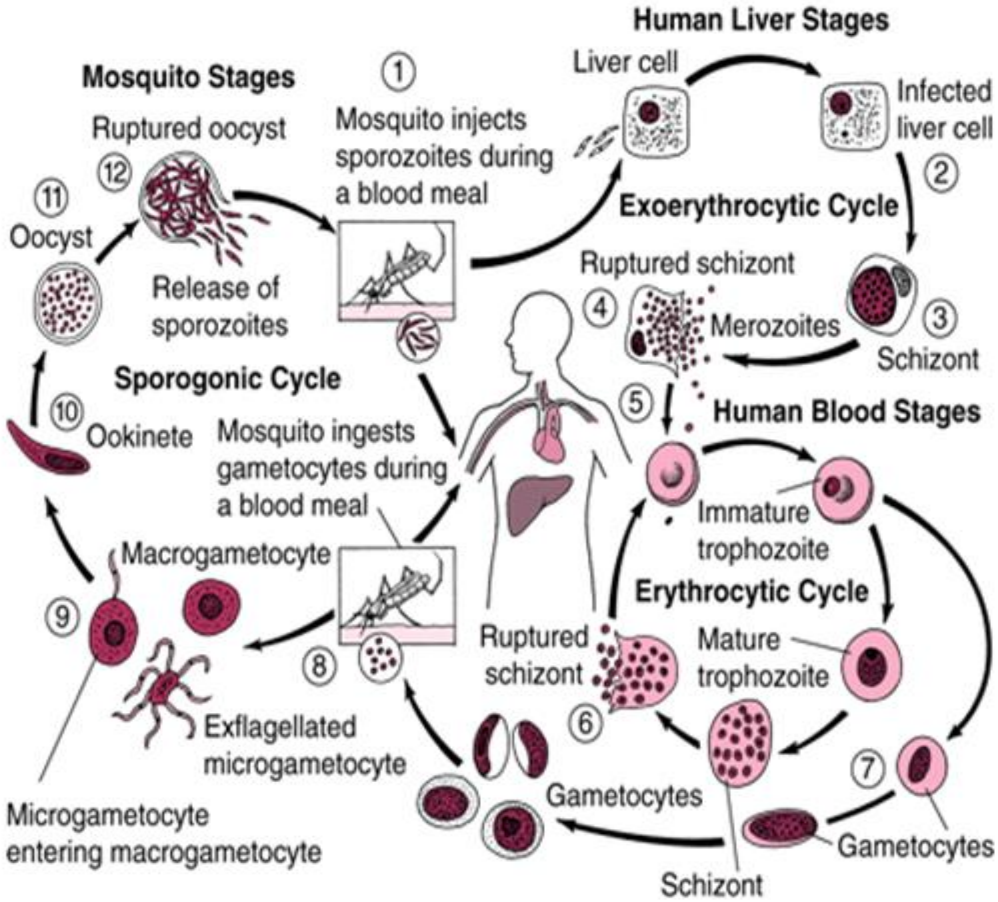
- The toxic effect takes about 48 hours (process) which causes a characteristic malaria fever.
- Some schizozoites stop dividing and grow to form gametocytes.
- Female gametocytes have a small nucleus and cytoplasm is rich in food materials and granulated.
- The male gametocyte has a large nucleus with clear cytoplasm.
- If the gametocytes are ingested by a female anopheles mosquito they develop into male and female gametes which unite and form a zygote (i.e. male gamete penetrates through the female gamete through papillae).
- From the zygote, multi nuclei structures called sporocysts develop which within a few days divide into thousands of tiny spindle shaped cells called sporozoites which migrate to the mosquito's salivary gland.

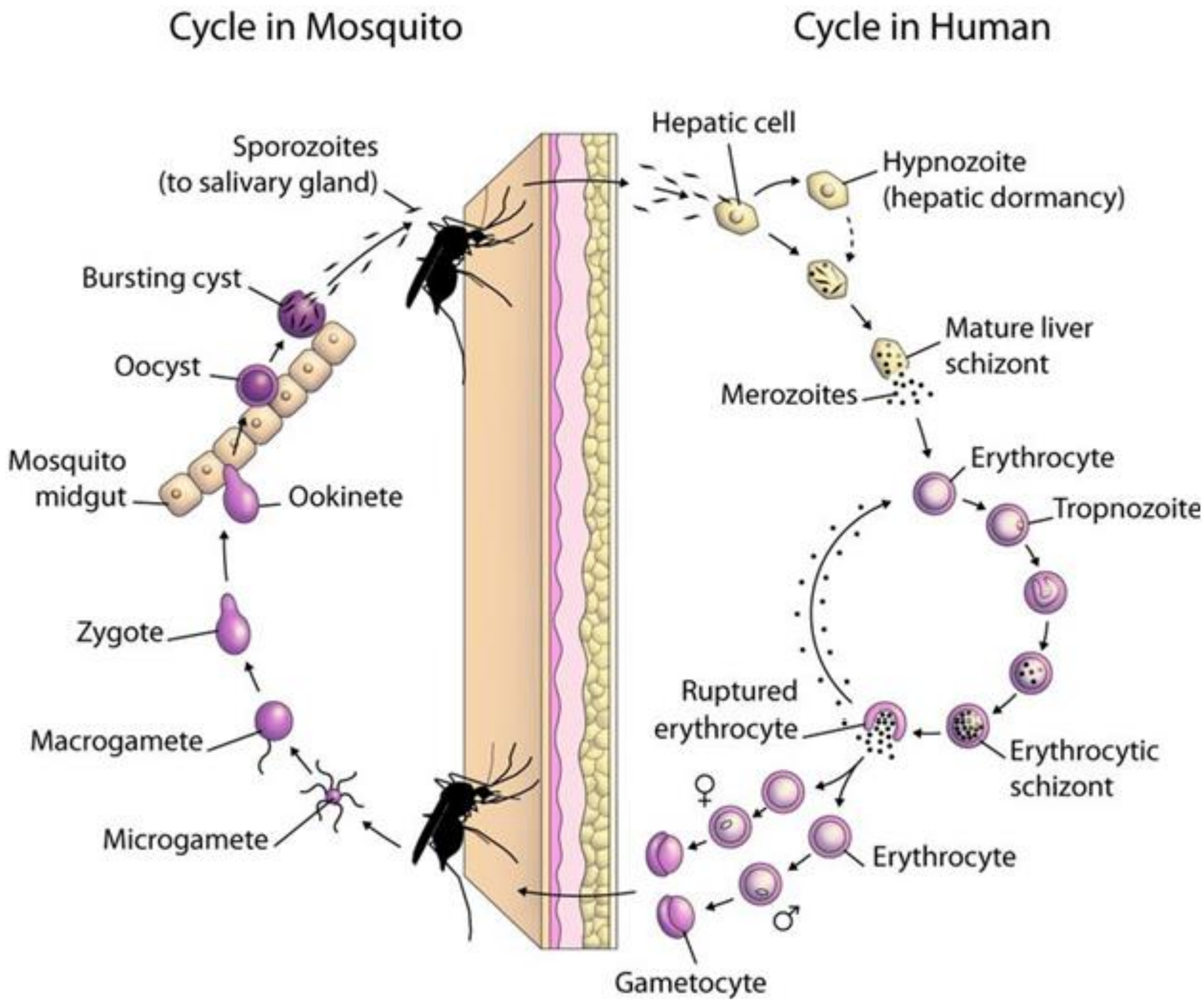
- When the mosquito bites another victim the cycle begins




Life cycle of *Plasmodium vivax*

again.


Human Liver Stages
Liver cell
Infected liver cell
2
Exoerythrocytic Cycle
Mosquito Stages
1
Mosquito injects sporozoites during a blood meal
Ruptured oocyst
12
11
Oocyst
Release of sporozoites
Ruptured schizont
4
Merozoites
3
Schizont
Sporogonic Cycle
10
Ookinete
Mosquito ingests gametocytes during a blood meal
5
Human Blood Stages
Immature trophozoite
Erythrocytic Cycle
Macrogametocyte
9
8
Ruptured schizont
6
Mature trophozoite
Exflagellated microgametocyte
7
Gametocytes
Gametocytes
Microgametocyte entering macrogametocyte
Schizont




**Adaptation to modes of life**

**Structural adaptation**

- Having a spindle/ sickle structure, they can easily penetrate the liver cells and RBC thus making it easier for them to re infect both liver cells and RBC's thus increasing chance of survival.
- The zygote may develop a cyst.

**Physiological adaptation.**

- Have well developed chemo tactic responses which enable it to detect different tissues/organs in the host's body e.g. sporozoites remain in the general circulation for one hour and migrate to the liver.
- In the mosquito's body mature sporozoites reside in the mosquitoes salivary gland
- They are resistant (highly) to hosts (i.e. humans and mosquitoes) anti bodies and toxins and gametocytes are not digested in the salivary gland by mosquitoes.

- The plasmodium is an obligate parasite confined to the hosts thus increases their chances of survival.
- They can live / tolerate low oxygen content as they are parasites they need very little energy because all processes are performed by the host except reproduction.
- They are adjusted to different osmotic conditions in the hosts i.e. mosquito and human beings and thus increase chance of survival.

**Reproductive adaptation**

- They have a high reproductive rate and this increases their chance of survival.

**Effects on the host**

- Plasmodium vivax causes tertian fever, recurring at 3days intervals and is at least with survival.
- Plasmodium malariae causes quartan fever recurring at 4days interval
- Plasmodium falciprum causes maligent quotidian malaria being most lethal with a continuous fever.
- The incubation period is 8 – 10 days. This is when the parasites are in the liver, over 8-10 days malaria fever begins characterized by cold, hot and sweating increases i.e. shivering occurs and the patient feels cold, temperature rises followed by sweating. The patient then shows recovery signs except for some weaknesses. But each fresh attack has an increasing debilitating effect.

## KINGDOM FUNGI

**Distinctive features.**

- Have rigid cell walls made of chitin (polysaccharide rich in nitrogen).
- The body is mycelium with thread like structure (hyphae). The hyphae can be septate or aseptate/coenocytic (no cross walls).the hyphae may be septate and multi nucleiate or uni nucleiate.
- They have heterotrophic mode of nutrition as they lack chloroplast. Some are holozoic e.g. micorhiza, some are saprophytic e.g. moulds/mucor species, some are parasitic like Candida species, epidemophyta (causes athletes foot), microsporum (causes ring worm).
- They store carbohydrate in form of glycogen.
- They have centrioles.
- They reproduce asexually by formation of spores and sexually by forming gametongia.
- They are non- motile/sessile.
- They grow on dead decaying organic matter some grow in terrestrial environment rich in organic matter and some grow in sugar solutions.

**CLASSIFICATION OF FUNGI**

1) Zygomycota e.g. mucor species, rhizopus.

2) Ascomycota e.g. saccharomyces.

3) Basidiomycota e.g. Agaricus.

**PHYLUM ZYGOMYCOTA**

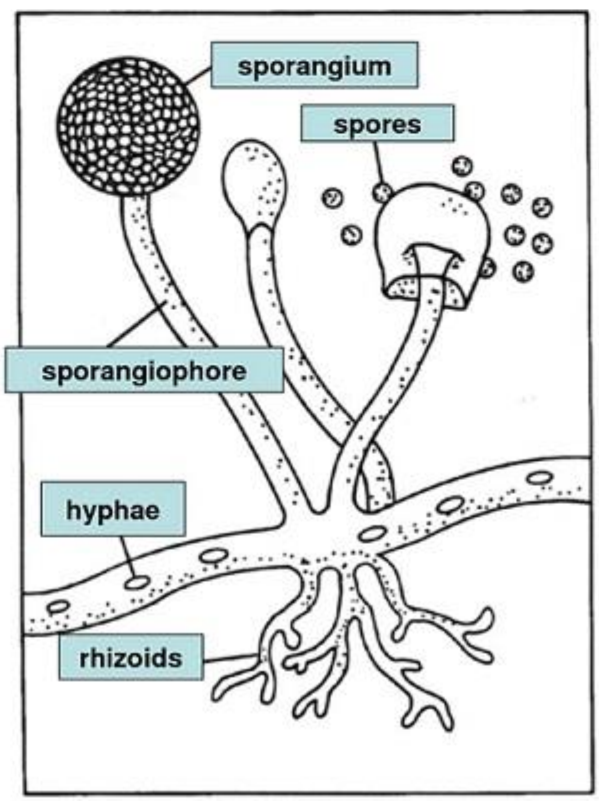
**Mucor species**

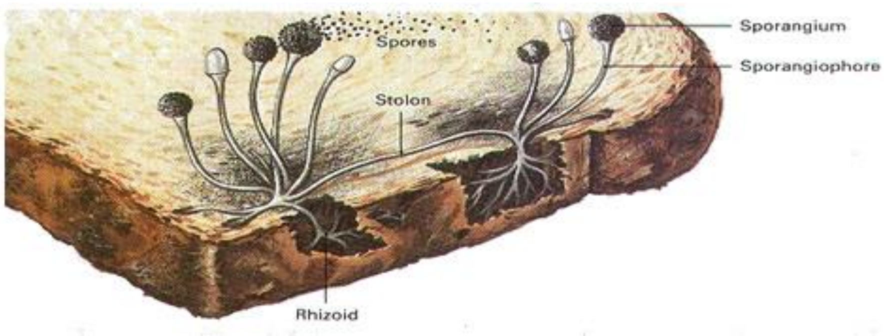
Characteristics

The body is mycelium with non septatic/coenocytic hyphi.

They reproduce asexually and sexually by zygospore formation also asexually by forming the sporangia.

**RHIZOPUS STOLONIFER**






**RHIZOPUS STOLONIFER**

**Adaptations to its mode of life.**

- Have branched rhizoids/ hyphae which secrets enzymes for extra-cellular digestion.
- The walls of the rhizoids are permeable thus are used for absorption of the digested food and they are also for attachment.
- The hyphae are aseptate for easy passage of the absorbed food.
- They have a high reproductive rate i.e. they produce large number of spores both sexually and asexually thus increases chances of survival.
- The sporangium are highly raised by the sporangiophore so that the spores can be easily be blown by the air current when the sporangium ruptures.
- The sporangium has collumela which changes its shape from Spherical to platform like when sporangium ruptures for easy dispersion of spores.
- The spores are light enough to be blown by wind and can remain dormant for a long period and are yet viable.

**PHYLUM BASIDIOMYCOTA**

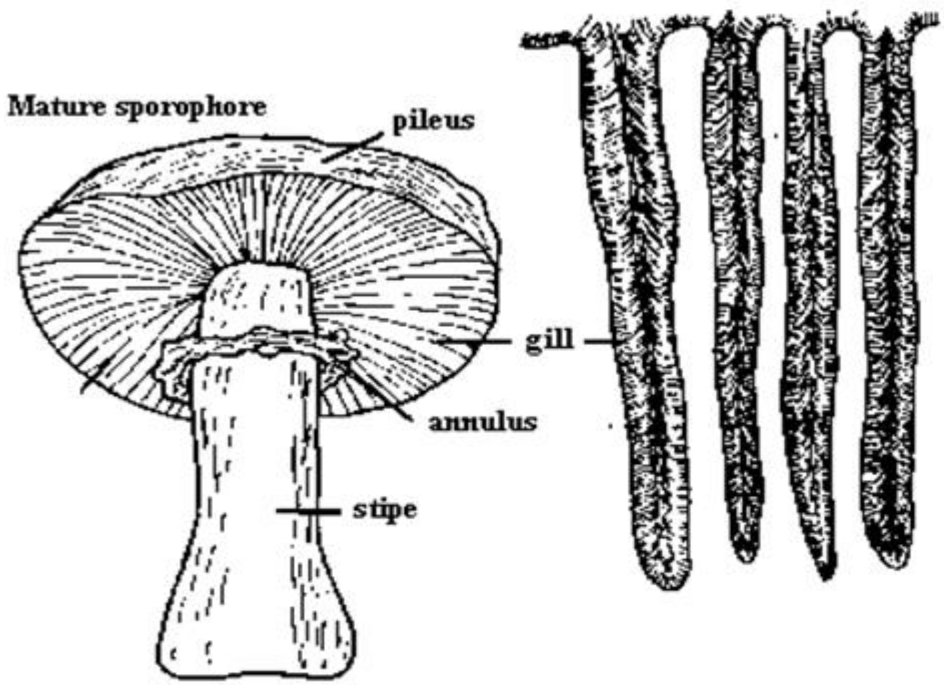
E.g. Agaricus campestris [mushroom]

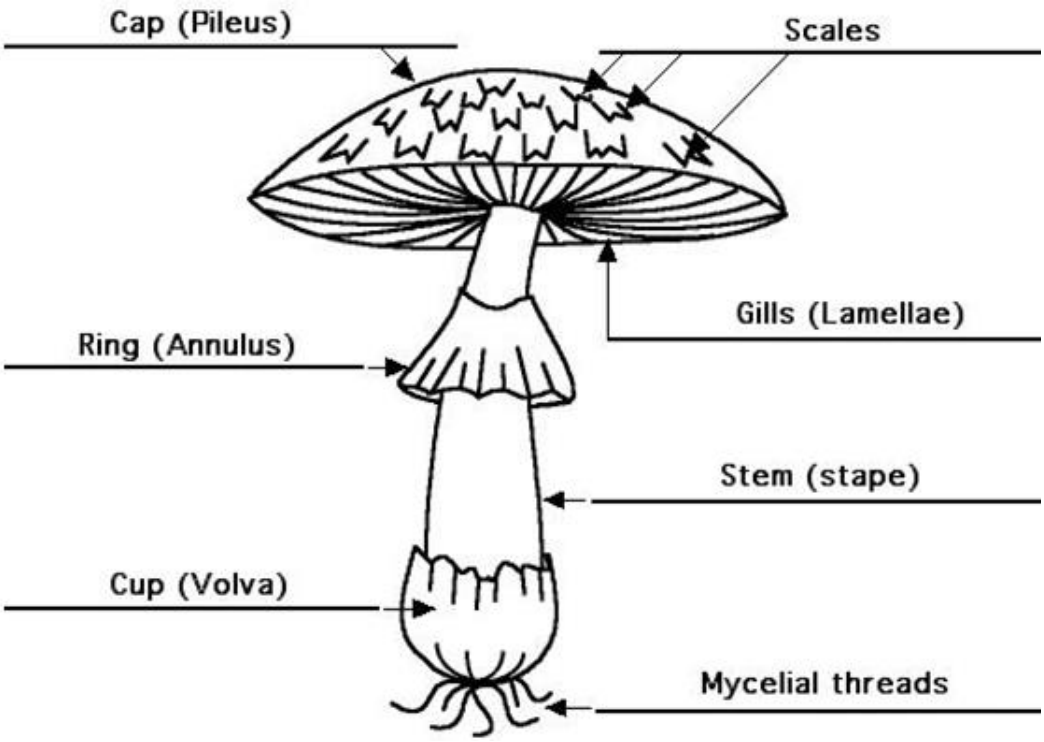
**Characteristics**

- The hyphae are septate and compacted /fused .This makes the basidiomycota to be more advanced compared to other phylum
- They reproduce sexually by basidiospores and asexual reproduction is not common.
- They live on dead decaying organic matter /damp soils rich in organic matter
- They are saprophytes i.e. digestion is extra cellular.

## AGARICUS CAMPESTRIS

9.201 Mushroom *Agaricus campestris*






**AGARICUS CAMPESTRIS**

**Adaptation to mode of life.**

- Have rhizomorphs for anchorage and act as perenating organ for vegetative propagation.
- The rhizomorphs produce a variety of hydrolytic enzyme for extra cellular digestion as they are saprophytic .The walls are permeable to digested nutrients and water thus serving as an absorbing organelle.
- The stipe also raises the pileus/cap well above the ground for easy dispersal of spores by the wind.
- The cap protects the gills inside which the spores are protected.
- They produce large number of basidiospores thus increasing chances of survival.

**PHYLUM ASCOMYCOTA**

E.g. genera

- Genus sacchromyces cerevisine (yeast).
- Genus penicillium notatum (penicillium).
- Genus Aspergillus campestral.

The Phylum consists of members which are of great economic importance.

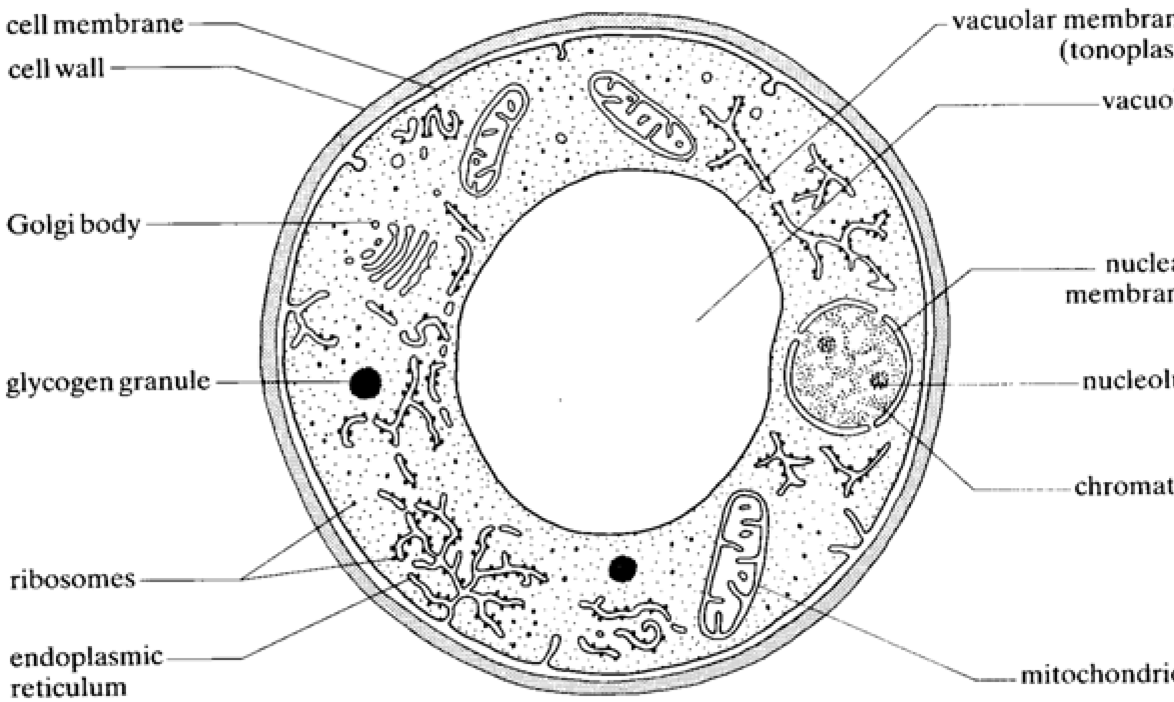
**Characteristics**.

- They have septate hyphae and some are unicellular.
- They reproduce sexually by ascospores (from the fruiting body ascus.) and asexually by conidiophores.
- They are terrestrial growing on rich soils or on sugary solutions (i.e. nectars of flowers, fruits, juices, slim wax from the trees).
- They are saprotrophs.

**GENUS SACCHROMYCES**.

**Structure of yeast**

**Yeast Cell**




- They are unicellular organisms.
- They reproduce asexually by budding.

**Adaptation to its mode of life.**

- They are anaerobic and they live in low oxygen content.
- They have a high rate/a fast rate of reproduction by budding (asexual) when conditions are unfavorable they conjugate.
- They are saprophytic producing enzymes for extra-cellular digestion.

**Differences between plants and fungi (Animal characteristics)**

| **FUNGI** | **PLANTS** |
|---|---|
| Carbohydrate stored in form of glycogen. | Carbohydrates stored in form of starch. |

| | |
|---|---|
| They are heterotrophic i.e. Saprophytic parasitic mutualistic thus have no chlorophyll and thus cannot photosynthesis. | They are autotrophic posses chlorophyll and can photosynthesize. |
| They possess centrioles<br><br>The cell wall is made of chitin | They do not posses centrioles<br><br>The cell wall is made of cellulose |
| They have thallus body i.e. Not differentiated into roots, stems and leaves. | They have a well developed and differentiated body. |

**ECONOMIC IMPORTANCE OF FUNGI**

**Beneficial effects.**

1. Source of food (direct source) e.g. Agaricus species i.e. mushroom, aspergillus.
2. Are decomposers i.e. bringing about the decaying of organic matter hence nutrient recycling e.g. rhizopus or mucor, moulds.
3. Source of antibiotics e.g. penicillium notatum produces penicillium, p.griscofulvum produces griseofulvin, Aspergillus fumigatus produces fumagillin.
4. Used in production of phyto hormones e.g. gibberellins from fungi gibberella
5. Used in extraction of vitamins e.g. B-complex from yeast
6. They are used in food industry and alcohol production particular in baking e.g.yeast in making of bread, fermentation in alcohol/liquor production e.g. yeast, citric acid production by Aspergillus lactic acid by rhizopus species.
7. Sewage treatment (including decomposers) e.g. moulds or rhizopus.
8. The toxication of cyanide especially in cassava e.g. moulds.
9. They are used in biological control fungi such as Chinese caterpillar fungus which parasite insects can be extremely important for controlling insects/ pests or crops. The spores of fungi are spread on the crop and control the beetles, leaf hoppers and citrus rust mites.
10. Used in genetic engineering and biological research e.g. neurosporal spps.
11. Involved in production of single cell protein.
12. Involved in micorhiza and plant growth vitally importance for the growth of plants including crops through development of micorhiza association. Micorhiza is a combination of fungi and flowering trees. About 50-90 percent of flowering plants have a symbiotic relationship with fungi. There are two types of micorhiza, endomicorhiza and ectomicorhiza. Endomicorhiza is a very common variety i.e. characteristics of most crop species endomicorhiza are unicellular fungi living inside the outer root cells of plant.

    Ectomicorhiza is a less common variety and is a characteristic of ferns and trees only.

13. **Generally advantage** –micorhiza develops when hyphae densely the root hair and penetrate the root cells.

**Harmful effects**.

1. They are poisonous e.g. some agarics species. Amanita species cause death to humans.
2. They cause diseases to humans e.g. Athletes foot by epidemophyton species, worm by Candida species and thrush by Candida species.
3. They cause diseases and damage to crop plants during growth e.g. puccinia species causes rust on leather materials, grains and seeds. They also spoil cooked food e.g. moulds on bread.
4. They cause damage to woods on both living and stored timber e.g. bracket fungi.

## KINGDOM PLANTAE.

### General Characteristics

- There are many variations of the kingdom and they all possess chlorophyll A and B thus capable of photosynthesizing i.e. convert sunlight energy into chemical energy and thus are producers of ecosystem.
- They have well developed vegetative bodies and are sometimes differentiated into roots, stems and leaves and also reproductive bodies.
- They are sessile/ limited locomotion which show curvature movements.
- Plants have cellulose cell walls.
- They have prominent large vacuoles in their cells and store carbohydrate in form of starch.
- They are multi-cellular organisms with apical growth and localized growth with indefinite number of parts.
- Their life cycle involves alteration of generation which is more prominent in the lower plants.

## CLASSIFICATION OF KINGDOM PLANTAE.

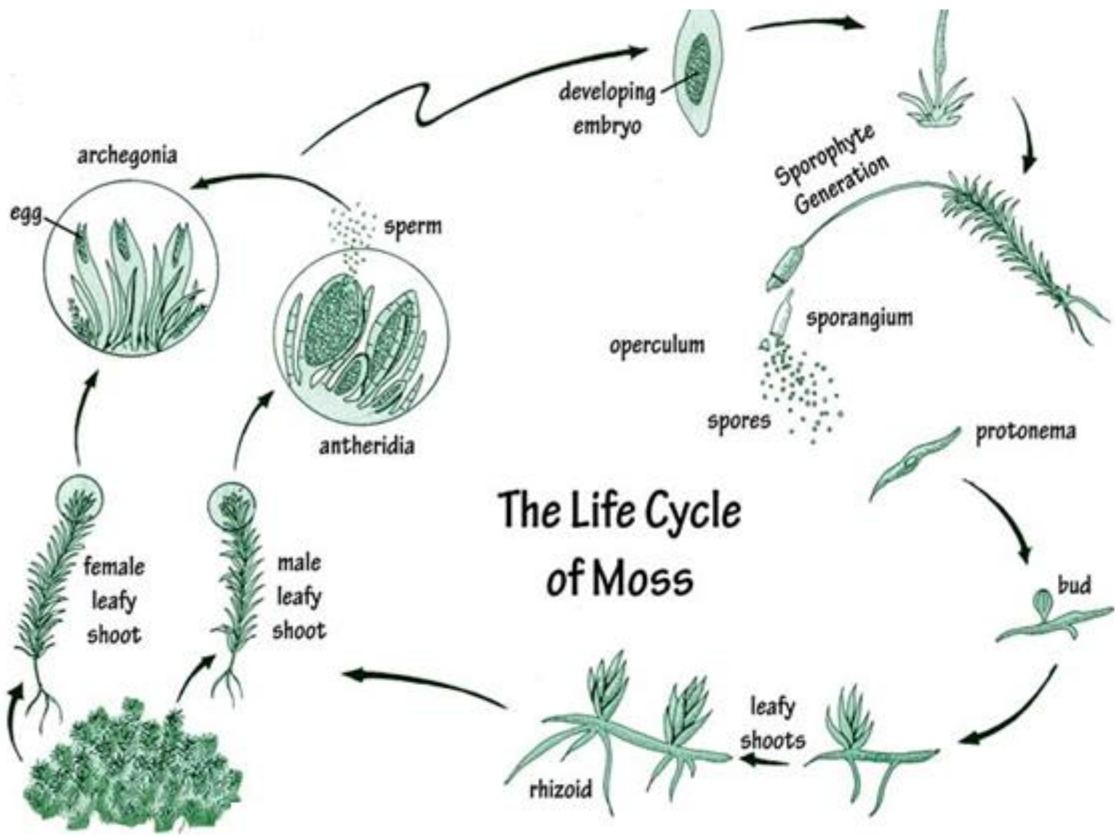
- Bryophyta e.g. musci e.g. funaria
- Filicinophyta (pteridophyta) e.g. dryopteris filix
- Coniferophyta e.g. pine (pinus sylivestris).
- Angiospermophyta. E.g. (flowering plants) class; monocotyledonae, dicotledonae.

## DIVISION BRYOPHYTA

### Characteristics

- They have vegetative bodies with no vascular tissues.

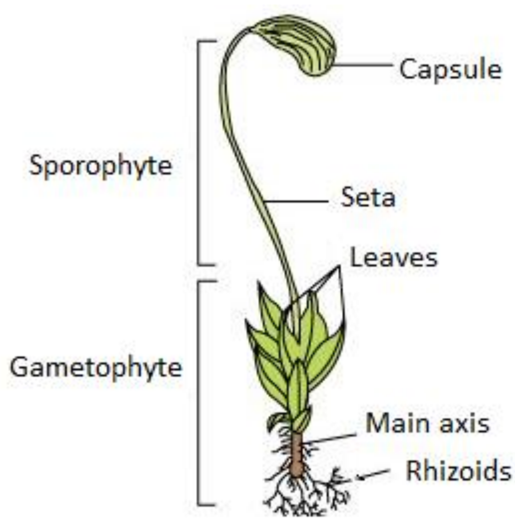
- They are terrestrial living in moist, shady organic rich soils.
- The body is thallus or differentiated into simple stems and simple leaves.
- The plants (gametophyte) have rhizoids for anchorage and there are no true roots, stems and leaves while the sporophyte is attached and is partially dependant on the gametophyte for nutrition.
    - They show alteration of generation. This is the occurrence of the phages in the cycle of the organism (plant) whereby a haploid gametophyte producing gametes (sexual phase) alternates with a diploid sporophyte producing spores (asexual phase). In the lower plants i.e. bryophyte the gametophyte phase is dominant over the sporophyte phase. Thus the sporophyte is attached to and semi dependant on gametophyte for its nutrition.




**Adaptations of funaria to its autotrophic mode of life**

- They have chlorophyll (gametophyte is green and the sporophyte) thus can photosynthesize therefore autotrophic mode of nutrition. The gametophyte also has multicellular rhizoids for absorption of water and mineral salts. Also anchores the plant to the soil.
- The reproductive structures i.e. antheridia and archegonia are protected by sterile hair.
- They show alteration of generation in their life cycle so that when one generation is weak it can depend on another one e.g. the sporophyte depends on gametophyte for nutrition and support.

- The plant can exploit both sexual and asexual reproduction
- The capsule of the sporophyte posses peristome and annuls cells which aid in dispersal of the spores. It also has an operculum which acts as a lid covering the capsule.
- The archegonia neck canal cells produce sugary solutions for a chemo tactic response to guide the anthrezoids into the ovum this increases the chances of fertilization.
- The sperms have flagella which aid in swimming through the water to the archegonia.
- The seta serves as upward means of transport of nutrients and water to the capsule.
- Seta is also raised well above the gametophyte so aiding the dispersal of spores by wind. The spores are light and produced by antheridia and are large in number increasing chances of survival.
- The gametes produced by antheridia are in large number thus increasing chances of fertilization.




**Moss Plant**

## DIVISION FILICINOPHYTA

### Characteristics.

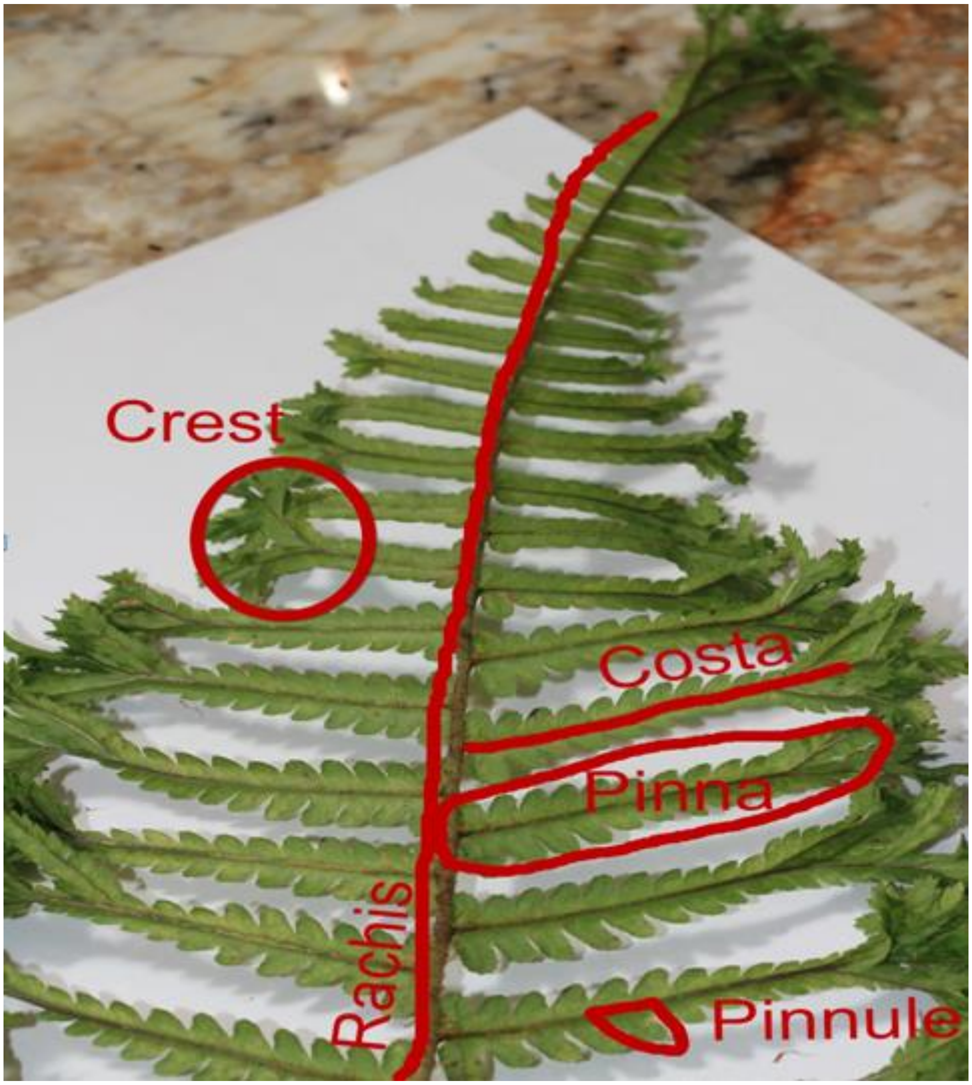
- Sporophyte has a well developed vegetative body with extensive adventitious roots, underground stem, rhizomes, and large leaves (the fronds)
- The leaves are called fronds because they are relatively larger than the stem and roots.
- The young leaves show circinate fashion**.**
- The sporophyte has a well developed vascular tissue primitive (siphonostele)hence the xylem contains tracheids with no vessels and the phloem has no companion cells.
- The spores are found underneath the leaves in cluster forming the sori.

- They also show alternation of generation with the sporophyte being dominant and gametophyte (pro thallus) short lived. Both Sporophyte and Gametophyte are independent.

**Description of dryopteris filix(fern)**

- It is a well developed plant with adventitious roots and stem is a rhizome.
- The leaves are relatively large compared to the other parts and are called fronds.
- The young leaves are rolled with circinate fashions which grow into a frond.
- A fronds consist of the rachis which is sub divided to pinna which in turn holds the pinnule.
- The rachis possess ramenta (brown scales) for protection.
- The fronds have spores underneath which are born in clusters called sori and the spores
- The gametophyte is a thin heart shaped pro-thallus which lacks cuticle therefore requires moist conditions to prevent them from drying out. The prothallus possess both the male antheridia which is attached near the rhizoids and the female archegonia which is attached near the notch. The gametes are produced and fertilization occurs giving rise to zygote which develops into sporophyte generation.

**External features of sporophyte generation of dryopteris filix mas (the male fern)**

- 


**ADAPTATION OF FERN TO MODE OF LIFE**

- The sporophyte is well developed with roots for anchorage and for absorption of water and mineral salts.
- Have stems for support and leaves with rachis for upward transport of water and mineral salts.
- They also possess chlorophyll thus can photosynthesize.
- The roots also serve as parenting organ for vegetative propagation.
- The rachis and young leaves possess ramenta for protection from mechanical injury and desiccation.
- They possess cuticle on their leaves to prevent excessive loss of water through transpiration.
- They have mechanical tissue (scterenchyma and collenchyma) for support a conducting tissue (phloem and xylem) for transport.

- The sori are found on the underside of the leaf, this prevents them from direct sunlight thus desiccation. The sori in turn are protected by inducium.
- The leaves are large in size to increase area for absorption of sun light.
- The sporangium has mechanism for dispersing the spores due to the presence of annulus cells and stadium cells.

**Importance of dry and wet conditions in the life cycle of mosses and dryopteris.**

**Wet conditions.**

- The stem is underground and can survive unfavorable conditions such as drought.
- The gametophyte and sporophyte are independent of each other and each can photosynthesize.
- The archegonia produce solutions which attract the anthrezoids chemotactically.
- The anthrezoids have flagella which can help them to swim to the archegonia.

**Dry conditions**

- Required for dispersal of spores by the wind.
- Required for drying and rupturing of the capsule.
- The gametes develop in protective structures, the antheridia and archegonia in dry conditions.

**COMPARISON OF MOSSES AND DRYOPTERIS**.

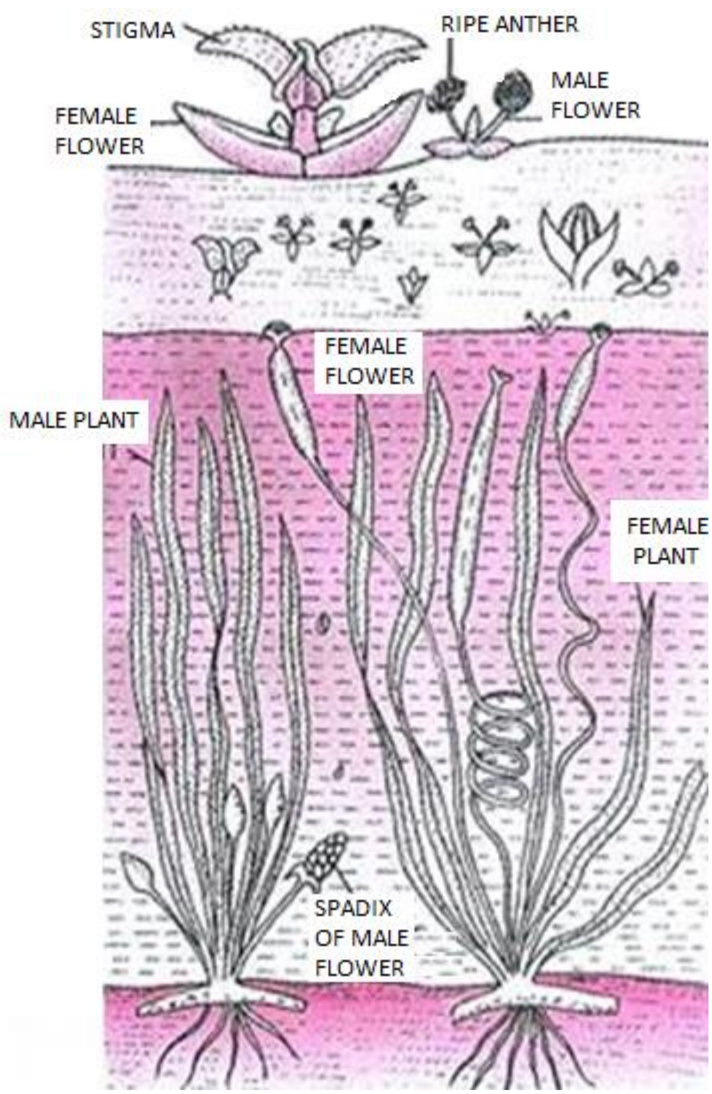
**SIMILARITIES**.

- Fertilization requires wet conditions because the flagellated anthrezoids have to swim through water to the archegonia.
- They both show alternation of generation with the gametophyte alternating with the sporophyte.
- They all produce spores which require dry conditions for dispersal.
- They both have archegonia and antheridia as reproductive structures.
- Meiosis occurs during spore formation in the spore mother cells contained in the capsule
- They have stomata for gaseous exchange
- The gametophyte has rhizoids for anchorage and absorption.

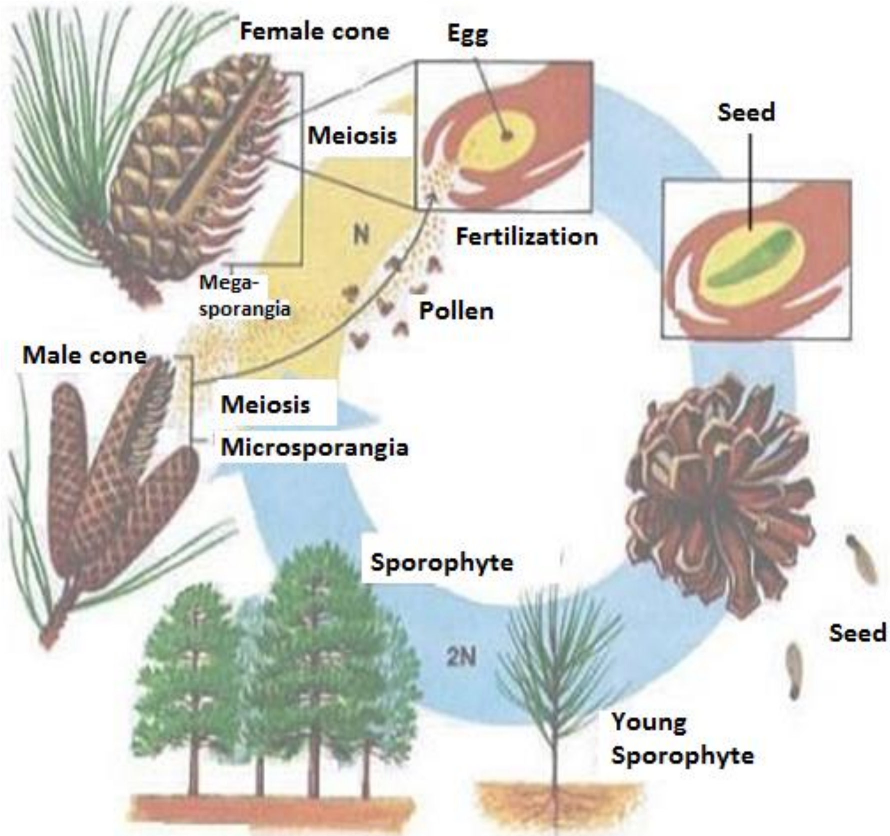
**DIVISION CONIFEROPHYTA**

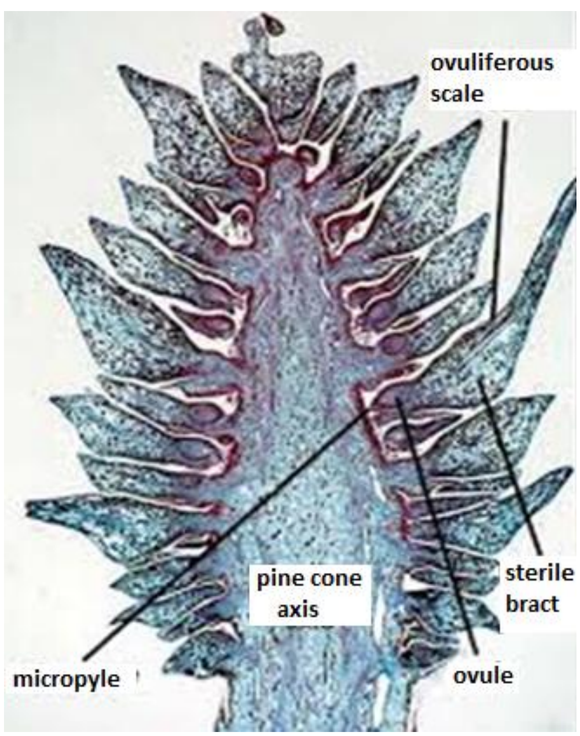
- The leaves are needle –like covered with a waxy cuticle and have sunken stomata.
- The tree is the sporophyte generation and is heterosporous. In spring male and female cones are produced on the same tree. The male cones are rounded and found in clusters behind the apical buds at the bases of new shoots. They develop in the area of scale leaves in place of dwarf shoots. Female cones arise in the axis of scales i.e. at the tip of new strong shoots at some distance from male cones and in a more clustered

arrangement. Both cones consist of spirally arranged, closely packed around a central axis.




- pollination in vallisneria (Tape grass)


Female cone
Egg
Seed
Meiosis
N
Fertilization
Mega-
sporangia
Pollen
Male cone
Meiosis
Microsporangia
Sporophyte
2N
Seed
Young
Sporophyte


ovuliferous
scale
pine cone
axis
sterile
bract
micropyle
ovule

**Adaptations of pinus to its mode of life.**

- The sporophyte is differentiated into roots which are well developed and grow deep into the soil for anchorage and absorption of underground water.
- The stem is reddish brown in colour and covered by scaly leaves to prevent water loss through transpiration.
- The leaves are needle like to minimize loss of water (as surface area is reduced).
- The leaves are evergreen for photosynthesis.
- The stomata are sunken which reduce water loss through transpiration.
- The leaves have hypodermis below the epidermis which prevent further desiccation.
- They have the conducting tissue, the xylem and phloem, for upward movement of water and mineral salts (xylem) and transport of food (phloem).
- They have developed mechanical tissues (woody stem) i.e. sclerenchyma and collenchyma) which provide mechanical support as the plant has to grow into tall trees.
- The microspores and megaspores have scales which prevent them from water loss.
- The presence of air sacs in the microspores facilitates wind dispersal thus conifers do not need water for fertilization since male gametes are blown by wind to reach the female gametes.
- The microspores develop a resistant wall for protection and they are small and light to be blown by wind.
- They produce a large number of seeds in the cones to increase chance of survival.
- Formation of resin canals that resist entry of fungi and other pathogens when the plant is injured. The resin normally covers up the injured part and the seed bearing habit enables the plant to survive during adverse conditions (unfavorable conditions ) as the seeds are protected by the seed coat.
- The stored food in the seed can be used by developing embryo during germination.

**PHYLUM ANGIOSPERMOPHYTA.**

They are common land plants with approximately 335,000 species. ¾ of them are dicots and ¼ of them are monocots. They live in all types of habitats. Some are terrestrial while others are aquatic (fresh water or marine).

They show diversity in morphology from simple grass with no cambium to trees such as baobab tree with cambium which allows development of girth.

**GENERAL CHARACTERISTICS.**

- The sporophyte is well differentiated into roots for anchorage and absorption of water and mineral salts, stem for support and transport and leaves for photosynthesis (i.e. they have chloroplast).
- They show alternation of generation with the sporophyte being dominant over the gametophyte, i.e. the gametophyte is reduced.

- Have well developed vascular tissues which consist of xylem with tracheids and vessels for transport of water and mineral salts and support and the phloem has got companion cells and sieve elements.
- They are heterosporous (microspore/pollen grain and megaspore/embryo)
- Fertilization does not depend on water because the male gamete is connected to the ovum by the pollen tube formed by germination of pollen grain when it lands on the stigma of the same species.

**DISTINCTIVE CHARACTERISTICS.**

- They provide flowers in which megaspores and microspores develop.
- They undergo double fertilization. After fertilization, ovary develops into fruit and the ovules into seeds which are enclosed in the ovary.
- Xylem contains vessels and tracheids and phloem has sieve tubes and companion cells.

The angiosperms are divided into two major groups;

1. Monocotyledonae
2. dicotelydonae

**MAJOR DIFFERENCES BETWEEN MONOCOTYLEDONS AND DICOTYLEDONS.**

| | **Class monocotylenae** | **Class dicotyledonae** |
|---|---|---|
| 1. Leaf morphology. | - Parallel venation (veins are parallel).<br><br>- Elongate.<br><br>- Identical dorsal and ventral surfaces. | - Reticular venation. (Net like vein pattern).<br><br>- Lamina (blade) and petiole (leaf stalk).<br><br>- Dorsal-ventral(dorsal and ventral surfaces differ) |
| 2. Stem anatomy. | - Vascularbundles scattered.<br><br>- Vascular cambium usually absent,no secondarygrowth(exceptions occur e.g. palms) | - Ring of vascular bundles. |

**The structure and function of flowers**



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Flowers are reproductive structures in flowering plants (angiosperms) whose evolutionary origin are unclear but sometimes regarded as collection of highly specialized leaves. The flowers are commonly referred to simply as organs of sexual reproduction.

**Parts of Flower**

They are arranged in spiral form in few primitive flowers or in whorls around the upper parts (receptacle) of a flower stalk (pedicel). Some flowers are found as a collection of flowers borne on the same stalk (inflorescence)

Parts

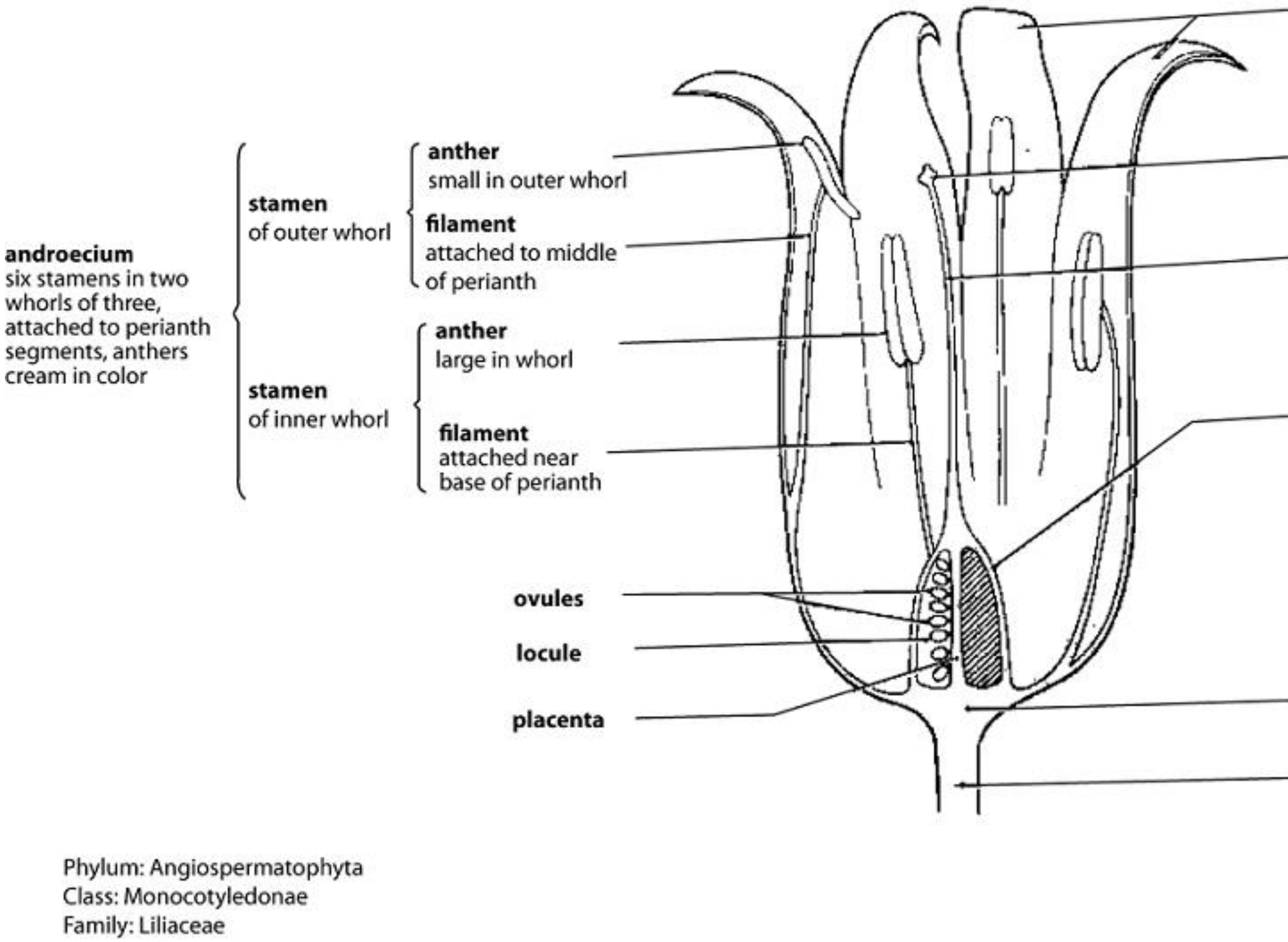
1. **Receptacle**- Is the end of the flower stalk (pedicel) from which the perianth, gynaecium, and androecium arises.
2. **Perianth**- Consists of two whorls of leaf like segments. The whorls are similar in monocoty but different in dicot. The outer whorl is called sepal (Calyx) and inner whorl is petal (corolla)

**Calyx-** Is the collection of sepals, they are usually green and leaf like structures that encloses and protect the flower buds.

**Corolla-** Is a collection of petals. In insects pollinated flowers the petals are usually large and brightly coloured to attract insects.

3. **Androecium**- is a collection of stamens forming the male reproductive organ of the flower. This consist of anther and filaments, in anther pollen grain are made. Filaments rises water to the anther.
4. **Genaecium** (Pistil) is the collection carpels forming the female reproductive organs of the flower. This consists of stigma, style and ovary. Stigma receive pollen grain during pollination, style holds in position stigma and ovary contains one or more ovules.

**Generalized structure of flower**




**Symmetry of flowers**

If the flower parts are arranged in radial symmetry around the receptacle, the flower is said to be regular or **actinomorphic** e.g. bluebell.

If the flower shows bilateral symmetry only, it is said to be irregular or zygomorphic e.g. pea.

**Floral formulae**

Is the presentation of floral parts of the flower by using symbols.

In floral formulae the following terms are used to describe the following terms are used to describe various parts of the flower.

**A. Symmetry of the flower**

⊕ Actinomorphic/ Radial or regular flower

·|· Zygomorphic/ Bilateral or irregular flower

**B. Sex of the Flower**

Diecious flower – The flower with separate male and female parts

♂ Staminate flower- The flower with male parts only

♀ Pistilate flower – The flower with female parts only

Momoecious flower- The flower with both male and female parts both on the same flower

⚥ Hermaphrodite- The flower with male and female parts

**C. Flower recepatacle**

Pedicelate flower – Is the type of flower with pedicale or flower stalk

Sessile flower – Is the type of flower without pedicel or flower stalk

N.B. This is not seen in floral formulae but appears in floral diagrams.

**Perianth**

Consists of two whorls of the flower which is

K- Calyx followed by the number of sepals. If sepals are free $K_5$ and if sepals are fused $K_{(5)}$

C- Corolla followed by number of petals. If the petals are free $C_5$ and if sepals are fused $C_{(5)}$.

**Male parts of the Flower**

A- Androecium followed by followed by the number of pollen grains e.g. $A_5$ if fused. A∞ if the number of pollen grains exceed 16.

**Female part of the flower**

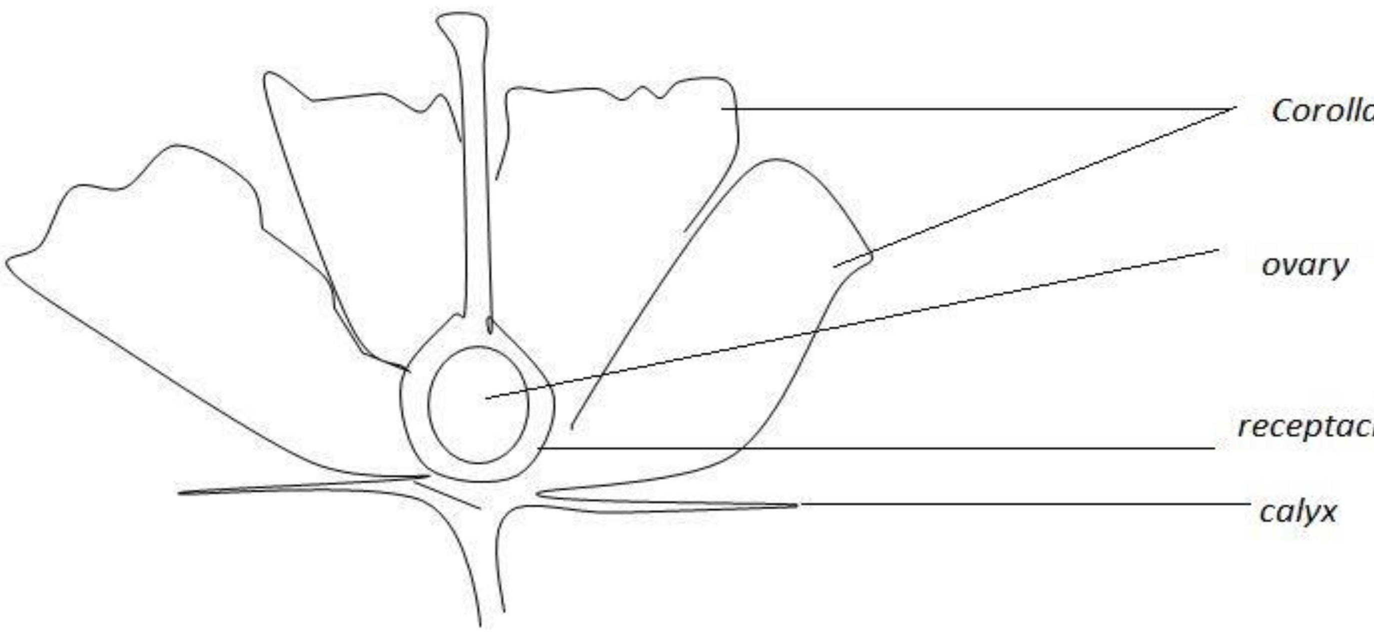
G- Gynaecium followed by the number of carpels eg $G_1$ is free , $G_{(2)}$ if fused. The position of ovary with respect to receptacle

**Hypogenous flower/ Inferior ovary**

A flower in which ovary is placed highest on the thalamus and the other floral structure underneath.

For the example $G_{\underline{1}}$

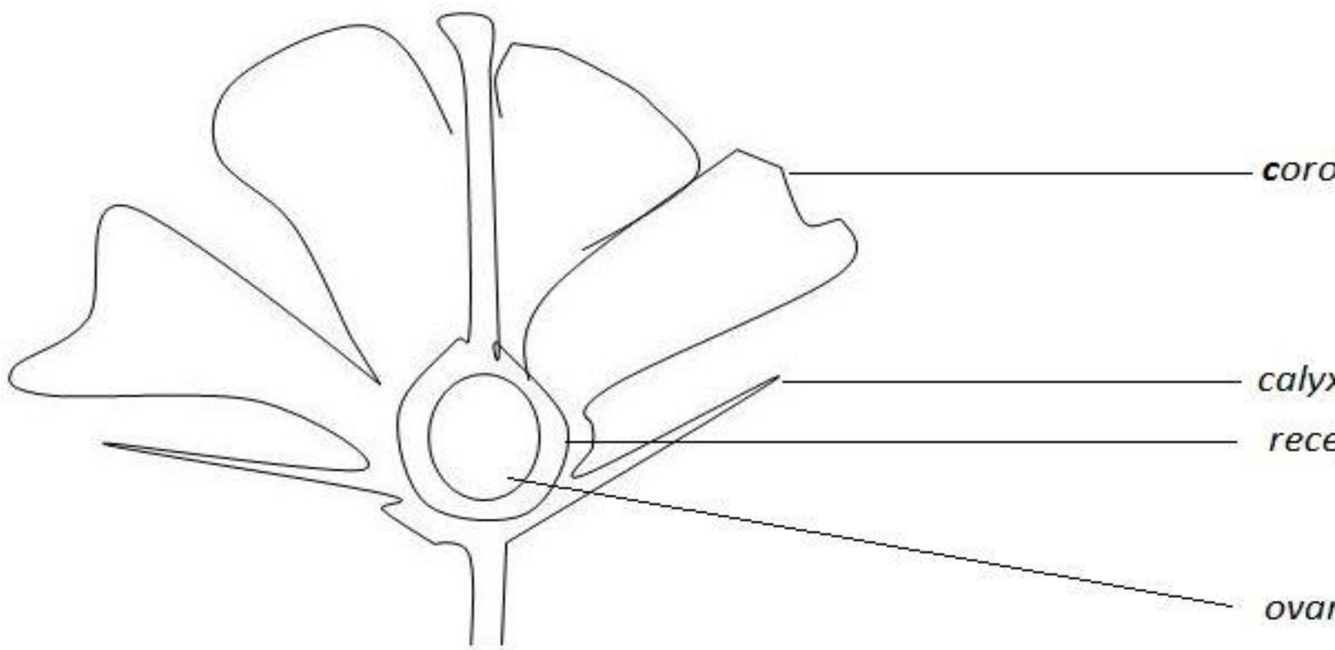
Diagram of hypogenous




**Perigynous flower**

A flower in which ovary is at the same plane as other floral structure.

For example $G_2$




**Epigynous/ Superior**

A flower in which ovary is placed lower to other floral structure on the thalamus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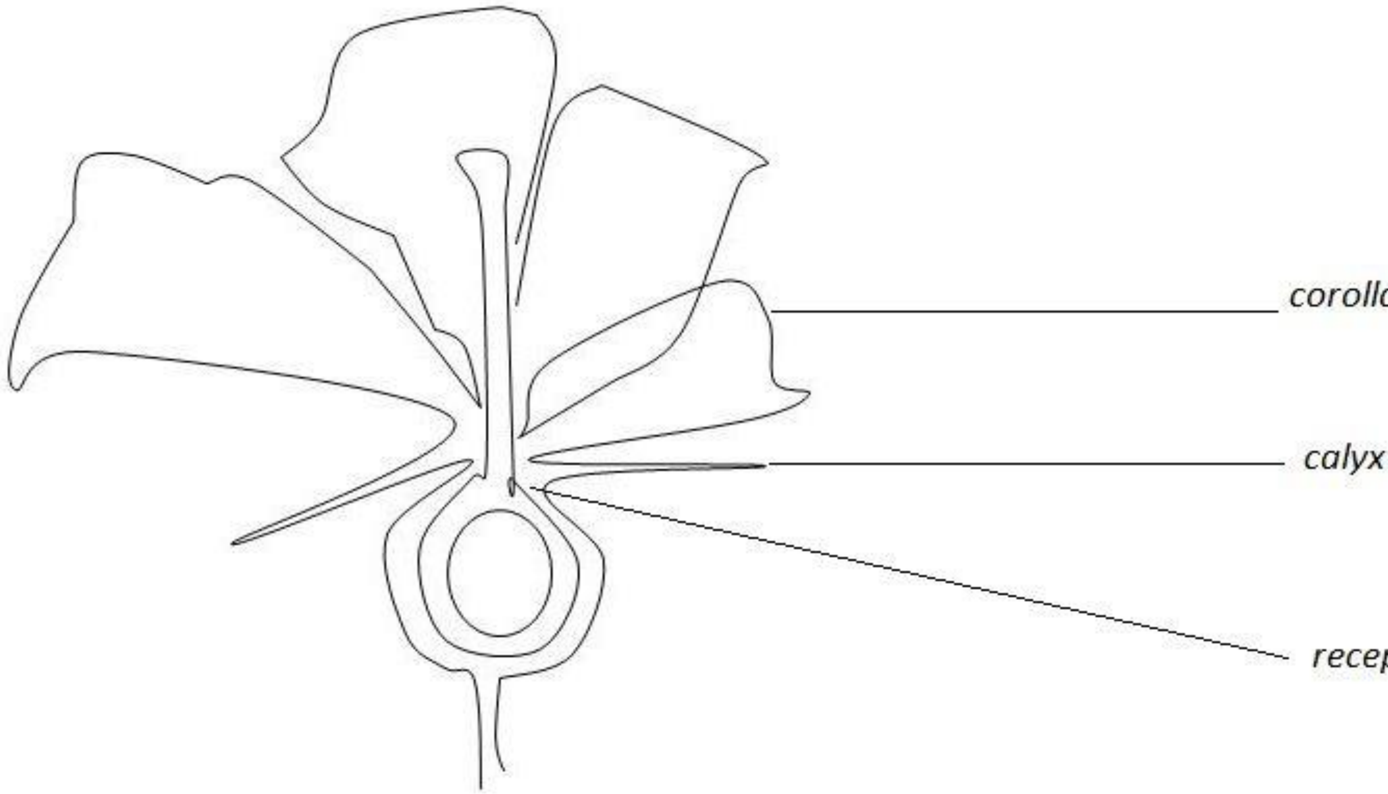
Example $G_2$




Also flower have first leaf which is known as **bracteates**; a flower with bract. Ebracteate a flower without a bract.

Symbols of Floral formulae

⊕ Actinomorphic flower

-|- Zygomorphic flower

♂ Staminate flower

♀ Pistilate flower

⚥ Bisexual flower

Br Bracteate flower

Ebr Ebracteate flower

K Calyx

C Corolla or $\overset{\frown}{C \quad A}$ = androecium born from corolla

G Gynoecium or $\overset{\frown}{G \quad A}$ – androecium born from corolla

A Androecium

Examples of Floral frolar formulae

1. Garden pea *Pisum satirum*

Floral formulae

.1. $⚥ \; K_{(5)}, C_{1+2+(2)}, A_{(9)+1}, G_1$

2. *Solanum*

$\oplus \; ⚥ \; K_{(5)}, C_{(5)}, A_{(5)} G_{\underline{(2)}}$

3. *Hibiscus* flower

$\oplus \; ⚥ \; K_{(5)}, C_{(5)}, A_{\infty} G_{\underline{(2)}}$

**Frolar Diagram**

This is the representation of flower parts by using concentric cycles to present various parts of the flower.

- The outer cycle represents the first whorl of the flower which calyx/ sepals

- The second cycle represents the corolla or petals

- The 3rd represents androecium

- The 4th part represent gynaecium

In floral diagram the gynaecium also show the ovary with placentation.

The ovary consists of ovary wall called locule. The ovules are situated on the inner or adaxial (ventral) forms a placenta. In carpel the placenta occurs close to the margin.

**Marginal placentation**

The placenta is natural in nature. The placenta occurs close to the margin.

**Axile placentation**

This occurs when carpels are folded, the ovary is multilocular and placenta occurs at the centre of the ovary where margin of the carpel meets.

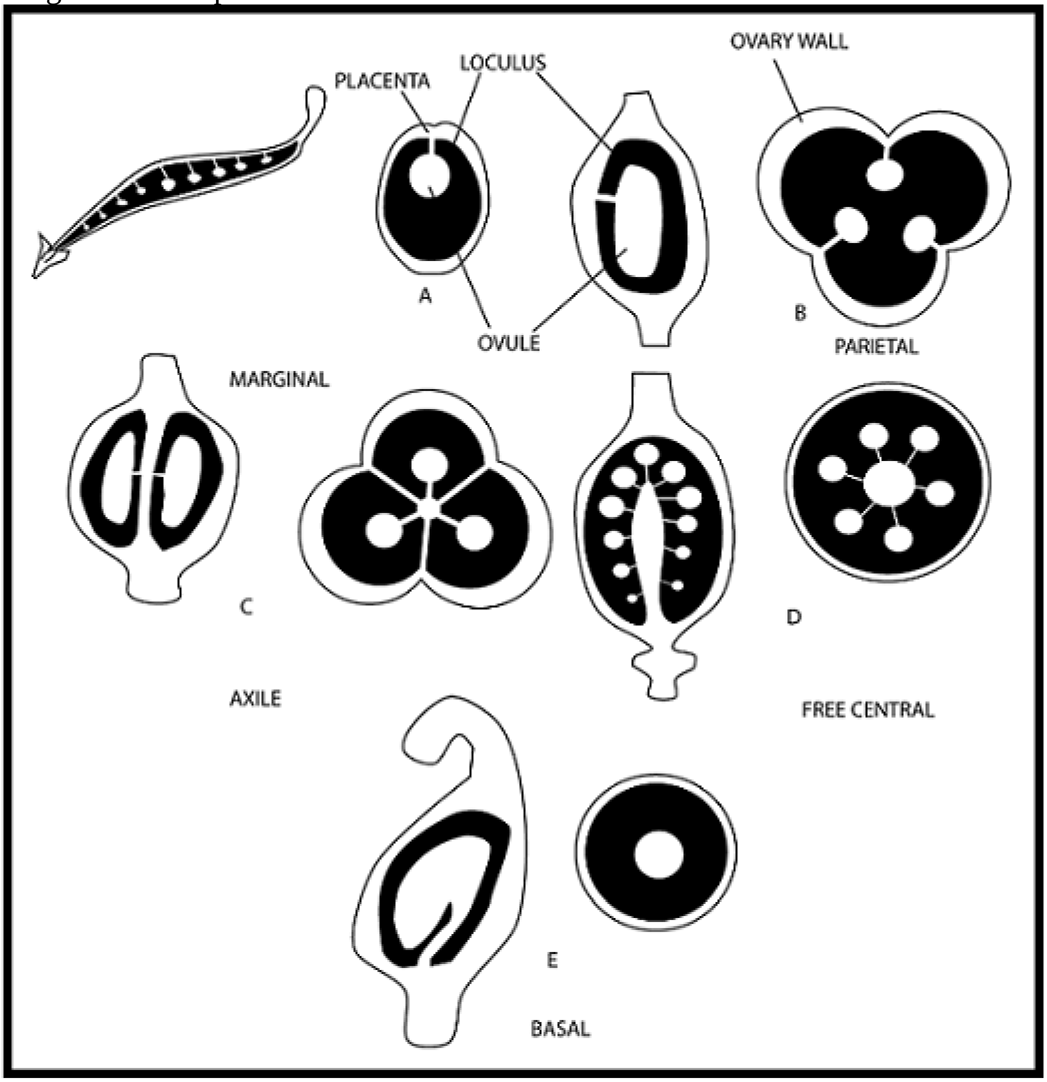
**Free Central**

This occurs when carpels partitious of the ovary disappears.

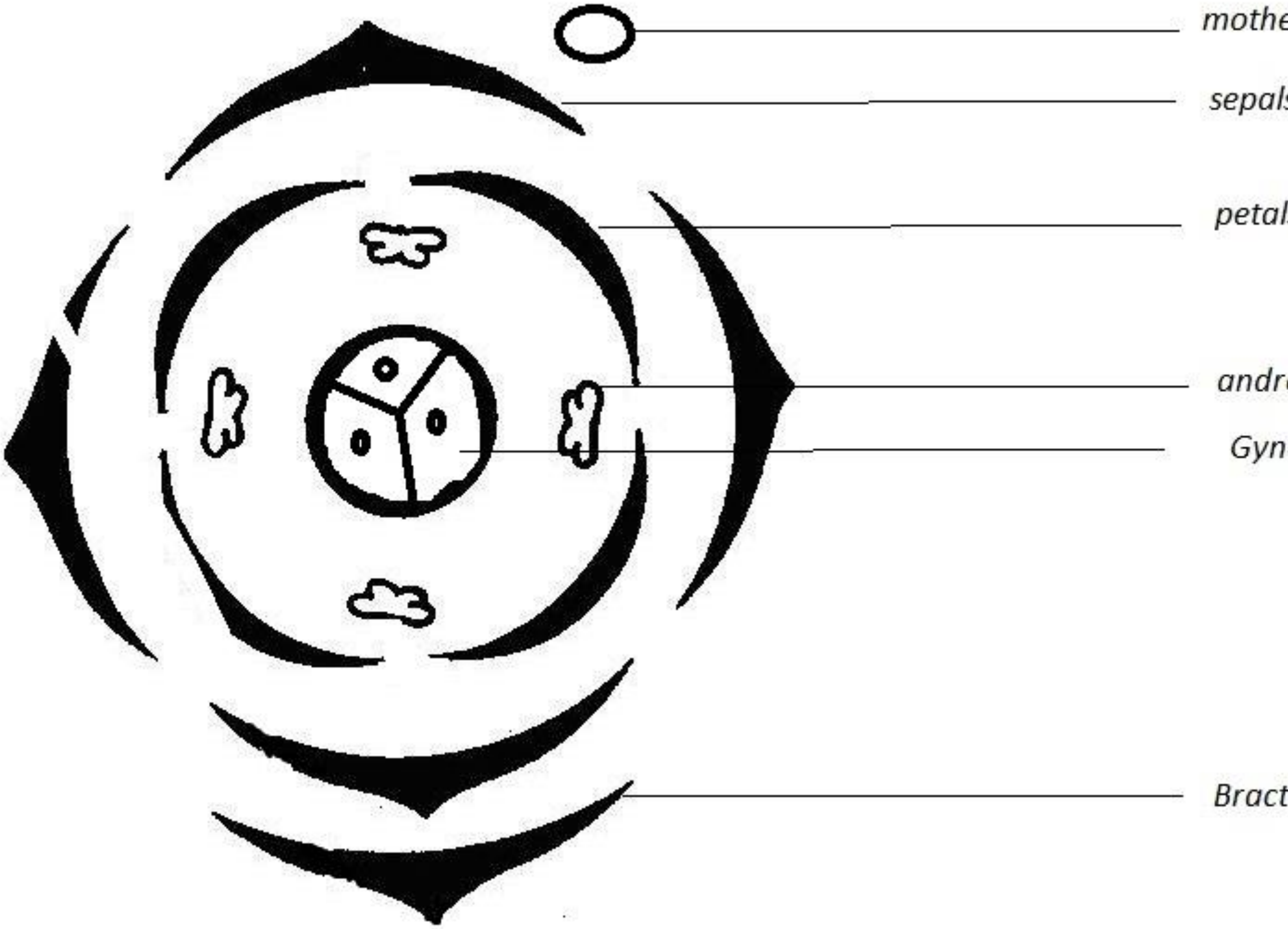
**Parietal pracentation**

This occur when the carpel are joined margin to margin and the placenta are found to be situated on the ovary walls.

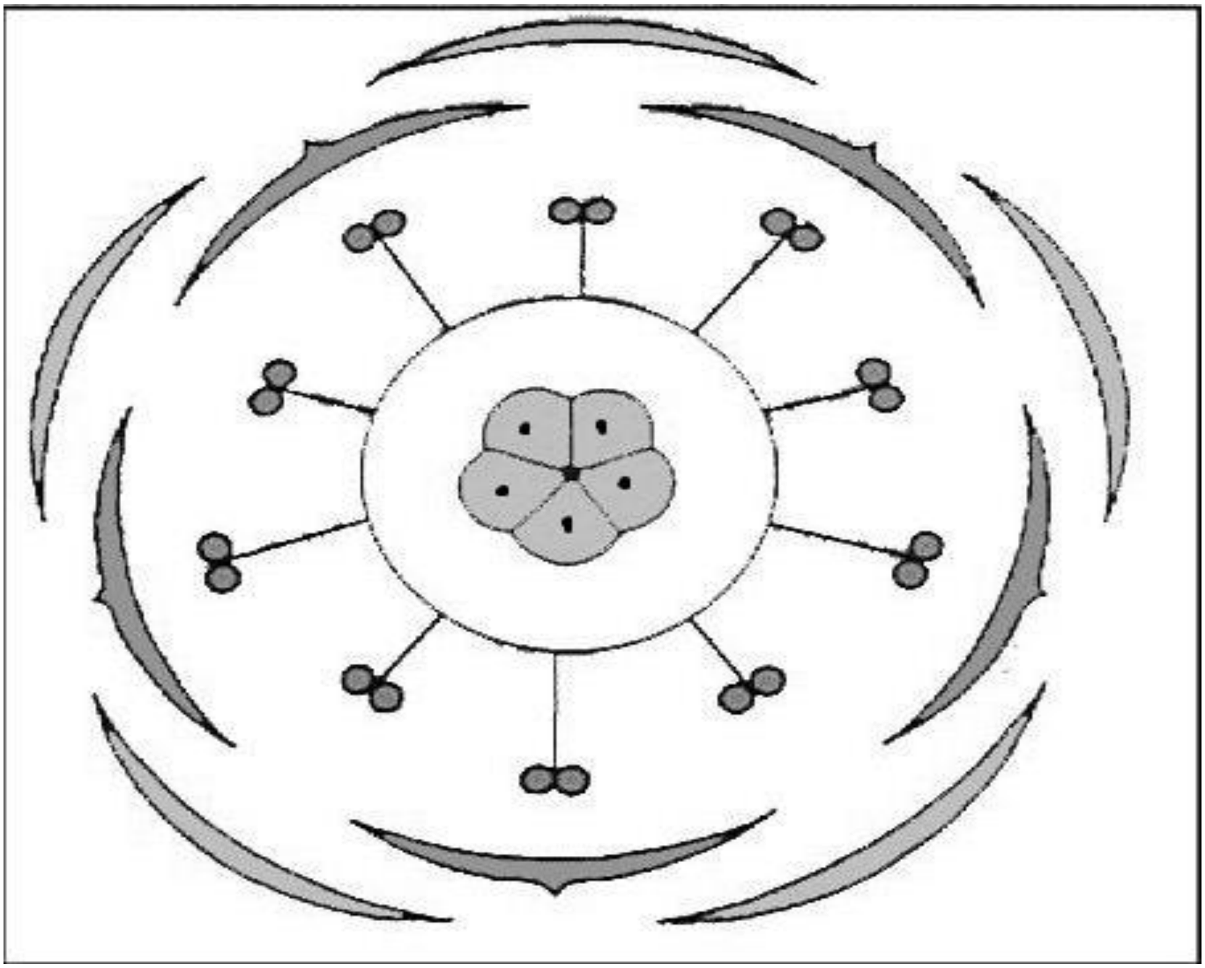
Diagrams of the placentation



Example of floral diagram




Frolar diagram of hibiscus flower



**KINGDOM ANIMALIA**

Animals are quite distinct from members of the other kingdoms. Unlike prokaryotes and protícts animals are multicellular. In fact some of the largest animals have trillions of cells. Unlike plants animals are heterotrophs.

Characteristics of the kingdom:

i) Animals are multicecullar eukaryotes with a high level of tissue diffentiation and specialized body organs.

ii)They have cells which have no cell walls.

iii)They have no chlorophy therefore have hetetrophic nutrition . They cannot manufacture their own food and instead must ingest it and braek it down metabolically for its energy content.

iv)They can move about at some point in their life cycle – usually through the entire cycle –to search for food and mates and to avoid danger.

v)They are diploid ,and their mode of reproduction is sexual ,because each individual grows and changes from organs ,it passes through various distant stages of development .

vi)They are radial or bilaterally symmetrical.

vii)Some they have diploblastic or triploblastic .

viii)Some they have exoskeleton .

ix)Some are pseudo coelom (coelom and acoelom).

**Classification of kingdom Animals**

a) Phyllum Platyhelminthes eg fasciola /Taenia

b) Phyllum Aschelminthes (Nematoda) eg ascans 9roundworms)

c) Phyllum Annelida eg earthworms

d)Phyllum Arthropoda eg cockroach,locus,millipede.

e)Phyllum chordate.

**PHYLLUM PLATYHELMINTHES**: eg fasciola/taenia

This is a group of animals commonly known as flat worms. They are also called solid worms or acoelomates because they have no coelom .The only internal space consists of the digestive cavity.

Characteristics :

i)They are ribbon shaped animals with soft bodies.

ii)They are dorso – ventrally flattened from top to bottom.

iii)They are triploblastic - ie their bodies are made of the three layers (Ectoderm,mesoderm and Endoderm.)

iv)They have no coelom.

v)They cinsist excretory structure called flame cells.

vi)The members may be free living, ecto or endoparasites.

vii)They are bilateral symmetrical.

viii)They have soft ciliated epidemic or cuticle with suckers and hooks for attachment (Trematoda and cestoda).

ix)They have muscles well developed from mesoderm.

x)They have well developed nervous system consisting of two lateral cerebral ganglia joined by a nerve ring and two main longitudinal nerve cord which give off numerous branches.

xi)They are hermaphrodite .

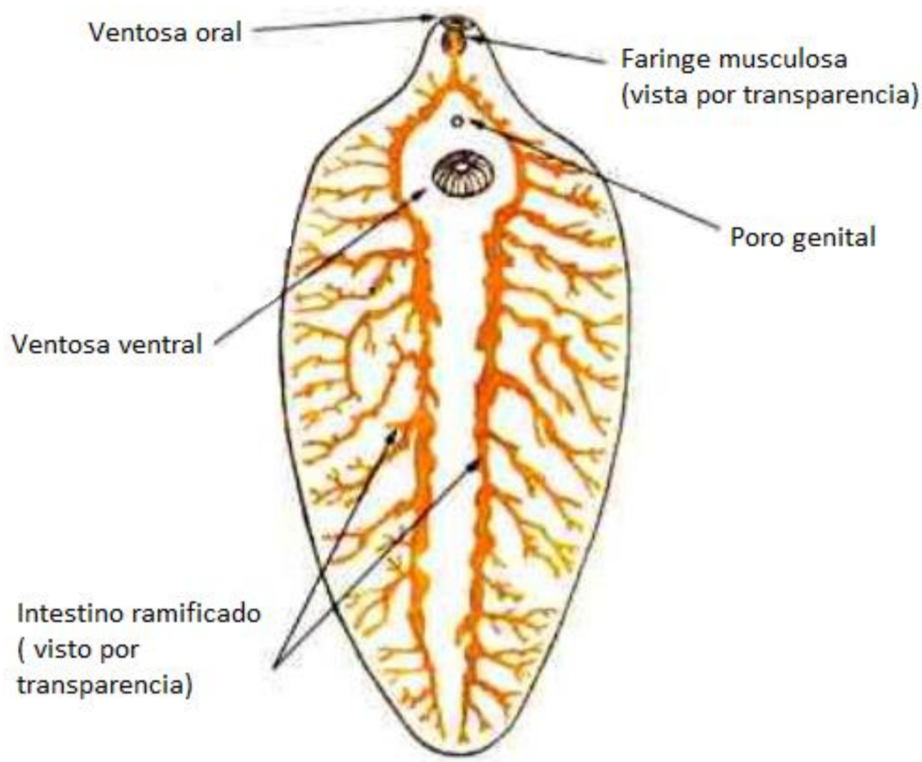
xii)Their life cycle involve at least two host . The intermediate host being an invertebrate .

xiii)The gut when present has a single aperture mouth.

xiv)They show cephalization a condition in which sense organs and nervers systems that serve as a brain in a definite head region of the organism.

nervous system – serve as a brain

Sense organ specialized in sense light, chemicals and pressure.




HABITAT

Found in marine and fresh water.

**Three classes of Platyhelminthes**

a) Turbellania eg planaria – which are mostly free living and a few and salty water and in moist soil.

Planaria is found in spring lakes ponds etc.

b) Trematoda (flukes) eg fasciolas peg fasciola hepatics – these are parastties the tropical liver fluke of cattle, sheep and sometimes infect man.

c)Cestoda eg Taeria sp (eg taenia sagnata,)

These are parasitics of the beef, pork etc.

**Class trematoda (the flukes)**

- The body surface is not ciliated, the body is flat and leaf like but in few case cylindrical eg blood flukes –ie schistosoma Manson causing bilharzia.

- The possess digestive system (gut)

- Mostly endoparasitic flukes of vertebrates with sexual and asexual reproduction.

- They are hermaphrodite.

- The life cycle involves at least two host, vertebrate and invertebrate.

- They have suckers, ventral and oral for attachment to the host.

- The members are Ector and endo parasites living

- Example: fasciola hepatica, the liver fluke belongs to this class. It is a parasite of sheep and other mammals.

**General features**

The adult fluke has a flattened oval shaped in the anterior region, there is a triangular projection at the apex of which lies the mouth, surrounded by the oral sucker and between the two sucker, there is a shallow depression the general atrium .

At the posterior and there a minute terminal excretory pore.

The animal feeds in the liver on the blood and cell which are ingested by the pumping action of the phyranx digestion and absorption takes place in the caeca and ingestion is through the mouth

**The reproduction system:**

The liver flukes is hermaphrodite and the reproductive organs are complex.

They have also development complex life history invading more than one host. The host harbouring the sexual stage are know as the final host and the host with the other stage are known as intermediate host.

Cross fertilization in liver flakes has been observed though self fertilization is also possible.

**Life Cycle**

The life cycle involves three oval stages the eggs pass out at the genital atrium and are carried into duodenum by the bile where the eggs leave the Liver tissue of enter the blood circulatory system and make their way into the alimentary canal. When they leave the body of the host the egg emerge with faces of the herbivorous and their development is completed if the are deposited in water because egg pass out while the embryo has not yet developed.

Larva stages:

1st stage:

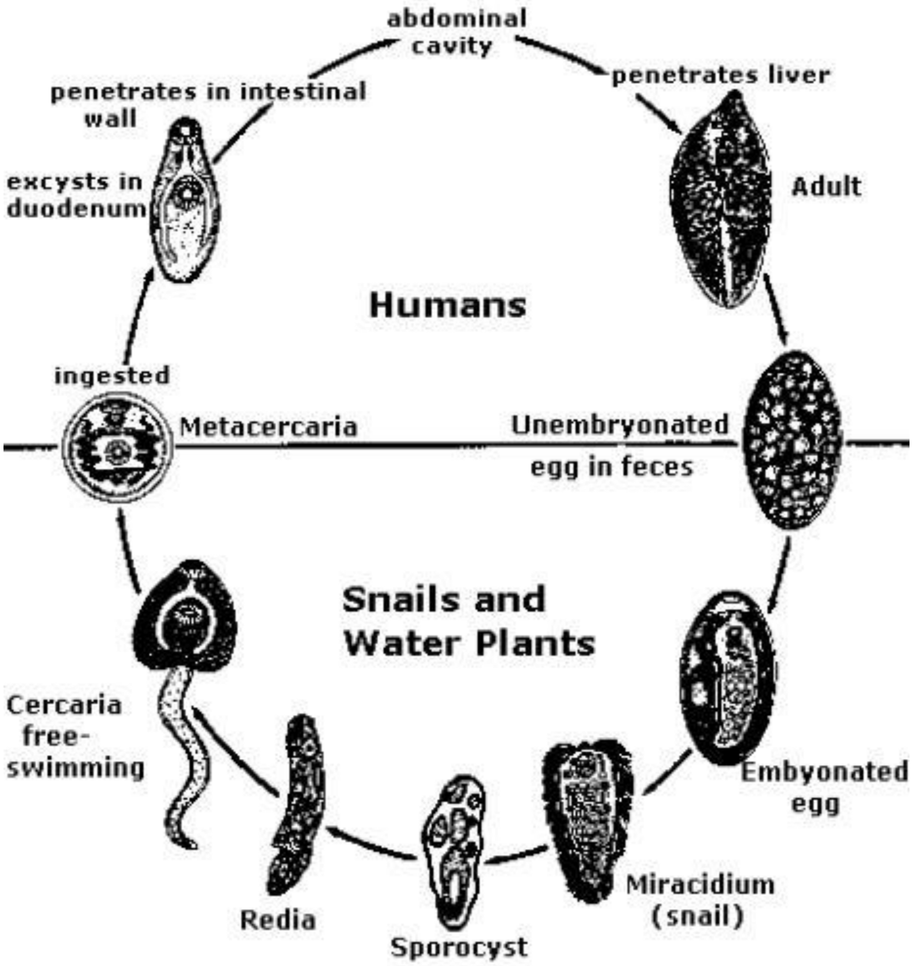
When the eggs in the faeces deposited in water hatch out into a ciliated larva called miracidium.

The miracidiu, swims actively to the suitable host and attracted to a fresh water snail of the genera *limnaea truncatula*. It enters the snails body through boring of the skin by proteoltytic enzymes secreted by penetration gland.

Before the ciliated larvae enter the snail it develops structure which can bore into the body of snail. This larva consist of ciliated cells one of which bears two pigmented eye sports and excretory system.

In the snail it normally stays in the digestive gland.

It loses its cilia and changes into a sphere shape known as sporocyst.




Life cycle of the live fluke.

2nd stage:

The laver that liberated into the body of the snail through ruptures of the sporocyst, called redial.

Each redial has a cylindrical central portion with two tapering ends, a muscular pharynx leading to the gut, flame cells, Circular and longitudinal muscles they also have germinal cells which give rise to more redial. This stage consists of active larvae which can move about in the snail body .

3rd stage:

The germinal cells of the redial give rise to cercaria larvae. This larva has a rounded body provided with a tail. It contains two suckers (oral of ventral) and the excretory system. When mature, they leave the snail through the pulmonary aperture of the snail and enter the water, encyst on vegetation or may be taken by a sheep when drinking water or eating the grass.

The cyst is small transparent objet with a yellow or browns tint. In the herbivorous the cyst wall is digested by the gastric juices. The metacercariae pass-through the gut wall and coelom, reaches the liver.

The young liver flukes lies in the tissue of the lived and later in seven weeks they reach the bile duct.

NB:

Miracidium develops into a sporocys -------> rediae -------a cercariae.

Write down the effect of liver fluke on the host?

**Adaptations of the flukes to parasitism:**

1. Production of large numbers of eggs followed by polyembrypny of each larva ensure survival and overcomes the great mortality rate during the course of the parasits to find the proper host.
2. Presence of secondary host enswer survival and production of more individuals by polymbry ony before primary host is reached.
3. Possession of anti – enzymes which make the parasite not to be effected in digestive enzymes of both hosts.
4. Possession of suckers for attachments to the host and spines below the outicle prevent them from being washed away when bile or blood flows.
5. Hermalphroditism ensures fertilization and where sexes are separated male and female are always in close association.

**Class cestoda (taenia sp / tapeworms )**

Characteristics

- The body is made up of separate but identical segments called progolottis. The progolotids are joined in series to the head to wards the posterior end.
- The body surface is not ciliated
- They have no digestive system .
- They have scolex at the anterior end which is attached to the host by hooks of snckers.
- They show strobilization, a process where proglohids are constantly budded off.
- They have a thin cuticle protect them from the hosts digestive enzymes. However it allows food such as glucose and amino acids to n be absorbed from the intestive of the host.
- Each proglotid (segment) consist reproductive organs. (ie they are hermaphrodite) self fertilization within one segment can occur.

**Adaptation to Parasitism:**

1. The taenia /Tapeworm has developed hooks e suckers for firm attachment to the intestine surface of the host intestine.
2. It is ribbon – like (highly flattened) so that it cannot be remove easily .
3. They produce anti –enzyme which prevents the effect of hosts digestive enzymes.
4. Surface prevent them to be digested by enzymes host.
5. They secret a layer of mucus on the body surface to prevent to be digested .
6. The problem of finding a new host;

-Each proglottids is sexually comlete being hermaphrodite , -this ensures fertilization of the egg, they are highly developed organism to the level of each proglottid being sexually sufficient in having both sexes.

-Production of large numbers of egg to overcome the high death rate and loss of the ears.

- Production of encysted eggs a larva to overcome adverse condictions.

**PHYLLUM ASCHELMININTHES** (Nematode eg Roundworms –Ascaris ).

Characteristics:
i)The body is round ,slender ,tapering at both ends.

ii)They are bilateral symmetry and cephalization .

iii)unsegment worms.

iv)The body is triploblastic and possess an unlined body cavity called psendocoelom (false body cavity).

Psendocoelom – acoelom which is not a true coelom because does not occur within the mesoderm but it is between mesoderm’s is not endoderm’s . Also the cavity is not lined by an epithelial peritoneum.

v)Body is covered with tough cuticle .

vi)Have a complete digestine tract with an anterior mouth and a posterior anus.

vii)They have only longitudinal muscles which give flexing motion.

viii)They possess separate sexes female larges than male – no asexual reproduction.

HABITAT

-Free living in soil or water or parasite of man, demostic animals and plants.]Example of parasitic

a)Ascaris lumbricoides –Intestinal roundworm in man.

b)Aricylostoma duodenale –Hookworm in mam intestine .

c)Wchereria bancrotti – cause elephantiasis

- live in blood a hymph.

d)Melodogyne –cause galls on the roots of tomato plants leading to wilting a poor growth.

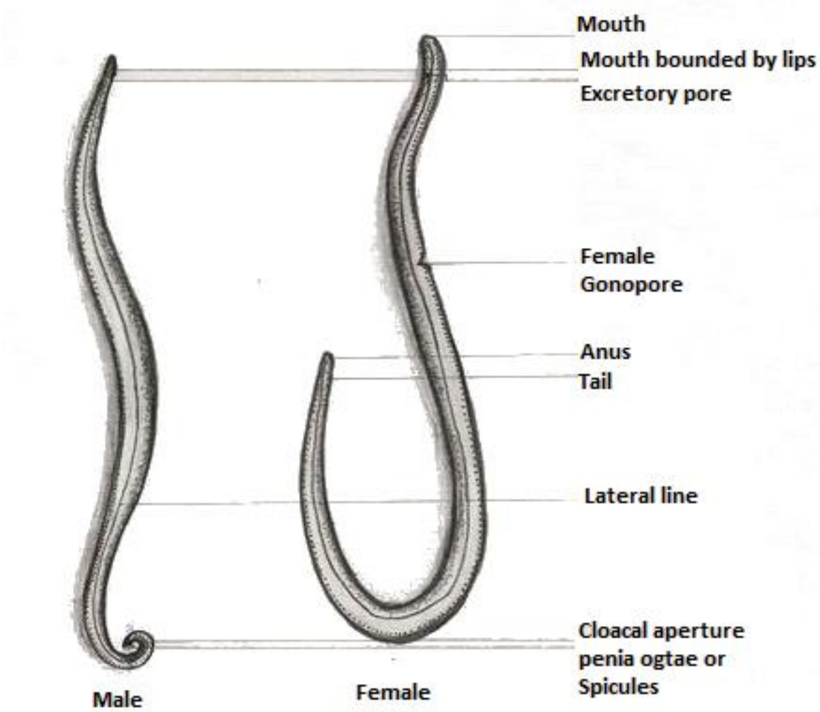



Fig: Ascaris Lumbricoides.

They are white or yellow to pinking ,cylindrical worms, non segmented ,tepering at both ends. At the anterior end there is a muscular sectorial pharynx which leads to a straight alimentary canal .

There is a false body cavity (pseudocoeom) and a brain but no circulatory system and no definite nerve cord.

Life cycle:

The parasites copulate in the hosts intestine and the unripe fertilized eggs with a farces in large numbers into the soil.

Alarva developed in the eggs after 3-4 weeks under warms, moist shady condition. In drought or cold condition s the eggs lie dormant for three or more years.

When eaten the embrocated eggs hatch in the ileum into a small motile larva which burrow and penetrate the mucosa lining and aculeate round the body through the veins or lymph vessels to the lungs ,where they mouth and groove in size pass up the air passage to the pharynx.

Coughed and swallowed again to the esophagus, stomach then to the intestine.

In the ileum they mature as they feed on partially digested food .Fertilization taken place and eggs are passes out in two month after infection of the eggs.

Pathogenicity (effects on the host)

1. Mainly abdominal pain.

2. Small hemorrhage of lung cause by burrowing of many larver .

3. Borrowing of many larvae through the liver a lungs cause inflammation of these organs and symptoms like pneumonia in lung inflammation.

4.Worms laver may migrate to other organ e.g. kidneys, brain ect a cause inflamition serious illiross or death of the host

Preventions:

1. Proper disposal of human faeces

2. Proper washing of hands after siol handling any food.

3. Vegetable eaten in raw must be well washed.

4. Keep short finger nail.

**Adaptation of the parasite**

1. Lays abundant number of eggs to overcome a great loss in the long life history.

2; Lays tough shelled egg so that they can withstand adverse condition.

3. Laying unripe eggs so that they can develop outside the host and give sample time to be taken by the host.

4. Possession of tough cuticle and antienzymes resistant to hosts enzymes digestions.

**COELOMATE ANIMALS;**

Annelids Arthropods and chordates tare called Coelomate Animals due to the possession of a true coelom.

Coelom is the main fluid filled, body cavity of many triploblastic animals occurring in the mesoderm in which the gut is suspended, and lined by a thin layer of epithelial cells known as the peritoneum.

The fluid filled coelom provides some advantage to the animals.

a)This space within the body cavity ,the reproduction and digestive organ can evolve more complex shapes and functions.

I.e. it provided large cavity in which organ can develop and function freely visceral organ are such as the heart, lungs, liver, kidneys gonads etc.

b) In this fluid filled chamber, the gut tube and other organ are cushioned and thus provide better protector.

c)Since ,this liquid cannot be compressed ,the pseudo coelom or true coelom when present can act as a hydrostatic skeleton /water skeleton providing support and rigidity for the soft animals e.g. earthworm which allow the locomotion by whipping movement .This is because the fluid cavity can change its shape without change in volume.

d) The activities of a suspended gut can take place undisturbed by the activity or inactivity of the animal’s outer body wall.

I.e. The coelom which separates the gut from the rest of the body wall enables the gut to move independently of the body as a whole .And thus food can pass along the gut by peristalsis while the animals is otherwise quiescent .

**PHYLLUM ANNELIDA**

The term Annelid means tiny rings and refers to the external segments visible on members of the phylum.

General characteristics ;

i) They are triploblastic and coelomate animals.

ii) They are bilaterally symmetrical there similar segments. Each segment or metalmark contains a number of eg portion of the body wall,gut, coelom,nerve,pair of chaetae (bristle /setae pair of nephritis, and segmental blood vessels.

∴.But the segment ,in metameric do not function as independent unit but are coordinated as integral parts of the body.

iii) Body wall and digestive track both with layers of circular and longitudinal muscles and each segment is separated from the next by an internal partition or septa (singular septum).

iv)Excretory system typically of one pair of nephritis per segment each removing excess water and blood stream by means of ciliated funnel and excretes them through a pore.

v)They have closed circulatory system of longitudinal blood vessels with lateral branches in each segment.

Ë¸.The contraction of several heart or muscular vessels, pumps the blood continuously through the closed circuit.

vi)Their sexes may or may not be separated .

Eg –earthworm –hermaphrodite. Marine worm – shed sperm a eggs into seawater ,where the gamete unite a develop.

vii)Their body covered by thin moist cuticle.

viii)Respiration is body by epidermis

ix)They have nervous system with pair of celebral ganglion (brain) and connective to a double mid ventral nerve cord extending length of the body with a gangling and pairs of lateral nerves in each segment.

i.e. –each segment contains dusters of nerve cell connected to the brain by nerve cords.

**Classification of phylum Annelid**

(a)Polychaetae -marine worms

They are marine worms characterized bt the presence of large no of bristles chaetae eg nareis.

-Aquatic being free swimming in water or burrow in the mud or sand

B) **OLIGACHAETA eg earthworms**

They have few number of chaetae eg lumbricus terrestris

**Habit**

In damp soil fresh water

c)Hirudinea - the leeches

These are ectoparasites commonly knowns as leaches. They are highly specialized and have lost mmost of structure typically of the phylum.

Eg.- chaetae are not present Few segments present Example Hirudo meducinallis

**Class oligochaeta**

This is a group of terrestrial earth worms and resh water species eg. Lumbricus terrestris

**Characteristics**

i)They are bilaterally symmetrical

ii)They show cephalization ie have head where the nerve ganglion are located

iii)They possess true coelom lined within mesoderm

iv)The body wall is concerned with a protecture cuticle.

v)They have longitudinal muscles that can shorten the worm and circular lengthem it.

vi)They are hermaphrodite

vii)They have no participodia (side feet) function in movement and gas exchange.

viii)Obtain a grip on the substratime during crawling.

There is a thickened region called clitellum used to secrete a cocoon which eggs pair.

ix)Every segment has four pair chaetae

x)Have thickened muscular blood vessels in the auterior regions act as a pums (heart) help to move the blood in the body,

**General structure**

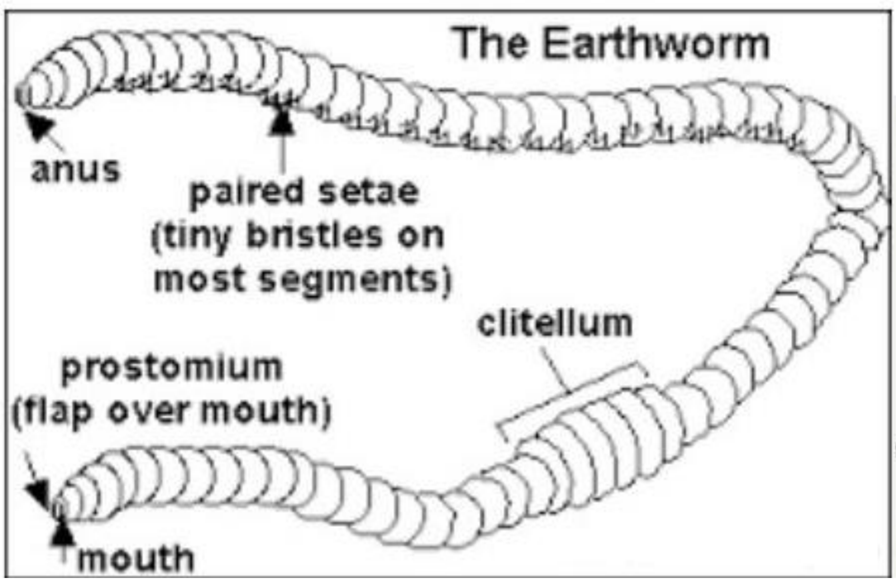
The body of an earth worm consisting of about 150 segments growth to about 25cm long. This animals is slender with a terminal mouth at the anterior and anus posterior.

Anteriorly is the mouth which over hung by the prostomium that is not a true segment the lower border of the mouth is know as peristomium

With the exception of the first segment has four chaeta/setae from segment 32-37 is a thickened region called the clitellum which secretes materials forming cocoon which contain eggs.

Excretory opening except on the 2nd and 3rd segment and the last each segment bears a Nephridiopore infront of chaete.

Reproduction – opening are separated the openings of the sperm thecae with seminal fluid is into these the seminal fluid from the other worm ventrally on segment are two very small slits which are the opening of the oviducts (female openings) and on segment 15 are two prominent open logs of the vasa deferential (male openings)



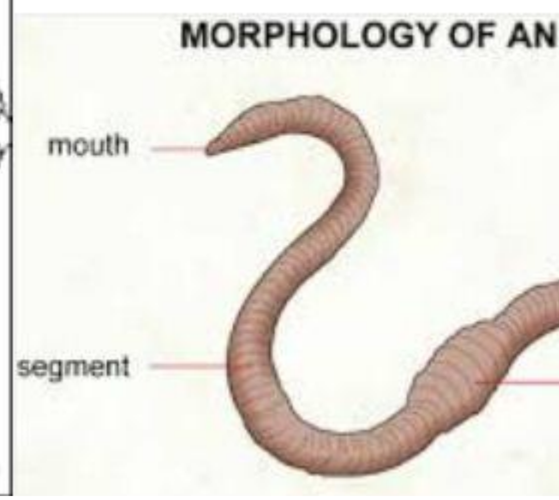



Fig: Earthworm

**Adaptations of earthworm**

a)Their tapered end shape is ideal for burrowing and the chaetae of each segment used to griping the ground when the animals move

b)Due to lack of an enzyme of digesting cellulose the efficient grinding apparatus in the gizzard is well suited to break up plant tissues.

c)The secretion of mucous by the worm skin serves to bind the walls during burrowing.

d)The ability of the worm to thrust the earth aside when it I looses or to consume it when it is tightly packed ensure sufficiently under both types of soil conditions.

e)The formation of cocoon ensure efficient provision offspring during unfavaurable condition .

f)They are eating soil containing dead and decaying plant endless food matter so ensures an endless food supply (ommirous).

**ECONOMIC IMPORTANCE OF THE EARTH WORM**

-Their burrows provide nature drainage channels and improving soil aeration

-They increase the depth of topsoil by burrowing into subsoil and bringing it to the surface.

The topsoil produced by worms is neutral thus tends to reduce both acidity and alikalimity in soil

-Improve soil fertility.

-The ability of swallowing soils and the letting it pass through the length of the worms out through the anus such soil is rich in minerals eg nitrogen and phosphorous since it is mixed with vegetable matter.Texture formation

-The constant passage of soil through the gut reduce the particles to a fine state of division which provide an ideal medium for germinating of seeds

-Used as baint by fishermen
-Food for fish

**PHYLLUM ARTHOPODA**

Arthropods are the most successful of all animals. About two third of all named species on earth are arthropods.

General characteristics of the phylum

1. The epiderma is covered by a hard chitinous cuticle that make the body covering water proof
2. They have exoskeleton or external skeleton that surround the animals and provides strong support as well as rigid levers.
3. They are bilaterail symmetry
4. They undergo moulting lecdysis process by costing off exoskeleton during development growth.
5. Their body show. metamerically segmented ie formation of segment which are more less similar.
6. The segmented body is regionally differentiated into regions/sections such as the head thorax and abdomen.

This tendency of the body being differentiated into distinct regions is knowns as Tagmatization.

Eg at the head read regions grew other appendages.

Mouthparts that allow chewing sucking.

Antennae that for sense

7. They have efficient respiratory organs provie a large surface areas for collecting oxygen and releasing co2 quickly which allo them to metabolize by generating enough energy move rapidly.

Eg insects have traclea branching networks od hiollow air passages spiders

Spider of relative have book lungs chamber with leaflike plates for exchanging gases

Aquatic arthropods have gills flat tissues plates that act as gas exchange surfaces.

8.Organs of special sensea are typically present.

Eg. Special compound eyes which consists facets and simple eyes capable for color vision and can detect the sli0ghtest movements of prey or predactors

9. Their circulatory system is open with few vessels that blood flows through cavities between the internal organs and not through closed vessels.

10.The coelom is greatly reduced the perivisceral cavity being the haemocoel

11.Excretory structute which eliminate metabolic waste products is by malpighian tubeles that extend from the digestive track into the blood.

12.They are triplobastics

13. Sexes are separated.

**Five main clases of arthropods**

- Crustaces
- Chilopoda
- Insecta
- Diplopoda
- Acachnida

**Class crustacean**

**Characteristics**

They posses two body divisions

Cephalothoraxes (the tendency of the head fused with thorax ) and the abdomen

Have carapase or an exoskeleton hardened with calcium salts that act as protective shell.

Have two pairs of antennas

The respiratory structure are gills

They are equatic

Example -crab

-cray fish

-lobster

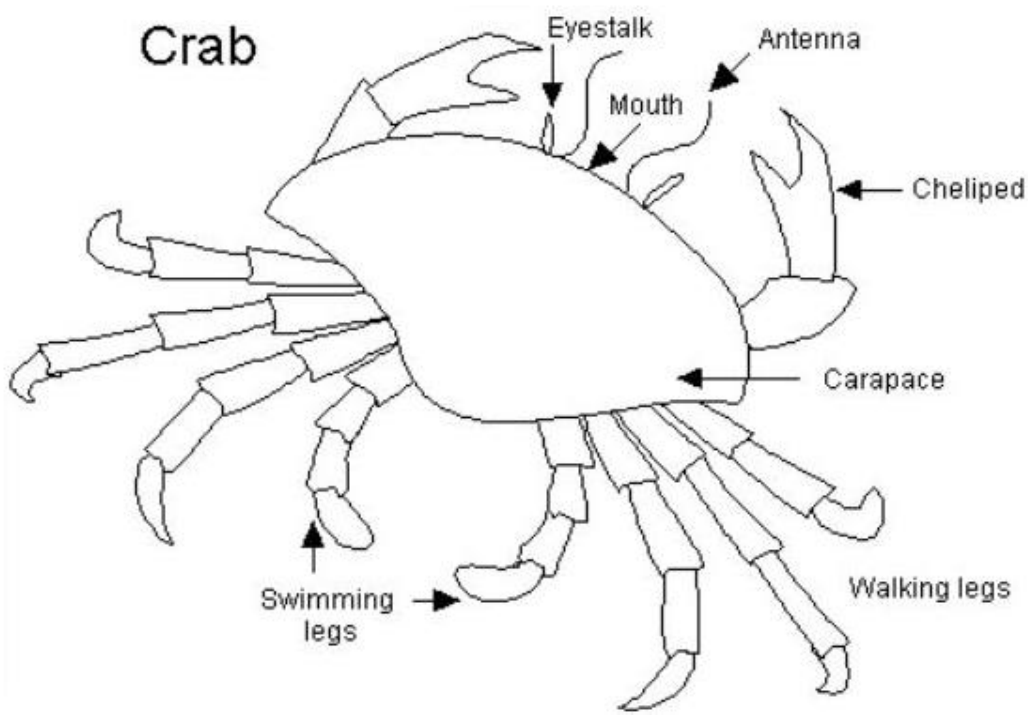



Fig: Crab

**Classification chilopoda**

**Characteristics**

-There is a district head but the trunk has no obvious divided into thorax and abdomen

-Have one pair of antennae

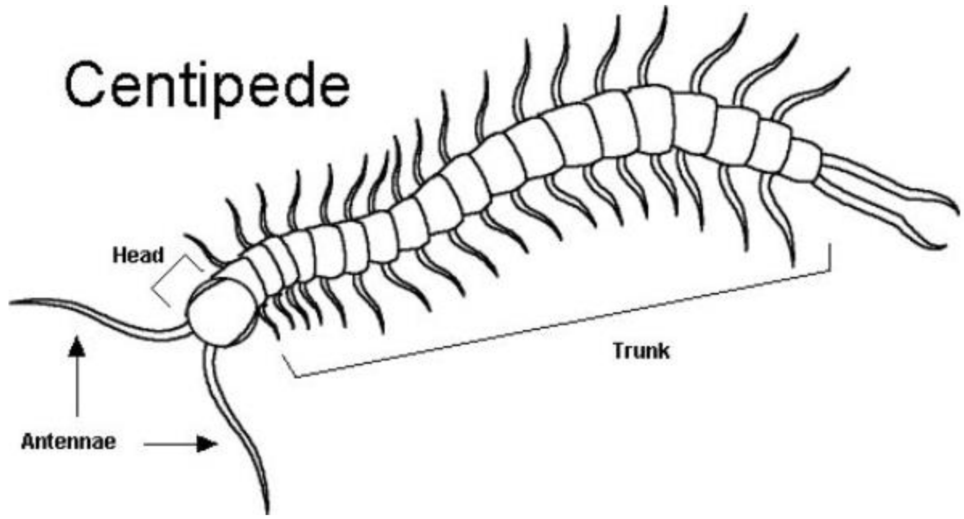
-Have one pair of legs on each body segment

-They are all carnivorous and feed mainly on insects worms etc

-The first trunk segment have appendages that modified into a pairs of poison fangs

-They are terrestrial animals which lives in moist places in soil under stone etc.

Example - centipede

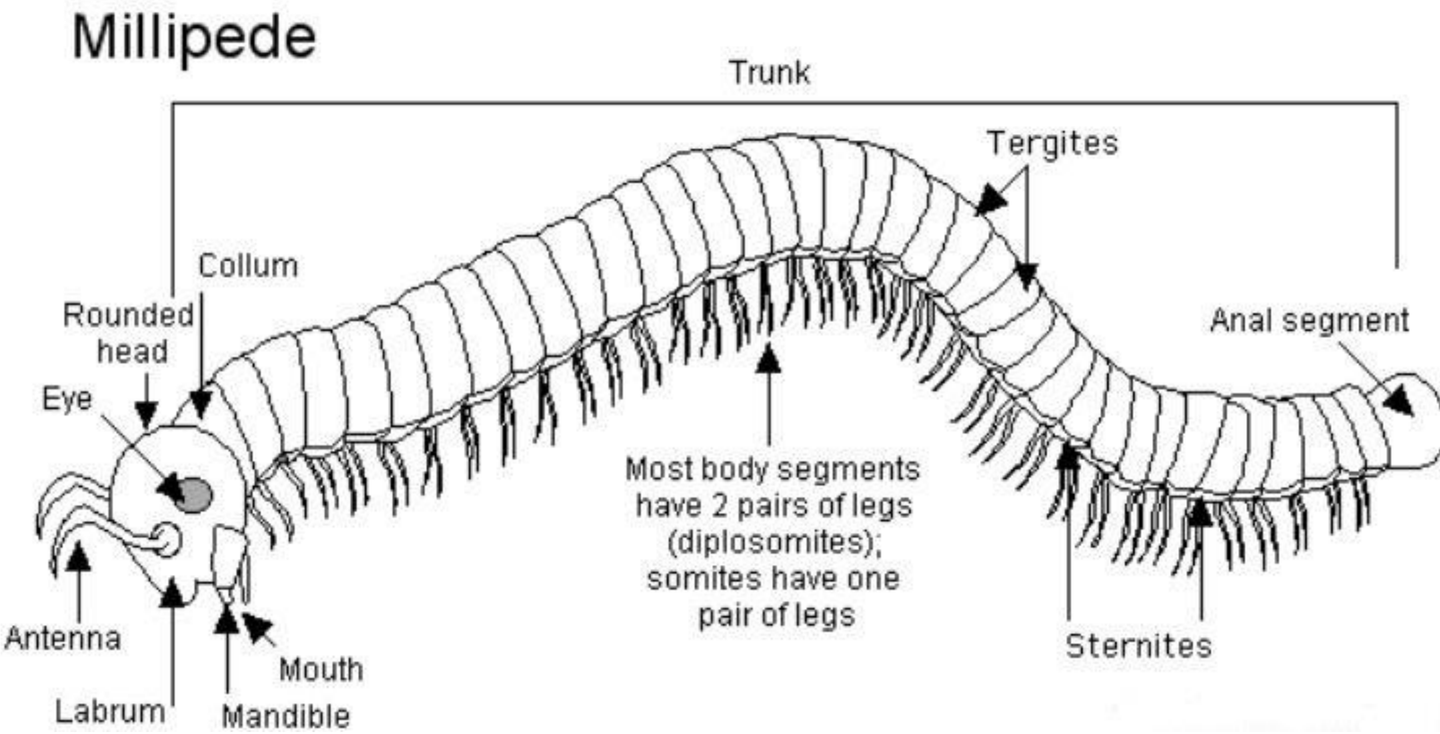



Centipede

**CLASS DIPLOPODA.**

Characteristics

- They are slow moving counterparts to centipede
- They have two pair of legs per segment
- They are round, not flattened body.
- Their bodies consists of haed region followed by numerous segments.
- Most millipede are herbivoures.
- Have one pair of antennae.




**Class Arachnida**

Characteristics

- They have no antennae

- The bodt is divided into two region a cephalothorax (prosoma) and abdomen (opisithosoma)

- Have six pairs of appendages born on the prosoma

  - one pair of chelicerae or poison fangas
  - used for killing prey or self defense
  - one pair of pedipalps that inject poison
  - foue pairs of walking legs

- Respiration pairs of walking legs.

- Most members are terrestrial

- Most are carnivorous except the mites which are herbivores

Example - spider

- Scorpion
- Tick
- Mites

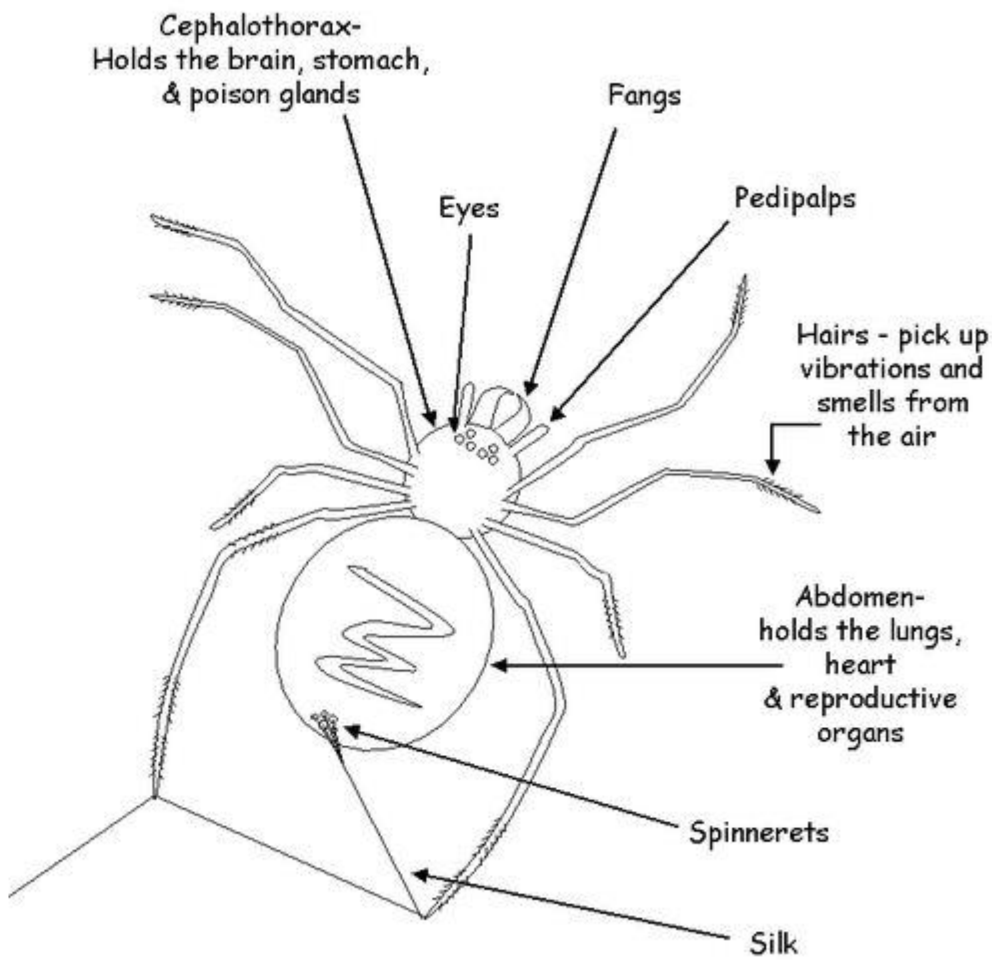



Fig: Spider

**Class insecta**

Characteristics

- The body is divided into three main regions head thorax and abdomen
- Have one pair of antennas born on the head
- Have three pairs of walking legs born on the thorax
- Have on or two pairs of wings or may not present
- Have one pair of common eyes
- The respiratory system is a yacheal system with segmentary spieacles arranged
- Metamorphosis occur during development ie period of rapid transformation of larva to adult or morphological changes animal such as insect

  -Locust

  -cockroach (preriplanet ariericana)

  -housefly

  -bee

  -ant

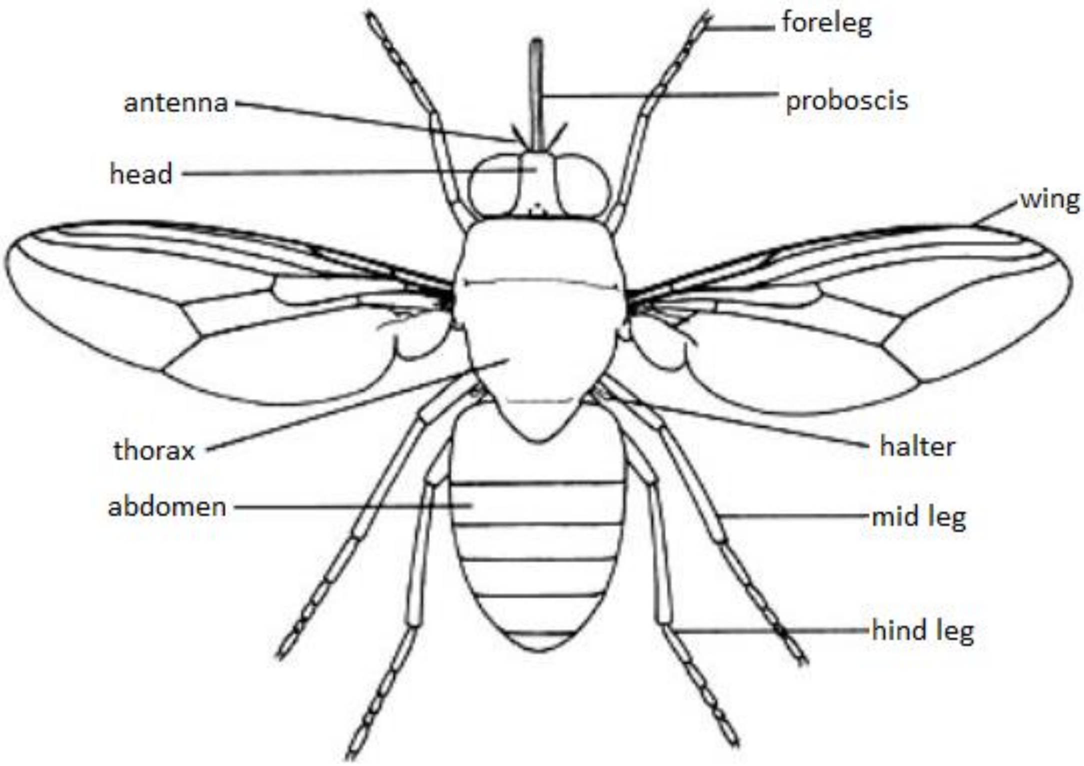



**Fig: Cocroach**

The adaptive features of the arthropods

1. Possession of cuticle

Have wax which restricts water loss from the body surfaces

It forms rigid wings which makes easily fly of the isects.

Also cuticle protect the arthropods from predators since predators found difficult because of hardened exoskeleton

- From invasion by parasite
- From physical environmental (mechanical injury)
- From chemicals such as insecticides
- From abrasion such as insecticides
- From abrasion by the food since the gut lined by cuticle.

2. The mouth parts show adaptive radiation

Their mouth parts modified and specialized according their feeing habits.

The arachnida do not ingest solid food, so they poor salivd containing protease over their prey p suck up the fluid eg spiders of scorpion

3. Presence of sill spinning organs called spinnerets which form we spinning used for trapping insects eg spider.

4. Possession of sensory organs.

5. Most have antennae capable of detecting slightest movements, sounds or chemicals

6. Compound eyes

7. possession of molting (ecdysis) process during development this remove the hard cover and become soft which allow growth

8. the flattened shape of the body enable them to insinuate themselves into small cracks crevices where they are almost inaccessible.

Eg cockproach, centipede.

9. deposition of there are aggs in small crevices ensure a considerable measure of safety for the eggs with the further protection of the tough coat

10. they used claws of the peripalps to crush their prey eg scorpion

The biological success of insects

**Exoskeleton cuticle**

As terrestrial animals prevent against desiccation and other danger to all land animals. Thus it limits size but then solved these problems by undergoing their ecdyses during larva stages usually protected against desiccation and other dangerous to all land animals.

Thus it limits size but then solved these problems by undergoing their ecdyses during against desiccation and by ceasing growth after metamorphosis

- support the body

Tagmatization

this is the tendence of the body segments being differentiated into districts regions such as head thorax and abdomen and each one specialized in function

example – hedd consist mouth pairs

compound eye antennae and each part specialized in function eg mouth parts for feeding cpd eye for sighting Anterna for sensitivity.

The high rate of reproduction

Rapid increase the number of individuals ensured high rate of be able to colonize rapidly a new territory .

**The economic importance of arthropods**

Beneficial insects Harmful

**Agriculture**

-act as a pollinators eg bees butter flies ect.

-pests of crops eg locust cause a great damage within a short period

-pests of stored food eg beetle

**Industry**

-production of honey eg. Honey bees

-production of wax used in polishes candles etc eg bees wax

Production of silk.

**Domestics**

Some insects destroy things at home such as furniture and clothes eg. Ants cockroach

Food for human and demestics animals eg locust honey produced by honey bees crabs drawn

**Vectors of disease**

Some insects transimit serious diseases for example malaria sleeping sickness yellow fever of eleplantiasis etc.

Eg mosquito housefly

Biological control insects have been used in a number of cases to control damaging pests I certain cases isects have been very effective as a predators or parasite to reduce the number of a pests.

Eg wasps ground beetle their lark eat insects that feed on and damage citrus fruits other trees.

Some arthropods cause painfully to human when defending them selves.

Eg scorpion certipende bees.

**PHYLLUM CHORDATA**

Characteristics

The notochord (chorda dorsalis ) of specialized vacuolated cells

This is a stiff but flexible rod situated dorsal to the gut flexible rod situated dorsal to the gut ventral to the nerve cord (cns)

Is the first axial structure bid down in the embryo

It has skeletal function eg muscle attachment and is a skeletal rod serves in supportive functional Extends from the head to during development replaced by the vertebral column.

Visceral clefts (pharyngeal gill slits or branchial clefts) these are paire series of openings (perforations) one the kiteral sides of pharynx.

In the simple (primitive charclates eg cephalochordate urochordata inotachord in the head region ) tail choidata) the pharynx is a sieve live structure with numerous slits used to strain food particles from the water (folter feeding)

In certebrates the number of slitts is greatly reduced and they may be modified for different purpose example.

- In aquatic- fish larval amphibians their walls are lined with feathery gills used for gas exchange.
- While in reptiles buids and mammals they occur only during embryonic development and in the adult from they disappear except the first which become the Eustachian tube.

The dorsal Hollow nerve coord above the notochord part from the brai case (cianium) skill) and posterior part by vertebral column.

Direction of blood flow in the main vessels

They have closed blood system in which blood flow in a special blood vessels.

The blood flows forward toward the heart ventrally and ack ward away from the heart dorsal to the gut.

The directions of blood flow in chordates are in shart contrast with those found in non chardate eg Annects

The blood flo-w is forward in the dorsal vessed downward around the gut in the hearts backward in theventral vessel.

The position of the heart.

In the higher chordates it becomes folded and divided into chambers it is always situated vetrally bellow the gut while in non- chordates it lies dorsally above the gut.

They are bilaterally symmetrical

Limbs formed from more than one segment

Their limbs are outgrowth of the body containing tissive derised from both ectoderm and mesoderm.

Post anal segment tail (true tail

-only found in the chordates

-in higher chordates it has often seven adapted to other uses

Eg – crocodiles as weapon

- many animals for flicking insets

- lizards store food

While in many chordates it is vestigical or absent in the adult

The body division into head neck trunk and fail

No more than two pairs of limbs or any locomotive structures

Eg fins limbs aims

Differences between

| Chordates | Non chordates |
|---|---|
| Possess tail metamerically segment | No true tail |
| Heart is ventral | Heart is dorsal |
| Possess gill slits in some stages of life | Absent |
| Possess notochord | Absent |
| CNS is dorsal hollow | CNS is ventral |

**Classes**;

1.Pisces eg fish

2.Amphibian eg topid, frogs

3. Reptiria eg lizards snakes, tortoise, crocodiles

4. Eves eg birds

5. Mammalian eg man whalesco.rat/mouse

**Class pisces**

Characteristics

-They are aquatic

-Paired limbs - fins pectoral and pelvic

-Visceral cefts persist in adult stage as respiratory well developed

-There is an exoskeleton of placoid

-No middle or external ear

-Eggs are laid in water ie fertilization is external or internal

**Sub-classes**

Chondrichthyes (cartilageous fish ) eg dogfish

Osteichyes (bony fish) eg Tilapia

Sub-classs osteichthyes eg Tilapia

**Characteristics**

-The body is streamlined shape

-The mouth is terminal and horny operaculum

-Eyelicls absent

-They are heaver than cartilaginous fish because bones are denser.

-They posse swim badder a sac filled with air which allows the fish to suspendes at any depth in the water.
-The body is covered with scales called ganoid scales which are over/aping bony plates, sometimes spiny along the edges which provide some protection for the fish.

-They have a highly developed lateral line system which enables fish to detect changes of water pressure and thus the movements ofpredactors prey and others objects in the water.

-Have tail called homocercal the lobes are more or less equal

-They are aquatic exchange of gas is by gills.

They are oviparous they lay eggs (external fertilization) they are poikilo thermic

-Have fins –pectorial pelvic

Habitat

In fresh water of salty water

**External features of Bony fish** eg Tilapia

Body is divided into 3 regions

- Head
- Trunk
- Tail

These given it a streamlined shape which allows it to move smoothly through the water. This are flattened laterally tapering at ends

Exoskeleton is made up of bony scales. This fish is covered with thin scales which overlap one another so that the free endes points backwards. It protected the animals but still allows it to move.

Head –is covered by plates of scales tapes towards the mouth

Function – offering the least resistance as has-a pair of nostril inside which ire the olfactory organs found on the top of the head, anterior to the eyes.

Ear – no external ears.

Organ for balance in addition to receiving vibrations carried by bones of the skull.

No eyelids

Pupils are big admit much light

Operculum (gift cover)- covered five pairs of gill slits found either side of the bo dy in the neck region.

Trunk – have fins of two types

Paired lateral fins

Unpaired median fins.

Paired fins are –pectoral (fore limbs)

-pelvic (h ind limbs )

Unpaired and are – dorsal

- anal (tail or caudal)

**Functions of the fins**

Dorsal and anal fins present the body from rolling side ways hence they help to stabilize the body also prevent unstable movement

**Caudal fins**

-control the direction

-Keeps the fish upright

**The paired fins** (pectoral pelvic)

-Steering and balancing the fish

-Help the fish to change its direction

-Control upward and downward movements

-As me brakes when they extend rapidly at right angels to the body stop the beat against the water they cause the slow forward or backward movement.

**Function of scales**:

Scales are known as dermal scales each other in which case when the fish is moving it offers less resistance or reduce fraction (can easily pass) through the water. They proved protection.

**Function of lateral line:**

To detect vibrations in water

**Function of swim bladder**

An air sac found below the backbone in some fish it is connected to the fish hence of fish can float

Floating – used the volume of gas in the swim bladder must be sinking the volume of gas must be decresed.

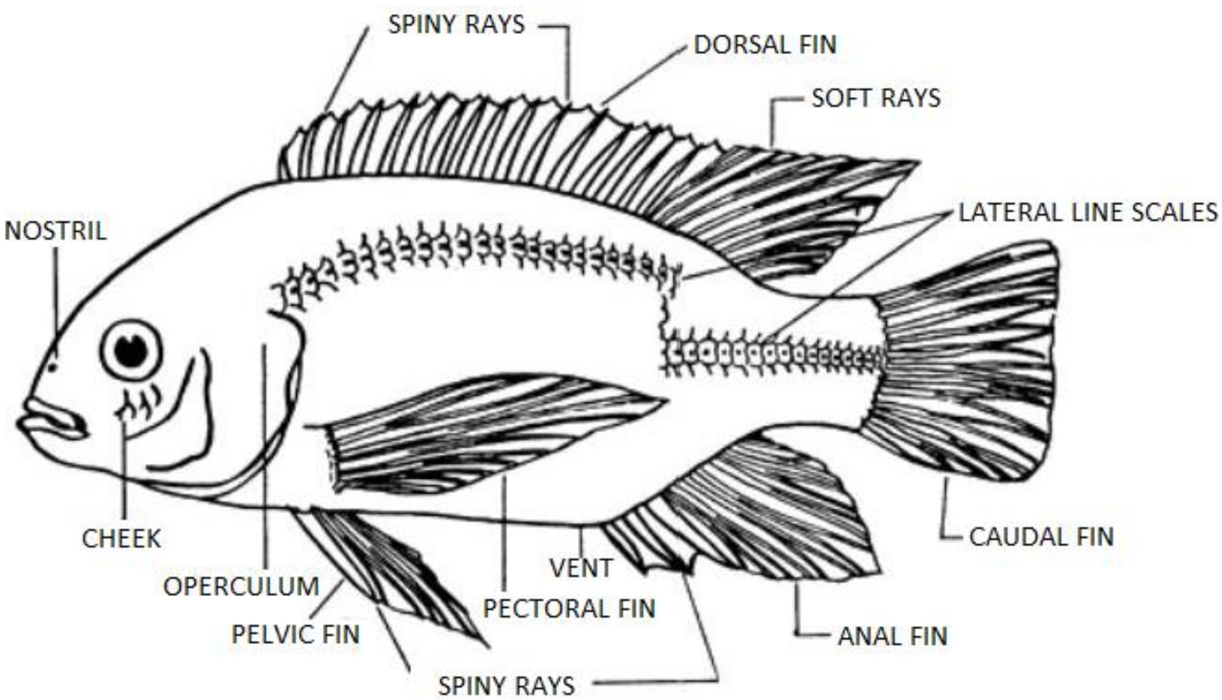



Fig: Tilapia

**Class chondrichthyes**:(cartilaginous fish) e.g. dog fish.

Characteristics:

-Is a marine fish with cartilaginous endoskeleton?

-The body is streamlined.

-They are thicker at the center and pointed at the ends.

-Have narrow eyes without eyelids.

-The mouth is transverse and crescentric .

-Nostrils are present.

-Their tail are heterocercal, the two lobes of the tail is unequal.

-The skin is covered with small pointed abnormal identical (placid scales) similar in structure to the teeth.

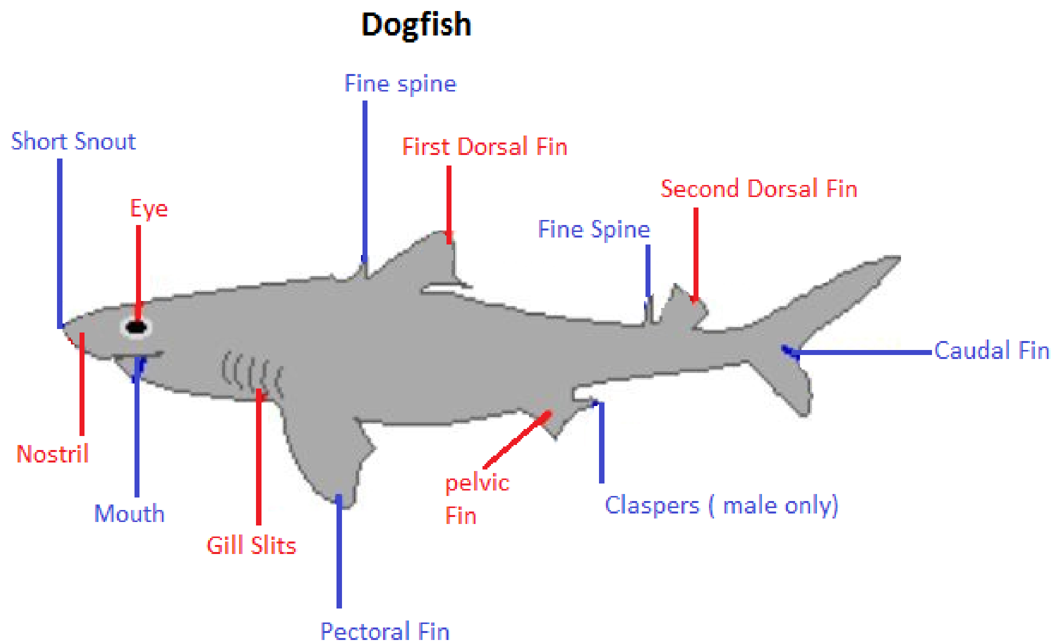



Fig: Dogfish

Adaptation of fish to aquatic life:

1. The body is streamlined to facilitate passage through the water.

2. Gill respiratory organ which enable the fish to utilize oxygen dissolved in water , gill slits outlets of water during breathing .

3. Lateral lines detects disturbance in water and the fish is easily made aware of any approaching danger (strong current or enemy).

4. The various types of fins which their overall function it to control the stability and direction of fish.

5. The body is provided with a powerfully muscular, tail and forms a strong propulsive organ and this combined with a smoothly streamlined body enable locomotion's in water swimming.

6. Eyes are covered with a transparent skin which present $H_20$ from the entering the eye.

7. Sharp scales – for protection from predators an addition of little resistance to forward motion.

- Also scale provides a protective exoskeleton.

Economic importance of fish:

1. Food for man -provide the first class protein hence food value
2. Fish supply many useful products

Eg – cod liver oil – one of the best sources of vitamin A &D.

–Fish oil is used in manufacture of certain paints.

--Provide food for animals e.g. cat, dogs etc.

-Glue is made and bones of fish scales of certain fish.

3. Also fish is a food for other aquatic animals and this is the ecological significant to the aquatic system.

(In food chain web).

**Class Amphibian:**

This is a class of animals which spend part of their life in water and part of it on land, Hence the term amphibian.

-This group of animals are between fish and reptiles. conquest of land necessity taste evolution of certain features which could adapt them to a dry hobbit. e.g frog.

**Characteristics**

-They adapt both aquatic a terrestrial.

- Have two pairs of limbs for swimming a jumping.

-The head is compressed if a very short neck separates the head to trunk.

- Young amphibians breathe by means of gills but the adult ones breath by lung except salamanders.

- Development is by metamorphosis eg frog…

-They are terrestrial but still depend on moist environment because of the constant loss of water through the skin.

- Some of amphibian's possess tails e.g. salamanders a newts.

- Found in the order caudate of no tails e.g. frog toad in order Anura.

Some they are legless scale e.g. caecilian in order gymnophionia .

- Circulatory system was modified so that lungs of skin could be supplied with the blood place through their moist, glandular skin and liming of regenerating most parts e.g. salamanders.

- They pay eggs in water moist places because eggs lack shells membranes that can retain water therefore the eggs can out rapidly.

- Fertilization is externally .

- They are poikilothermic.

- Heart have 3 chambered, 2 articles of 1 ventricle.

- Some amphibians eg Toad, frog have ability of changing the colour of their skin from light to dark.

- This change is controlled by the hormones inter

- Median secreted by the intermediate lobe of the pituitary glands.

- Some frog's toads secrete poisons substance which serves as a means of protection for animals which act as predators.

- Have unitary bladder called all antic bladder used for preservation of water absorbed from blood vessels during dry period or miner nation.

- Young are period herbivorous while adult are carnimonors except salamanders.

Habitat

- Found in grass near water in damp.

e.g. frog, toad ram temporalis

External features.

The body is divided into

-Head

-trunk

-no neck a fail

The body:

-The body usually green with black or dark brown patches of some tints of yellow.

-They are flattened dorsally ventrally

Head

-The head tapers in front a is bluntly rounded.

-Have wide amount in the terminal

-Have pair of nostril for respiration

-Two spherical eyes c are large and protruding, lie almost dorsally but face laterally.

-Eyelids are poorly developed.

- Upper stiff an immovable.

- Lower represent a instating membrane that is transparent, can move upward over the eyeball, to keep it moist in the cur and as a protection when was under water.

-Behind each eye have flat eardrum or tympanic membrane that receive sound waves in the air or water.

Trunk:

- Widens laterally them tapers btn the hind limbs to end at cloaca, c form the anus,discharge undigested food water of urine.

- Ventrally – thoracic reign is firm while abdominal is soft.

- The front limbs are short shout a have four digits.

- It supports the front of the body in the ground a the resting position

- The land limbs are long, muscular folded two three progress .

- The skin is soft, moist a slippery to the touch.

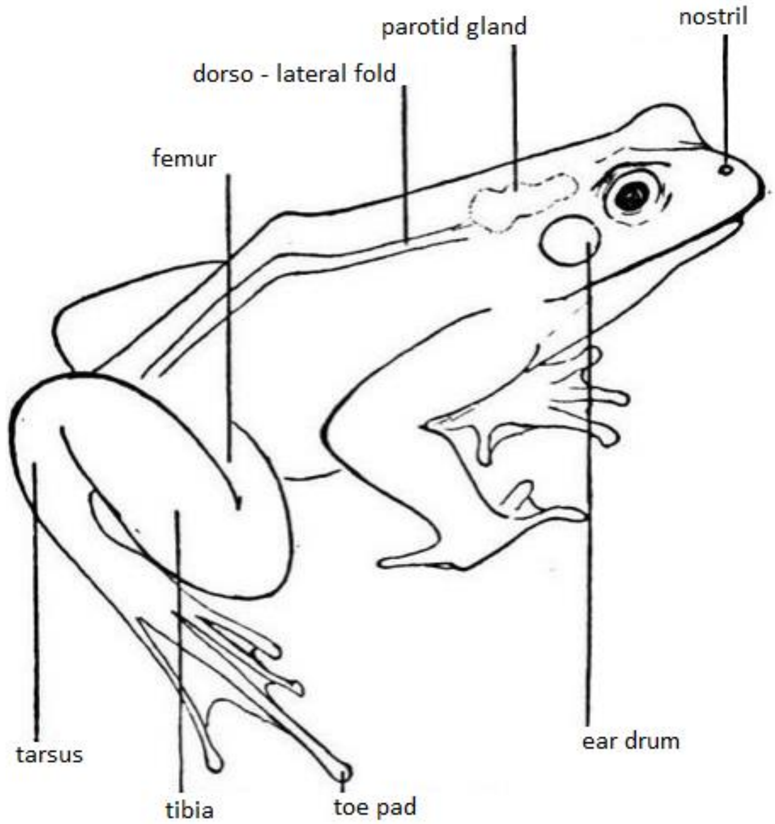



Fig: Frog

Function of the body walls (the skin).

1. Protection by – slippery a poisonous substance which render the animals unpalatable to larger carnivorous.

2. Sensory organs.

-sensitivity is located in various types of sense organ which are stimulated by organ and by temperature changes.

3. Respiratory.

-The moist surface with the thin skin and excellent blood supply make the body wall a very important respiratory organ .

4. Excretory

-The presence of seculars glands which secret mucus, keeps the skin moist thus enabling absorption of $0_2$ and elimination of $CO_2$.

**Adaptations:**

1. Camouflage ,

Pattern of the pigment patches breaks up the shape and act as camouflage in the grass or in the water.

Ë¸Ability to change color blends it to its background.

2.Limbs of girdles modified for jumping and swimming .

3. Swift movement of tongue aids in catching prey , and teem with their sharp backward points render escape of large prey.

4. Protruding eye give a wide field of view and has an accessory function in assisting swallowing.

5. Hibernations, reduce metabolism enables survival when there is no food available and food is stored in special organ eg hiver, store glycogen a facts, allantois bladder stored water.

6. Production of large number of offspring and protection of the embryo in felly ensures survival.

**Class Reptilian:**

Reptilian are air breathing animals and were the earliest vertebrates to become well adapted to life on land.

Members of this class together with bird and mammals are called amniotic since

(a)They bear young ones dive (full developed)

(b)They bear shelled eggs on land.

(c)Complicated mode of development.

Characteristics

1.They lay soft shelled eggs called amniotic egg which protects the embryo from drying out, nourishes it, and enable it to develop outside the water,

-The term amniotic comes from the word animus which is the membrane containing fluid in the which the embryo lies and another membrane allantois visualize contain blood vessels and also possess egg yolk, which contain noonisgment for long period .

2. They have long tail and two pairs of walking legs except snakes, used for clawling a wringgling along using to tail.

3.Frtilization is said to be internally .

4. Have fawns contain teeth set in sockets and all of the same shape (Homodentel teeths)

5. They are poikilothermic

6. Have major nitrogenous waste products called uric acid.

7. Breathing by using lungs.

8. They don’t have a diaphragm.

9. They are aquatic or terrestrial.

External features: e.g. lizard.

-They are covered by scales and shed several times a year when the animals mount.

-They lay small eggs

-Have two pairs of limbs fore limbs a hinds limbs both have 5 digits with claws.

The body divided into

-Head

-Trunk

-Neck.

The head:

-Is pyramid in shape – slightly depressed

- Opening the external nostrils.

-The eyes have lower upper opaque movable eyelids.

- Have tympanic membranes which are more sunk compared with those of the frog.

The trunk,

-Elongated strongly convex dorsally.

- There is a cloaca aperture at the root the tail on the ventral surface.

-Skin –periodical the outer layer disintegrates into fragments interact of being shelled off as in many snakes.

Adaptation of Reptiles: e.g. Lizard.

1. Possessions of dry scale skin is practically impermeable thus prevent water loss.

2.Posses lungs for respiration – breathing is coordinated with movement of muscles a ribs.

3. Reabsorption of water in kidney of rectum is efficient thus reptiles excrete uric acid and the faces in semisolid form .

4. Soft shelled eggs provided protection but porous allow aeration.

5. Herb nation during adverse condition allow them to continue in surviving.

6. Ability to regenerate i.e. their tail may cut off when attached but latest regenerates.

7. Body shape (long narrow body) and color help to give it camouflage.

Eg for moving into holes or underneath vegetation.

8. Improvements of necessary sense organs e.g. eyes, ears, noses.

9.Their brain is more developed than that of amphibians .

Eg development of cerebral cortex .

10.The neck enable the lizard to move so it can catch the prey without moving the the body,

11. Development of limbs for running.

12.Cleidoic development renders the embryo independent of aquatic surrounding because the embryo develop in a ware medium within the egg shell.

Since the sperm could not penetrate the egg shell for fertilization, must occur wthin the body of female before the shell is added.

**Advantages of Reptilians over the Amphibians**

1. Possession of dry scaly body covertly adapted to life away from water.

2. Limbs suits for rapid locomotion

3. Further separation of the oxygenated and deoxygenated blood in the heart, due to their which are imperfectly i.e. have 4 chambered =2 auricles and a partly divided of vertricle.

4.Eggs suits for development on land with membranes and shells to protect the embryo.

**Class mammalian:**

Characteristics:

- The are warm - blooded and have a four chambers heart is 2 auricles of 2 ventricles.
- Possession of dermal milk glands, the mammary glands which produce milk for feeding their young's.
- Most of mammals are at least partially covered by heiry called fur except the whale and porposes, have virtually no hail at all.

Function of fur:

- Temperature regulation acting as insulator
- May also be tactile (sensory of function)
- Protective in function
- They have external ears with a soft flap called the pinna, which used to collects some waves that entering the ear.
- Mammals are heterodyne.

They made up different kind of teeth in the cavity eg incisors, molars, premolars and canine, according their feeding habit.

- Have specialized limbs with bones elongated shortened or broadened, depending on the animals particular locomotors or food gathering needs

Eg antelope have strong slender bones that ailon swift running.

- Majority have a special reproductive structure the placenta, that supports the growth of the embryo to a fairly complete stage of development before birth.

Eg sub-class eutherian.

- Possession of a muscular cliaphram
- Separate the thoracic cavity from the abdominal cavity.
- Importance for efficient breathing mechanism.
- They are viviparity – fertilization is internally, and produce their young ones alive.
- They have highly developed nervous systems and senses smell and hearing in most mammals of sight in a few.
- They provide parental care not only on suckle their young, but depending on the species to guard the new generation fiercely and teach their survives skills.

- Some have dermal glands

Eg. Sweat glands – sweat

Secretion for temp regulation.

- Sebaceous glands – hair secrete sebum a substance of lubricates hair is bactenocidal in nature.

External feature: eg rat / mouse

- They body divided into

- Head
- Neck
- Trunk
- Tail

- Varies in colour from nearly black to pale grey brown.
- They body covered by ur consisting of short few hairs set closely enough form a thick pile
- Have long scaly tail.

Head

- Head is avoid in shape, tapering in the front, where the mouth is small and terminal – bounded by soft upper a lower lips.
- Upper lip exposed large incisor teeth for chiseling action.
- Have pair of nostril.
- Towards to dorsal surface, are the large eyes with movable upper of lower lids.
- At the inner corners of the eyes there are nictacting membranes which can be moved across the eyes to wash it.
- Have long, stiff sensitive hairs called vibrissae, at the side of the mouth nostrils of the around the eyes.
- Sensitive to touch of dark ross of the barrow.

- Have ear with long flexible plena.

The trunk:

- Although wades from the neck, divided into thorax of abdomen by diagram partition.

- Ventrally, the thorax is firm b'se of the sternum of rips while the abdomen is soft.

- On the ventral surface, in the female there are six pairs of mammary glands bear the teats – three on the thorax or three on the abdomen.

- Beneath the tail is the anus of ventral to it is the urinogenital opening.

- On the old male, there is a perineal glands fond between the anus of urinogenital opening (hairless) patch of skin – gives an oclour characteristic.

- Male :

  - The male opening is born on a projection, the penis, which bears a retractable sheath called prepuce. At the sides of the Panis are the tastes contained in the scrotal sacs.

- Female:

  - The female opening is longitudinal slit the vulva which bears a vestigial penis called the clitons on the ventral side. The tail is short and usually bent upward.

- The front limbs are shorter than hind limbs, and both bears five digits ending with sharp claws, modified for jumping.

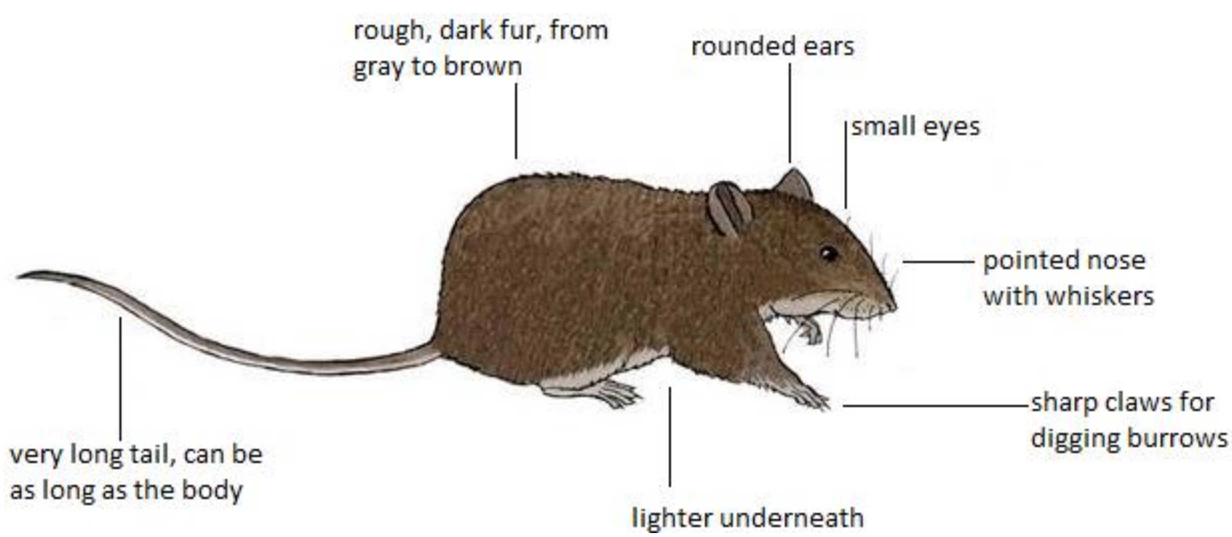


Fig: Rat

Function of mammalian skin: (body wall)

The body wall (skin) provides protection from various hazards: it is an excretory regulation and sensitivity.

a)Physical protection from damage is provided by stratum corneum and fur, while the colour gives some measure of camouflage.

b)Insulation

The hair traps a layer of air near the body surface and this acts as an insulating layer, preventing excessive loss of heat as as well as thickness of the adipose tissue.

c)Excretory organ

The sweet is to some extent an excretory. It consists of water , dissolved salts (Na &Ch) a small quality of urea Co2, where is passed from the capillaries into the cells of the tubules and secreted by them. Generally the sweat is evaporated, but in condition of high temperature or great muscular activity, it may run off the body as fluid.

d)Sensitivity

Nerve ending in the skin are sensitive to a variety of stimuli which are commonly grouped together under the sense of touch. There are endings sensitive to mechanical contact, others for pain and others for high and low temperatures.

e)Regulation of heat loss

The greatest quantity of heat is lost by evaporation of sweat from the surface.

There fore regulation of the amount of sweat will mean regulation of heat loss. It is accomplished by control of the surface blood vessels including those which supply the sweat glands.

**Adaptation of mammals eg rat / mouse**

1. The great length of the gut enables maximum absorption.
2. Viv parity entails internal fertilization of provision for attachment of the embryo by placenta, through which it receives all necessary supplies.

3. In the reproductive organs, the mechanism of internal fertilization is present of coordinated to occur at the heat periods (at the right time)
4. Possession of placenta which provides an ideal means of exchange between the mother's and embryo's blood with the necessary safeguard against dangerous materials.
5. Parental care

The birth process and lactation at the correct period, show further adaptation for care of the young until they are able to fend for themselves.

6. Possession of nictation membrane which protect the eye in duty condition by washing it.
7. `presence of vibrissae for gauge the width of the burrow in its darkest depths.
8. Possession of natural colour for camouflage from predators.
9. Possession of great efficiency in respiratory and circulatory systems and the structure of the skin is admirable adapted to control heat loss.
10. Possession of large Iscor teeth in the upper lip for chiseling action of presence of ear or pinna used to reflect sound waves into the canal of determine the direction of the sound.

H/W

Discuss the economic importance of the phylum Chordata.

**Class Aves eg pigeon** .

This a group of homoeothermic, terrestrial vertebrates which have features. They are highly specialized vertebrates which fly almost every part to their organization, are modified to serve aerial life.

**Characteristics**

1. They are homoeothermic, their body temperature is between 40 -42 c provided by effective insulation of smooth features.

2. They are covered with features which act as an epidermal exoskeleton which provide effective insulation as they maintain a higher body temperature than do most other animals.

3. The fore limbs modified to wings, which provided with large feathers, to give the power of fighting.

4. The sternum and pectoral girdles are modified and save as origin of powerful muscles of wings.

ie. They have lightweight, hollow bones and a breast bone or sternum, enlarged into a blade – shaped anchor for the powerful pectoral muscle that raise and lower the wings.

5. The pelvis girdles and hind limbs are modified to support the entire coat of the body on the ground.

6. Have efficient respiratory system that have a series of connected lungs and air sacs that exchange oxygen of CO2 in an efficient one way flow.

7. Absence of teem, eyes are efficient to enhance vision.

8. Have beak formed in the upper of lower flaws covered by horny sheath.

9. Laying tough egg shelled which are internally fertilized.

10. The skin is loose of dry worn-out sweat gland.

11. Have scaly feet of no urinary bladder.

External features:

Head:

- Small rounded with prominent beak covered with a horny sheath.
- The eyes are large with an upper of lower eyelid, and transparent
- Long mobile neck

Trunk

- Covered by feather – directed forwards and overlap the true tail.
- The domestic pigeon loose heat by painting and have many air spaces in their lungs of evaporation, of moisture occurs from the tongue of epithelia surface of the buccal cavity.
- They have nervous system which is responsible for the regulation of heat loss.

Fore limbs:

- Know as wings bear large quill feathers, divided into three (3) regions

- Upper
- Fore
- Hind which is close bound by skin with only 3 digits

Hind limb:

- Divided into 3 regions

(i) Thigh (ii) shark (iii) foot.

The body wall:

- Has an outer epidermis of an inner dermis.
- Feather are out growths from the epidermis.

Exoskeleton:

- Includes feathers consisting of protective horny scales.
- The scales cover the torso-meta tarsus and the four digits of the foot.
- Each digits terminals into a claw which is also a horny product of the epidermis.

Types of feathers:

Basically 3 types:

1. Quill features

- Found in wings also known as flight wings also known as flight wings, they are large. Strongly joined to the body wall.

- Restricted to the wings of tail.

2. Contour feathers

- Cover the body smooth hairs fills the gaps between the quill feathers.

- They have bulbs which are not strongly joined can be separated easily

- Structurally they are smiler to quill feathers but they are smaller than quill.

- Main suppose of contour feathers insulation against heat loss.

3. Down feather (filo plumes)

- Are stumpy hair like structures beneath the contour feather their bulbs do no interlock

- Are the only feather of a newly hatched birds later on replaced by quill of contour as the bird growths

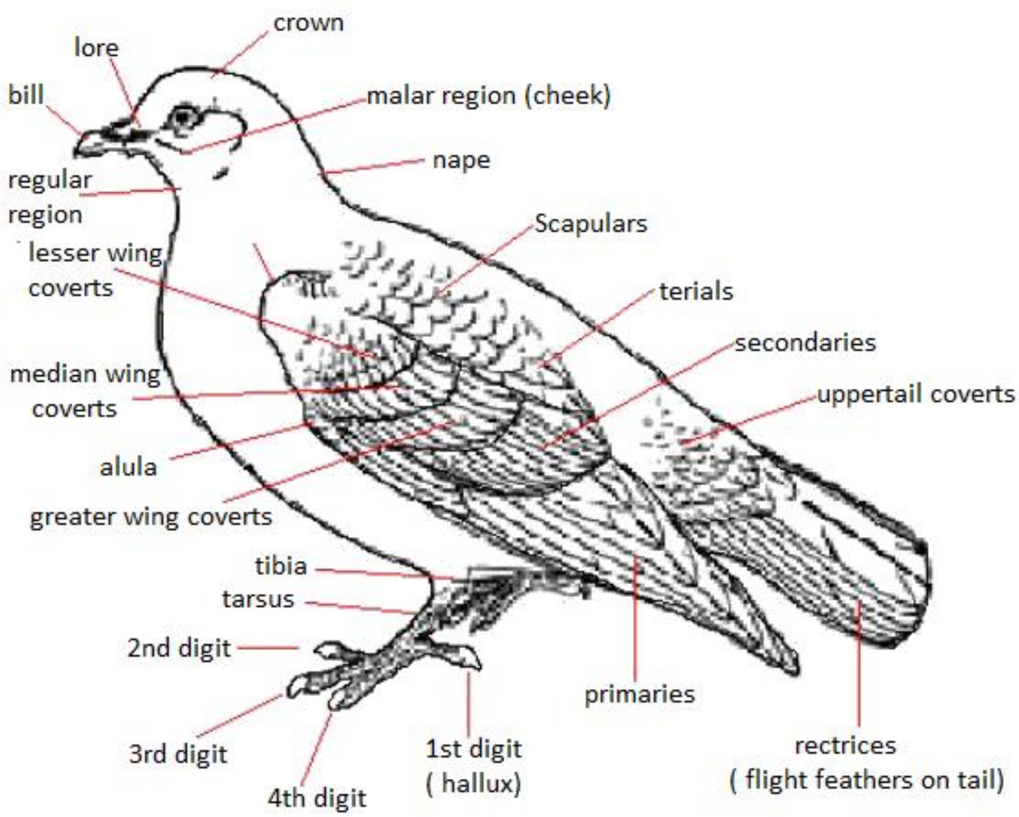



Fig: Pigeon

Function of feathers:

1. For insulation against heat loss especially contour feathers.
2. Importance in flight esp. quall feathers
3. Defense of offence features especially the wings in some birds can be used for fighting.

Adaptation feature of Aves

1) Connection with flight:

- The skeleton is modified for accommodating a large flight muscles and hollow bones (field with air instead of narrow ) to reduce body weight.

- Feathers designed for flight of the fore limbs provide large surfaces area by feathers off small wing area as well as tail that stabilize the bird braking and landing.

- Have an efficient respiratory system supplied by the large air sacs.

- Have got excellent sense of vision

- Very good muscular coordination eg the extension of the sternum (breastbone) for the attachment of the pectoral muscles.

- High body temp:- allow high metabolic rates, which in turn fuels the activities of the flight and leg muscles.

- The body modified into streamlined that makes easily to pass trough air.

2) Cleidoic development:

- Provide large shelled eggs with large yolk amniotic.

- Possess embryonic membranes

ie a) yolk sac

b) amnion – amniotic fluid – most prevention from mechanical injury.

c) allantois – ventral outgrowth of the gut functions as an embryonic bladder, store waste products since the duct of the kidney lead to it.

d) chorion – respiration – it expends of come to lie next or close to egg to shell, also s

Supplied with blood vessels hence functions as an embryonic lungs.

- Form waste products c are insoluble thus require small space for storage .

- Reduction in the ovaries esp. oviduct.

3) Homoeothermic condition:

- Have high metabolic rate which account for high body temp.

- The body is covered by feathers which prevent heat loss – through insulation.
- They lack sweat glands hence prevent heat evaporation.

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# COORDINATION 1

**Coordination** is a linking together of the functions of different organs so that they work at a fine time and rate required by the body.

Coordination is achieved through a nervous and endocrine or hormonal system.

### DIFFERENCE BETWEEN NERVOUS AND ENDOCRINE

| NERVOUS SYSTEM | ENDOCRINE SYSTEM |
|---|---|
| 1. Electrical and chemical transmission (nerve impulse and chemical across synapses). | Chemical transmission through blood system (hormones are the chemical transmitted). |
| 2. Rapid transmission and response. | Slower transmission and relatively slow acting. |
| 3. Often short time changes. | Often long time changes. |
| 4. Pathway is specific (through nerve cells). | Pathways not specific (blood around the whole body) target is specific. |
| 5. Response often very localized e.g. one muscle. | Response may be wide spread e.g. growth. |

### THE NERVOUS SYSTEM

**Nervous system** involves five main components: These are

1.**Stimulus:** A change in the external or internal environment e.g. touch, pain, smell and sound.

2.**Receptor:** A structure which detects the change in the environment e.g. eyes, ears, nose, skin and tongue (sense organs).

**3.Coordinator**: An organ which receives message from receptor and use the message to coordinate the activities in the body e.g. brain, spinal cord, and messages received (impulses).

4.**Effectors**: An organ which is controlled by the brain or spinal cord to bring about appropriate response e.g. muscles and glands.

5. **Responses**: A body activity provoked by a stimulus e.g. pulling away a hand when accidentally one touches a hot object.

Nervous system is made up of interconnected nerve cells or neurones.

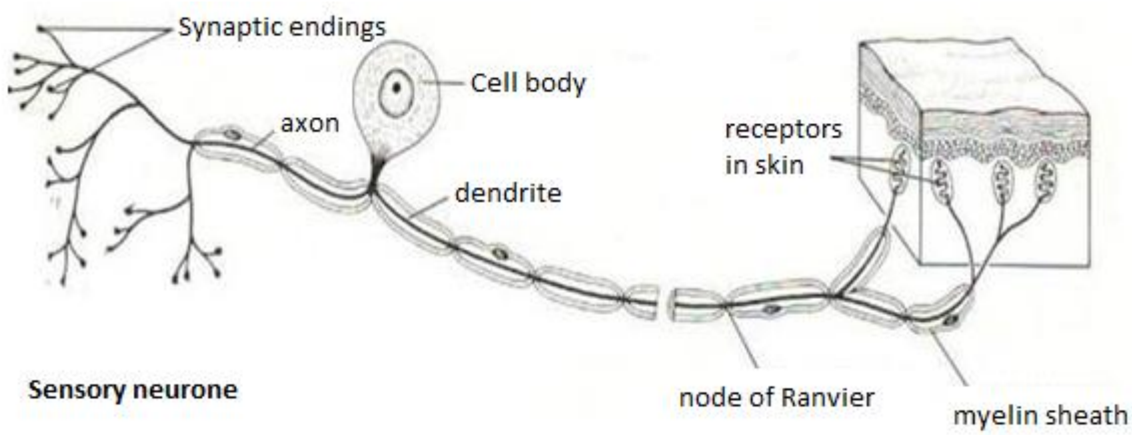
**Properties of neurones which distinguish it from other cells.**

1. **Excitability**– highly capable of responding to stimuli.
2. **Conductivity-** capable of conducting massage along it.

**Functions of the nervous system.**

1. Receive stimuli.
2. Convert stimuli into the form of electrical impulses.
3. Transmit the impulses over a considerable distance.

**STRUCTURE OF NEURONES.**




Neurones are the basic units of nervous system.

1. **Cell body**

Contains the nucleus, mitochondria and other organelles along with Nissl's granules. The prominent groups of ribosomes for protein synthesis.

The cell body has slender finger – like processes called dendrites which connect with neighboring nerve cells.

2. **Nerve fibre**

In nerve fibre we have axon and dendrites. **Axon** transmits impulses away from the cell body and the **dendrites** transmit impulses towards cell body.

3. **Schwann cell.**

Some vertebrates are associated with this cell. The Schwann cell membrane is wrapped repeatedly around the neurone forming a fatty layer known as myelin sheath. This is important for two reasons.

1. It protects nerve from damage.
2. Speeds up the transmission of the nerve impulse (refer saltatory conduction).

- The myelin sheath is surrounded by a thin layer known as neurilemma which is not part of the neurone but the membrane of another cell (Schwann cell) or glial cells.
- Each axon is filled with axoplasm.

  Nerve cells are referred as unipolar, bipolar, multipolar, etc. according to how many dendrones project from the cell body.

Intermediate nerve cells are bipolar has two unconnected fibres a Dendron and axon which enter and leave at opposite sides of the cell body.

Nerve fibres are bonded together to form nerves some carry only sensory fibre and are known as sensory nerves while other carry a mixture of motor and sensory fibres and are called mixed nerve.

## CLASSIFICATION OF NERVES

### AFFERENT OR SENSORY NEURONE

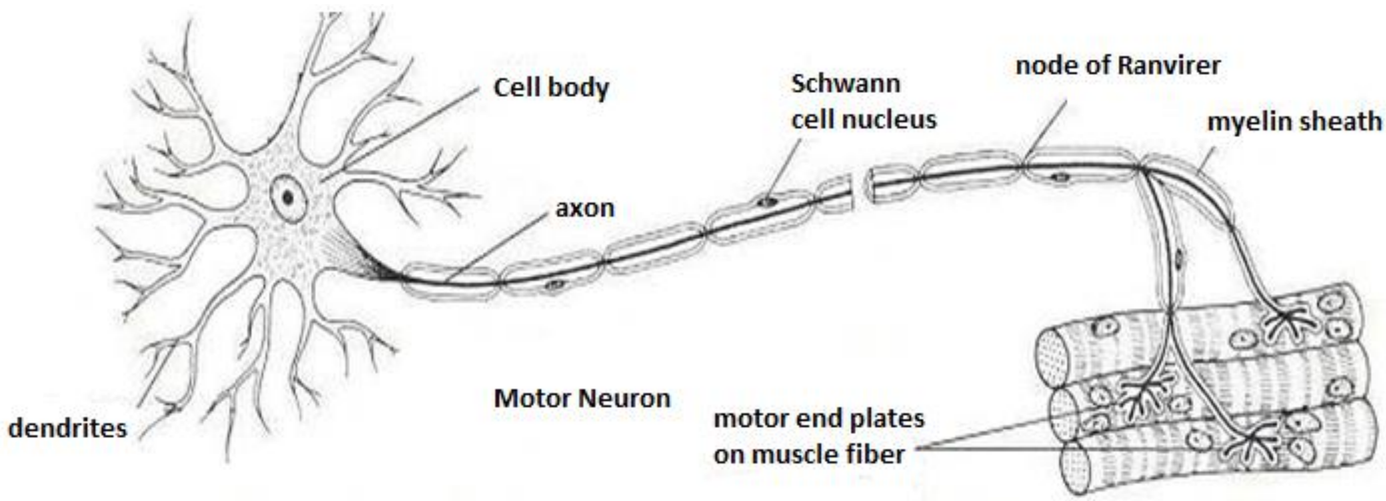
Transmit impulse towards the brain or towards the spinal cord. The dendrite terminates into sense organ. The cell bodies of sensory cells are found to one side of the main nerve fibre and are frequently collected together in a ganglion.

**EFFERENT OR ASSOCIATION NEURONE (MOTOR)**

Carries impulses from the brain or from the spinal cord to the effectors organ.

It is situated in the brain or spinal cord. The terminal part of axon is situated in an effectors organ.

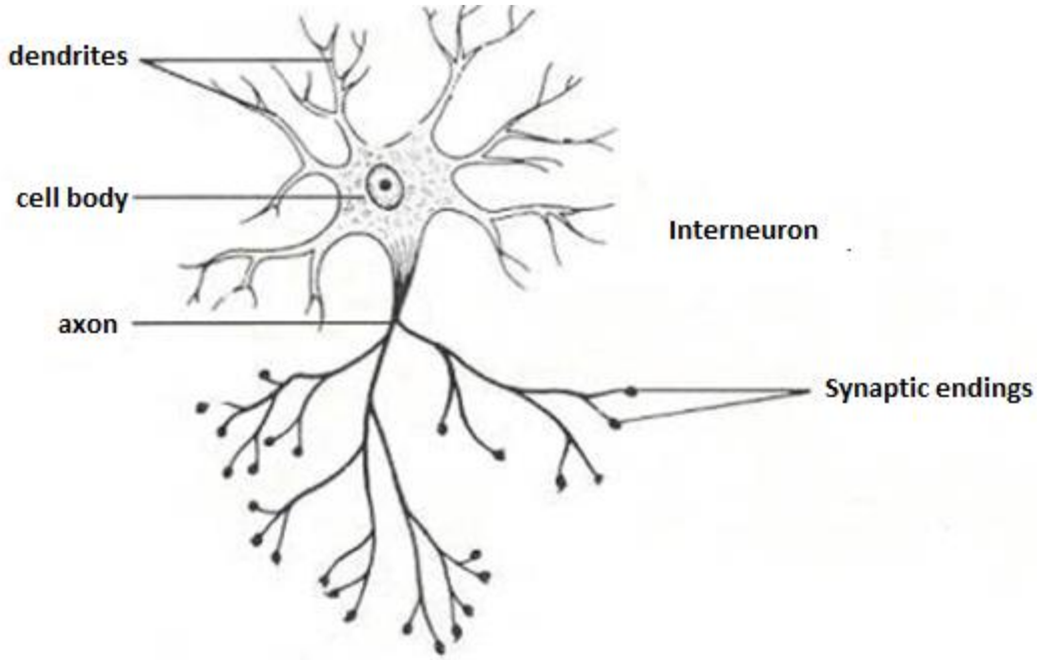
Infantile paralysis or poliomyestitis (polio) sometimes cause destruction of efferent neurons leading to tissue atrophy of skeletal muscles. When this happens no nerve impulse will be reaching the muscles and as such relaxation will no longer be possible. This condition is called paralysis. Under such a condition the muscles diminished in size due to decrease, should paralysis vital organs, the animal dies.




1. **RELAY OR INTERMEDIATE NEURONES.**

   Link afferent and efferent neuron. The terminal part of the dendron receives the impulses from the terminal part of the axon or relay neuron are passed into the dendrites of a motor neuron.

   Relay neuron eternal entirely use in the spinal cord and in the brain.




**SPEED OF TRANSMISSION IN NEURONES.**

2.

The speeds at which the message can be carried depend largely on two things.

1. **The diameter of axon of the nerve fibre.**

   In general the larger the diameter the more rapid impulses travel along it.

2. **The presence or absence of myelin sheath.**

   Myelinated neurone can carry impulses much faster than a (non myelinated neurone.)

- Invertebrate do not have myelin sheath on any of their fibres which are less than 1.0mm in diameter so in general invertebrate nerve impulses it's a well quite slowly at around 0.5m/s. But there are more times when even a relatively slow invertebrate needs to react quickly to avoid danger and allow more rapid passage of impulse to travel at around 100m/s fast for most escape strategies to have a chance of success.

- Vertebrates have both myelinated and unmyelinated neurones. The voluntary motor nerves that transmit impulse to voluntary muscles for example, to control movement are myelinated muscle such those in digestive system have some unmayelinated fibres.

The effect of the myelin sheath is to speed up the transmission of a nerve impulse without a need for giant axons.

**NERVE IMPULSES.**

The nerve impulse is a minute electrical event which is the result of charge differences across the membrane of the nerve fibre.

- It is based on ion movement through specialized protein pores and by an active transport mechanism.
- To look at the event of a nerve impulse we shall consider a typical axon ignoring for the movement size, myelination or type.

**THE RESTING NEURONE**

- The cytoplasm inside the axon ( i.e. axoplasm) has high concentration of $k^+$ and low concentration of $Na^+$ in contrast to the fluid outside the axon which has low concentration of $K^+$ and high con of $Na^+$

- The potential difference (or charge) which exists across the cell surface membrane of all cells is usually negative inside with respect to the outside.

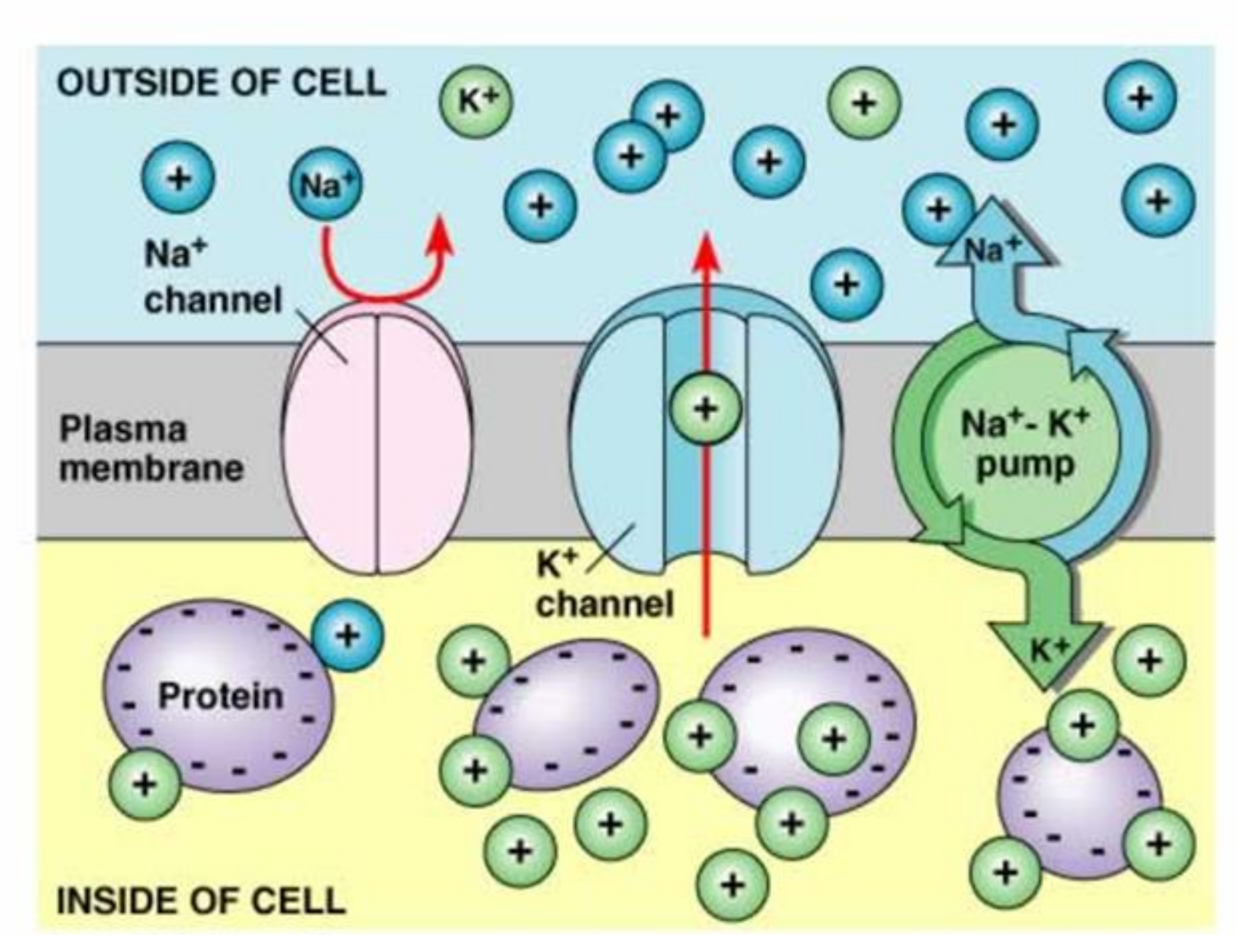
- The potential difference across the membrane at rest is called the resting potential and this is about -70mv. The negative sign indicate that the inside of the cell is negative.

The membrane of the axon like any other cell surface membrane is partially permeable. It is the difference in permeability of this membrane to sodium and potassium ions which sets neurones apart from other cells and gives them their special conducting properties.

The axon membrane is relatively impermeable to sodium ions but quite freely permeable to potassium ions.

It also contains a very active sodium/ potassium pump which use ATP to move sodium/potassium pump which uses ATP to move sodium ions out of the axon and potassium ions in. The function of this is to reduce the concentration of sodium ions inside the axon. They are pumped out and cannot diffuse back in. At the same time potassium ions are moved in but then diffuse out again along the concentration gradient.

As a result the inside of the cell is left slightly negative charged relative to the inside. It is polarized. There is a potential difference across the membrane of - 70mv which is known as the resting potential.




NB:

The resting potential of the axon is maintained by the sodium pump the relative permeability of the membrane and the movement of potassium ions.

**THE ACTIVE NEURONE**

When the impulse travels along an axon there is a change in permeability of the cell surface membrane to sodium ions. This change occurs in response to a stimulus.

When a neuron is stimulated the axon membrane shows a sudden and dramatic increase in its permeability to sodium ions specific sodium channels or sodium gates open up, allowing sodium ions rich in both concentration and electrochemical gradients. As a result the potential difference across the membrane is briefly released, the cell becoming positive on the inside with respect to the outside.

The depolarization lasts about 1 millisecond. The potential difference across the membrane at this point is about +40mv. This is knows as action potential.

At the end of this brief depolarization, the sodium channels close again and the excess sodium ions are rapidly pumped out by the sodium pump.

Also the permeability of the membrane to potassium ions is temporarily increased so that the excess potassium ions diffuse in along an electrochemical gradient.

It takes a few millisecond (about 3 ms) before the resting potential is restored and nerve fibre is ready to carry another impulse. It is this refractory period which ensures that the nerve impulses only transmits in one direction until the resting potential is restored, the part of the nerve fibre that the impulse has just left and cannot conduct another impulse so the impulse can only continue travelling in the same direction.

**REFRACTORY PERIOD.**

Refractory period is the period of in excitability that accompanies the recovery phase of the axon.

**ACTION POTENTIAL.**

The action potential is brought about by the movement of sodium ions through the opened sodium channels.

The resting potential is restored by the closing of channels the action of the sodium pump removing excess sodium ions and the movement of potassium ions along an electrochemical gradient.

**THE THRESHOLDS**

The threshold for any nerve fibre is the point at which sufficient sodium channels open such that the rush of sodium ions into axon is greater than the outflow of potassium ions.

Once the threshold has been reached the action potential occurs. The size of this action potential is always the same. It is all – or- nothing response.

**STUDY QUESTIONS.**

1. a) by using large, well labeled diagram explain the two types of cells from the two different systems of a body of a mammal.

b) The all –or– nothing law states that "The response of an excitable unit is independent of the intensity of the stimulus". Clearly explain

It means that the action potential is either generated in which case it is always the same or it is not generated when the stimulus is too small.

2. Explain the influence of each of these characters in the transmission of a nerve impulse.

i) Myelin sheath.

ii) Diameter of axon

iii) Temperature

iv) Ion concentration in tissue fluid

v) ATP

vi) Osmotic pressure of axoplasm.

3. Explain the structure and function of a synapse

a) Explain why a nerve is always indirectional

4. a) Explain the concept

i) spatial summation

ii) Temporal summation

b) Explain the usefulness of these concepts as far as nerve impulse transmission is concerned.

5. Examine the ionic movements' across the neurons –membrane and the associated phenomena.

6. What is the importance of refractory period?

**REFRACTORY RERIOD**

Refractory period is .....

The refractory period is the time it takes for an area of the axon membrane to recover after an action potential that it takes for the ionic movement to reporalize. This is brought about by the sodium pump and membrane permeability to potassium ions.

For the first millisecond or so after the action potential it is impossible to restimulate the nerve fibre the sodium channels are completely blocked and the resting potential not yet been restored. This is known as the absolute refractory period.

After this, there is a period at several milliseconds drawing which the nerve fibre may be stimulated, but it will only respond to a much longer stimulus than before. The threshold has effectively been raised. This is known as relative refractory period.

**IMPORTANCE OF REFRACTORY PERIOD.**

The refractory period is important in the functioning of the nervous system as a whole.

1. It limits the frequency with which impulses may flow along a nerve fiber to 500 – 1000 each second.
2. It also ensures that impulses flow only in one direction along nerve making it possible to have motor and sensory system with no internal confusion.

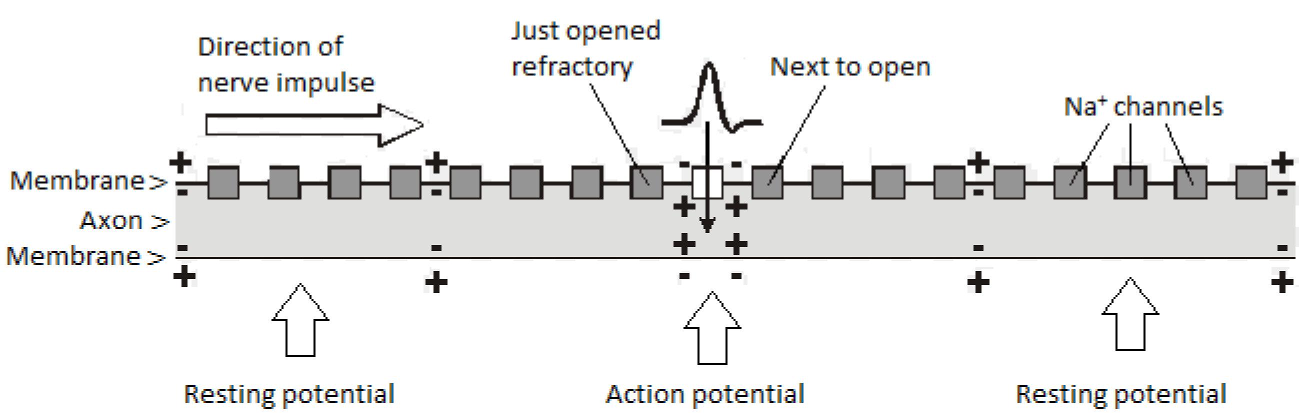
**PROPAGATION OF THE NERVE IMPULSE.**

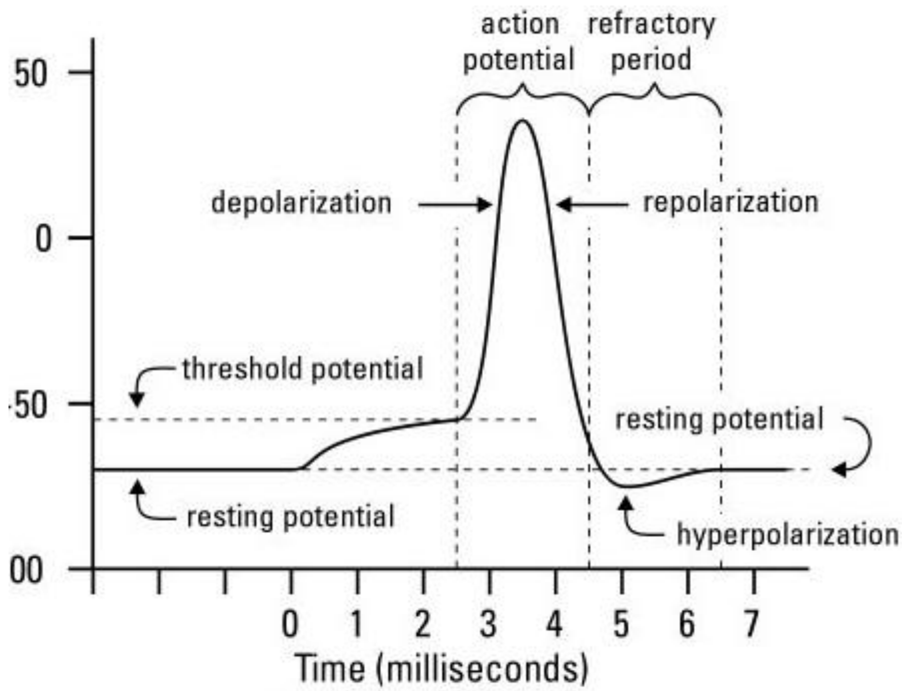
So far we have considered the action potential as isolated events in one area of a nerve fibre. In fact once an action potential has been set up in response to a stimulus; it will travel the entire length of the fibre, which may be many centimeters or even meters long.

The movement of the nerve impulse along the axons the result of local currents set up by the ion movements at the action potential itself. They occur both in front and depolarize the membrane sufficiently to the sodium channels to open in front of the action potential as shown below.

(The refractory period prevents the sodium channels opening between the spikes.) In this way impulse to be continually propagated in the required direction.

The result of these ions movement is to depolarize the membrane sufficiently to set up a new action potential in on one direction only. It cannot go backward due to the refractory period.



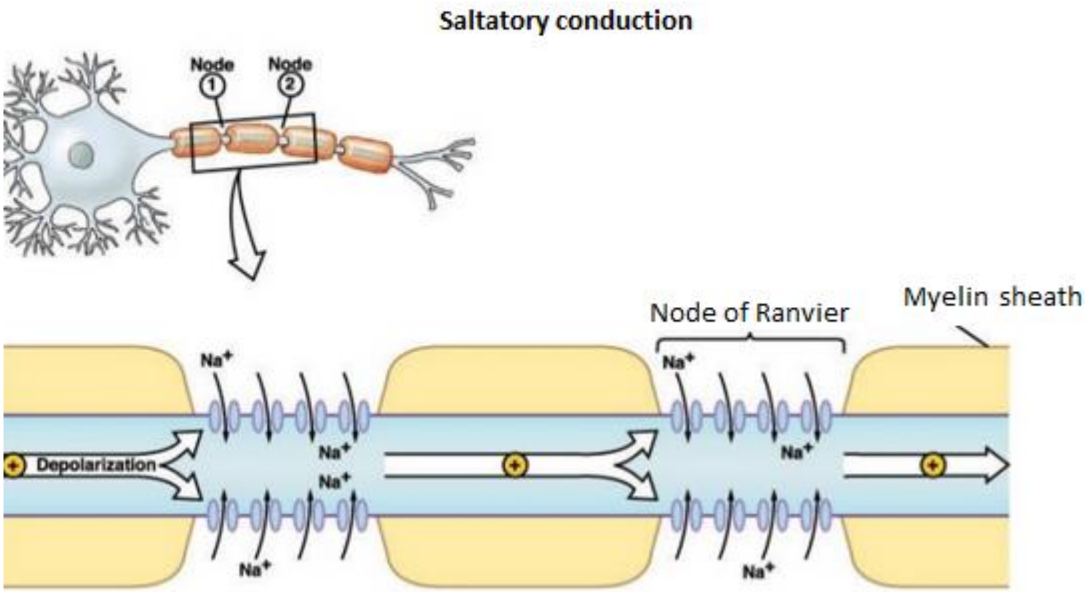


Action Potential in a Neuron

**SALTATORY CONDUCTION.**

In myelinated vertebrate nerves, the mechanism of propagation is strongly more complex. Ions can only pass freely into and out of the axon at the nodes of ranvier which are about 1mm apart.

This means that action potential can only occur at the nodes of ranvier and so they appear to jump from one node to the next as the diagram shows. The effects of this is to speed up transmission as the concentration movements associated with the action potential occurs much less frequently taking less time. This condition is known as saltatory condition from the Latin verb which means to jump.




**LINKING THE SYSTEM**

The nerves are basic units of the nervous system adopted for the rapid passage of electrical impulses to inter communicates. Receptors must pass their information into the sensory nerves, which in turn must relay the information to the central nervous must be communicated to the effectors organ so that action can be taken.

Whenever two nerve cells meet, they are linked by synapse as shown in the figure below.

Every cell in the central nervous system is covered with synaptic knob from other cells several hundred some cases.

- Neurons never actually touch their target cells so a synapse is a gap between two nerve cells with the nerve message must be somehow crossing.

- The electrical nature of the nerve impulse as detected long before to its could be accurately recorded and measured similarly it was suspected that transmission at the synapses was not electrical but chemical long before the electrons microscope and other technique could demonstrate this clearly.

- Once the structure at the synapse had been seen using the electron microscope, the synapse gap would be measured. This settled the argument.

- The gap is simply too wide for an impulse or the size of an axon potential to jump across. Synaptic transmission had to be chemical and all the available evidence confirms this.

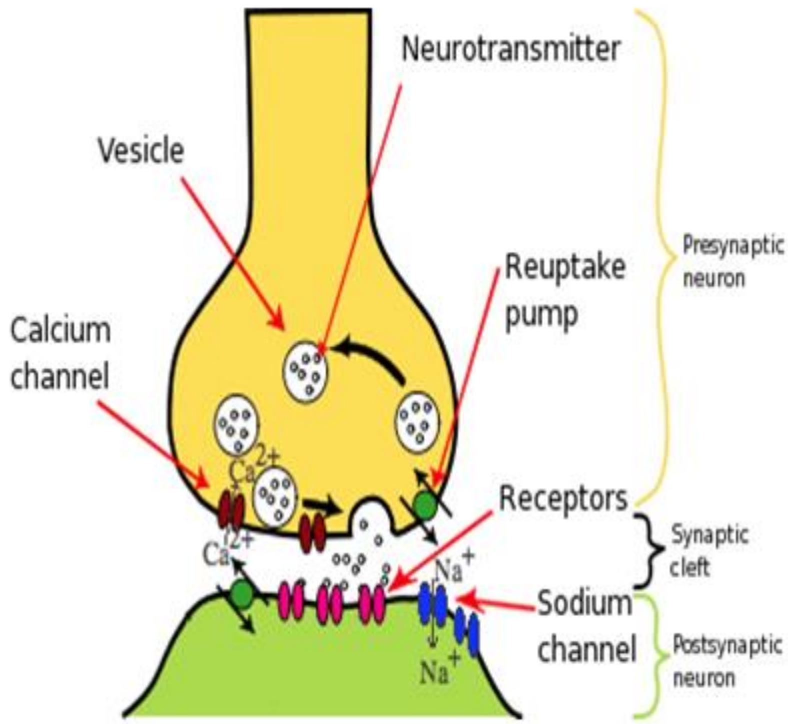
**THE SYNAPSE AT WORK**

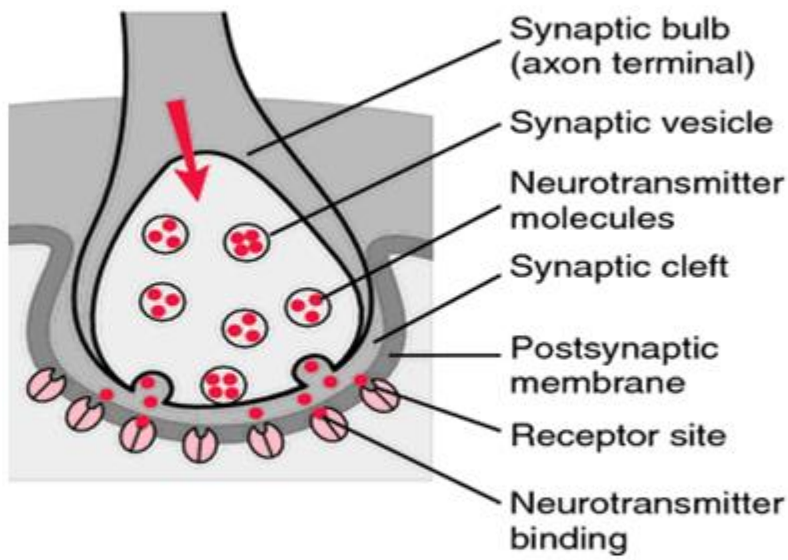
The arrival of an impulse at the synaptic knob increases the permeability at the synaptic membrane to calcium ions.

Calcium ions therefore move into the synaptic knob along concentration gradients the effect of these calcium ions is to cause the synaptic vesicles containing transmitters' substance to move to the pre-synaptic membrane. Each vesicle fuses with the membrane and release the transmitters. Some of the vesicles fuse with the membrane and release the transmitters. Some of the vesicles fuse with the membrane and release the transmitter substance into the synaptic cleft.

- The transmitters diffuse across the gap and become attached to the specific protein receptor sites on the post synaptic membrane.

- As a result, ions channels are opened and there is usually a local depolarization and influx of sodium ions, causing an excitatory post synaptic potential (EPSP) to be set up. If there are sufficient of the potential the positive charge in the postsynaptic cell build up to the threshold level and an action potential in set up this then travels on a long the post synaptic neuron.




In some cases the transmitters have the opposite effect channels allowing the inward movement of negative ions are opened, in the post synaptic membrane, which makes the inside more negative than the normal resting potential. An inhibitory post synaptic potential results, which makes it less likely than an action potential occur in the past synaptic fibre.

Once the transmitter has its effects it is destroyed by enzymes. This is very important because unless the transmitter is removed from the synaptic cleft subsequent impulses would have as effect, as the receptors on the post synaptic membrane would the entire bound.

**THE TRANSMITTER SUBSTANCES.**

The most common transmitter substance found at the majority of synaptic is acetylcholine (Ach). It is synthesized in the synaptic knob using ATP produced in many mitochondria present.

Nerves using Acetylcholine has done its job it is very rapidly, hydrolyzed by the enzymes cholinesterase.

This ensures that it no longer affects the post synaptic membrane, and it also releases the components to be recycled they pass back into the synaptic knob and are resynthesized into acetylcholine

Some vertebrates' nerves particularly those of the sympathetic nervous system produce noradrenaline in their synaptic vesicles and are known as adreneigic nerves.

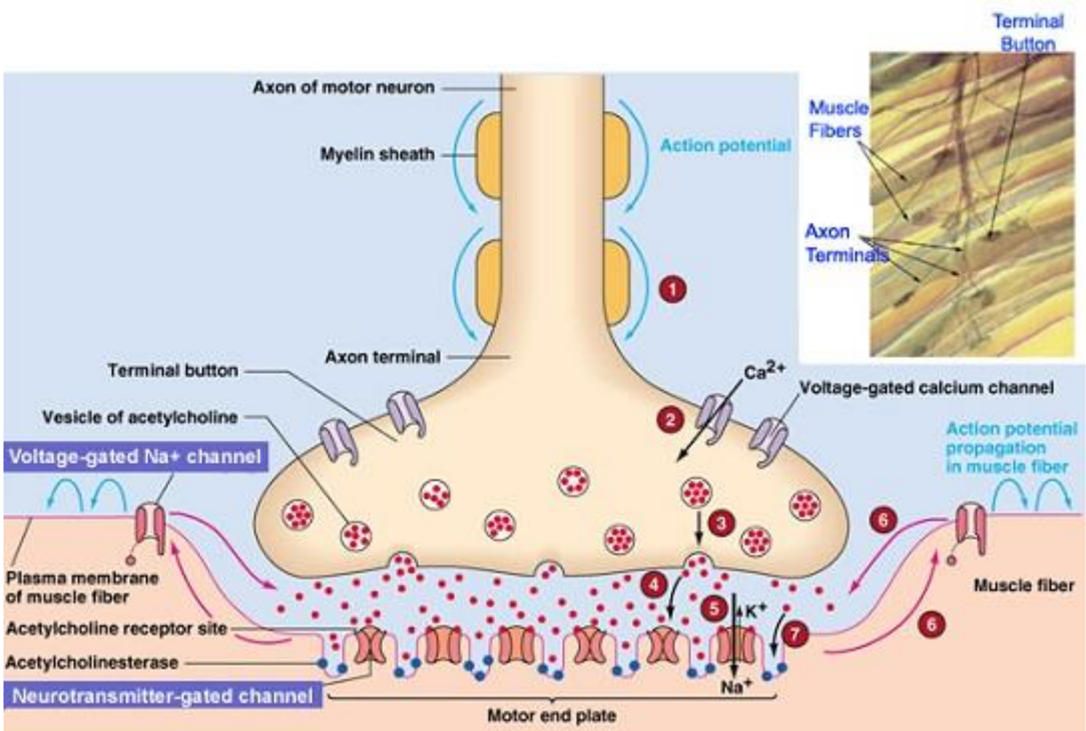
**NEUROMUSCULAR JUNCTION**

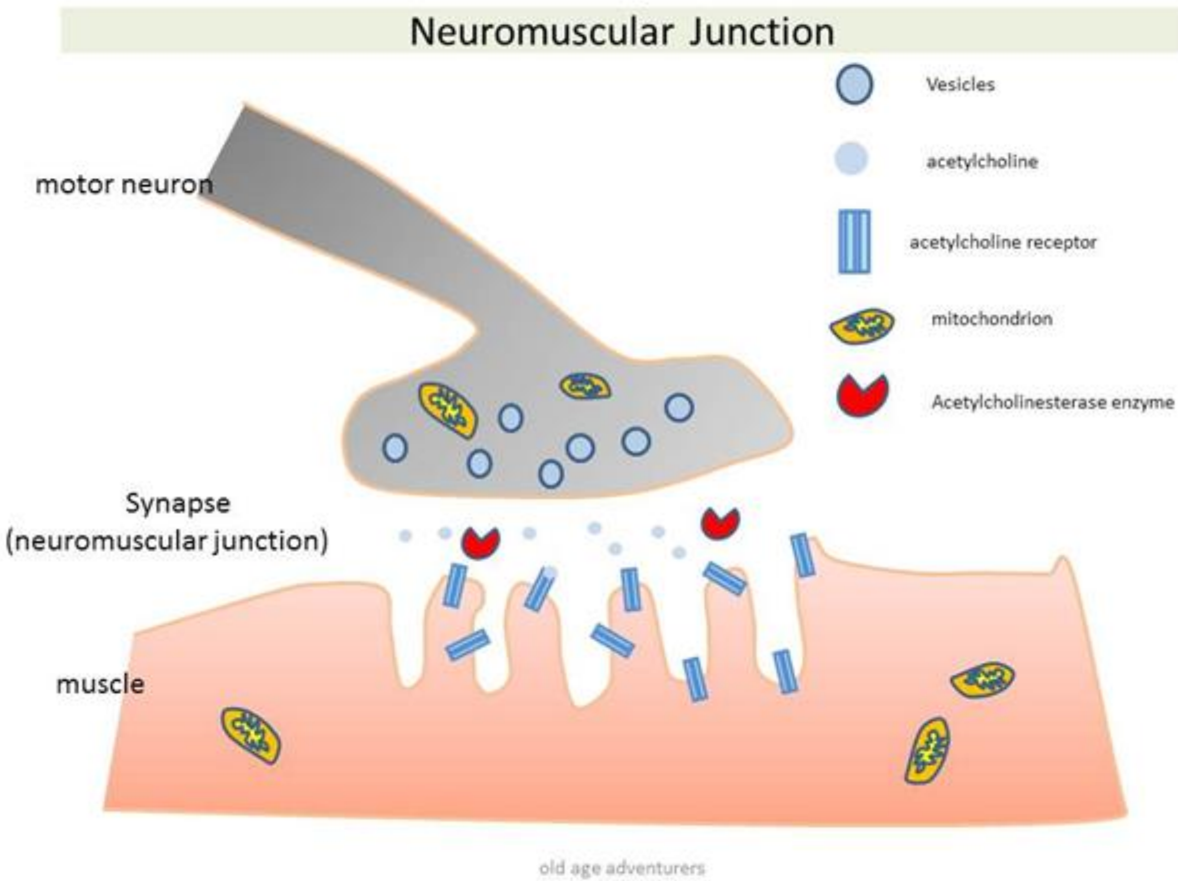
Nerves have to communicate not only with each other but with receptors and effectors as well. Motor nerves need to communicate with muscles. Where a motor nerve and muscles fibre meet a special kind of synapse is formed known as a neuromuscular junction.

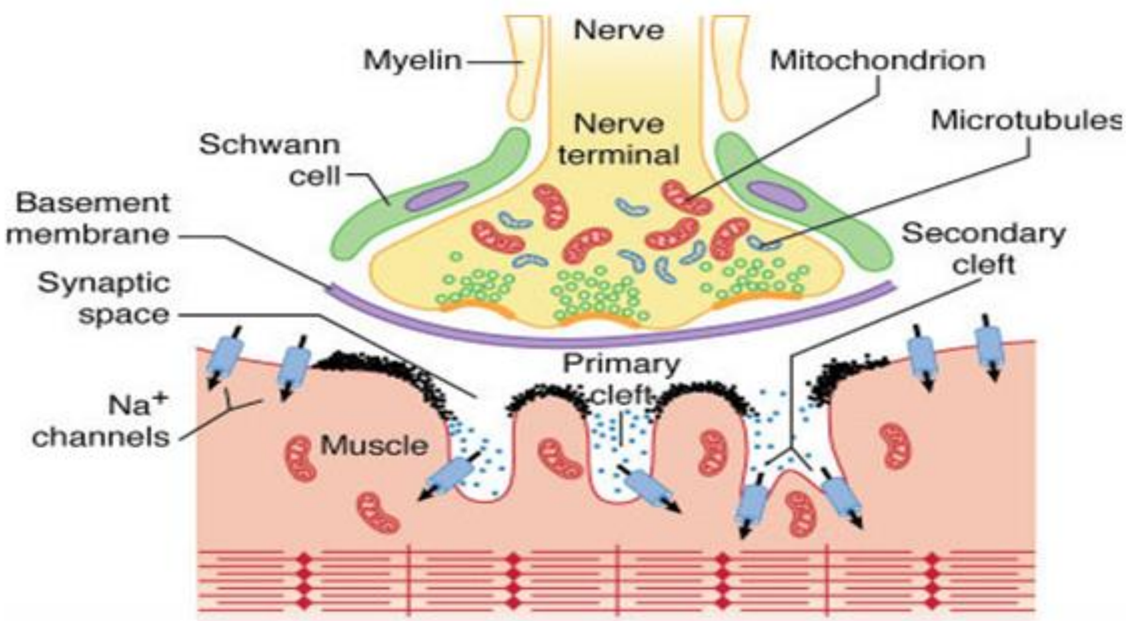
The membrane of the muscle fibre is very folded in this region and forms a structure known as an endplate to which the end of the motor nerve joins. Electron microscope shows us that the structure of the neuro muscular junction is remarkably similar to that of any other synapse as the figure below shows. The end of the motor neurons is full of mitochondria and synaptic vesicles which contain acetylcholine. It appears that when an impulse arrives at the end of the motor neurone acetylcholine is discharged into the synaptic cleft.

As a result of its effect on the postsynaptic membrane an end potential is set up which can be recorded, If sufficient end plate potentials are set up on action potential is fired off on the muscle fibre spreading through the tubules and leading to a contraction of the muscle.

The Neuromuscular Junction




Neuromuscular Junction
Vesicles
acetylcholine
acetylcholine receptor
mitochondrion
Acetylcholinesterase enzyme
motor neuron
Synapse
(neuromuscular junction)
muscle
old age adventurers


Nerve
Myelin
Mitochondrion
Nerve
terminal
Schwann
cell
Microtubules
Basement
membrane
Secondary
cleft
Synaptic
space
Primary
cleft
Na+
channels
Muscle

# COORDINATION AND CONTROL OF NEURONES SUMMATION AND FACILITATION

Neurons interact in a variety of complex ways. Sometimes single nerve fibre will carry an action potential to a synapse with another cell and transmission. But in many cases the situation is much more complex than this.

Often a single synaptic knob does not release enough transmitter substance to set up an action potential in the post synaptic fibre however, if two or more synaptic knobs are stimulated and release transmitters at sometimes onto the same post synaptic membrane the effects add together and a post synaptic action potential results. This is known as spatial summation; as illustrated below.

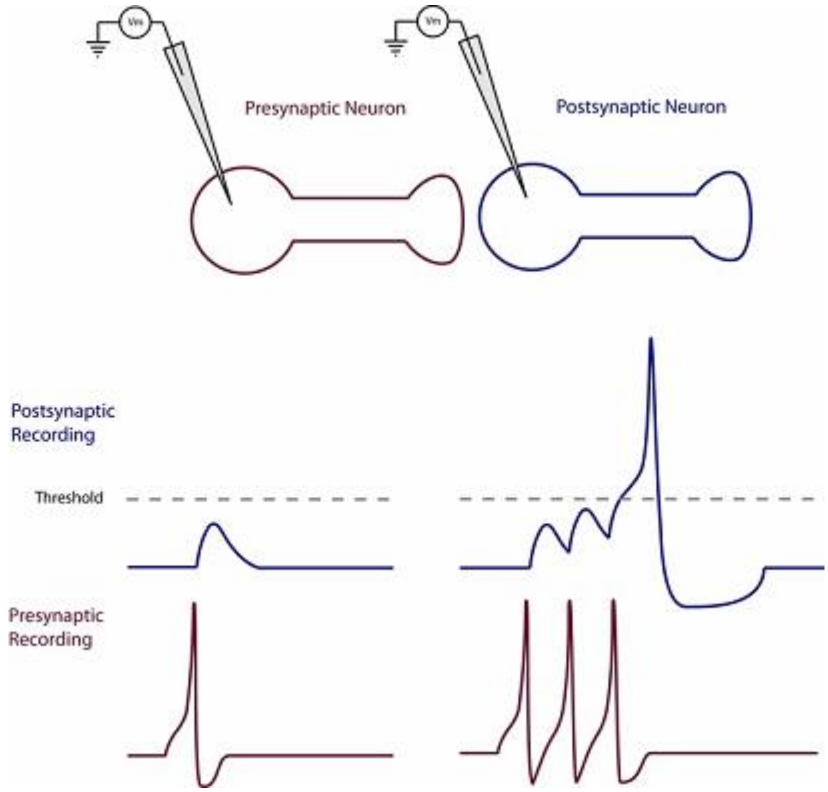
In other cases, a single knob does not release enough transmitter substance to stimulate the post synaptic nerve fibre, but if a second impulse is received from the same knob in quick succession an action potential results.

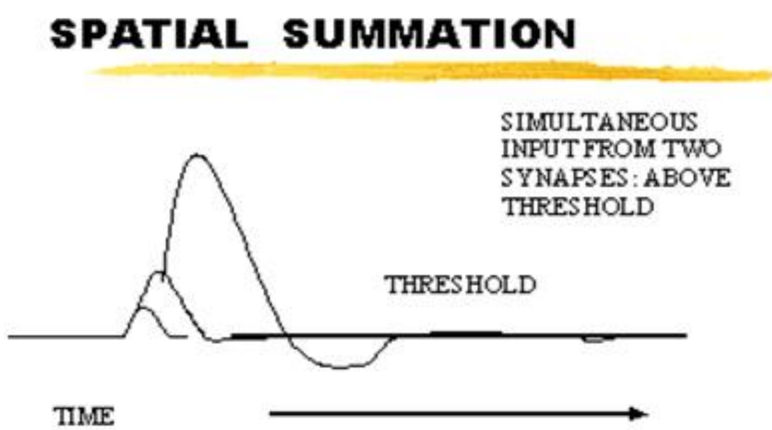
This effect is known as temporal summation (i.e. adding over time). It involves facilitation in other words, the first impulse does not trigger off a response but it has an effect which make easier (facilitate) the passage of the next impulse.

The arrival of the impulse at one synaptic knob triggers an action potential in the post synaptic fibre.

## Spatial summation

Action potential needs to arrive at several synapses at once to release the amount of neurotransmitter required to trigger as action potential in the postsynaptic fibre.

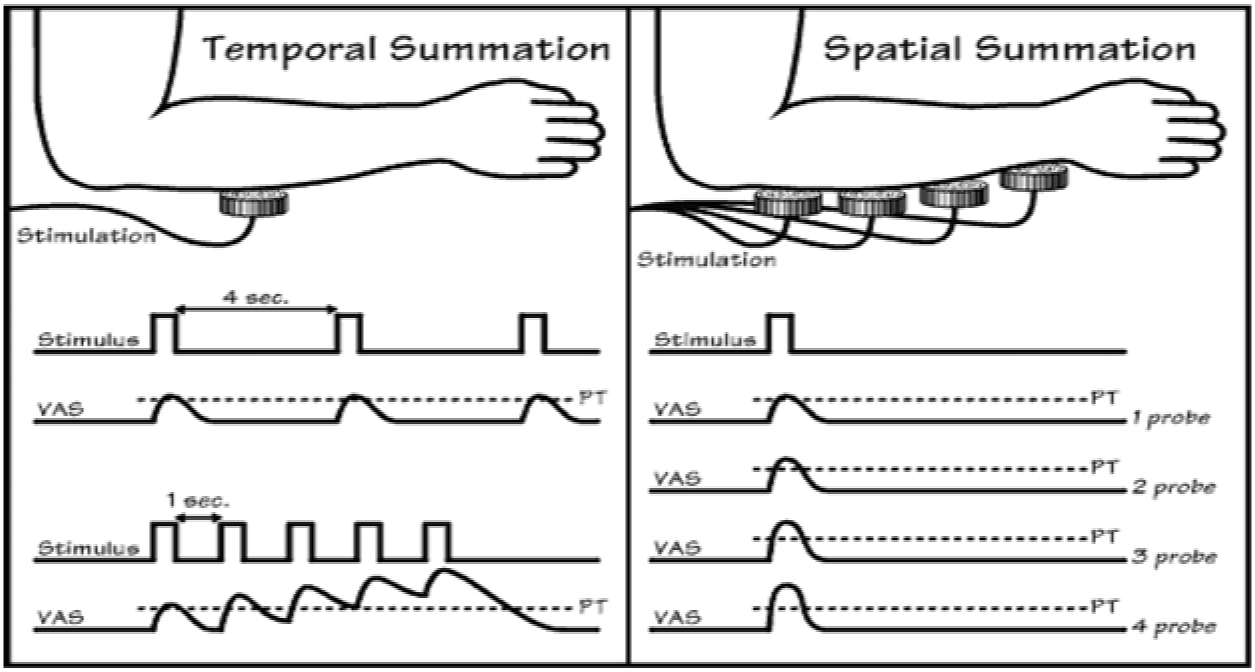


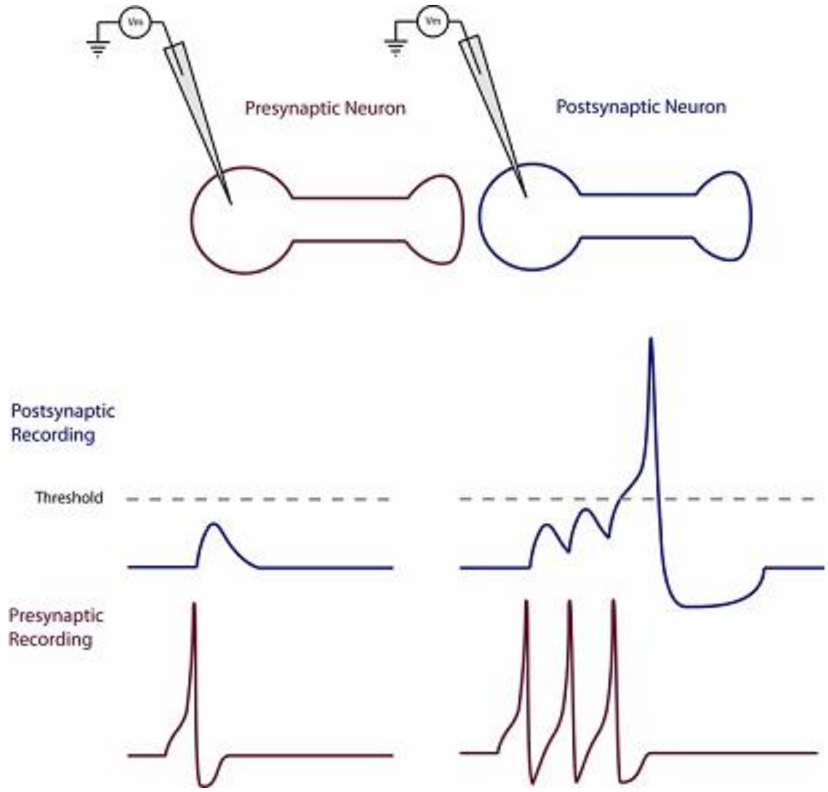




**Temporal summation**

One action potential arises and although it does not release sufficient transmitter substance itself to set up another potential it makes it easier for the next impulses which arises to do so.

# Temporal and Spatial Summation






**ADAPTATION**

On first applying perfume or after shave we tend to be very aware of the smell ourselves. After a short time we lose that awareness and it is other people who notice how pleasant we smell. If we apply our scent another day, we can smell it again. This reaction is the same as that of a sea anemone which when poked with a pointer, will withdraw its tentacles. If the sea anemone is pocked repeatedly the response is lost. If left alone for a while the sea anemone reacts to the results of process known as accommodation.

If a nerve is repeatedly, it eventually loses ability to respond. Each time on impulse arrives at a synapse, vesicles, full of transmitter discharge their contents into the synaptic cleft. The transmitter can only be synthesized at a certain rate if the synapse is used too often all of the vesicle are discharged into the synaptic cleft and the rate of synthesis simply cannot keep up. At this point the nerves can no longer respond to the stimulus, they are said to have accommodated or fatigued. A short rest restores the response as new vesicles and transmitter molecules are made. Some synapses nerve fatigue they have no extremely rapid synthesis is rate whilst others accommodate very quickly.

**THE IMPLICATION OF THE ORGANIZATION OT THE NERVOUS SYSTEM.**

The nerve fibre and synapses which have been considering in isolation make up enormously complicated systems. Bundles of nerve fibres from nerves capable of carrying vast number of messages in different directions, together all the available information and control all the actions of the body.

Nervous and synapses in the central nervous system collect information and sends out instructions, synapses susceptible to both fatigue and drugs, allow for great flexibility, intercommunication between cells, facilitation and inhibition. They also play a vital role incompletely understood in the brain, closely linked with both learning and memory.

Nerves give rapid communication; they also give the ability to people at least for long and involved nervous activity to take place in the brain before a particular action to is undertaken. But for simpler organisms most nervous activity and behavior involves reflex action which have a minimum of input from the central system. Even human beings are ruled by reflexes to a remarkable extent.

**STUDY QUESTIONS**

- Explain the following terms relating to a nervous system

  i) Resting membrane potential

  ii) Action potential

  iii) Refractory period

  iv) Saltatory conduction in a myelinated axon.

  v) Motor end – plate

2. Describe what happens to the ion gated channel of the axon membrane and the consequent distribution of $Na^+$ and $K^+$ ions during

   i)Action potential

   ii)Resting potential

   iii)Under shoot

3. Explain in details two characteristics of a nerve impulse

4. (a) Define the following terms with reference to nervous coordination

   i) Adaptation
   ii) Synaptic vesicle

**FUNCTIONS OF THE SYNAPSE.**

1. Transmission of impulses from one neuron to another.
2. To ensure the undirectional flow of impulses by the following mechanisms.

- The neurotransmitters are only released in the pre-synaptic neuron.
- The receptor molecule for the neurotransmitters are only located on the post synaptic membrane.
- Enzymes for degrading neurotransmitters are found in the post synaptic knob.
- The mitochondria and energy production to resynthesize the ACL are found at the pre-synaptic knob.

3. They act as a junction i.e. they allow spatial summation. This means that the impulses passing along the different neurone between them release a neurotransmitter substance sufficient to generate an action potential where as individually they would not i.e. facilitation.

4. Filter out low level stimulus i.e. They block the passage of stimuli that are enabled to release a sufficient neurotransmitter for propagating a new impulse in the post synaptic neurone.

5. To allow accommodation to intense stimulus i.e. is case where the rate of release of neurotransmitter substances exceeds the rate of its formation the synapse becomes fatigued. No further neurotransmitter substance is released and no further impulse is transmitted.

6. a). Define “synapse” and show how it differs from synapsis.

b). Explain the phrase “synapse ensure a unidirectional flow of impulses”

c). Describe the other functions of synapse besides that in (b) above.

7. Annotate the structure of cholinergic synapse

8. Outline how an impulse passes across the synapse

**SYNAPSE**

Definition; **synapse** is a region where the branches of an axon are in contact with the dendrites of another neurone.

OR

**Synapse** is a function between a neurone and another cell either by passage of electrical signals or more enormously by a chemical called a neurotransmitter.

**Types of synapses**

1. **Chemical synapses**

   These are synapses that neurons communicate with each other by means of neurotransmitters.

   The neurons are not in direct contact with each other, they join at a synapse which have synaptic cleft, a small gap of about 20nm.

   The neurotransmitter is released from one membrane is the synapse the pre-synaptic membrane then it diffuses across the synaptic cleft and binds into receptors on the post synaptic membrane. The post synaptic cell may be in an effectors organ such as muscle or gland.

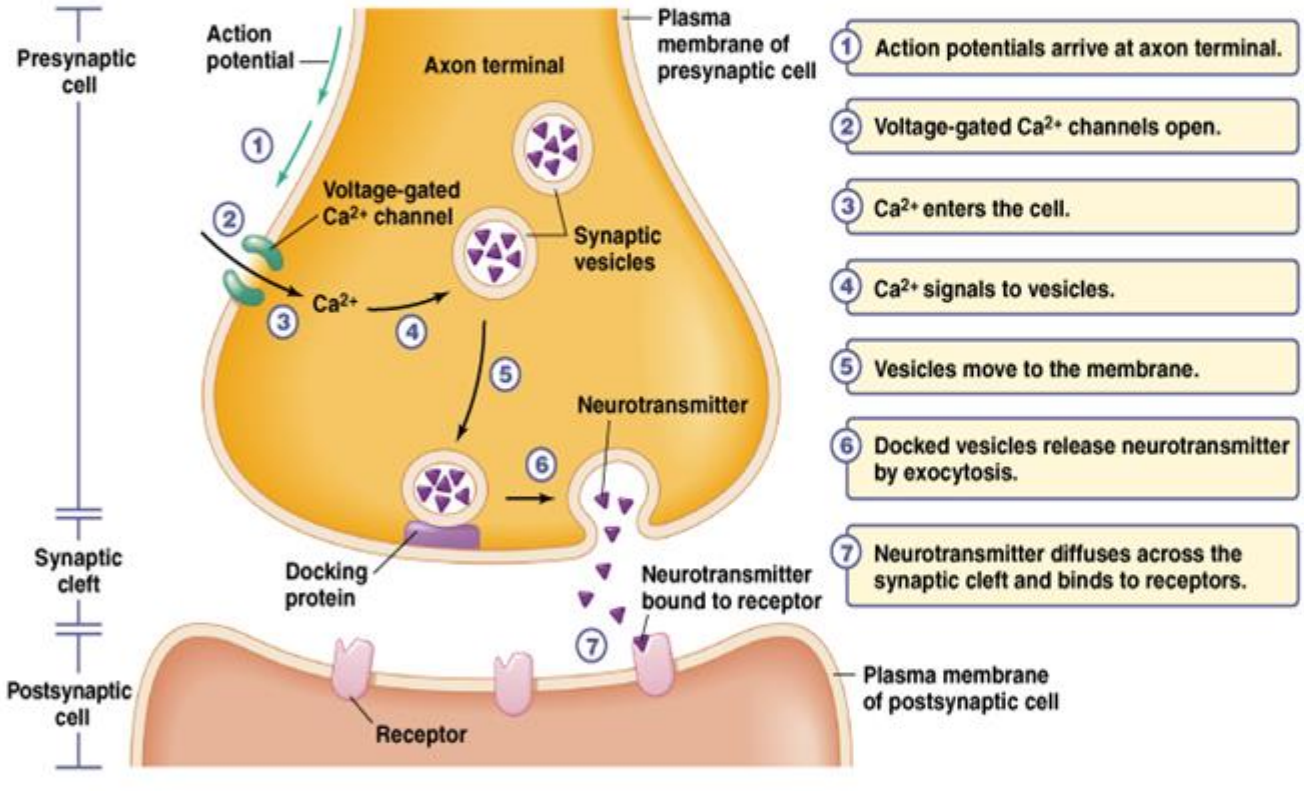
**Types of chemical synapses**

The chemical synapses are of two kinds; excitatory synapses and inhibitory synapse.

**Excitatory synapse**

These are synapses where the pre synaptic neurone releases neurotransmitter that makes the post synaptic membrane more excitable and more likely to generate nerve impulses.

**The diagram of a chemical synapse**




The diagram above shows various events takes place in a chemical synapse which uses acetylcholine as a neurotransmitter.

Acetylcholine is synthesized within the pre synaptic knob and stored in special organelles called synaptic vesicles (some neurotransmitters neither decrease nor increase the tendency of a postsynaptic cell to fire an action potential instead they work like hormones; e.g. noradrenaline released by axons of the sympathetic nervous system has an effect to on cells similar to that of the hormone adrenaline.

When an action potential reaches the presynaptic membrane, it depolarizes the membrane, that is; it makes the membrane less negative than at rest. This depolarization triggers the opening of calcium ions channels in the pre synaptic membrane.

The calcium ions diffuse into the presynaptic knob; causing the pre synaptic vesicles containing acetylcholine to migrate and fuse with the presynaptic membrane.

The acetylcholine is released into the synaptic cleft and diffuses across the synapse. The synapse then it binds to specific protein receptor molecules on the post synaptic membrane a process known as receptor activities.

Receptor activation causes sodium ion channels to open making the membrane more permeable and produce a graded potential, if enough acetylcholine is released the graded potential may become large enough an action central.

If an excitatory synapse receives a continuous stream of action potential at high frequency eventually transmission across synapse stops.

This is because the neurotransmitter cannot be resynthesised fast enough and it runs out. The synapse becomes fatigued (i.e. adapted).

Acetylcholine is then broken down by acetylcholinesterace to its constituents groups acetic acid (or ethanoic acid) and choline groups; which diffuses back into the pre synaptic membrane and used to resynthesize the neurotransmitter under the influence of ATP from the mitochondria concentrated here and refilled in vesicles for future transmission.

**Inhibitory synapse.**

These release neurotransmitter that makes the postsynaptic membrane less excitable and less likely to transmit an impulse.

E.g. In mammals, they occur in nerve pathways which central rapid eye movements, they are also common in the heart.

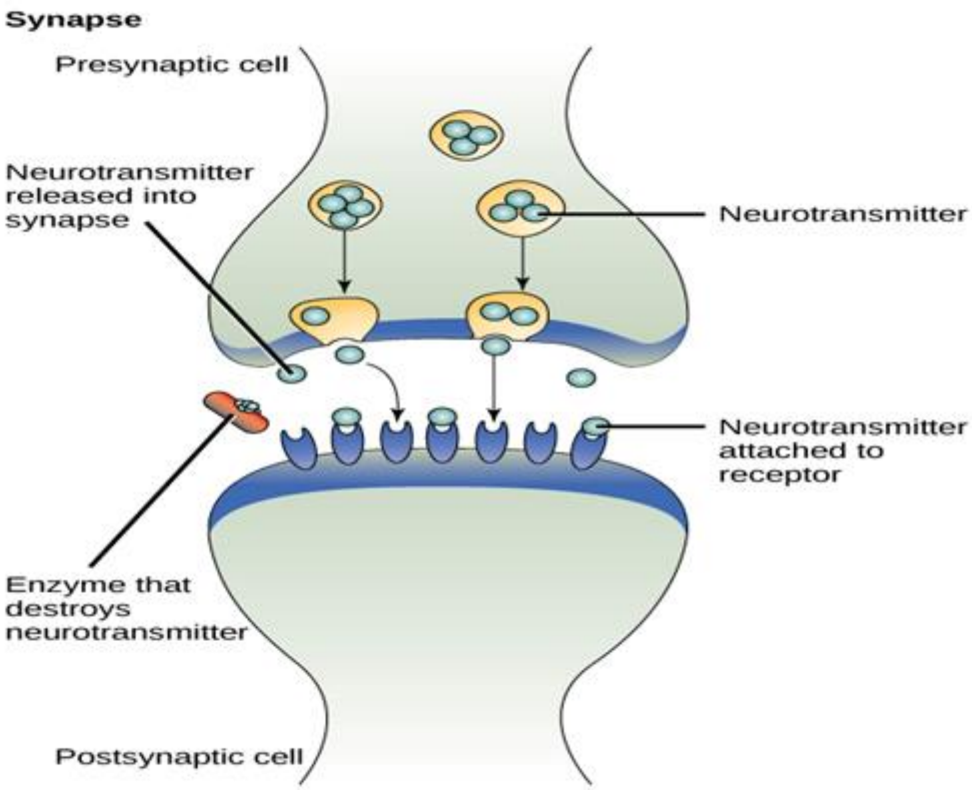



**Diagram above**: An electrical synapse in which the nerve impulse is transmitted through the protein pores that line the cytoplasm of the two cells.

**Qn;** 1. Write short notes on a synapse

2. Discuss the role played by the synapse

3. Discuss the characteristics of a synapse

## SENSORY ORGANS

### Receptor cells

These are specialized cells in the body forming the body's principal means of gaining information about the environment.

### Characteristics of receptor cells

- They may be either proportions of nerve cells e.g. many sensory endings in the skin OR they may be specialized intimate contact with nerve cells e.g. the cells in the tongue.
- Each type of receptor is responsive to a particular kind of stimulus, stretching, pressure, light. Most receptors will not respond stimuli other than those for which they are specialized.
- Each type of receptor functions as a transducer; converting the energy that constitutes the particular stimulus to which it is attained into the electrochemical energy to the nerve impulse.
- Each type of receptor sends impulse to a particular part of the brain.

**Mechanism of receptor function.**

**Qn**; By what process do the environment phenomena that constitute stimuli causes receptors to initiate impulses?

In the previous discussion about the post synaptic depolarization, we saw the excitatory transmitter substance at synapse induce impulse in the post synaptic neuron by reducing the polarization of the membrane of that to a critical level i.e. by inducing an EPSP that reaches threshold potential for impulse generation. A similar process is involved in the case of sensory receptors; the stimulus causes sufficient depolarization of the membrane of the receptor cells causes it to initiate an impulse.

- The stretching of the muscle spindle produces a local depolarization of a receptor cell. This depolarization is called generator potential. When the generator potential reaches the threshold level it triggers an action potential in the nerve fibre.
- An increase in intensity of the stimulus causes the proportional rise in generator potential. This rise in turn and the rate at which it occurs determine the frequency of the triggered impulses. Thus the output from the receptors conveys a measure of the strength of the stimulus.

Qn; How does the stimulus produce the generator potential?

- The membrane becomes more permeable to Na+ ions which thus flow inward.

Qn; How does the stimulus increase the permeability of the membrane to $Na^+$ ions?

- Since different receptors are stimulated by different stimuli the mechanism may as well vary.

e.g. i) In the case of vision, light energy is known to cause chemical change in receptor pigments and these changes are presumed to initiate chemical reactions that produce some sort of transmitter substance may depolarize the membrane of the next cell in the pathway.

ii) In the case of stretch receptors and pressure receptors mechanical distortion of the membrane is thought to cause a permeability change directly, either by opening channels or through the membrane that allows Na+ to leak inward, or by increasing the size of the channels (for electrical synapses) otherwise too small for the passage of Na+ ions.

NB;

The size of the generator potential is directly proportional to the size of the stimulus.

The direct relationship between strength of stimulus and magnitude of generator potential could be explained by assuming that stronger stimuli distort a greater area of membrane; there are openings, more channels and allowing more ions to pass through the membrane.

**THE MAJOR SENSES**

In biology, human being have five senses; touch, taste, smell, vision and hearing.

**TYPES OF RECEPTORS**

Receptors are cells that receive information from the environment and send impulses via conductors to the central nervous system.

Receptors may be categorized on the basis of;-

i) Types and function of the stimuli they respond to

- Mechanoreceptors-detect movement, pressure or tension.
- Photoreceptors-detect variation in light
- Chemoreceptors-detect chemicals
- Thermoreceptors-respond to both internal and external heat and cold
- Pain receptors-respond to tissue damage.

ii) Complexity of receptor structure

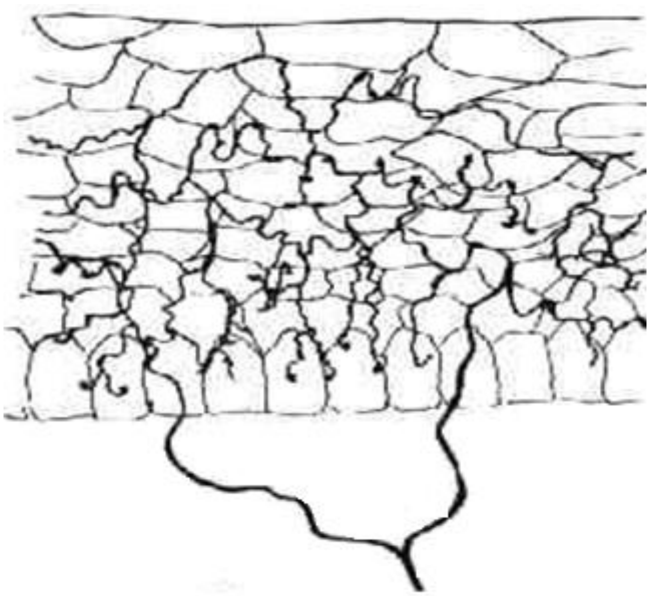
- Primary receptors
- Secondary receptors
- Sense organs

iii) Source of stimulus.

- Exteroreceptors-respond to stimulus outside the body
- Interoreceptors- respond to stimuli inside the body
- Proprioreceptors- specifically sensitive to the relative positions of the skeleton and degree of muscle contraction.

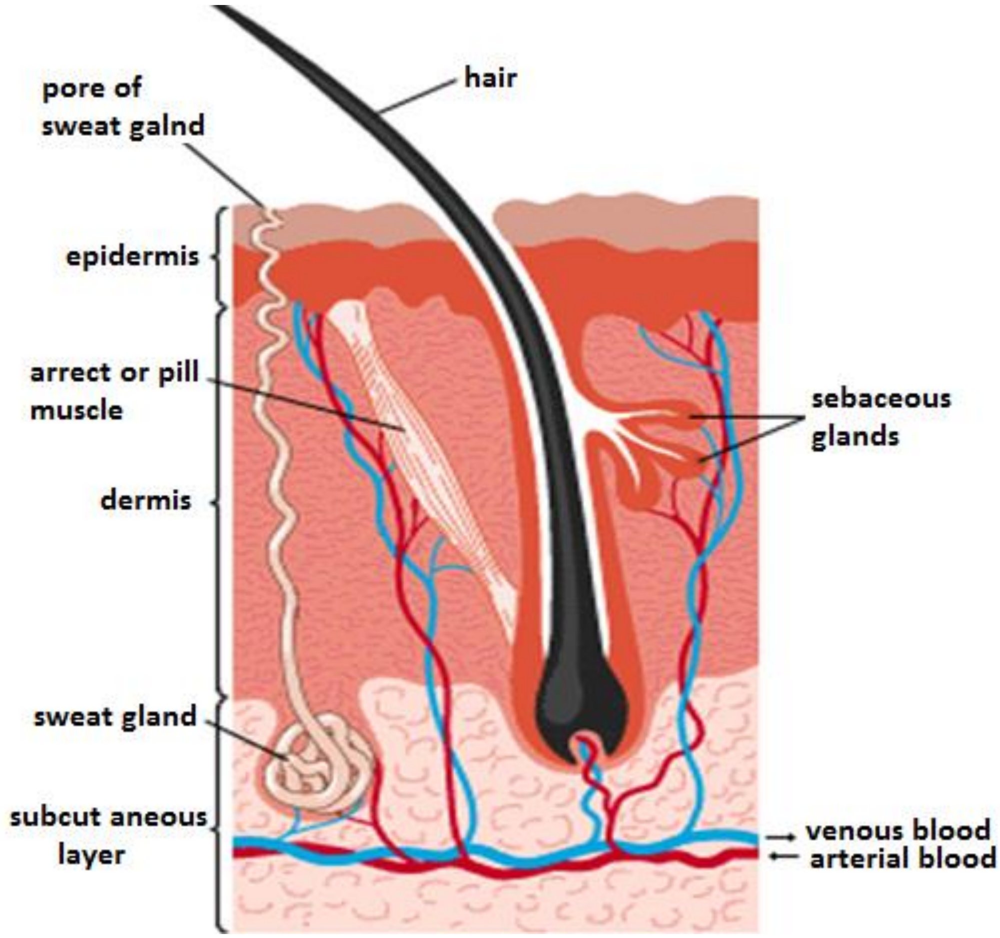
**SENSORY RECEPTORS OF THE SKIN**

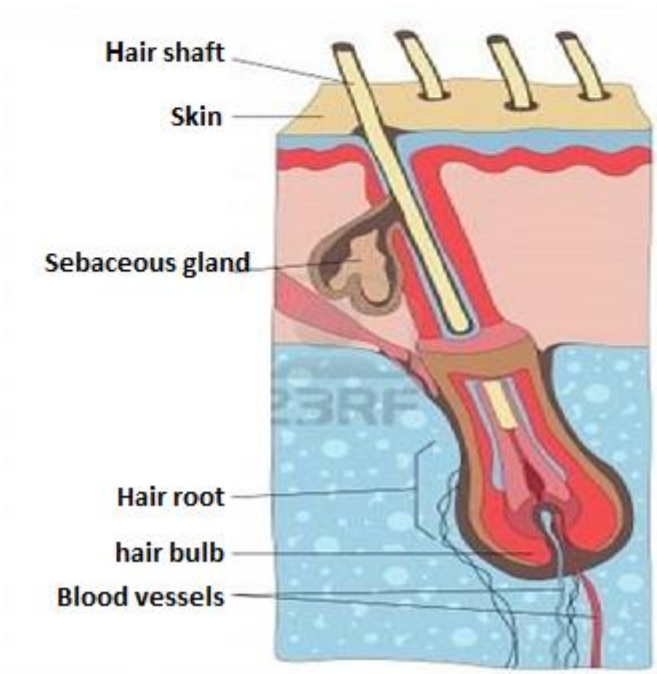
There are numerous types of sensory receptors in the skin which shows some receptors in place. These receptors are concerned with at least five different senses namely touch, pressure, heat, cold and pain. Some of the skin receptors particularly those concerned with pain are simply the unmyelinated terminal braches of neurons.



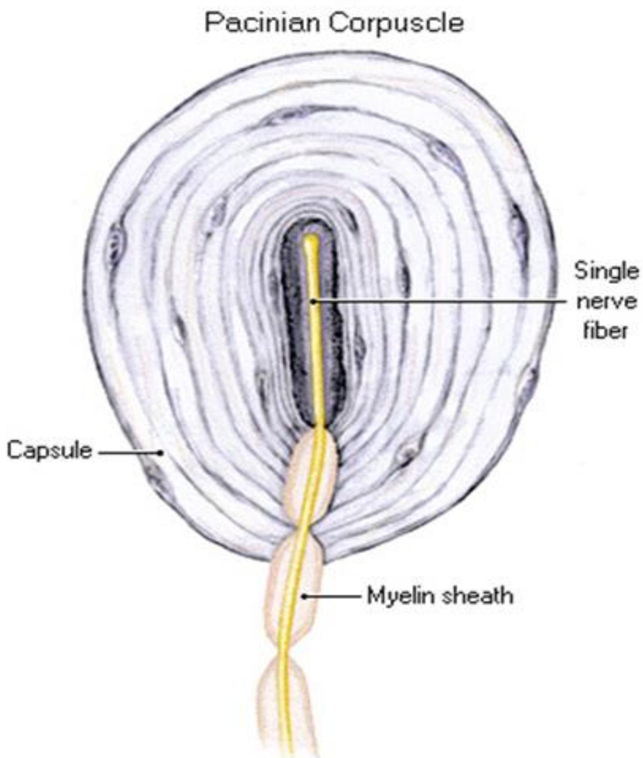
Free nerve endings
( pain )

Others are nets of nerve fibres surrounding the bases of hairs. These are particularly important in the sense of touch.


hair
pore of
sweat galnd
epidermis
arrect or pill
muscle
dermis
sebaceous
glands
sweat gland
subcut aneous
layer
venous blood
arterial blood


Hair shaft
Skin
Sebaceous gland
Hair root
hair bulb
Blood vessels

- These are stimulated by the slightest displacement of the tiny hairs present on most parts of the body.
- Other skin receptors are more complex consisting of nerve endings surrounded by a capsule of a specialized connective tissue cells.




**NB;**

The relative abundance of the various types of the receptors differs greatly e.g. pain receptors are nearly 27 times more abundant than cold receptors and cold receptors are nearly 10 times more abundant than heat receptors.

The receptors are not evenly distributed over the entire body e.g. touch receptors are much more numerous the finger tips than in the skin of the back.

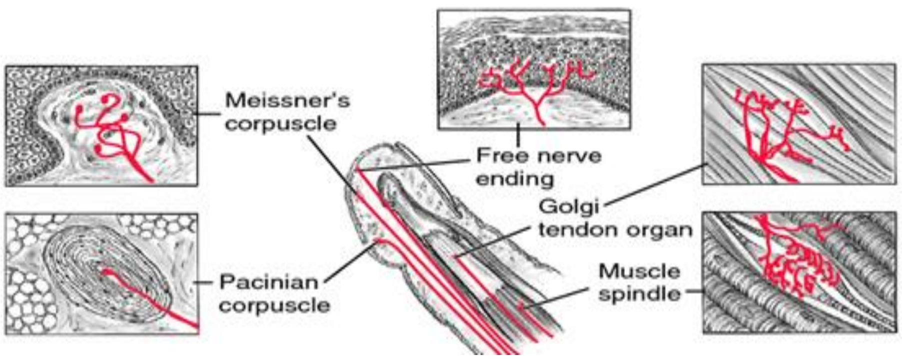
**THE PROPRIOCEPTIVE AND VISCERAL SENSES.**

These are widely distributed over the internal body and function primarily in receiving information about the condition of the body itself.

Though the senses receptors mediate are not included in traditional classification of the five, they are in immense importance in the life of an organism.

Examples are the stretch receptors (proprioreceptors) in the muscles and tendons, which are involved in the knee jerk reflex.

They are sensitive to the changing tension of muscles and tendons and send impulses to the central nervous system in forming it of the position and movements of the various parts of the body.




The terminal branches of sensory nerve fibre are intimately associated with several specialized muscle fibre that form an apparatus called neuromuscular spindle.

Other dispersed receptors include those of visceral senses located in the internal organs e.g. receptor in the carotid artery sensitive to carbon dioxide concentration in the blood and to blood pressure.

The firing of such visceral receptors seldom results in sensations (i.e. we are not aware of their action) the responses to the stimulation of visceral receptors produces conscious sense such as thirst, hunger and nausea.

**THE SENSE OF TASTE AND SMELL**

The receptors of taste and smell are chemoreceptor i.e. they are sensitive to solutions of certain types of chemicals, which can find to them by weak bonds.

The two sensations are much alike and when we speak about a taste sensation we are not referring to a compound sensation produced by stimulation of both taste and smell receptors.

One reason why we cannot "taste" food well with a cold is that with nasal passages inflamed and coated mucus, the smell receptors are essentially non functional.

In other words; much of what we call taste is really smell.

Consequently some vapours entering our nostrils pass across the smell receptors and down into the mouth where they stimulate taste receptors.

In each case taste and smell, chemicals must go into solution in the film of liquid coating the membranes of the receptor cells before they can be detected.

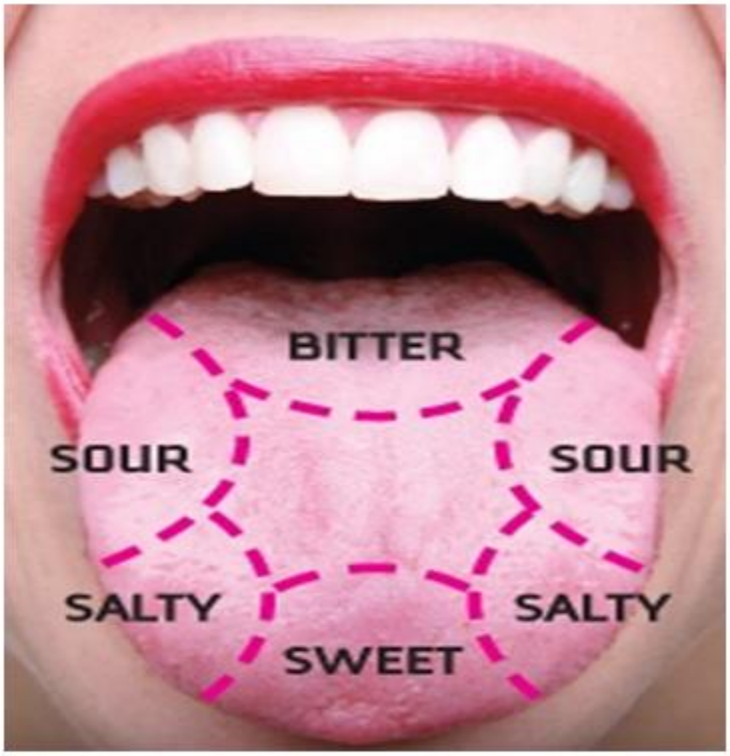
The major functional difference between the two kinds of receptors is that taste receptors are specialized for detection of chemicals present in quantity in the mouth itself while smell receptors are more specialized for detecting vapours coming to the organisms from distant source. They are much more sensitive that taste receptors as much 3000 times more in some instances. One reason why hot foods often have more "taste" than cold food is that they vaporize more. The vapours passing from mouth upward into the nasal passage and these stimulate smell receptors.

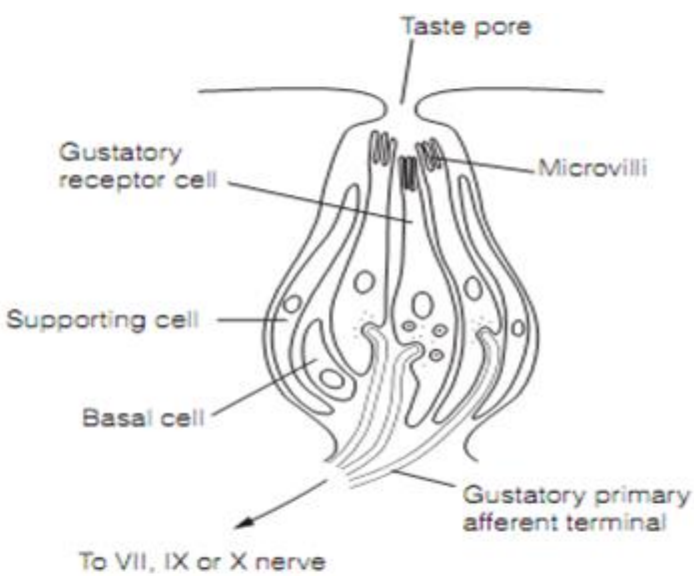
**TASTE.**

The receptor cells for taste are located in taste buds or the upper surface of the tongue and to a lesser extent on the surface of the pharynx and larynx.

The receptor cells themselves are not neurons but specialized cells with microvillus on their outer ends.

The end of nerve fibres lie very close to these receptor cells, and when a receptor cell is stimulated, it generates impulses in the fibres.




The picture above shows the structure of the tastebud

(Each test bud contains specialized receptor cells bearing sensory microvilli that are exposed in pits on the tongue surface. The ends of sensory neurons (coloured) are closely associated with this receptor cells).

**SMELL**

The receptor cells for the sense of smell (olfaction) in humans are located in two clefts in the upper parts of the nasal passages. Unlike the receptor cells of taste, the olfactory receptors re true neurons. The cell bodies to the surface of epithelium where they bear a cluster of modified cilia, which function as receptor sites.

**FUNCTIONAL PROPERTIES OF RECEPTORS.**

1. ADAPTATIONS.

Adaptation is the decline in the frequency of impulses when a strong or constant stimulus is perceived by a sensory receptor cell e.g. on entering a room you may immediately notice a clock ticking but after a while you become unaware of its presence.

The rate and extent of adaptation in a receptor cell is related to its function and there are types; rapidly and slowly adapting receptors.

Slowly adapting receptors (ionic receptors) register constant stimulus with a slowly decaying frequency of impulses.

The adaptation is thought to be due to decrease in the permeability of the receptor membrane to ions due to substance stimulation. This progressively reduces the size and the duration of the generation potential and when this falls below threshold level, the sensory neuron ceases to fire the impulse.

**Advantage of adaptations**

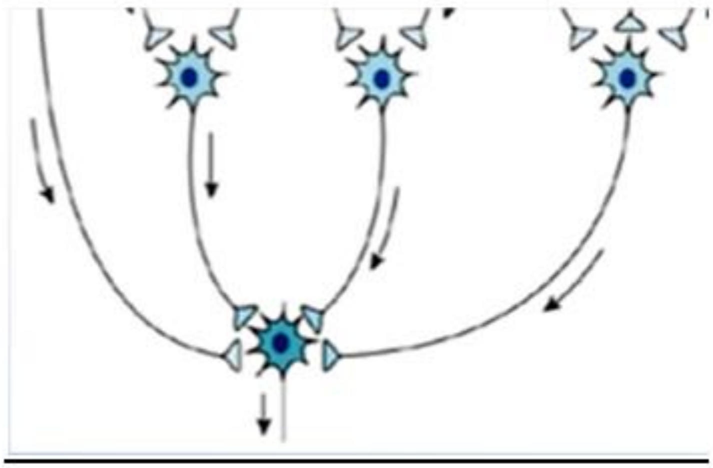
It provides animals with precise information about change in the environment. At other times the cells do not send signals thus preventing over loading of the central nervous system with irrelevant and unmanageable information. This ensures efficiency and economy of the nervous system.

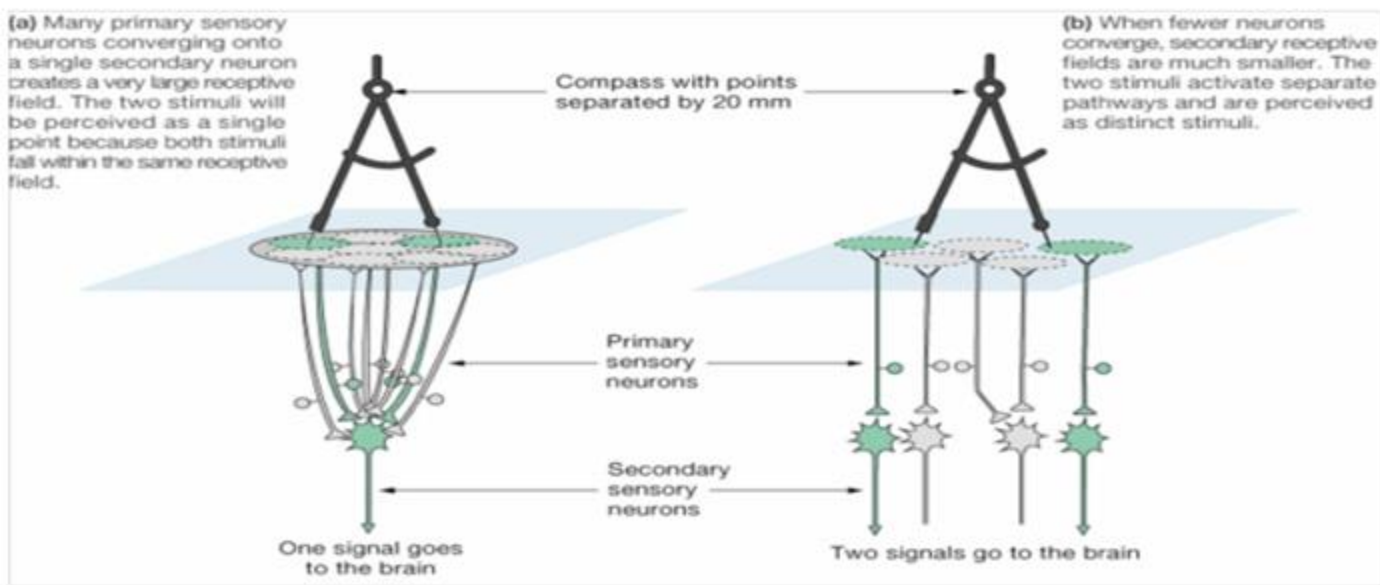
2. **RAPIDLY ADAPTING RECEPTOR (PHASIC RECEPTOR)**

Respond to changes in stimulus level by producing a high frequency of impulses at the movements when the stimulus switched “on” or “off”

E.g. Pacinian corpuscle and other receptors concerned with touch and the detection of sudden changes acts in this way.

**CONVERGENCE**






In sensory receptors, several receptor cells will often synapse with a single receptor neuron as shown in a figure above.

This means that while the generator potential from an individual receptor cell may be insufficient to set up an action potential across the synapse. The generator potential from receptor cells may add together or summate and trigger an action potential. This is known as convergence and is a useful adaptation for increasing the sensitivity of a sensory system to low level stimuli.

**THE SENSE ORGAN.**

Single sensory receptor cells are very useful and can carry vital information. But groups of receptor cells specialized for picking up a particular stimulus can be even more useful.

Relatively early in the development of the animal groups' collection of receptors evolved together to form specialized regions which are called sense organs.

Throughout the animal kingdom, the most common sense organs are those which respond to light and sound or vibrations. We shall consider in some detail the human eye and ear, with reference to some of the alternative structures which are found in other groups.

## THE HUMAN EYE; THE EYE AT WORK.

### a) The role of iris

Iris is a circular sheet of muscles dividing the eye into two chambers.

The pigment it contains gives the eye its colour. The reflex contraction and relaxation of the muscles of the iris control the amount of light entering the eye.

When we look at something our eyeballs are moved in their sockets by muscles so that the pupil at the centre of the iris is pointing at the object of our interest.

Light from the object enters the eye through the pupil and the amount of light entering is controlled by the size of the opening. This in turn is controlled by the Iris muscles.

## ACCOMMODATION

Accommodation is the reflex mechanism by which light rays from an object are brought to focus on the retina.

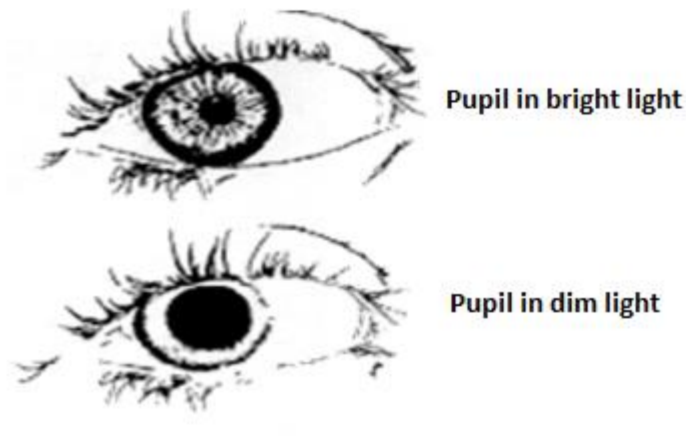
It involves two processes which are,

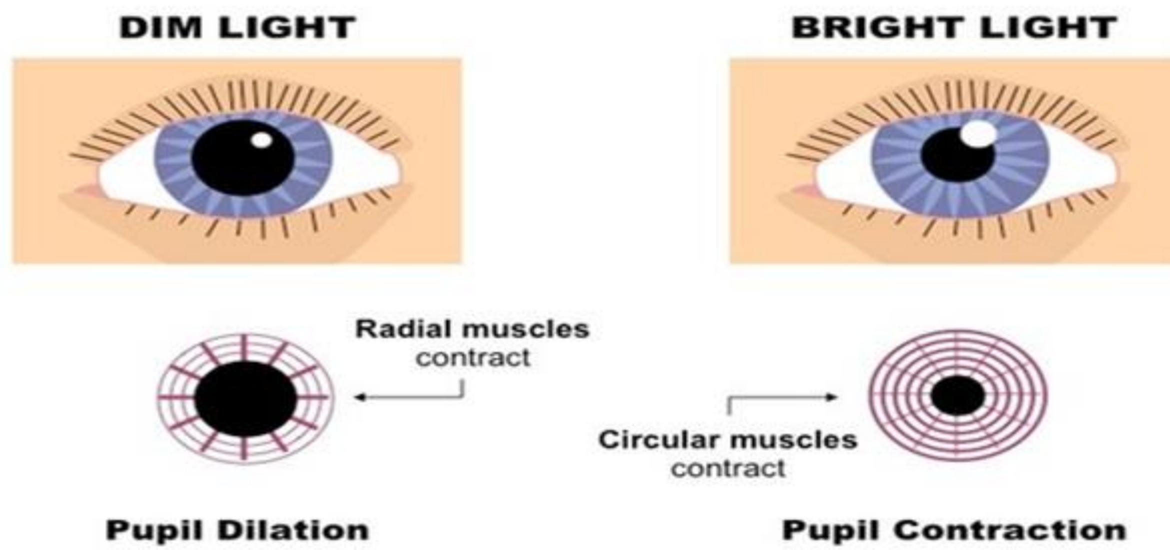
- Reflex adjustment of the pupil size
- Refraction of light rays

## REFLEX ADJUSTMENT OF PUPIL SIZE

1. **In bright light**

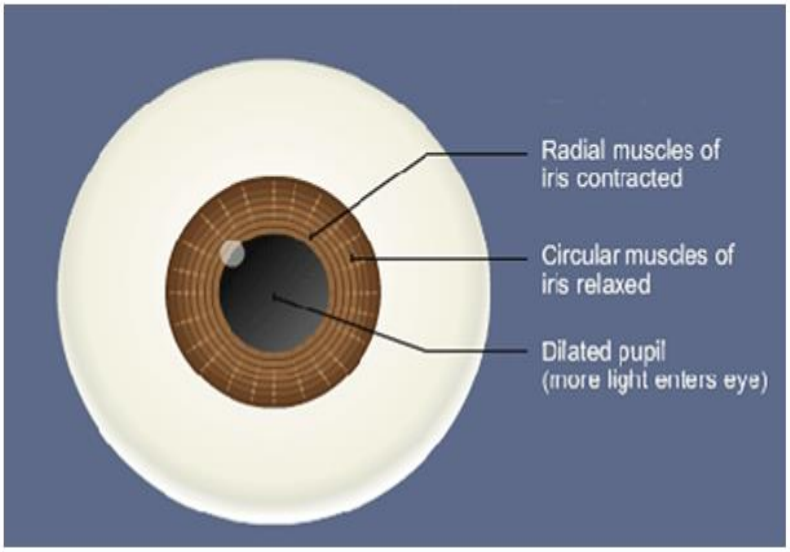
   The iris reduces the size of pupil by contracting its circular muscles and relaxing its radial muscles to prevent damage to the light sensitive cells by strong light.




2. **In dim light /poor light intensity**

The circular muscles relax and the radial muscle contract opening the pupil aperture as wide as possible to the maximum amount of light to ensure the best possible vision.




3.

**CHANGING THE SHAPE OF THE LENS.**

The ciliary muscles are arranged circularly around the ciliary body, the effects of their contractions and relaxations are relayed to the lens by the suspensory ligaments. The lens itself is elastic and its unstretched shape is relatively short and fat.

When ciliary muscles relax, the gap around the lens gets longer, increasing the tension in suspensory ligaments. These in turn pull on the lens making it long and thin. Its ability to bend light is now minimum and it is said to be unaccommodated.

When ciliary muscles contract they reduce the gap around the lens. This reduces the tension in the suspensory ligaments allowing the lens to become short and fat. In this state it is fully accommodated and its ability to bend the light is maximum.

**REFRACTION OF LIGHT RAYS**

Light rays from a distant object are parallel when they strike the eye. Light rays from new object are diverging when they strike the eye. Both cases light rays must be refracted or bent to focus on the retina and refraction must greater for light from near objects.

Refraction occurs when light passes from one medium into another with a different refractive index, and this occurs at the air to the cornea at the surface of the lens.

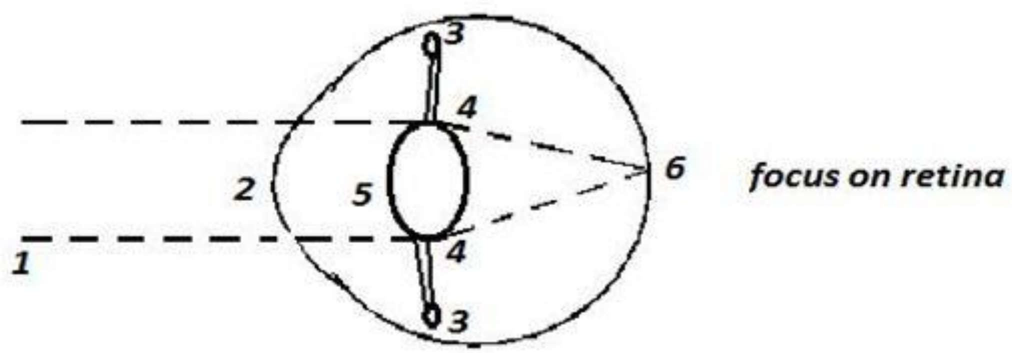
The degree of refraction at the cornea surface depends on the angle at which light strikes the cornea; also depend upon the distance of object from the cornea.

Most of the refraction occurs in the cornea and consequently the function of the lens is to produce the final refraction that brings light to sharp focus on the retina.

The light interring the eye is refracted by its passage through the conjunctiva, cornea, aqueous humour and vitreous humour in exactly the same way regardless of whether it is from a near or a distant object.

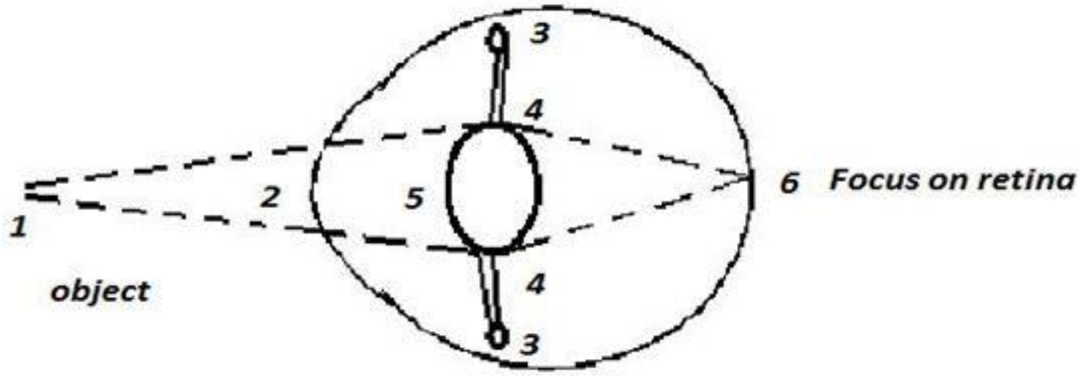
But by changing the shape of the lens the degree of bending of the light can be altered. Light from distant objects needs relative little bending to bring it into focus on the retina and so the lens has to be thin. (Because they are almost parallel and not diverging like for near object).

1. **Light from a distant object**




1. Parallel light rays reach the eye
2. Cornea refract (bends) light rays
3. Circular ciliary muscles relaxes
4. Suspensory ligament taut
5. Lens pulled out thin
6. Light focused on the retina.

1. **Light from near object**




1. Diverging light rays reach the eye
2. Cornea refracts (bends) light rays
3. Circular ciliary muscles contracted
4. Suspensory ligament slack
5. Elastic lens more convex
6. Light focused on retina

To bring light from near objects into the focus on the retina more refraction is needed and so the lens has to be short and fat.

This ability to focus light from objects of various distances is known as accommodation.

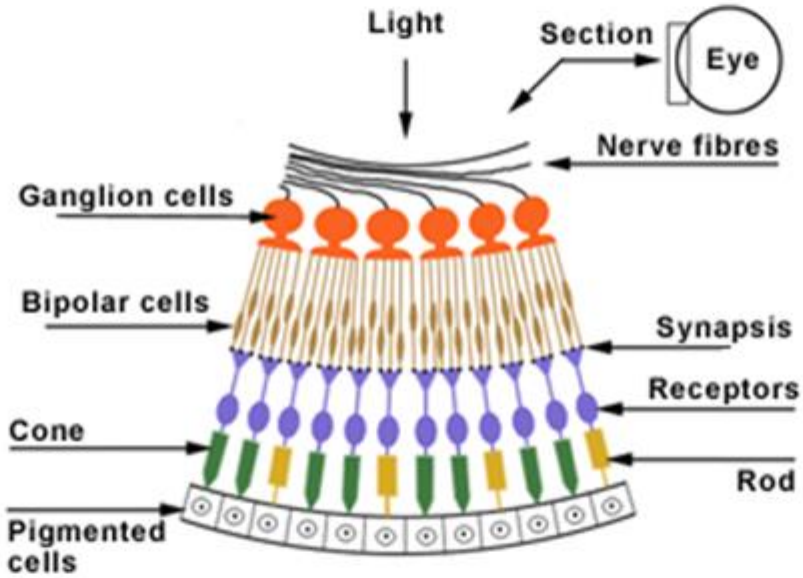
**THE ROLE OF RETINA.**

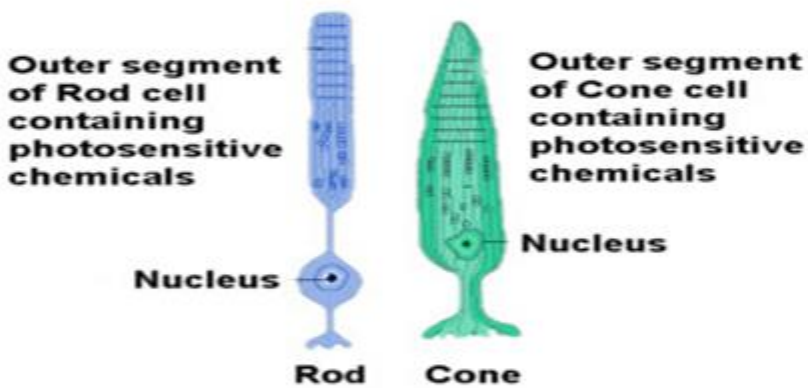
Retina is a layer of light sensitive cells (i.e. rods and cones and the neurones leading from these photoreceptors to the optic nerve.

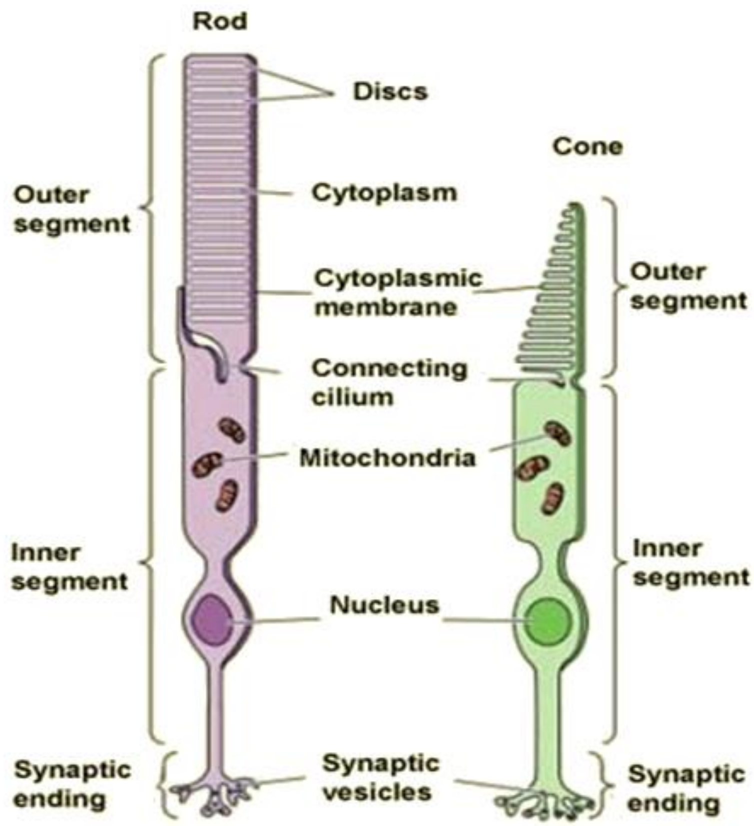
The light from the objects is focused into the retina. The retina must then perceive that light and inform the brain of its presence.

In order to do this the retina contains about a hundred million light sensitive (photoreceptors) along with the neurones with which they synapse.

There are two main types of photoreceptors in the retina known as the rods and the cones; shown in the figure below.


Light
Section
Eye
Nerve fibres
Ganglion cells
Bipolar cells
Synapsis
Receptors
Cone
Rod
Pigmented cells


Outer segment of Rod cell containing photosensitive chemicals
Outer segment of Cone cell containing photosensitive chemicals
Nucleus
Nucleus
Rod
Cone




**THE STRUCTURE OF THE RETINA**

The retina is composed of three layers of cells each containing a characteristic type of cell; these are:

1. Photoreceptor layer (outermost layer) containing photosensitive cells; the rods and cones partially embedded the pigmented epithelial cells of the choroid.
2. Intermediate layer containing bipolar neurons with synapse connecting the photoreceptor layer to the cell of the third layer.

   -cells called horizontal and amacrine cells found in this layer enable lateral inhibition to occur.

3. Internal surface layer containing ganglion cells with dendrite in contact with bipolar neurons and axons of the optic nerve.

**Note;**

Those three layers of the retina are arranged anatomically in reverse order from what it might be expected; the receptor cells are in the back of the retina; and light must pass through the ganglion cells and bipolar – cell layers to reach them.

The reason for this somewhat unexpected arrangement is the origin of the retinal cells in the embryo and the way in which the eye is formed during the embryonic development.

To add to this confusion; the optic nerve carrying the visual information cross over on their way to the visual cortex in the brain so that the information seen with the right eye is taken to the left side of the brain for processing.

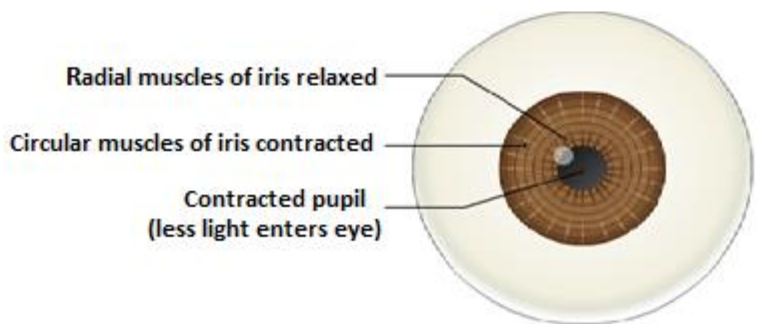
Qn:

1. Explain the occurrence of blind spot in the retina.
2. Explain the mechanism of controlling the amount of light entering the eye.

**Answer plan**

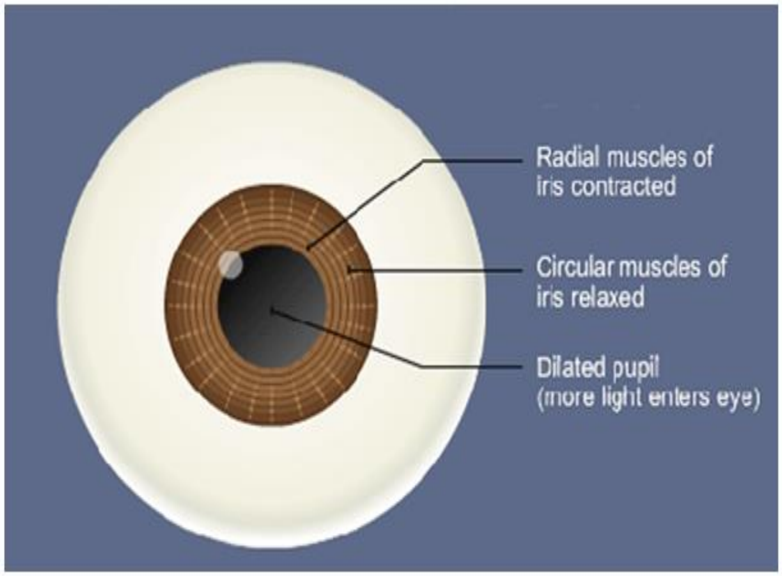
**In bright light**

- More photoreceptor cells in the retina are stimulated by increase in light intensity.
- Greater number of impulses along neurons to the brain.
- Brain sends nerve impulses along parasympathetic nervous system to the iris diaphragm
- In the iris circular muscles contract and the radial muscles relax.
- Pupil constricts reducing its size of aperture.
- Less light enters the eye.



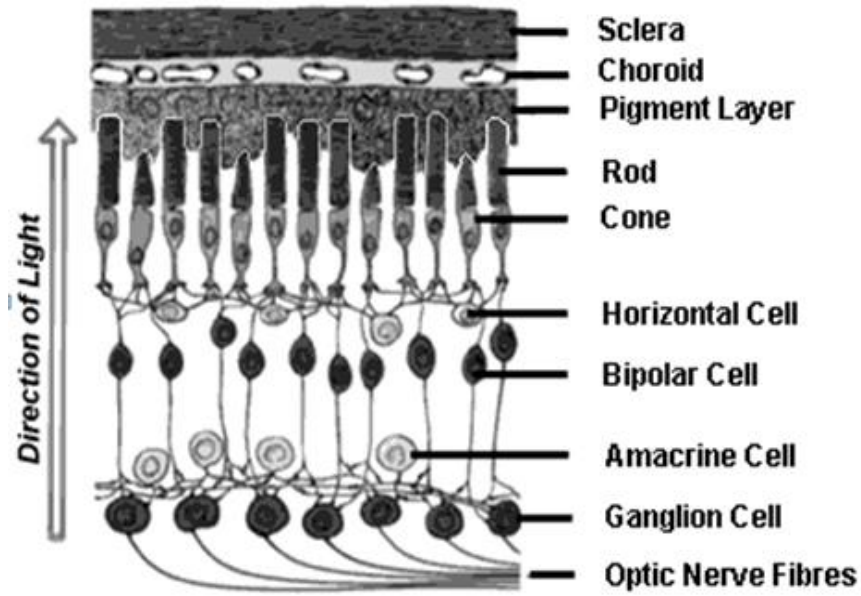

**In dim light**

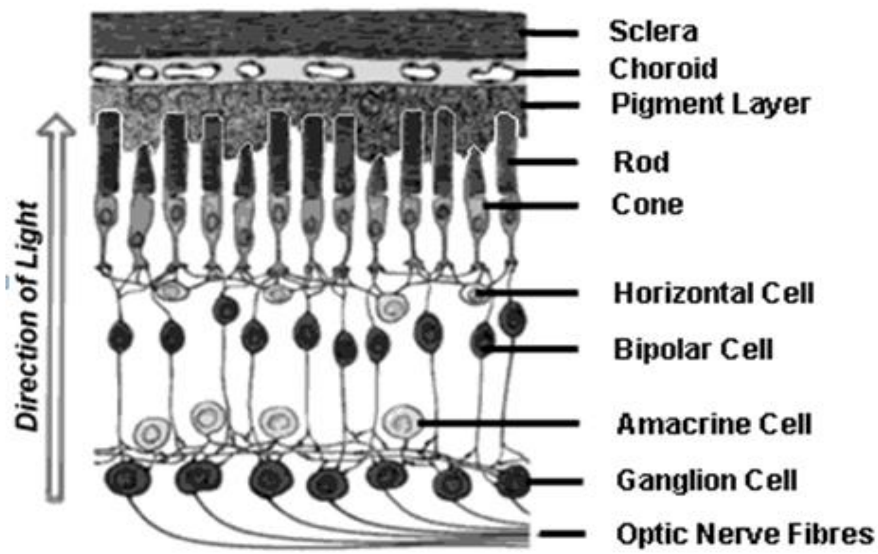
1. Few photoreceptor cells are stimulated due to decrease in light intensity.
2. Fewer impulses pass along sensory neurons to the brain which sends impulses along the sympathetic nervous system.
3. In the iris diaphragm, circular muscles relax and radial muscles contract
4. Pupil relax (dilates)
    1. More light enters eye.

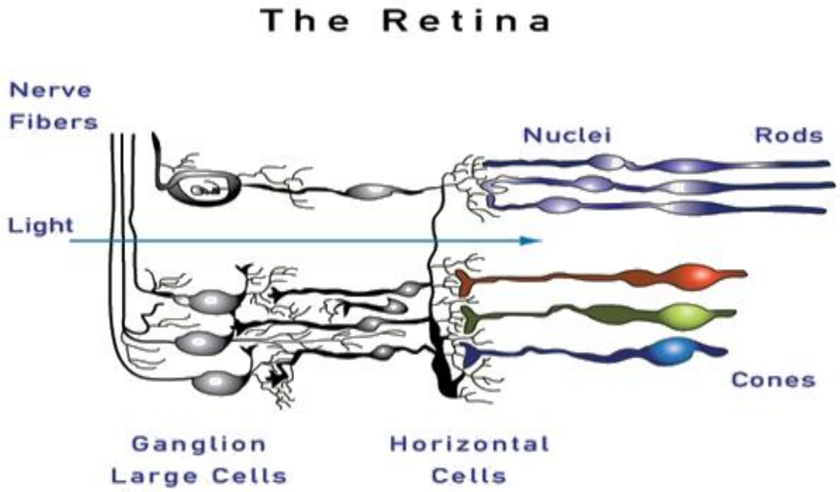


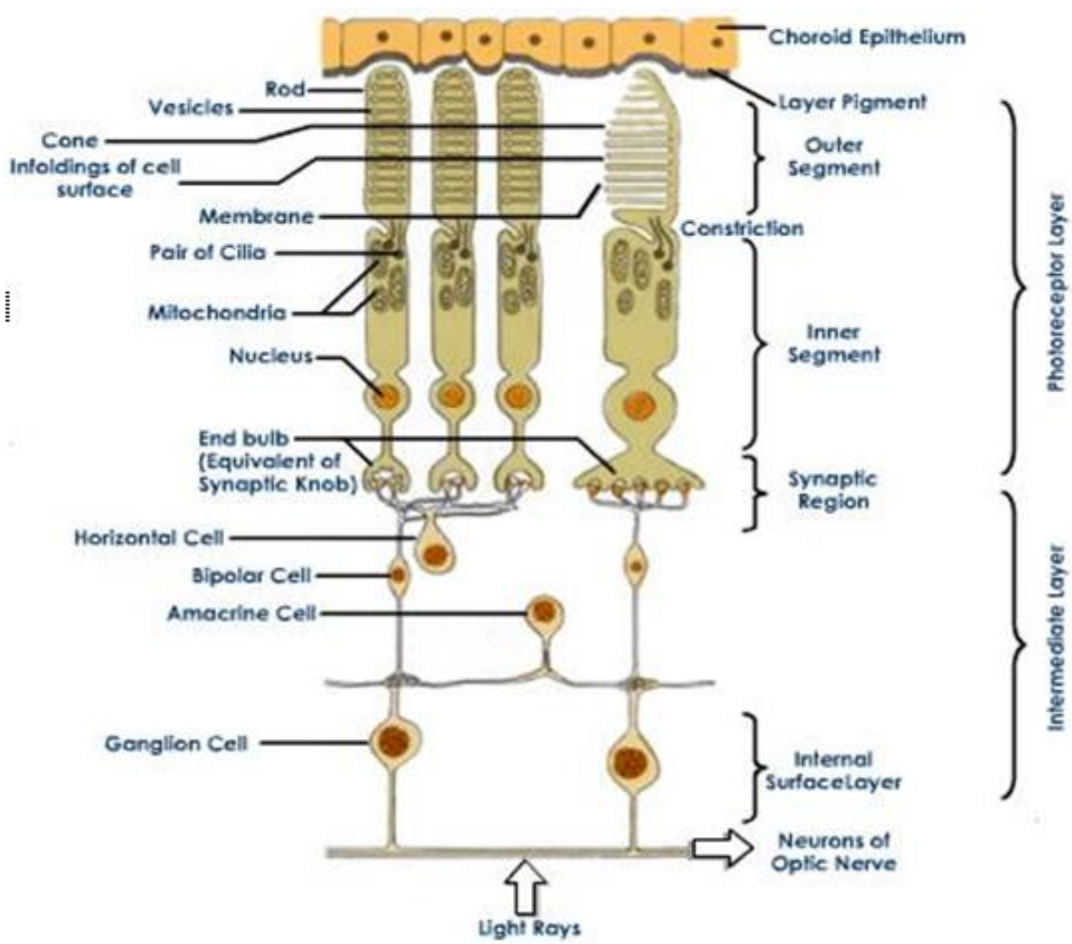

A diagrammatic section through the retina of the eye showing the ultra structure of a rod and a cone.

**A diagrammatic section through the retina of the eye showing the ultra structure of a rod and a cone.**


Sclera
Choroid
Pigment Layer
Rod
Cone
Horizontal Cell
Bipolar Cell
Amacrine Cell
Ganglion Cell
Optic Nerve Fibres
Direction of Light


Sclera
Choroid
Pigment Layer
Rod
Cone
Horizontal Cell
Bipolar Cell
Amacrine Cell
Ganglion Cell
Optic Nerve Fibres
Direction of Light


The Retina
Nerve Fibers
Nuclei
Rods
Light
Cones
Ganglion Large Cells
Horizontal Cells


Choroid Epithelium
Rod
Vesicles
Layer Pigment
Cone
Infoldings of cell surface
Outer Segment
Membrane
Constriction
Pair of Cilia
Mitochondria
Inner Segment
Nucleus
Photoreceptor Layer
End bulb (Equivalent of Synaptic Knob)
Synaptic Region
Horizontal Cell
Bipolar Cell
Amacrine Cell
Intermediate Layer
Ganglion Cell
Internal SurfaceLayer
Neurons of Optic Nerve
Light Rays

**Outer segments**

**Outer segment** is the light sensitive region where the light acts as a stimulus to the production of generator potential

They contain flattened membranous vesicles filled with photosensitive pigments.

**Constriction:**

Constriction is a very narrow region between the outer and inner segment.

- It contains two cilia with unusual structure.
- They have inner strands of their 9 + 2 structure missing.

**Inner segment**

This is packed with mitochondria which produce energy for various processes and ribosome's which synthesize proteins for the vesicles and visual pigments.

**Synaptic region.**

The cells from synapses with the bipolar cells and several rods synapse with one bipolar cell join to give increased sensitivity to light (convergence phenomenon).

Once connected with one bipolar cell giving great visual activity.

**NB:**

**Visual acuity**: is the ability of the eye to resolve two or more stimuli spatially separated.

The cells of the human retina

The human retina has the following cells.

1. The receptor cells (rods and cones) making the outer layer.
2. The bipolar cells which synapse at their tips with receptor cells these make up the in middle layer of retina.
3. Ganglion cells: Which synapse at their tip with the bipolar cells; make the third layer

   -Their axons form the optic nerve, which run from the eyes to the brain.

**NB;**

1. Processing the information can occur within the retina because of the several bipolar cells synapses with a single ganglion cells
2. Besides convergence of information; there is lateral transfer of information from pathway to pathway via horizontal cells (each of which receives synapses from many receptor cells and synapses on many bipolar cells on the other horizontal cells) and via amacrine cells. (which both receive synapses from and synapse on bipolar cells, and also synapse on many ganglion cells)

Roles of horizontal cells and amacrine cells.

1. **Horizontal cells**

   Synapse with several bipolar neurons; this increases visual acuity and sensitivity of the vision. By exerting lateral inhibition. If they receive stimuli from two rods of equal intensity they cancel out (inhibit the stimuli).

   They therefore enhance contrast between areas that are strongly stimulated and there that are weakly stimulated.

   This makes features such as edge of objects stand cut more clearly.

2. **Amacrine cell** (are stimulated by bipolar neurons and synapses with ganglion cells.)

- They transmit information about changes in the level of illumination.
- And hence comment on the mode of action of the two nervous system based on the type of neurotransmitter substance they produce.
  - The rods and cones synapse in the retina with short sensory neurons (bipolar neurons) which themselves synapse in the retina with longer neurons (ganglion cells) whose axons bundled together as the optic nerve, run to the visual centers of the visual centers of the brain.
  - The presence of several sets of synapses within the retina enables the eye to modify extensively the information transmitted from the receptor cells to the b

**THE LIGHT SENSITIVITY OF RODS AND CONES.**

- Both rods and cones contain light sensitive pigments
- In rods the pigment, which is built into the membrane of the flattened vesicles in the outer segment as called rhodopsin
- Rhodopsin is made up of a protein scotopsin (opsin) rended with a light absorbing prosthetic group called retinene retinal, which is a derivative of vitamin A.
- When a molecule of rhodopsin is struck by a photon of light, the retinal is converted into a slightly different isomer i.e.
- When converted to Trans- isomer; rhodopsin then breaks up into opsin and retinene.

- The breaking of rhodopsin sets up a generator potential in the rod and if this is large enough or if several rods are stimulated simultaneously, an action potential is set up in the receptor neuron.
- Once bleaching/ breaking of the rhodopsin have occurred, the rod cannot be stimulated again until rhodopsin is resynthesized. It takes energy from ATP produced by the many mitochondria in the inner segment to convert retinene back to the cis - isomer and rejoin and opsin.

**QUESTIONS**

Qn. 1

1. Explain the structure of a rod and cone cells. Briefly show how each is adapted to its function.
2. Name the cellular components of retina and state the role of each type of a cell.
3. Name the various layers making up the retina.
4. Give evidence of information processing in retina before it is interpreted in the grain. Explain briefly.
5. Explain the concept of visual acuity and show the reality that cones have high visual acuity than rods.

Qn. 2

a)State any two special anatomical exceptions noted as far as the retina and associated neurons are concerned.

b) Explain what happens in iris and retina when one

1. Gets into a dark room.
2. Gets in bright light.

Use illustrative diagrams where possible in supporting your answer and explain the biological terms (if any) that applied to any of your answers above.

Qn. 3

a) Explain the process of accommodation based on

1. Eye lens
2. Receptors neurons

Qn. 4

a) What is a neuromuscular function illustrate with a well labeled diagram

b) Name the neurotransmitter substances in the neuromuscular junctions from

1. Parasympathetic nervous system
2. Sympathetic nervous system.

MECHANISM OF PHOTORECEPTION

Rods contain the photosensitive pigments called Rhodopen or vival putple. Rhodopsin is made by combination of a protein called satopsin with a small light absorbing molecule called retinene (retired) which is a derivative of vitamin A.

In the presence of lights rhodopsin decomposes into retinene and scetopsin a process known as bleaching. Rhodopsin is formed in the absence of further stimulation of light a process known as Dark adaptation. The retinal exist into two isomers.

Bleaching leads to the creation of a generator potential in the rod cell which is sufficiently large, generate on action potential along the neutrons leading from the cell to the brain.

For the daylight cones are used. They contain photosensitive pigments called Iodepsin.

PHYSIOLOGY OF SEEING:

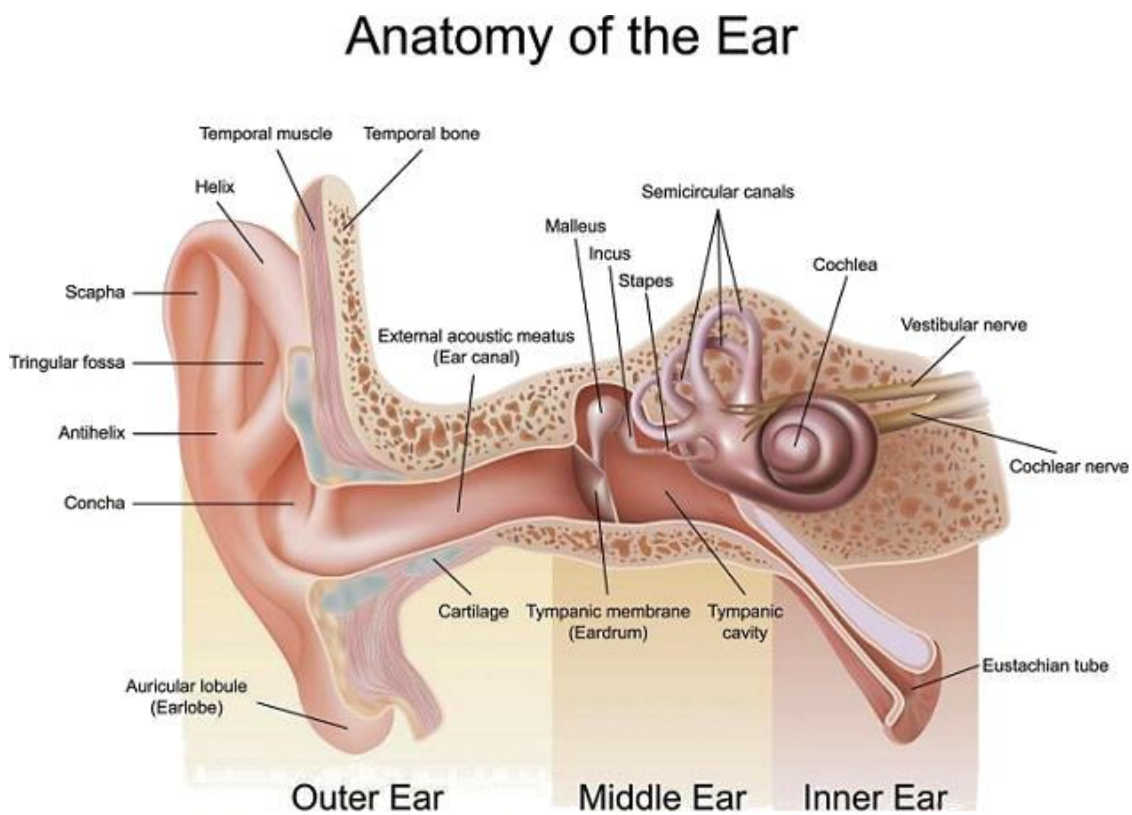
The light rays from an object reach the eye and pass through the transparent conjunctive, cornea, aqueous humor and crystalline line.

The cornea bends the light rays and the line causes more bending there refracted light rays passes through the vibreake humour and finally came to focus at a point in the reline. The point at which the image focus is called fovea or yellow spot and the image formed is Real, smaller than object and invested.

On the fovea, the light impulse are converted into electrochemical impulses and are sent to the visual area of the brain through the .. nerve. In the brain an Interpretation of the size, nature, distance and uprightness of the object is made.

THE MAMMALIAN EAR:

The ear is a sense organ containing mechanoreceptors sensitive to body displacement and sound. Movement and portion of the head relative to gravity are detected by the vestibular apparatus composed semicircular canals, succulus and utricle. All other structures the ear are involved in receiving amplifying and transdusing. Energy into electrical impulse and promotion of the sensation of the inner ear is principally heating and balancing part of the ear.



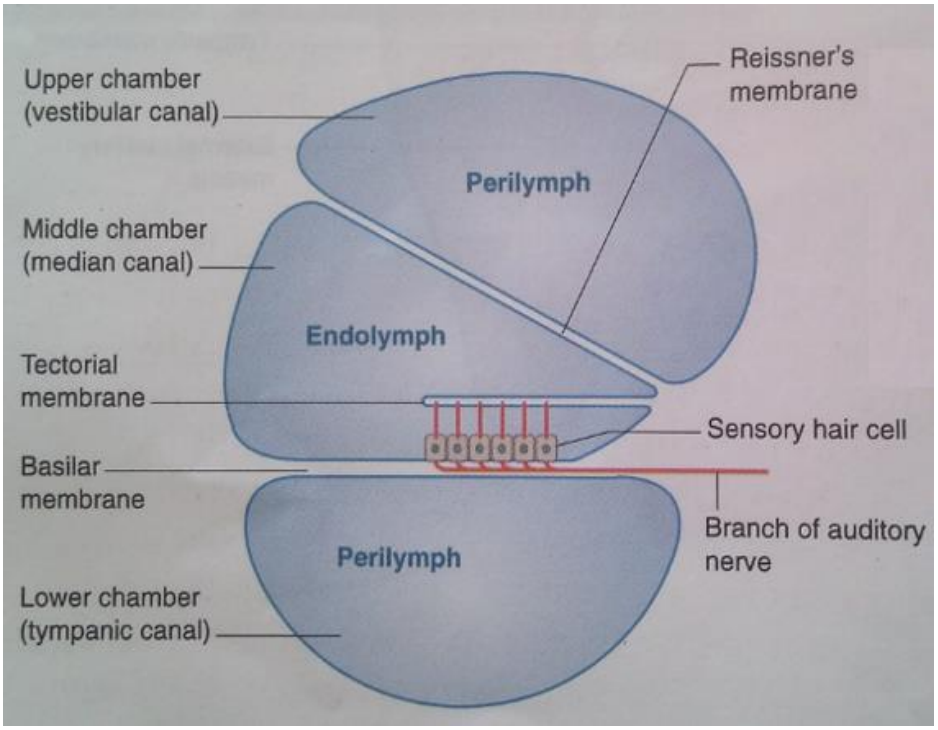

STRUCTURE OF THE MEMBRANEOUS LABYRINTH

Pointed out earlier, the membranous labyrinth is involved in hearing and balance. It is found in the inner ear. It is structurally compound of three semicircular canals that lie, at right angles to one another.

The canals arise from a swollen utricules, Below is high coiled  that is involved in hearing. The succulus and a connection between the ampula is known as ductus utriaili.

COCHLEA AND HEARING:

Cochlea is spiral sub deviled into three layers vertibular canal and tympanic canal contains perilymph and median canal which contain endolymph. The basilar membrane separates the median and tympanic canals and supports sensory hair cell that can be brought into contact with the tecterial membrane above. This unit consists basilar membrane, sensory cells and tectorial membrane is called ….organ of coit and is the region where transduction of sound … into electrical impulse occurs




Organ of Corti.

MECHANISM OF HEARING:

Sound waves are directed toward the inner ear through the External auditory meatices where they cause the tympanic membrane to vibrate. In the middle ear the vibration of the tympanic membrane are across the oval window by movement of the three ear asides, the mallcus, incurs and stapes.

The vibration are than transmitted into the innear ear where they cause perilymph of the vestibular canal to vibrate and these are transmitted via Reissner's membrane to the endolymph in the median canal. From there they are transferred to the basilar membrane and the perilymph in the tympanic canal, and are finally dispirited, into the air of the middle ear as vibration of the round window.

Vibration of basilar membrane pushes the sensory hair against the tectorial membrane and forces the two membrane to slide part each other. The distortion produced in the sensory hair cells due to the shearing forces causes a depolarization of the sensory cells, the production of generator potential, and initiation of action potentials in the axons of the auditory nerve. The latter transfer the impulse to Auditory part of the brain where an interpretation of the pitch note, intensity and quality of the sound is mode.

THE MAMMALIAN EAR AND BALANCE:

Several parts of the body are involved in maintaining balance at … and during movements. The parts that are involved include eyes, …. Receptors. In joints and muscles etc. however vital information, ….. to position and movements of the head is provided by the vestibular apparatus of the ear, the utricle, sucaule and semicircular canals.

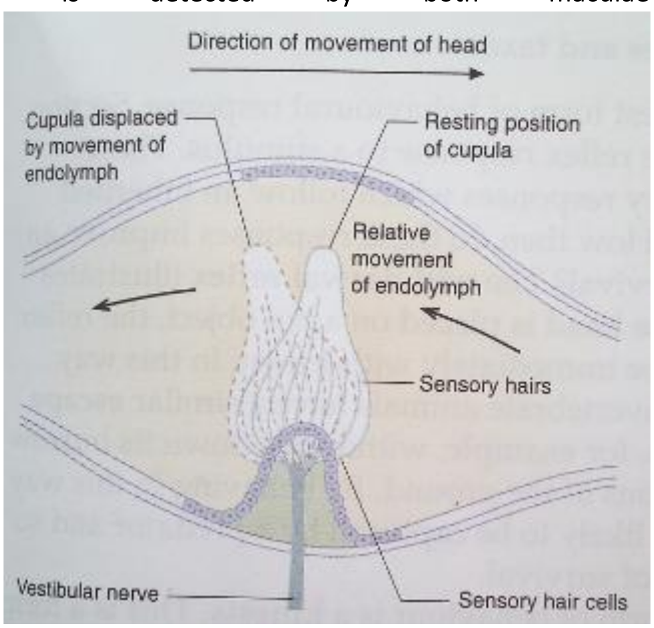
The basic sensory receptor in these structure consist of the hair cells attached to dense structures supported in the Endolymph, the region of the walls of utricle and saccule, the maculae contains granules called atoconia in association to receptor cells.

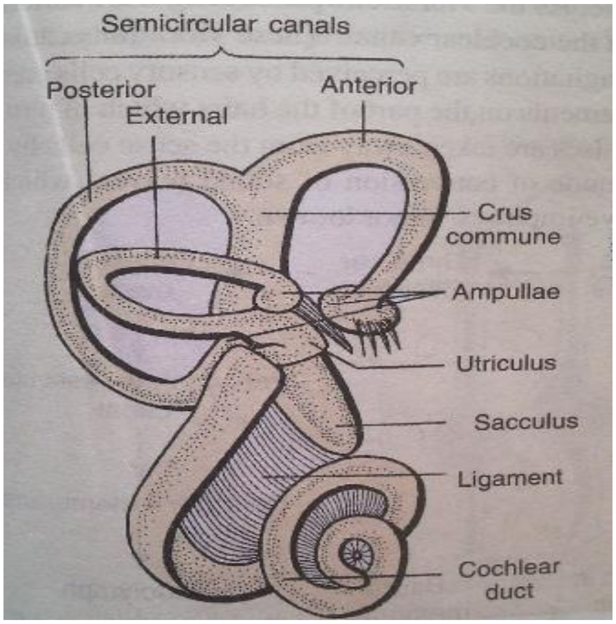
The atoconia responds to gravitational pull and mainly detect the direction of movement of the head with respect to gravity.

The utricle respond to vertical movement of the head e.g. when the body is upside down.

The saccule responds to lateral movement of the head. The semicircular canals responds to rotational movements of the head and they contains cupules that works in the same way of maculae.

Linear acceleration is detected by both maculae and ampullae.






Ampulla of semi-circular canal Membranous labyrinth of human

N.B: Adaptation of organ of corti

(i) It has vibration and movable membranes

(ii) Has sensory cells as that detect sound waves

(iii) Has auditing nerve for carrying electrical impulse to the hearing part of the brain

(iv) Has vibratory fluid which amplify sound vibrations.

HORMONAL CO-ORDINATION:

In mammals and other higher animals there are two co-coordinating system those include nervels system and hormonal system.

Defn: A hormone is a chemical substance which is produced at one part of the body and exerting it's effect at another part of the body away from it's centre of production.

The organ/part that receives effects of hormones are called target organe or target parts. The hormone is secreted directly into the blood stream. Such ductless gland which secrete hormone are called endocrine glande which constitute the endocrine system.

Mechanism of Hormone Action:

The mechanism of controlling the release of Hormones by the glands is as follows:-

(1 Presence of specific metabolite in the blood, e.g. Presence of Excess Glucose in the blood, causes the release of Insulin

(2 Presence of another hormone in the blood e.g. Many of hormones released by the anterior pituitary cases the release of other hormones.

(3 Stimulation by neurons from autonomic nervous system e.g. adrenaline and noradreline are released by the Adrenal gland following the arrival of impulses in the condition of anxiety, stress and danger

FEEDBACK MECHANISM OF HORMONAL CO-ORNATION:

Feedback mechanism is a self regulating mechanism in the body which tends to restore the physiological equilibrium or stability of the body or increase in the instability of the body.

TYPES OF FEEDBACK:

(a (a) Positive Feedback:

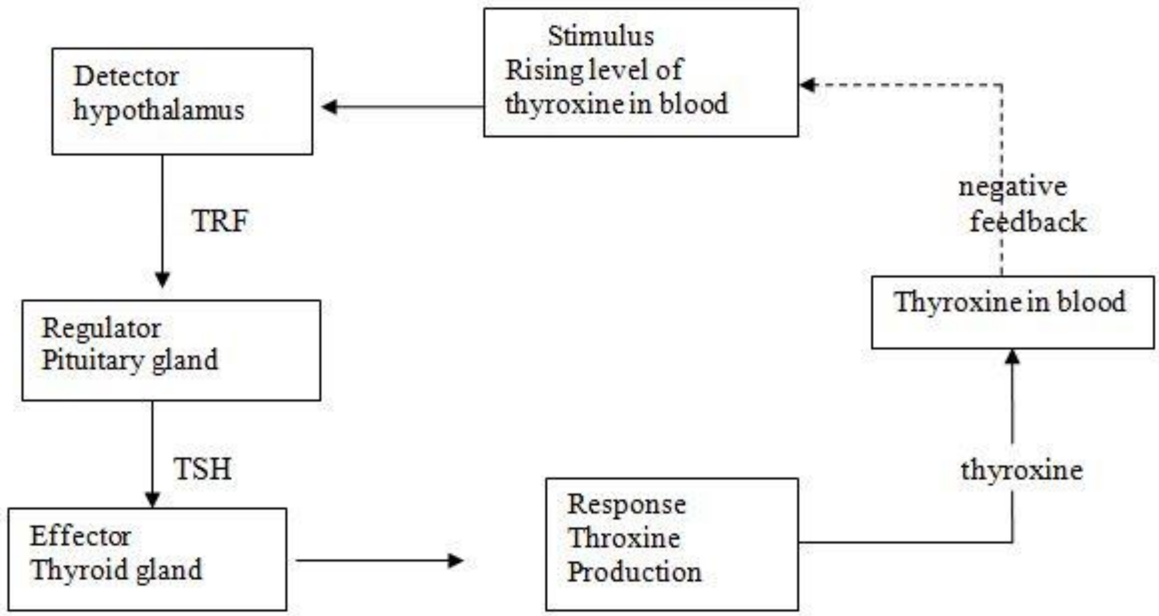
This is a type of Feedback that tends to increase the effect of the disturbance. Positive feedback responses are rare in biological systems because they increase instability of the body.

(b) Negative Feedback:

This brings the body back to its normal physiological states thus the negative feedback mechanism, are important in the biological systems.

- Examples of biological negative feedback mechanisms include the control of heartbeat, blood pressure, body temperature and hormone levels i.e. secretion of insulin.

- Consider the feedback mechanism of Thyroxine production:-




N.B:

TRF – Thyroid releasing factor

TSH – Thyroid stimulating hormone

Note: Examples of positive feedback: During labour when hormone oxytocin stimulate muscular contraction of the uterus which in turn stimulate the release of more oxytocin.

Interaction between Hormonal and Nervous Systems:

The two co-ordinating systems i.e. hormonal and nervous system at one point depend on one another. For example the release of hormone sometimes depend on the response reaching the Gland through the nerve cell. For example adrenalin and neradreline are released by the adrenal gland following the arrival of impulse in conditions of danger, anxienty and stress. Thus hormonal and nervous system depends one another when co-ordinating the body system.

NERVOUS AND HORMONAL CONTROL OF SECRETION:

In mammals the production of digestive secretion is under both nervous and hormonal control.

- Nervous stimulation occurs before the food reaches the mouth, then sight smell or thought of food causes salivary gland to produce saliva.

- The following are number of juices secreted and the actions of hormones and nervous towards secretions.

SALIVA:

As above explained sight, smell and thought can lead to secretion of saliva.

Also presence of food in the tongue stimulate further recreation of saliva.

Note: There are three important hormones secreted in the stomach and small intestinal region called:-

(i) Gastrin
(ii) Secretion
(iii) Choleoystokinin (CCK)/Panreozymin.

GASTRIN:

Presence of food in the stomach stimulates the walls of stomach to pralls a hormone called " gastrin" which passes into the blood stream. Gastrin stimulate the production of gastric juice from gastric gland for up to 4Ø occurs

Note: Digestion of fats takes longer and requires less acidic conditions ….. sence of fats in the stomach initials the production of hormone called terogesterone which inhibits any further secretion of the acid by oxyntic of the stomach.

SECRETIN:

This hormone is produced by the small intestinal wall cells and passes the blood stream and meets the three target liver, stomach and increase.

IN THE STOMACH: It inhibits the secretions of gastric juice by inhibiting the secretion of gastrin

IN THE LIVER: It stimulates the bile to produce salts like $NaHCO_2$ used in neutralization of ocidic style chime.

IN PANCREASE: It stimulates the pancreas to produce alkaline salts e.g. $NaHCO_3$

CHOLE CYSTOKININ/PANCRE: OZYMIN

- This hormone also it recreated by small intestinal wall cells and …. into three targets; liver, stomach and pan crease.

* IN THE STOMACH; Inhibits stomach emptying

*IN THE PANCREASE: It stimulates the secretion of pancreatic juice to the duodenum.

*IN THE LIVER: It stimulate the contraction of gall bladder walls hence secretion of bile through bile through bile duct.

EPITHELIAL AND GLANDULAR TISSUES IN RELATION TO THEIR DIGESTIVE ROLES:

- Epithelial tissue is a type of tissue which covers the external parts of the body as well as internal parts, such as lining of atemosmestory canal.
- Epithelium performs various functions such as diffusion in transportation and secretion of substances as well as protection of the body parts
- Example of Epithelial tissue.

(a Columnar Epithelial tissue:

This consists of elenejated calls which are quite narrow, thus providing more cytoplasm per unit area of epithelium. Each all possesses a nucleus situated at its basal end. Also it certain goblet cells:

There is a striated border or brush border of microvillus at the force surface end of each cell.

Location: stomach small intestine, kidney ducts and thyroid gland.

Functions:

(i) Mucus secreted by goblet cells in the epithelium of stomach protects the stomach lining from the acidic contents of the stomach and from digestion by enzymes.
(ii) Mucus secreted by goblet cells in the epithelium of small intestine protect it from self digestion and lubricates the passage of food
(iii) Microvillus increase surface area for absorption and secretion in the ileum.

**Comparison:**

Comparison of Hormonal and Nervous system:

| Nervous system | Hormonal system |
|---|---|
| Information passes as electrical<br><br>Passes along the axon (chemical the synapse)<br><br>Rapid transmission<br><br>Response is immediate<br><br>Response is short lived<br><br>Response is very exact | Information passes as chemical substance through the blased stream<br><br>- Slow transmission<br><br>- Response is usually slow e.g: Growth<br><br>- Response is long lasting<br><br>- Response is usually wide spread |

THE ENDOCRINE GLANDS

There are ductless glands that secrete Hormones directly into the blood stream. Such glands include.

THE PITUITARY GLAND:

Pituitary gland, also known as master gland is divided into two ….

Pasterior pituitary:- This does not synthesize any hormone but … and release two hormones, Ant diuretic hormone (ADH) and ………which are produced by neurosecretory cell bodies lying in hypothalamus and pass down the nerve fibres.

(i) ADH or VASOPRESSIN:- Is released in response to a in the water content of blood plasma and leads to an increase ..meability of water of the distal and collecting tubules of the … in the kidney so that water is retained in the blood plasma, reduced volume of urine is excreted.

(ii) OXYTOCIN: - Cause contraction of uterus during birth

- Stimulate ejection of milk from the nipple

Anterior pituitary:- This is connected to the hypothalamus by blood vessels which form potal system. Pituitary gland produce and store hormones known as trophic hormones. A trophic hormone is one which stimulate other endocrine gland to release their hormone.

Anterior pituitary is regarded as a master gland because it controls secretion of hormone from other glands

Interior of hormone secreted by anterior pituitary gland are controlled by hypothalamus hormones such as:-

(i) Corticotrophin by releasing hormone (CTRH) – this stimulates the release of ACTH which acts on the adrenal gland.

(ii) Thyroid releasing Factor (TRF) – This stimulate the release of Thyroid stimulating hormone (TSH) which acts on thyroid gland to release thyroxine hormone.

(iii) Genadotiopin releasing hormone GnRH) – This stimulate the release of FSH and LH.

(iv) Growth releasing Hormone – This stimulate the release of Growth hormone (GH)

(v) Growth inhibiting hormone (GIH) – This inhibits the release of growth hormone.

(vi) Prolactin releasing factor – This stimulate release of prolactin

(vii) Prolactin inhibiting factor – This inhibits the release of prolectin.

HORMONES OF THE ANTERIOR PITUITARY:

The hormones secreted by the anterior pituitary include the following:-

(i) Thyroid stimulating Hormone (TSH)

Roles:- Stimulate the growth of thyroid gland

- Stimulate T. gland to release thyroxine hormones

(ii) Adrenal corticotrophin Hormones (ACTH)

Roles:- It regulates growth of the adrenal cortex

- Stimulates adrenal cortex to release hormones such as adrenaline.

(iii) Follicles stimulating Hormone (FSH)

Roles:- Stimulate the development of Gracifian follicles

- Initiates sperm formation in the testis

(iv) Luterising Hormone (LH)

Roles:- Stimlates ovulation and formation of corpus luterising

- Stimulates secretion of testerone from the cells in to…

(v) Prolactin (Luteotrophic hormone) LTH

Roles:- Maintain progesterone production from the corpus luterim

- It induces milk production in pregnant females.

(vi) Growth hormone (GH) or somatotrophin Hormone (STH)

Roles:- Promotes growth of the skeleton and muscles

- Controls protein synthesis and general body metabolism

Stimulates the production of glucagon by the X-Cells of islets of langerhane of the pancreases

**Abnormality of Pituitary Gland:**

(i) Deficiency (hypor secretion) of growth hormones before maturity leads to dwarfism.

(ii) Overproduction (hyper secretion) of growth hormones during skeretal development results to Giantism (gigantism)

Excess of Growth hormones at maturity causes excessive growth of certain part of the body such as palm of the hand. This called Acremegally

THE THYROID GLAND:

This gland is found in the neck region in each side if the junction …… the Larynx (veils box) and trachea (wind pipe)

Hormones of the thyroid gland:

Trilodo thyroxine ($T_3$)

Tryroxine ($T_4$)

Calatorin

$T_3$ and $T_4$ are similar structurally and functionally they differ the fact that $T_3$ contains three Iodine atoms while $T_4$ 4 Iodine atoms

(i) To control the basal metabolic rate (BMR):- Basal metabolic rate is the rate at which oxygen and food are used to release energy. It is rate at rest.
(ii) To promote the breakdown of glucose and fats to provide energy
(iii) Thyroxine and growth hormone 9GH) has joint Ermlattatory effect on protein synthesis, leading to an increase in growth rate, particulary of the skeletal system
(iv) Thyroxine stimulate brain development $7_3$ and $7_4$ work in conjuction with insulin, Adreneline and glucose corticoid

Calatorin

Roles:- Controls calcium metabolism

Abnormalities of the Thyroid gland:

(a) Hypothyroidism (Under activity)

(1) In immature creatures, Its result into a condition called cretin
A cretin has the following features:-
(i) Dwarf
(ii) Mentally retardat
(iii) Irregular development of bones and musdes
(iv)
(v) Skin become dry the eyes are puffy, hair is brittle and shoulder are sag.

(2) Myoxedema – Results when the thyroid gland become underactive during adult hood. This condition results into:-
(i) Swallon facial features
(ii) Tiredness
(iii) Passible mental retardation
(iv) Intolerance to cold, due to law basal metabolic rate (BMR)

(3) GOITRE, Results due to insufficient production of thyroxine hormone, the thyroid gland swells. This swelling in the neck .. caused by insufficient Iodine in the diet which force the thyroid to expand in an effort to produce more thyroxine

Over activity of the thyroid gland (Hyper thyroidism)
Over activity may be due to overproduction of thyroxin from an …. Thyroid gland.

The symptoms are:-
(i) Increase in heart rate
(ii) Increase in ventilation rate
(iii) Increase in body temperature
(iv) The basal metabolic rate may increase by 50% with associated
(v) Increase in oxygen consumption and hear production
(vi) Extreme hyperthyroidism is thyrotoxicosis and is associated with released excitability of cardiac muscle which my lead to heart lure failure.

(C) PARATHYROID GLAND

These are four tiny gland embedded in the thyirod gland. They stimulate a single hormone called parathormone

- it maintain the level of calcium in the blood at a sufficiently required amount. Hence maintaining proper working of the muscle and nerve.

(D) ADRENAL GLAND:

These are pair of adrenal glands located one just above each kidneys. The outer region is called cortex and inner region is called Medulla.

Adrenal gland secrete several hormones which effect body metabolism.

Adrenal cortex produce two types of hormones

Mineralocorticoids e.g. Aldosterone

(i) Controls water and salt content of body stimulating cation pumps in membrane to conserve $Na^{-1}$ and $Cl^{-}$ and remove $K^{+}$
(ii) Prevent excessive $Na^{+}$ loss in seat, saliva and urine
(iii) Maintain asmotic concentration of body fluids at a steady state.

Glucocorticoids e.g. costisol

(i) Promote gluconeogenosis, linier glucagen formation and raise blood glucose level
(ii) Promote breakdown of plasma, protein and increase availability of amino acids for enzyme synthesis in the liver
(iii) Prevent inflarrunatory and allergic reactions
(iv) Decrease antibody production

Adrenal medulla produce two hormones which are adrenaline and noradrenaline

The roles of adrenaline and noradrenaline are that they .. body for action and therefore sometimes called fight, flight fear hormones as they allow the body is react quickly to urgencies.

(E) THE PANCREASE

The pancrease rest just below the stomach. It 99% exocrine and endocrine gland. Hormone s secreted by the pancrease in a duster called islet of langerhane . the hormones are:-

Insulin:- Secreted by the B-cells of the islets of langerhane is hormones converts Glucose into Glycogen i.e. It regulate the amount of sugar in the blood.

Glucagon:- Secreted by the X-cel of lolet of langerhane. This increase the blood glucose level by transmitting the liver to convert glycogen into glucose.

DISORDER OF THE PANCREASE

Diabates Mellitus:

This is caused by insufficient production of insulin from the ß -cells islets of langerhans, glucose accumulates in blood and is deposited in the kidney but the glucose never enters the cells

Symptoms:

Sugar in Urine:

Hardening of arteries

High degree of dehydration and thirty

(F) GONADS:

These Includes:

The tests:- Male gonads

These secretes the sex hormones called testosterone from the interstitial cells also it stimulates the development of sexual secondly features

Eg. Developments of beard and moustache, penlarge genital organs using and broken voice and increase sexual desire.

Desecration of testosterone leads to decrease size and activity of reproductive organ penis erection and volume of ejaculation.

Secondary sexual features are also affected:

The Ovarice – Female genads

secretes hormones like:-

Oestrogen the development of sexual secondary features of females. The development and enlargement of female reproductive organs soft voice, the growth of pubic hair and in the armpit and start of menstrual cycle.

Progesterone:

Progesterone:- Is secreted by the corpus luteram it inhibits the release of egg and it stimulate thickening of uterus wall.

LOCATION OF HORMONE IS IMPROVING HUMAN LIFE AND ANIMAL HUSBANDRY:

synthetic hormones has been of great use in improving life and animal husbandry.

Example:

Growth hormone have been much used to induce rapid growth animals such as chicken, cow etc.

Some of the reproductive hormones are used to induce increased production of eggs by chicken.

Hormones like prolactin and oxytocine are used to induce caused mil production in cows and goat etc.

In man the synthetic oxytocin is used to induce labour pain the process of birth.

Synthetic sex hormones such as progesterone hormone are used as contraceptive method. The contraceptive pills contains progesterone

CO-ORDINATION IN PLANTS:

Its pointed out earlier plants are less irritable than animals because they have only one co-ordinating system i.e. Hormonal co-ordination constituting the phytohormones. Their responses are therefore slow and they often involve growth. Growth in turn can result in movement of organ.

The responses that are indicated by plants involves movement and they are due either external or internal stimuli. The response that are due to internal stimuli are called spontaneous responses

Example protoplasmic streaming of cell e.g. In Amoeba.

Responses due to external stimuli are called induced responses.

TYPES OF MOVEMENTS WITH RESPECT TO RESPONSES:

The types of movements exhibited by plants and plant like, organism due to response include the following:-

(a) Tactic movement
(b) Nastic movement
(c) Tropic movement

A. TACTIC MOVEMENT:

A taxis is the process whereby an organism move from one place to another in response to external stimuli. Such a movement is referred to as Tactic movement. Where the whole of an organism shift from one place to another in response to external stimuli. This movements is not confirmed to plants, it is exhibited by animals and plant like euglena.

If an organism move towards the source of stimuli, it is said to exhibit positive tactic movements, but if it moves away from stimulus it is said to exhibits negative taxis.

B. TYPES OF TAXES:

(a) Photo taxis – The organism movies in response to the stimulus of light e.g. cockroach moves away from light (Negative phototaxis or towards light (positive phototaxis) e.g. Euglera.
(b) Chemotaxis – the organism in response to the stimulus of chemical
(c) Positive chemotaxis – sperme of messes and ferns swim towards substances released by ovum

- Negative chemotaxis – Mosquito avoid insect repellent

(i) Aerotaxis – The organism moves in response to stimulus of air (oxygen)

Example motile aerobic bacteria move towards oxygen.

(ii) Geotaxis - The organism moves in response to the e.g. plarula larvas swim towards sea bed

(iii) Rheotaxis – The organism move in the response to the stimulus of resistance. E.g planaria move against water current

(iv) Megnetotaxis – The organism moves in response to the stimulus of magnetic field. E.g. certain motile bacteria.

**Significance of Tactic Movements:**

Enable organisms to escape unfavourable environment

e.g: Euglena moves away from excess light it avoids the effect of light it such movements increase survival chances of an organism.

Enable an organism to move towards the required material e.g. bacteria to move towards oxygen

They bring together into contacts some cells e.g. sperm and ova (chemotoxis) whose fusion leads to the formation of zygote.

NASTIC MOVEMENT:

A nasty is a process where by a fixed part of stationary plant exhibits non-directional movement in response to external stimulus

## (A) TYPES OF NASTIC MOVEMENT:

Nyctinasty:

These are sleep movement of certain parts of plants such … flowers and leaves where they can close and open on …………………

Forms of nyctinasty:

(i) Photonasty - sleep movement due to stimulus of light
(ii) Thermonasty - sleep movement due to stimulus of temperature
(iii) Hyponasty - The type of movement in which some flowers e.g. tulip close at night by the flower side of the petals growing more rapidly
(iv) Epinasty - The type of movements in which opening is caused by more rapid growth of the upper side of the petals
(v) Haptonasty - Type of nastic movement in which the stimulus is touch e.g. closure of the leaves of the Mimasa pudica on being touched

Seismonasty - This is the nastic movement in which stimulus is stuck

## (B) MECHANISM OF NASTIES:

Consider the leaves of the mimosa plant, these have swelling called palvinus at the base of a petiole or leaflet which posses large parenchyma cells. Rapid tiger pressure changes in these cells result in the pulvina acting as a hinge joint and bring about movement.

The stimulus is said to be transmitted by a hormone moving through the xylem, electrical changes are associated with its passage but there are no nervous system.

Significance of Nastic movement.

(i) Defence of the leaves or plant against external enemies such as high temperature etc.

(ii) Opening of petals which increase the chance for pollination.

(C) TROPISM:

Tropic movements, these are the directional movements exhibited by the fixed part of a stationary plant in response to external stimulus.

(D) TYPES OF TROPIC MOVEMENT:

Phototropism - Response due to light

Emotropism - response due to chemical

Hydrotropism - response due to water

Thigmotropism/haptotropism - response due to touch

Theotropism - response due to gravity

Significance of Tropism

Positive phototropism of plant sheets enhance exposure of leaves to light is enable photosynthesis to take place

Positive hydrotropism of roots increases the chance for water absorption plant.

Positive geotropism of roots increases the chance for mineral absorption plant and encourage ……… of plant in the soil

Positive chemotropism e.g. movement of pollen tubes in response to chemical used at micropyle of ovule enable fertilization to occur hence … of seeds and fruits

PHYTOHORMONES:

These are plant hormones which are commonly known as plant with substances or regulators. They can be either stimulating growth stimulants or retarding growth i.e. growth retardants.

TYPE OF PHYTOHORMONES:

- Auxin
- Gibberellins
- Cytokirin
- Absassic acid
- Ethylene

The first three are growth stimulants and last two are growth retardants

A: AUXINS:

These are the prime plants growth hormones. They are synthesized the roots and shoot apices as well as in the young leaves.

The commonly known group of hormones includes. The indole acetic acid (I.A.A)

**Role of Auxins**

They promote growth of the roots at very low concentration.

They promote cell elongation in region behind apex, hence stein growth.

The promote growth of roots from cuttings.

They promote fruit growth and sometimes induce pethenocarpy

They promote apical dominance i.e. They inhibit lateral bud growth

They inhibit abscission. Hence prevent the pre-mature falling of leaves and fruits.

COMERCIAL APPLICATION OF AUXINS:

Promoting- They help in natural setting in the absence of pollination (parthenocapy)

Acoine promote development of root in cuttings also weed killers Selective they are used as selective weed killers they kill broad leaved species.

GIBBERELLINS:

Gibberellins derive their name from the fungus called gibberella Fujikuroi which causes abnormal elongation of the rice condition called foolish speedling. The commonly known gibberellins is the Gibberellic acid (G.A.)

Plants: GA are abundant in young expanding organ where synthesized at young apical leaves, buds, seeds and roots tips of Gibberellins.

it promote cell enlargement in the presence of auxine
it promote cell division in apical menstems and cambium.
it promote fruit growth and sometimes paxthenocapy,
it break bud and seed dormancy.

it promote flowering in long day plants and inhibit in short plants.

COMMERCIAL APPLICATION:

Promote fruit setting and are used for growing seedless grayer element of seedless fruits can sometimes occur in fertilization

in place and is known as parthenocaspy

Are used in the brewing industry to stimulate $\alpha$-amylase in barley and hence promote malting.

use of anti-gibberellins" result in short (dwarf), study plant keep green leaves and sometimes greater pest and disease resistence

CYTOKININ:

Are most abundant where rapid cell division are occurring especially goods where there is embryo growth and development.

Role of Cytokinln
Promote Cell division in the presence of auxins
promote fruit growth
Promote note lateral but growth
They break seed and bud dormancy in the presence of light and high temperature

It delay leaf senescence.

Commercial application:

They are used to prolong life of fresh leaf crops such as cabbage

They are used to keep flowers fresh

They are used to break dormancy of some seeds

ABSCISSIC ACID:

These is synthesized in the leaves, stem and seeds. It is a major plant growth inhibitor. It is sometimes referred to as “abscissia hormone”

It is antagonistic to all other classes of plant growth promoters

**Role of Abscissa acid (ABA)**

Inhibit stem growth especially during physiological stress e.g. in drought and water logging they promote bud dormancy

Promote abscission

**Commercial application of ABA**

Can be sprayed on tree crops to regulate fruit drop at the season. This removes the need for picking over a long

Can be sprayed to the plant to increase closure of the stomata during

drought.

ETHYLENE (ETHENE)

These gaseous compound which is transported in solution form in plant

**Role of Ethylene**

Growth of the stem notably during the period of physiological stress

Promotes root growth

Promotes bud dormancy

Promotes flowering in pineapple

Promotes fruit ripening

**Commercial application of ethane**

Induces flowering in pineapple

stimulates ripening of tomatoes and citrus fruits

it is applied to rubber plants to stimulate the floor of latex

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# NUTRITION

**Nutrition** is the process of acquiring energy and materials such as proteins, glucose, minerals, fats etc.

Living organisms can be grouped on the basis of their source of energy or source of carbon.

1. **Autotrophic**

   Use of inorganic sources of carbon i.e. $CO_2$, for example plant, Algae and Bacteria e.g. cyanobacteria.

2. **Heterotrophic**

   The source of carbon is organic for example animals and protoctista.

**PHOTOSYNTHESIS.**

Photosynthesis is the process whereby green plants, algae makes their own food in which complex organic molecules, glucose is formed by the use of simple inorganic materials such as $CO_2$, $H_2O$ and minerals in the presence of light absorbed by chlorophyll.

**IMPORTANCE OF PHOTOSYNTHESIS.**

1. It converts light energy into chemical energy.
2. Maintains life in the ecosystem.
3. Convert the inorganic forms in the world i.e. reduce $CO_2$ from the air.
4. Almost life on the earth depends on photosynthesis either directly or indirectly.
5. Release of oxygen
6. Sources of fossil fuel

**THE LEAF STRUCTURE**

The leaf is the main photosynthetic organ of the plant although other parts like stems, sepals, roots and other parts may also photosynthesize.

Adaptations of leaf for photosynthesis

1. They grow positively to phototropism
2. Rapid elongations of shoots in dark to ensure leaves are brought into light as soon as possible.
3. The leaves are arranged in mosaic form (avoiding or minimizing overlapping) in order to allow maximum absorption of light.
4. Leaves have large surface area to volume ratio to capture as more sunlight as possible.

   Example: in cold areas where sunlight is scarce leaves are

   (Very small). This is an adaptation so that each leaf will receive sun light

5. The cuticle and epidermis (protective cells) are transparent. They can allow passage of light.
6. Mesophyll cell are packed with chloroplast.
7. Chloroplast holds chlorophyll

- Chloroplast is surrounded by two membranes which forms envelope.
- Chloroplasts contain green pigments i.e. chlorophyll and photosynthetic pigments like carotenoids
- Inside the envelope fluid is stroma.
- Membrane system of chloroplast is a site for light depending reactions.
- Stroma is a site for light independent reaction it contain enzymes particularly for Calvin cycle and sugar and inorganic materials.

BASIC PHYSICS OF LIGHT

Light is a form of radiant energy; part of electromagnetic spectrum

- Photosynthesis makes use of visible spectrum.

| | |
|---|---|
| $10^{-10}$ | ȣ-rays |
| $10^{-8}$ | x-rays |
| $10^{-6}$ | Uv |
| $10^{-4}$ | Visible spectrum |
| $10^{-2}$ | infrared |
| $10^{-0}$ | microwave |
| $10^{-2}$ | Radio wave |

| | |
|---|---|
| violet | 400nm |
| blue | 500nm |
| green | 600nm |
| yellow | |
| orange | |
| red | 750nm |

**Properties of light**

Light behaves as a particle and wave.

According to the quantum theory light is transferred in the form of discrete units known as quanta. One quantum of light is known as photon.

According to wave theory light is transferred in form of waves. The properties of waves include wavelength, velocity, frequency etc.

- These entities are related to plank's theory.

$$\triangle E = E_2 - E_1 = hf$$
$$\triangle E = hc/ƛ$$

**Where h = is plank's constant.**

**f= is frequency of light**

**c= is the velocity of light 3.0 x $10^5$ m/s**

**f= is the wavelength.**

Wavelengths that correspond to colors of visible lights are 400 – 750 nm.

There are three important properties of light to photosynthesis.

1. Spectral quality (colour of light) e.g. chlorophyll is sensitive to blue and red.
2. Time (Duration).
3. Light intensity (amount of light) i.e. the amount of lights which falls on a photosynthetic pigments within a certain period of time.

- Light intensity is measured in photons $cm^2$/sec

**PHOTOSYNTHETIC PIGMENTS**

The types of photosynthetic pigments in high plants are.

1. Chlorophyll (b) carotenoid

Their role is to absorb light energy and convert it to chemical energy.

Chlorophyll

The types of chlorophyll include

1. Chlorophyll a and b
2. Chlorophyll b and c
3. Chlorophyll a and c

The most important ones for photosynthesis are chlorophyll a and b.

Carotenoids.

- They are yellow, red or brown, mostly present in carrots, red, pepper responsible for flower colour.
- Absorb strongly in blue – violet range
- They are necessary pigments because they pass absorbed light to the chlorophyll.

The types of carotenoids include

1. Carotenes
2. Xanthophylls (divided from carotenoids)

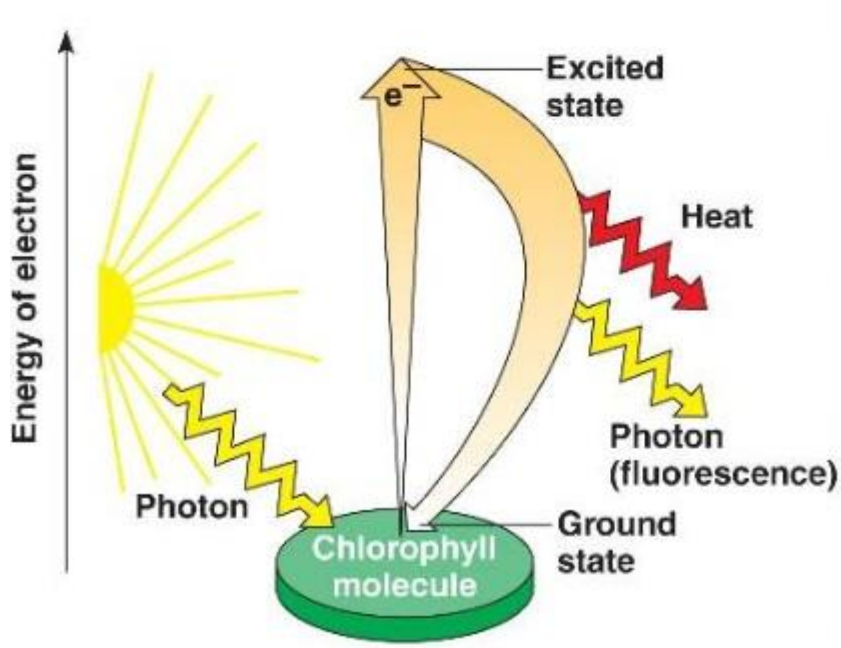
EXCITATION OF CHLOROPHYL BY LIGHT MECHANISM

The important parts of reactions are:

1. Antennal chlorophyll

2. Reaction center
3. Electron acceptor

**EXCITATION OF CHLOROPHYLL BY LIGHT**




Chlorophyll ⟶ Chlorophyll$^{+}$ + e
(Reduce (Oxidized)

Chlorophyll replaces electrons from electron donor

**PHOTOSYSTEM**

The photosynthetic pigments molecules are isolated in two types of photosynthesis.

**Photosystem I**

- $P_{700}$ reaction centre i.e. has ability to absorb light for a wavelength 700nm.
- They have about 200 chlorophyll molecules and 50 carotenoids molecules
- There is Ferodoxin ( protein ) which acts as a w-Ractor electron acceptor

**Photosystem II**

- $P_{680}$ reaction centre i.e. have ability to absorb light of wavelength 680nm.
- They have about 200 chlorophyll molecules and 50 carotenoids molecules.

- Surrounded by Mg atom i.e. The light harvesting complex (antennae molecule) is surrounded by magnesium atom.

$$Mg \longrightarrow Mg^{2+} + 2e$$

**BIOCHEMISTRY OF PHOTOSYNTHESIS.**

- In photosynthesis light energy to first converted into electrical energy (e – moving) and finally to chemical energy (ATP).

This involves three phases.

1. Light harvesting

   Light energy is captured by chlorophyll pigments. This is done by antennae molecules.

2. Light dependent stage.

   A flow of electrons results from the effects of light on chlorophyll and so causes the splitting of water into hydrogen on electrons and oxygen.

3. light independent stage

The use of hydrogen ions and chemical energy ATP is used in reducing $CO_2$ to form sugar

**PHOTOPHOSPORYLATIONS**

This is the synthesis of ATP from ADP and phosphate when the chloroplast is exposed to the light. The NADP is reduced to $NADPH_2$ and Oxygen is evolved. In dark reaction however when ATP and $NADPH_2$ and provided Carbon dioxide is reduced to Carbohydrate.

If energy comes from light the process will be called photophosphorylation. When Oxygen is used which comes from oxidation of food substances usually glucose the process is Oxidative phosphorylation (conversion of ADP + Pi to ATP using chemical energy obtained from food by respiration).

Photophosphorylation is the conversion of ADP + Pi to ATP using light energy from photosynthesis.

$$ADP + Pi \longrightarrow ATP$$

$$NADP^{-} + H^{+} \longrightarrow NADPH$$

**LIGHT DEPENDENT REACTION.**

These are sequence of reactions which depends on the light directly for boosting of electrons, leading to the formation of ATP and NADP.

$ADP + P_i \longrightarrow ATP$

$NADP^- + H^+ \longrightarrow NADPH$

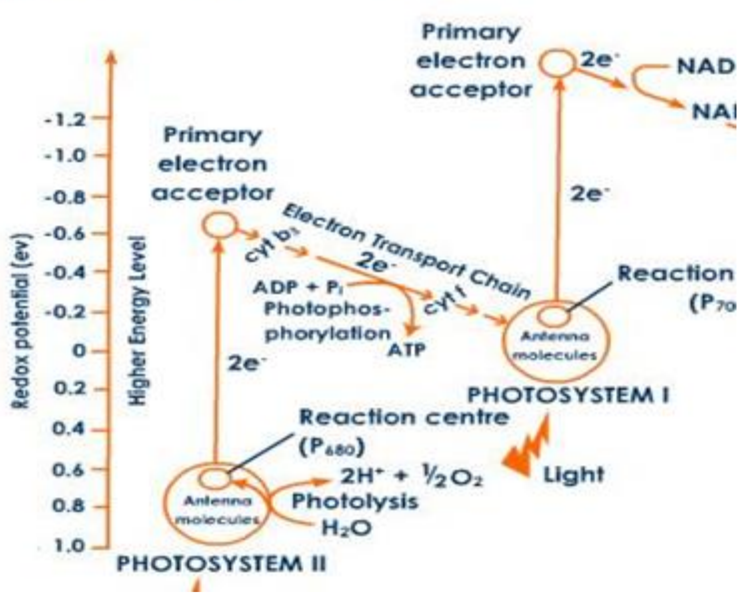
Light dependent reactions divided into two pathways

1. cyclic electron pathways (cyclic phosphorylation)
2. Non cyclic election pathway (Non cyclic Phosphorylation) directly.

Non cyclic electron pathway (z scheme)

- The electrons removed are not returned back to their sources directly.
- The electrons are supplied by photolysis of water.

i.e. $H_20 \longrightarrow 2H^+ + 2E^- + \frac{1}{2}\ 0_2g$



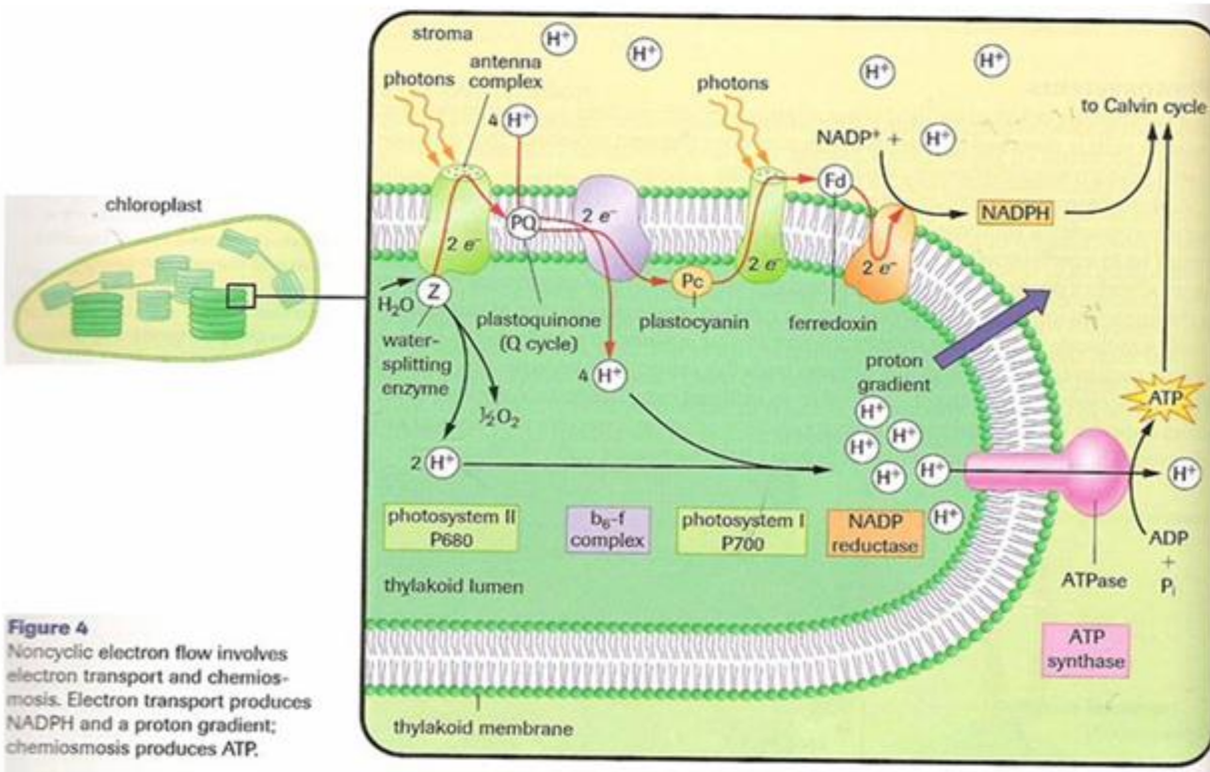



Figure 4
Noncyclic electron flow involves electron transport and chemiosmosis. Electron transport produces NADPH and a proton gradient; chemiosmosis produces ATP.

## Roles of photons of light

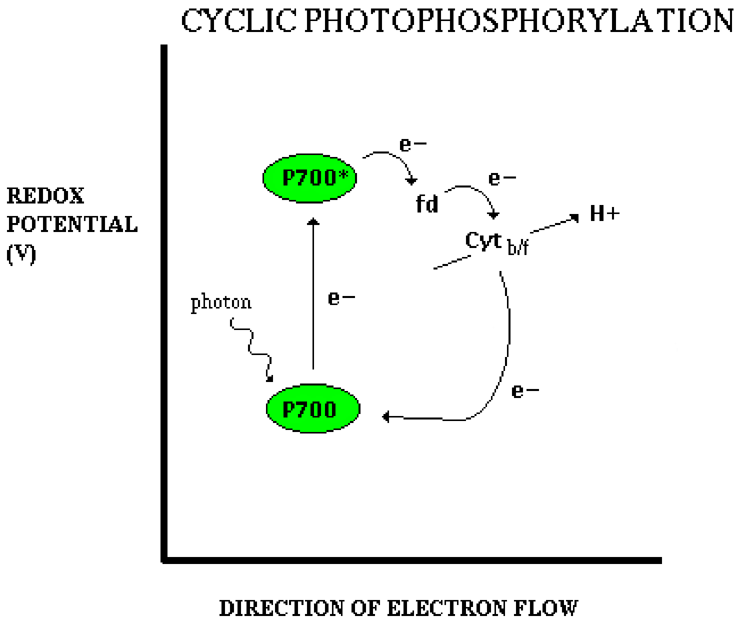
Roles of photons of light

1. Break down of $H_20$ molecules (photolysis)
2. Boosting of electrons
3. Activate enzymes

Factors for recurrence of cyclic pathways.

1. Mostly occur in bacteria and algae since they need immediate energy.
2. When the ratio of NADPH and $NADP^+$ is high.
3. Availability of $NADPH^+$ from dark reactions.
4. When there is a need of more ATP than NADPH

5. Cyclic electron pathway.




**Events on the non-cyclic electron pathway**

Events on the non-cyclic electron pathway.

- Light energy is trapped in the reactive chlorophyll a molecule of photo system II boost electrons to higher energy level and electrons are accepted by primary electron acceptor quinone.

These electrons are replaced by electrons coming from photolysis of water.

- The electrons are passed from the primary electron acceptor along an electron transport chain to a lower energy level; the reaction of photo system I.
- As they pass along this electron transport chain the energy contains in them is used to pump the protons from stroma to the lumen. (Thylakoid space) creating thylakoid protein gradient. An electrochemical energy contained in protons is used to drive photophosphorylation.

$$\textbf{ADP} + \textbf{P}_i \longrightarrow \textbf{ATP}$$

- Light energy absorbed by photo system I boost electrons to another primary acceptor (ferrodoxin). They are passed via other electron carries to NADPH ($NADPH^+$)

  The electrons removed from photo system I are replaced by these from photo system II.

- ATP and NADPH replaced the net gain from the energy capturing.

NB: This pathway is called non-cyclic because the isoelectrons do not come back to their original position $P_{680}$ or $P_{700}$ reaction center.

To generate one molecule of NADPH; two electrons must be boosted from photo system II and two from photo system I.

Two molecules of water are split into protons and oxygen gas also making available the two replacement electrons needed by photo system II.

To generate one molecule of NADPH; few protons must be absorbed; two by photo system II and two by photo system I.

Events in the cyclic electron pathway.

This event is the alternative pathway which is used to occur when the ratio of NADPH /$NADP^+$ is high or when the cell needed more ATP than NADPH.

- Light strikes chlorophyll molecules at photo system 1 ($P_{700}$) and electrons are boasted to higher energy level.
- They are accepted by the primary electron accepted (Ferredoxin) then they are transferred back to photo system I via cytochrome complex to plastocyanin to $P_{700}$ reaction centre; the energy contained in them is used to pump the protons from stroma to the thylakoids space. (Lumen) creating the proton gradient. The latter drives phosphorylation i.e. ADP + $P_i$ ATP. This is called cyclic pathway because the boosted electron return back to their original position i.e. $P_{700}$ reaction center.

  QUESTION

  How is electron flow along the thylakoid membrane related to ATP synthesis in the chloroplast?

  ANSWER

  This can be explained by the concept of photosynthetic phosphorylation chemiosmotic hypothesis.

- In this process; Electrons from chlorophyll are boosted to a high energy level by sunlight. Slow down an electron transport chain in the thylakoid membrane.
- The energy released as they move to a lower energy level is used to pump protons from the stroma into the thylakoids space; creating proton electrochemical gradient of potential energy.

  As the protons flow down the gradient from the thylakoids space back into the stroma (passively by diffusion) ADP is phosphorylated to ATP through ATP syntheses.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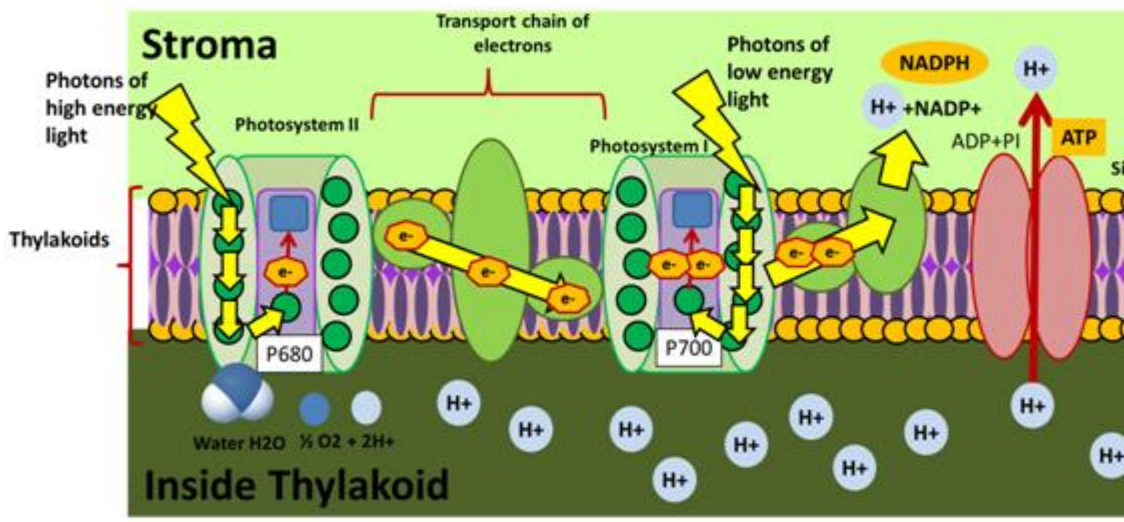
NB

The potential energy gradient possessed by protons catalyses phosphorylation as proton diffuses passively from the thylakoid space to the stroma.

**THYLAKOID MEMBRANE**




**LIGHT INDEPENDENT REACTION (DARK REACTIONS)**

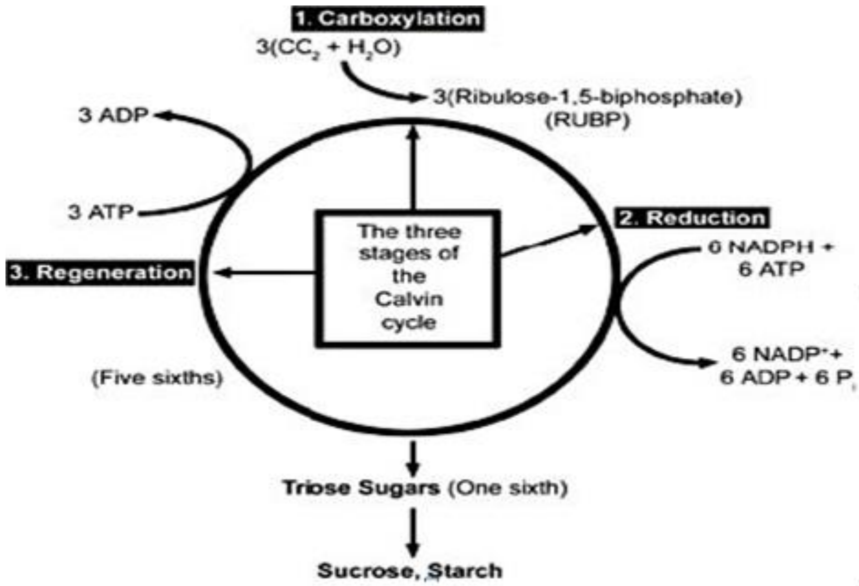
It is a sequence of events which was discovered by a man called Calvin Benson in 1946 – 53. Therefore is called Calvin Benson cycle.

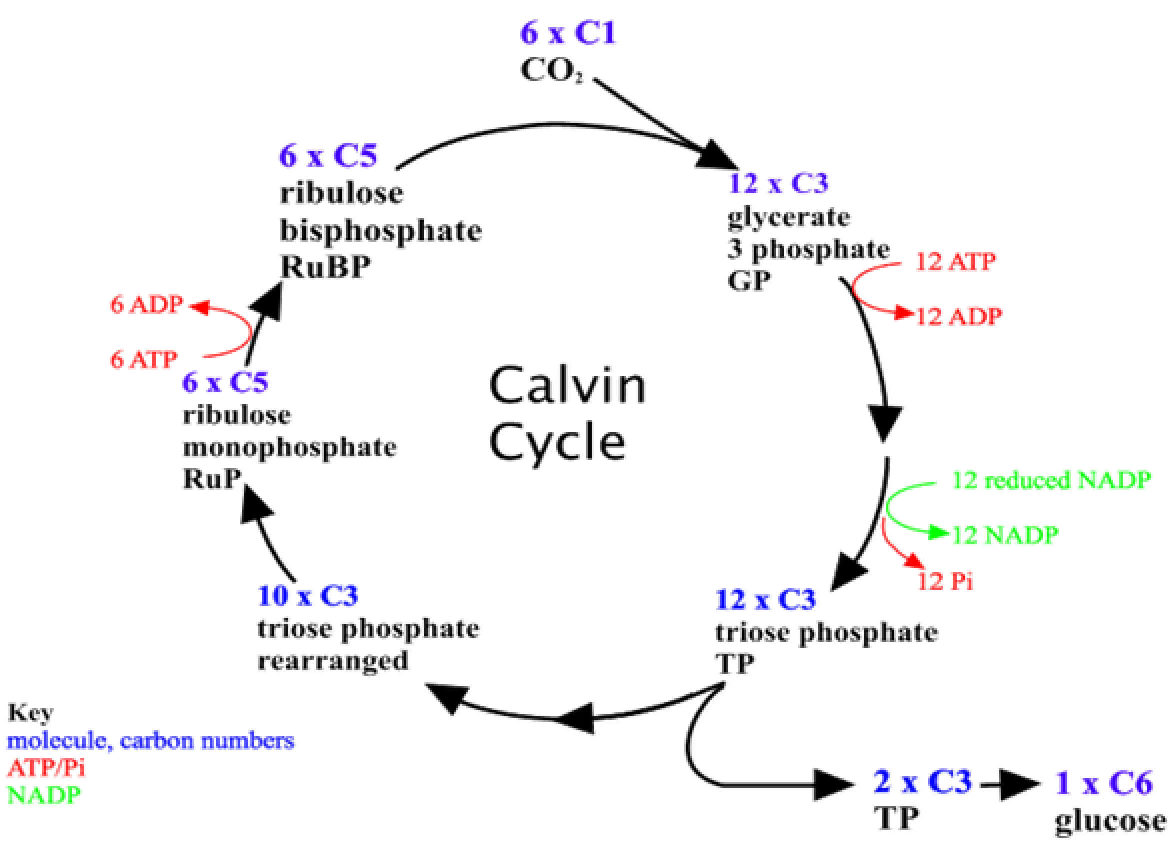
- Takes place in stroma of chloroplast does not depend on light but uses ATP and NADPH/ The reduced Nicotinamide. Adenine Diphosphate) to reduce $CO_2$ to from sugar.
- The Calvin cycle functions as a sugar factory within the chloroplast uses inputs like $CO_2$, ATP, and NADPH to construct out part energy by rich sugar molecule.

Stages of Calvin cycle

1. Carbon dioxide fixation (Acceptance of carbon dioxide).
2. Energy consumption.

3. Release of one molecule of G 3 P ( Glycetaldehyde- 3-phosphate)
4. Regeneration of RUBP (Ribulose Biphosphate).



RUBP – Ribulose Bisphosphate (6 – C)

Rubisco – Ribulose Biphosphate carboxylase/ oxyginase.

PGA – Phosphoglyceric Acid (3c)

DiPGA – Diphosphoglycene Acid

3 – PGAL – glyceralaldehyde - 3-phosphate.

RUMP – Ribulose monophosphate.

1. **Acceptance of $CO_2$ (carbon dioxide fixation)**

The $CO_2$ acceptor is a 5C sugar (pentose) is RUBP. Addition of $CO_2$ to a compound is called carboxylation; the enzyme involved in is carboxylase. The 6C products is unstable and breakdown immediately to two molecules of glycerate phosphate (GP). This is the first products of photosynthesis.

- The enzyme Ribulose biphosphate is present in large amounts in the chloroplast stoma and is in fact the world's common protein.

**I.e. RUBP + $CO_2$ $\longrightarrow$ unstable 6c**

**(Ribulose 1, 5 – Bisphosphate) product**

**The unstable 6C compound $\xrightarrow{\text{hydrolysis}}$ 2molecules of glyceric acid**

**2. Energy consuption.**

The product is a 3C sugar, phosphate (a triose phosphate i.e. a sugar with a phosphate ground attached. This contains more chemical energy than the 3 – phosphoglyceric acid, and is the first carbohydrate made in photosynthesis.

**3. Release of two molecule of 3-PGAL.**

One molecule of 3 – PGAL (3- phosphoglyceraldehyde) for the synthesis of organic compound is isomerizes to DHAP (Dihydroxyacetone phosphate) accordingly.

Secondly; the 3 – PGAL combine with DHAP

What is the role of 3-PGAL?

**Oxidation of NADPH and reduction of 3-phosphoglyceric acid (3-PGA) which uses 1 ATP**

**3-PGA + ATP $\longrightarrow$ 1,3 Diphosphoglycerate + ADP**

**Then, the 1, 2 Diphosphoglycerate is reduced by NADP**

**1, 3 Diphosphoglycerate $\xrightarrow{\text{3-PGAL}}$**

**NADPH + $H^+$ NADP$^+$ + $H_2O$**

#### 4. Regeneration of RuBP

Uses energy to regenerate RuBP

3 – PGAL RUMP

- Some of the triose phosphate TP has to be used to regenerate ribulose biphosphate consumed in the first reaction
- This process involves a complex cycle containing 3,4,5,6 and 7c sugar phosphates.
- It's here that the remaining ATP is used to convert RUMP to RuBP.
- There are six turns of Calvin cycle so as to generate a 6c compound such as glucose from one molecule $CO_2$. This is according to philosophy.

**GENERAL EQUATIONS**

**For light dependent reaction**

$$2H_2O + 2NADP^+ \xrightarrow[\text{Chlorophyll}]{\text{light}} O_2 + 2NADPH + 2H^+$$

$$ADP + P_i \longrightarrow ATP$$

**For light independent reaction**

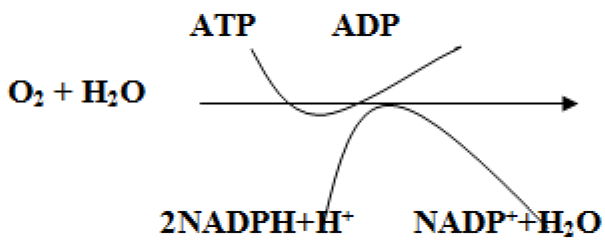
3ATP 5ADP+3P$_i$

$$CO_2 + H_2O \longrightarrow [CH_2OH]_n$$

2NADPH$^+$+2H 2NADP+2H$_2$O

C$_3$ PLANTS

- C$_3$ plants are the plants which after fixing CO$_2$ the first product has three carbons.
- Most of C$_3$ plants are found in temperate and most cold regions so they don't need any modifications since the environment support them.
- Enzyme for fixing CO$_2$ is Rubisco.
- Under high light intensity and high concentration of O$_2$ the C$_3$ plants can fix O$_2$ instead of CO$_2$. This condition is called photorespiration this reveals that the C$_3$ plant are not efficient for photosynthesis
- Photorespiration is wasteful oxidation process since in the normal Calvin cycle, the oxygen is used instead of CO$_2$ forming nothing (No food formed)




When $O_2$ is fixed instead of $CO_2$ the enzyme is Ribulose Biphosphate Oxygenase. This shows that RUBISCO has high affinity to $O_2$ than $CO_2$.

Example Potato, Tobacco, Beans, Wheat etc

(Have only fixing enzyme)

$C_4$ plants

The scientists krantz and Hatch slack discovered the $c_4$ plants and so the name krantz and Hatch pathway.

- $C_4$ plants are plants in which the first compound to formed after mixing $CO_2$ has 4 carbon atoms (Oxaloacetate )

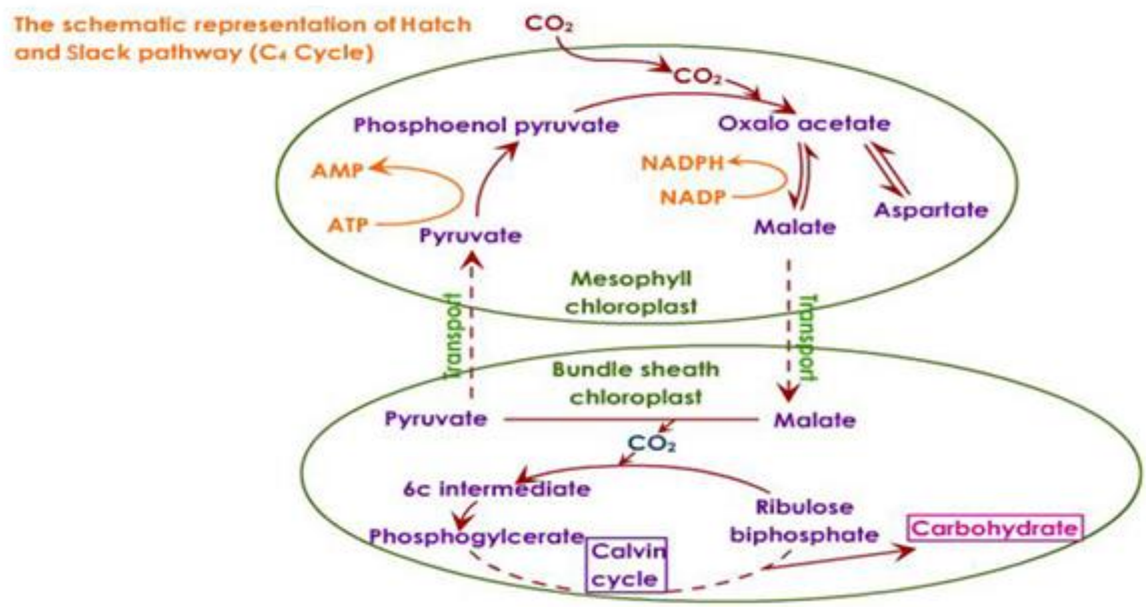
  E.g. Maize, sorghum etc.

  There is distinct arrangement of chloroplast in mesophyll cells and bundle such each one has its chloroplast, the mesophyll cells has grain but few starch grain compared to the bundle sheath.

- This way of arrangement of chloroplast is called kranz anatomy
- The role of this is to fix $CO_2$ as twice as much as $C_3$ plants.
- This is an adaptation since the $C_4$ live in drought areas ( with no water)
- There is a rapid opening and closing of stomata so as to conserve water.
- ( $C_4$ pathway has two fixing enzyme i.e. PEP(phosphenol pyruvate in mesophyll cells and RUBISCO in bundle sheath (normal calvin

Cycle)

- PEP has high affinity to carbon dioxide since it can fix it at low concentration and high temperature. This is an adaptation.




NB; Carbon dioxide fixation and Calvin cycle are separated in space.

- The role of this is to conserve water. $C_4$ plants have PEP which can fix carbon dioxide 120 times the $C_3$ plants.
- Another adaptation is that it can fix carbon dioxide even when stomach is closed. This occurs in all mesophyll cells.

- The compound oxaloacetate acts as a compound for fixing $CO_2$
- Uses a lot of water.
- PEP can work above $25^0$C which RUBISCO is affected by high temperature.

Significance of $C_4$ Plants

1. They are maximum rate of $CO_2$ fixation at high light intensity and high temperatures. $C_4$ plant increase in dry mans more rapidly than $C_3$ plants.
2. More tolerant to dry conditions in order to reduce water loss. $C_4$ plants can adapt drought condition.

DIFFERENCE BETWEEN $C_3$ AND $C_4$ PLANTS

| | $C_3$ PLANTS | $C_4$ PLANTS |
|---|---|---|
| Examples | Most crop plants e.g. | Maize and sugar |
| | Cereals, Tobacco, Beans | |
| Amounting light intensity | 10000 – 30000 fact candles | Not saturated at $10^5$ |
| $CO_2$ Fixation | Occurs once | Occurs twice 1st in mesophyll 2nd in Bundle sheath cells. |
| Effects on Temperature rise from $25^0C$ – $35^0C$ | No change in rate or low rate | 50% greater at $35^0C$ |
| $CO_2$ ACCEPTOR | RuBP, a 5 C compound | Mesophyll cell – PEP, a 3C compound, Bundle sheath cell – RUBP. |
| $CO_2$ fixation Enzyme | Only one type of chloroplast no bundle sheath | Krantz anatomy i.e. two type of cells each with its chloroplast (own type). |
| Leaf anatomy | RUBP carboxylase which is very efficient | Mesophyll cell – PEP carboxylase which is efficient |
| Amount of energy used | Low energy | A lot of energy. |
| Efficiency | Less efficient in photosynthesis | More efficient in photosynthesis |

CAMPLANT

- Live in very dry environment (almost desert)
- Fix $CO_2$ during the night.
- This physiciological mechanism was discovered in plants genus crassulacea and therefore called CAM (crassulacea Acid Metabolic )
- They experience different PH forms i.e. during day time they are alkaline while during night they are acidic.

- They open stomata during night because the temperature is low and humidity is high. The vice versa happen during the day.
- Closes during the day to conserve water, by the time already it has $CO_2$ from its night time. So fixed $CO_2$ stored in vacuole.
- $CO_2$ is fixed in stem
- E.g. cacti, Pineapple, spinach, ferns, (Plants that live in dry environment fix $CO_2$ at night).
- Use enzyme PEP carboxylase.
- The only difference between $C_4$ and CAM plant is in anatomy.

FACTORS EFFECTING PHOTOSYNTHESIS

The rate of photosynthesis is affected by a number of factors; the level of which determines the yield of material by a plant. Before reviewing these factors, it is necessary to understand the principle of limiting factors.

The concept of limiting factors.

In 1905; F.F black man; a British plant physiologist; measured the rate of photosynthesis under varying condition of light and carbon dioxide supply. As a result of his works, he formulated the principle of limiting factors; it states that.

“At any given moment; the rate of physiological process is limited by the one factor which is in the shortest supply and that factor alone.

In another words it is the factor which is nearest to its minimum value which will determine the rate of the reaction.

Any changes in the level of this factor; called a limiting factor will affect the rate of reaction. Changes in the level of other factors have no effects.

E.g. Photosynthesis cannot proceed in the dark because the absence of light limits the process.

The supply of light will alter the rate of photosynthesis i.e. more light, more photosynthesis). However if more $CO_2$ or high temperature is supplied to a plant in the dark; there will be no change in the rate of photosynthesis. Light is the limiting factor therefore only a change can affect the rate.

If the amount of light given to a plant is increased the rate of photosynthesis increases up to a point and then fails off.

At this point, some other factors such as the $CO_2$ concentration is in short supply and so limit the rate/ increase in $CO_2$ concentration increases the amount of photosynthesis until some other factors

E.g. temperature limits the process.

Factors affecting photosynthesis.

The rate of photosynthesis increases as controlled by limited external and internal factors.

**EXTERNAL FACTORS**

1. Light intensity
2. Carbon dioxide
3. Temperature
4. Water

1. **Light intensity**

   The rate of photosynthesis increases as light intensity increases and vice versa.

   The rate of photosynthesis is proportional to the light intensity provided that other conditions are suitable.

2. **Temperature**

This affects the activity of enzymes below the optimum temperature. The rate of photosynthesis increases as the temperature is raised; beyond the optimum temperature i.e. $60^0$c. The enzymes are destroyed.

The rate of photosynthesis therefore decreases.

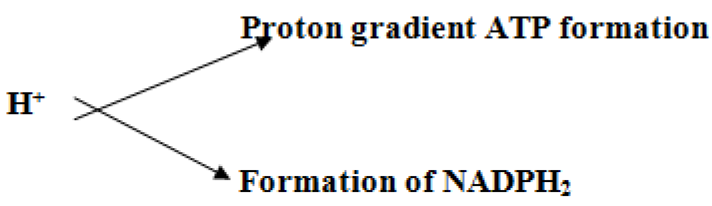
3. **$CO_2$ concentration**

   Provided other conditions are suitable for this process the rate of photosynthesis increases as $CO_2$ concentration increases especially for $C_3$ plants.

4. **Water.**

   Water is important in reaction i.e. photolysis.

$$2H_2O \longrightarrow 4H^+ + 4e^- + O_2$$




The rate of photosynthesis depends on how much water is present in the plant body. The water present in plant body depends on the water present in the surroundings.

When water is so scarce; the plant will wilt and the rate of photosynthesis decreases.

**INTERNAL FACTORS.**

These are factors which are related to the plant structure.

1. Leaf surface area.
2. Number of chloroplast
3. Number of stomata
4. Orientation of plants body to the direction of sunlight

## HETEROTROPHIC NUTRITION

Hetero - other different

Trophic – feeding

Heterotrophic means depends on other feeding.

### Meaning

Heterotrophic nutrition is the type of nutrition which involves the organisms that are not capable of manufacturing their own food by the process of photosynthesis.

The organisms involved in this mode of feeding are called heterotrophs. They comprise of animals, fungi and majority of bacteria and few flowering plants (insectivorous plants)

In heterotrophic type of nutrition organisms depend on the organic sources of carbon, carbohydrates, lipids and proteins.

## FORMS/TYPES OF HETEROTROPHIC NUTRITION

There are three types of heterotrophic nutrition.

1. Holozoic nutrition
2. Saprotrophic nutrition
3. Parasitic nutrition

## HOLOZOIC NUTRITION

Means feeding on solid organic materials from bodies of living or dead organisms which may either be plants or animals.

This method is usually seen in animals and carnivorous plants and some protoctists

## PARASITIC NUTRITION

A parasite feeds on organic materials often but not always soluble from the body of another living organism known as hosts.

**SAPROTROPHITIC NUTRITION.**

A means of feeding on soluble organic materials dead plants and animals.

Saprophytic nutrition can be grouped into:-

1. Saprophitic nutrition i.e. feed on dead plants.
2. Saprozoic nutrition i.e. feed on dead animals.

Saprotrophs secrete enzymes into food when it is digested.

- It occurs mainly in protoctists, bacteria and fungi although there are some saprophytic animal e.g. Hyena.
- Saprotrophic nutrition is of biological great importance because it plays a role in decomposition of biological materials and retaining nutrients to the soil and at the atmosphere and hence nutrient circulation in the ecosystem.

NB; in saprotrophic nutrition materials should first decay.

**HOLOZOIC NUTRITION**

The process involved in Holozoic nutrition is:-

1. Ingestion: The intake of food.
2. Digestion: The breakdown of food into simple molecules
3. Absorption: The uptake of those ample molecules into living cells.
4. Assimilation: The use to which absorbed molecules are put.
5. Egestion: Expulsion of undigested food materials from the body.

**DIGESTION**

Digestion is the breakdown of large organic molecules into smaller simple soluble which can be absorbed.

There are two types of digestion.

a)Physical digestion

This involves mechanical breakdown of fossils by teeth and abdominal muscles.

b). Chemical digestion.

This involves activities of enzymes in the digestive canal

**DIGESTION IN MAMMAL**

Digestion in the mouth.

Mechanical breakdown of food begins in the mouth or buccal cavity.

Humans are omnivores and hence have an unspecialized diet of mixed animals and plants origin. The teeth reflect the lack of specialization. All types being present and developed to a similar extent.

Apart from assisting speech, the tongue also manipulate all the food during chewing and ensures it is well mixed saliva produced from three pairs of salivary gland/about 1.0 – 1.5$dm^3$ saliva are produced daily.

**SALIVA CONTAINS**

1. Water – Over 99% of saliva in water.
2. Salivary amylase. A digestive enzyme which hydrolyses starch to maltose.
3. Mineral salt e.g. $NaHCO_3$ this helps to maintain a PH of around 6.5 – 7.5 which is the optimum of salivary amylase.
4. Mucin – a sticky material which helps to bind food particles together and lubricate them to assist swallowing the thoroughly chewed food is rolled into bolus and passed to the back of the mouth for swallowing. The process of digestion starts in the mouth (buccal cavity).

- After ingestion of food there is physical/ mechanical digestion
- Physical digestion begins as the process of food are bitten off by teeth and then chewed.

**AIMS OF PHYSICAL DIGESTION.**

Breaking down food into smaller pieces making it easier for swallowing and also increasing the surface area for the enzyme to act on. Chemical digestion is brought about by saliva.

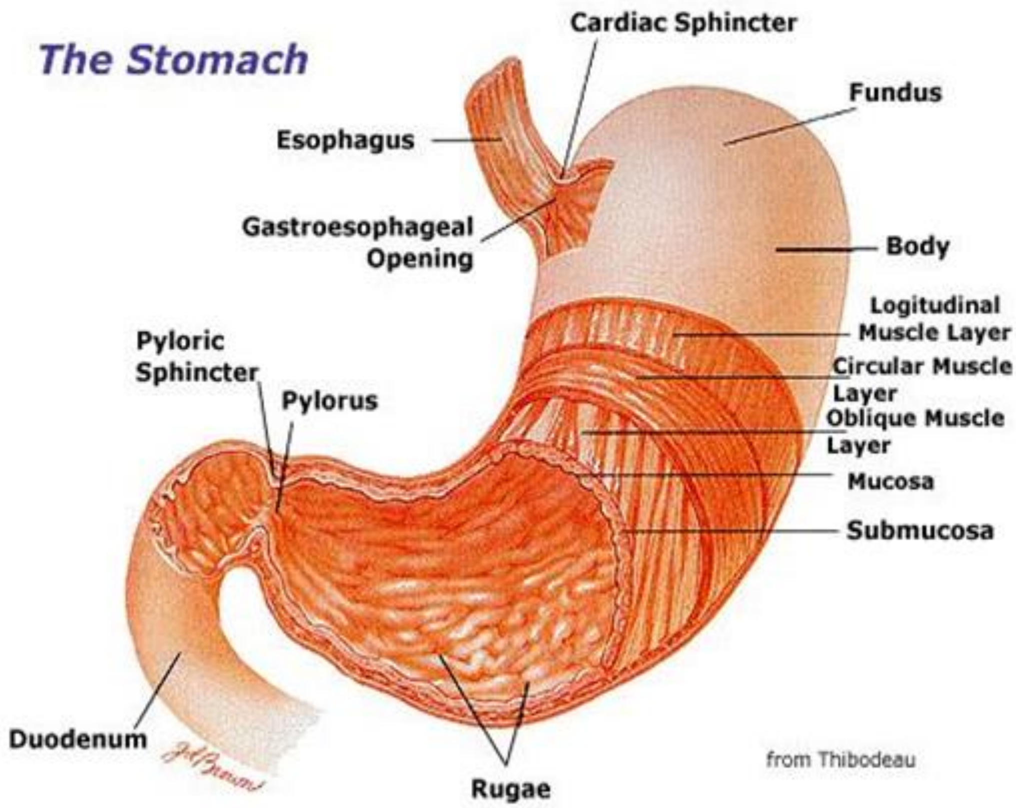
**ROLES OF SALIVA**

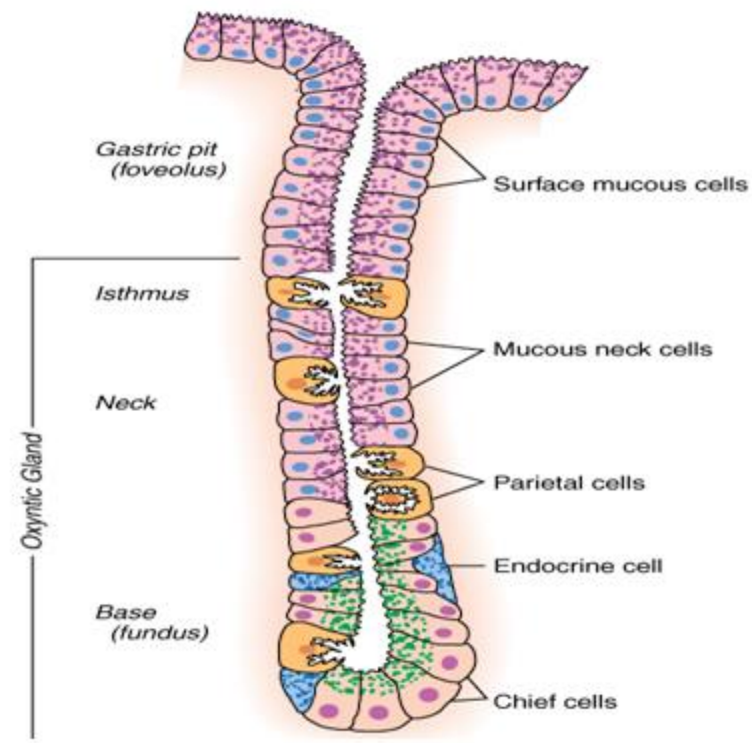
1. It is slightly alkaline neutralized the effects of acidic foods or acids produced by the bacteria in the mouth.

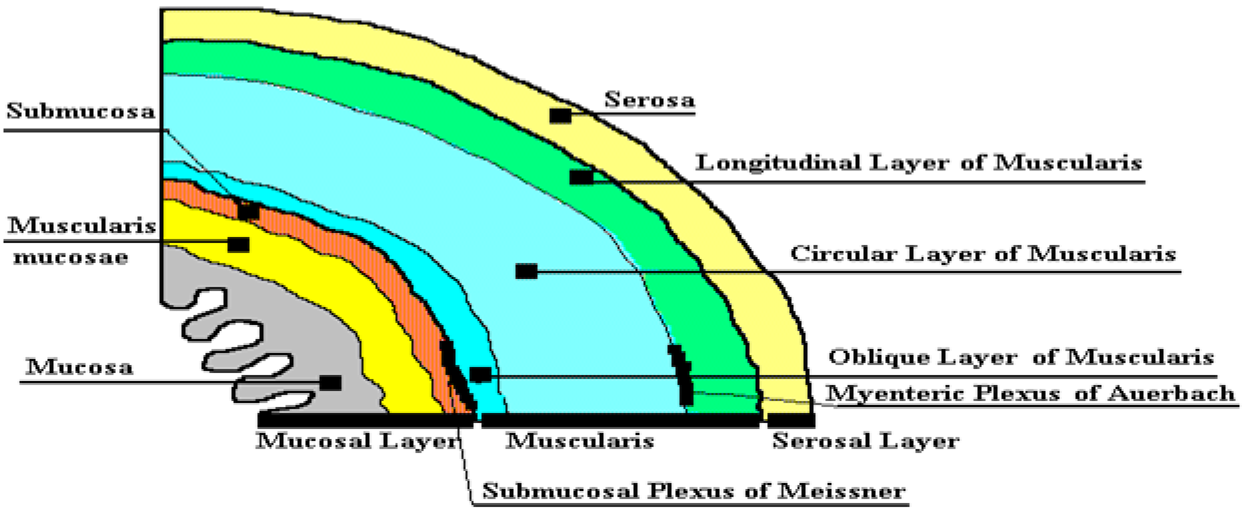
2. Contains an enzyme salivary amylase which hydrolysis polysaccharide starch to maltose.

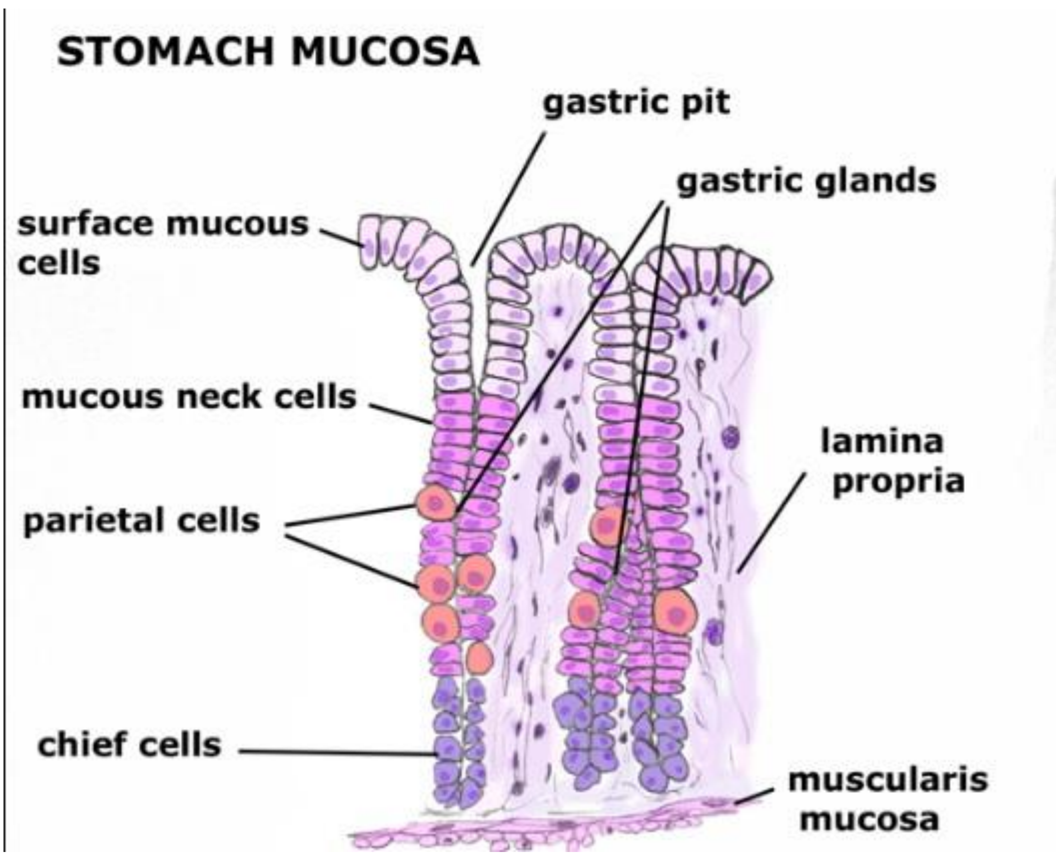
3. It contains mucus which moistens and lubricates make swallowing easier.

4. Defensive mechanism: It contains ant bacterial enzyme for killing bacterial for preventing the growth of bacteria.


The Stomach
Cardiac Sphincter
Fundus
Esophagus
Gastroesophageal
Opening
Body
Logitudinal
Muscle Layer
Pyloric
Sphincter
Circular Muscle
Layer
Pylorus
Oblique Muscle
Layer
Mucosa
Submucosa
Duodenum
Rugae
from Thibodeau


Gastric pit
(foveolus)
Surface mucous cells
Isthmus
Mucous neck cells
Neck
Oxyntic Gland
Parietal cells
Endocrine cell
Base
(fundus)
Chief cells


Submucosa
Serosa
Longitudinal Layer of Muscularis
Muscularis mucosae
Circular Layer of Muscularis
Oblique Layer of Muscularis
Mucosa
Myenteric Plexus of Auerbach
Mucosal Layer
Muscularis
Serosal Layer
Submucosal Plexus of Meissner


STOMACH MUCOSA
gastric pit
gastric glands
surface mucous cells
mucous neck cells
lamina propria
parietal cells
chief cells
muscularis mucosa

**DIGESTION IN THE STOMACH.**

Stomach is roughly U shaped situated below the diaphragm. It is a muscular sac with a folded minor layer called the gastric mucosa. Embedded in this is a series of gastric pits which are lined with secretory cells. These produce

gastric juice which contains.

1. Water :

The bulk of secretories is water in which are dissolved other constituents.

2. Hydrochloric acid

This is produced by the oxyntic cells and with the water forms dilute solution giving gastric juice it PH of around 2.

It helps to kill bacteria brought in with food particles and activates the enzymes pepsinogen and prorenin.

It also initiates the hydrolysis of glucose and nucleic protein (nucleic acid)

3. Pepsinogen

This is produced by the zymogen chief cells in inactive form to prevent it from hydrolyzing the proteins and the cells producing it once in the stomach it activates the pepsin by hydrochloric acid. Pepsin is an endopepsidal which hydrolyses protein into polypeptides.

4. Prorennin

This not produced by zymogen cells and is an inactive form of renin an enzyme which coagulates milk converting it into the soluble caseinogens to insoluble casein. It is therefore especially important in young mammals.

- Prorenin is too activated by HCL

5. Mucus

This is produced by goblet cells and forms a protective layer on the stomach wall thus preventing pepsin and HCL from breaking down gastric mucosa. (Preventing autolysis). If protection is not effective and the gastric juice attacks the mucosa an ulcer results.

Mucus also helps to lubricate movement of food within the stomach.

During its stay in the stomach food is thoroughly churned and mixed with gastric juice by periodic contraction of the muscular stomach wall. In this way a creamy fluid called chyme and contraction of the stomach walls as the chyme to enter duodenum

The chyme from any one meal is released gradually over a period of 3-4 hours. This enables the small intestine to work on little material of time and provides a continuous supply of food and for absorption thoroughly the period between meals.

**FUNCTIONS OF HCL**

1. It has a PH of 1- 2.5 which makes the stomach content ideal for the optimum activity of the stomach enzyme.
2. It kills bacteria which are associated food defensive mechanism.
3. It denatures many protein their tertiary structure is altered making them unfold and easy to digest.
4. It converts

- **pepsinogen** $\longrightarrow$ **pepsin**
  **Inactive** **active**
- **prorenin** $\longrightarrow$ **renin**
  **Inactive** **active**
- **protein** $\xrightarrow{\text{pepsin}}$ **smaller polypeptide**
- **Soluble milk** $\xrightarrow{\text{renin}}$ **insoluble casein**
- **protein (Caseinogen)** $\xrightarrow{\text{pepsin}}$ **shorter polypeptide**

**DIGESTION IN SMALL INTENSTINE**

In humans the small intestine is over 6 m in length and its coils fill much of the abdominal cavity.

- It consists of two main parts.

  i).In humans the small duodenum where most digestion occurs and the pancreatic and bile ducts into about 25cm

- ii).The longer ileum which is largely concerned with absorption.

- The duodenum leads in the ileum which is 3m long in a living body.
- The walls of the illeum are folded and possess finger like projections called villi, the villi contains fibres of smooth muscles and regularly contracts and relax. This helps to mix the food in it. The enzyme secretions and keep press supplies in contact which the villi for absorption.

  The digestive juice which appears in the small intestine comes from three sources.

- Liver
- Pancreas
- Intestinal wall

**THE LIVER**

Produce bile juice which is complex green fluid.

- It contains no enzyme but possesses two other substrates important in digestion.

1. Mineral salts.

   They help to neutralize the acidic chyme from the stomach and secrete more neutral PH for the enzyme of the small intestine to work.

2. Bile salt: sodium and glycocholate and teurochorate.

   They emulsify lipids, breaking them down into minute droplets. This is the physical not chemical change which provides a greater surface area for pancreatic lipase to work on.

The liver performs other functions some associated with digestion. These are

- Carbohydrate metabolism i.e. Glucose glycogen
- Lipid metabolism
- Protein metabolism
- Production of bile
- Detoxification
- Production of heat during its physiological activities.

**Pancreatic Juice**

The pancrease is situated below the stomach and is unusual in that it produces both on exocrine secretion, the pancreatic juice and endocrine secretion, the hormone insulin and glucagon. The endocrine is not concerted directly with digestion and pancreatic juice in addition to water, contains.

1. Mineral salt ($NaHCO_3$)

- Helps to neutralize acidic enzyme from the stomach and so provide a more neutral PH in which the intestine enzymes can operate.

2. **Protease**

These include trypsinogen which when activated by enterokinase from the intestinal wall forms the endopeptidase called trypsin which hydrolyses proteins to peptides.

Trypsin also activates another protease in the secretion chymotrytripsnogen into chymotrypsin this is to convert proteins into peptides.

Also present in the exopeptidase called carboxypeptidase which convert peptides into smaller peptides and some amino acids.

3. **Pancreatic amylase**- Completes the hydrolysis of starch to maltose which began in the mouth.
4. **Lipase** - Breaks down fats into fatty acids and monoglycerides (Glycerol + one fatty acid) by hydrolysis.
5. **Nuclease** - Converts nucleic acids into their constituent nucleotides

**Intestine Juice** (Succus entericus)
The mucus and sodium hydrogen carbonate in intestinal juice are made by coiled Brunner's glands whereas the enzymes are produced by the breakdown (lysis) of cells at the tips of the villi.
1. **Mucus** - Helps to lubricate the intestine walls and prevents autolysis.
2. **Mi**neral salts (e.g. sodium hydrogen carbonate)
Produced by the Brunner's glands in order to neutralize the acid chyme from the stomach and so provide a more suitable pH for the action of enzymes in the intestine.
3. **Protease (erepsin)**
These include the exopeptidase called aminopepeptidase, which converts peptides into smaller peptides and amino acids, and dipeptidase, which activates the trypsinogen produced by the pancrease.
4. Enterokinase - A non- digestive enzyme which activates the trpsinogen produced by the pancrease.
5. Nucleotidase - Converts peptides into pentose sugars, phosphoric acid and organic bases.
6.Carbohydrates- These include amylase, which helps complete the hydrolysis of starch to maltose; maltase, which hydrolyses maltose to glucose; lactase, which hydrolyses the milk sugar lactose into glucose and galactose; and sucrase, which hydrolyses sucrose into glucose and fructose.

**HORMONAL CONTROL OF SECRETION OF THE DIGESTIVE JUICE**

The production of digestive secretion must be timed to coincide with the presence of food in the appropriate region of the gut. The secretion of such juices in mammals are under both nervous and hormonal control. The sight, smell or even thought of food may cause salivary glands to secrete saliva. This is a conditional reflex response.

Hormonal control of secretions begins with the presence of food in stomach. This stimulates the stomach to secrete hormone called gastrin which passes through blood stream to stimulate the production of gastric juice.

- When food leaves the stomach and enters the duodenum it stimulates the production of two hormones from duodenal walls. These are

- **Secretin** – This pass through blood stream to the liver where it stimulate the production of bile and to the pancreases where it stimulate the secretion of the mineral salts.
- **Cholecystokinin- pancreozymin**- This causes the gall bladder to contract (releasing the bile juice into the duodenum) and stimulate the pancreases to secrete its enzymes.

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# GASEOUS EXCHANGE AND RESPIRATION

**Gaseous exchange** is the movement of oxygen and carbondioxide between the organism and its environment at the respiratory surfaces.

Oxygen goes in and carbon oxide goes out – These gases move in and out through diffusion.

**Respiratory surfaces** – These are surfaces on which gaseous exchange takes places.

In case of unicellular organisms, gaseous exchange usually takes place throughout the whole body i.e. the cell and the distance through which gases have to travel is small.

In large multicellular organisms there are well developed respiratory systems through which gases move in and out of the organism from and to the external environment.

**Types of respiratory surfaces**

1. **Skin** – amphibians e.g. toads /frogs.
2. **Lungs** - chordata and aves.
3. **Lung books**- arachnida e.g. scorpion
4. **Gills** – external gills e.g. larval amphibians and crustaceous. Internal gills e.g. fishes
5. **Tracheal** in insects. Tracheal receive and give out gases directly.

6. **Buccal cavity**-amphibians.

**Characteristics (Properties) of respiratory surfaces**

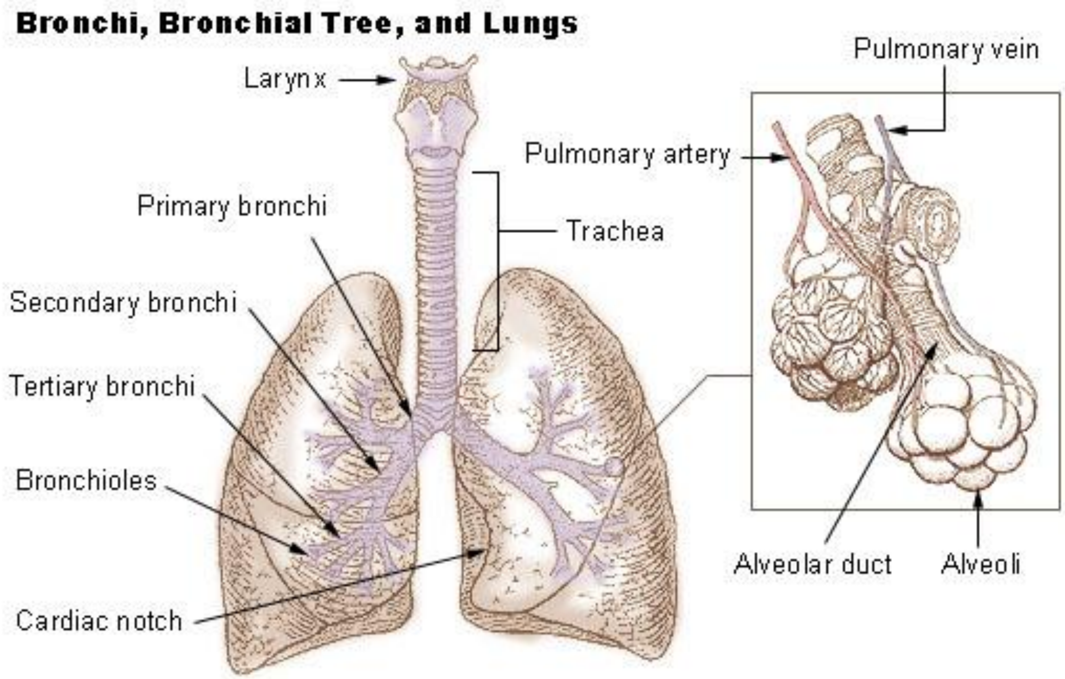
1. They should be **moist** in order to dissolve the gases ( gases diffuse better when they are in solution they must also be permeable)
2. They must have **large surface area to volume** ratio to take in or take out gases.
3. They must be **thin** to minimize the distance through which the gases have to travel.
4. They must have a **respiratory pigment** e.g. Haemoglobin-iron containing pigment; Haemocynine-copper containing pigment.
5. **Ventilation** i.e. there must be a constant supply of air or water to the respiratory surface because as oxygen diffuses inwards it tends to be depletal immediately next to the gaseous exchange surface. Therefore the supply of the oxygen from the external environment can be much more efficiently replaced. A flow of this kind is called ventilation.
6. They must be **highly vascularised** i.e. supplied with blood capillaries (vessels) to transport the gases.

**GASEOUS EXCHANGE IN MAMMALS (MAN)**

The organ of gaseous exchange is the lung and the respiratory surfaces are the alveoli, the gaseous exchange takes place along the respiratory rate.

- Air enters the body through the nose
- It then moves to the trachea
- The trachea branches into 2 bronchi (bronchus)
- The bronchi further branch into several bronchioles. (The bronchioles contain less cartilage than the bronchi).
- The respiratory surfaces are the alveoli where gaseous exchange takes place

  The two lungs of the body contain about 700million alveoli which can stretch out to about an area of 140m squared(140$m^2$). The two lungs have different size due to the presence of the heart on the left side, to accommodate this area; the lungs have a highly organized internal structure supported by connective tissue. The lungs are compact relatively, firm and highly elastic to allow expansion when filled with air




**Features contributing to the efficiency of the respiratory tract.**

1. The walls of the passage/tract are lined with **ciliated epithelial cells** (have hair like structure) and goblet cells which produce mucus. The mucus traps foreign particles like dust, bacteria which enter the respiratory tract with air. The vibration of the cilia sweeps the trapped particles backwards into the pharynx and then they are swallowed.
2. Presence of **hair** in the nasal cavity. This traps the particles coming in along with air. They act as filters of dust and foreign particles.
3. The mucus produced not only traps the foreign particles but also moistens the respiratory tract.
4. Presence of **numerous blood capillaries** whose blood provide a continuous supply of moisture to air to keep it moist before it reaches the alveoli and also supplies heat to warm the incoming air so that the air is warmed up to the body temperature so that the alveoli are not damaged.
5. The **trachea remains open** for continuous **inhalation** and **exhalation**. This is made possible by the **cartilage** which also gives strength to the passage.

   Presence of **collagen** and **elastic fibres** in the alveoli which allow the alveoli to expand and recoil easily.

6. Special cells in the walls of the alveoli produce a chemical called **SARFACTANT**, its roles are;

- It prevents alveoli walls from sticking together.

- Kills any bacteria that make it to the alveoli.
- It speeds up the transportation of carbon dioxide and oxygen between the air and the liquid lining of alveoli.
- It lowers the surface tension of the liquid layer lining the alveoli.

7. Presence of microphages on the surface of the alveoli which keep them clean by scavenging the bacteria that reaches the alveoli. Microphages are actually what reaches the alveoli. Microphages are actually white blood cells.

## INTERNAL STRUCTURE OF THE GASEOUS EXCHANGE PATHWAY TRACT

### THE NASAL CAVITY

- The nasal passages have a relatively large gaseous area but no gaseous exchange takes place here, the passages have a good blood supply and the lining secretes mucus and it is covered by hair. The air is cleaned moistened and warmed as it passes the nasal cavity.

### THE TRACHEA

- The trachea is a major airway, heading down to the chest cavity. It is lined with columnar epithelial cells. In the layers below the epithelium are mucus secreting cells (goblet cells). The inner side of the columnar cells is lined with air.

-The trachea is made up of cartilage rings which prevent them from collapsing. The cartilage rings are incomplete to allow the easy passage of food down the oesophagus that runs below the trachea.

- The cartilage rings are C – shapes

### THE BRONCHUS

- The trachea divides into two bronchi within the chest cavity one leading to the left lung and the other leading to the right.
- The bronchi are very similar to the trachea in structure, only that they are narrow
- The left bronchus divided into two while the right bronchus divided into three.

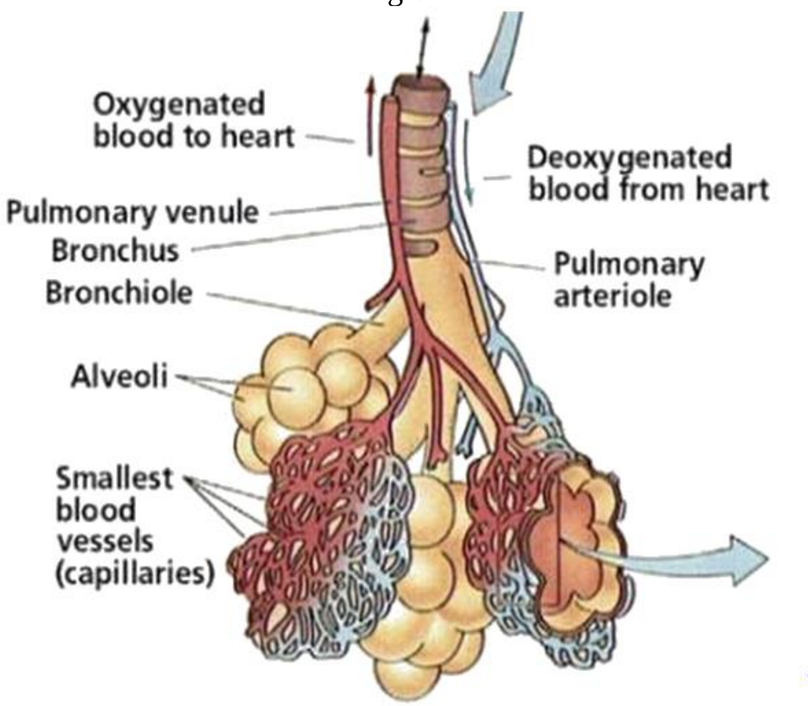
### THE BRONCHIOLES

The bronchioles are much smaller than the bronchi and these are many of them decreasing in size as they go down to the alveoli (different sizes). Larger bronchioles have cartilage rings unlike those which are smaller. These small bronchioles collapse quite easily as the bronchioles get smaller. The lining epithelium changes from columnar to flattened cuboidal cells making diffusion more likely.

**THE ALVEOLI**

The tiny bronchioles terminate into millions of microscopic air sacs or alveoli in grape like clusters.

- The alveoli are 0.1 mm in diameter and they are 0.5 mm in thickness.
- They have elastic walls lined (supplied) with blood capillaries from the pulmonary artery
- The alveoli are made up of squamous epithelial cells which facilitate diffusion because they have a large surface area and are thin reducing the distance through which gases travel.
- The capillaries which run close to the alveoli also have walls which only one cell thick are creating the best possible conditions for gaseous exchange. Between the capillaries and the alveolus is a layer of elastic connective tissues which holds them together.
- The elastic elements in the tissue help to force air out of the stretched lungs; this is known as elastic recoil of the lungs.

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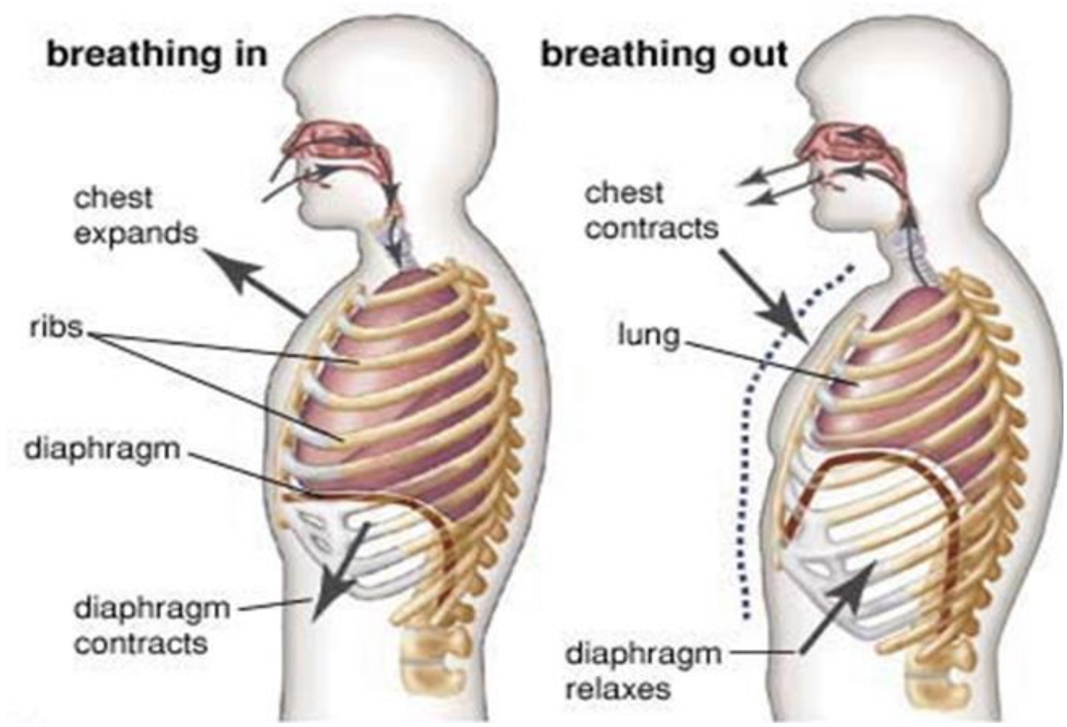
**Breathing in ( inspiration) humans**

- External intercostal muscles contract and internal intercostal muscles relax.
- The ribs move upwards and outwards (anteriorly & ventrally)
- The diaphragm muscle contracts and flattens
- These two movements of the ribs and diaphragm cause the volume of the thoracic cavity to increase and therefore the pressure inside it falls.
- The pressure inside the lungs is lower than that of the atmosphere.
- This causes air to rush into the lungs from the exterior.

**Breathing out (expiration) in humans**

- **Breathing in** is an active process but **breathing out** is largely passive.
- Internal intercostals muscles contract and external intercostals muscles relax
- The ribs move downwards (posteriorly) and inwards (dorsally)
- The diaphragm muscle relaxes and resumes its dome – shape
- These movements cause the volume of the thoracic cavity to decrease and therefore pressure inside increases.
- This causes air to be forced out of the lungs as their elastic walls recoil.




**TRANSPORTATION OF OXYGEN**

There are two ways in which oxygen is transported to the respiring cells. It is carried in the blood in two forms

**1. Dissolved oxygen**

Oxygen is dissolved in the plasma then transported to the respiring cells. It is a simple physical solution. About 2% of the oxygen in the body is transported in this way.

2. **Chemical form**

It is transported in combination with haemoglobin. About 98% of the $O_2$ in the body is transported in this way.

**THE CHEMICAL FORM**

Oxygen is transported in combination with haemoglobin.

$$\text{Haemoglobin} + O_2 \longrightarrow \text{oxyhaemoglobin}$$

Haemoglobin is a protein that consists of four sub- units 2∝ chains and 2β chains [haemoglobin has four sub – units 2 alpha chains and 2 B chains].

These form in a quaternary structure from the haemoglobin. Each of these four subunits contains a special pigment or Haem group.

The haem group has an iron atom located at its centre. A single Fe atom builds/ binds one molecule of oxygen ($0_2$), one molecule of haemoglobin and therefore combines reversibly with up to 4 molecules of oxygen.

Haemoglobin is found in the red blood cells. It has high affinity for oxygen. It combines readily with oxygen.

4. different kinds of oxyhaemoglobin can be formed as follows;

$$Hb_4 + O_2 \rightleftharpoons Hb_4O_2 \text{ (oxhyhaemoglobin 1)}$$

$$Hb_4O_2 + O_2 \rightleftharpoons Hb_4O_4 \text{ (oxhyhaemoglobin 2)}$$

$$Hb_4O_2 + O_2 \rightleftharpoons Hb_4O_6 \text{ (oxhyhaemoglobin 3)}$$

$$Hb_4O_2 + O_2 \rightleftharpoons Hb_4O_8 \text{ (oxhyhaemoglobin 4)}$$

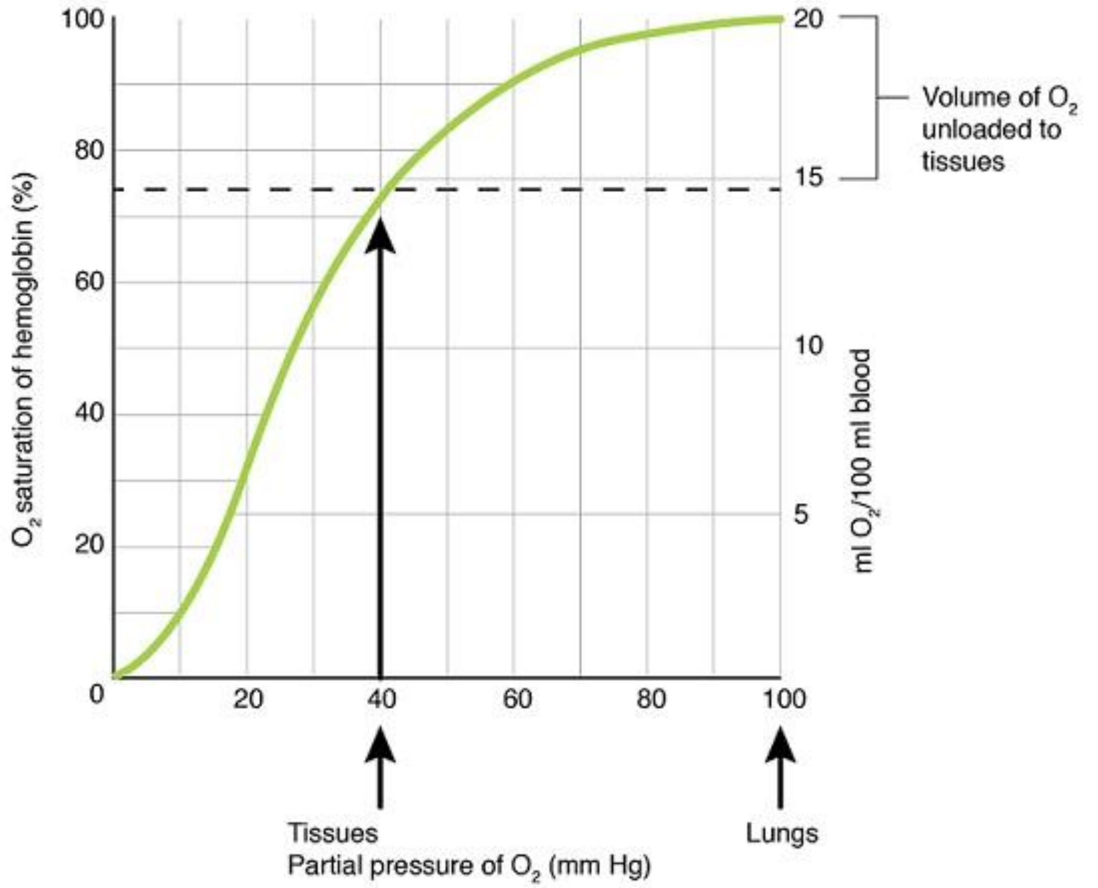
OR

$$\underset{\text{(Haemoglobin)}}{Hb_4O_2} + 4O_2 \underset{\text{Tissue}}{\overset{\text{lungs}}{\rightleftharpoons}} \underset{\text{(Oxyhaemoglobin)}}{Hb_4O_8}$$

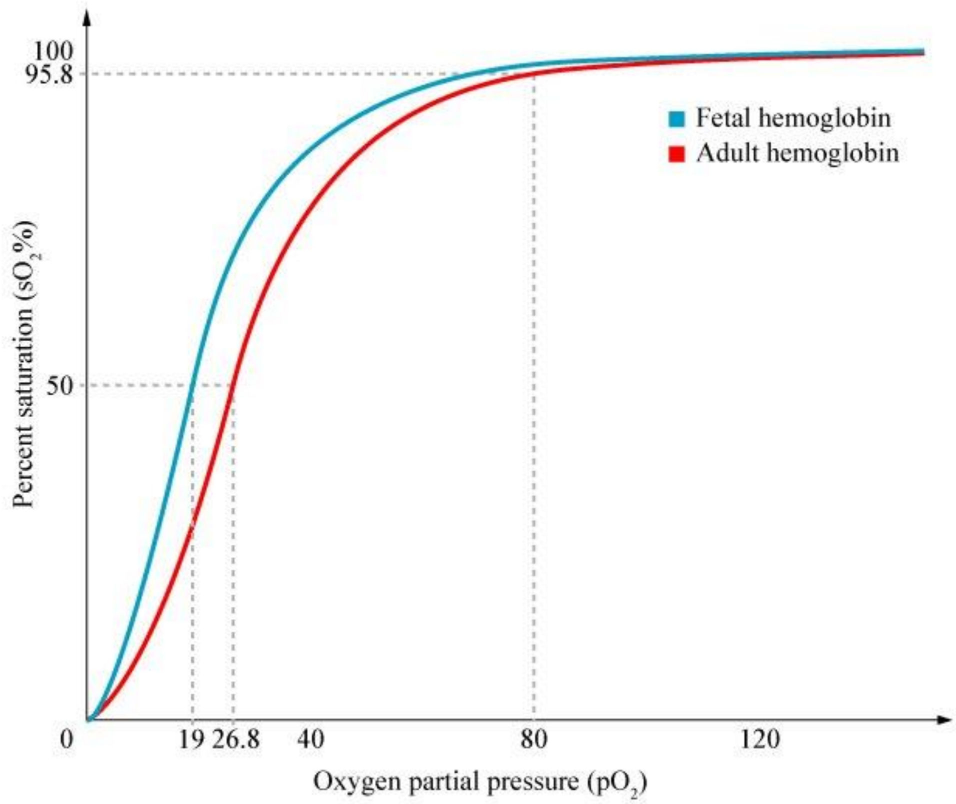
The 4 oxyhaemoglobin differ according to the degree of dissociation $Hb_4O_8$ dissociates to release $O_2$ more readily than $Hb_4O_6$ and $Hb_4O_6$ dissociates more readily than $Hb_40_4$ and so on.

The degree of dissociation represented gives a character sigmoid (s – shaped) curve called the oxygen dissociation curve.

**An oxygen dissociation curve** is therefore a curve in which the percentage saturation of haemoglobin is potted against the oxygen concentration (partial pressure)




Partial pressure of oxygen and hemoglobin saturation




**MYOGLOBIN**

- Myoglobin is another respiratory pigments in vertebrates
- It consists of a single polypeptide chain and a single haem group.
- It has an oxygen dissociation curve displaced to the left of the haemoglobin.
- This means it has higher (greater) affinity for oxygen

**THE ADAPTATIONS TO OXYGEN UPTAKE**

a) **DIVING VERTEBRATES**

E.g. Seals, whales, dolphins

The duration of a single dive in seals rarely exceeds 20 minutes where as that of sperm whale may extend to 75 min. Bottle nose dolphin have been known to dive for up to two hours.

The remarkable ability of these mammals to endure such long periods without replenishing the air supplies is a result of

1. A large total volume of blood

2. An increased concentration of RBC
3. Greater haemoglobin concentration
4. Reduced sensitivity to blood pH
5. Muscles rich in myoglobin
6. Reduction in cardiac out put
7. Restriction of blood supply to vital organs
8. Tolerance to high lactate levels (muscles respire anaerobically thus accumulation of lactic acid, but they can tolerate lactic acid which would cause fatigue and cramps in other mammals).
9. Reduction of metabolic rate during diving
10. Larger tidal volume
11. Lungs may be entirely collapsed to allow exchange of air (they have few ribs) attached to the sternum making the ribcage more flexible permitting it to collapse partially when under pressures, experienced during a deep dive
12. Cartileginous rings extend further into the lungs. The rings extend down into the bronchioles to prevent these collapsing under pressures experienced during a deep dive.
13. Expulsion of air during the dive. This reduces the danger of excessive nitrogen becoming dissolved in the blood (Accumulation of nitrogen, it may dissolve in blood and cause narcotic (harmful nitrogen bubbles)
14. Closure of the nostrils, anatomical modifications allows the nostrils to be closed during a dive to prevent entry of water into the lungs.

**NB:-**

As a diver goes deeper, the pressure increases by 1atm for every 10m; in order to pass air from the tanks to lungs its pressure must be increased thus this condition cause greater concentration of oxygen and nitrogen enter the blood. Oxygen may be toxic and nitrogen has a narcotic effect. Also nitrogen may come out of the solution and form bubbles. If a diver rises to the surface rapidly thus gibe painful symptoms known as bends. On returning to normal atmospheric pressure the nitrogen dissolves in blood expanding to form bubbles causing pain (bends) and blocking circulation in small blood vessels in the brain and elsewhere.

**HIGH ALTITUDE DWELLERS**

The amount of oxygen at high altitude levels is the same as that at sea levels. The respiratory problems associated with living at high altitude levels are a result of reduced pressure it means it is more difficult to lead the haemoglobin with $O_2$ effectively. Some human settlements exist at high altitudes and the inhabitants have become acclimated/ adapted to living in conditions of low atm pressure) the acclimatization involves:-

1. **Adjustment of blood pH**

The reduced leading of haemoglobin lead to deeper breathing (hyper ventilation in an attempt to compensate for the lack of $O_2$ in the blood). This leads to excessive removal of $CO_2$ and raised blood pH. Nervous responses are triggered causing reduced depth of breathing. In acclimatized individuals the $HCO_3$ ions are removed by the kidney restoring the blood PH to normal (7.4)

2. **Increased Oxygen uptake**

   More $O_2$ is absorbed by the lungs as a result of an improved capillaries network in the lungs and deeper breathing.

3. **Improved transport of $O_2$** to the tissues thus results from

- **Increased RBC conc.** (45% - 60% of total blood volume)

1. Changes in **haemoglobin affinity** for oxygen.

   The oxygen dissociation curve is shifted to the right to facilitate release of $O_2$ to the tissues

2. **Increased myoglobin level** in muscles with its higher affinity for $O_2$, this facilitates the exchange of $O_2$ from blood to the tissues.

**TRANSPORT OF CARBONDIOXIDE ($CO_2$)**

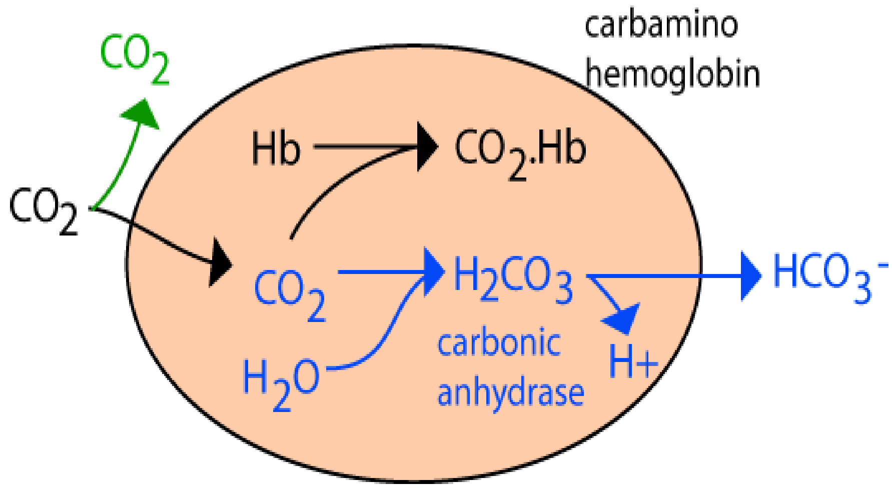
The transport of $CO_2$ is closely linked with the transport of $O_2$. $CO_2$ is more soluble in $H_2O$ than $O_2$ but its transport in solution is inadequate to meet the needs of most organisms (vertebrates)

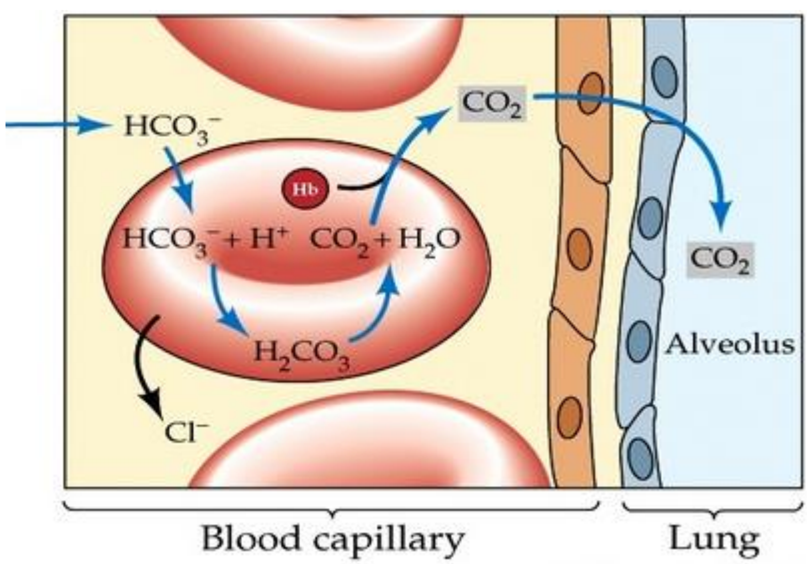
$CO_2$ is transported in 3 ways from the tissues (respiring cells) to the gaseous exchange surfaces.

1. **Aqueous soln**: About 5% of the $CO_2$ is transported in soln in the blood plasma. $CO_2$ is directly dissolved in blood, it occurs in the blood plasma.

1. **In combination with haemoglobin**: Around 10% of $CO_2$ combines with the amine group in the four polypeptide chains which make up each haemoglobin molecules. It occurs in the RBC

$CO_2$ is transported in the form of carbamino haemoglobin ($HbO_2$)



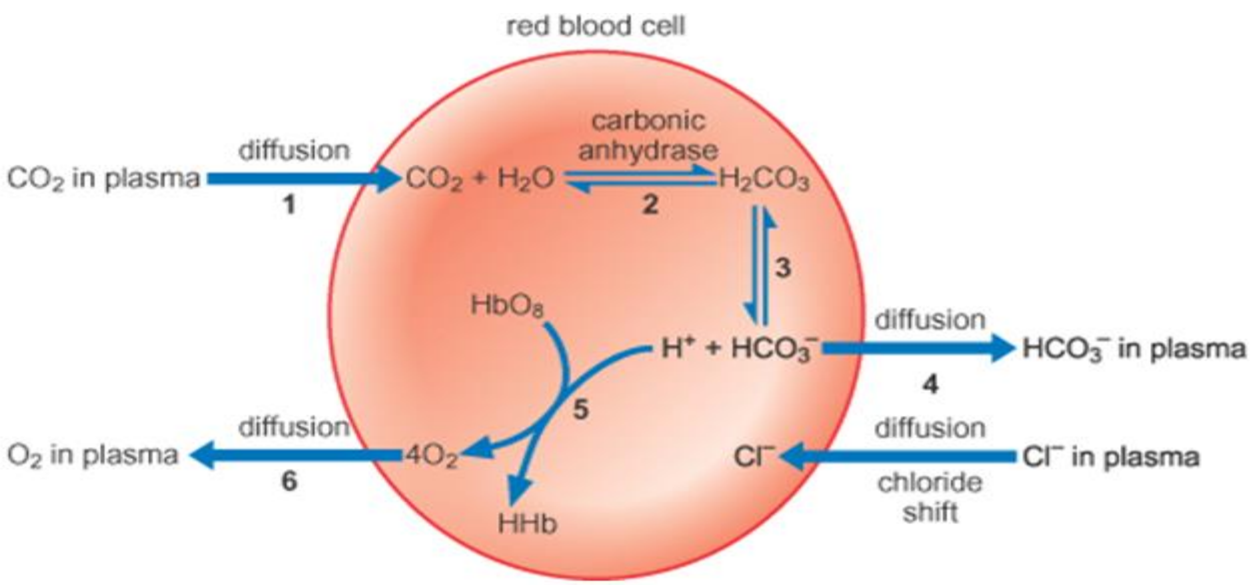




1. **In form of hydrogen carbonate ($HCO_3$)** 85% of the $CO_2$ produced by tissues combines with water to form carbonic acid

$$H_2O + CO_2 \xrightarrow[\text{Anhydrase}]{\text{carbonic}} H_2CO_3 \text{ (carbonic acid)}$$

This reaction is catalyzed by a zinc containing enzyme called carbonic anhydrase.

The carbonic acid dissociates to form the hydrogen carbonate ions.



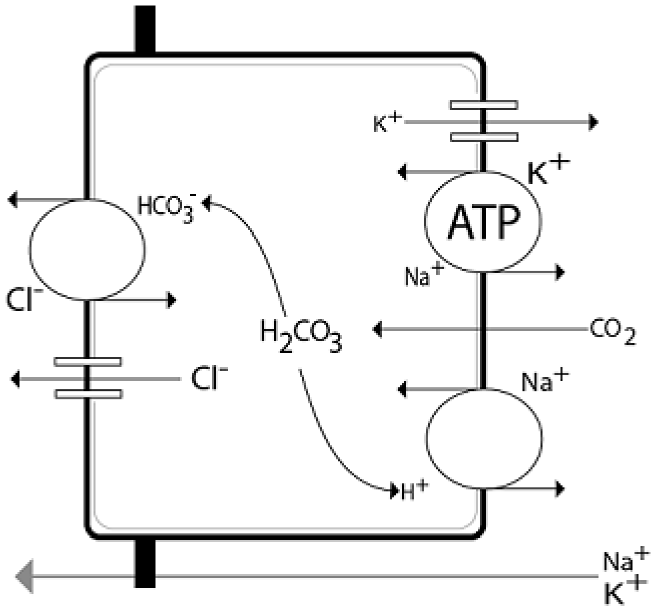

2. **The fate of hydrogen ion ($H^+$)**

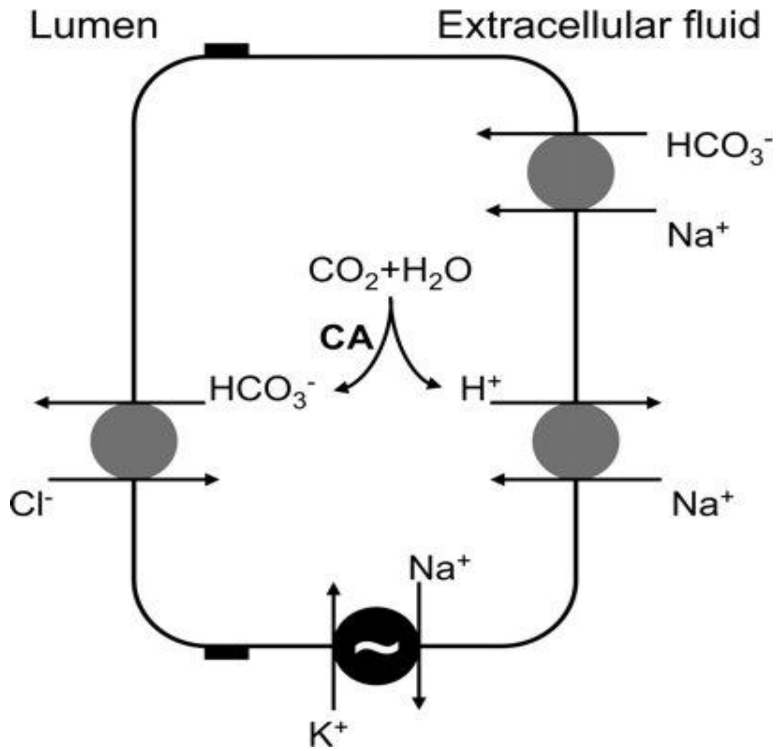
The H+ combines with haemoglobin which loses its $O_2$ . The $O_2$ so released from the Hb diffuses out of the RBC through the capillary wall and tissue fluid into the respiring tissues. Thus the more $CO_2$, the more carbonic acid formed the more $H_2CO_3$ dissociates, the more H+ ions released which will combine with the Hb which will then release its $O_2$ to go into the respiring cells. This explains the **Bohr's effect.**

**Bohr's effect**- the release of oxygen from haemoglobin is facilitated by the presence of carbon dioxide, where $CO_2$ is high in respiring tissues oxygen is released more rapidly.

**3. The fate of $HCO_3^-$**

The $HCO_3^-$ diffuses out of the RBC into the plasma where they combine with Na+ ions from the dissociation of NaCl to form $NaHCO_3$.






It is largely in this form that the $CO_2$ is carried to gaseous exchange surface; the reverse process is carried out releasing $CO_2$ which diffuses out the body

$$NaHCO_3 \longrightarrow Na^+ + HCO_3^-$$
$$HCO_3 \longrightarrow H_2O + CO_2$$

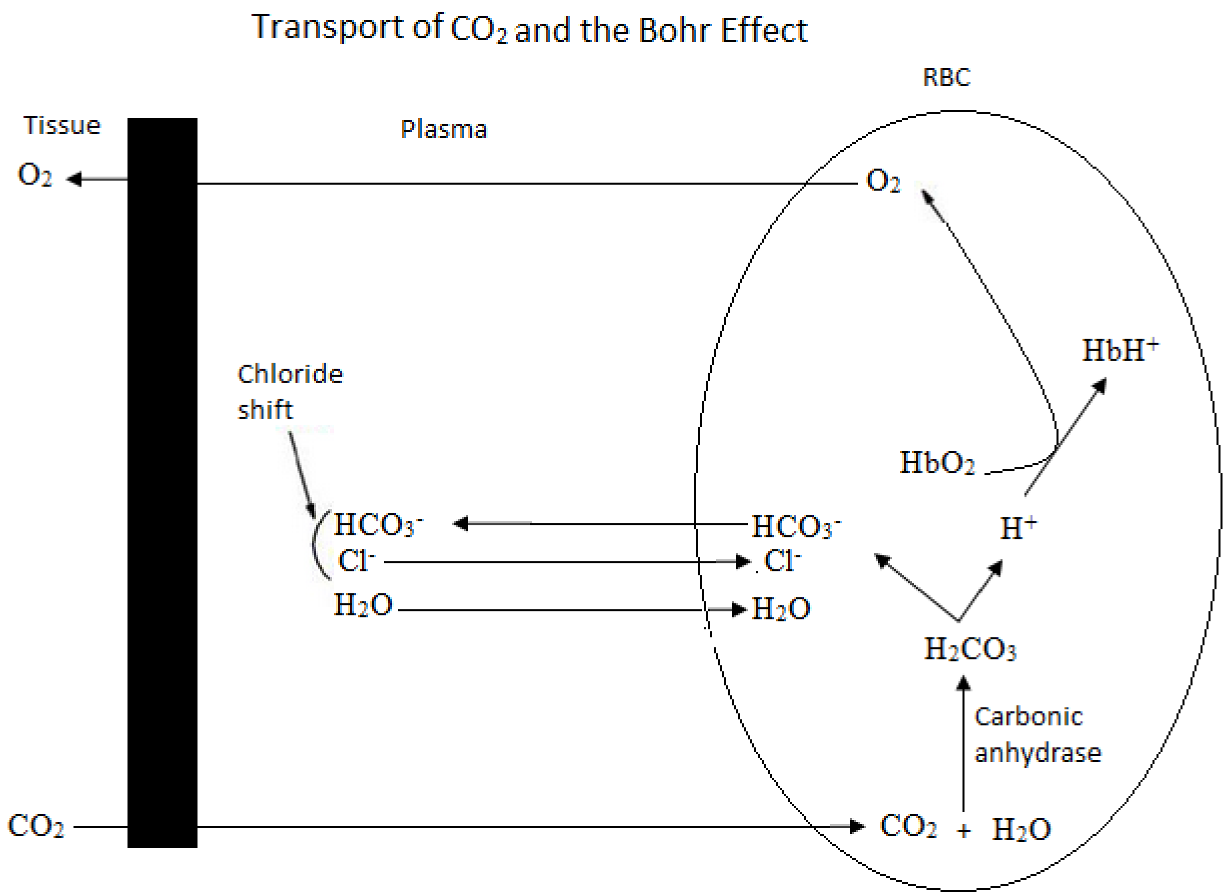
**THE CHLORIDE SHIFT**

- It is the inward diffusion of Cl- into the RBC.
- The loss of the negatively changed $HCO_3$ ion from the RBC is balanced by the inward diffusion of the negative chloride ion ($Cl^-$) from the dissociation of the NaCl.

ie

$$NaCl \longrightarrow Na^+ + Cl^-$$

- The negativity of $HCO_3^-$ ions is compensated by $Cl^-$ ion in RBC in equal amount
- In this way the electrochemical neutrality is restored.




**Chloride shift**

## RESPIRATION

Tissue respiration or cellular respiration or internal respiration is a chemical processes in which food substances such as carbohydrates, lipids and proteins are oxidized in the cells to yield energy.

During respiration the energy that was fixed into the synthesized organic matter is released and made available for use the living organisms.

The Site of Respiration:

The site of respiration depends on the step of the process involved:

(i) Glycolysis takes place in the cytoplasm of the cell.
(ii) Krebs cycle and respiratory chain reaction take place in the mitochondrial

Respiratory Substrate:

There are food substances which upon being oxidized yield energy in form of ATP, they include carbohydrates, lipids and proteins. However the most preferred respiratory substrates are the carbohydrate especially glucose.

Respiration of Glucose:

Glucose is the mostly used respiratory substances. When glues completely oxidized aerobically a molecule of glucose yield 38 ATP molecules.

STAGES OF RESPIRATION:-

Respiration is completed in the following stages:

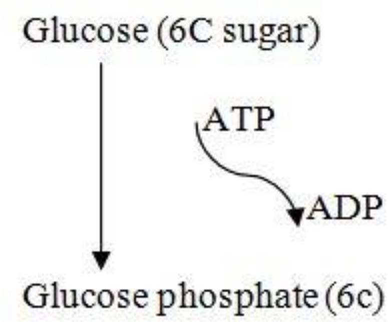
(i) Glycolysis
(ii) Krebs cycle (if oxygen available)
(iii) Fermentation (if oxygen not available)
(iv) Electron transport system

GLYCOLYSIS:

Glyolysis (glycol – sugar lyses broken down)

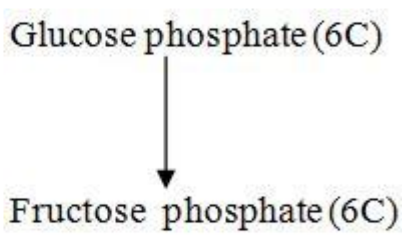
Is the breakdown of hexose sugar, usually glucose into two molecule of 3 – carbon compound pyruwate (pyruwic acid). It sews in a all cell in anaerobic organisms it is the only stage of respiration.

Initially the glucose is insufficiently reactive and so it is phosphotylated poor to split into two trios sugar molecules.

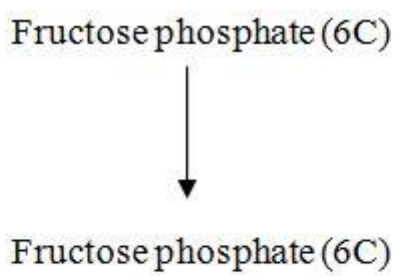



1. The glucose molecule is phosphorylated to make it more reactive. The phosphate molecule come from the conversion of ATP to ADP

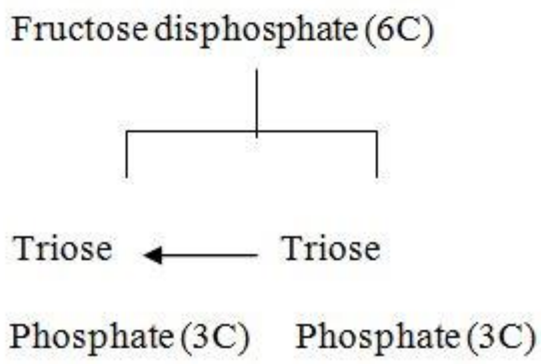
2. The glucose molecule is heorganized into its isomer fructose phosphate.



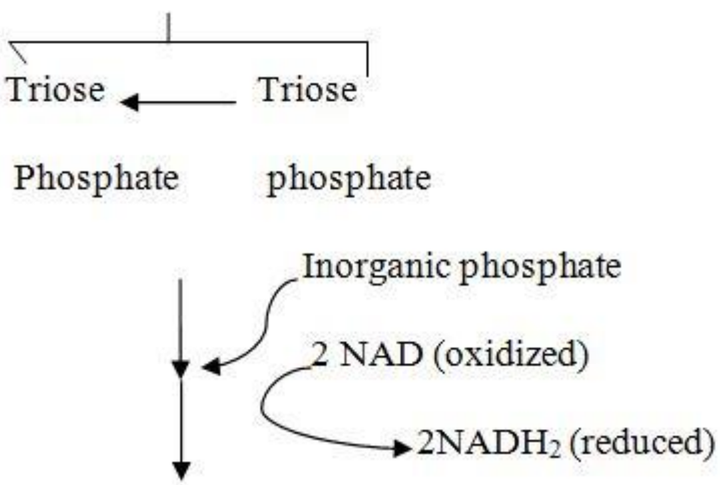

3. The fructose phosphate is further activated by the donations of a second phosphate group by a ATP molecule to make it more reactive.



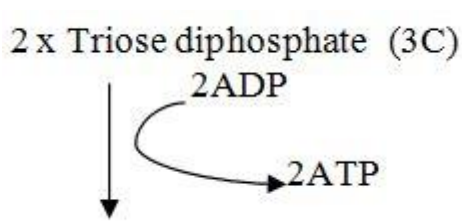

4. The 6 – carbon fructose diphosphate is split into two 3 – carbon triose phosphate molecule




5. Hydrogen atom are removed from the triose phosphate molecule and taken up by NAD. Inorganic phosphate is added to further activate the triose phosphate.

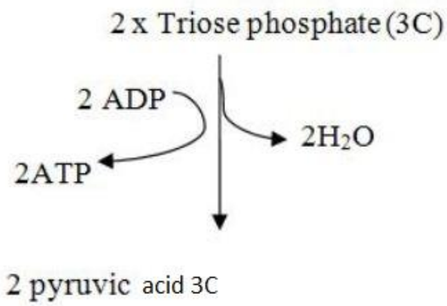



6. a phosphate molecule is lost and ATP is regenerated




7. A phosphate molecule is lost and ATP is formed A water molecule is also

lost for each triose phosphate




8. Each glucose molecule produces two molecules of glycerate 3 – phosphate
∴a pair of every glucose molecule.

The energy yield is a net gain of two molecules of ATP.

The total yield of energy therefore two molecule of ATP directly and six molecule of ATP produced from the two reduced NAD molecules. A total of eight ATP molecule.

**KREBS (tricarboxylic acid) CYCLE:**

The pyruvic acid formed as a result of glycolysis may in the absence of oxygen being converted to a variety of substances to yield a little energy. This is anaerobic pathways.

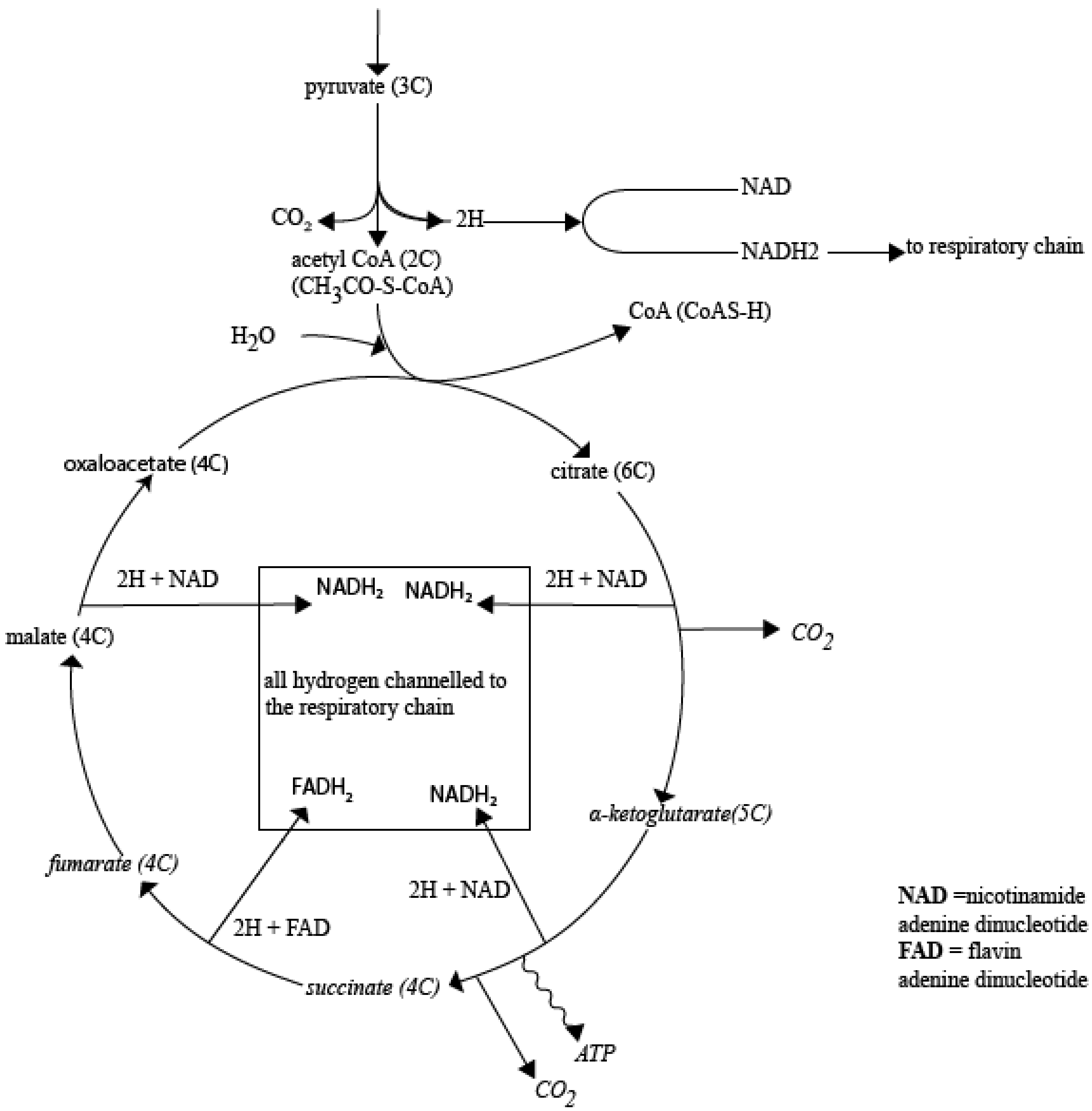
In the presence of oxygen the pyruvic acid enters the Krebs cycle.

Before entering the actual cycle one of the 3-C atom of pyruvic acid is oxidized to $CO_2$ and a molecule of NA is reduced by addition of two hydrogen atom.

This leaves the acetyl group ($CH_3\,CO$) which is readily accepted by a coenzyme called coenzyme A.

The two carbon acetyl group of this compound combine with 4 – carbon substance called oxaloacetic acid to give a six carbon molecule atric acid.

In a series of reaction two carbondioxide produced and 4 – carbon oxaloacetic acid regenerated in readness to receive another 2 – carbon acetyl group from acetyl coenzyme A. other products includes a total of 8 hydrogen atoms which are used to reduce three molecules of NAD and one molecule of FAD.



These reduced electron carriers (NAD & FAD) eventually pass on the hydrogen atoms to oxygen yielding 11 more ATP molecule for each pyruvic acid. In addition of further ATP molecule is yielded. Directly during the cycle to give a total of 12 ATB per pyruvic acid molecule.

Importance of Krebs's cycle:

1. It provide hydrogen atoms which ultimately yield the major part of the energy derived from the oxidation of glucose molecule.

2. It is a valuable source of intermediate which are used to manufacture other substances pg. Fatty acids, amino acids, carotenoids.

**ELECTRON TRANSPORT SYSTEM:**

Is the means by which the energy From the Krebs cycle inform of hydrogen atom is converted to ATP.

Much of the energy is in the form of hydrogen atoms which are attached is the hydrogen carries NAD and FAD.

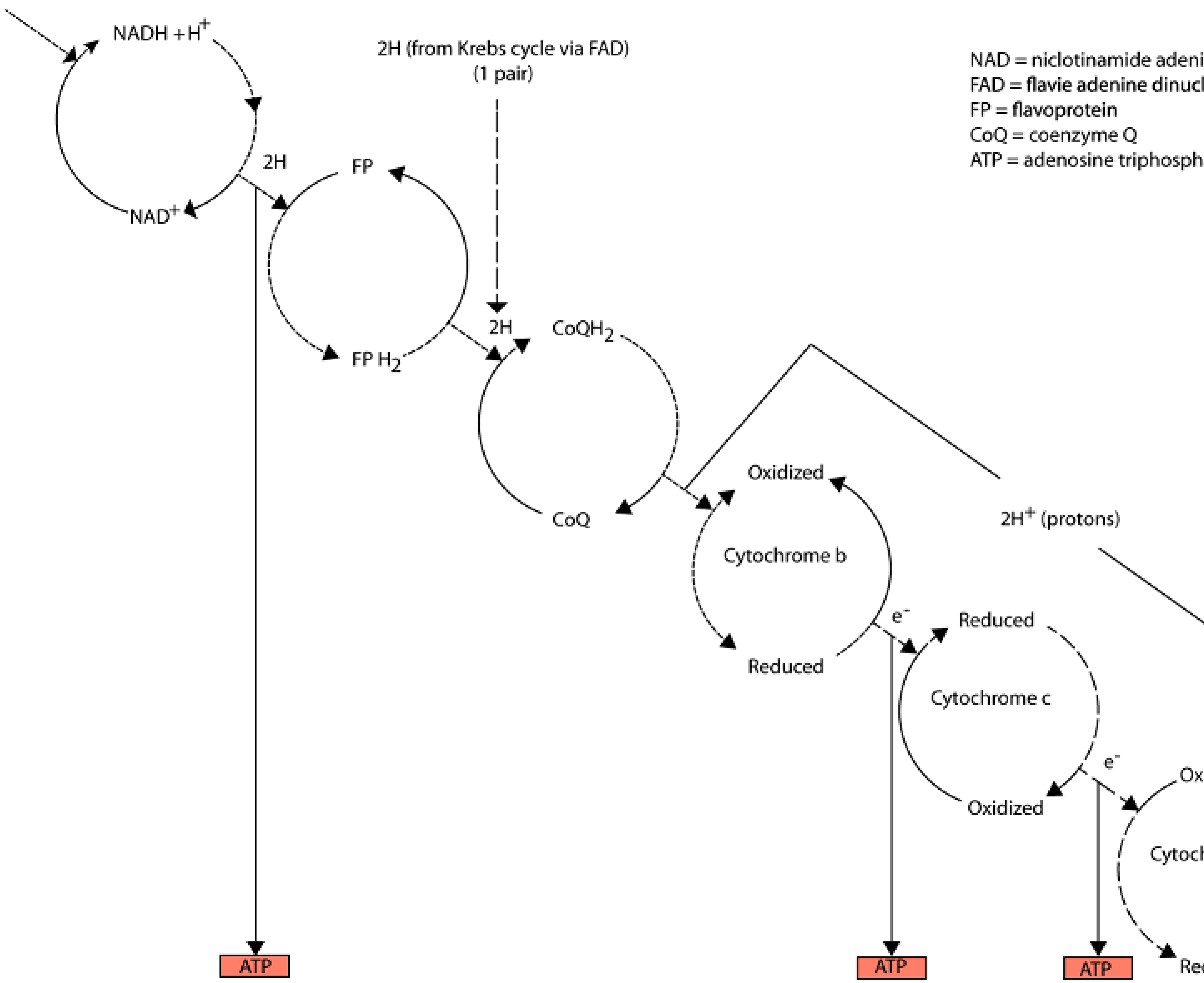
These atoms passed along a serves of carriers at progressively cover energy levels, as they lose their energy it is harnessed to produce ATP molecule.

There for each molecule of NAD and two for each one FAD

The other camers in the system are iron containing protein called cytochromes. The hydrogen split into their protons and electrons during the pathway.

They combine with their proton before the find stage where the newly reformed hydrogen atoms combine with oxygen to form water.

It is very essential in aviabic respiration only play a role at this final stage, it is vital since it drives the process.




Summary of the Electron transport system.

In absence of oxygen only anaerobic resp. continues the transfer of hydrogen atom is catalyzed by the enzyme cytochrome oxidize. This enzyme is intrubited by cyanide, so preventing the removal of hydrogen atoms at the end of the respiratory chain. In these circumstances the hydrogen atoms accumulate and aerobic respiratory ceases, making cyanide a most effective respiratory incubator.

Anaerobic Pathways:-

If no oxygen is available the pyruvic acid formed at the glycolysis do not enter the Krebs cycle but follow one of the anaerobic pathways are often reffered as fermentation.

Three major anaerobic pathways:-

A. Acetaldehyde fermentation

Pyruvic acid ($CH_3CO\ COOH$)

$$\downarrow \searrow CO_2$$

Acetaldehyde

$CH_3\ CHO$

Eg. Certain anaerobic bacterica

B. Alcoholic fermentation

$CH_{3CO}COOH$ Pyruvic acid

$$2H \searrow \downarrow \searrow CO_2$$

$CH_3\ CH_2OH$ ethanol

Yeast and other plants. This process forms the basis of brewing and baking

C. Lactic acid fermentation

$CH_3CO\,COOH$ Pyruvic acid

$$CH_3COCOOH \xrightarrow{2H} CH_3CHOHCOOH$$

$CH_3\,CHOH\,COOH$ lactic acid

This happen in higher animals especially in middles when oxygen used exceeds supply.

The role of vitamin B complex in cellular respiration

B1 – Thiamine : - Involve in formation of some Krebs's enzymes

Forms a part of acetyl coenzyme A.

B2 – Riboflavin: - Form part of hydrogen carrier flavo protein (FP)

B3 – Niacic: - Forms part of coenzymes NAD & NADP
(Nuotinic acid) Form part of acetyl coenzyme A

B5 – Partothenic acid
Form part of acetyl coenzyme A

TO COMPLETE TOTAL YIELD OF ATP WHEN OXYGEN RESPIRE AEROBICALLY
ATP and energy yields
ATP is the form in which energy from the breakdown of glucose is temporarily stored.

When glucose is completely oxidized aerobically the sources of ATP are:-

(i) In Glycolysis: This yields only 2 ATP

(ii) Krebs cycle: Also yield 2ATP molecules

(iii) Respiratory chain : -The number of ATP depend on the number of carrier molecules $NADH_2$ and $FADH_2$

(a) From Glycolysis $2NADH_2$

(b) Convention of pyruwate to acetyl Co A yields $2NADH_2$

(c) FROM THE Krebs cycle 6 $NADH_2$ and 2 $FADH_2$ molecules.

Therefore there are total of $10NADH_2$ and $2FADH_2$ molecules.

Each pair of atoms carried by NAD produces in respiratory chain as $NADH_2$, shunts its hydrogen to carrier 1. Where NAD occurs and each pair of hydrogen atom carried by FAD shunts into hydrogen to carrier 2 where FAD occurs.

Thus $10NADH_2$ produce a total of 3ATP X $10NADH_2$

= 30 ATP

$2FADH_2$ produce a total of $2FADH_2 \times 2ATP$

= 4 ATP

Summation

From Glycolysis = 2 ATP

From Krebs's cycle = 2 ATP

From Respiratory chain 34 ATP = <u>34 ATP</u>

<u>38 ATPS</u>

Thus when a molecule of glucoseis completely oxideized aerobically a total of 38 ATP molecules is synthesized.

The total ATP produced in one

| stage: | ATP produced directly | ATP indirectly | Total |
|---|---|---|---|
| Glycolysis | 2ATPs | 6ATPs | |
| Krebs cycle | 2 ATPs | 22 ATPs | |
| Pyruvate to acetate | - | 6 ATPs | |
| Total | <u>4 ATPs</u> | <u>34 ATPs</u> | <u>38 ATPs</u> |

## TOTAL YIELD OF ATP WHEN GLUCOSE RESPIRES ANAEROBIC RESPIRATION

We have seen in the previous section that only glycolysis occurs during anaerobiosis and that the NADH + H+ it yields is not available for oxidative phosphorylation.

The total energy released is therefore restricted to the two ATP's formed directly.

In lactate fermentation all is not lost, and the lactate may be converted to pyruvate by the liver and so enter Krebs cycle thus releasing the remaining energy.

RESPIRATORY PATHWAY USING LIPID AND PROTEIN

Sugar are not only material which can be oxidized by cells to release energy. Both fats and protein in certain circumstances be used as a respiratory substrates.

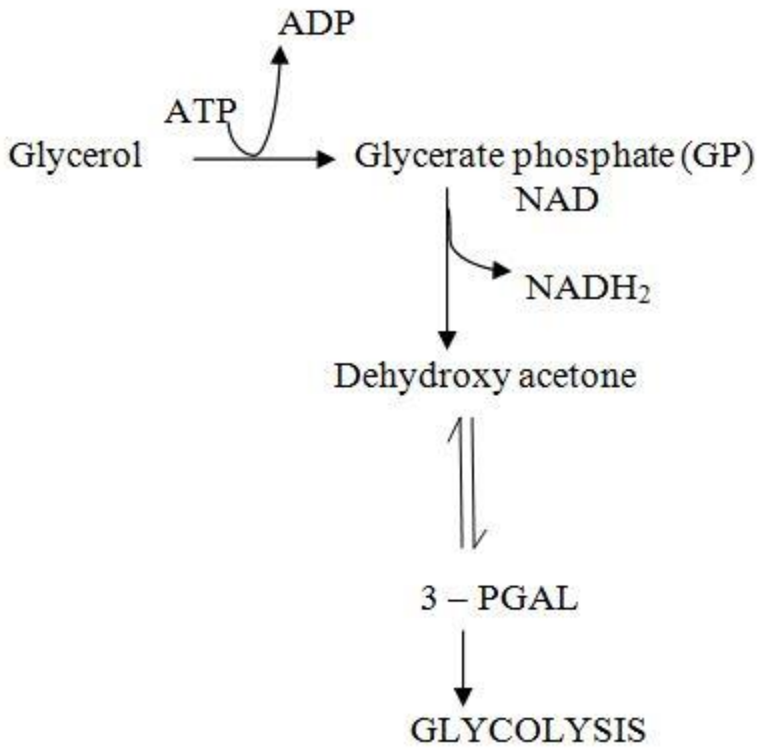
**Respiration of Fats:**

Fats are used as respiratory substrate when there is unsufficient amount of carbohydrates the oxidation of fats is proceeded by its hydrolysis to glycerol and fat acids.

$$\text{Fats} \xrightarrow{\text{Lipase}} \text{Fatty acid} + \text{glycerol}$$

GLYCEROL:

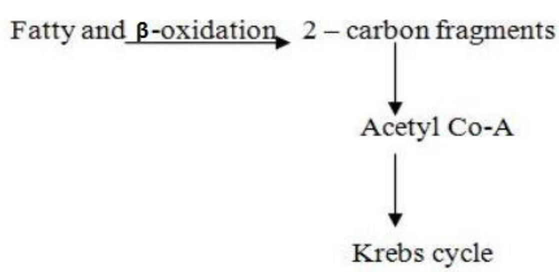
Glycerol is phosphatylated by an isnorganic phosphate to form glycerate phosphate (GP). Then oxidized by NAD to form dehydroxy acetone which is then converted its isomer 3PGAL then feel into the glycolytic pathway at the point where PGAL occurs.




The $NADH_2$ then passed to the respiratory chain with a total yield of 3ATP molecules. The PGAL is passed to the glycolytic and Krebs cycle pathway with a total yield of 17ATP molecules. Thus the net gain of ATP when glycerol is aerobically oxidized is 20 – 3 ATP.

**FATTY ACIDS**:

Each fatty acid in the matrix of mitochondria undergoes oxidation in the process called β-oxidation involves the fragmentation of fatty acid to 2-cabon fragments. Each of these will be converted into acetyl Co-A and then fed into the Krebs at the point where acetyl Co-A occurs.



The advantage of respiring fats is that fatty acid have large number of hydrogen atom which when passed through respiratory chain yield a large amount of ATP molecule.

E.g. The respiration of asteric acid, fatty acid and animal adipose tissue yields a total of 147 ATP molecules, Total number of ATP's formed are 166 ATP's from glycezid and fatty acids.

**Respiration of Protein**:

Protein is respired only when both carbohydrates fats are totally absent or need up is used in the condition of starvation. When proteins are to the respired first hydrolysed to amino acids, then diamination.

**Oxidative Diamination**:

This process occurs in the inner cells and it involves the removal of ammonia from amino acid. This is by dehydrogenation and hydrolysis.

Consider the diamination of glutaric acid

$$\text{Glutaric acid} + NAD + H_2O \longrightarrow \alpha\text{-Ketiglutaric acid} + NADH_2 + NH_3$$

The ammonia is then exceted as either wric acid urea or pure $NH_3$ depend on the nature of the environment the diaminated amino acid is converted into one the Krebs cycle intermediate depending on the number of carbon atoms. If it is a 5-carbon amino acid. It will be converted into α- ketoglutaric acid.

And if it is a 4-carbon amino acid will be converted into oxaloacetic acid. If it is a 3-carbon amino acid will be converted into pyruvic acid, latter converted into acetyl COA then fed into Krebs cycle.

**Transamination**:

This is a process whereby on amino group from one amino acid is transferred to a keto group of another amino acid so as to form a new amino acid. Hence the conversion of one amino acid into another is controlled by transaminase oenym and it can produce α-keto acids that directly enter Kreb's cycle.

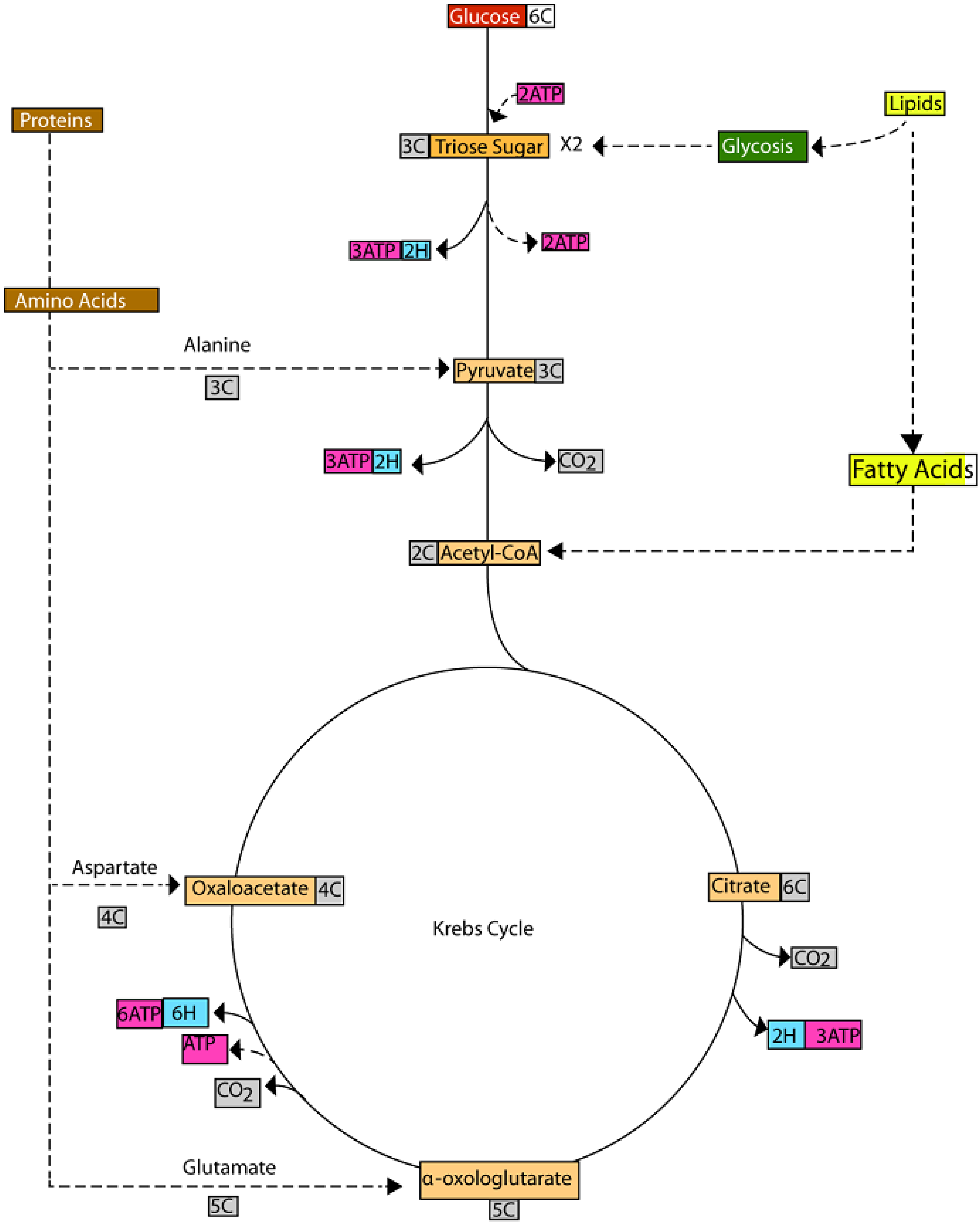



Fig 16.6 Summary of respiratory pathways

**Study questions:**

1. Briefly describe the respiration of Fats

2. Explain why fats ax more carsfic than the carbohydrate

3. Describe the changes that a protein undergo before entering the respiratory pathways.

4. Why it advantageous to respire glycogen than glucose?

5. Compute the total number of ATP molecule produced when glucose is completely oxidized aerobically.

6. In the aerobic respiring cell glycolysis yields net gain of $ATP molecule; however the whole process contributes 10 ATP'S. How do you account for this?

7. Show that the majority of energy produced when glucose is completely oxidized aerobically depend on oxidative phosphorylation?

8. What is actually transported through the system hydrogen or electron?

RESPIRATORY QUOTIENT (RQ)

Respiratory quotient is a ratio of the volume of Carbondioxide evolved to oxygen consumed over a period of time.

RQ = <u>Volume of $CO_2$ evolved</u>

Volume of $O_2$ consumed

Significance of RQ:

The value of RQ tells the type of a substrate that is being oxidized

Example (a) For glucose the value f RQ = 1

$\longrightarrow C_6H_{12}O_6 + 60_2 \qquad 6CO_2 + 6H_2O$

$$RQ = \frac{\text{Vol of } CO_2}{\text{Vol of } O_2}$$

$$= \frac{6\ CO_2}{6\ O_2}$$

$$= 1$$

(b) Fats the RQ value is less than 1.
Consider the respiration of asteric acid.

$\longrightarrow C_{18}H_{36}O_2 + 260_2 \qquad 18C0_2 + 18\ H_20$

$$RQ = \frac{\text{Vol of } C0_2}{\text{Vol of } 0_2}$$

$$= \frac{18\ C0_2}{26\ 0_2}$$

$$= 0.7$$

(c) For protein the RQ value are valid but they are around 0.9

However in practice the above theoretically, call caulated values cannot be obtain this is because:-

(i) A substrate is rarely fatty oxidized

(ii) A mixture of substrates may be oxidized

2. The value of RQ tells the type of metabolism which is taking place.

(i) The RQ value exceeding 1.0 tess that the respiring cell or tissue is in short supply oxygen. Hence respire an anaerobically.

(ii) The high RQ value also show that: the conversion of carbohydrates into fats because the process $Co_2$ is evolved.

(iii) A low RQ value shows that:-

(a) Some or all of the $Co_2$ is evolved is used other process as far photosynthesis

(b) The $Co_2$ evolved is used in the formed in calcareous shows as in shelled animals

(c) A mixture of substrates is oxidized.

Qn: what is the RQ of a photosynthesis green plant at its compensation points?

What will be the nature of the RQ values when aerobic and anaerobic respiration are occurring together

**BASAL METABOLIC RATE (BMR)**

BMR is defined as the minimum rate of energy conversion required just to stay alive during absolute rest or sleep.

Because it is difficult to ensure a subject is absolute rate the BUR is usually estimated as the amount of energy used by a pelscon restring quietly after at least 13 hours or sleep and 12 hours after the last meal.

The BMR does not remain constant through out life but changes as growth development and aging take place e.g. Newly BMR is 220 and 220 $KJM_{-1}$ hr. By the end of the year one.

The BMR also varies with sex, and health of the individual for a healthy young women. It is about 150 $KJMol_{-2}$ $hr_{-1}$ and for the health young man it is about 170 KJ $mol^{-2}$ $hr^{-1}$

# HOMEOSTATIS

**Homeostasis** is defined as the maintenance of a constant internal environment within an organism.

Internal environment means the immediate surroundings of the cells. In mammalian tissues the cells are generally surrounded by tiny channels and spaces filled with fluid.

The most important features of the internal environment that must be kept constant are:

- Chemical constituents, for example, glucose ions, etc.
- Heart rate
- Its osmotic pressure, determined by the relative amounts of water and solutes.
- The level of carbon dioxide
- Its temperature

The importance of a constant internal environment to the well-being of cells can be shown by removing tissues from the body. If they are subjected to conditions markedly different from those prevailing in the body they will die, but if maintained under the correct conditions they will survive.

**Example:**

The Homeostatic control of glucose

The normal value of glucose in the human blood stream is approximately 90mg per 100cm$^3$ and even after the heaviest carbohydrate meal rarely exceeds 150mg per 100cm$^3$.

After entering the hepatic portal vein, it is conveyed to the liver. In the liver three main things may happen to it.

- It may be broken down into $CO_2$ and water (cell respiration).
- It may be built up into glycogen and stored.
- It may be converted into fat and sent to the body's fat deposits for storage.
- Instead of being metabolized or stored, it may pass on from the liver to the general circulation. In fact under certain circumstances the glycogen stores in the liver may be broken down so as to add the level of glucose in the body.

- The level of glucose in the blood and tissue fluids at any given moment is mainly determined by the relative extent to which these different processes occur in the liver if there is too much glucose, as for example, after a heavy meal rich in carbohydrate, the liver metabolizes what it can, and stores the rest as glycogen. If there is a deficiency of glucose, the liver breaks down glycogen, into glucose, thereby raising the glucose level in the body.

- In cases of prolonged deficiency; glucose may be formed from the non-carbohydrate sources, including proteins. This is called gluconeogenesis. The wasting away of the tissues, which occurs in extreme starvation is because the body resorts to converting its tissue protein into carbohydrate.

The role of Pancreas

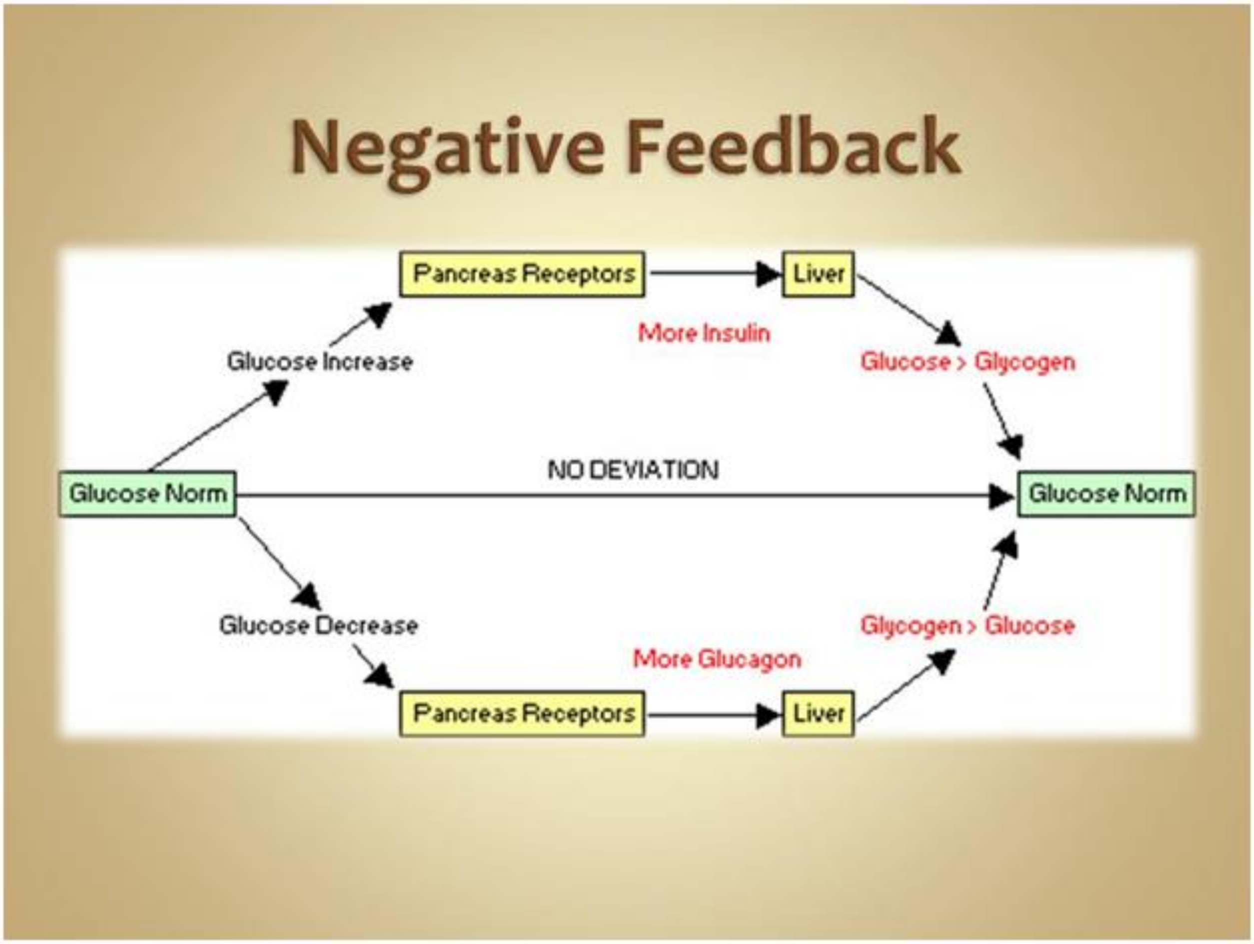
The liver cannot perform this homeostatic function unaided. It has to receive information instructing it what to do. This is provided by the hormone insulin which is secreted into the blood stream by special group of cells, the islets of langerhans in the pancreas.

On reaching the liver, insulin exerts its effect increasing the oxidative breakdown of glucose the formation of glucose from glycogen and non-carbohydrate sources. Insulin thus achieves the overall effect of lowering the level of glucose in the body.

In the absence of insulin the reverse takes place, oxidative breakdown of glucose is inhibited, and additional glucose is formed from storage compounds.

As a result the glucose level raises an effect which is enhanced by another hormone from the islets of langerhans called glucagon.

Clearly insulin plays a vital role in the regulation of glucose without it the liver cannot respond appropriately to the needs of the body. This can be illustrated considering what happens if the pancreas is surgically removed from an animal. The result is a drastic increase in general level of the glucose in the blood, accompanied by a decrease in the glycogen content of the liver and muscles content.




## DIABETES

Certain individuals have islets of langerhans which for one reason or another are unable to produce as much insulin as they should. The result is a condition known as diabetes mellitus, the symptoms of which are similar to those seen in an animal deprived of its pancreas. There is an increase in the blood glucose level condition known as (hyperglycaemia), and glucose appears in the urine (glycosuria). If untreated the condition is fatal. Diabetes can be controlled by regular injections of insulin. Unfortunately the hormone cannot be taken by mouth as it is a protein and is digested in the alimentary canal, though mild cases can be controlled by means of other chemical agents taken orally.

It is amount of glucose in the blood itself which is the effective agent for the control of secretion of insulin. If the blood glucose level is abnormally high, this stimulates the islets cells to produce correspondingly more insulin. On other hand if the glucose level is low, less insulin is secreted. In other words the glucose itself switches on the mechanism by which it is itself regulated, an excess of glucose setting into motion the physiological processes which return the glucose level to its normal value.

## COMPONENTS OF HOMEOSTATIC MECHANISM

- Reference point/set point

This is the set level at which the system operates. Only be deviating from this norm or set-point then that the homeostatic mechanism is brought into play.

- Reception/Detectors

Signals the extent of any deviation from the reference point and are capable of detecting the change.

- Controller/control mechanism

Capable of initiating the appropriate corrective measures/coordinates the information from various detectors and sends out instructions which will correct the deviation.

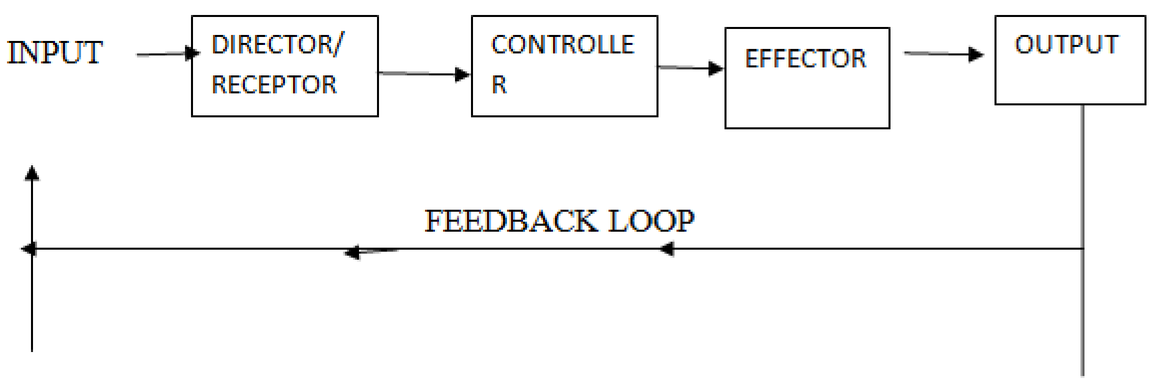
- Effectors

  Bring about a response to a certain change.

  ã€€

**Feedback loop**

Change in the system as a result of action by the effectors




**FEEDBACK MECHANISMS/HOMEOSTATIC MECHANISMS**

- The efficiency of the control system is measured in terms of how little displacement from the reference point (optimal level) occurs and the speed with which the level is restored.
- Homeostatic mechanisms must be free to fluctuate, as it is the fluctuations themselves which activate the control systems and return its parameter towards its optimal level.
- Such control systems rely upon their components being linked together so that the output can be regulated in terms of the input, a concept known as feedback mechanism.
- **Feedback mechanisms** require the action of the system to be referred back to a reference point, which is the optimal level of the parameter, so that subsequent action may be modified to restore the set point.
- There are two forms of feedback, **negative** and **positive**, the former being most common in homeostatic mechanisms of organisms.
- **Negative feedback** is associated with increasing stability of systems. If the system is disturbed, the disturbance or error sets in motion a sequence of events which counteract the disturbance and tend to restore the system to its original state. This serves as an advantage.

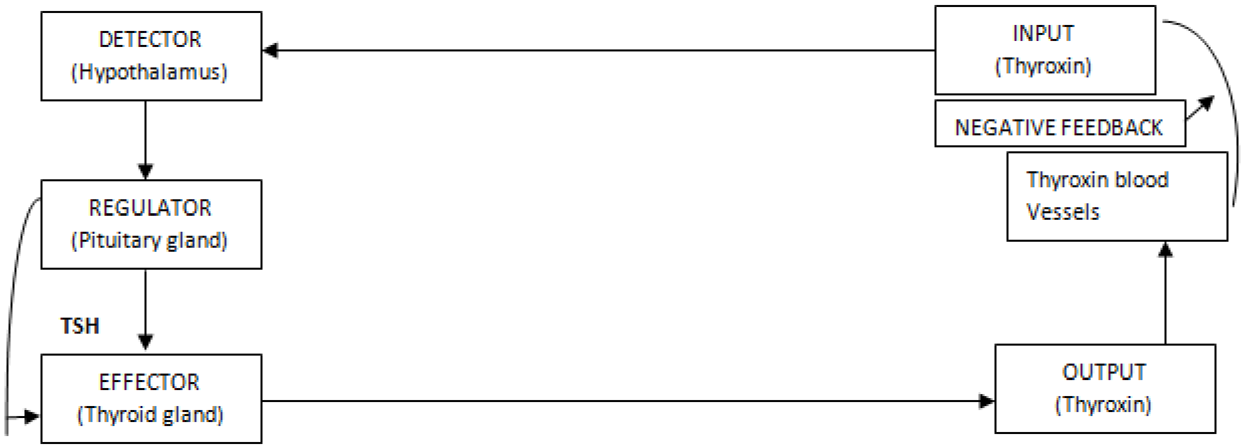
Whenever there is an increase in normal state the response causes to decrease or whenever there is a decrease in normal state the response causes an increase.

**HOMEOSTATIC CONTROL SYSTEM**

The directions of the lines of the diagram indicate the directions of stimulus and response.

Examples of biological negative feedback mechanisms include the control of gas tensions in the blood, heart, rate, arterial blood pressure, hormone and metabolite levels, water and ionic balances, the regulation of pH and body temperature.

The below figure illustrates the rate of negative feedback in the control of thyroxin release by the thyroid gland.




**A BIOLOGICAL EXAMPLE OF A SIMPLE CONTROL SYSTEM, THE CONTROL OF THYROXINE PRODUCTION**

TRF, thyroid releasing factor; TSH Thyroid stimulating hormone.

**Positive feedback** is rare in biological systems since it leads to an unstable situation and extreme states. In these situations a disturbance leads to events which increase the disturbance even further. This acts as a disadvantage. For example, depolarization of the neuronal membrane produces an increase in its sodium permeability and sodium ions pass into the axon through the membrane and produce a further depolarization which leads to the production of an action potential. In this case, positive feedback acts as an amplifier of the response whose extent is limited by other mechanisms.

## THERMOREGULATION

It is a well known fact that irrespective of fluctuations in the environmental temperature, the body temperature of humans is approximately $36.9^0$C. Many of the body's structures and physiological processes contribute towards the maintenance of this constant temperature.

- Death occurs if our temperature raises much above $42^0$C.
- A constant body temperature of about $36.9^0$C is necessary because it is the optimum temperature for the action of enzymes, upon which the organized functioning of the cells depends. Enzymes are proteins. If the temperature raises much above $40^0$C the proteins are denatured and enzyme activity ceases.
- Thermoregulation is the maintenance of constant internal temperature in the body of an organism.

- Mammals and aves are endotherms, i.e. generate heat from within the body and conserve it they maintain constant temperature independent of the environmental temperature by using physiological mechanism.

- Amphibians, reptiles and Pisces are ectotherms. I.e. their body temperature fluctuates with the environment temperature therefore rely on heat delivered from the environment than metabolic heat.

**Endortherms may loose heat through**

**Evaporative cooling through sweating -** this depends on various factors such as temperature, humidity and air currents but it can account for a substantial loss heat.

**Conduction** - Transfer of heat from the body to the nearest surrounding things which are in contact OR transfer of energy in form of heat in solids by vibration of its particles.

**Convection-**is the movement of air resulting from local currents of warm air being adjacent to each other replaced by cooler air and vice versa. These air movements speed up loss of heat by radiation and evaporation.

Or

**Convection**- is the transfer of energy in fluids in form of heat due to density difference of the molecules where they are moving and carrying the heat energy.

**Radiation** – Movement of energy in form of electromagnetic waves from a warm body to relatively colder objects. Via the air/vacuum can be a major source of heat loss.

Heat may be gained in two main ways

- Metabolism

  Release of heat as a result of chemical reactions within the cell.

- Absorption of solar energy (external environment)

**NOTE:**

When reference is made to body temperature in animal studies, it usually refers to the core temperature. This is the temperature of tissues below a level of 2.5cm beneath the surface of the skin. Temperature near the surface of the body can vary tremendously depending upon position and external temperature.

## MAINTENANCE OF A CONSTANT BODY TEMPERATURE IN WARM ENVIRONMENTS

Endothermic organisms which live permanently in warm climates have developed a range of adaptations to help them maintain a constant body temperature. These adaptations may be anatomical, physiological or behavioral and include the following.

### 1. <u>Vasodilation</u>

- Blood in the network of capillaries in the skin may take three alternative routes. It can pass through capillaries close to the skin surface, through others deeper in the dermis or it may pass beneath the layer of subcutaneous fat.

- Many of the capillaries form loops and have shunts which enable the body to vary the amount of blood flowing through them.

- The hypothalamus detects the change in blood temperature (thermoregulatory centre) and send nerve impulses to the vasomotor centre in the medulla oblongata of the hind brain

- The vasomotor control of superficial arterioles causes them to dilate encouraging blood flow through the capillary beds. The shunt veins and connecting veins are constricted. Therefore more blood flows closer to the skin surface and heat from this blood is lost through the epidermis by conduction, convection and radiation.

**2. Evaporative cooling through sweating**

- Sweat consists mainly of: water, mineral salts and urea

It is less concentrated than blood plasma and is secreted from tissue fluid by activity of the sweat glands i.e. the sweat gland cells absorb fluid (water, dissolved mineral salts and urea) from the surrounding capillaries and secrete it into sweat ducts which lead to the surface of the skin

- When sweat evaporates from the skin, energy (heat) is lost from the body as latent heat of evaporation and this reduces body temperature.

- Being furless humans have sweat glands over the whole body, making them efficient at cooling by this means, animals with fur generally have sweat glands confined to areas of the skin where fur is absent e.g. pads of the feet of dogs and cats and ears of rats (sweating beneath a covering of thick fur is in efficient as the fur prevents air movements which would otherwise evaporate the sweat)

**NB**: the evaporation of each gram of water requires 2.5 KJ of energy.

**3. Flattening of hair/fur**

- At high environmental temperatures, the hair erector muscles are relaxed and the elasticity of the skin causes the fur/hair to lie closer to its surface. The thickness of insulatory warm air trapped is thus reduced and therefore the body looses heat by conduction and radiation.

**4. Panting and licking**

- Where animals have few or no sweat glands cooling by evaporation of water nonetheless takes place from the mouth and nose.
- Painting in dogs may result in the breathing rate increasing from 30 to 300 breaths per min. This result in excessive removal of $CO_2$ from the blood which is partly offset by a reduction in the depth of breathing. Even so, dogs are able to tolerate depletion of $CO_2$ which would prove fatal to other organisms.

  **Panting** is also common in birds

  - **Licking** while not as effective as sweating may help cool the body. It has been reported in Kangaroos, cats and rabbits. Licking cools the body as heat from the body is required to evaporate the wet fur.

**5. Increase in metabolic rate**

The metabolic rate decreases in order to decrease heat production. The metabolic rate is controlled by the hormone thyroxine by negative feedback mechanisms involving the hypothalamus and anterior pituitary.

ã€€

**MAINTENANCE OF A CONSTANT BODY TEMPERATURE IN COLD ENVIRONMEN**

**1. Vasoconstriction**

The hypothalamus detects the change in blood temperature and sends nerve impulses to the vasomotor centre in the medulla oblongata of the hind brain – bulb of Krause.

The vasomotor control of superficial arterioles causes them to constrict so reducing the quantity of blood reaching the skin surface.

The shunt vein and connecting vein are dilated and therefore less blood flows close to the skin surface and hence less heat is lost through the epidermis by conduction, convection and radiation.

**2. Shivering**

When the body's temperatures fall below the core, the skeletal muscles of the body may undergo rhythmic; involuntary contracting which produce metabolic heat. This shivering may be proceeded by asynchronous twitching of groups of muscles.

**3. Erection of hair (increase in thickness of the air layer)**

At low environmental temperatures the hair erector muscles contract and the elasticity the skin causes a pull in the hair.

The hair becomes erect; goose bumps/pimples develop due to skin being pushed up by hair and so increase the thickness of the layer of air trapped. Therefore less heat is lost from the body.

**4. Increased Metabolic Rate**

The liver may increase its metabolic rate during cold conditions. Low temperature induces increased activity of the adrenal, thyroid and pituitary glands. All these produce hormones which help to increase the body's metabolic rate and so produce additional heat.

(Adrenal produce cortisol and adrenaline, thyroid produce thyroxine and pituitary produce somatotrophin).

This requires increased consumption of food; arctic animals consume more food per gram of body weight than their tropical relatives. Rats kept at $3^0$C take in 50% more food than those at $20^0$C.

## EXCRETION

Excretion is a process whereby waste products from the metabolic activities of the body are eliminated from the body.

**OR**

Excretion is the removal from the body of the waste products of metabolism.

Excretory products in animals:

- Carbon dioxide

**Source ;**( from carbohydrate metabolism and is produced during respiration in the Krebs cycle) when and alpha – ketoglutarate changes to succinate. $CO_2$ is formed in the body tissues. It diffuses out of the body through gaseous exchange surface e.g. Lungs in man, gills in fish and trachea in arthropods.

The concentration gradient will make the $CO_2$ move out of the body through the lungs, alveoli, alveoli duct, trachea and the nose.

- Excess water and mineral salts.

**Source;** from carbohydrate metabolism and mineral metabolism removed from the body trough special organs e.g.: as sweat from sweating glands, kidneys in man.

- **Bile pigment**.

**Source;** from the breakdown of haemoglobin in the liver spleen or bone marrow. Excreted by the liver in bile and eliminated with faces.

- **Nitrogenous waste**.

Source: from the breakdown of amino acids.

**Forms of nitrogenous wastes**.

Ammonia (gas)
**Source:** from the breakdown of amino acids

- Its nature is highly toxic and highly soluble in water. Thus must be removed from the body quickly i.e. must not be allowed to accumulate in the tissue
- It diffuses quickly from the body where there is plenty of water.
- Oesteichythes, marine invertebrates and all fresh water animal can afford to excrete it unchanged
- The animals excreting ammonia are referred to as ammoniotelic.

- Urea
  - Made from the molecule of $CO_2$ and 2 molecules of $NH_3$.It's soluble and relatively non toxic and harmless(less harmful) in moderate concentrations. Thus animals can retain it for some time in their bodies before being excreted.
  - Mammals can afford to lose some amount of water because they can replace it's by drinking, thus every time urea is excreted some water is lost since urea is highly soluble in water thus mammals always drink water.
  - Formed in the liver through cyclical reactions referred to as ornithine cycle. Marine and cartilegenous fish and animals excrete urea and TMO and are known as ureoteric.

Role of river in protein metabolism

- Formation of urea
- Transamination
- Production of plasma protein.

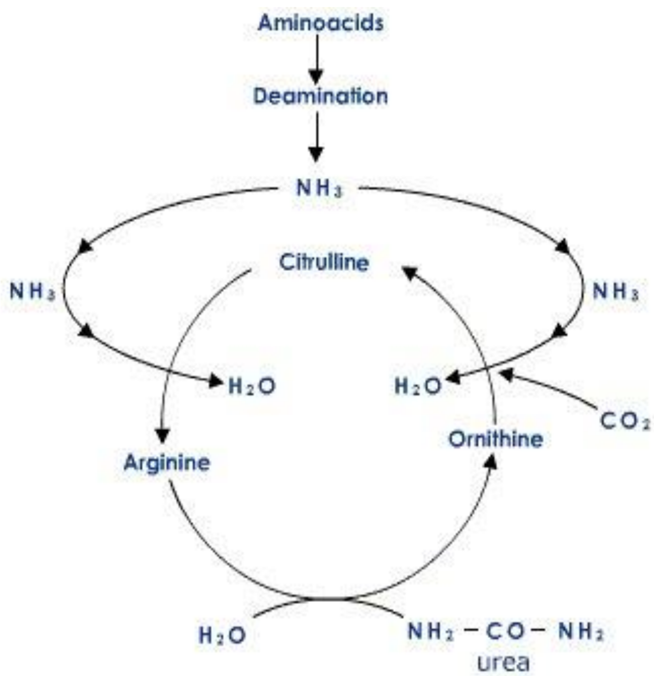
## Formation of urea.

- Excess amino acids cannot be stored
- In the liver they undergo a process called deamination which involves splitting amino acids to amine and ketogroups. Amines are converted to ammonia ($NH_3$) and ketogroups are converted to carbohydrates.
- Mammals are ureotelic hence $NH_3$ is converted to urea in series of reaction which constitute ornithine cycle whose steps are as follows:

Steps;

- The molecule of $NH_3$ from deamination and $CO_2$ enter the cycle and react with ornithine to form $H_2O$ and citruline.
- Another molecule of $NH_3$ is fed into the cycle to read with citruline forming water and arginine.
- Reaction of arginine with water forms ornithine and urea and it is catalyzed by arginase enzyme.

**THE ORNITHINE CYCLE**




**Transamination** is the process whereby amino acids are synthesized by transferring an amine group from amino acids to another organic acid.eg; glutamic acid is synthesized from alanine.

The process occurs in the liver.

## ii. Uric acid.

- It is non toxic and relatively insoluble.
- For this reason it can be stored in the body for longer periods before excreting it.
- It is excreted as pallets or thick paste hence little water is lost e.g.; arthropods (insects) and aves and reptiles.
- Suitable for excretions.
- Animals which excrete uric acid are called uricotelic.

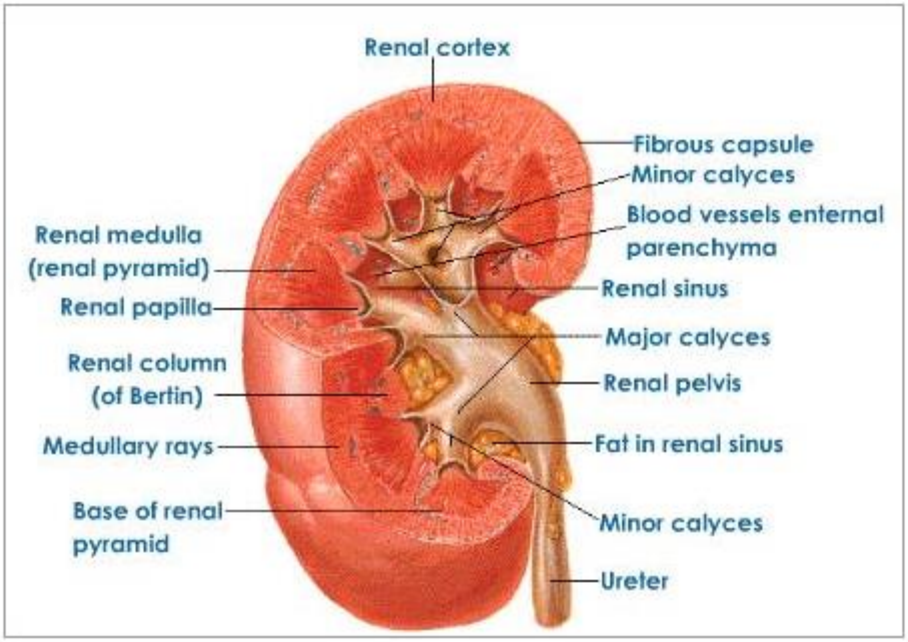
Fate of amino acid

They are deaminated to urea, uric acid or ammonia if not they are transaminated.

KIDNEY:

- Found towards the back of the lower part of the abdominal cavity.
- Held in position by a thin layer of tissue called the peritoneum and are usually surrounded by fat.
- Each kidney is supplied with blood from the renal artery and drained by a renal vein. The urine which is produced by the kidney is removed by a ureter for temporary storage in the urinary bladder
- Within each kidney there are a number of clearly defined regions
- The outer region is cortex. It mainly comprises of collagen fibre, fibrous connective tissues, glomeruli, bowman’s capsules and convoluted tubules with their associated blood supply.
- Medulla contains blood vessels, loop of henle and collecting duct. These structures are in group known as renal pyramids.
- Pelvis is almost empty with only colleting ducts empting there.
- The whole kidney is nephron. Each kidney has 1 million nephrons; each of 3cm. Total length of tubules is 120 km.

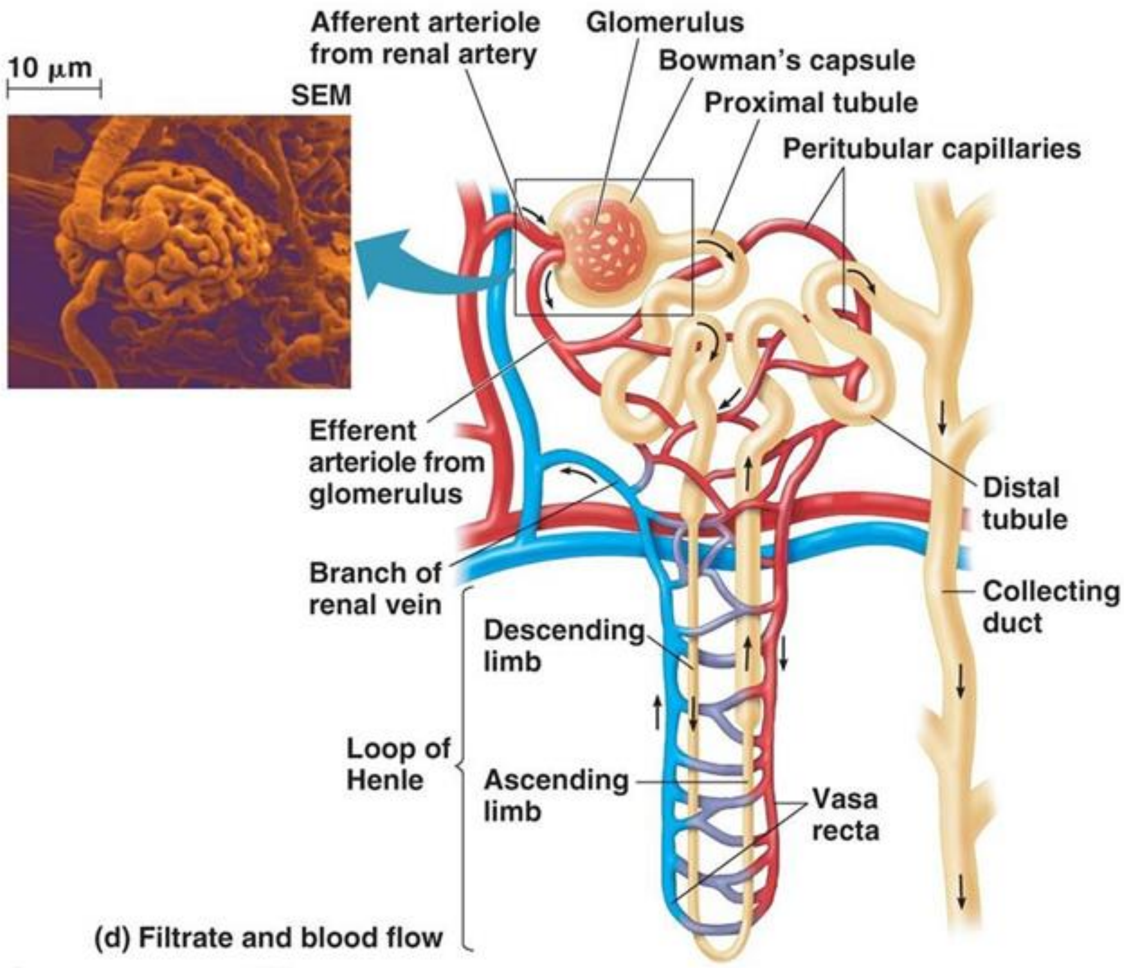
## MAMMALIAN KIDNEY (T.S)




### General functions of the kidney

- Removal of metabolic waste especially urea.
- **Osmoregulation** ( maintenance of constant osmotic conditions in the body osmotic involves regulation of water content and solute concentration of body fluids i.e. $Na^+$, $K^+$,$Cl^-$
- Maintains the acid- base balance of the body effected by either excreting or retaining $H^+$/ $HCO_3$, thus varying the pH of the urine between 4.5 – 8 (regulates pH)
- Maintains the ionic concentration in the body i.e. $Na^+$, $K^+$, $Cl^-$ , $Mg^{2+}$, $HCO_3$,.
- Regulate blood pressure

## DIAGRAM SHOWING THE STRUCTURE OF A NEPHRON.




Mammalian nephron (human beings)

**Nephron** is the structural and functional unit of the kidney i.e. it is an independent urine making machine.

**Two types of nephron**

- **Cortical nephron**- found in cortex and have short loop of henle.
- **Juxta medullary nephron** – renal corpuscle in junction of cortex and medulla long descending and ascending loop of Henle

## Structure of the nephron

Have 6 main regions;

- Renal corpuscle (bowman's capsule & glomerulus)
- Proximal convoluted tubule
- Descending limb of loop of Henle
- Ascending limb of loop of Henle
- Distal convoluted tubule
- Collecting tubule(ducts)

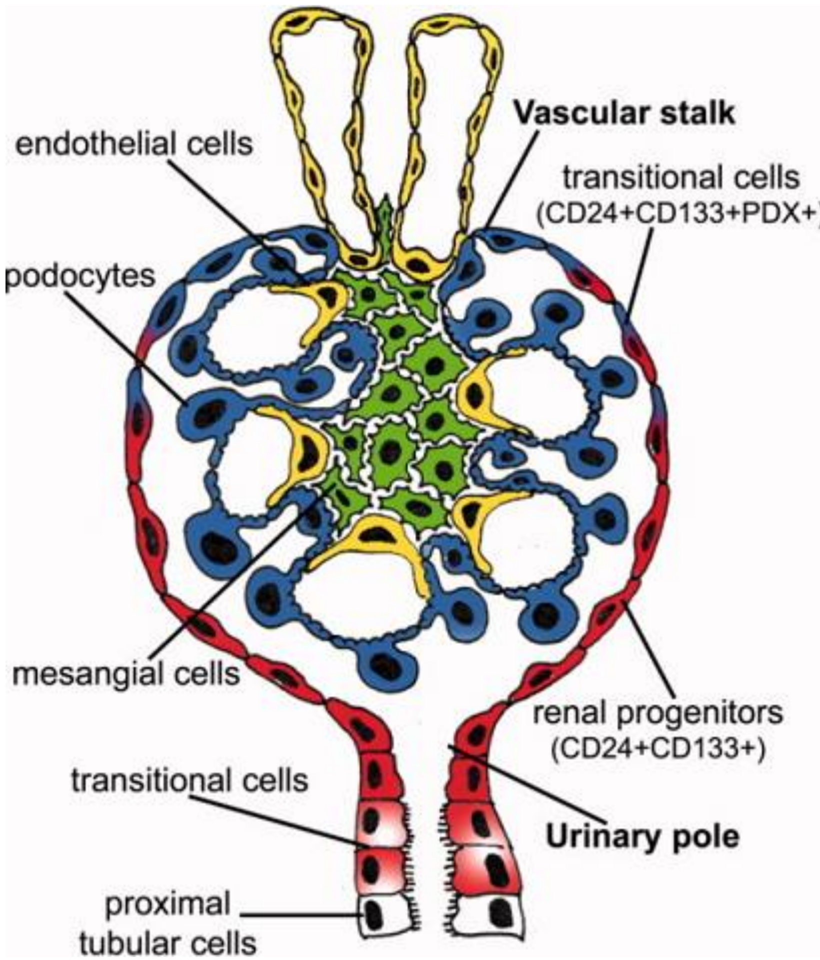
Renal corpuscle (malphigian body)

- **Ultra filtration** is a passive process, of filtration under pressure involving the passage of materials from the blood to the Bowman's capsule.

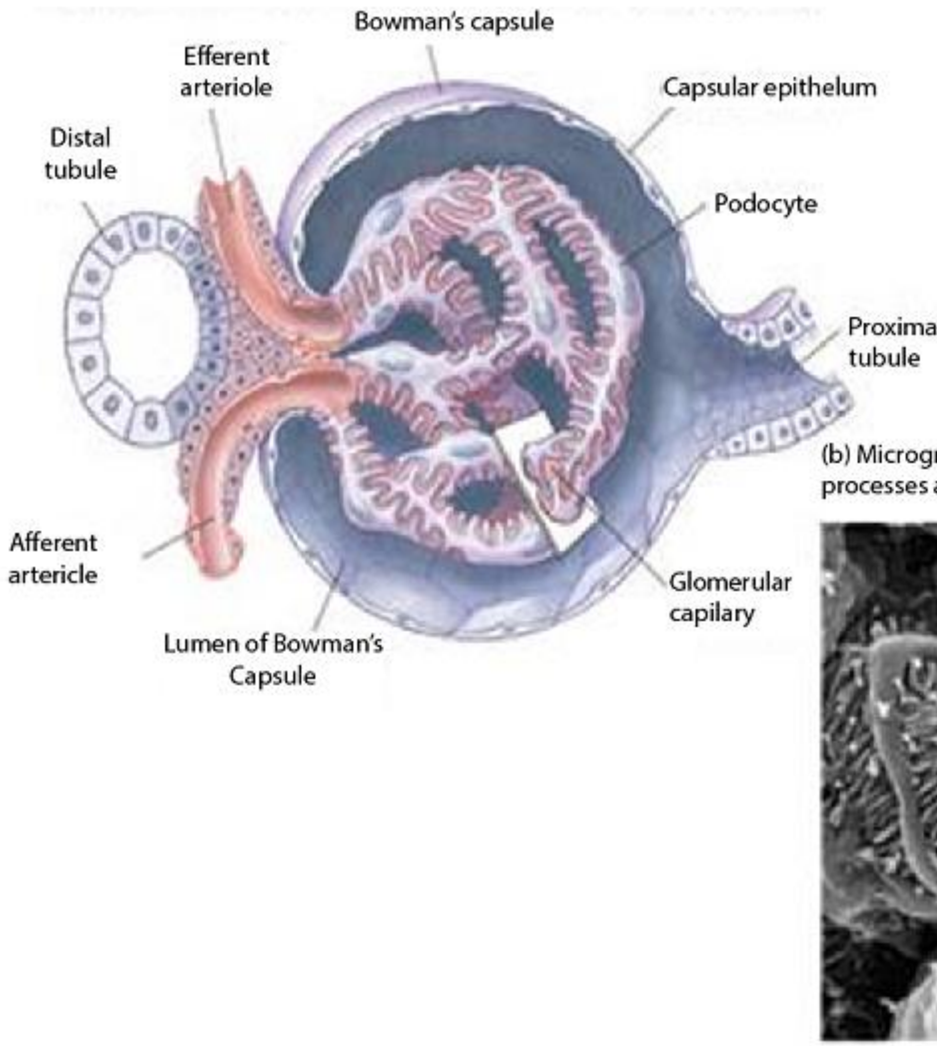
## Adaptations of renal corpuscle to Ultra filtration.

- The afferent arteriole is thick which later on breaks down to small blood capillaries.
- The endothelial cells contain pores so that materials can leak
- The inner layer of the Bowman's capsule is made up of special cells called podocyte cells which have many infoldings to allow materials to enter the Bowman's capsule.
- The capillaries have a single layer of endothelial cells which are perforated to allow easy diffusion.
- The arterioles break into capillaries which are one cell thick.
- They are special podocyte cells to increase surface area for filtration and have got filtration slits.
- The endothelial cells press against basement membrane to allow rapid diffusion.
- Afferent arteriole has larger diameter than the efferent arteriole, this sets up high pressure in the glomerulus and the whole kidney.
- On the outside of the capsule they have got squamous epithelium for easy passage of glomeruli filtrate into the tubule.

Cuboid epithelium line the proximal and distal convoluted tubule and collecting ducts.


Vascular stalk
endothelial cells
transitional cells
(CD24+CD133+PDX+)
podocytes
mesangial cells
renal progenitors
(CD24+CD133+)
transitional cells
Urinary pole
proximal
tubular cells

(a) The epithelium around glomerular capillaries is modified into podocytes.

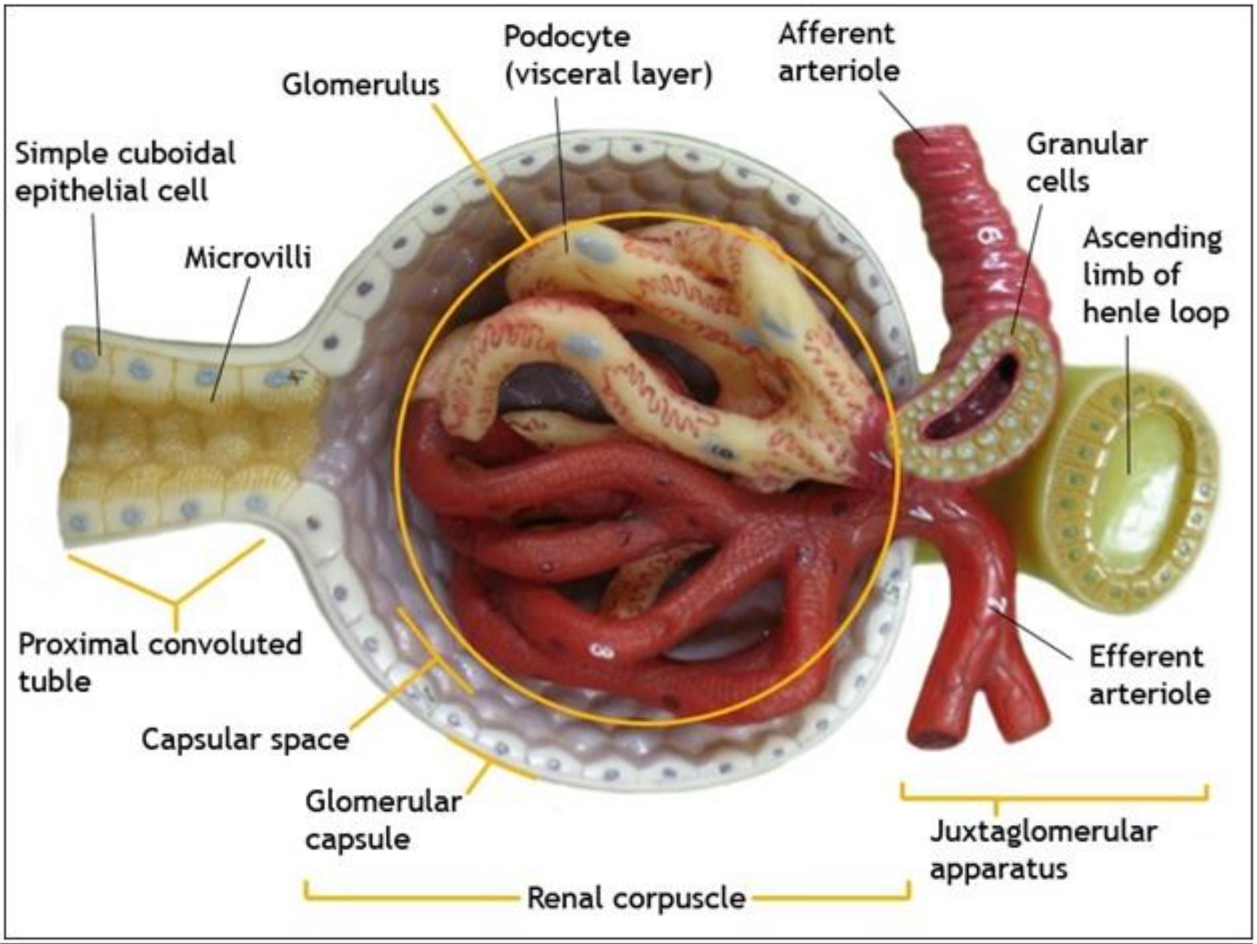



## The ultra filtration process.

- Blood enters the kidney by the renal artery.
- Renal artery branches further to form the afferent arteriole which then branches to a mass of capillaries, the glomerulus.
- The glomerular capillaries then join to form the efferent arteriole which has a small diameter.
- This sets up high pressure in the glomerulus which in turn forces substances such as glucose, amino acids, vitamins, some hormones, urea, trace of uric acid, ions, water through endothelial pores of capillaries across basement membrane into bowman's capsule by ultra filtration.

- Blood cells, RBCs, proteins molecules, WBCs, platelets are too large to pass through however large molecule can pass through due to hormonal and nervous signals which cause further constriction of the efferent arteriole.

**RENAL CORPUSCLE.**




Proximal convoluted tubule:

**Function**; Selective reabsorption of materials. The process is both active and passive.

**Adaptations of the proximal convoluted tubule.**

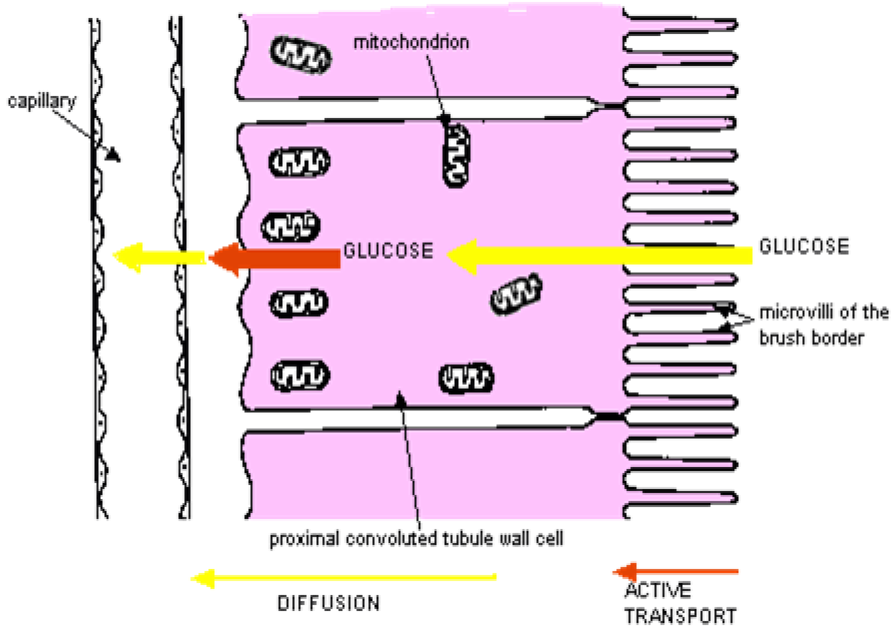
- Longest region of nephron to allow materials to be reabsorbed.
- Single layer of cells (one cells Thick on either side) to allow rapid diffusion.

- The cells are cuboids and have lumen with brush border (microvillus) hence increases surface area to volume ratio for rapid re-absorption of materials.
- The other ends of cells adjacent to blood capillaries have their bases convoluted (infoldings) with many intercellular spaces (channels) to reabsorb substances.
- Cells have many mitochondria which provide energy (ATP) for active re-absorption process (active transport of glomerular) selective inward re-absorption of materials from glomerular filtrate.
- The basement membrane of epithelium is likely to allow materials to pass through.
- Immediately after basement membrane there is blood capillary reducing the diffusion distance.
- The other end of proximal cells resting on basement membrane has infoldings known as basal channels to increase surface area.
- Many blood vessels to maintain the concentration (diffusion) gradient

## Mechanism of the re-absorption process

- As many glomerular filtrate is passing through proximal convoluted tubule (PCT) all the food substances as mentioned are reabsorbed i.e. amino acids, glucose, ions, diffuse into the proximal convoluted cells where they are then actively transported into the intercellular spaces (the channels) then diffuse into the surrounding blood vessels.
- $Na^+$ ions & others raise osmotic pressure in the cells and water enters by osmosis.
- Small proteins which may not be able to diffuse are taken up at the base of microvilli by phagocytosis.
- All glucose, amino acids, vitamins and hormones are reabsorbed
- 80%,of $H_2O$, $Na^+$, $Cl^-$, are reabsorbed
- 40 – 50% urea is reabsorbed.
- The active transport is out into the space in basal channel then it is diffused into the blood capillaries.

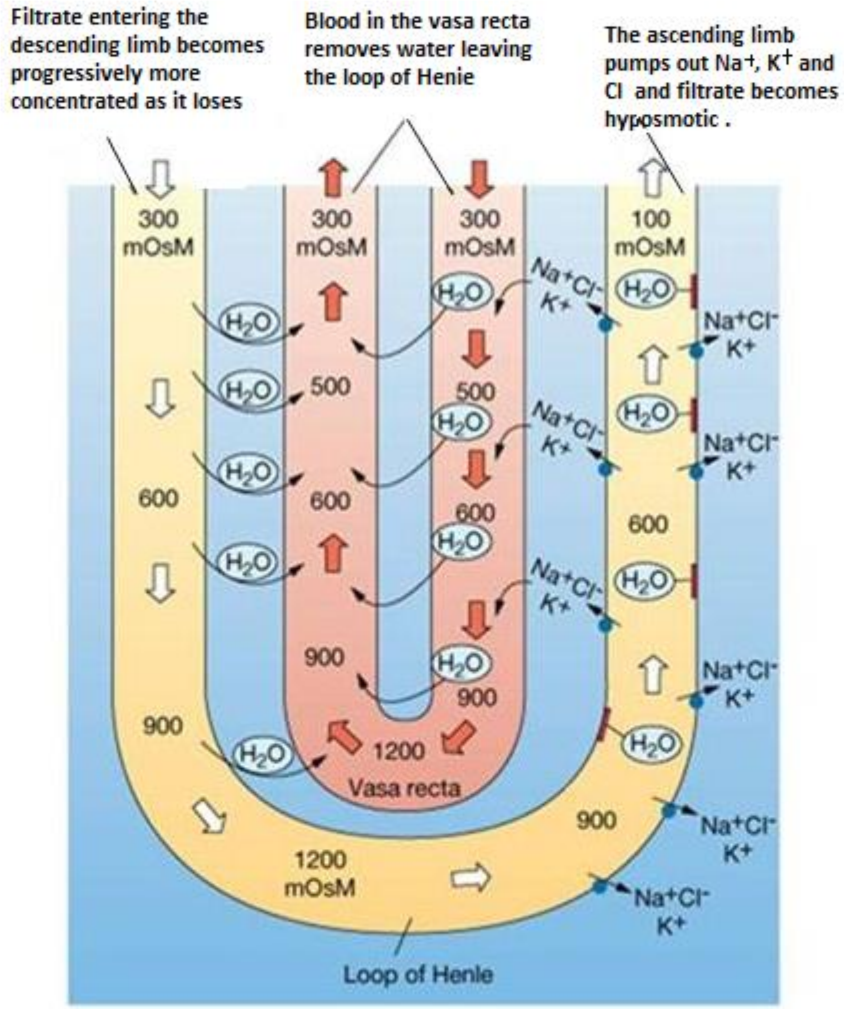
**Structure and function of the proximal convoluted tubule.**

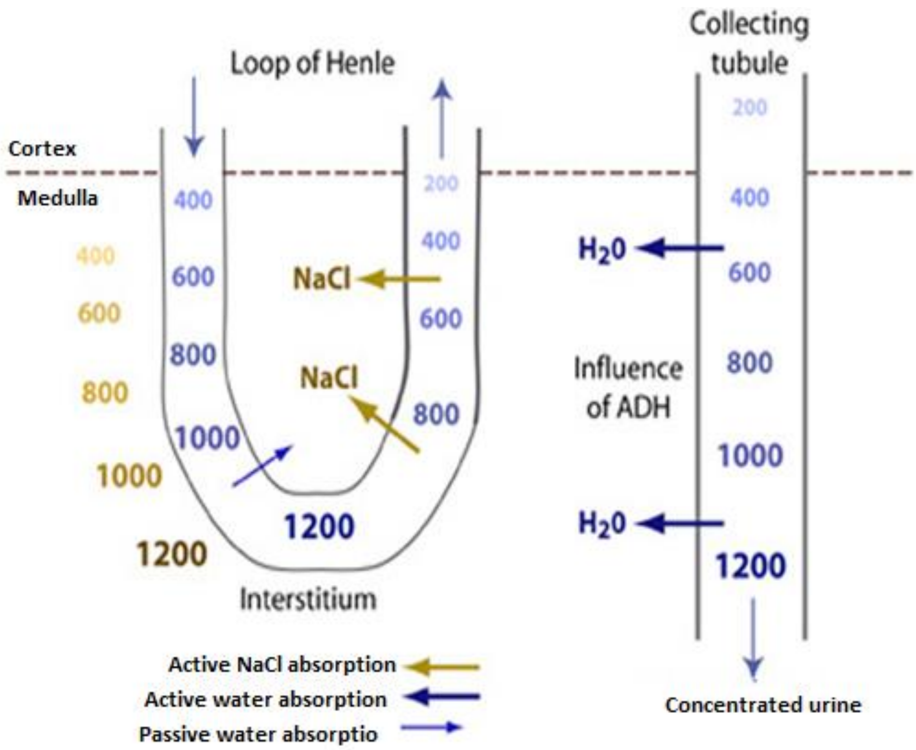



**The loop of henle** (Counter current multiplier i.e. fluids move in difference directions and effects is accumulative)

- Consists of the longer thinner (descending limb) and shorter wider (ascending limb)
- The limbs are slightly apart
- A blood vessel, the vasa recta runs parallel through them.
- The descending limb is permeable to water (the ascending limb is impermeable to water)
- The Na pump operates in the ascending limb i.e. Na and Cl ions are actively removed from the glomerular filtrate in the ascending limb into the interstitial region of the medulla thus raising the local concentration and the concentration of the vasa recta vessels,
- Water moves by osmosis from the descending limb into the vasa recta vessels which are permeable to water, ions and urea.
- As vasa recta capillaries enter a high concentration in medulla they lose water from the plasma by osmosis and gain Na ions, Cl ions and urea, But as the vasa recta capillaries leaves the medulla to enter cortex which is under low concentration, they gain water by osmosis from the cortex and lose Na, Cl ions and urea from the plasma. Thus operate under – counter – current mechanism.

Below the diagram shows the movement of ions and $H_2O$ from the loop of henle into the medulla of the kidney.





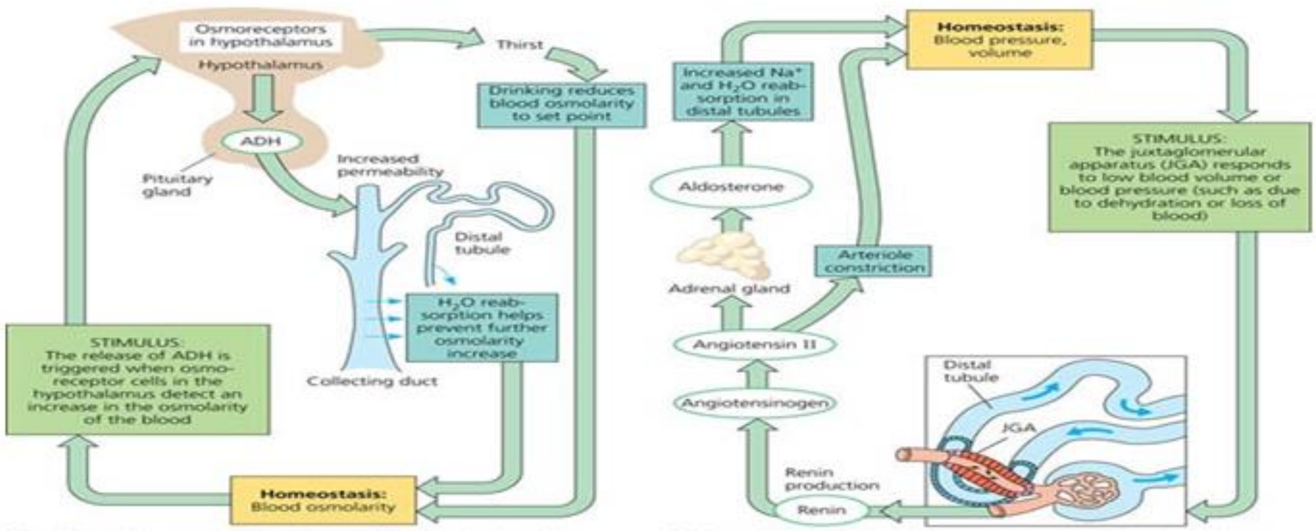

## Distal convoluted tubule (DCT)

- Absorption in the distal convoluted tubule is active
- The cells have brush border and numerous mitochondria. The permeability of their membranes affected by hormones and so precise control of the salt and water balance of the blood is possible.
- Re-absorption of $H_2O$, ions depends on the body needs thus it is controlled by ADH/ vasopressin.
- High osmotic potential (less $H_2O$ in the blood) is detected by osmoreceptors by hypothalamus which sends nerve impulses in the posterior pituitary gland and make it produce ADH.
- In the presence of ADH (which moves through blood) the epithelium of the distal convoluted tubule become permeable to $H_2O$ hence more re-absorption by blood vessels.
- This result in production of small amounts of concentrated urine summary: - less $H_2O$, ADH released, epithelium permeable and urine.
- Low osmotic potential (more water in blood) is detected by hypothalamus which stops the sending of nerve impulse to the posterior pituitary gland and thus ADH release is inhibited.
- The epithelium of the distal convoluted tubule become impermeable to $H_2O$ hence less $H_2O$ (water is not) reabsorbed by the blood vessels (filtrate is dilute)
- This result in production of large volume of diluted urine

Summary: - more than $H_2O$, ADH inhibited, epithelium impermeable and urine is dilute.

**NOTE**: - failure to release sufficient ADH leads to a condition known as diabetes insipidus in which large quantities of dilute urine are produced (diuresis) and is replaced by lots of drinking.

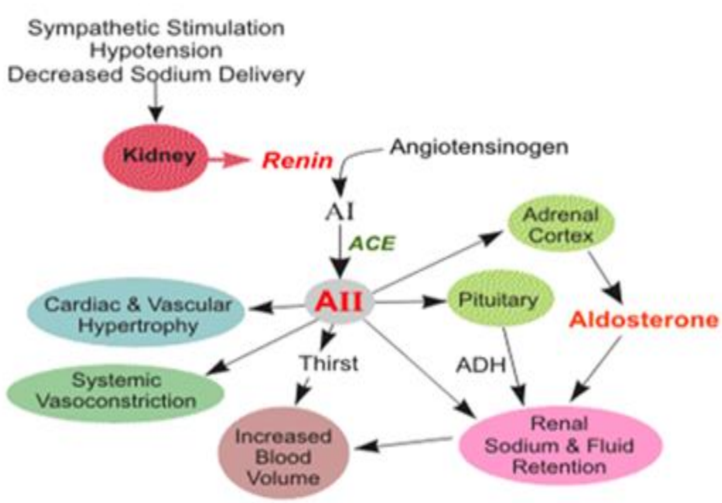
## Summary of the control of blood solute potential




(a) Antidiuretic hormone (ADH) enhances fluid retention by making the kidneys reclaim more water.

(b) The renin-angiotensin-aldosterone system (RAAS) leads to an increase in blood volume and pressure.

The role of kidney in osmoregulation (feedback mechanism)




CONTROL OF $Na^+$, IONS IN THE BLOOD/PLASMA

Low blood volume results from loss of $Na^+$ ions because less water enters the blood by osmosis and this leads to decrease in blood pressure.

The low blood pressure is detected by juxtraglomerular apparatus (JGA (mass secretory cells)) lying between the afferent arteriole and the distal convoluted tubule.

Aldosterone also stimulates $Na^+$ absorption in the gut decreases loss $Na^+$ through the sweat.

**Effect**: more water enters the blood by osmosis the blood volume and blood pressure rises.

Regulation:

Maintenance of the solute potential of blood (water and salts) at steady state by balancing water up take from the water lost in evaporation, sweating, egesting urine.

**Regulation in fresh water fish**.

In relation to their environment, they are faced with two major conditions.

Are hypertonic to the environment. There is continuous flooding water into their bodies due to the osmosis gradient.

Aching of salt out of their bodies through the highly permeable gills to the surroundings.

Adaptations

- They have large and many glomeruli thus producing large volume of glomerular filtrate.

Salts are selectively reabsorbed into the capillaries surrounding the tubule and hence produce large volume of dilute (cupious) urine

- Their gills have got specialized NaCl cells which actively uptake salts from the water passing through them.
- Some salts are replaced by absorption of food they take.
- They do not drinking water.

Osmoregulation in marine cartilagenous fish.

- The body fluids of marine are hypotonic to the environment. There is excessive loss of water to the environment thus leading to dehydration.
- High osmotic pressure of the blood (because of loosing $H_2O$ & retaining the salts)

Adaptations

- They synthesize and retain urea within their tissue and body fluids together with TMO (trimethly amine oxide).

The above makes their bodies concentration higher than their environment so take in water by osmosis through their gills.

- The kidney has long tubules for selective reabsorption of urea and not for the elimination of salts.

Not salts because if salts are absorbed then water will follow by osmosis making blood dilute and loss of $H_2O$ to the surrounding as the surrounding is more concentrated than the blood.

- Excess NaCl ions are removed from the body fluids by active secretion into the rectum by the cells of the rectal gland and through the faces they are out.
- The gills are impermeable to nitrogenous waste and thus their removal is controlled by the kidneys.

If the gills were permeable to urea then the concentration of the urea in blood would be low and thus blood would lose water to surrounding as we know that urea has to be retained in the body.