Applied Biology 1 - Biological sciences

Food, Dietetics and Nutrition (Kenyatta University)

1. INTRODUCTION TO BIOLOGY

What is Biology?

Biology is the branch of science that deals with the study of living things/organisms.

In Greek, Bios means life while Logos means knowledge.

Branches of biology

There are two main branches:

1. **Botany:** Study of plants
2. **Zoology:** Study of animals

The others include:

1. **Ecology:** Study of living things in their surroundings.
2. **Genetics:** The study of inheritance and variation.
3. **Entomology**: Study of insects
4. **Parasitology:** Study of parasites
5. **Taxonomy:** Study of classification of organisms
6. **Microbiology:** Study of microscopic organisms
7. **Anatomy: S**tudy of structure of cells/ study of internal structure of organisms
8. **Cytology:** Study of cells
9. **Biochemistry:** Study of chemical changes inside living organisms
10. **Morphology** - study of external structure of organisms.
11. **Anatomy** - study of internal structure of organisms.
12. **Physiology** - study of the functioning or working of the cells or body.
13. **Biochemistry** - study of the chemistry of materials in living organisms.
14. **Ecology-** study of the relationship between organisms and their environment.
15. **Taxonomy** - sorting out of organisms into groups.
16. **Histology** - study of fine structure of tissues.
17. **Virology** - study of viruses.
18. **Bacteriology** - study of bacteria.
19. **Ichthyology** - study of fish

Importance of Biology

- One learns about the functioning of the human body.
- One understands the developmental changes that take place in the body.
- It contributes immensely to improved life.
- It enables one to enter careers such as: Medicine, Nutrition, Public Health, Dentistry, Agriculture, Environmental Studies and Teaching

- Solving environmental problems e.g. Food shortage, poor health services, pollution, misuse of environmental resources etc.

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- Acquiring scientific skills e.g. observing, identifying, recording, classification, measuring, analyzing, evaluating etc.
- International co-operation e.g. Development of HIV\AIDS vaccine, fight against Covid 19, fight to save ozone layer from depletion, management of resources through international coordination.

Characteristics of Living Things

Life defined through observations of activities carried out by living things;

- **Nutrition –**
  - Nutrition is the processes by which food/nutrients are acquired/made and utilized by living organisms.
  - Green plants and certain bacteria make their own food.
  - All other organisms feed on complex organic materials.
- **Respiration –**
  - This is the breakdown of food to provide energy.
  - The energy released is used for various activities in the organism.
- **Gaseous Exchange –**Process throw which respiratory gases(CO_2&O_2) are taken in and out through a respiratory surface.
- **Excretion –**
  - Excretion is the removal of metabolic wastes from the body.
  - Substances like urea, carbon dioxide (Carbon (IV) oxide).
  - These substances are poisonous if allowed to accumulate in the body.
- **Growth and Development –**
  - Growth means irreversible change in size.
  - All organisms increase in size that is, they grow.
  - Development is irreversible change in complexity.
  - As they do so, they also become differentiated in form.
- **Reproduction-**Reproduction is the formation of new individuals of a species to ensure continued existence of a species and growth of its population.
- **Irritability –**
  - The ability of organisms to detect and respond to changes in the environment. This is of great survival value to the organism.
- **Movement –**
  - Is the progressive change in position from one place to another

- Some organisms are sessile (i.e. fixed to the substratum).
- The majority of plants move only certain parts.

2. TAXONOMY

Classification

- Classification is putting organisms into groups.
- Classification is based on the study of external characteristics of organisms.
- It involves detailed observation of structure and functions of organisms.
- Organisms with similar characteristics are put in one group.
- Differences in structure are used to distinguish one group from another.
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Historical Background of Classification

- Long time ago classification was artificial where living things were classified as either plants or animals.
- Plants were classified as herbs, shrubs and trees.
- Animals were further divided into carnivores, herbivores and omnivores.
- Today modern classification uses evolutionary relationships between living organisms.

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What is classification?

-Is an area of biology that deals with the grouping of living organisms according to their structure

Classification is based on the study of external characteristics of organisms.

It involves detailed observation of structure and functions of organisms. Organisms with similar structures are put under one group referred to as **a taxon- taxa** (plural).

The groupings also consider evolutionary relationships (phylogeny)—since all living organisms had a common origin at one time.

Taxonomy—Science of classification

Taxonomist—Biologist who studies taxonomy

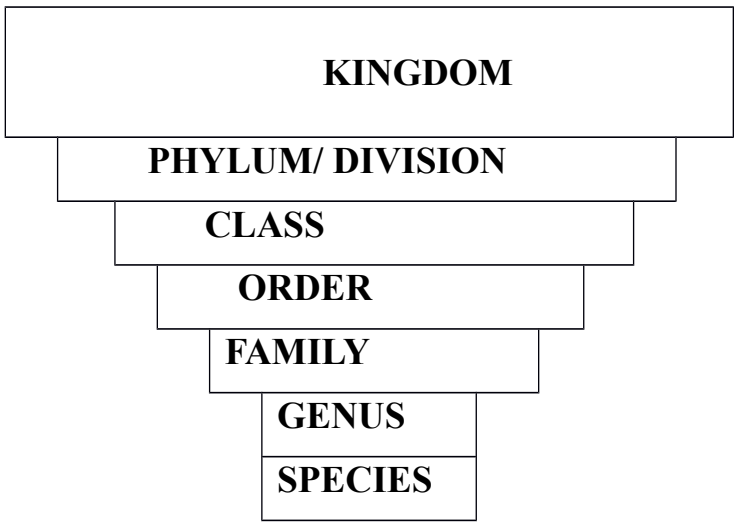
Need for classification.

1. To identify living organisms into their correct groups for reference and study
2. To bring together living organisms with similar characteristics but separate those with different features.

3. To arrange information of living organisms in an orderly manner. This avoids chaos and confusion.
4. To understand the evolutionary relationship between different organisms

Taxonomic Units

Are groups (taxa) into which organisms are placed as a matter of convenience.
Groups are based on observable characteristics common in the group.
In a classification scheme (taxonomic units or groups, a hierarchy of groups are recognized starting with the first largest and highest group; the **Kingdom** to the smallest and lowest unit; the **species**.
There are 7 major taxonomic units.



The Kingdom

There are five Kingdoms of living organisms, namely:

1. **Kingdom Monera**: bacteria
2. **Kingdom protoctista**: algae, protozoa, amoeba, paramecium
3. **Kingdom Fungi**: Moulds, Yeast, Mushrooms
4. **Kingdom Plantae**: Moss plants, ferns, maize, garden pea, pine, meru oak, bean etc.
5. **Kingdom Animalia**: hydra, tapeworms, bees, human beings etc.

A kingdom is divided into **Phyla** in animals or divisions in plants and sorts out organisms based on body plan and form.
Plan is the adaptation to a special way of life.
The **Class** is further divided into small groups; **Orders** using structural features.

Orders are divided **into families** using structural features, then Families into **Genera** (singular genus) –based on recent common ancestral features that are less adaptive.
Genus is divided into **species** i.e. kind of plant, or animal.
Down the hierarchy, the number of organisms in each group decreases but their similarities increases.
The Species group members naturally interbreed to produce fertile off springs.
Minor differences are exhibited in the species groups e.g. on colour of the skin in human beings and varieties of plants.
The groups of the species are termed to as varieties, races or strains.

Classification of A human being and a maize plant

Taxonomic unit	**Human being**	**maize**	**Bean**
Kingdom	**Animalia**	**plantae**	**plantae**
Phylum or division	Chordata	**Angiospermaphyta**	**Angiospermae**
Class	**Mammalia**	**monocotyledonae**	**Dicotyledonae**
Order	Primates	**Graminales**	**Rosales**
Family	**Hominidae**	**Graminaceae**	**Leguminosae**
Genus	**Homo**	**Zea**	**Phaseolus**
Species	**Sapiens**	**mays**	**Vulgaris**
Scientific name	*Homo sapiens*	*Zea mays*	*phaseolus vulgaris*

Scientific Naming of living Organisms

Present naming was developed by carolus Linnaeus 18th c, where organisms were given 2 names in Latin language.
Living organisms have their scientific names and common names i.e. local or vernacular names.
Scientific naming uses the double naming system—**Binomial system**.
In binomial system, an organism is given both the **genus** and **species** name.
Binomial nomenclature (Double –naming system)-Is the assigning of scientific names to living organisms governed by a definite set of rules recognized internationally.

Principles of binomial nomenclature

a) The first, genus name, should begin with a capital letter and the second name, species, should begin or written in small letters e.g.
Lion---- *Panthera leo*

Leopard----- *Panthera pardus*
Domestic dog----- *Canis farmiliaris*
Human being--- *Homo sapiens*
Maize plant---*Zea mays*

Lion and Leopard are closely related ---Same genus but distantly related—different species.

b) The scientific names must be printed in italics in textbooks and where hand written to be underlined e.g. *Panthera leo.*
c) The specific name (species) is frequently written with the name of the scientist who first adequately described and named the organism e.g.*Phaseolus* vulgaris i.e. Vulgaris is the scientist who described and named the bean plant.
d) Biologists should give a Latinized name for a newly described animal or plant species where Latin name is missing e.g.
Meladogyne kikuyuensis – Is a scientific name of a nematode from kikuyu.
Aloe kilifiensis --- A member of Aloeceae family from Kilifi discovery.
Garinsoga parviflora waweruensis --- a member of Macdonald eye family discovered by Waweru.

Exercise

Complete the table below

Taxon	Lion	Domestic dog	Garden pea	Napier grass
Kingdom				
Phylum/division				
Class				
Order				
Family				
Genus				
Species				
Scientific Name				

Comparison between Plants and Animals

Plants	Animals
1. Green in color (have chlorophyll) hence make their own food through	1. Lack chlorophyll thus feed on readymade food.

photosynthesis.	
2. Their cells have cellulose cell walls.	2. Cells lack cellulose cell walls.
3. Respond slowly to changes in the environment.(stimuli)	3. Respond quickly to stimuli
4. Lack specialized excretory organs.	4. Have complex excretory organs.
5. Do not move about.	5. Move about in search of food and water.
6. Growth occurs in shoot and root tips.(apical growth)	6. Growth occurs in all body parts (intercalary growth).

3. THE CELL

Introduction

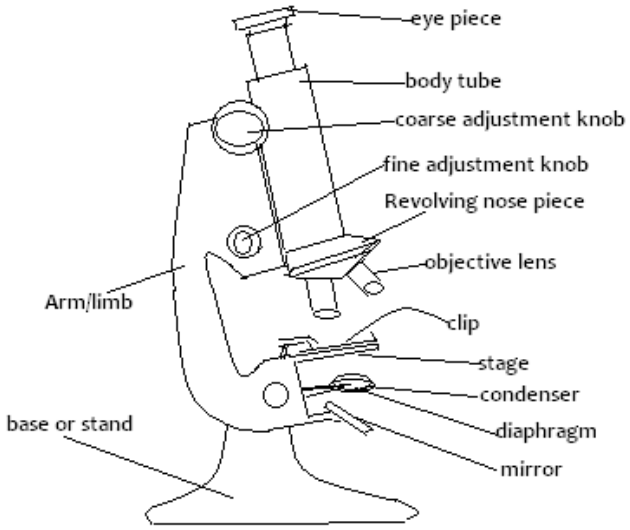
- The cell is the basic unit of an organism.
- All living organisms are made up of cells.
- Some organisms are made up of one cell and others are said to be multi cellular.
- Other organisms are made of many cells and are said to be multi cellular.
- Cells are too little to see with the naked eye.
- They can only be seen with the aid of a microscope.

The microscope

The microscope is used to magnify objects.

Magnification

- The magnifying power is usually inscribed on the lens.
- To find out how many times a specimen is magnified, the magnifying power of the objective lens is multiplied by that of the eye piece lens.
- If the eye piece magnification lens is x10 and the objective lens is x4, the total magnification is x40.
- Magnification has no units.
- It should always have the multiplication sign.e.g.x40



The light microscope

Microscope parts and their functions

Parts	*Function(s)*
Eye piece	Has a lens which contributes to the magnification of the object under view.
Coarse	Moves the body tube up and down for long distances and it into focus.
Fine adjustment knob	Moves the body tube and brings the image into fine focus.
Body tube	Holds the eye piece and the revolving nose piece. It Connects the objective lenses to the eye piece lens.
Revolving nose	Holds and brings objective lenses into position.
Objective lens	Contributes to the magnification of the object.
Arm/limb	It is for handling the microscope and also tilting it.
Stage	Is the flat platform onto which the slide with the object is placed.
Clips	They hold the slide firmly onto the stage.
Condenser	Concentrates light onto the object.
Diaphram	Regulates the amount of light passing through the object.

Mirror	Reflects light into the condenser.
Hinge screw	Fixes the arm to the base and allows for tilting of the arm.
Base/stand	Provides support to the microscope.

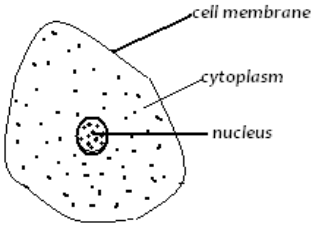
To View the Object

- Turn the low power objective lens until it clicks into position.
- Looking through the eye piece, ensure that enough light is passing through by adjusting the mirror.
- This is indicated by a bright circular area known as the field of view.
- Place the slide containing the specimen on stage and clip it into position.
- Make sure that the specimen is in the centre of the field of view.
- Using the coarse adjustment knob, bring the low power objective lens to the lowest point.
- Turn the knob gently until the specimen comes into focus.
- If finer details are required, use the fine adjustment knob.
- When using high power objective always move the fine adjustment knob upwards.

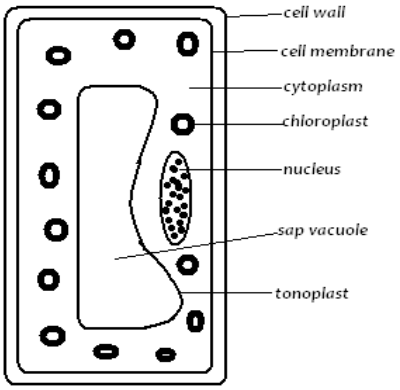
Care of a Microscope

- Great care should be taken when handling it.
- Keep it away from the edge of the bench when using it.
- Always hold it with both hands when moving it in the laboratory.
- Clean the lenses with special lens cleaning paper.
- Make sure that the low power objective clicks in position in line with eye piece lens before and after use.
- Store the microscope in a dust-proof place free of moisture.

Cell Structure as Seen Through the Light Microscope



A typical animal cell



Generalised plant cell

The cell as seen above has the following:
Cell membrane (Plasma membrane):

- This is a thin membrane enclosing cell contents.
- It controls the movement of substances into and out of the cell.

Cytoplasm:

- This is a jelly-like substance in which chemical processes are carried out.
- Scattered all over the cytoplasm are small structures called organelles.
- Like an animal cell, the plant cell has a cell membrane, cytoplasm and a nucleus.

vacuole.

- Plant cells have permanent, central **vacuole.** It contains cell sap where sugars and salts are stored.

Cell wall:

- This is the outermost boundary of a plant cell.
- It is made of cellulose.
- Between the cells is a middle lamella made of calcium pectate.

Chloroplasts;

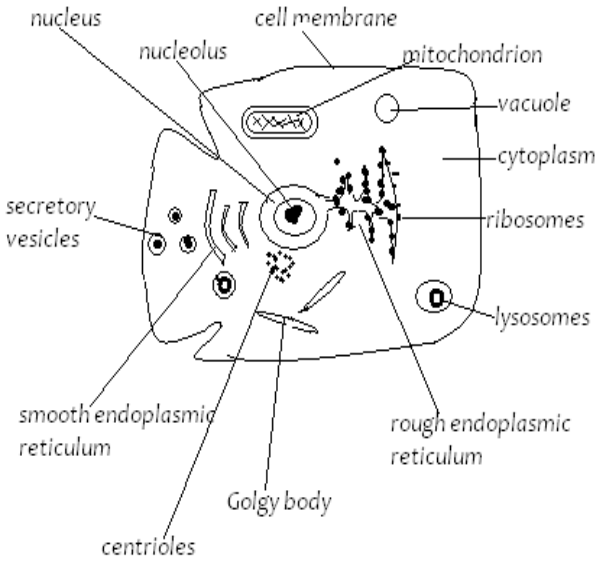
- With special staining techniques it is possible to observe **chloroplasts.**
- These are structures which contain chlorophyll, the green pigment responsible for trapping light for photosynthesis.

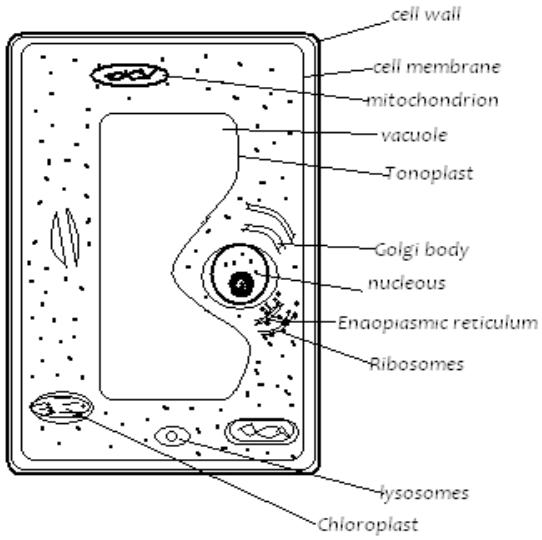
The Electron Microscope (EM)

- Capable of magnifying up to 500,000 times.
- The specimen is mounted in vacuum chamber through which an electron beam is directed.
- The image is projected on to a photographic plate.
- The major **disadvantage** of the electron microscope is that it **cannot be used to observe living objects**.
- However, it provides a **higher magnification** and **resolution** (ability to see close points as separate) than the light microscope so that specimen can be observed in more detail.

Cell Structure as Seen Through Electron Microscope

A generalised anumal cell as seen under Electron microscope

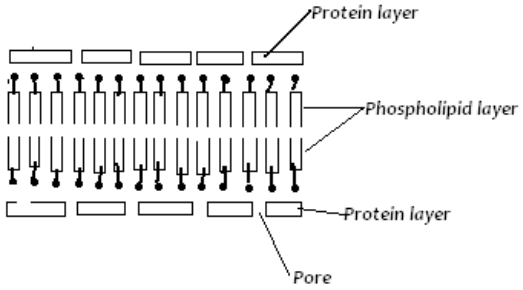




A generalised plant cell as seen under the electron microscope

The Plasma Membrane

- Under the electron microscope, the plasma membrane is seen as a double layer.
- This consists of a lipid layer sandwiched between two protein layers.
- This arrangement is known as the unit membrane and the shows two lipid layers with proteins within.
- Substances are transported across the membrane by active transport and diffusion.



Cell membrane Structure

The Endoplasmic Reticulum (ER)

- This is a network of tubular structures extending throughout the cytoplasm of the cell.
- It serves as a network of pathways through which materials are transported from one part of the cell to the other.
- An ER encrusted with ribosomes it is referred to as **rough endoplasmic reticulum**.
- An ER that lacks ribosomes is referred to as **smooth endoplasmic reticulum.**
- The rough endoplasmic reticulum transports **proteins** while the smooth endoplasmic reticulum transports **lipids.**

The Ribosomes

- These are small spherical structures attached to the ER.
- They consist of protein and ribonucleic acid (RNA).
- They act as sites for the synthesis of proteins.

Goigi Bodies

- Golgi bodies are thin, plate-like sacs arranged in stacks and distributed randomly in the cytoplasm.
- Their function is packaging and transportation of glycol-proteins.
- They also produce lysosomes.

Mitochondria

- Each mitochondrion is a rod-shaped organelle.
- Made up of a smooth outer membrane and a folded inner membrane.
- The foldings of the inner membrane are called **cristae.**
- They increase the surface area for respiration.
- The inner compartments called the matrix.
- Mitochondria are the sites of cellular respiration, where energy is produced.

Lysosomes

- These are vesicles containing hydrolytic enzymes.
- They are involved in the breakdown of micro-organisms, foreign macromolecules and damaged or worn-out cells and organelles ..

The Nucleus

- The nucle s is surrounded by a nuclear membrane which is a unit membrane.

- The nuclear membrane has pores through which materials can move to the surrounding cytoplasm.
- The nucleus contains proteins and nucleic acid deoxyribonucleic acid (DNA) and RNA.
- The chromosomes are found in the nucleus.
- They are the carriers of the genetic information of the cell.
- The nucleolus is also located in the nucleus but it is only visible during the non-dividing phase of the cell.

The Chloroplasts

- These are found only in photosynthetic cells.
- Each chloroplast consists of an outer unit. membrane enclosing a series of interconnected membranes called lamellae.
- At various points along their length the lamellae form stacks of disc like structures called grana.
- The lamellae are embedded in a granular material called the stroma.
- The chloroplasts are sites of photosynthesis.
- The light reaction takes place in the lamellae while the dark reactions take place in the stroma.

Comparison between animal cell and plant cell

Plant	***Animal Cell***
• Has a cell wall and a cell membrane.	• Has cell membrane only.
• Nucleus at periphery.	• Nucleus at the center.
• Have chloroplasts.	• Have no chloroplasts.
• Has a large central vacuole.	• Has no vacuoles, they are small and scattered.
• Are usually large.	• Are usually small.
• Are regular in shape.	• Irregular in shape.
• Has no centriole.	• Has centrioles.
• Stores starch, oils and protein.	• Store glycogen and fats.

Cell Specialisation

Cells are specialised to perform different functions in both plants and animals.

Example;

- Palisade cells have many chloroplasts for photosynthesis.
- Root hair cells are long and thin to absorb water from the soil.
- Red blood cells have hemoglobin which transports oxygen.
- Sperm cells have a tail to swim to the egg.

- Multicellular organisms cells that perform the same function are grouped together to form a tissue.
- Each tissue is therefore made up of cells that are specialized to carry out a particular function.

Animal Tissues- Examples of animal tissues

Type of Tissue	Functions	Characteristics
l. Epithelial Tissue	Covering. allowing movement of materials	
(a) Squamous epithelium	Covering of internal organs. Lining for body cavity.	Thin flat cells.
(b) Columnar	Secretion. Absorption e.g. in the	Cells that are longer than
(c) stratified	Covering surfaces, protection e.g. the	Several layers of epithelial squamous. cuboidal or columnar).
(d) Cuboidal epithelium	Absoption e.g. in the kidney tubules.	cube like cells.
2. Muscular Tissue	Contraction, bringing about movement of body parts.	Contists of units called myofibrils.
(a) Striated (skeletal or voluntary	Contract and allow movement.	Are multicleated; have transverse striations; controlled by voluntary
(b) Smooth (visceral or involuntary muscle)	cover internal organs; allow movement e.g. peristalsis.	Are spindle-shaped. mononucleated; controlled by involuntary nervous system.
(c) Cardiac muscle	Cause contraction of the heart.	contract rhythmically; are myogenic (ability to contract is

3. Supporting Tissue (a) Cartilage (b) Bone	Support the body. provide a rigid framework, protect soft tissue.	Cells that produce hard materials.
4 Blood	Transport of materials, protection	A complex tissue consisting of cells suspended in a fluid medium (Plasma)
5. Nerve Tissue	Receive stimuli and transmit impulses; co-ordinate body activities	Consists of cells called neurones which are interconnected through axons to enable transmission of impulses

Plant Tissues
Example of plant tissues

Type of Tissue	***Functions***	***Characteristics***
L *Meristematic*	Undergo division and cause growth, e.g. increase in length and girth	Small thin-walled celis, contain a lot of cytoplasm; found mostly at the tip of shoots and roots.
2. Parenchyma	Photosynthesis gaseous exchange; support; storage.	Thin walled cells; vary in shape and size; many intercellular spaces.
3. *Collenchyma*	Strengthening.	Thickened walls; no intercellular spaces; found in cortex of stems.
4. Sclerenchyma	Strengthening.	Vary in shape; thick cell walls; are usually dead.

5. *Vascular* (a) Xylem (b) Phloem	Transport materials. Transport of water and mineral salts. Transport of organic materials (manufactured food).	Tubular vessels and trancheids joined end to end. Sieve elements joined to each other through sieve pores.

Organs

- An organ is made up of different tissues
- e.g. the heart, lungs, kidneys and the brain in animals and roots, stems and leaves in plants.

Organ systems

- Organs which work together form an organ system.
- Digestive, excretory, nervous and circulatory in animals and transport and support system in plants.

organism

- Different organ systems form an organism.

Cell Physiology

Meaning of cell physiology

- The term physiology refers to the functions that occur in living organisms.
- Cell physiology refers to the process through which substances move across the cell membrane.
- Several physiological processes take place inside the cell.e.g. Respiration.
- Oxygen and glucose required enter the cell while carbon (IV) oxide and water produced leave the cell through the cell membrane.
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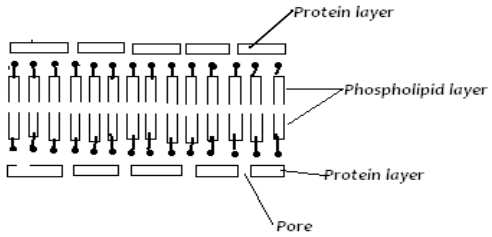
Structure and properties of cell membrane

- The cell membrane is the protective barrier that shelter cellular contents.

- Movement of all substances into and out of the cells takes place across the cell membrane.
- It is made up of protein and lipid molecules.
- Lipid molecules have phosphate group attached to it on one end.
- They are then referred to phospholipids.
- The phospholipids are arranged to form a double layer.
- The ends with phosphate group face outwards.
- the proteins are scattered throughout the lipid double layer.
- Some of these proteins act as carrier molecules that channel some material in and outside the cells.
- The cell membrane allows certain molecules to pass through freely while others move through with difficulty and still others do not pass through at all.
- This is selective permeability and the cell membrane is described as semi-permeable.



Cell membrane Structure

Properties of cell membrane

Permeability

- The cell membrane is semi-permeable.
- it allows small molecules that are soluble in lipid to pass through with more ease than water soluble molecules.
- this is due to the presence of the phospholipids double layer.

Polarlity

- The cell membrane has electrical charges across its surface. it has positive charged ions on the outside and negatively charged ions on the inside. This property contributes to electrical impulses sent along nerve cells.
- Sensitivity to changes in temperature and pH
- Very high temperatures destroy the semi-permeability nature of the cell membrane because the proteins are denatured by extreme pH values have the same effect on the membrane permeability.
- Physiological processes
- Some of the physiological processes include diffusion, osmosis and active transport.

Diffusion

- Diffusion is the movement of molecules or ions from a region of high concentration to a region of low concentration aided by a concentration gradient..
- Diffusion continues to occur as long as there is a difference in concentration between two regions (concentration gradient).

- Stops when an equilibrium is reached i.e., when the concentration of molecules is the same in both regions.
- Diffusion is a process that occurs inside living organisms as well as the external environment.
- Does not require energy.

Factors Affecting Diffusion

- **Concentration Gradient**

An increase in the concentration of molecules at one region results in a steeper concentration gradient which in turn increases the rate of diffusion.

- **Temperature**

High temperature increases kinetic energy of molecules. They move faster hence resulting in an increase in rate of diffusion, and vice versa.

- **Size of Molecules or Ions**

The smaller the size of molecules or ions, the faster their movement hence higher rate of diffusion.

- **Density**

The denser the molecules or ions diffusing, the slower the rate of diffusion, and vice versa.

- **Medium**

The medium through which diffusion occurs also affects diffusion of molecules or ions. For example, diffusion of molecules through gas and liquid media is faster than through a solid medium.

- **Distance**

This refers to the thickness or thinness of surface across which diffusion occurs. Rate of diffusion is faster when the distance is small i.e., thin surface.

- **Surface Area to Volume Ratio**

The larger the surface area to volume ratio, the faster the rate of diffusion.
For example, in small organisms such as Amoeba the surface area to volume ratio, is greater hence faster diffusion than in larger organisms.

Role of Diffusion in Living Organisms

Some processes that depend on diffusion include the following:

- Gaseous exchange: Movement of gases through respiratory surfaces is by diffusion.
- Absorption of materials into cells. Cells obtain raw materials and nutrients from the surrounding tissue fluid and blood through diffusion, e.g., glucose needed for respiration diffuses from blood and tissue fluid into cells.
- Excretion: Removal of metabolic waste products like carbon (IV) oxide, and ammonia out of cells is by diffusion.
- Absorption of the end-products of digestion from the intestines is by diffusion.

Osmosis

- Osmosis is the movement of water molecules from a region of high water concentration to a region of low water concentration through a semi-permeable membrane.
- Osmosis is a special type of diffusion that involves the **movement of water molecules only** and **not solute molecules.**

- Osmosis takes place in cells across the cell membrane as well as across non-living membranes
- e.g. cellophane or visking tubing which are also semi-permeable,
- It is purely a physical process.
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Factors Affecting Osmosis

- **Size of solute molecules-**

Osmosis' occurs only when solute molecules are too large to pass through a semi-permeable membrane.

- **Concentration Gradient .**

Osmosis occurs when two solutions of unequal solute concentration are separated by a semi-permeable membrane.

- **Temperature**

High temperatures increase movement of water molecules hence influence osmosis. However, too high temperatures denature proteins in cell membrane and osmosis stops.

- **Pressure**

Increase in pressure affects movement of water molecules.
As pressure increases inside a plant cell, osmosis decreases.

Roles of Osmosis in Living Organisms

The following processes depend on osmosis in living organisms:

- Movement of water into cells from the surrounding tissue fluid and also from cell to cell.
- Absorption of water from the soil and into the roots of plants.
- Support in plants especially herbaceous ones, is provided by turgor pressure, which results from intake of water by osmosis.
- Absorption of water from the alimentary canal in mammals.
- Re-absorption of water in the kidney tubules.
- Opening and closing stomata.

Water Relations in Plant and Animal Cells

- The medium (solution) surrounding cells or organisms is described by the terms **hypotonic, hypertonic** and **isotonic.**
- A solution whose solute concentration is more than that of the cell sap is said to be **hypertonic**.
  A cell placed in such a solution loses water to the surroundings by osmosis.
- A solution whose solute concentration is less than that of the cell sap is said to be **hypotonic**.
  A cell placed in such a solution gains water from the surroundings by osmosis.

- A solution which has the same solute concentration as the cell sap is said to be **isotonic**.
  When a cell is placed in such a solution there will be no net movement of water either into or out of the cell.

Osmotic Pressure

- The term osmotic pressure describes the tendency of the solution with a high solute concentration to draw water into itself when it is separated from distilled water or dilute solution by a semi-permeable membrane.
- Osmotic pressure is measured by an osmometer.
- When plant cells are placed in distilled water or in a hypotonic solution, the osmotic pressure in the cells is higher than the osmotic pressure of the medium.
- This causes the water to enter the cells by osmosis.
- The water collects in the vacuole which increases in size.
- As a result the cytoplasm is pushed outwards and it in turn presses the cell membrane next to the cell wall.
- This builds up water pressure (hydrostatic pressure) inside the cell.
- When the cell is stretched to the maximum, the cell wall prevents further entry of water into the cell.
- Then the cell is said to be **fully** turgid.
- The hydrostatic pressure developed is known as **turgor** pressure.

Plasmolysis

- When a plant cell is placed in a hypertonic medium, it loses water by osmosis.
- The osmotic pressure of the cell is lower than that of the medium.
- The vacuole decreases in size and the cytoplasm shrinks as a result of which the cell membrane loses contact with the cell wall.
- The cell becomes flaccid. The whole process is described as plasmolysis.
- **Incipient** plasmolysis is when a cell membrane just begins to lose contact with the cell wall.
- Plasmolysis can be reversed by placing the cell in distilled water or hypotonic solution.
- However, full plasmolysis may not be reversed if cell stays in that state for long.

Wilting

- The term wilting describes the drooping of leaves and stems of herbaceous plants after considerable amounts of water have been lost through transpiration.
- It is observed in hot dry afternoons or in dry weather.
- This is when the amount of water lost through transpiration exceeds the amount absorbed through the roots.
- Individual cells lose turgor and become plasmolysed and the leaves and stems droop.
- The condition is corrected at night when absorption of water by the roots continue while transpiration is absent.
- Eventually, wilting plants may die if the soil water is not increased through rainfall or watering.

Water Relations in Plants and Animals

Haemolysis

- Haemolysis is the bursting of cell membrane of red blood cells releasing their haemoglobin.
- It occurs when red blood cells are placed in distilled water or hypotonic solution.
- This is because the cell membrane does not resist further entry of water by osmosis after maximum water intake.

Crenation

- Takes place when red blood cells are placed in hypertonic solution.
- They lose water by osmosis, shrink and their shape gets distorted.
    - **Animal cells** have mechanisms that regulate their salt water balance (osmoregulation) to prevent above processes that lead to death of cells.
    - An Amoeba placed in distilled water, i.e. hypotonic solution, removes excess water using a contractile vacuole.
    - The rate of formation of contractile vacuoles increases.

Active Transport

- Active transport is the movement of solutes such as .glucose, amino acids and mineral ions;
- From an area of their low concentration to an area of high concentration.
- It is movement against a concentration gradient and therefore energy is required.
- As such it only takes place in living organisms.
- The energy needed comes from respiration.
- Certain proteins in the cell surface membrane responsible for this movement are referred to as **carrier proteins or channel proteins.**
- The shape of each type of carrier protein is specific to the type of substances conveyed through it.
- It has been shown that the substance fits into a particular slot on the protein molecule,
- As the protein changes from one form of shape to another the substance is moved across and energy is expended.

Factors Affecting Active Transport

Availability of oxygen

- Energy needed for active transport is provided through respiration.
- An increase in the amount of oxygen results in a higher rate of respiration.
- If a cell is deprived of oxygen active transport stops .

Temperature

- Optimum temperature is required for respiration, hence for active transport.
- Very high temperatures denature respiratory enzymes.
- Very low temperatures inactivate enzymes too and active transport stops.

Availability of carbohydrates

- Carbohydrates are the main substrates for respiration.
- Increase in amount of carbohydrate results in more energy production during respiration and hence more active transport.
- Lack of carbohydrates causes active transport to stop.

Metabolic poisons

- Metabolic poisons e.g. cyanide inhibit respiration and stops active transport due to lack of energy.

Role of Active Transport in Living Organisms

Processes requiring active transport:

- Absorption of mineral salts from the soil into plant roots.
- Absorption of end products of digestion e.g. glucose and amino acids from the digestive tract into blood stream.
- Excretion of metabolic products e.g.urea from the cells.
- Re-absorption of useful substances and mineral salts back into blood capillaries from the kidney tubules.
- Sodium-pump mechanism in nerve cells.
- Re-absorption of useful materials from tissue fluid into the blood stream.

4. GENERAL MICROBIOLOGY

Microbiology

It is the study of microscopic organisms such as bacteria, fungi. It also includes the study of viruses which are not technically classified as living organisms but do contain genetic material**.**

General Characteristics of Kingdoms

Organisms are classified into 3 kingdoms.

1. **Kingdom Monera**: bacteria
2. **Kingdom protoctista**: algae, protozoa, amoeba, paramecium
3. **Kingdom Fungi**: Moulds, Yeast, Mushrooms

Viruses do not fit neatly into any of the above kingdoms.

- They are simple and not cellular.
- They are metabolically inactive outside the host cell.
- Most of them can be crystallized like chemical molecules.
- Therefore they do not exhibit the characteristics of living organisms.

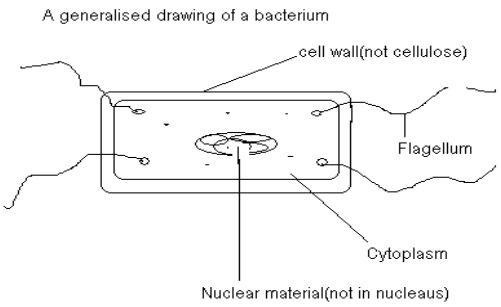
Characterist	*Monera*	*Protoctista*	*Fungi*	*Plantae*	*Animalia*
Cell type	Prokaryotic	Eucaryotic	Eucaryotic	Eucaryotic	Eucaryotic
U nicellularl Multicellular	Unicellular	Unicellular multicellular	Unicellular multicellular	Multicellular	Multicellular
Mode of Feeding	Autotrophic or heterotrophic by absorption	Autotrophic or heterotrophic absorption or phagocytosis	Heterotrophism by absorption	Autotrophism	Heterotrophic by ingestion
Reproductio	Asexual by binary	Asexual binary fission, fragmentation, Sporulation	Asexual fission Fragmentation, sporulation	Asexual by sporulation and fragmentatio Sexual	Sexual

Examples of Organisms in Each Kingdom and Their Economic Importance

Kingdom Monera

General Characteristics

- Unicellular and microscopic
- Some single cells ,others colonial
- Nuclear material not enclosed within nuclear membrane-prokaryotic
- Have cell wall but not of cellulose.
- Have few organelles which are not membrane bound
- Mitochondria absent
- Mostly heterotrophic, feeding saprotrophically or parasitically,some are autotrophic.
- Reproduction mostly asexual through binary fission
- Most of them are anaerobes but others are aerobes
- Most move by flagella



- Examples include ***Escherichia coli, Vibrio cholerae*** and ***Clostridium tetani.***
- Spherical known as Cocci.

- Rod shaped - e.g. *Clostridium tetani*
- Spiral shaped e.g. sprilla
- Coma shaped- Vibrios -e.g., *Vibrio cholerae.*

Economic importance of bacteria Benefits to man include:

- They are used in food processing e.g., *Lactobacillus* used in processing of cheese, yoghurt.
- Involved in synthesis of vitamin Band K, in humans and breakdown of cellulose in herbivores.

Genetic Engineering

- Bacteria are easily cultured and are being used for making antibiotics, aminoacids and enzymes e.g. amylase, and invertase e.g., ***Escherichia coli.***

Nutrient cycling:

- Saprophytes
- They are involved in decomposition of dead organic matter.
- They are useful in the nitrogen cycle.
- Nitrogen fixing and nitrifying bacteria.
- They increase soil fertility.
- Modem sewage works use bacteria in treatment of sewage.
- Cleaning oil spills in oceans and lakes.

Harmful Effects

- Bacteria cause disease:
- To humans (e.g. Cholera).
- To animals (e.g. Anthrax).
- Bacteria cause food spoilage.
- Others cause food poisoning e.g. *Salmonella.*

- Denitrifying bacteria reduce soil fertility e.g., *Pseudomonas denitrificans.*

Kingdom Protoctista

Examples include ;

- Algae such as spirogyra, Chlamydomonas, euglena, Sargassum
- And protozoa such as amoeba, paramecium and Trypanosoma.

General Characteristics

- They are said to be eukaryotic since their nucleus is bound by a membrane
- Most are mobile, and use flagella, cilia and pseudopodia.
- Some are sessile.
- They reproduce mainly asexually, by binary fission, fragmentation and sporulation.
- Some reproduce sexually by conjugation.
- Some are heterotrophic e.g. paramecium.
- Others are autotrophic e.g. spirogyra.

Economic importance of protoctista

- Algae are the primary producers in aquatic food chains.
- They release a lot of oxygen to the atmosphere.
- Some cause human diseases like malaria and amoebic dysentry ,sleeping sickness
- Some are source of food for humans e.g. sargassum is a source of iodine
- Skeletons of diatoms used in paint making.

Spirogyra: They have spiral chloroplast.

- They are green, thread-like filaments

Chlamydomonas:

- This is a unicellular green algae and has a cup shaped chloroplast.
- They move towards light using the flagella
- Cilia assist the organism to move.
- The shape is due to the presence of a thin flexible pellicle.

Kingdom Fungi

- Multicellular fungi are made of thread-like structures called hyphae (singular hyphae) that form a mycelium.
- .e.g.Saccharomyces cereviseae(bread yeast).
- Others include Penicillium, Rhizopus, and edible mushroom

Economic Importance of Fungi

Beneficial Effects

- Some fungi are used as food e.g. mushrooms.

- Some are decomposers which enhance decay to improve soil fertility - recycling of nutrients e.g., toadstools.
- Some are useful in brewing and bread making e.g., yeast. Yeast is used as food - a rich source of Vitamin B.
- Some are useful in production of antibiotics e.g., *Penicillium griseofulvin.*
- Used in sewage treatment e.g., *Fusarium spp.*

Harmful Effects

- Some cause food poisoning by producing toxic compounds e.g. *Aspergillus flavus* which produces aflatoxins.
- Some cause food spoilage, fabric and wood spoilage through decomposition.
- Some cause diseases to humans e.g., athlete's foot and ringworms.
- Others cause diseases to plants e.g., potato blight (Irish potatoes) rust in tomatoes and smuts in cereals.

Sterilization

Sterilization refers to any process that removes, kills, or deactivates all forms of life (in particular referring to microorganisms such as fungi, bacteria, viruses, spores, unicellular eukaryotic organisms such as Plasmodium, etc.) and other biological agents like prions present in a specific surface, object or fluid, for example food or biological culture media.[1] [2] Sterilization can be achieved through various means, including heat, chemicals, irradiation, high pressure, and filtration. Sterilization is distinct from disinfection, sanitization, and pasteurization, in that those methods reduce rather than eliminate all forms of life and biological agents present. After sterilization, an object is referred to as being sterile or aseptic.

Types of Sterilization

Common methods of **sterilization** include physical methods and chemical methods. Physical methods include dry heat, steam, radiation, and plasmas. Radiation encompasses a variety of **types**, including gamma radiation, electron beam, X-ray, ultraviolet, microwave, and white (broad spectrum) light

Growth of microorganisms and cultivation

Microbial Growth: Refers to an increase in **cell number**, not in cell size. Bacteria grow and divide by **binary fission**, a rapid and relatively simple process

Requirements for microbial Growth
Physical Requirements

1. Temperature: Microbes are *loosely* classified into several groups based on their preferred temperature ranges.
A. Psychrophiles: "Cold-loving". They can grow at 0^{o}C .Two groups:

True Psychrophiles: Sensitive to temperatures over 20^{o}C. Optimum growth at 15^{o}C or below. Found in very cold environments (North Pole, ocean depths). They rarely cause disease or food spoilage.

Psychrotrophs: Optimum growth at 20 to 30^{o}C. Responsible for most low temperature food spoilage.

B.Thermophiles: "Heat loving".Optimum growth between 50^{o}C to 60^{o}c Many cannot grow below 45^{o}c. Are adapted to live in sunlit soil, compost piles, and hot springs.Some thermophiles form extremely heat resistant endospores.

Extreme Thermophiles (Hyperthermophiles):
Optimum growth at 80^{o} C or higher. Archaebacteria. Most live in volcanic and ocean vents.

C. Mesophiles: "Middle loving". Most bacteria and most pathogens and common spoilage organisms.
Best growth between 25 to 40^{o}C
Optimum temperature commonly 37^{o}C
Many have adapted to live in the bodies of animals.

Growth Rates of Bacterial Groups

3. **pH**: Organisms can be classified as:

A. Acidophiles: "Acid loving".
Grow at very low pH (0.1 to 5.4)
Lactobacillus produces lactic acid, tolerates mild acidity.

B. Neutrophiles:
Grow at pH 5.4 to 8.5.
Includes most human pathogens.

C. Alkaliphiles: "Alkali loving".

Grow at alkaline or high pH (7 to 12 or higher)
Vibrio cholerae and *Alkaligenes faecalis* optimal pH 9.
Soil bacterium *Agrobacterium* grows at pH 12.
Most **bacteria** prefer neutral pH (6.5-7.5).
Molds and **yeast** grow in wider pH range, but prefer pH between 5 and 6.
Acidity inhibits most microbial growth and is used frequently for food preservation (e.g.: pickling).
Alkalinity inhibits microbial growth, but not commonly used for food preservation.
Acidic products of bacterial metabolism interfere with growth. Buffers can be used to stabilize pH.

3.Osmotic Pressure : Cells are 80 to 90% water.
A. Hypertonic solutions: High osmotic pressure removes water from cell, causing shrinkage of cell membrane (plasmolysis).
Used to control spoilage and microbial growth.
a. Sugar in jelly.
b. Salt on meat.
B. Hypotonic solutions: Low osmotic pressure causes water to enter the cell. In most cases cell wall prevents excessive entry of water. Microbe may lyse or burst if cell wall is weak.

Effects of Osmosis on Bacterial Cells
Halophiles: Require moderate to large salt concentrations. Ocean water contains 3.5% salt. Most bacteria in oceans.

Extreme or Obligate Halophiles: Require very high salt concentrations (20 to 30%).Bacteria in Dead Sea, brine vats.
Facultative Halophiles: Do not require high salt concentrations for growth, but tolerate 2% salt or more.

Requirements for Growth
Chemical Requirements

1.Carbon: Makes up 50% of dry weight of cell.Structural backbone of all organic compounds.
Chemoheterotrophs: Obtain carbon from their energy source: lipids, proteins, and carbohydrates.
Chemoautotrophs and Photoautotrophs: Obtain carbon from carbon dioxide.
2. Nitrogen, Sulfur, and Phosphorus:.

B.Sulfur: Used to form proteins and some vitamins (thiamin and biotin).
Sources of sulfur:
Protein: Most bacteria
Hydrogen sulfide
Sulfates: Salts that dissociate to give SO

2. Nitrogen, Sulfur, and Phosphorus: .
A.Nitrogen: Makes up 14% of dry cell weight. Used to form amino acids, DNA, and RNA.
Sources of nitrogen:
Protein: Most bacteria
Ammonium: Found in organic matter
Nitrogen gas (N): Obtain N directly from atmosphere.
Important **nitrogen fixing bacteria** live free in soil or associated with legumes (peas, beans, alfalfa, clover, etc.). Legume cultivation is used to fertilize soil naturally.
Nitrates: Salts that dissociate to give NO
3. Hydrogen Peroxide (H2O): Peroxide ion is toxic and the active ingredient of several antimicrobials (e.g.: benzoyl**2**peroxide).
There are two different enzymes that break down hydrogen peroxide:
A. Catalase: Breaks hydrogen peroxide into water and O
.
B. Peroxidase: Converts hydrogen peroxide into water

3. Other Elements: Potassium, magnesium, and calcium are often required as enzyme cofactors.
Calcium is required for cell wall synthesis in Gram positive bacteria.

4. Trace Elements: .
Many are used as enzyme cofactors.
Commonly found in tap water.
Iron
Copper
Molybdenum
Zinc
C.Phosphorus: Used to form DNA, RNA, ATP, and phospholipids .
Sources: Mainly inorganic phosphate salts and buffers.

5. Oxygen: Organisms that use molecular oxygen (O), produce more energy from nutrients than anaerobes. We can classify microorganism based on their oxygen requirements:
A. Obligate Aerobes: Require oxygen to live.
Disadvantage : Oxygen dissolves poorly in water.
Example: *Pseudomonas*, common nosocomial pathogen.
B. Facultative Anaerobes: Can use oxygen, but can grow in its absence. Have complex set of enzymes.
Examples: *E. coli, Staphylococcus*, yeasts, and many intestinal bacteria.
C. Obligate Anaerobes: Cannot use oxygen and are harmed by the presence of toxic forms of oxygen.
Examples: *Clostridium* bacteria that cause tetanusand botulism.

D. Aerotolerant Anaerobes: Can't use oxygen, but tolerate its presence. Can break down toxic forms of oxygen.
Example: *Lactobacillus*carries out fermentation regardless of oxygen presence.
E. Microaerophiles: Require oxygen, but at low concentrations. Sensitive to toxic forms of oxygen.
Example: *Campylobacter*.

Culture Medium: Nutrient material prepared for microbial growth in thelaboratory.
Requirements:
- **Must be sterile**
- **Contain appropriate nutrients**
- **Must be incubated at appropriate temperature**

Culture: Microbes that grow and multiply in or on a culture medium.

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Culture Media
Solid Media: Nutrient material that contains a solidifying agent (plates, slants, deeps).
The most common solidifier is **agar,** first used by Robert Koch.
Unique Properties of Agar:
Melts above 95oC.
Once melted, does not solidify until it reaches 40C

Cannot be degraded by most bacteria.
Polysaccharide made by red algae.
Originally used as food thickener (Angelina Hesse).

Types of culture media

Chemically Defined Media: Nutrient material whose ***exact*** chemical composition is known.
For chemoheterotrophs, must contain organic source of carbon and energy (e.g.: glucose, starch, etc.).
May also contain amino acids, vitamins, and otherimportant building blocks required by microbe.
Not widely used.
Expensive.

Anaerobic Growth Media: Used to grow anaerobes that might be killed by oxygen.
Reducing media
Contain ingredients that chemically combine with oxygen and remove it from the medium.
Example: Sodium thioglycolate
Tubes are heated shortly before use to drive off oxygen.
Plates must be grown in oxygen free containers (anaerobic chambers).

Pure Culture: Contains a ***single microbial species***.
Most clinical and environmental specimens contain several different microorganisms.
To obtain a pure culture, individual organisms must be ***isolated***.
The most common method of isolation is the **streak plate** , in which a sterile loop is inserted into asample and streaked onto a plate in a pattern, to
obtain individual colonies

Complex Media: Nutrient material whose ***exact*** chemical composition is **not** known.
Widely used for heterotrophic bacteria and fungi.
Made of extracts from yeast, meat, plants, protein digests, etc.
Composition may vary slightly from batch to batch.
Energy, carbon, nitrogen, and sulfur requirements are primarily met by protein fragments (**peptones**).
Vitamins and organic growth factors provided by meat and yeast extracts.

Two forms of complex media:
Nutrient broth: Liquid media
Nutrient agar: Solid media

Special Culture Techniques: Used to grow bacteria with unusual growth requirements.
4 **Bacteria that do not grow on artificial media**:
• *Mycobacterium leprae* (leprosy): Grown in armadillos.
• *Treponema pallidum* (syphilis): Grown in rabbit testicles.
• Obligate intracellular bacteria (rickettsias and chlamydias): Only grow in host cells.
4 **Bacteria that require high or low CO2**
• **Capnophiles**: Grow better at high CO2 levels. Similar to environment of intestinal tract,respiratory tract, and other tissues.

Selective Media: Used to suppress the growth of unwanted bacteria and encourage the growth of desired microbes.
4 **Saboraud's Dextrose Agar:** pH of 5.6 discourages bacterial growth. Used to isolate fungi.
4 **Brilliant Green Agar**: Green dye selectively inhibits gram-positive bacteria. Used to isolate gram-negative *Salmonella* .
4 **Bismuth Sulfite Agar**: Used to isolate *Salmonella typhi*. Inhibits growth of most other bacteria.

Differential Media: Used to ***distinguish*** colonies of a desired organism.
4 **Blood Agar:** Used to distinguish bacteria that destroy red blood cells (**hemolysis**).
Hemolysis appears as an area of clearing around colony.
Example: *Streptococcus pyogenes*.

Both Selective and Differential Media: Used both to ***distinguish*** colonies of a desired organism, and ***inhibit*** the growth of other microbes.
4 **MacConkey Agar:** Used to distinguish and select for *Salmonella* .
• Bile salts and crystal violet discourage growth of grampositive bacteria.
• Lactose plus pH indicator: Lactose fermenters produce pink or red colonies, nonfermenters are colorless.

4 **Mannitol Salt Agar:** Used to distinguish andnselect for *Staphylococcus aureus*.
• High salt (7.5% NaCl) discourages growth of other organisms.

• pH indicator changes color when mannitol is fermentednto acid

Colony: A group of descendants of an original cell.

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Microbial Growth

Culture Media

Enrichment Culture: Used to favor the growth of a microbe that may be found in very small numbers.

u Unlike selective medium, does not necessarily suppress the growth of other microbes.

u Used mainly for fecal and soil samples.

u After incubation in enrichment medium, greater numbers of the organisms, increase the likelihood of positive identification.

Pure Culture: Contains a ***single microbial species***.

Most clinical and environmental specimens contain several different microorganisms.

To obtain a pure culture, individual organisms must be ***isolated***.

The most common method of isolation is the **streak plate,** in which a sterile loop is inserted into a sample and streaked onto a plate in a pattern, to obtain individual colonies

Growth of Bacterial Cultures

Bacterial Division: Occurs mainly by binary fission.

A few bacterial species reproduce by budding.

Generation Time: Time required for a cell to divide ***and*** its population to double.

Generation time varies considerably:

E. coli divides every 20 minutes.

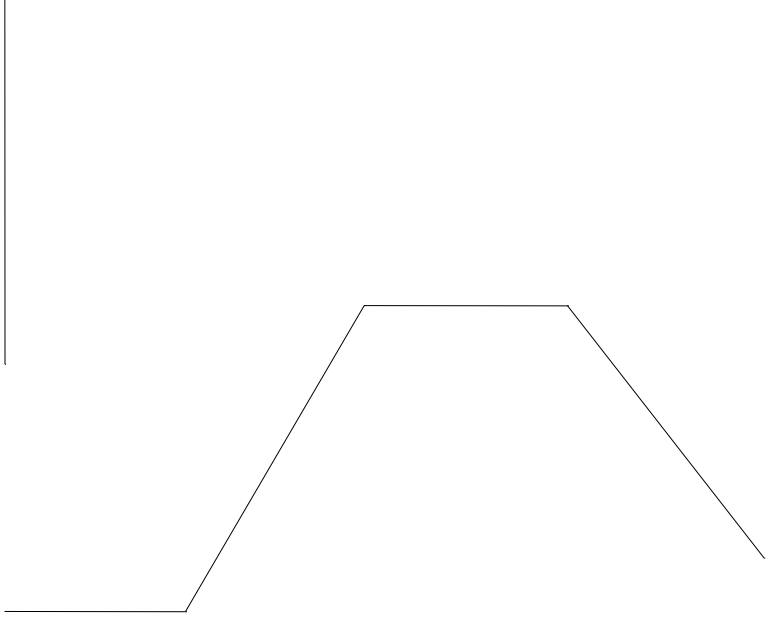
Most bacteria divide every 1 to 3 hours.

Some bacteria require over 24 hours to divide.

Phases of Growth

Bacterial Growth Curve: When bacteria are inoculated into a liquid growth medium, we can plot of the number of cells in the population over time.

Four phases of Bacterial Growth:



1. Lag Phase:

Period of adjustment to new conditions
Little or no cell division occurs, population size doesn't increase.
Phase of intense metabolic activity, in which individual organisms grow in size.
May last from one hour to several days

2. Log Phase:

Cells begin to divide and generation time reaches a constant minimum.
Period of most rapid growth
Number of cells produced > Number of cells dying
Cells are at highest metabolic activity.
Cells are ***most susceptible*** to adverse environmental factors at this stage.
- Radiation
- Antibiotics

3. Stationary Phase:

Population size begins to stabilize.
Number of cells produced = Number of cells dying
Overall cell number does not increase.
Cell division begins to slow down.
Factors that slow down microbial growth:
- Accumulation of toxic waste materials
- Acidic pH of media
- Limited nutrients
- Insufficient oxygen supply

Logarithmic Representation of Bacterial Growth :

We can express the number of cells in a bacterial generation as **2**, where n is the number of doublings that have occurred.
n

4. Death or Decline Phase:
Population size begins to decrease.
Number of cells dying > Number of cells produced
Cell number decreases at a logarithmic rate.
Cells lose their ability to divide.
A few cells may remain alive for a long period of time.

Method to Measure Numbers of Bacteria
Direct Methods of Measurement
1. Plate count
Most frequently used method of measuring bacterial populations.
Inoculate plate with a sample and count number of colonies.
Assumptions:
Each colony originates from a single bacterial cell.
Original inoculum is homogeneous.
No cell aggregates are present.
Advantages:
- Measures **viable** cells

Disadvantages:
- Takes 24 hours or more for visible colonies to appear.
- Only counts between 25 and 250 colonies are accurate.
- Must perform **serial dilutions** to get appropriate numbers/plate.

Types
A. Pour Plate:
Introduce a 1.0 or 0.1 ml inoculums into an **empty** Petri dish.
Add liquid nutrient medium kept at 50 C.
Gently mix, allow to solidify, and incubate

Disadvantages:
Not useful for heat sensitive organisms.
Colonies appear under agar surface.

B. Spread Plate:
Introduce a 0.1 ml inoculum onto the **surface** of Petri dish.
Spread with a sterile glass rod.
Advantages: Colonies will be on surface and not exposed to melted agar.

2. Filtration:
Used to measure small quantities of bacteria.
• **Example**: Fecal bacteria in a lake or in ocean water.
A large sample (100 ml or more) is filtered to retain bacteria.
Filter is transferred onto a Petri dish.
Incubate and count colonies.

3. Most Probable Number (MPN):
Used mainly to measure bacteria that will not grow on solid medium.
Dilute a sample repeatedly and inoculate several broth tubes for each dilution point.
Count the number of positive tubes in each set.

Statistical method: Determines 95% probability that a bacterial population falls within a certain range.

4. Direct Microscopic Count:
A specific volume of a bacterial suspension (0.01 ml) is placed on a microscope slide with a special grid.
Stain is added to visualize bacteria.
Cells are counted and multiplied by a factor to obtain concentration.
Advantages:
• No incubation time required.
Disadvantages:
• Cannot always distinguish between live and dead bacteria.
• Motile bacteria are difficult to count.
• Requires a high concentration of bacteria (10 million/ml)

Measuring Microbial Growth
Indirect Methods of Measurement
1. Turbidity:
As bacteria multiply in media, it becomes turbid.
Use a spectrophotometer to determine % transmission or absorbance.
Multiply by a factor to determine concentration.
Advantages:
• No incubation time required.
Disadvantages:
• Cannot distinguish between live and dead bacteria.
• Requires a high concentration of bacteria (10 to 100 million cells/ml).

2. Metabolic Activity:
As bacteria multiply in media, they produce certain products:
Carbon dioxide
Acids
Measure metabolic products
Expensive
3. Dry Weight:
Bacteria or fungi in liquid media are centrifuged.
Resulting cell pellet is weighed.
Doesn’t distinguish live and dead cells

STAINING

NUTRITION IN PLANTS AND ANIMALS

Nutrition

- This is the process by which organisms *obtain and Assimilate* nutrients.
- There are two modes of nutrition; **Autotrophism and Heterotrophism.**

Autotrophism

- This is where living organism *manufacture its own* complex food substances from simple substances such as carbon (iv) oxide, water, *light or chemical energy.*
- Where sunlight is used as a source of energy, the process is referred to as **photosynthesis**.
- **Photo** means light while **synthesis** means to make.
- Some **none green plants** make their own food using energy obtained from certain chemicals through a process called **chemosynthesis.**
- Organisms that make their own food are referred to as **autotrophs**.

Heterotrophism

- This is where organisms *take in complex food* materials such as carbohydrates, proteins and fats obtained from bodies of plants and animals.
- Organisms that feed on already manufactured foods are called **Heterotrophs**.

Autotrophism

External Structure of a Leaf

A leaf is a flattened organ which is attached to the stem or a branch of a plant.

Diagrams

Parts of a leaf

Lamina: This is the flat surface. It is green in color and contain the photosynthetic tissue.

Midrib: This is a thick structure running through the middle of the leaf

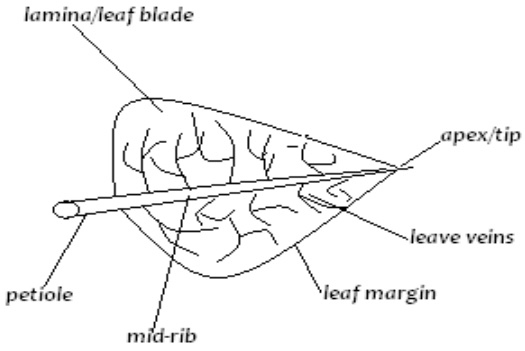
Veins: They arise from the midrib to forming an extensive network of veins.

Leaf Apex: This is the tip of the leaf and usually it is pointed.

Petiole: It attaches the leaf to the stem or branch.

In some monocotyledonous plants the leaves are attached to the stem by the leaf sheath.

Draw and name the external parts of a leaf.



External structure of a leaf

Internal Structure of a Leaf

- Internal structure of the leaf is composed of the following parts.

i.) Cuticle.

- It is a thin waterproof and transparent layer that coats the upper and lower surfaces of the leaf.
- It reduces excess water loss and protects the inner tissue of the plant against mechanical injury.
- It also prevents entry of disease causing micro organisms.
- Since it is transparent, it allows penetration of light for photosynthesis.

ii.) Epidermis.

- It is a one cell thick tissue on both the upper and lower leaf surfaces.
- It secretes the cuticle and also protects the inner tissues from mechanical damage and prevents entry of pathogens.
- Epidermal cells have no chloroplast except the **guard cells**.

- Guard cells are special bean shaped cells. They have chloroplast and are able to carry out photosynthesis hence controlling the opening and closing of the stomata.
- Air moves into and out of the leaf through the stomata.

iii.) *Palisade layer.*

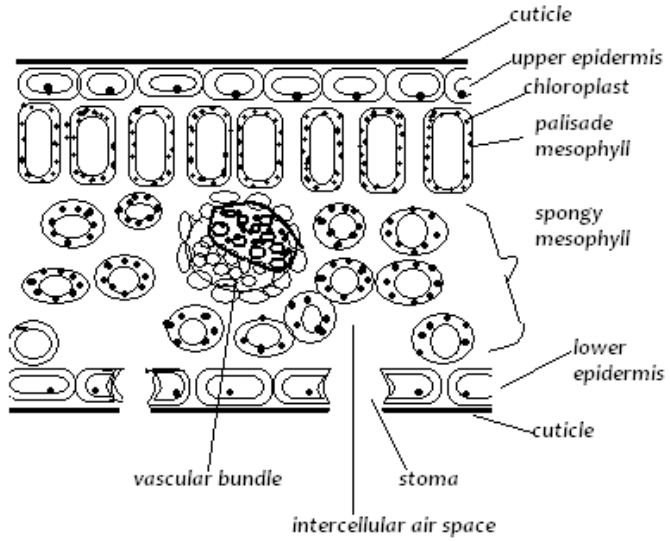
- This is layer of cells located beneath the upper epidermis.
- It is made of cylindrical shaped cells ***closely packed*** together. They have ***numerous chloroplasts*** containing chlorophyll.
- Their position and arrangement enables them to receive maximum light.

iv.) *Spongy Mesophyll Layer.*

- This is below the palisade layer. The cells are ***irregularly shaped and loosely packed*** creating large air spaces in between them.
- The ***air spaces allow gases to diffuse*** in between the cells. They contain fewer chloroplasts as compared to the palisade cells.

v.) *Leaf Veins.*

- Each vein is a vascular bundle consisting of xylem and phloem.
- Xylem conducts water and mineral salts from the roots to the leaves while the phloem translocates manufactured food from the leaves to the rest of the plant.



Transvers section of a leaf showing internal structure

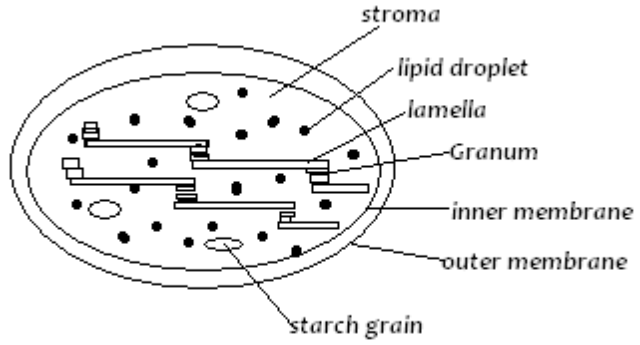
Adaptations of Leaves to Photosynthesis.

1. Broad and flat lamina to increase surface area of Carbon (IV) oxide and sunlight absorption.

2. Thin transparent cuticle and upper epidermis; to allow easier penetration of light to photosynthetic cells;
3. Thin; for faster diffusion of gases;
4. Palisade cells placed next to the upper surface; to trap maximum light for photosynthesis;
5. Palisade cells with numerous chloroplasts; to trap maximum amount of light for photosynthesis;
6. Large/ intercellular air spaces in the spongy mesophyll layer; for storage of Carbon (IV) oxide for easier gaseous exchange;
7. Waxy water proof cuticle; to reduce water loss sand reflect excess light;
8. Leaf mosaic/ non-overlapping leaves; for maximum exposure to light;
9. Guard cells, modified cells to open and close stomata; to control amount of water loss from the leaf and allows gaseous exchange;
10. Leaves have leaf veins; xylem to conduct water to photosynthetic cells, Phloem to translocate products of photosynthesis to other parts of plant;

The Chloroplast

- They are disc shaped organelles found in the cytoplasm of plant cells.
- Each chloroplast has a double membrane; the inner and outer membrane.
- Chloroplasts are made of layers of membranes called ***lamellae*** contained in a fluid matrix called ***stroma***.
- Several lamellae come together to form the ***granum (grana).***
- Granum contains ***chlorophyll molecules*** and other ***photosynthetic pigments***.
- The stroma contains ***enzymes*** that speed up the rate of photosynthesis.



Structure of Chloroplast

The Process of Photosynthesis

- The raw materials for photosynthesis are; water and carbon (IV) oxide. The process however requires the presence of sunlight energy and chlorophyll pigment.
- The products of photosynthesis are glucose and oxygen. The process can be summarized using an equation as shown below.

$6H_2O + 6CO_2$ ----------> $C_6H_{12}O_6 + 6O_2$
Water + Carbon (IV) oxide Glucose + Oxygen.

The above chemical equation translates as:

Six molecules of water plus six molecules of carbon (IV) Oxide produce one molecule of sugar plus six molecules of oxygen

- The process of photosynthesis is however more complex than shown in the above equation and can be divided into two stage; the *light* and *dark* stages.

Light stage (Light Dependent Stage)
- Occurs in the grana containing chlorophyll which traps / absorbs sun light energy**.**
- This Energy is used to split water molecules into hydrogen ion and oxygen gas.
- This process is called **photolysis** of water and is shown below.

$2H_2O$ **4H** + **O_2**
(Water) **Hydrogen atom** **Oxygen**
- Hydrogen atoms produced here enter into the dark stage.
- Oxygen gas removed through stomata or is used for respiration within the plant**;**
- Some Light energy is used in ***Adenosine Triphosphate*** (ATP) formation; **ATP** an energy rich compound.
- ATP is later used in the dark stage.

Dark stage. (Light Independent Stage)
- Carbon (IV) oxide combines with hydrogen atoms to form glucose/simple carbohydrate.
- This is called *Carbon (IV) Oxide fixation.*

Carbon (IV) oxide + Hydrogen Atom Simple Carbohydrate
CO_2 + 4H $C_6H_{12}O_6$

- This stage takes place in the stroma and proceeds whether light is present or not.
- ATP Energy from light stage is used to provide the required energy in this reaction**;**
- Simple sugars formed are used for respiration to provide energy or are converted to storable forms e.g lipids, proteins, starch, cellulose, etc.

Factors Affecting the Rate of Photosynthesis

i.) Light Intensity.

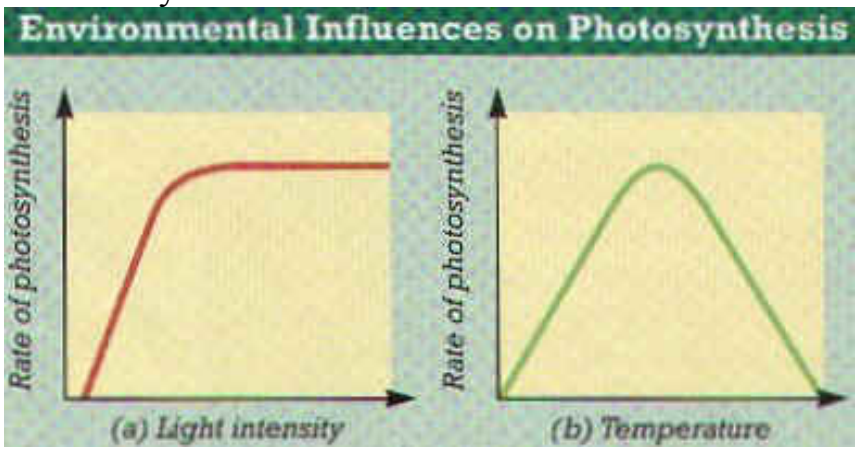
- Increase in light intensity increase the rate of photosynthesis up to a certain level where it slows down and finally levels off.
- Very bright sunshine may damage the plant tissues due to high amount of ultra violet light.
- Light quality or light wavelength also affects the rate of photosynthesis.
- Red and blue wavelengths of light are required by most plants for photosynthesis.

ii.) Carbon (IV) oxide concentration

- Increase in Carbon (IV) oxide concentration increases the rate of photosynthesis linearly up to a certain level after which it slows down and levels off.

iii.) Temperature

- Photosynthesis is an enzyme controlled process, therefore increase in temperature increase the rate of photosynthesis up to the optimum temperature.
- Increase in temperature beyond the optimum decreases the rate sharply as the enzymes become denatured.



iv.) Water

- Plants need water for photosynthesis. Hydrogen atoms required in the dark stage during Carbon (IV) oxide fixation are derived from water during photolysis.

Heterotrophism

This is where organisms *take in complex food* materials such as carbohydrates, proteins and fats obtained from bodies of plants and animals

Examples of heterotrophic nutrition

i. Symbiosis- A relationship or interaction between two dissimilar organisms. It is sometimes but not always beneficial to both parties.
ii. Parasitism- is a mode of feeding whereby one organism called the parasite feeds on or lives in another organism called the host and harms it.
iii. Saprophytism- occurs in most fungi and some forms of bacteria. Saprophytes feed on dead organic matter and cause its decomposition or decay
iv. Holozoic Nutrition- It is a type of heterotrophic nutrition which involves the ingestion and the internal processing of food particles. It involves ingestion, digestion, absorption and assimilation of liquid or solid food particles. It also includes the conversion of complex matter into simpler forms so that they can be easily soaked by cells.

The Human Digestive System and Associated Glands

- Human digestive system starts at the mouth and ends at the anus.
- This is the alimentary canal.
- Digestion takes place inside the lumen of the alimentary canal.
- The epithelial wall that faces the lumen has mucus glands (goblet cells).
- These secrete mucus that lubricate food and prevent the wall from being digested by digestive enzymes.
- Present at specific regions are glands that secrete digestive enzymes.
- The liver and pancreas are organs that are closely associated with the alimentary canal.
- Their secretions get into the lumen and assist in digestions.

Exercise: Draw and label the human digestive system

Digestive system consists of:

- Mouth.
- Oesophagus.
- Stomach.
- Small intestines - consist of duodenum, the first part next to the stomach, ileum - the last part that ends up in a vestigial caecum and appendix which are nonfunctional.
- Large intestines consist of: colon and rectum that ends in the anus.

Ingestion, Digestion and Absorption

- Feeding in humans involves the following processes:
- *Ingestion*: This is the introduction of the food into the mouth.
- *Digestion:* This is the mechanical and chemical breakdown of the food into simpler, soluble and absorbable units.
- *Absorption:* Taking into blood the digested products.
- *Assimilation:* Use of food in body cells.
- Mechanical breakdown of the food takes place with the help of the teeth.
- Chemical digestion involves enzymes.

Digestion in the Mouth

- In the mouth, both mechanical and chemical digestion takes place.
- Food is mixed with saliva and is broken into smaller particles by the action of teeth.
- Saliva contains the enzyme amylase.
- It also contains water and mucus which lubricate and soften food in order to make swallowing easy.
- Saliva is slightly alkaline and thus provides a suitable pH for amylase to act on cooked starch, changing it to maltose.
- The food is then swallowed in the form of semisolid balls known as boluses.
- Each bolus moves down the oesophagus by a process known as peristalsis.
- Circular and longitudinal muscles along the wall of the alimentary canal contract and relax pushing the food along.

Digestion in the Stomach

- In the stomach, the food is mixed with gastric juice secreted by gastric glands in the stomach wall.
- Gastric juice contains pepsin, rennin and hydrochloric acid.
- The acid provides a low pH of 1.5-2.0 suitable for the action of pepsin.
- Pepsin breaks down protein into peptides.
- Rennin coagulates the milk protein casein.
- The stomach wall has strong circular and longitudinal muscles whose contraction mixes the food with digestive juices in the stomach.

Digestion in the Duodenum

- In the duodenum the food is mixed with bile and pancreatic juice.
- Bile contains bile salts and bile pigments.

- The salts emulsify fats, thus providing a large surface area for action of lipase.
- Pancreatic juice contains three enzymes:
  - Trypsin which breaks down proteins into peptides and amino acids,
  - Amylase which breaks down starch into maltose, and
  - Lipase which breaks down lipids into fatty acids and glycerol.
- These enzymes act best in an alkaline medium which is provided for by the bile.

Digestion in ileum

- Epithelial cells in ileum secrete intestinal juice, also known as succus entericus.
- This contains enzymes which complete the digestion of protein into amino acids, carbohydrates into monosaccharides and lipids into fatty acids and glycerol.

Absorption

- This is the diffusion of the products of digestion into the blood of the animal.
- It takes place mainly in the small intestines though alcohol and some glucose are absorbed in the stomach.

The ileum is adapted for absorption in the following ways:

- It is highly coiled.
- The coiling ensures that food moves along slowly to allow time for its digestion and absorption.
- It is long to provide a large surface area for absorption.
- The epithelium has many finger-like projections called villi (singular villus).

- They greatly increase the surface area for absorption.
- Villi have microvilli that further increase the surface area for absorption.
- The wall of villi has thin epithelial lining to facilitate fast diffusion of products of digestion.
- Has numerous blood vessels for transport of the end products of digestion.
- Has lacteal vessels; for absorption of fatty acids and glycerol and transport of lipids.

Absorption of Glucose and Amino Acids

- Glucose and other monosaccharides as well as amino acids are absorbed through the villi epithelium and directly into the blood capillaries.
- First they are carried to the liver through the hepatic portal vein, then taken to all organs via circulatory system.

Absorption of Fatty Acids and Glycerol

- Fatty acids and glycerol diffuse through the epithelial cells of villi and into the lacteal.
- When inside the villi epithelial cells, the fatty acids combine with glycerol to make tiny fat droplets which give the lacteal a milky appearance.

- The lacteals join the main lymph vessel that empties its contents into the bloodstream in the thoracic region.
- Once inside the blood, the lipid droplets are hydrolysed to fatty acids and glycerol.

Absorption of Vitamins and Mineral Salts

- Vitamins and mineral salts are absorbed into the blood capillaries in' the villi. Water is mainly absorbed in the colon.
- As a result the undigested food is in a semi-solid form (faeces) when it reaches the rectum.
- ***Egestion*:** This is removal of undigested or indigestible material from the body. Faeces are temporarily stored in the rectum then voided through the anus. Opening of the anus is controlled by sphincter muscles
- ***Assimilation:*** This is the incorporation of the food into the cells where it is used for various chemical processes.

Carbohydrates

- used to provide energy for the body.
- Excess glucose is converted to glycogen and stored in the liver and muscles.
- Some of the excess carbohydrates are also converted into fat in the liver and stored in the adipose tissue' (fat storage tissue), in the mesenteries and in the connective tissue under the skin, around the heart and other internal organs.

Proteins

- Amino acids are used to build new cells and repair worn out ones.
- They are also used for the synthesis of protein compounds.
- Excess amino acids are de-aminated in the liver.
- Urea is formed from the nitrogen part.
- The remaining carbohydrate portion is used for energy or it is converted to glycogen or fat and stored.

Lipids

- Fats are primarily stored in the fat storage tissues.
- When carbohydrates intake is low in the body, fats are oxidised to provide energy.
- They are also used as structural materials e.g. phospholipids in cell membrane. They act as cushion, protecting delicate organs like the heart.
- Stored fats under the skin act as heat insulators.

Summary of digestion in humans

Digestive and juice produced	*pH*	*Contents*	*Foo*	*Products*	*Notes*
		Water, mucus and salts			Soften and lubricate food, provide neutral pH.

Salivary	7.4				
(Saliva)		Amylase	Starch	Maltose	Glucose if food stays longer in mouth.
Stomach (Gastric	1'.8	Hydrochloric acid	Nucleo-protein	Nucleic acid + protein	Not an enzyme but hydrolyses the nuclear proteins. 1. Kills micro-organisms. 2. Provides acidic medium. 3. Activates enzyme precursors, pepsinogen and protennin.
		Rennin	Milk protein	Cud - coagulated milk (casein)	abundant in infants secreted as prorennin.
		Pepsin	Protein	Peptones	Secreted as pepsinogen
Pancrease (Pancreatic juice)	8.8	Trypsin	Protein	Peptones	Secreted as trypsinogen activated by enterokinase to trypsin
		Chymotrypsin	Pept	Amino acids	Secreted as chymotrypsin activated to trypsin.
		Amylase	Starch glycogen	Maltose Maltose	
				Fatty acids	PH in duodenum lowered to 5.5

		Lipase	Lipi	and glycerol	by acid from stomach
		Sodium bicarbonate			Provides alkaline conditions
Ileum (entericus)	8.3	Peptidases (erepsin)	Peptides	Amino acids	Erepsin contains a mixture of peptidases
		Invertase made of sucrase	Sucr	Fructose + glucose	
		Lactase	Lactose	Galactose + glucose	
		Maltase	Malt	Glucose	
		Lipase	Lipids	Fatty acids and glycerol	
		Enterokinase			Activates trypsinogen to trypsin.

TRANSPORT IN PLANTS AND ANIMALS.

Introduction

- Transport is the movement of substances within an organism.
- All living cells require oxygen and food for various metabolic processes.
- These substances must be transported to the cells.
- Metabolic processes in the cells produce excretory products which should be eliminated before they accumulate.
- The excretory products should be transported to sites of excretion.
- Organisms like amoeba are unicellular.
- They have a large surface area to volume ratio.
- The body is in contact with the environment.
- Diffusion is adequate to transport substances across the cell membrane and within the organism.
- Large multi-cellular organisms have complex structure where cells are far from each other hence diffusion alone cannot meet the demand for supply and removal of substances.
- Therefore an elaborate transport system is necessary.

Transport in plants

- Simple plants such as mosses and liverworts lack specialized transport system.
- Higher plants have specialized transport systems known as the vascular bundle.
- Xylem transports water and mineral salts .
- Phloem transports dissolved food substances like sugars.

Internal structure of roots and root hairs

- The main functions of roots are ;
  - Anchorage
  - absorption.
  - storage
  - gaseous exchange.
- The outermost layer in a root is the piliferous layer.
- This is a special epidermis of young roots whose cells give rise to root hairs.
- Root hairs are microscopic outgrowths of epidermal cells.
- They are found just behind the root tip,
- They are one cell thick for efficient absorption of substances.
- They are numerous and elongated providing a large surface area for absorption of water and mineral salts.
- Root hairs penetrate the soil and make close contact with it.
- Below the piliferous layer is the cortex.
- This is made up of loosely packed, thin walled parenchyma cells.
- Water molecules pass through this tissue to reach the vascuiar bundles.
- In some young plant stems, cortex cells contain chloroplasts.
- The endodermis (starch sheath) is a single layer of cells with starch grains.
- The endodermis has a casparian strip which has an impervious deposit controlling the entry of water and mineral salts into xylem vessels.
- Pericyc1e forms a layer next to the endodermis.
- Next to the pericycle is the vascular tissue.
- In the Dicotyledonous root, xylem forms a star shape in the centre, with phloem in between the arms.
- It has no pith. In monocotyledonous root, xylem alternates with phloem and there is a pith in the centre.

Internal structure of a root hair cell

The Stem

- The main functions of the stem are;
  - support and exposure of leaves and flowers to the environment,

- conducting water and mineral salts
- conducting manufactured food from leaves to other parts of the plant.

- In monocotyledonous stems, vascular bundles are scattered all over the stem, while in dicotyledonous stems vascular bundles are arranged in a ring.
- Vascular bundles are continuous from root to stems and leaves.
- The epidermis forms a single layer of cells enclosing other tissues.
- The outer walls of the cells have waxy cuticle to prevent excessive loss of water.
- The cortex is a layer next to the epidermis.
- It has collenchyma, parenchyma and schlerenchyma cells.

Collenchyma

- Is next to the epidermis and has thickened walls at the corners which strengthen the stem.

Parenchyma

- Cells are irregular in shape, thin walled and loosely arranged hence creating intercellular spaces filled with air.
- They are packing tissues and food storage areas.

Sclerenchyma

- Cells are closely connected to vascular bundles.
- These cells are thickened by deposition of lignin and they provide support to plants**.**

Pith

- Is the central region having parenchyma cells.

Absorption of Water and Mineral Salts Absorption of Water

- Root hair cell has solutes in the vacuole and hence a higher osmotic pressure than the surrounding soil water solution.
- Water moves into the root hair cells by osmosis along a concentration gradient.
- This makes the sap in the root hair cell to have a lower osmotic pressure than the surrounding cells.
- Therefore water moves from root hair cells into the surrounding cortex cells by osmosis.
- The process continues until the water gets into the xylem vessels .

Uptake of Mineral Salts

- If the concentration of mineral salts in solution is greater than its concentration in root hair cell, the mineral salts enter the root hair cell by diffusion.
- If the concentration of mineral salts in the root hair cells is greater than in the soil water, the mineral salts enter the root hairs by active transport.
- Most minerals are absorbed in this way.
- Mineral salts move from cell to cell by active transport until they reach the xylem vessel.

- Once inside the xylem vessels, mineral salts are transported in solution as the water moves up due to root pressure, capillary attraction and cohesion and adhesion forces.

Transpiration

- Transpiration is the process by which plants lose water in the form of water vapour into the atmosphere.
- Water is lost through ***stomata, cuticle and lenticels.***
- ***Stomatal transpiration*:**
  - This accounts for 80-90% of the total transpiration in plants.
  - Stomata are found on the leaves.

- ***Cuticular transpiration:***
  - The cuticle is found on the leaves, and a little water is lost through it.
  - Plants with thick cuticles do not lose water through the cuticle.

- ***Lenticular transpiration***
  - Is loss' of water through lenticels.
  - These are found on stems of woody plants.
  - Water lost through the stomata and cuticle by evaporation leads to evaporation of water from surfaces of mesophyll cells .
  - The mesophyll cells draw water from the xylem vessels by osmosis.
  - The xylem in the leaf is continuous with xy lem in the stem and root.

Structure and function of Xylem

- Movement of water is through the xylem.
- Xylem tissue is made up of vessels and tracheids.

Xylem Vessels

- Xylem vessels are formed from cells that are elongated along the vertical axis and arranged end to end.
- During development, the cross walls and organelles disappear and a continuous tube is formed.
- The cells are dead and their walls are strengthened by deposition of lignin.
- The lignin has been deposited in various ways.
- This results in different types of thickening
  - Annular.
  - Simple spiral.
  - Double spiral.
  - Reticulate.
- The bordered pits are areas without lignin on xylem vessels and allow passage of water in and out of the lumen to neighbouring cells.

Tracheids

- Tracheids have cross-walls that are perforated.
- Their walls are deposited with lignin.
- Unlike the xylem vessels, their end walls are tapering or chisel-shaped.
- Their lumen is narrower.
- Besides transport of water, xylem has another function of strengthening the plant which is provided by xylem fibres and xylem parenchyma.

Xylem fibres ;

- Are cells that are strengthened with lignin.
- They form wood.

Xylem parenchyma:

- These are cells found between vessels.
- They form the packing tissue.

Forces involved in Transportation of Water and Mineral Salts

Transpiration pull

- As water vaporises from spongy mesophyll cells into sub-stomatal air spaces, the cell sap of mesophyll cells develop a higher osmotic pressure than adjacent cells.
- Water is then drawn into mesophyll cells by osmosis from adjacent cells and finally from xylem vessels.
- A force is created in the leaves which pulls water from xylem vessels in the stem and root.
- This force is called ***transpiration pull .***

Cohesion and Adhesion:

- The attraction between water molecules is called cohesion.
- The attraction between water molecules and the walls of xylem vessels is called adhesion.
- The forces of cohesion and adhesion maintain a continuous flow of water in the xylem from the root to the leaves.

Capillarity:

- Is the ability of water to rise in fine capillary tubes due to surface tension.
- Xylem vessels are narrow, so water moves through them by capillarity.

Root Pressure:

- If the stem of a plant is cut above the ground level, it is observed that cell sap continues to come out of the cut surface.
- This shows that there is a force in the roots that pushes water up to the stem.
- This force is known as root pressure.

Importance of Transpiration

- Transpiration leads to excessive loss of water if unchecked.

Some beneficial effects are:

- Replacement of water lost during the process.
- Movement of water up the plant is by continuous absorption of water from the soil.
- Mineral salts are transported up the plant.
- Transpiration ensures cooling of the plant in hot weather.
- Excessive loss of water leads to wilting' and eventually death if water is not available in the soil.

Factors Affecting Transpiration

The factors that affect transpiration are grouped into two.

- i.e. environmental and structural.

Environmental factors

Temperature

- High temperature increases the internal temperature of the leaf .
- which in turn increases kinetic energy of water molecules which increases evaporation.
- High temperatures dry the air around the leaf surface maintaining a high concentration gradient.
- More water vapour is therefore lost from the leaf to the air.

Humidity

- The higher the humidity of the air around the leaf, the lower the rate of transpiration.
- The humidity difference between the inside of the leaf and the outside is called the saturation deficit.
- In dry atmosphere, the saturation deficit is high.
- At such times, transpiration rate is high.

Wind

- Wind carries away water vapour as fast as it diffuses out of the leaves.
- This prevents the air around the leaves from becoming saturated with vapour.
- On a windy day, the rate of transpiration is high.

Light Intensity

- When light intensity is high; more stomata open hence high rate of transpiration.

Atmospheric Pressure

- The lower the atmospheric pressure the higher the kinetic energy of water molecules hence more evaporation.
- Most of the plants at higher altitudes where atmospheric pressure is very low have adaptations to prevent excessive water-loss.

Availability of Water

- The more water there is in the soil, the more is absorbed by the plant and hence a lot of water is lost by transpiration.

Structural Factors

Cuticle

- Plants growing in arid or semi-arid areas have leaves covered with a thick waxy cuticle.

Stomata

- The more the stomata, the higher the rate of transpiration.
- Xerophytes have few stomata which reduce water-loss.
- Some have sunken stomata which reduces the rate of transpiration as the water vapour accumulates in the pits.
- Others have stomata on the lower leaf surface hence reducing the rate of water-loss.
- Some plants have reversed stomatal rhythm whereby stomata close during the day and open at night.
- This helps to reduce water-loss.

Leaf size and shape

- Plants in wet areas have large surface area for transpiration.
- Xerophytes have small narrow leaves to reduce water-loss.
- The photometer can be used to determine transpiration in different environmental conditions.

Translocation of organic compounds

- Translocation of soluble organic products of photosynthesis within a plant is called translocation.
- It occurs in phloem in sieve tubes.
- Substances translocated include glucose, amino acids, vitamins.
- These are translocated to the growing regions like stem, root apex, storage organs e.g. corms, bulbs and secretory organs such as nectar glands.

Phloem

phloem is made up of;

- sieve tubes,
- companion cells
- parenchyma, a packing tissue
- schlerenchyma, a strengthening tissue

Sieve Tubes

- These are elongated cells arranged end to end along the vertical axis.
- The cross walls are perforated by many pores to make a sieve plate.

- Most organelles disappear and those that remain are pushed to the sides of the sieve tube.
- Cytoplasmic strands pass through the pores in the plate into adjacent cells.
- Food substances are translocated through cytoplasmic strands.

Companion Cells

- Companion cells are small cells with large nuclei and many mitochondria.
- They are found alongside each sieve element.
- The companion cell is connected to the tube through plasmodesmata.
- The mitochondria generate energy required for translocation.

Phloem Parenchyma

- These are parenchyma cells between sieve elements.
- They act as packing tissue.

Transport in Animals

The Circulatory System

- Large and complex animals have circulatory systems that consist of tubes, a transport fluid and a means of pumping the fluid.
- ***Blood*** is the transport fluid which contains dissolved substances and cells.
- The tubes are blood vessels through which dissolved substances are circulated around the body.
- The heart is the pumping organ which keeps the blood in circulation.

The types of circulatory system exist in animals: open and closed.

- ***In an open circulatory system***;
  - The heart pumps blood into vessels which open into body spaces known as haemocoel.
  - Blood comes into contact with tissues.
- ***A closed circulatory system***;
  - Found in vertebrates and annelids where the blood is confined within blood vessels and does not come into direct contact with tissues.

Transport in Insects

- In an insect, there is a tubular heart just above the alimentary canal.
- This heart is suspended in a pericardial cavity by ligaments.
- The heart has five chambers and extends along the thorax and abdomen .
- Blood is pumped forwards into the aorta by waves of contractions in the heart.
- It enters the haemocoel and flows towards the posterior.
- The blood flows back into the heart through openings in each chamber called ostia.
- The ostia have valves which prevent the backflow of blood.
- Blood is not used as a medium for transport of oxygen in insects.
- This is because oxygen is supplied directly to the tissues by the tracheal system.

- The main functions of blood in an insect are to transport nutrients, excretory products and hormones.

Mammalian Circulatory System

- Mammals have a closed circulatory system where a powerful heart pumps blood into arteries.
- The arteries divide into smaller vessels called arterioles.
- Each arteriole divides to form a network of capillaries inside the tissues.
- The capillaries eventually re-unite to form venules, which form larger vessels called veins.
- The veins take the blood back to the heart.
- Blood from the heart goes through the pulmonary artery to the lungs and then back to the heart through pulmonary vein.
- This circulation is called pulmonary circulation.
- Oxygenated blood leaves the heart through the aorta and goes to all the tissues of the body.
- From the tissues, deoxygenated blood flows back to the heart through the vena cava.
- This circulation is called systemic circulation.
- In each complete circulation, the blood flows into the heart twice.
- This is called double circulation.
- Some other animals like fish have a single circulation.
- Blood flows only once through the heart for every complete circuit.

Structure and Function of the Heart

- The heart has four chambers:
- Two artria (auricles) and two ventricles.
- The left and right side of the heart are separated by a muscle wall (septum) so that oxygenated and deoxygenated blood does not mix.
- Deoxygenated blood from the rest of the body enters the heart through the vena cava .
- Blood enters the right atrium, then through tricuspid valve into right ventricle.
- Then via semi-lunar valve to the pulmonary artery to the lungs.
- Oxygenated blood from the lungs enters the heart through pulmonary vein.
- It enters the left atrium of the heart, then through bicuspid valve into left ventricle.
- Then via semi-lunar valves to aorta which takes oxygenated blood round the body.
- A branch of the aorta called coronary artery supplies blood to the heart muscle.
- The coronary vein carries blood from the heart muscle to the pulmonary artery which then takes it to the lungs for oxygenation.

Pumping Mechanism of the heart

- The heart undergoes contraction (systole) and relaxation (diastole).

Systole

- When the ventricular muscles contract, the cuspid valves (tricuspid and bicuspid) close preventing backflow of blood into auricles.
- The volume of the ventricles decreases while pressure increases.
- This forces blood out of the heart to the lungs through semi-lunar valves and pulmonary artery, and to the body tissues via semi-lunar valve and aorta respectively.
- At the same time the atria are filled with blood.
- The left ventricle has thicker muscles than the right ventricle, and pumps blood for a longer distance to the tissues.

Diastole

- When ventricular muscles relax, the volume of each ventricle increases while pressure decreases.
- Contractions of atria force the bicuspid and tricuspid valves to open allowing deoxygenated blood from right atrium into right ventricle which oxygenated blood flows from left atrium into the left ventricle.
- Semi-lunar valves close preventing the backflow of blood into ventricles.
- The slight contractions of atria force the , blood flow into ventricles.

The Heartbeat

- The heart is capable of contracting and relaxing rhythmically without fatigue due to its special muscles called cardiac muscles.
- The rhythmic contraction of the heart arise from within the heart muscles without nervous stimulation.
- The contraction is said to be myogenic.
- The heartbeat is initiated by the pacemaker or sino-artrio-node (SAN) which is located in the right atrium.
- The wave of excitation spreads over the walls of atria.
- It is picked by the artrio-ventricular node which is located at the junction:
- Of the atria and ventricles, from where the purkinje tissue spreads the wave to the walls of the ventricles.
- The heart contracts and relaxes rhythmically at an average rate of 72 times per minute.
- The rate of the heartbeat is increased by the sympathetic nerve, while it is slowed down by the vagus nerve.
- Heartbeat is also affected by hormones e.g. adrenaline raises the heartbeat.

Structure and Function of Arteries,Capillaries and Veins

Arteries

- Arteries carry blood away from the heart.
- They carry oxygenated blood except pulmonary artery which carries deoxygenated blood to the lungs.

- Arteries have a thick, muscular wall, which has elastic and collagen fibres that resist the pressure of the blood flowing in them.
- The high pressure is due to the pumping action of the heart.
- The pressure in the arteries originate from the pumping action of the heart.
- The pulse or number of times the heart beats per minute can be detected by applying pressure on an artery next to the bone.
- e.g. by placing the finger/thumb on the wrist.
- The innermost layer of the artery is called endothelium which is smooth.
- It offers least possible resistance to blood flow.
- Have a narrow lumen .
- The aorta forms branches which supply blood to all parts of the body.
- These arteries divide into arterioles which further divide to form capillaries.

Capillaries

- Capillaries are small vessels whose walls are made of endothelium which is one cell thick.
- This provides a short distance for exchange of substances.
- Capillaries penetrate tissues,
- The lumen is narrow therefore blood flowing in capillaries is under high pressure.
- Pressure forces water and dissolved substances out of the blood to form tissue fluid.

- Exchange of substances occurs between cells and tissue fluid.

- Part of the tissue fluid pass back into capillaries at the venule end.
- Excess fluid drains into small channels called lymph capillaries which empty their contents into lymphatic vessels.
- Capillaries join to form larger vessels called venules which in turn join to form veins which transport blood back to the heart.

Veins

- Veins carry deoxygenated blood from the tissues to the heart (except pulmonary vein which carries oxygenated blood from the lungs to the heart).
- Veins have a wider lumen than arteries.
- Their walls are thinner than those of arteries.
- **Blood pressure in the veins is low.**
- Forward flow of blood in veins is assisted by contraction of skeletal muscles, hence the need for exercise.
- Veins have valves along their length to prevent backflow of blood.
- This ensures that blood flows towards the heart.
- The way the valves work can be demonstrated on the arm.
- By pressing on one vein with two fingers, leaving one and pushing blood toward the heart then releasing the latter finger, it can be observed that the part in between is left with the vein not being visible.
- This is because bleed does not flow back towards the first finger.

Lymphatic System

- The lymphatic system consists of lymph vessels.

- Lymph vessels have valves to ensure unidirectional movement of lymph.
- Lymph is excess tissue fluid i.e. blood minus blood cells and plasma proteins.
- Flow of lymph is assisted by breathing and muscular contractions.
- Swellings called lymph glands occur at certain points along the lymph vessels.
- Lymph glands are oval bodies consisting of connective tissues and lymph spaces.
- The lymph spaces contain lymphocytes which are phagocytic.
- Lymph has the same composition as blood except that it does not contain red blood cells and plasma proteins.
- Lymph is excess tissue fluid.
- Excess tissue fluid is drained into lymph vessels by hydrostatic pressure.
- The lymph vessels unite to form major lymphatic system.
- The main lymph vessels empty the contents into sub-clavian veins which take it to the heart.

GASEOUS EXCHANGE IN PLANTS AND ANIMALS

Necessity for Gaseous Exchange in Living Organisms

- Living organisms require energy to perform cellular activities.
- The energy comes from breakdown of food in respiration.
- Carbon (IV) oxide is a by product of respiration and its accumulation in cells is harmful which has to be removed.
- Most organisms use oxygen for respiration which is obtained from the environment.
- Photosynthetic cells of green plants use carbon (Iv) oxide as a raw material for photosynthesis and produce oxygen as a byproduct.
- The movement of these gases between the cells of organisms and the environment comprises gaseous exchange.
- The process of moving oxygen into the body and carbon (Iv) oxide out of the body is called breathing or ventilation.
- Gaseous exchange involves the passage of oxygen and carbon (IV) oxide through a respiratory surface.
- Diffusion is the main process involved in gaseous exchange.

Gaseous Exchange in Plants

- Oxygen is required by plants for the production of energy for cellular activities.
- Carbon (IV) oxide is required as a raw material for the synthesis of complex organic substances.

- Oxygen and carbon (IV) oxide are obtained from the atmosphere in the case of terrestrial plants and from the surrounding water in the case of aquatic plants.
- Gaseous exchange takes place mainly through the stomata.

Structure of Guard Cells

- The stoma (stomata - plural) is surrounded by a pair of guard cells.
- The structure of the guard cells is such that changes in turgor inside the cell cause changes in their shape.
- They are joined at the ends and the cell walls facing the pore (inner walls) are thicker and less elastic than the cell walls farther from the pore (outer wall).
- Guard cells control the opening and closing of stomata.

Mechanism of Opening and Closing of Stomata

- In general stomata open during daytime (in light) and close during the night (darkness).
- Stomata open when osmotic pressure in guard cells becomes higher than that in surrounding cells due to increase in solute concentration inside guard cells. Water is then drawn into guard cells by osmosis.
- Guard cells become turgid and extend.
- The thinner outer walls extend more than the thicker walls.
- This causes a bulge and stoma opens.
- Stomata close when the solute concentration inside guard cells become lower than that of surrounding epidermal cells.
- The water moves out by osmosis, and the guard cells shrink i.e. lose their turgidity and stoma closes.

Proposed causes of turgor changes in guard cells.

Accumulation of sugar.

- Guard cells have chloroplasts while other epidermal cells do not.
- Photosynthesis takes place during daytime and sugar produced raises the solute concentration of guard cells.
- Water is drawn into guard cells by osmosis from surrounding cells.
- Guard cells become turgid and stoma opens.
- At night no photosynthesis occurs hence no sugar is produced.
- The solute concentration of guard cells falls and water moves out of the guard cells by osmosis.
- Guard cells lose turgidity and the stoma closes.

pH changes in guard cells occur due to photosynthesis.

- In day time carbon (IV) oxide is used for photosynthesis. This reduces acidity while the oxygen produced increases alkalinity.
- Alkaline pH favours conversion of starch to sugar.

- Solute concentration increases inside guard cells, water is drawn into the cells by osmosis. Guard cells become turgid and the stoma opens.
- At night when no photosynthesis, Respiration produces carbon (IV) oxide which raises acidity .This favours conversion of sugar to starch. low sugar concentration lead to loss of turgidity in guard cells and stoma closes.

Explanation is based on accumulation of potassium ions

- In day time (light) adenosine triphosphate (ATP) is produced which causes potassium ions to move into guard cells by active transport.
- These ions cause an increase in solute concentration in guard cells that has been shown to cause movement of water into guard cells by osmosis.
- Guard cells become turgid and the stoma opens.
- At night potassium and chloride ions move out of the guard cells by diffusion and level of organic acid also decreases.
- This causes a drop in solute concentration that leads to movement of water out of guard cells by osmosis.
- Guard cells lose turgor and the stoma closes.

Process of Gaseous Exchange in Root Stem and Leaves of Aquatic and Terrestrial Plants

Gaseous Exchange in leaves of Terrestrial Plants

- Gaseous exchange takes place by diffusion.
- The structure of the leaf is adapted for gaseous exchange by having intercellular spaces that are filled.
- These are many and large in the spongy mesophyll.
- When stomata are open,carbon(IV)oxide from the atmosphere diffuses into the substomatal air chambers.
- From here, it moves into the intercellular space in the spongy mesophyll layer.
- The CO_2 goes into solution when it comes into contact with the cell surface and diffuses into the cytoplasm.
- A concentration gradient is maintained between the cytoplasm of the cells and the intercellular spaces.
- CO_2 therefore continues to diffuse into the cells.
- The oxygen produced during photosynthesis moves out of the cells and into the intercellular spaces.
- From here it moves to the substomatal air chambers and eventually diffuses out of the leaf through the stomata.
- At night oxygen enters the cells while CO_2 moves out.

Gaseous exchange in the leaves of aquatic(floating)plants

- Aquatic plants such as water lily have stomata only on the upper leaf surface.
- The intercellular spaces in the leaf mesophyll are large.
- Gaseous exchange occurs by diffusion just as in terrestrial plants.

Observation of internal structure of leaves of aquatic plants

- Transverse section of leaves of an aquatic plant such as Nymphaea differs from that of terrestrial plant.

The following are some of the features that can be observed in the leave of an aquatic plant;

- Absence of cuticle
- Palisade mesophyll cells are very close to each other ie.compact.
- Air spaces (aerenchyma) in spongy mesophyll are very large.
- Sclereids (stone cells) are scattered in leaf surface and project into air spaces.
- They strengthen the leaf making it firm and assist it to float.

Gaseous Exchange Through Stems

Terrestrial Plants

- Stems of woody plants have narrow openings or slits at intervals called **lenticels.**
- They are surrounded by loosely arranged cells where the bark is broken.
- They have many large air intercellular spaces through which gaseous exchange occurs.
- Oxygen enters the cells by diffusion while carbon (IV) oxide leaves.
- Unlike the rest of the bark, lenticels are permeable to gases and water.

Aquatic Plant Stems

- The water lily, *Salvia* and *Wolfia* whose stems remain in water are permeable to air and water.
- Oxygen dissolved in the water diffuses through the stem into the cells and carbon (IV) oxide diffuses out into the water.

Gaseous Exchange in Roots

Terrestrial Plants

- Gaseous exchange occurs in the root hair of young terrestrial plants.
- Oxygen in the air spaces in the soil dissolves in the film of moisture surrounding soil particles and diffuses into the root hair along a concentration gradient.
- It diffuses from root hair cells into the cortex where it is used for respiration.
- Carbon (IV) oxide diffuses in the opposite direction.
- In older roots of woody plants, gaseous exchange takes place through lenticels.

Aquatic Plants

- Roots of aquatic plants e.g. water lily are permeable to water and gases.
- Oxygen from the water diffuses into roots along a concentration gradient.
- Carbon (IV) oxide diffuses out of the roots and into the water.
- The roots have many small lateral branches to increase the surface area for gaseous exchange.

- They have air spaces that help the plants to float.
- Mangroove plants grow in permanently waterlogged soils, muddy beaches and at estuaries.
- They have roots that project above the ground level.
- These are known as breathing roots or pneumatophores.
- These have pores through which gaseous exchange takes place e.g. in *Avicenia* the tips of the roots have pores.
- Others have respiratory roots with large air spaces.

Gaseous Exchange in Animals

- All animals take in oxygen for oxidation of organic compounds to provide energy for cellular activities.
- The carbon (IV) oxide produced as a by-product is harmful to cells and has to be constantly removed from the body.
- Most animals have structures that are adapted for taking in oxygen and for removal of carbon (IV) oxide from the body.
- These are called "respiratory organs".
- The process of taking in oxygen into the body and carbon (IV) oxide out of the body is called breathing or ventilation.
- Gaseous exchange involves passage of oxygen and carbon (IV) oxide through a respiratory surface by diffusion.

Types and Characteristics of Respiratory surfaces

Different animals have different respiratory surfaces.

- The type depends mainly on the habitat of the animal, size, shape and whether body form is complex or simple.
- ***Cell Membrane***: In unicellular organisms the cell membrane serves as a respiratory surface.
- ***Gills:*** Some aquatic animals have gills which may be external as in the tadpole or internal as in bony fish e.g. tilapia.
- They are adapted for gaseous exchange in water.
- ***Skin:*** Animals such as earthworm and tapeworm use the skin or body surface for gaseous exchange.
- The skin of the frog is adapted for gaseous exchange both in water and on land.
- The frog also uses ***epithelium lining of the mouth or buccal cavity*** for gaseous exchange.
- ***Lungs:*** Mammals, birds and reptiles have lungs which are adapted for gaseous exchange.

Characteristics of Respiratory Surfaces

- They are permeable to allow entry of gases.
- They have a large surface area in order to increase diffusion.
- They are usually thin in order to reduce the distance of diffusion.
- They are moist to allow gases to dissolve.
- They are well-supplied with blood to transport gases and maintain a concentration gradient.

Gaseous Exchange in Amoeba

- Gaseous exchange occurs across the cell membrane by diffusion.
- Oxygen diffuses in and carbon (IV) oxide diffuses out.
- Oxygen is used in the cell for respiration making its concentration lower than that in the surrounding water.
- Hence oxygen continually enters the cell along a concentration gradient.
- Carbon (IV) oxide concentration inside the cell is higher than that in the surrounding water thus it continually diffuses out of the cell along a concentration gradient.

Gaseous Exchange in Insects

- Gaseous exchange in insects e.g., grasshopper takes place across a system of tubes penetrating into the body known as the tracheal system.
- The main trachea communicate with atmosphere through tiny pores called spiracles.
- Spiracles are located at the sides of body segments;

- Two pairs on the thoracic segments and eight pairs on the sides of abdominal segments.
- Each spiracle lies in a cavity from which the trachea arises.
- Spiracles are guarded with valves that close and thus prevent excessive loss of water vapour.
- A filtering apparatus i.e. hairs also traps dust and parasites which would clog the trachea if they gained entry.
- The valves are operated by action of paired muscles.

Mechanism of Gaseous Exchange in Insects

- The main tracheae in the locust are located laterally along the length of the body on each side and they are interconnected across.
- Each main trachea divides to form smaller tracheae, each of which branches into tiny tubes called tracheoles.
- Each tracheole branches further to form a network that penetrates the tissues. Some tracheoles penetrate into cells in active tissue such as flight muscles.
- These are referred to as intracellular tracheoles.
- Tracheoles in between the cells are known as intercellular tracheoles.
- The main tracheae are strengthened with rings of cuticle.
- This helps them to remain open during expiration when air pressure is low.

Adaptation of Insect Tracheoles for Gaseous Exchange

- The fine tracheoles are very thin about one micron in diameter in order to permeate tissue.
- They are made up of a single epithelial layer and have no spiral thickening to allow diffusion of gases.
- Terminal ends of the fine tracheoles are filled with a fluid in which gases dissolve to allow diffusion of oxygen into the cells.

- Amount of fluid at the ends of fine tracheoles varies according to activity i.e. oxygen demand of the insect.
- During flight, some of the fluid is withdrawn from the tracheoles such that oxygen reaches muscle cells faster and the rate of respiration is increased.
- In some insects, tracheoles widen at certain places to form air sacs.
- These are inflated or deflated to facilitate gaseous exchange as need arises.
- Atmospheric air that dissolves in the fluid at the end of tracheoles has more oxygen than the surrounding cells of tracheole epithelium'.
- Oxygen diffuses into these cells along a concentration gradient. '
- Carbon (IV) oxide concentration inside the cells is higher than in the atmospheric .
- Air and diffuses out of the cells along a concentration gradient.
- It is then removed with expired air.

Ventilation in Insects

- Ventilation in insects is brought about by the contraction and relaxation of the abdominal muscles.
- In locusts, air is drawn into the body through the thoracic spiracles and expelled through the abdominal spiracles.
- Air enters and leaves the tracheae as abdominal muscles contract and relax.
- **The muscles contract laterally so the** abdomen becomes wider and when they relax it becomes narrow.
- Relaxation of muscles results in low pressure hence inspiration occurs while contraction of muscles results in higher air pressure and expiration occurs.
- In locusts, air enters through spiracles in the thorax during inspiration and leaves through the abdominal spiracles during expiration.
- This results in efficient ventilation.
- Maximum extraction of oxygen from the air occurs sometimes when all spiracles close and hence contraction of abdominal muscles results in air circulating within the tracheoles.
- The valves in the spiracles regulate the opening and closing of spiracles.

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Gaseous Exchange in Bony Fish (e.g, Tilapia)

- Gaseous exchange in fish takes place between the gills and the surrounding water.
- The gills are located in an opercular cavity covered by a flap of skin called the operculum.
- Each _gill consists of a number of thin leaf-like lamellae projecting from a skeletal base branchial arch (gill bar) situated in the wall of the pharynx.
- There are four gills within the opercular cavity on each side of the head.
- Each gill is made up of a bony gill arch which has a concave surface facing the mouth cavity (anterior) and a convex posterior surface.
- Gill rakers are bony projections on the concave side that trap food and other solid particles which are swallowed instead of going over and damaging the gill ftlaments.
- Two rows of gill filaments subtend from the convex surface.

Adaptation of Gills for Gaseous Exchange

- Gill filaments are thin walled.
- Gill filaments are very many (about seventy pairs on each gill), to increase surface area.
- Each gill filament has very many gill lamellae that further increase surface area.
- The gill filaments are served by a dense network of blood vessels that ensure efficient transport of gases.
- It also ensures that a favourable diffusion gradient is maintained.
- The direction of flow of blood in the gill lamellae is in the opposite direction to that of the water (counter current flow) to ensure maximum diffusion of gases.

Ventilation

- As the fish opens the mouth, the floor of the mouth is lowered.
- This increases the volume of the buccal cavity.
- Pressure inside the mouth is lowered causing water to be drawn into the buccal cavity.
- Meanwhile, the operculum is closed, preventing water from entering or leaving through the opening.
- As the mouth closes and the floor of the mouth is raised, the volume of buccal cavity decreases while pressure in the opercular cavity increases due to contraction of opercular muscles.
- The operculum is forced to open and water escapes.
- As water passes over the gills, oxygen is absorbed and carbon dioxide from the gills dissolves in the water.
- As the water flows over the gill filaments oxygen in the water is at a higher concentration than that in the blood flowing, in the gill.
- Oxygen diffuses through the thin walls of gill filaments/lamellae into the blood.
- Carbon (IV) oxide is at a higher concentration in the blood than in the water.
- It diffuses out of blood through walls of gill filaments into the water.

Counter Current Flow

- In the bony fish direction of flow of water over the gills is opposite that of blood flow through the gill filaments .
- This adaptation ensures that maximum amount of oxygen diffuses from the water into the blood in the gill filament.
- This ensures efficient uptake of oxygen from the water.
- Where the flow is along the same direction (parallel flow) less oxygen is extracted from the water.

Gaseous Exchange in an Amphibian - Frog

- An adult frog lives on land but goes back into the water during the breeding season.
- A frog uses three different respiratory surfaces.

- These are the ***skin, buccal cavity and lungs.***

Skin

- The skin is used both in water and on land.
- It is quite efficient and accounts for 60% of the oxygen taken in while on land.

Adaptations of a Frog's Skin for Gaseous Exchange

- The skin is a thin epithelium to allow fast diffusion.
- The skin between the digits in the limbs (i.e. webbed feet) increase the surface area for gaseous exchange.
- It is richly supplied with blood vessels for transport of respiratory gases.
- The skin is kept moist by secretions from mucus glands.
- This allows for respiratory gases to dissolve.
- Oxygen dissolved in the film of moisture diffuses across the thin epithelium and into the blood which has a lower concentration of oxygen.
- Carbon (IV) oxide diffuses from the blood across the skin to the atmosphere along the concentration gradient.

Buccal (Mouth) Cavity

- Gaseous exchange takes place all the time across thin epithelium lining the mouth cavity.
- Adaptations of Buccal Cavity for Gaseous Exchange
- It has a thin epithelium lining the walls of the mouth cavity allowing fast diffusion of gases.
- It is kept moist by secretions from the epithelium for dissolving respiratory gases.
- It has a rich supply of blood vessels for efficient transport of respiratory gases.
- The concentration of oxygen in the air within the mouth cavity is higher than that of the blood inside the blood vessels.
- Oxygen, therefore dissolves in the moisture lining the mouth cavity and then diffuses into the blood through the thin epithelium.
- On the other hand, carbon (IV) oxide diffuses in the opposite direction along a concentration gradient.

Lungs

- There is a pair of small lungs used for gaseous exchange.

Adaptation of Lungs

- The lungs are thin walled for fast diffusion of gases.
- Have internal foldings to increase surface area for gaseous exchange.
- A rich supply of blood capillaries for efficient transport of gases.

- Moisture lining for gases to dissolve.

Ventilation

Inspiration

- During inspiration, the floor of the mouth is lowered and air is drawn in through the nostrils.
- When the nostrils are closed and the floor of the mouth is raised, air is forced into the lungs.
- Gaseous exchange occurs in the lungs, oxygen dissolves in the moisture lining of the lung and diffuses into the blood through the thin walls.
- Carbon (IV) oxide diffuses from blood into the lung lumen.

Expiration

- When the nostrils are closed and the floor of mouth is lowered by contraction of its muscles, volume of mouth cavity increases.
- Abdominal organs press against the lungs and force air out of the lungs into buccal cavity.
- Nostrils open and floor of the mouth is raised as its muscles relax.
- Air is forced out through the nostrils.

Gaseous Exchange in a Mammal -Human

- The breathing system of a mammal consists of a pair of **lungs** which are thin-walled elastic sacs lying in the thoracic cavity.
- The thoracic cavity consists of vertebrae, sternum, ribs and intercostal muscles.
- The thoracic cavity is separated from the abdominal cavity by the diaphragm.
- The lungs lie within the thoracic cavity.
- They are enclosed and protected by the ribs which are attached to the sternum and the thoracic vertebrae.
- There are twelve pairs of ribs, the last two pairs are called 'floating ribs' because they are only attached to the vertebral column.
- The ribs are attached to and covered by internal and external intercostals muscles.
- The diaphragm at the floor of thoracic cavity consists of a muscLe sheet at the periphery and a central circular fibrous tissue.
- The muscles of the diaphragm are attached to the thorax wall.
- The lungs communicate with the outside atmosphere through the bronchi, trachea, mouth and nasal cavities.
- The trachea opens into the mouth cavity through the larynx.
- A flap of muscles, the epiglottis, covers the opening into the trachea during swallowing.
- This prevents entry of food into the trachea.
- Nasal cavities are connected to the atmosphere through the external nares(or nostrils)which are lined with hairs and mucus that trap dust particles and bacteria, preventing them from entering into the lungs.
- Nasal cavities are lined with cilia.
- The mucus traps dust particles,

- The cilia move the mucus up and out of the nasal cavities.
- The mucus moistens air as it enters the nostrils.
- Nasal cavities are winding and have many blood capillaries to increase surface area to ensure that the air is warmed as it passes along.
- Each lung is surrounded by a space called the pleural cavity.
- It allows for the changes in lung volume during breathing.
- An internal pleural membrane covers the outside of each lung while an external pleural membrane lines the thoracic wall.
- The pleural membranes secrete pleural fluid into the pleural cavity.
- This fluid prevents friction between the lungs and the thoracic wall during breathing.
- The trachea divides into two bronchi, each of which enters into each lung.
- Trachea and bronchi are lined with rings of cartilage that prevent them from collapsing when air pressure is low.
- Each bronchus divides into smaller tubes, the bronchioles.
- Each bronchiole subdivides repeatedly into smaller tubes ending with fine bronchioles.
- The fine bronchioles end in alveolar sacs, each of which gives rise to many alveoli.
- Epithelium lining the inside of the trachea, bronchi and bronchioles has cilia and secretes mucus.

Adaptations of Alveolus to Gaseous Exchange

- Each alveolus is surrounded by very many blood capillaries for efficient transport of respiratory gases.
- There are very many alveoli that greatly increases the surface area for gaseous exchange.
- The alveolus is thin walled for faster diffusion of respiratory gases.
- The epithelium is moist for gases to dissolve.

Gaseous Exchange Between the Alveoli and the Capillaries

- The walls of the alveoli and the capillaries are very thin and very close to each other.
- Blood from the tissues has a high concentration of carbon (IV) oxide and very little oxygen compared to alveolar air.
- The concentration gradient favours diffusion of carbon (IV) oxide into the alveolus and oxygen into the capillaries .
- No gaseous exchange takes place in the trachea and bronchi.
- These are referred to as dead space.

Ventilation

- Exchange of air between the lungs and the outside is made possible by changes in the volumes of the thoracic cavity.
- This volume is altered by the movement of the intercostal muscles and the diaphragm.

Inspiration

- The ribs are raised upwards and outwards by the contraction of the external intercostal muscles, accompanied by the relaxation of internal intercostal muscles.
- The diaphragm muscles contract and diaphragm moves downwards.
- The volume of thoracic cavity increases, thus reducing the pressure.
- Air rushes into the lungs from outside through the nostrils.

Expiration

- The internal intercostal muscles contract while external ones relax and the ribs move downwards and inwards.
- The diaphragm muscles relaxes and it is pushed upwards by the abdominal organs. It thus assumes a dome shape.
- The volume of the thoracic cavity decreases, thus increasing the pressure.
- Air is forced out of the lungs.
- As a result of gaseous exchange in the alveolus, expired air has different volumes of atmospheric gases as compared to inspired air.

Lung Capacity

- The amount of air that human lungs can hold is known as lung capacity.
- The lungs of an adult human are capable of holding 5,000 cm^3 of air when fully inflated.
- However, during normal breathing only about 500 cm^3 of air is exchanged.
- This is known as the tidal volume.
- A small amount of air always remains in the lungs even after a forced expiration.
- This is known as the residual volume.
- The volume of air inspired or expired during forced breathing is called vital capacity.

Control of Rate Of Breathing

- The rate of breathing is controlled by the respiratory centre in the medulla of the brain.
- This centre sends impulses to the diaphragm through the phrenic nerve.
- Impulses are also sent to the intercostal muscles.
- The respiratory centre responds to the amount of carbon (IV) oxide in the blood.
- If the amount of carbon (IV) oxide rises, the respiratory centre sends impulses to the diaphragm and the intercostal muscles which respond by contracting in order to increase the ventilation rate.
- Carbon (IV) oxide is therefore removed at a faster rate.

Factors Affecting Rate of Breathing in Humans

- Factors that cause a decrease or increase in energy demand directly affect rate of breathing.
- Exercise, any muscular activity like digging.
- Sickness
- Emotions like anger, flight
- Sleep.

Respiration

Meaning and Significance of Respiration

- Respiration is the process by which energy is liberated from organic compounds such as glucose.
- It is one of the most important characteristics of living organisms.
- Energy is expended (used) whenever an organism exhibits characteristics of life, such as feeding, excretion and movement.
- Respiration occurs all the time and if it stops, cellular activities are disrupted due to lack of energy.
- This may result in death e.g., if cells in brain lack oxygen that is needed for respiration for a short time, death may occur.
- This is because living cells need energy in order to perform the numerous activities necessary to maintain life.
- The energy is used in the cells and much of it is also lost as heat.
- In humans it is used to maintain a constant body temperature.

Tissue Respiration

- Respiration takes place inside cells in all tissues.
- Every living cell requires energy to stay alive.
- Most organisms require oxygen of the air for respiration and this takes place in the mitochondria.

Mitochondrion Structure and Function

Structure

- Mitochondria are rod-shaped organelles found in the cytoplasm of cells.
- A mitochondrion has a smooth outer membrane and a folded inner membrane.
- The folding of the inner membrane is called cristae and the inner compartment is called the matrix.

Adaptations of Mitochondrion to its Function

- The matrix contains DNA ribosomes for making proteins and has enzymes for the breakdown of pyruvate to carbon (IV) oxide, hydrogen ions and electrons.
- Cristae increase surface area of mitochondrial inner membranes where attachment of enzymes needed for the transport of hydrogen ions and electrons are found.
- There are two types of respiration:
  - Aerobic Respiration
  - Anaerobic. Respiration

Aerobic Respiration

- This involves breakdown of organic substances in tissue cells in the presence of oxygen .
- All multicellular organisms and most unicellular organisms e.g. some bactena respire aerobically.
- In the process, glucose is fully broken down to carbon (IV) oxide and hydrogen which forms water when it combines with the oxygen.
- Energy produced is used to make an energy rich compound known as adenosine triphosphate (ATP).
- It consists of adenine, an organic base, five carbon ribose-sugar and three phosphate groups.
- ATP is synthesised from adenosine diphosphate (ADP) and inorganic phosphate.
- The last bond connecting the phosphate group is a high-energy bond.
- Cellular activities depend directly on ATP as an energy source.
- When an ATP molecule is broken down, it yields energy.

Process of Respiration

- The breakdown of glucose takes place in many steps.
- Each step is catalysed by a specific enzyme.
- Energy is released in some of these steps and as a result molecules of ATP are synthesised.
- All the steps can be grouped into three main stages:

Glycolysis.

- The initial steps in the breakdown of glucose are referred to as glycolysis and they take place in the cytoplasm.
- Glycolysis consists of reactions in which glucose is gradually broken down into molecules of a carbon compound called pyruvic acid or pyruvate.

- Before glucose can be broken, it is first activated through addition of energy from ATP and phosphate groups.
- This is referred to as phosphorylation.
- The phosphorylated sugar is broken down into two molecules of a 3-carbon sugar (triose sugar) each of which is then converted into pyruvic acid.
- If oxygen is present, pyruvic acid is converted into a 2-carbon compound called acetyl coenzyme A (acetyl Co A).
- Glycolysis results in the net production of two molecules of ATP.
- The next series of reactions involve decarboxylation i.e. removal of carbon as carbon (IV) oxide and dehydrogenation, removal of hydrogen as hydrogen ions and electrons.
- These reactions occur in the mitochondria and constitute the Tri-carboxylic Acid Cycle (T.C.A.) or Kreb's citric acid cycle.
- The acetyl Co A combines with 4-carbon compound with oxalo-acetic acid to form citric acid - a 6 carbon compound.
- The citric acid is incorporated into a cyclical series of reactions that result in removal of carbon (IV) oxide molecules, four pairs of hydrogen, ions and electrons.
- Hydrogen ions and electrons are taken to the inner mitochondria membrane where enzymes and electron carriers effect release of a lot of energy.
- Hydrogen finally combines with oxygen to form water, and 36 molecules of ATP are synthesised.

Anaerobic Respiration

- Anaerobic respiration involves breakdown of organic substances in the absence of oxygen.
- It takes place in some bacteria and some fungi.
- Organisms which obtain energy by anaerobic respiration are referred to as anaerobes.
- Obligate anaerobes are those organisms which do not require oxygen at all and may even die if oxygen is present.
- Facultative anaerobes are those organisms which survive either in the absence or in the presence of oxygen.
- Such organisms tend to thrive better when oxygen is present e.g. yeast.

Products of Anaerobic Respiration

- The products of anaerobic respiration differ according to whether the process is occurring in plants or animals.

Anaerobic Respiration in Plants

- Glucose is broken down to an alcohol, (ethanol) and carbon (IV) oxide.
- The breakdown is incomplete.
- Ethanol is an organic compound, which can be broken down further in the presence of oxygen to provide energy, carbon (IV) oxide and water.

$$C_6H_{12}0_6 \rightarrow 2C_2H_50H + 2C0_2 + \text{Energy}$$

(Glucose) (Ethanol) (Carbon (IV) oxide)

Fermentation-

- Is the term used to describe formation of ethanol and carbon (IV) oxide from grains.
- Yeast cells have enzymes that bring about anaerobic respiration.

Lactate Fermentation

- Is the term given to anaerobic respiration in certain bacteria that results in formation of lactic acid.

Anaerobic Respiration in Animals

- Anaerobic respiration in animals produces lactic acid and energy.

$$C_6H_1P6 \_ 2CH_3CHOH.COOH + energy$$

(Glucose) (Lactic acid) + energy

- When human muscles are involved in very vigorous activity, oxygen cannot be delivered as rapidly as it is required.
- The muscle respire anaerobically and lactic acid accumulates.
- A high level of lactic acid is toxic.
- During the period of exercise, the body builds up an oxygen debt.
- After vigorous activity, one has to breathe faster and deeper to take in more oxygen.
- Rapid breathing occurs in order to break down lactic acid into carbon (IV) oxide and water and release more energy.
- Oxygen debt therefore refers to the extra oxygen the body takes in after vigorous exercise.

Comparison Between Aerobic and Anaerobic Respiration

	Aerobic Respiration	*Anaerobic Respiration*
1. Site	In the mitochondria	In the cytoplasm
2. Products	Carbon dioxide and	Ethanol in plants and lactic
3. Energy yield	38 molecules of A TP (2880 KJ) from each molecule of glucose.	2 molecules of ATP 210KJ from each molecule of glucose.
4. Further reaction	No further reactions on carbon dioxide and water.	Ethanol and lactic acid can be broken down further in the presence of oxygen

Comparison Between Energy Output in Aerobic and Anaerobic Respiration

- Aerobic respiration results in the formation of simple inorganic molecules, water and carbon (Iv) oxide as the byproducts.
- These cannot be broken down further. A lot of energy is produced.
- When a molecule of glucose is broken down in the presence of oxygen, 2880 KJ of energy are produced (38 molecules of ATP).
- In anaerobic respiration the by products are organic compounds.
- These can be broken down further in the presence of oxygen to give more energy.
- Far less energy is thus produced.
- The process is not economical as far as energy production is concerned.
- When a molecule of glucose is broken down in the absence of oxygen in plants, 210 KJ are produced (2 molecule ATP).
- In animals, anaerobic respiration yields 150 kJ of energy.

Substrates for Respiration

- Carbohydrate, mainly glucose is the main substrate inside cells.
- Lipids i.e. fatty acids and glycerol are also used.
- Fatty acids are used when the carbohydrates are exhausted.
- A molecule of lipid yields much more energy than a molecule of glucose.
- Proteins are not normally used for respiration.
- However during starvation they are hydrolysed to amino acids, dearnination follows and the products enter Kreb's cycle as urea is formed.
- Use of body protein in respiration result to body wasting, as observed during prolonged sickness or starvation.
- The ratio of the amount of carbon (IV) oxide produced to the amount of oxygen used for each substrate is referred to as Respiratory Quotient (RQ) and is calculated as follows:

$$\text{R.Q.} = \frac{\text{Amount of carbon (IV) oxide produced}}{\text{Amount of oxygen used}}$$

- Carbohydrates have a respiratory quotient of 1.0 lipids 0.7 and proteins 0.8.
- Respiratory quotient value can thus give an indication of types of substrate used.
- Besides values higher than one indicate that some anaerobic respiration is taking place.

Application of Anaerobic Respiration in Industry and at Home

Industry

- Making of beer and wines.
- Ethanol in beer comes from fermentation of sugar (maltose) in germinating barley seeds.
- Sugar in fruits is broken down anaerobically to produce ethanol in wines.

- In the dairy industry, bacterial fermentation occurs in the production of several dairy products such as cheese, butter and yoghurt.
- In production of organic acids e.g., acetic acid, that are used in industry e.g., in preservation of foods.

Home

- Fermentation of grains is used to produce all kinds of beverages e.g., traditional beer and sour porridge.
- Fermentation of milk.

REPRODUCTION IN PLANTS AND ANIMALS

Introduction

- The process by which mature individuals produce offspring is called reproduction.
- Reproduction is a characteristic of all living organisms and prevents extinction of a species.
- There are two types of reproduction: sexual and asexual reproduction.
- Sexual reproduction involves the fusion of male and female gametes to form a zygote.
- Asexual reproduction does not involve gametes.

Cell Division

- Cell division starts with division of nucleus.
- In the nucleus are a number of thread-like structures called chromosomes, which occur in pairs known as homologous chromosomes.
- Each chromosome contains-genes that determine the characteristics of an organism.
- The cells in each organism contains a specific number of chromosomes.

Asexual Reproduction

- Asexual reproduction is the formation of offspring from a single parent.
- The offspring are identical to the parent.

Types of asexual reproduction.

- Binary fission in amoeba.
- Spore formation in *Rhizopus.*

- Budding in yeast.

Binary fission

- This involves the division of the parent organism into two daughter cells.
- The nucleus first divides into two and then the cytoplasm separates into two portions
- Binary fission also occurs in bacteria.

Spore formation in Rhizopus

- *Rhizopus* is a saprophytic fungus which grows on various substrate such as bread, rotting fruits or other decaying organic matter.
- The vegetative body is called mycelium which has many branched threads called hyphae.
- Horizontal hyphae are called stolons.
- Vertical hyphae are called sporangiophore.
- The tips of sporangiophore become swollen to form sporangia, the spore bearing structure.
- Each sporangium contains many spores.
- As it matures and ripens, it turns black in colour.
- When fully mature the sporangium wall burst and release spores which are dispersed by wind or insects.
- When spores land on moist substratum, they germinate and grow into a new *Rhizopus* and start another generation.

Spore formation in ferns

- The fern plant is called a sporophyte.
- On the lower side of the mature leaves are sari (Singular: sorus) which bear spores.

Budding in Yeast

- Budding involves the formation of a protrusion called a bud from the body of the organism.
- The bud separates from the parent cell, in yeast budding goes on so fast and the first bud starts to form another bud before the separation.
- A short chain or mass of cells is formed.

Sexual reproduction versus asexual reproduction

Advantages of Asexual Reproduction

- Good qualities from parents are retained in the offspring without variation.

- New individuals produced asexually mature faster.
- Process does not depend on external factors which may fail such as pollination.
- New individuals obtain nourishment from parent and so are able to survive temporarily under unsuitable conditions.
- No indiscriminate spreading of individuals which can result in wastage of offspring.
- Takes a shorter time and leads to rapid colonization.

Disadvantages of asexual reproduction

- New offspring may carry undesirable qualities from parents.
- Offspring may be unable to withstand changing environmental conditions.
- Faster maturity can cause overcrowding and stiff competition.
- Reduced strength and vigour of successive generations.

Advantages of sexual reproduction

- Leads to variations.
- Variations which are desirable often show hybrid vigour.
- High adaptability of individuals to changing environmental conditions.
- Variations provide a basis for evolutionary changes.

Disadvantages of sexual reproduction

- Fusion is difficult if two individuals are isolated.
- Some variations may have undesirable qualities.
- Population growth is slow.

Sexual Reproduction in Plants

- In flowering plants, the flower is the reproductive organ which is a specialised shoot consisting of a modified stem and leaves.
- The stem-like part is the pedicel and receptacle, while modified leaves form corolla and calyx.

Structure of a flower
EXERCISE; DRAW AND NAME PARTS OF A FLOWER

- A typical flower consists of the following parts:

Calyx –

- made up of sepals.
- They enclose and protect the flower when it is in a bud. Some flowers have an outer whorl made of sepal-like structures called epicalyx.

Corolla –

- consists of petals. The petals are brightly coloured in insect - pollinated flowers.

Androecium –

- Is the male part of the flower. It consists of stamens.
- Each stamen consists of a filament whose end has an anther.
- Inside the anther are pollen sacs which contain pollen grains.

Gynoecium (pistil) –

- Is the female part of the flower.
- It consists of one or more carpels.
- Each carpel consists of an ovary, a sty le and a stigma.
- The ovary contains ovules which become seeds after fertilisation.
- A ***monocarpous pistil*** has one carpel e.g. beans.
- ***A polycarpous pistil*** has many carpels.
- If the carpes are free, it is called ***apocarpous*** as in rose and *Bryophyllum,*
- In carpels that are fused it is called ***syncarpous*** as in *Hibiscus.*
- ***A complete flower*** has all the four floral parts.
- A regular flower can be divided into two halves by any vertical section passing through the centre. e.g. morning glory.
- Irregular flower can be divided into two halves in only one plane e.g. crotalaria.

Pollination

- This is the transfer of pollen grains from the anther to the stigma.

Types of pollination

- ***Self pollination*** is the transfer of pollen grains from the anther of one flower to the stigma of the same flower.
- ***Cross-pollination*** is the transfer of pollen grains from the anther of one flower to the stigma of a different flower, of the same species.

Agents of pollination

- Agents of pollination include wind, insects, birds and mammals.

- Insect pollinators include bees, butterflies and mosquitoes.

Mechanisms that hinder self-pollination

- Stamens ripen early and release their pollen grains before the stigma, mature. This is called protandry e.g. in sunflower.
- The stigma matures earlier and dries before the anthers release the pollen grains.
- This is called protogyny and is common in grasses.
- Self sterility or incompatibility
- Pollen grains are sterile to the stigma of the same flower, e.g. in maize flower.
- Shorter stamens than pistils.

Fertilisation in Plants

- The pollen grain contains the generative nucleus and a tube nucleus.
- When the pollen grain lands on the stigma, it absorbs nutrient and germinates forming a pollen tube.
- This pollen tube grows through the style pushing its way between the cells.
- It gets nourishment from these cells.
- The tube nucleus occupies the position at the tip of the growing pollen tube.
- The generative nucleus follows behind the tube nucleus, and divides to form two male gamete nuclei.
- The pollen tube enters the ovule through the micropyle.
- When the pollen tube penetrates the ovule disintegrates and the pollen tube bursts open leaving a clear way for the male nuclei.
- One male nucleus fuses with the egg cell nucleus to form a diploid zygote which develops into an embryo.
- The other male gamete nucleus fuses with the polar nucleus to form a triploid nucleus which forms the primary endosperm.
- This is called double fertilisation.

After fertilisation the following changes take place in a flower:

- The integuments develops into seed coat (testa).
- The zygote develops into an embryo.
- The triploid nucleus develops into an endosperm.
- The ovules become seeds.
- The ovary develops into a fruit.
- The ovary wall develops into pericarp.
- The style, dries up and falls off leaving a scar.
- The corolla, calyx and stamens dry up and fall off.

- In some the calyx persists.

Fruit formation

- Fruit development without fertilisation is called parthenocarpy
- e.g. as in pineapples and bananas.
- Such fruits do not have seeds.

Classification of fruits

- False fruits develops from other parts such as calyx, corolla and receptacle, e.g. apple and pineapple which develops from an inflorescence.
- True fruits develop from the ovary, e.g. bean fruit (pod).
- True fruits can be divided into fleshy or succulent fruits e.g. berries and drupes and dry fruits.
- The dry ones can be divided into Dehiscent which split open to release seeds and indehiscent which do not open.

Placentation

- This is the arrangement of the ovules in an ovary.

Marginal placentation:

- The placenta appears as one ridge on the ovary wall e.g. bean.

Parietal placentation:

- The placenta is on the ridges on ovary wall.
- Ovules are in them e.g. pawpaw.

Axile placentation:

- The placenta is in the centre.
- Ovary is divided into a number of loculi. e.g. orange.

Basal placentation.

- The placenta is formed at the base of the ovary e.g. sunflower.

Free Central placentation.

- Placenta is in the centre of the ovary.
- There are no loculi e.g. in primrose.

Methods of fruit and seed dispersal

Animal dispersal

- Fleshy fruits are eaten by animals.

- Animals are attracted to the fruits by the bright colour, scent or the fact that it is edible.
- The seeds pass through the digestive tract undamaged and are passed out with faeces. E.g. tomatoes and guavas.
- Such seeds have hard, resistant seed coats.
- Others have fruits with hooks or spines that stick on animal fur or on clothes.
- Later the seeds are brushed of or fall off on their own e.g. *Bidens pilosa* (Black jack).

Wind dispersal

- Fruits and seeds are small and light in order to be carried by air currents.
- A fruit that is a capsule e.g. tobacco split or has pores at the top e.g. Mexican poppy.
- The capsule is attached to along stalk when swayed by wind the seeds are released and scattered.
- Some seeds have hairy or feather-like structures which increase their surface area so that they can be blown off by the wind e.g. *Sonchus.*
- Others have wing-like structures e.g. Jacaranda and Nandi Flame.
- These extensions increase the surface area of fruits and seeds such that they are carried by the wind.

Water dispersal

- Fruits like coconut have fibrous mescocarp which is spongy to trap air, the trapped air make the fruit light and buoyant to float on water.
- Plants like water lily produce seeds whose seed coats trap air bubbles.
- The air bubbles make the seeds float on water and are carried away.
- The pericarp and seed coat are waterproof.

Self dispersal (explosive) Mechanism

- This is seen in pods like bean and pea.
- Pressure inside the pod forces it to open along lines of weakness throwing seeds away from parent plant.

Reproduction in Animals

- Sexual reproduction involves the fusion of gametes.
- In animals two individuals are involved, a male and a female.
- Special organs known as gonads produce gametes.
- In males testes produce sperms while in females ovaries produce ova.

- The fusion of male gamete and female gamete to form a zygote is called fertilisation.

There are two types of fertilisation. External and internal.

External fertillsation

- Example in amphibians takes place in water.
- The male mounts the female and shed sperms on the eggs as they are laid.
- Eggs are covered by slippery jelly-like substance which provides protection.
- Many eggs are released to increase the chances of survival.

Internal fertilisation

- This occurs in reptiles, birds and mammals.
- Fertilisation occurs within the body of the female.
- Fewer eggs are produced because there are higher chances of fertilisation since sperms are released into the female body.

Reproduction in Humans

EXERCISE; Draw and label the Structure of female reproduction system

The female reproduction system consist of the following:

Ovaries

- Are two oval cream coloured structures found in lower abdomen below the kidneys.

Oviducts.

- They produce the ova.
- Are tubes which conduct the ova produced by the ovaries to the uterus.
- Fertilisation occurs in the upper part of the oviduct.

Uterus

- The uterus is a hollow muscular organ found in the lower abdomen.
- The embryo develops inside the uterus.
- The inner lining endometrium supplies nutrients to embryo.
- The embryo is implanted into the inner uterine wall- the endometrium which nourishes the embryo.
- The thick muscles of the uterus assist in parturition.

Cervix

- Has a ring of muscles that separates the uterus from the vagina.
- It forms the opening to the uterus

Vagina

- Is a tube that opens to the outside and it acts as the copulatory and birth canal through the vulva.

EXERCISE; Drawand label the Structure of male reproductive system

The male reproductive system consists of the following:

Testis:

- Each testis is a mass of numerous coiled tubes called semniferous tubules.
- Each is enclosed within a scrotal sac that suspends them between the thighs.
- This ensures that sperms are maintained at a temperature lower than that of the main body.

Seminiferous tubules

- The lining of seminiferous tubules consists of actively dividing cells which give rise to sperms.
- Between the seminiferous tubules are interstitial cells which produce the male hormones called androgens e.g. testosterone.
- The seminiferous tubules unite to form the epididymis, which is a coiled tube where sperms are stored temporarily .
- Vas deferens (sperm duct) is the tube through which sperms are carried from testis to urethra.
- Seminal vesicle produces an alkaline secretion which nourishes the spermatozoa.

Prostate gland

- Produces an alkaline secretion to neutralise vaginal fluids.

Cowpers' gland

- Secretes an alkaline fluid.
- All these fluids together with spermatozoa form semen.

Urethra

- Is a long tube through which the semen is conducted during copulation.
- It also removes urine from the bladder.

Penis

- Is an intro-mittent organ which is inserted into the vagina during copulation .

Fertilization in Animals

- Fertilization is preceded by copulation in which the erect penis is inserted into the vagina.
- This leads to ejaculation of semen.
- The sperms swim through the female's genital tract to the upper part of the oviduct.
- The head of the sperm penetrates the egg after the acrosome_ releases lytic_ enzymes t dissolve the egg membrane.
- The tail is left behind.
- Sperm nucleus fuses with that of the ovum and a zygote is formed.
- A fertilisation membrane forms around the zygote which prevents other sperms from penetrating the zygote.

Implantation:

- After fertilisation the zygote begins to divide mitoticaly as it moves towards the uterus.
- It becomes embedded in the wall of the uterus a process called implantation.
- By this time the zygote is a hollow ball of cells called blastocyst or embryo.
- In the uterus the embryo develops villi which project into uterus for nourishment later the villi and endometrium develop into placenta.

Embryonic membranes

- Embryonic membranes develop around the embryo.
- The outermost membrane is the chorion which forms the finger-like projections (chorionic villi) which supply nutrients to the embryo.
- The amnion surrounds the embryo forming a fluid filled cavity within which the embryo lies.
- Amniotic cavity is filled with amniotic fluid.
- This fluid acts as a shock absorber and protects the foetus against mechanical injury.
- It also regutates temperature.
- The chorionic villi, allantois together with the endometrium from the placenta.
- The embryo is attached to the placenta by a tube called umbilical cord which has umbilical vein and artery.
- The maternal blood in the placenta flows in the spaces lacuna and surrounds capillaries from umbilical vein and artery.
- The umbilical cord increase in length as the embryo develops.

Role of placenta

Protection

- Maternal blood and foetal blood do not mix.
- This ensures that the pathogens and toxins from maternal blood do not reach the foetus.
- The placenta allows maternal antibodies to pass into the foetus, providing the foetus with immunity.

Nutrition

- The placenta facilitates the transfer of nutrients from maternal blood to foetus.

Excretion

- Placenta facilitates the removal of nitrogenous wastes from the foetus' blood to maternal blood.

Gaseous exchange

- Oxygen from the maternal blood diffuses into the foetal blood while carbon (IV) oxide from foetal blood diffuse into maternal blood.

Production of hormones

- Placenta produces progesterone and oestrogen.

Gestation period

- The period between conception and birth is called gestation.
- In humans gestation takes nine months (40 weeks).
- The embryo differentiates into tissues and organs during this period.

Week 1 to 3:

- Zygote divides to form blastocyst.
- Implantation takes place.
- The three germ layers form endoderm, mesoderm and ectoderm.
- Nervous system starts to form.

Week 4 to 7:

- Development of circulating and digestive systems.
- Further development of nervous system, formation of sensory organs,
- All major internal organs are developed.
- At week 5, heartbeat starts .

Week 8 to 24:

- All organs well developed including sex organs.
- Hair, finger and toe nails grow.
- Foetus move and eyelids open.

Week 25- 30:

- The fully developed foetus responds to touch and noises and moves vigorously.
- The head turns and faces downwards ready for birth.

Week 31-40:

- Foetus increases in size.
- Birth occurs.

Reproductive Hormones

Hormone	***Source***	***Functions***
Follicle Stimulating Hormone (FSH)	Pituitary gland	Development of ovarian follicle; stimulates secretion of oestrogen by the ovary
Luteinising Hormone (LH)	Pituitary gland	Causes ovulation; causes development of Graafian follicle into the corpus luteurn; causes secretion of progesterone by the ovary
Prolactin	Pituitary gland	Initiates production and secretion of milk by the mammary glands
Oxytocin	Pituitary gland	Causes contraction of the uterus during parturition (birth)
Progesterone	Corpus luteum in the ovary	Causes contraction of wall of the uterus to thicken after ovulation
Oestrogen	Ovary	Causes changes in the uterine wall in preparation for implantation; initiates development of secondary sexual characteristics
Androgens-Testosterone	Interstitial cells of testis	Stimulates the development of secondary sexual characteristics
Interstitial Cell Stimulating Hormone (lCSH)	Pituitary gland	Stimulates the interstitial cells of testis to release androgens
Human Chorionic Gonadotrophin (HCG)	Chorionic villi	Stops the degeneration of the corpus luteum for production of oestrogen and progesterone

Secondary Sexual Characteristics

Male

- Testerone is the main androgen that stimulates the development of secondary sexual characteristics.
- Broadening of the shoulders.
- Deepening of the voice due to enlargement of larynx.
- Hair at the pubic area, armpit and chin regions.
- Penis and testis enlarge and produce sperms.
- Body becomes more masculine.

Female

- Enlargement of mammary glands.
- Hair grows around pubic and armpit regions.
- Widening of the hips.
- Ovaries mature and start producing ova.
- Menstruation starts.
- Oestrogen triggers the onset of secondary sexual characteristics.

Menstrual Cycle

- This is characterized by discharge of blood and tissue debris (menses) from the uterus every 28 days.
- This is due to the breakdown of the endometrium which occurs when the level of progesterone falls and the girl starts to menstruate.
- The follicle stimulating hormone (FSH) causes the Graafian follicle to develop and also stimulate the ovary to release oestrogen.
- Oestrogen hormone triggers the onset of secondary sexual characteristics.
- Luteinising hormone (L.H) causes the mature ovum to be released from the Graafian follicle - a process called ovulation.
- After ovulation progesterone hormone is produced.
- After menstruation, the anterior lobe of the pituitary gland starts secreting the follicle stimulating hormone (FS.H) which causes the Graafian follicle to develop in the ovary.
- It also stimulates the ovary tissues to secrete oestrogen.
- Oestrogen brings about the repair and healing of the inner lining of the uterus (endometrium) which had been destroyed during menstruation.

- Oestrogen level stimulates the pituitary gland to produce (Luteinising Hormone (L.H).
- This hormone makes the mature Graafian follicle to release the ovum into the funnel of oviduct, a process called ovulation.
- After releasing the ovum, the Graafian follicle changes into a yellow body called corpus luteum.
- The luteinising hormone stimulates the corpus luteum to secrete a hormone called progesterone which stimulates the thickening and vascularisation of endometrium.
- This prepares the uterine wall for implantation of the blastocyst.
- If fertilisation takes place, the level of progesterone increases and thus inhibits FSH from stimulating the maturation of another Graafian follicle.
- If fertilisation does not occur, the corpus luteum disintegrates and the level of progesterone goes down.
- The endometrium, sloughs off and menstruation occurs.

BIRTH CONTROL METHODS

Birth control (contraception) is any method, medicine, or device used to prevent pregnancy**.** They include:

Levonorgestrel intrauterine device (LNG IUD)—The LNG IUD is a small T-shaped device like the Copper T IUD. It is placed inside the uterus by a doctor. It releases a small amount of progestin each day to keep you from getting pregnant. The LNG IUD stays in your uterus for up to 3 to 6 years, depending on the device.

Copper T intrauterine device (IUD)—This IUD is a small device that is shaped in the form of a "T." Your doctor places it inside the uterus to prevent pregnancy. It can stay in your uterus for up to 10 years.

Implant—The implant is a single, thin rod that is inserted under the skin of a women's upper arm. The rod contains a progestin that is released into the body over 3 years.

Injection or "shot"—Women get shots of the hormone progestin in the buttocks or arm every three months from their doctor.

Combined oral contraceptives—Also called "the pill," combined oral contraceptives contain the hormones estrogen and progestin. It is prescribed by a doctor. A pill is taken at the same time each day. If you are older than 35 years and

smoke, have a history of blood clots or breast cancer, your doctor may advise you not to take the pill.

Progestin only pill—Unlike the combined pill, the progestin-only pill (sometimes called the mini-pill) only has one hormone, progestin, instead of both estrogen and progestin. It is prescribed by a doctor. It is taken at the same time each day. It may be a good option for women who can't take estrogen.

Patch—This skin patch is worn on the lower abdomen, buttocks, or upper body (but not on the breasts). This method is prescribed by a doctor. It releases hormones progestin and estrogen into the bloodstream. You put on a new patch once a week for three weeks. During the fourth week, you do not wear a patch, so you can have a menstrual period.

Hormonal vaginal contraceptive ring—The ring releases the hormones progestin and estrogen. You place the ring inside your vagina. You wear the ring for three weeks, take it out for the week you have your period, and then put in a new ring.

Diaphragm or cervical cap—Each of these barrier methods are placed inside the vagina to cover the cervix to block sperm. The diaphragm is shaped like a shallow cup. The cervical cap is a thimble-shaped cup. Before sexual intercourse, you insert them with spermicide to block or kill sperm. Visit your doctor for a proper fitting because diaphragms and cervical caps come in different sizes.

Sponge—The contraceptive sponge contains spermicide and is placed in the vagina where it fits over the cervix. The sponge works for up to 24 hours, and must be left in the vagina for at least 6 hours after the last act of intercourse, at which time it is removed and discarded.

Male condom—Worn by the man, a male condom keeps sperm from getting into a woman's body. Latex condoms, the most common type, help prevent pregnancy, and HIV and other STDs, as do the newer synthetic condoms. "Natural" or "Condoms can only be used once.

Female condom—Worn by the woman, the female condom helps keeps sperm from getting into her body. It is packaged with a lubricant and is available at drug stores. It can be inserted up to eight hours before sexual intercourse

Spermicides—These products work by killing sperm and come in several forms—foam, gel, cream, film, suppository, or tablet. They are placed in the vagina no more than one hour before intercourse. You leave them in place at least six to eight hours after intercourse. You can use a spermicide in addition to a male condom, diaphragm, or cervical cap. They can be purchased at drug stores.

Natural rhythm methods — Not using a type of birth control but instead avoiding sex and/or using birth control only on the days when you are most fertile (most likely to get pregnant). An ovulation home test kit or a fertility monitor can help you find your most fertile days

Fertility awareness-based methods—Understanding your monthly fertility pattern can help you plan to get pregnant or avoid getting pregnant. Your fertility pattern is the number of days in the month when you are fertile (able to get pregnant), days when you are infertile, and days when fertility is unlikely, but possible. If you have a regular menstrual cycle, you have about nine or more fertile days each month. If you do not want to get pregnant, you do not have sex on the days you are fertile, or you use a barrier method of birth control on those days.

Lactation amenorrhea-For women who have recently had a baby and are breastfeeding, the Lactation Amenorrhea Method (LAM) can be used as birth control when three conditions are met: 1) amenorrhea (not having any menstrual periods after delivering a baby), 2) fully or nearly fully breastfeeding, and 3) less than 6 months after delivering a baby. LAM is a temporary method of birth control, and another birth control method must be used when any of the three conditions are not met.

Emergency contraceptive pills—Women can take emergency contraceptive pills up to 5 days after unprotected sex, but the sooner the pills are taken, the better they will work over the counter.

Female Sterilization—Tubal ligation or "tying tubes"— A woman can have her fallopian tubes tied (or closed) so that sperm and eggs cannot meet for fertilization. The procedure can be done in a hospital or in an outpatient surgical center. You can go home the same day of the surgery and resume your normal activities within a few days. This method is effective immediately.

Male Sterilization–Vasectomy—this operation is done to keep a man's sperm from going to his penis, so his ejaculate never has any sperm in it that can fertilize an egg. The procedure is typically done at an outpatient surgical center. The man can go home the same day. Recovery time is less than one week. After the operation, a man visits his doctor for tests to count his sperm and to make sure the sperm count has dropped to zero; this takes about 12 weeks. Another form of birth control should be used until the man's sperm count has dropped to zero.

ECOLOGY

Introduction

- Ecology is the study of organisms and their environment.
- All organisms show interdependence on one another.
- Organisms are affected by their environment, and they in turn affect the environment.
- Green plants manufacture food by photosynthesis which other organisms obtain directly or indirectly.
- Growth of plants is mainly affected by environmental factors such as soil and climatic factors.
- On the other hand, organisms modify the environment through various activities.
- This interrelationship comprises the study of ecology.
- The study of ecology is important in several fields of study such as agriculture and environmental studies.

Concepts and Terms Used in Ecology

- ***Habitat:***
  - This is the place or "home" that an organism lives or is found,
  - e.g., forest or grassland.
- ***Niche:***
  - A niche is the functional unit in the habitat.
  - It includes not only the specific place in which an organism lives but also how the organism functions.
  - To avoid or reduce competition, organisms are separated or segregated by their niches,
  - for example, different species of birds make their nest on one tree, some at tips of terminal branches, and others feed on leaves, some on flowers and yet others on fruits of the same tree, i.e., food niche.
  - Yet others feed on same food, e.g., worms in the same place but at different times - time niche.
- ***Population:***
  - The term population refers to the total number of individuals of a species living in a given area at a particular time.
  - ***Density*** is the number of ***individuals*** of a population found in a ***unit area***, i.e.,

$$= \frac{\text{Number of individuals}}{\text{Area}}$$

- ***Dispersion:***
  - This is the distribution of individuals in the available space.
  - Dispersion may be uniform as in maize plants in a plantation;
  - random as in cactus plants in the savannah ecosystem or clumped together as in human population in cities.
- ***Community:***
  - This is the term used to describe all the organisms living together in an area.
  - During the development of an ecosystem, the species composition of a community changes progressively through stages.
  - Finally a steady state is reached and this is described as the ***climax community.***
  - This development of an ecosystem is termed succession.
  - Each stage in development of an ecosystem is a sere.
  - Succession is ***primary*** when it starts with bare ground, and ***secondary*** when it starts in a previously inhabited area e.g. after clearing a forest.
- **The Ecosystem:**
  - The community and the abiotic or non-living environment together make up an ecosystem or ***ecological system***.
  - In this system ***energy*** flow is clearly defined from producers to consumers and nutrient cycling takes place in paths that links all the organisms and the non-living environment.
- ***Biomass:***
  - This is the mass of all the organisms in a given area.
  - Ideally, it is the dry mass that should be compared.
- ***Carrying capacity:***
  - This is the maximum sustainable density in a given area e.g. the number of herbivores a given area can support without overgrazing.

Factors in an Ecosystem

- **Abiotic factors (environmental factors)**

Temperature

- Is the hotness or coldness of an area or habitat.
- It directly affects the distribution and productivity (yield) of populations and communities.
- Most organisms are found in areas where temperature is moderate.
- However, certain plants and animals have adaptations that enable them to live in areas where temperatures are in the extremes such as the hot deserts and the cold polar regions.
- Temperatures not only influence distribution of organisms but also determine the activities of animals.

- High temperature usually accelerates the rates of photosynthesis, transpiration, evaporation and the decomposition and recycling of organic matter in the ecosystem.

Light –

- Light is required by green plants for photosynthesis.
- Light intensity, duration and quality affect organisms in one way or another.

Atmospheric Pressure

- The force per unit area of atmospheric air that is exerted on organisms at different altitudes.
- Growth of plants and activity of animals is affected by atmospheric pressure
- e.g., rate of transpiration in plants and breathing in animals.

Salinity

- This is the salt content of soil or water.
- Animals and plants living in saline conditions have special adaptations.

Humidity

- This describes the amount of moisture (water vapour) in the air.
- Humidity affects the rate of transpiration in plants and evaporation in animals.

pH

- Is the measure of acidity or alkalinity of soil solution or water.
- pH is very important to organisms living in water and soil.
- Most prefer a neutral pH.

Wind:

- Is moving air currents and it influences the dispersion of certain plants by effecting the dispersal of spores, seeds and fruits.
- Air currents also modify the temperature and humidity of the surroundings.

Topography:

- These are surface features of a place.
- The topographical factors considered include altitudes, gradient (slope), depressions and hills.
- All these characteristics affect the distribution of organisms in an area
- e.g., the leeward and windward sides of a hill.

Biotic factors:

- These are the living components in an ecosystem,
- competition
- predation,
- symbiosis,
- parasitism,

- human activities.

Inter-relationships Between Organisms

- The relationships between organisms in a given ecosystem is primarily a feeding one.
- Organisms in a particular habitat have different feeding levels referred to as trophic levels.
- ***There are two main trophic levels:***

Producers:

- These organisms that occupy the first trophic level.
- They manufacture their own food hence are autotrophic.

Consumers:

- These are the organisms that feed on organic substances manufactured by green plants.

They occupy different trophic levels as follows:

- ***Primary consumers:***
  - These are herbivores and feed on green plants.
- ***Secondary consumers:***
  - These are carnivores and feed on flesh.
  - First order carnivores feed on herbivores while second order carnivores feed on other carnivores, i.e., tertiary consumers.
- ***Omnivores:***
  - These are animals that feed on both plant and animal material.
  - They can be primary, secondary or tertiary consumers.

Competition:

- This describes the situation where two or more organisms in the same habitat require or depend on the same resources.
- Organisms in an ecosystem compete for resources like food, space, light, water and mineral nutrients.
- Competition takes place when the environmental resource is not adequate for all.

Intraspecific competition.

- This is competition between organisms of the same species.
- For example, maize plants in a field compete for water and nutrients among themselves.

Interspecific competition.

- **This refers to** competition between organisms of different species, e.g., different species of predators can compete for water and prey among themselves.

Predation

- It is a relationship whereby one animal (the predator) feeds on another (the prey).

Saprophytism

- Saprophytism is the mode of nutrition common in certain species of fungi and bacteria.
- Such organisms feed on dead organic material and release nutrients through the process of decomposition or decay.
- Saprophytes produce enzymes, which digest the substrates externally.
- The simpler substances are then absorbed.
- Saprophytes help in reducing the accumulation of dead bodies of plants and animals.
- Harmful saprophytes cause rapid decay of foods such as fruits, vegetables, milk and meat.
- Others damage buildings by causing wood rot.
- Some fungi produce poisonous substances called aflatoxins.
- These substances are associated with cereal crops which are stored under warm, moist conditions.
- If the infected grain is eaten, it may cause serious illness, and death.

Parasitism

- This is an association between members of different species.
- The parasite lives on or in the body of another organism, the host.
- The parasite derives benefits such as food and shelter from the host but the heist suffers harm as a result.

Symbiosis

- This is an association in which organisms of different species derive mutual benefit from one another.
- Some symbiotic associations are loose and the two partners gain very little from each other.
- Other symbiotic associations are more intimate and the organisms show a high degree of interdependence.

Nitrogen cycle –

- Is the interdependence of organisms on one another and the physical environment as nitrogen is traced from and back into the atmosphere
- Although nitrogen is abundant in the atmosphere, most organisms are not able to utilise it directly.
- Some bacteria are capable of converting atmospheric nitrogen into forms which can be used by other living organisms.

- These bacteria are referred to as **nitrogen fIxing bacteria.**
- **Symbiotic nitrogen** fixing **bacteria** live in the root nodules of leguminous plants such as beans and peas.
- Non-symbiotic nitrogen fixing bacteria live in the soil.
- **Nitrifying' bacteria** convert ammonia into nitrites and nitrates.
- **Denitrifying bacteria** convert nitrates into **atmospheric** nitrogen.

Energy Flow in an Ecosystem

- Most of the energy used in an ecosystem is derived from the sun.
- Solar energy is trapped by photosynthetic plants.
- It flows through different trophic levels .
- At each level energy is lost as heat to space and also through respiration.
- Besides animals lose energy through excretion and defecation.
- The amount of energy passed on as food from one trophic level to another decreases progressively.
- The energy in the organisms is recycled back to plants through the various nutrient or material cycles.

Food Chains

- A food chain is a linear relationship between producers and consumers.
- It represents the transfer of food energy from green plants through repeated stages of eating and being eaten.

Types of Food Chain

- Grazing food chain - starts with green plants.
- Detritus food chain - starts with dead organic material (debris or detritus).

Detritivores:

- Detritivores feed on organic wastes and dead matter derived from the grazing food chain.
- Many different types of organisms feed on detritus.
- They include fungi, protozoa, insects, mites annelids and nematodes.

Examples of Food Chains

Green plants~ aphids ~ lady-bird beetle
Green plants ~antelope -lion
Algae ~Tilapia ~ kingfisher
Plant debris ~bacteria -protozoa ~ mosquito larva
Phytoplankron-Zooplankton ~ Tilapia
~ Nile perch ~ Human

Food Web

- In a natural community, several food chains are interlinked to form a food web.
- Several herbivores may feed on one plant .
- Similarly, a given herbivore may feed on different plants and may in turn be eaten by different carnivores.

Decomposers

- These are mainly bacteria and fungi.
- These organisms feed on dead organic matter thereby causing decomposition and decay and releasing nutrients for plants.
- They form a link between the biotic and the abiotic components.

Pyramid of Numbers

- Refers to the number of organisms in each trophic level presented in a graphic form and a pyramid shape is obtained.
- The length of each bar is drawn proportional to the number of organisms represented at that level.
- This is because a herbivore feeds on many green plants.
- One carnivore also feeds on many herbivores.

- In a forest the shape of the pyramid is not perfect.
- This is because very many small animals such as insects, rodents and birds feed on one tree.

Pyramid of Biomass

- This is the mass of the producers and consumers at each trophic level drawn graphically.

Pollution

Effect of Pollution on Human Beings and other Organisms

Pollution

- This is the introduction of foreign material, poisonous compounds and excess nutrients or energy to the environment in harmful proportions.
- Any such substance is called a pollutant.

Effects and Control of causes of Pollutants in Air, Water and Soil

- Industrialisation and urbanisation are the main causes of pollution.

- As human beings exploit natural resources the delicate balance in the biosphere gets disturbed.
- The disturbance leads to the creation of conditions that are un-favourable to humans and other organisms.

Sources of Pollutants

- Motor vehicles release carbon (II) oxide, sulphur (IV) oxide, and nitrogen oxides and hydrocarbons.
- Agricultural chemicals, fertilisers and pesticides.
- Factories, manufacturing and metal processing industries.
- They release toxic substances and gases as well as synthetic compounds that are bio-undegradable.
- They release solid particles or droplets of poisonous substances e.g. arsenic, beryllium, lead and cadmium.
- Radioactive waste: Leakages from nuclear power stations and testing sites release radioactive elements like strontium-90 which can eventually reach man through the food chain.
- Domestic waste and sewage are released raw into water bodies.
- Oil spills from accidents in the seas and leakage of oil tankers as well as from offshore drilling and storage and processing.

Water Pollution.

- In most cases, chex,pical wastes from industries are discharged into water.
- Toxic chemicals such as mercury compounds may be ingested by organisms.
- Insecticides like DDT, and weedkillers eventually get into the water and contaminate it.
- Oil and detergents also pollute water.
- Excess nitrates and phosphates from sewage and fertilisers cause overgrowth of algae and bacteria in water.
- This is called ***eutrophication.***
- As a result there is insufficient oxygen which causes the deaths of animals in the water.

Air pollution:

- Smoke from industries and motor vehicles contains poisonous chemicals like carbon (II) oxide, carbon (IV) oxide, sulphur (IV) oxide and oxides of nitrogen.
- When sulphur (IV) oxide and oxides of nitrogen dissolve in rain, they fall as acid rain.
- Accumulation of carbon (IV) oxide in the atmosphere causes the infrared light to be confined within the atmosphere, the earth's temperature rises.

- This is called the greenhouse effect.
- Carbon particles in smoke coat the leaves of plants and hinder gaseous exchange and photosynthesis.
- The particles also form smog in the air.
- Lead compounds are from vehicle exhaust pipes.
- All these have negative effects on man and the environment.

Soil/Land pollution:

- Plastics and other man-made materials are biologically non-degradable i.e they are not acted upon by micro-organisms.
- Scrap metal and slag from mines also pollute land.
- Failure to rehabilitate mines and quarries also pollute land.

Effects of Pollutants to Humans and other organisms

- Chemical pollutants e.g. nitrogen oxides, fluorides, mercury and lead cause physiological and metabolic disorders to humans and domestic animals.
- Some hydrocarbons as well as radioactive pollutants acts as mutagens (cause mutations) and carcinogens induce cancer.
- Radioactive pollutants like strontium, caesium and lithium are absorbed into body surface and cause harm to bone marrow and the thyroid gland.
- Communicable diseases like cholera are spread through water polluted with sewage.
- Thermal pollution result in death of some fish due to decreased oxygen in the water.
- Oil spills disrupt normal functioning of coastal ecosystems.
- Birds that eat fish die due to inability to fly as feathers get covered by oil.
- Molluscs and crustaceans on rocky shores also die.

Control of Air Pollution

- Use of lead-free petrol and low sulphur diesel in vehicles.
- Use of smokeless fuels e.g electricity or solar.
- Filtration of waste gases to remove harmful gases.
- Liquid dissolution of waste gases.
- In Kenya, factories are subjected to thorough audits to ensure that they do not pollute the environment.
- Factories should be erected far away from residential areas.
- Reduce volume or intensity of sound.
- Use of ear muffs.
- Vehicle exhaust systems should be fitted with catalytic oxidisers.
- Regular servicing of vehicles to ensure complete combustion of fuel.

Water Pollution

- Treatment of sewage.
- Treatment of industrial waste before discharge into water.
- Use of controlled amounts of agrochemicals.
- Organic farming and biological control.
- Avoid spillage of oils and other chemicals into water.
- Good water management.
- Stiff penalties for oil spillage.
- Use of *Pseudomonas* bacteria that naturally feed on oil and break it up.

Soil Pollution

- Addition of lime to farms to counteract the effect of agrochemicals.
- Recycling of solid waste.
- Compacting and incineration of solid waste.
- Use of biodegradable materials and chemicals.
- Good soil management to avoid soil erosion.

- is recorded in each area studied e.g. using a quadrat.
- The total area of the habitat studied is measured.
- The average number of organisms per quadrat (1 m^2) is calculated after establishing as many quadrats as are necessary to cover the area adequately.
- Total population of organisms is calculated from the area.
- Abiotic environment is studied within the area sampled.
- Air temperature soil surface temperature are taken and recorded.
- This is best done at different times of day, i.e., morning afternoon and evening.
- Any variations are noted.
- pH of the soil is measured using pH distilled water to make a solution.
- Litmus papers can be used to indicate if soil is acidic or alkaline, but pH paper or meter gives more precise pH values.
- Humidity is measured using anhydrous blue cobalt chloride paper which gives a mere indication of level of humidity.
- A windsock is used to give an indication of direction of wind.
- As all the abiotic factors are recorded observations are made to find the relationships between behaviour of organism and the environmental factors for example:
  - The temperature affects the behaviour of animals.
  - The direction of wind will affect growth of plants.
  - The level of humidity determines the type, number and distribution of organisms in an area.

GENETICS

Introduction

- Genetics is the study of inheritance.
- The fact that the offspring of any species resemble the parents indicates that the characters in the parents are passed on to the offspring.
- Factors that determine characters (genes) are passed on from parent to offspring through gametes or sex cells.
- In fertilisation the nucleus of the male gamete fuses with the nucleus of the female gamete.
- The offspring show the characteristics of both the male and the female.
- Genetics is the study of how this heritable material operates in individuals and their offspring.

Variations within Plant and Animal Species

Variation

- The term variation means to differ from a standard.
- Genetics also deals with the study of differences between organisms belonging to one species.
- Organisms belonging to higher taxonomic groups e.g. phyla or classes are clearly different.
- Although organisms belonging to the same species are similar, they show a number of differences or variations such that no two organisms are exactly the same in every respect.
- Even identical twins, though similar in many aspects, are seen to differ if they grow in different environments.
- Their differences are as a result of the environment which modifies the expression of their genetic make-up or genotype.
- The two causes of variations are the genes and the environment.
- Genes determine the character while the environment modifies the expression of that character.

Continuous and Discontinuous Variation

Continuous Variations

- The differences between the individual are not clear-cut.
- There are intermediates or gradations between any two extremes.

- Continuous variations are due to action of many genes e.g. skin complexion in humans.
- In continuous variation, the environment has a modifying effect in that it may enhance or suppress the expressions of the genes.
- Continuous variation can be represented in form of a histogram.
- Example of continuous variation in humans is weight, height and skin complexion.
- Linear measurements:
- In humans, height shows gradation from tall, to tallest.
- So does the length of mature leaves of a plant.
- In most cases, continuous variation is as a result of the environment.

Discontinuous Variations

- These are distinct and clear cut differences within a species.

Examples include:
- Ability to roll the tongue.
- An individual can either roll the tongue or not.
- Ability to taste phenylthiourea (PTC); some individuals can taste this chemical others cannot.
- Blood groups - and individual has one of the four blood groups A, B AB or O.
- There are no intermediates.
- Albinism - one is either an albino or not.
- Discontinuous variations is determined by the action of a single gene present in an individual.

Structure and Properties of Chromosomes
- These are threadlike structures found in the nucleus.
- They are normally very thin and coiled and are not easily visible unless the cell is dividing.
- When a cell is about to divide, the chromosomes uncoil and thicken.
- Their structure, number and behaviour is clearly observed during the process of cell division.
- The number of chromosomes is the same in all the body cells of an organism.
- In the body cells, the chromosomes are found in pairs.
- Each pair is made up of two identical chromosomes that make up a homologous pair.
- However sex chromosomes in human male are an exception in that the **Y-** chromosome is smaller.

Number of Chromosomes

Diploid Number (2n)
- This is the number of chromosomes found in somatic cells.

- For example, in human 2n = 46 or 22 pairs (44 chromosomes) are known as autosomes (body chromosomes")
- while 1 pair is known as the sex chromosomes.
- In *Drosophila melanogaster,* 2n = 8.

Chromosome Structure

- All chromosomes are not of the same size or shape.
- In human beings; each of the twenty three pairs have unique size and structure .
- On this basis they have been numbered 1 to 23.
- The sex chromosomes formthe 23rd pair.

Properties of Chromosomes

- Chromosomes are very long and thin.
- They are greatly and loosely coiled and fit within the nucleus.
- During cell division they shorten, become thicker and are easily observable.
- Each consists of two chromatids.
- The two chromatids are held at same position along the length, at the centromere.
- Chromatids separate during cell division in mitosis and in the second stage of meiosis.
- Chromosomes take most dyes and stain darker than any other part of the cell.
- This property has earned them the name "chromatin material"
- ***Each chromosome is made up of the following components:***
- Deoxyribonucleic acid (DNA) - this carries the genes.
- It is the major component of the genetic material.
- Protein e.g. histones.
- Ribonucleic acid (RNA) is present in very small amounts.
- Enzymes concerned with DNA and RNA replication - these are DNA and RNA polymerases and ligases.

Structure of DNA

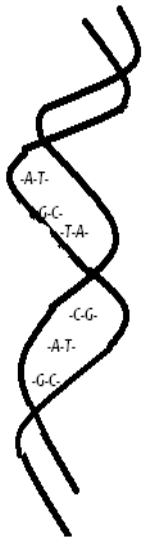
- The structure of DNA was first explained in 1953 by Watson and Crick.
- DNA was shown to be a double helix that coils around itself.
- The two strands are parallel and the distance between the two is constant.

Components of DNA

- DNA is made up of repeating units called nucleotides.
- ***Each nucleotide is composed of:***
- A five-carbon sugar (deoxyribose).
- Phosphate molecule.
- Nitrogenous base, four types are available i.e,
  - Adenine - (A)
  - Guanine - (G)
  - Cytosine - (C)
  - Thymine - (T)

- The bases are represented by their initials as A, G, C and T respectively.
- The sugar alternates with the phosphate, and the two form the backbone of the strands.
- The bases combine in a specific manner, such that Adenine pairs with Thymine and Guanine pairs with Cytosine.
- The bases are held together by hydrogen bonds. A gene is the basic unit of inheritance consisting of a number of bases in linear sequence on the DNA.
- Genes exert their effect through protein synthesis.
- The sequences of bases that make up a gene determine the arrangement of amino acids to make a particular protein.

- The proteins manufactured are used to make cellular structures as well as hormones and enzymes.
- The types of proteins an organism manufactures determines its characteristics.
- For example, albinism is due to failure of the cells of an organism to synthesise the enzyme tyrosine required for the formation of the pigment melanin.



A coiled double helix strand of DNA

First Law of Heredity

- It is also known as ***Law of Segregation (Mendel's First Law).***
- The characters of an organism are controlled by genes occurring in pairs known as Alleles.
- By definition, an allele is an alternative form of a gene controlling a particular characteristic.
- Of a pair of such alleles, only one is carried in each gamete.
- This is explained by first meiotic anaphase stage, when the homologous chromosomes are separated so that each carries one of the allelic genes.

Monohybrid Inheritance

- This is the study of the inheritance of one character trait that is represented by a pair of genes on homologous chromosomes.
- Gregor Mendel (an Austrian monk) was the first person to show the nature of inheritance.
- He did this through a series of experiments using the garden pea, *Pisum sativum.*
- As opposed to others before him, the success in his work lay in the fact that:
- He chose to study first a single character at a time (monohybrid inheritance).
- He then proceeded to study two characters at time (dihybrid inheritance) .
- He quantified his results by counting the number of offspring bearing each trait.
- Each character he chose was expressed in two clearly contrasting forms.

Examples

- Stem length: some plants were tall while others were short.
- Colour of unripe pods: some were green, others yellow.
- There were no intermediates.

Mendel's Procedure

- For each character, Mendel chose a plant that bred true.
- A true or pure breed continues to show a particular trait in all the offspring in several successive generations of self-fertilisation.
- He made one plant to act as the female by removing the stamens before the ovary was mature and protecting (e.g. by wrapping with paper).
- The female plant from contact with any stray pollen.
- When the ovary was mature, he carefully dusted pollen from the anthers of the selected male plant and transferred it to the stigma of the female plant.
- Observations were then made on the resulting seeds or on the plants obtained when those seeds were planted.

Results

- For each pair of contrasting characters he studied, Mendel obtained the same results.
- For example, when he crossed pure breeding tall plants with pure breeding short plants, the first offspring, known as the ***first filial generation*** (F_I) were all tall.
- When these were selfed i.e. self-fertilisation allowed to take place, the second generation offspring also known as the ***second filial generation*** or ***F2*** occurred in the ratio of 3 tall: 1 short.
- The same ratio was obtained for each of the other characters studied.
- From this it is clear that one character i.e. tall is ***dominant*** over the short character.
- A dominant character is that which is expressed alone in the offspring even when the opposite character is represented in the genotype.
- The unexpressed character is said to be recessive.
- From these results and others obtained when he studied two characters at the same time, Mendel concluded that gametes carry factors that are expressed in the offspring.
- These factors are what we know today as genes.
- Mendel put forward the following laws of inheritance:
- Of a pair of contrasting characters, only one can be represented in a gamete.
- For two or more pairs of such contrasting characters, each factor (gene) in the gamete acts independently of the others and may combine randomly with either of the factors of another pair during fertilisation.
- Genetic experiments carried out to date confirm Mendel's Laws of inheritance e.g. T.H. Morgan's work on inheritance in the fruit fly *Drosophila melanogaster.*

Terms used in Genetics

Genotype:

- The genes present in an individual. The genetic constitution of an individual. It is expressed in alphabetical notation.e.g TT,Tt

Phenotype:

- The observed character or appearance i.e. the expression of the genes in the structure and physiology of the organism.
- In some cases the phenotype is the product of the genotype and the environment. Phenotype is expressed in words.eg TALL,SHORT,RED WHITE .etc.

Alleles:

- These are alternative forms of the same gene that control a pair of contrasting characters e.g. tall and short.
- They are found at the same position or ***gene-locus*** on each chromosome in a ***homologous*** pair.

Homozygous:

- This is a state where the alleles in an individual are similar e.g. TT (for tall)

Heterozygous:

- This is a state where the alleles are dissimilar i.e. each of the two genes responsible for a pair of contrasting characters are present
- e.g. Tt. (T for tall; t for short)

Hybrid:

- This is the offspring resulting from crossing of two individuals with contrasting characters.

Hybrid vigour or Heterosis:

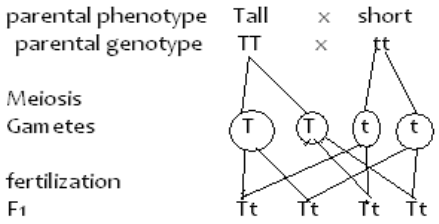
- The hybrid develops the best characteristics from both parents
- i.e. it is stronger or healthier, or yields more than either parent.

Use of Symbols

- To represent genes in the chromosomes, letters are used.
- It is customary to use a capital letter for the dominant characteristic and small letter for the recessive one.
- The gametes are encircled.
- For example,a cross between a tall and a short pea plant is illustrated as follows;

➢ Let –***T-*** represent gene for tallness.

➢ Let -***t-*** represent gene for shortness.

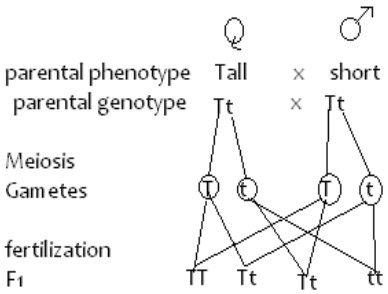


female / male	T	T
t	Tt	Tt
t	Tt	Tt

Fertilization-using checker board or Punnet square

F1 genotype ***Tt***

F1 Phenotypic ratio =***All tall.***



female / male	T	t
T	TT	Tt
t	Tt	tt

F2 Genotype TT,2Tt,tt
F2 Phenotypic ratio;3 Tall;1 short

Test Cross or Back Cross

- This is a eras made between the F 1 bearing the dominant trait with the homozygous recessive parent.
- It is called a back cross because of using the first parent.
- It is also a test cross because it tests the genotype of the individual.

female gamete / male gamete	A	A
a	Aa	Aa
a	Aa	Aa

Offspring genotype 2Tt;tt
Phenotypic ratio 1Tall;1short

Complete Dominance

- Mendel happened to choose characters that showed complete dominance,

- i.e. the dominant trait completely masked the recessive one in the F1 generation.
- In man, certain characters are inherited in the same way
- e.g. colour of the skin; normal colour is dominant to albinism (lack of skin pigment).

Normal parent x Albino
AA x aa
Gametes (A)(A) x (a) (a)

female gamete / male gamete	A	A
a	Aa	Aa
a	Aa	Aa

- The children are all normal but have the gene for albinism.
- Such individuals are referred to as carriers.

Other characters that show complete dominance in humans are:

- Ability to roll the tongue.
- Polydactyly (having more than 5 digits in one limb).
- Brachydactyly - having short fingers.
- Achondroplasia - dwarf with bow legs.

Incomplete Dominance

- In this kind of inheritance there is no dominant or recessive gene but the two are expressed equally in the offspring,
- Resulting in blending of the characters.
- The gene for red colour (R) in cattle and the gene for white colour(W) show incomplete dominance or co-dominance.

♂ / ♂	W	W
R	RW	RW
R	RW	RW

- The offspring are neither red nor write but are intermediate between the two.
- They are said to be roan.
- In humans, the sickle cell gene and the normal gene are co-dominant.

Inheritance of ABO blood groups in humans

- Blood groups in human are determined by three alleles, A, B, and O.
- An individual can have only two of these genes.
- Genes A and Bare codominant, while gene 0 is recessive to A and B.
- These are referred to as ***multiple alleles.***

The ABO Blood Group System

blood group	posible genotype	type of Antigen on Red blood cells	Type of Antbody in plasm a
A	AA;AO	A	b
B	BB;BO	B	a
AB	AB	AB	none
O	OO	None	a and b

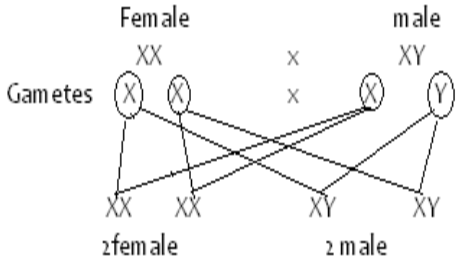
The ABO Blood Group System

Rhesus Factor

- The Rhesus factor is responsible for the presence of a protein (Antigen D) in the red blood cells.
- If blood from a Rhesus positive (Rh+) person is transferred into a person without the Rhesus factor (Rh-);
- The recipients' body produces antibodies against the Rhesus factor.
- This causes agglutination of red blood cells which can be fatal if subsequent transfusion with Rh+ blood is done.

Sex Determination in Humans

- XY type e.g. human male
- In males, two types of sperms are produced.
- Half of then containing ***X*** chromosomes and half ***Y*** chromosomes.
- During fertilisation only one sperm fuses with the egg.
- If it is an X-carrying sperm then a female zygote is formed;
- If it is a Y-carrying sperm then a male zygote is formed.
- It follows then that the chances of getting a boy or girl are half or fifty-fifty.
- Note also that it is essentially the type of sperm that fertilises the egg that determines the sex.



Linkage

- The term linkage describe the situation where genes or certain characters are located on the same chromosome.
- Offspring produced by sexual reproduction show only the parental characteristics and only sometimes few new recombinants.
- i.e. offspring with combinations of characteristics not found in either of the parents due to crossing over in first prophase of meiosis.
- Genes are said to be linked when they are located close together on the same chromosome such that they are always inherited together.

Sex linked genes

- These are genes that are located on the sex chromosomes.
- Sex-linkage - refers to carrying of the genes on the sex-chromosome.
- Gene for a trait may be present, yet offspring does not show the trait.
- This happens in human females (XX) where a gene for the trait is recessive.
- The female acts as a carrier.

I***n human, sex linked characters found on the X chromosome include:***
Haemophilia:

- This is a disease that affects the rate of clotting of blood, leading to excessive bleeding even from a minor cut.
- Haemophilia is more common in males than in females.
- A female my have the gene for haemophilia and not show the trait because the normal gene is dominant over the gene for haemophilia.
- Such females are referred to as carriers.
- If the carrier female offspring will be carriers while the other half will be normal.
- Half the males will be normal and the other heamophilic.

Red-green colour-blindness

- Red-green colour-blindness is caused by a recessive gene found on the X chromosome.
- It is inherited in the same way as haemophilia.
- More males 1:10,000, less female 1: 100 million afflicted.
- It is the inability to distinguish between red and green colours in humans.

Genes found on y-chromosome include:

- Hairy pinna and hairy nose are carried on the Y - chromosome.
- Premature balding.

Protein synthesis

-A process in which cells make proteins. It occurs in two stages: transcription and translocation.

Transcription is the transfer of genetic instructions in DNA to mRNA (messenger RNA) in the nucleus. It includes the steps of initiation, elongation and termination. After the mRNA is processed, it carries the instructions to a ribosome in the cytoplasm.

Translocation occurs at the ribosome which consists of rRNA (replication RNA) and proteins. In translocation, the instructions in mRNA are read and tRNA brings the correct sequence of amino acids to the ribosome. Then rRNA helps bonds form between the amino acids producing a polypeptide chain.

After a polypepetide chain is synthesiszed, it may undergo additional processing to form the finished protein.

Mutations

- Mutations are sudden changes in the genotype that are inherited.
- Mutations are rare in nature and mutated genes are usually recessive to the normal (wild type) genes.
- Most mutations are generally harmful and some are lethal.
- A somatic mutation is a genetic change in somatic cells.
- Somatic mutations are only inherited if asexual reproduction takes place e.g. as in plants and unicellular animals.
- A gene mutation is a change in genes of reproductive cells and is always inherited.
- The resultant individual is called a mutant.
- The mutant has different characteristics from the rest of the population.

Types of Mutations

- Chromosomal mutations - are changes in number or structure of chromosomes.
- Gene mutations - also called point mutations - are changes in the chemical nature of the gene.

Mutagens:

- These are agents that cause mutations.
- The include ultra-violet light, Gamma rays., x-rays and cosmic rays.
- Certain chemicals e.g. mustard gas and colchicines also induce mutations.

Causes and consequences of chromosomal mutations

- There are three main types of chromosomal mutations.
- Changes in the diploid number of chromosomes (allopolyploidy).
- The diploid number changes to 3n (triploid) or 4n (tetraploid) and so on.
- This results from the doubling of the chromosome number in the gamete (2n).

- This is due to failure of the chromosome sets to separate during meiosis.
- The phenomenon is known as polyploidy.
- It is common in plant's and has been employed artificially to produce varieties of crops with hybrid vigour e.g. bread wheat is hexaploid (6n). This is allopolyploidy).
- Change in the total number of chromosomes involving the addition or loss of individual chromosomes (autopolyploidy).
- This is due to failure of individual chromosomes to separate during meiosis.
- One gamete gains an extra chromosome while the other loses a chromosome.
- The term non-disjunction is used to describe the failure of chromosomes to separate.

Non-disjunction results in several disorders in humans:

Down's syndrome

- The individual has 47 chromosomes due to non-disjunction of chromosome 21.
- It is also known as trisomy 21.
- The individual has slanted eyes with flat and rounded face, mental retardation and large tongue and weak muscles.

Turner's Syndrome

- This brings about to a sterile and abnormally short female.
- It is due to loss of one of the sex chromosomes
- i.e. the individual has one X chromosome (44 + X) instead of two (44 + XX).

Klinefelter's Syndrome

- This results in a sterile male who may be mentally retarded.
- It is due to an additional X chromosome
- i.e. the individual i.e. 47 chromosomes (44 + XXY) instead of 46 (44 + XY).

Changes in the structure of a chromosome during meiosis.

- A portion of a chromosome may break off and fail to unite again or it may be joined in the wrong way or to the wrong chromosome.

These mutations are described as follows:

Deletion:

- This is the loss of a portion of a chromosome,
- Deletion results in individuals born with missing body parts .
- e.g. limbs in the extreme of cases.

Inversion:

- A portion may break from a chromosome and then rejoin to it after turning though an angle-of 180^0 .

Translocation:

- This is when a portion is joined to a non-homologous chromosome.

Duplication:

- A certain section of an intact chromosome replicates such that the genes are repeated.

Gene Mutations

- A gene mutation is a change in the structure of a gene.
- It may involve only a change in one base, e.g. adenine in place of thyamine yet the effect on the individual is profound e.g. sickle cell anemia .
- There are two main type of gene mutations:
  - Due to insertion or deletion of one or more (base) pairs.
- Substitution of base pairs e.g. purine for pyrimidine.

Genetically inherited disorders in humans

- Albinism is a mutation that alters the gene responsible for synthesis of skin pigment (melanin).
- The gene for albinism is recessive.
- **Sickle cell anemia** is a common condition in Kenya.
- Individuals with the sickle-cell gene produce abnormal haemoglobin.
- It is due to gene mutation caused by substitution of the base adenine for thymine.
- The result is the inclusion of the amino acid valine (in place of glutamic acid) in the haemoglobin synthesised.
- As a result the red blood cells become sickle shaped when oxygen concentration becomes low i.e. inside tissues.
- This leads to blockage of capillaries.
- Tissues do not get sufficient oxygen.
- Homozygous individuals are seriously anaemic and die in early childhood.
- Heterozygous individuals have a mixed population of normal and sickled red blood cells.
- They are not seriously anaemic and can lead fairly normal lives.

- Haemophila (bleeder's diseases) is due to lack of gene for production of proteins responsible for blood clotting.

Practical Applications of Genetics

- Study of genetics has been put into a wide variety of uses en-compasing plants and animals and in particular humans.

Blood transfusion

- Blood groups are genetically determined.

- As discussed earlier a person of blood group A can only get blood from another one of A or O.
- In case of emergencies and unavailability of blood, a patient may be given blood group A + when he/she is A-.
- First transfusion is fine since, by the time enough antibodies are produced most of the red blood cells of donor have completed their lifespan but a subsequent transfusion of A+ blood is fatal.

Plant and Animal breeding

- Genetics is applied mostly in plant and animal breeding in order to produce varieties that are most suitable to man's needs.
- This is done through artificial selection.
- Varieties are developed that are resistant to pests, diseases or harsh climatic conditions.

Genetic counselling

- Genetic counselling involves advising about hereditary diseases and disorders so that they can make informed decisions.

This is done through:

- Taking family history.
- Screening for genotypes e.g. through amniocentesis.
- In amniocentesis, cells are obtained from amniotic fluid during pregnancy.
- Conditions such as Down's syndrome can be detected using microscopy.

Genetic Engineering

- This is a technology that involves the manipulation of the genotype of an organism to get the desired trait.
- It also involves the transfer of gene coding for the desired trait from one organism to another.

Application of Genetic Engineering

Pharmaceutical industries:

- Making of hormones e.g. Human insulin and human growth hormone.
- Enzymes e.g. Alph-Anti-Trypsin (AAT) used to treat emphysema. (c) Proteins.
- Drugs and vaccines.

Agricultural industries:

- Transgenic animals and plants are produced which are also called Genetically Modified Organisms (GMO's).
- A variety of tomato with improved paste and a longer shell life.
- Sheep for producing desired proteins in milk.
- Plants resistant to pests and diseases.

Cloning

- This is the making of identical copies of genes, DNA and whole organisms.
- Cloning is used in plants - that is tissue culture e.g. in development of various varieties of bananas and *Eucalyptus* trees.
- The first mammal to be cloned successfully was Dolly - the sheep.

- A nucleus from the cell obtained from the udder of the sheep was inserted in an unfertilised egg without a nucleus.
- This zygote was introduced into the uterus of a sheep and developed to full term.

Gene therapy

- Involves injecting genes into patients of certain diseases
- e.g. Parkinson's diseases.
- The injected gene alters metabolism to bring about the cure of the disease.

THE NERVOUS SYSTEM

Components of the nervous system in humans

- Every organ is the human body is connected to nerves.
- The nervous system is made up of nerve cells (neurons) which transmit impulses from one part of the body to another.

It consists of the following:

- The Central Nervous System (CNS) is a concentrated mass of interconnected nerve cells which make up the brain and the spinal cord.
- The peripheral nervous system is made up of nerves which link the CNS to the receptors and the effectors.
- Sensory nerves link the sensory cells (receptors) to the central nervous system and transmit nerve impulses from a sense organ to the CNS.

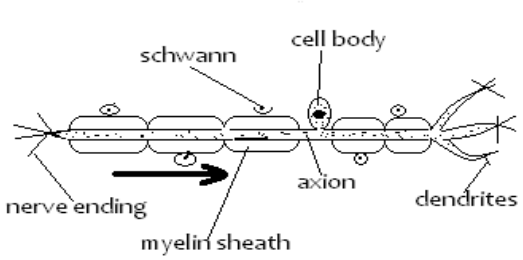
Structure and Functions of Neurons

- A nerve cell consists of a cell body (centron) where the nucleus is located, and projections called dendrites arise.
- One of the projections is drawn out into an axon i.e. the longest process.
- Each axon contains ***axoplasm*** which is continuous with the cytoplasm in the cell body.
- The axon is enclosed in a fatty myelin sheath which is secreted by Schwarm cell.
- The myelin sheath is interrupted at approximately 1 mm intervals by constrictions known as nodes of Ranvier.
- The myelin sheath is enclosed by a thin membrane called the ***neurilemma,*** which is part of the ***Schwann cell*** in contact with axon.
- The myelin sheath and ***nodes of Ranvier*** enhance transmission of the impulse.

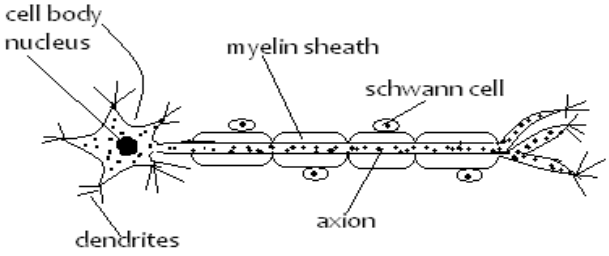
There are three types of neurons:

Sensory neurone

- Also known as afferent neurone.
- Transmits impulses from sensory cells to the CNS.
- The cell body of a sensory nerve cell is located at some distance along the length of the axon outside the CNS.



sensory nerve cell



motor nerve cell

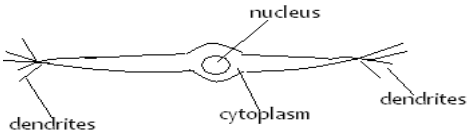
Motor neurone

- Known as efferent or effector neurone
- Transmit impulses from the CNS to the effectors(muscles and glands)
- Its cell body is located inside the CNS.

Intermediate or connector neurone

- Also called relay neurone
- Found inside the CNS.

- The connect sensory and motor neurons with each other and with other nerve cells in the CNS.

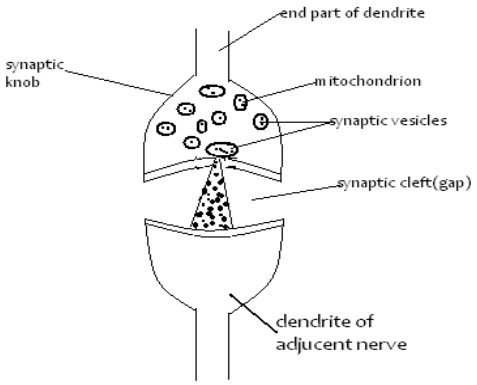


Intermediate neurone

Functions of the neurone

- The nerve impulse is electrical in nature.
- Its transmission depends on differences in electrical potential between the inside and the outside of the axion.
- The outside is positive while the inside is negative.
- The stimulus triggers a change that affects the permeability of neurone membrane.
- The result is a change in the composition of ions on either side of the membrane.
- The outside becomes negative as the inside becomes positive due to sodium ions rushing in.
- The above constitutes a nervous impulse which is transmitted along the sensory neurone to the CNS.
- The speed of transmission is very high.
- Certain mammalian axions transmit impulses at the rate of 100m/s.
- The dendrites of neurons do not connect directly to each other, but they leave a small gap called synapse.
- The transmission of an impulse from one cell to the next takes place through synapse.
- Synaptic knobs are structures found at the ends of dendrites.
- Thus the dendrites of one nerve cell make contact with the dendrites of the adjacent nerve cell through the synapses.
- Impulses are transmitted in the form of a chemical transmitter substance which crosses the gap between one dendrite and the next.

- The transmitter substance is found within synaptic vesicles.
- The chemical substance is either ***acetylcholine*** or ***noradrnaline.***
- The synaptic vesicles burst and release the transmitter substance when an impulse arrives at the synaptic knob.
- Impulses in motor neurone s are trans mitted to effectors.
- The space between motor end dendrite and muscle is known as neuro-muscular Junction.
- Synaptic vesicles in the ends of the dendrites release the transmitter substance across the neural muscular junction.



structure of synapse

Functions of Major Parts of the Human Brain

- The Central Nervous System (CNS) consists of the brain and the spinal cord.
- The CNS co-ordinates body activities by receiving impulses from sensory cells from different parts of the body.
- It then sends the impulses to the appropriate effectors.
- The brain is enclosed within the cranium or braincase.
- It is covered and protected by membranes known as meninges.
- When meninges are infected by bacterial or fungi they cause meningitis.

The brain consist of the following parts:

Cerebrum.

- This is the largest part of the brain.
- It consists of two cerebral hemispheres.
- It is highly folded in order to increase the surface area.
- The cerebrum controls learning, intelligence, thought, imagination and reasoning.

The medulla oblongata (brain stem).

- The medulla oblongata has centres which control breathing (ventilation) rate,
- heart beat rate (cardiac frequency),
- swallowing, salivation, blood pressure
- temperature regulation, hearing, taste and touch.

The cerebellum

- Is located in front of the medulla and is a folded dorsal expansion of the hindbrain.
- It controls posture movement and balance.

The hypothalamus

- Controls functions such as body temperature and osmoregulation.

The pituitary gland

- Is an endocrine organ that secretes a number of hormones which control osmoregulation, growth, metabolism and sexual development.

Optic lobes -control the sense of sight.

Olfactory lobes -control the sense of smell.

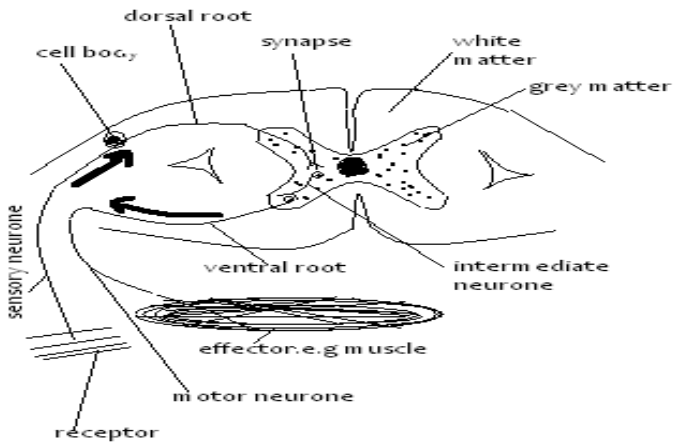
Spinal Cord

- The spinal cord is located within the vertebral column and consist of the following:
- The ***grey matter*** forms the central part of the spinal cord.
- It consists of nervecell bodies and intermediate nerve fibres.
- The ***white matter*** of the spinal cord carries sensory nerve fibers while the ventral root carries motor nerve fibers.

Simple And Conditioned Reflex Actions

Simple Reflex Action

- A simple reflex action is an automatic response to a stimulus.
- The route that is followed by impulses during a reflex action is called a ***reflex arc.***



The reflex arc

A reflex action follows the following sequence:

- A receptor is stimulated and an impulse is transmitted along a sensory nerve fibre to the spinal cord.
- The impulse is picked up by an intermediate neurone within the CNS.
- The intermediate nerve fibre transmit the impulse to a motor nerve fibre which is connected to an effector.
- The effector responds.

Examples of reflex action include:

- Pulling the hand away from a hot object.
- The knee jerk.
- Sneezing.

Conditioned Reflexes

- These are learned responses.
- When two or more stimuli are presented to an animal at the same time and repeatedly, the animal eventually responds to either stimulus.
- For example, if a hungry animal is presented with food, it will respond by salivating.
- If a bell is rung at the same time as the food is presented to the animal, the animal will learn to associate the sound of the bell with food.
- Eventually, the animal can be made to salivate at the sound of the bell alone.
- This response is called ***conditioned reflex*** and is one of the ways by which animals learn.

The Role of Endocrine System in Human Beings

- Endocrine system consists of glands that secrete hormones.
- The glands have no ducts and are known as endocrine glands.
- Other glands are known as exocrine glands because they have ducts.
- The pancreas has an outer exocrine portion and an inner endocrine portion.
- Hormones are chemical substances, protein in nature which are secreted at one part of the body and have effects on other parts not necessarily near the point of secretion.
- They are secreted directly into blood and transported by blood.
- Each hormone either has a generalised co-ordinating effect on the body or brings about a specific response in a particular target organ.

Hormones produced in humans and the in effects on the body.

Endocrine	Hormone(s)	Role of	Effect of deficiency	Effect of excess
1. Pituitary	Trophic Hormones (i) Somatotropin (Growth	Controls	Dwarfism	Gigantism
	(ii) Thyrotrophic	Controls of thyroxin by thyroid gland	Same as for deficiency of thyroxin	Same as for of tyroxine
	(iii) Adrenocorticotroph Hormone	Stimulates the activity of cortex		
	(iv) Follicle stimulating Hormone (FSH)	Development of Graafian the ovary		
	(v) Luteinising (L.H)			
2. Thyroid	Thyroxine	Regulates the metabolic rate;	Retardation of physical and mental	High metabolic rate, rapid heartbeat, general wasting

			development (cretinism)	the body: protrusion of eyeballs (exopthalrnic
3.1slets of Langerhans in pancreas	(i) Insulin	Regulates blood sugar by conversion of glucose to	Hyperglycaemia (high blood sugar); mellitus	Hypoglycaemia (low blood
	(ii) Glucagon	Regulates blood sugar by causing conversion of glucose into glycogen	Hypoglycaemia (low blood sugar)	Hyperglycemia (high blood sugar)
4. Gonads Testis and ovaries	Androgens and	Development secondary characteristics.	Secondary characteristic fail to	In females development of male.? In males to development female characteristics.
(i) Ovaries	Oestrogen	Repair of wall		
	Progestrone	Causes thickening of wall of inhibits during prevents of uterus	Miscarriage when level falls pregnancy	
(ii)Testis (interstitial cells)	Testosterone	Promote spermatogenesis; and male sexual characteristics.	Male sterility	

5.Adrenal	(i) Adrenaline	Changes in response to stress or shock; increased conversion of glycogen to glucose; pupils; blood flow to skeletal		
	(ii) Hydrocortisone	Metabolism of carbohydrates, lipids and	Less stored in the and muscles	
	(iii) Aldosterone	Promotes of sodium and ions	Kidneys too much sodium, and ions	

Adrenaline

- Enhance activity of sympathetic nervous system.

Over secretion

- Increased heartbeat
- High blood pressure
- Thin toneless muscles.

Under secretion

- Low blood pressure
- Inability to withstand stress
- Muscular weakness

Thyroxine

Over secretion is termed hyperthyroidism this causes:

- Increased Basal Metabolic Rate (BMR) hence increased temperature.
- Person becomes very angry, nervous and hands may shake.
- Increased heartbeat which lead to cardiac failure.

Under secretion is termed hypothyroidism:

- Poor growth and mental retardation (cretinism).
- Reduced metabolic rate hence decreased temperature.
- Person becomes inactive and slothful.
- Eyes and face become puffy as fluid gets stored under skin.
- In extreme cases the tongue is swollen and skin becomes rough.
- Enlarged thyroid gland.

Comparison between endocrine and nervous system

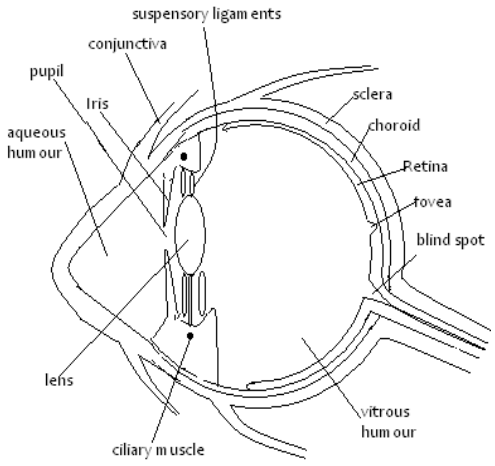
	Nervous communication	Endocrine communication
Speed of Transmission	Usually rapid	Usually slower
Response	Usually specific in a given Effector	Usually widespread; in some cases in particular target organ.
Nature of impulse	Electrochemical along Axion; chemical across synapses	Chemical; in the form of a hormone that travels in blood
Duration of Response	Usually short lived	Usually long-lasting.e.g. growth

Similarities

- Both endocrine and nervous system are involved in the coordination of body functions.
- Both have target organs.
- Both are controlled via a negative feedback mechanism, i.e too high production results in a reduced production.

Structure and Function of Parts of the Human Eye

Structure



vertical section of the human eye

- The human eye is spherical in shape and situated within a socket or orbit in the skull.
- It is attached to the skull by three pairs of muscle, which also control its movement.
- It is made up of three main layers; ***sclerotic layer, choroid and the light sensitive retina.***

Sclerotic layer

- Outermost white part situated at the sides and back of the eye.
- Made up of collagen fibres.
- It protects the eye and gives its shape.

Cornea

- This is the transparent front part of the sclera that allows light to pass through.
- It is curved, bulging at the front. It thus reflects light rays hence helps to focus light rays onto the retina.

Choroid

- The second or middle layer.
- It has many blood vessels that supply nutrients to the eye and remove metabolic wastes from the eye.
- It has dark pigments to absorb stray light and prevent its reflection inside the eye.

Ciliary body

- Is glandular and secretes aqueous humour.
- It has blood vessels for supplying of nutrients excretion and gaseous exchange.
- It has ciliary muscles - which contract and relax to change the shape of lens during accommodation.

Suspensory ligaments

- Are inelastic and attach the lens onto the cilliary body holding it in position.

Lens

- Biconvex in shape, to refract light.
- Crystalline and transparent to allow light to pass through and focus it on to the retina.

Aqueous humour

- Found between lens and the cornea.
- Transparent to allow light to pass through it.
- It is watery thus helping in focusing.
- Helps maintain shape of eye ball.
- To convey nutrients and oxygen to cornea, and remove waste products.

Iris

- The coloured part of the eye has an opening - the pupil at the centre.
- Iris has circular and radial muscles which controls size of the pupil, hence the amount of light entering the eye through the pupil.

Vitreous humour

- It is a fluid.
- Found between lens and retina.
- Is viscous and gives eye the shape.
- It is transparent and refracts light.

Retina

- Retina contains light sensitive cells and is situated at the back of the eye.
- There are two types of light sensitive cells in the retina:
- ***Rods -*** are sensitive to low-intensity light and detect black and white. Nocturnal mammals have more rods.
- ***Cones -*** are sensitive to high intensity of light;
- They detect bright colour.
- Diurnal mammals have more cones.

Fovea centralis

- Fovea centralis (yellow spot) is the most sensitive part of the retina.
- Consists mainly of cones for accurate vision (visual acuity).

Optic nerve

- Optic nerve, has neurons for transmission of impulse to the brain for interpretation.

Blind spot

- Blind spot is located at the point where the optic nerve leaves the eye on its way to the brain.
- It is not sensitive to light it has no rods or cones.

Eye lid

- Eye lid is a loose skin that covers the eye. It closes by reflex action.
- Protects it from mechanical damage and from too much light.

Eyelashes

- Prevent dust and other particles from entering eye.

Conjuctiva

- It is transparent and thin and allows light to pass through.
- It is a tough layer that is continuous with the epithelium of the eye lids.
- It protects the cornea.

Accommodation

- Accommodation refers to the change in the shape of the lens in order to focus images.
- Rays from a distant object would be focused at a point behind the retina if the lens were not adjusted appropriately.
- When the eye is focusing at a distant object, the cilliary muscles are relaxed and the suspensory ligament are stretched tight.

- The lens is pulled thin, thus allowing light rays from a distant object to be properly focused on to the retina.
- When the eye is looking at near object, the ciliary muscles contract and the suspensory ligament become slack.
- The lens becomes more convex.
- This allows light rays from near object to be focused onto the retina.

Control of light intensity entering the eye

- In bright light (high intensity) the circular muscles of the iris contract.
- The diameter of the pupil decreases and less light enters.
- This protects retina from damage by too much light.
- In dim light circular muscles of iris relax (radial ones contract).
- Pupil's size (diameter) increases, more light enters the eye.

Image formation and Interpretation

- Light rays from an object enter the cornea and are directed onto the lens through the pupil.
- They are refracted by the cornea and the lens.
- The latter brings the rays into fine focus.
- It makes the light rays converge so that an image is focused at a point on the retina.
- The image on the retina is inverted.
- This stimulate, the rods and cones on the retina and impulses generated are transmitted through the optic nerve to the brain.
- The brain interprets the image as upright.

Common Eye Defects and their Correction

Short-sightedness (Myopia)

- A shortsighted person cannot focus distant objects properly.
- Light rays from a distant object fall at a point in front of the retina.
- This may be due to the eyeball being too long.
- This defect can be corrected using spectacles with concave lenses.
- The lenses make the light rays diverge before they reach the eye.

Long-sightedness (Hypermetropia)

- A long-sighted person cannot focus near objects properly.
- Light rays from the object are not focused on the retina.
- This may be due to the eyeball being too short.

- This defect may be corrected by using spectacles with convex lenses which make light rays converge before they reach the eye.

Astigmatism

- Astigmatism refers to a condition in which the cornea or the lens is uneven, so that images are not focused properly on the retina.
- This defect can be corrected by wearing spectacles with special cylindrical lenses.
- Presbyopia is a condition in which light rays from a near object are not focused on the retina.
- This is caused by hardening or loss of elasticity of lense due to old age.
- This defect is corrected by wearing convex (converging) lenses.

Structure and Functions of Parts of Human Ear

The Mammalian Ear

- The mammalian ear performs two major functions:
- hearing and detecting changes in the positions of the body to bring about balance and posture.

The ear is divided into three sections.

The Outer Ear

This consists of:

- An outer flap, the ***pinna*** which is made up of cartilage.
- The function of the pinna is to catch and direct sounds.
- ***The external auditory canal*** is a tube through which sound travel.
- The lining of the tube secretes wax, which traps dust particles and microorganisms.
- The ***tympanum*** is a membrane stretching across the inner end of the external auditory canal.
- The tympanum vibrates when it is hit by sound waves.

The Middle Ear

- This is a chamber containing three small bones called the ear ossic1es, the malleus, incus and stapes.
- The three ossic1es articulate with one another to amplify vibrations.
- The vibrations are transmitted from the tympanum to the oval window.
- At the end of the chamber is a membrane called the oval window.

- When the tympanum vibrates, it causes the ear ossic1es to move forwards and backwards.
- This causes the oval window to vibrate.
- The Eustachian tube connects the middle ear to the pharynx.
- It allows air to get in and out of the middle ear, thus equalising the pressure between the inside and the outside of the tympanum.

The Inner Ear

- This consists of a series of chambers filled with fluid.
- It comprises the cochlea and semicircular canals.
- Cochlea is a coiled tube that occupies a small space and accommodates a large number of sensory cells.
- The cells are connected to the brain through the auditory nerve.
- They detect vibrations which lead to hearing.

Hearing

- The sound waves set the tympanum vibrating and are transformed into vibrations.
- The vibrations are transmitted to the oval window by the three ossicles.
- Vibrations of the oval window cause the fluids inside the cochlea tube to vibrate.
- The membranes inside the cochlea have sensory cells which change the sound vibrations to nerve impulses.
- These are transmitted to the brain through the auditory nerve.
- Hearing is perceived in the brain.

Balance and posture

- ***The semi-circular canals***
- There are three semi-circular canals in each ear.
- They are situated at right angles to each other and each one is sensitive to movement in a different plane.
- They are filled with fluid and each has a swelling called the ampulla at one end.
- Inside the ampulla are sensory cells.
- Balance and posture are detected by these cells.

- Movement of the head in a given direction causes the fluid to move the hairs on sensory cells.
- This transmit impulses to the brain through the auditory nerve so that the movement is registered.

Defects of the ear

Acute labyrinthitis

- This is an inflammation of the middle ear and cochlea.
- It may lead to deafness.
- It can be treated by using certain drugs but sometimes an operation may be necessary.

Tinnitis:

- This is a sensation of noises in the ear.
- It is caused among others by accumulation of wax in the ear or use of certain drugs e.g. quinine.
- Treatment is by removal of wax, stopping use of the causative drug.

Vertigo - Giddiness

- This is disorientation of body in space - one of the causes is dilation of endolymph.
- ***Corrections***: Use of appropriate drugs.

Deafness.

- This is inability to hear.
- It is presented in various degrees in various individuals, some have partial hearing, others are completely deaf.

This may be as a result of:

- Chronic infection of cochlea.
- Lack of sensory cells.
- Excess wax in external auditory canal.
- Fusion of ear ossicles.

Otitis Media

- This is the inflammation of middle ear due to build-up of fluid.
- It is marked by the swelling of tissues surrounding the Eustachian tube due to infection or severe congestion.
- A strong negative pressure creates a vacuum in the middle ear.
- Treatment - use of antibiotics or surgery.

LOCOMOTION

Support and Movement in Animals

Necessity for support and movement in animals.

Animals move from place to place:

- In search of food.
- To escape from predators.
- To escape from hostile environment.
- To look for mates and breeding grounds.
- The skeleton, which is a support structure helps to maintain the shape of the body.
- Movement is effected by action of muscles that are attached to the skeleton.

Types and Functions of Skeletons

- Two main types will be considered.
- These are exoskeleton and endoskeleton.

Exoskeleton

- Exoskeleton is hard outer covering of arthropods made up of mainly chitin.
- Which is secreted by epidermal cells and hardens on secretion.
- It is strengthened by addition of other substances e.g. tannins and proteins to become hard and rigid.
- On the joints such as those in the legs the exoskeleton is thin and flexible to allow for movement.

Functions of Exoskeleton

- Provide support.
- Attachment of muscles for movement.
- Protection of delicate organs and tissues.
- Prevention of water loss.

Endoskeleton:

- It forms an internal body framework.
- This is a type of skeleton characteristic of all vertebrates.
- The endoskeleton is made of cartilage, bone or both.
- It is made up of living tissues and grows steadily as animal grows.
- Muscles are attached on the skeleton.

- The muscles are connected to bones by ligaments.

Functions

- The functions of endoskeleton include support, protection and movement.
- Locomotion in a finned fish e.g. tilapia.
- Most of the fishes are streamlined and have backward directed fins to reduce resistance due to water.

External features-of Tilapia

- Scales tapers towards the back and overlap forwards to provide a smooth surface for a streamlined body.
- The head is not flexible.
- This helps the fish to maintain forward thrust.
- Slimy mucous enables the fish to escape predators and protects the scales from getting wet.
- The pectoral and pelvic fins are used mainly for steering, ensuring that the fish is balanced.
- They assist the fish to change direction.
- The dorsal and anal fins keep the fish upright preventing it from rolling sideways.
- The caudal or tail fin has a large surface area, and displaces a lot of water when moved sideways creating forward movement of the fish.
- In order to change position in water the fish uses the swim bladder.
- When filled with air the relative density of the body is lowered and the fish moves up in the water.
- When air is expelled, the relative density rises and the fish sinks to a lower level.
- Swimming action in fish is brought about by contraction of muscle blocks (myotomes).
- These muscles are antagonistic when those on the left contract, those on the right relax.
- The muscles are attached to the transverse processes on the vertebra.
- The vertebra are flexible to allow sideways movement.

Mammalian skeleton

The mammalian skeleton is divided into two:

- Axial and appendicular.
- Axial skeleton is made up of the skull and the vertebral column.
- Appendicular skeleton is made up of the pelvic and pectoral girdles and limbs (hind limb and forelimbs).

The Axial Skeleton

This consists of the ;

- ***skull,***
- ***the sternum,***
- ***ribs,***
- ***the vertebral column.***

The Skull

- The skull is made up of cranium and facial bones.
- The cranium; encloses and protects the brain.
- It is made up of many bones joined together by immovable joints.
- The facial bones consists of the upper and lower jaws.
- At the posterior end of the cranium are two smooth rounded protuberances, the occipital condyles.
- These condyles articulate with the atlas vertebra to form a hinge joint, which permits the nodding of the head.

Sternum and ribs –

- They form the rib-cage.
- The rib-cage encloses the thoracic cavity protecting delicate organs such as the heart and lungs.
- The ribs articulate with the vertebral column at the back and the sternum at the front.

The Vertebral Column

- The vertebral column is made up of bones called vertebrae placed end to end.
- The vertebrae articulate with one another at the articulating facets.
- In between one vertebra and another is the cartilaginous material called intervertebal disc.
- The discs act as shock absorbers and allow for slight movement.
- Each vertebra consists of a centrum and a neural arch which projects into a neural spine.
- The neural canal is the cavity enclosed by the centrum and the neural arch.
- The spinal cord is located inside the canal.
- The neural spine and other projections e.g. transverse processes serve as points of attachment of muscles.

Cervical Vertebrae

- These are found in the neck region of a mammal.
- The distinguishing feature is a pair of verte-braterial canals in the neural arch, through which the blood vessels of the neck pass.
- Another feature is the structure of the transverse processes.
- They are flattened out and are known as cervical ribs.
- The fIrst cervical vertebra is known as the Atlas.
- It has a large neural canal and no centrum.
- The second cervical vertebra, is called axis.
- The other five cervical vertebrae have no specific names.
- They have the same structure.
- The cervical vertebrae possess numerous processes for muscle attachment.

Thoracic Vertebrae

- Each thoracic vertebra has a large centrum ,a large neural canal, neural arch and a long neural spine that projects upwards and backward.
- There is a pair of prezygapophyses and postzygapophyses for articulation with other vertebra .
- They have a pair of short transverse process.
- The thoracic vertebra also articulates with pair of ribs at tubercular and capitular facets.

Lumbar Vertebrae

- Each lumbar vertebra has a large, thick centrum for support of the body.
- It has a neural spine that projects upwards and forwards.
- There is a pair of large transverse process that are directed forwards.
- Above the prezygapophyses lies a pair of processes called metapophyses,
- Below postzygapophyses lies the anapophyses.
- Metapophyses and anapophysis serve for attachment pf muscles of the abdomen.
- In some mammals, there may be another process on lower side of centrum called hypapophysis also for muscle attachment.

Sacral Vertebrae

- The sacral vertebrae are fused together to form a rigid bony structure, the sacrum.
- The centrum of each vertebra is large, but the neural canal is narrow.
- The neural spine is reduced to a small notch.
- The transverse processes of the first sacral vertebra are large and wing-like
- They are firmly attached to the upper part of the pelvic girdle.

Caudal Vertebrae

- Human beings have only four of these vertebrae which are fused together to form coccyx.
- Animals with long tails have many caudal vertebrae.
- A typical caudal vertebra appears as a solid rectangular mass of bone.
- The entire bone consists of the centrum only.

Appendicular Skeleton

- The appendicular skeleton consist of the limbs and their girdles.

Bones of Fore-limbs

Pectoral girdle

- Pectoral girdle is made of scapula, coracoid and clavicle.
- A cavity known as glenoid cavity occurs at the apex of the scapula.
- The humerus of the fore limb fits into this cavity.
- The clavice is a curved bone connecting the scapular to the sternum.

Humerus

- Humerus is found in the upper arm.
- It articulates with the scapula at the glenoid cavity of the pectoral girdle and forms a ball and socket joint.

Ulna and radius

- These are two bones found in the forearm.
- The ulna has a projection called olecranon process and a sigmoid notch which articulates with the humerus.

Bones of hind limb

Pelvic Girdle

- The pelvic girdle consists of two halves fused at the pubic symphysis.
- Each half is made up of three fused bones:
  - the ilium,

- ischium
- pubis.

- Each half has cup-shaped cavity for the acetabulum for articulation with the head of the femur.
- Between the ischium and pubis is an opening obturator foramen where spinal nerves, blood vessels and a tough inflexible connective tissues pass.
- The ilium, ischium and pubis are fused to form the innominate bone.

The Femur

- The femur is the long bone joining the pelvic girdle and the knee.
- The head of the femur articulates with acetabulum forming the ball and socket joint at the hip.
- The femur has a long shaft.
- At the distal end it has condyles that articulate with the tibia to form a hinge joint at the knee.
- The patella covers the knee joint and prevents the upward movement of the lower leg.

Tibia and Fibula

- The tibia is a large bone, and the fibula a smaller bone is fused to it on the distal part.
- In humans the tibia and fibula are clearly distinguishable.

Joints and Movement

- Ajoint is a connection between two or more bones.
- Joints provide articulation between bones making movement possible.
- However some joints do not allow any movement e.g. the joints, between bones of the skull.
- Movable joints are of three main types:

Gliding joint

- e.g., joints which occur between the vertebrae wrists and ankles.
- The ends of the bones that make the joint are covered with cartilage.
- The bones are held together by tough ligaments.

Synovial joint

- The joint is enclosed by fibrous capsule lined by synovial membrane which secretes synovial fluid into the synovial cavity.
- The synovial fluid lubricates the joint.
- They are called synovial joints.
- They include hinge joint and ball and socket joint.

Hinge joint

- e.g. knee joint.
- The joint allows movement in one plane.

Ball and socket joint.

- e.g., hip joint.
- The joint allows rotation in all directions.

Types, Locations and Function of Muscles

- There are three types of muscles, located at various parts of the body.
- In order to function all use energy in form of ATP.
- These include smooth, skeletal and cardiac muscles.

Smooth Muscle (Involuntary Muscles)

- These are spindle-shaped and contain filaments with myofibrils.
- Each muscle is bound by plasma membrane.
- They are found lining internal organs such as alimentary canal, bladder, and blood vessels.
- They are controlled by involuntary part of the nervous system.
- They are concerned with movement of materials along the organs and tubes.
- They contract slowly and fatigue slowly.

Skeletal Muscle (striated or voluntary muscle)

- Skeletal muscles are striated and have several nuclei.
- They are long fibres each containing myofibrils and many mitochondria.
- They have cross-striations or stripes.
- They are also called voluntary muscles because the contraction is controlled by voluntary nervous system.
- They are surrounded by connective tissue and are attached to bones by tendons.
- Their contraction brings about movement of bone, resulting in locomotion.
- They contract quickly and fatigue quickly.

Cardiac Muscle

- Consist of a network of striated muscle fibres connected by bridges.
- Are short cells with numerous mitochondria and uninucleate.
- They are found exclusively in the heart.
- Contractions of cardiac muscles are generated from within the muscles and are rhythmic and continuous hence they are myogenic.
- They do not tire or fatigue.
- The rate can be modified by involuntary nervous system.
- Their contractions result in the heart pumping blood.

Role of muscles in movement of the human arm

- Muscles that bring about movement are antagonistic, i.e. when one set contracts the other relaxes.

Antagonistic muscles of human forelimb

- The biceps muscles of the forelimb act as flexors while the triceps muscles act as extensors.
- The biceps has its point of origin on the scapula and the point of insertion on the radius.
- The triceps has its points of origin on the scapula and humerus and is inserted on the ulna.
- When the muscles contract, the limb acts as a lever with the pivot at the joint.
- Contraction of biceps muscles bends (flexes) the arm while a contraction of triceps extends the arm.

Movement in land, water and Air

Ameoboid movement.

Amoeboid movement occurs as an extension of the cytoplasm, called a pseudopod ("false foot"), flows outward, deforms the cell boundary, and is followed by the rest of the cell. Many pseudopodia may be formed at the same time, and their actions do not seem to be coordinated.
A crawling-like type of movement in which the cell forms temporary cytoplasmic projections called pseudopodia (false feet) towards the front of the cell.The pseudopodianflows outward, deforms the cell boundary formed and is followed by the rest of the cell.

This type of movement is observed in amoebae (e.g. *Amoeba proteus*)
Their cytoplasm consists of plasmasol (central fluid) surrounded by a more viscous plasmagel. The plasmagel is converted to plasmasol causing the cytoplasm to slide and form a pseudopodium in front to move the cell forward.

Cells that move this way are referred to as amoeboids. Apart from amoeba, other examples are cellular slime moulds (e.g. *Dictyostelium discoideum*) and human cells, particularly Kupffer cells of liver, monocytes, neutrophils, macrophages, and cancerous cells.

EXCRETION AND HOMEOSTASIS

Introduction

- ***Excretion*** is the process by which living organisms separate and eliminate waste products of metabolism from body cells.
- If these substances were left to accumulate, they would be toxic to the cells.
- ***Egestion*** is the removal of undigested materials from the alimentary canals of animals.
- ***Secretion*** is the production and release of certain useful substances such as hormones, sebum and mucus produced by glandular cells.
- ***Homeostasis*** is a self-adjusting mechanism to maintain a steady state in the internal environment

Excretion in Plants

- Plants have little accumulation of toxic waste especially nitrogenous wastes.
- This is because they synthesise proteins according to their requirements.
- In carbohydrate metabolism plants use carbon *(IV)* oxide released from respiration in photosynthesis while oxygen released from photosynthesis is used in respiration.
- Gases are removed from the plant by diffusion through stomata and lenticels.
- Certain organic products are stored in plant organs such as leaves, flowers, fruits and bark and are removed when these organs are shed.
- The products include tannins, resins, latex and oxalic acid crystals.

- Some of these substances are used illegally.
- Khat, cocaine and cannabis are used without a doctor's prescription and can be addictive.
- Use of these substances should be avoided.

Plant Excretory Products their source and uses

Plant	*Source*	*Use*
Caffeine	Tea and coffee	Mild CNS stimulant.
Quinine	Cinchona tree	Anti malaria-drug.
Tannins	Barks of Acacia,	Tanning hides and
Colchicin	Corms of crocus	Prevents spindle formation in cell
Cocaine	Leaves of coca plant	Local anaesthesia. -
Rubber	Latex of rubber plant	Used in shoe
Gum	Exudate from acacia	Used in food processing and
Cannabis	Flowers, fruits and leaves of *cannabis sativa*	Used in manufacture of drugs.
Nicotine	Leaves of tobacco plant	Manufacture of insecticides. Heart and CNS stimulant.
Papain	Pawpaw (fruits)	Meat tenderiser Treats indigestion.
Khat	*Khatha edulis* (miraa)	Mild stimulant.
Morphine	Opium Poppy plant	Narcotic. Induces sleep /
Strychnin	Seeds of strychnos	CNS stimulant.

Excretory products in animals

Substance	***Origin***
1. Nitrogenous (i) Ammon (ii Urea (iii) Uric	Excess amino acids Deamination of Deamination of amino acids; then addition of Ammonia (from deamination of amino acids).
2. Carbon	Homeostasis and
3. Biliverdin and	Breakdown of
4. Water	Osmoregulation.
5. Cholesterol	Excess intake of --

6. Hormones	Excess production

Excretion and Homeostasis in Unicellular Organisms

- Protozoa such as amoeba depend on diffusion as a means of excretion.
- They have a large surface area to volume ratio for efficient diffusion.
- Nitrogenous waste and carbon (IV) oxide are highly concentrated in the organism hence they diffuse out.
- In amoeba excess water and chemicals accumulation in the contractile vacuole.
- When it reaches maximum size the contractile vacuole moves to the cell membrane, bursts open releasing its contents to the surroundings.

Excretion in Human Beings

- Excretion in humans is carried out by an elaborate system of specialised organs.
- Their bodies are complex, so simple diffusion cannot suffice.
- Excretory products include nitrogenous wastes which originate from deamination of excess amino acids.

- The main excretory organs in mammals such as human beings include lungs, kidneys, skin and liver.

Structure and function of the human skin

Nerve Endings:

- These are nerve cells which detect changes from the external environment thus making the body to be sensitive to touch, cold, heat and pressure.

Subcutaneous Fat:

- Is a layer beneath the dermis.
- It stores fat and acts as an insulator against heat loss.
- The skin helps in elimination of urea, lactic acid and sodium chloride which are released in sweat.

The Lungs

- Carbon (IV) oxide formed during tissue respiration is removed from the body by the lungs.
- Mammalian lungs have many alveoli which are the sites of gaseous exchange.

- Alveoli are richly supplied with blood and have a thin epithelium.
- Blood capillaries around the alveoli have a high concentration of carbon (Iv) oxide than the alveoli lumen.
- The concentration gradient created causes carbon (IV) oxide to diffuse into the alveoli lumen.
- The carbon (IV) oxide is eliminated through expiration.

Structure and Functions of the Kidneys

- The kidneys are organs whose functions are excretion, osmoregulation and regulation of pH.
- Kidneys are located at the back of the abdominal cavity.
- Each kidney receives oxygenated blood from renal artery,
- while deoxygenated blood leaves through the renal vein.
- Urine is carried by the ureter from the kidney to the bladder, which temporarily stores it.
- From the bladder, the urine is released to the outside via the urethra.
- The opening from the urethra is controlled by a ring-like sphincter muscle.
- A longitudinal section of the kidney shows three distinct regions: a darker outer cortex, a lighter inner medulla and the pelvis.
- The pelvis is a collecting space leading to the ureter which takes the urine to the bladder from where it is eliminated through the urethra.

The Nephron

- A nephron is a coiled tubule at one end of which is a cup-shaped structure called the Bowman's capsule.
- The capsule encloses a bunch of capillaries called the glomerulus.
- The glomerulus receives blood from an afferent arteriole a branch of the renal artery.
- Blood is taken away from the glomerulus by efferent arteriole leading to the renal vein.
- The Bowman's capsule leads to the proximal convoluted tubule that is coiled and extends into a U-shaped part called loop of Henle.
- From the loop of Henle is the distal convoluted tubule that is also coiled.
- This leads to the collecting duct which receives contents of many nephrons.
- Collecting ducts lead to the pelvis of the kidney.

Mechanism of Excretion

- Excretion takes place in three steps:
- Filtration, reabsorption and removal.

Filtration

- The kidneys receive blood from renal artery a branch of the aorta.
- This blood is rich in nitrogenous waste e.g. urea.
- It contains dissolved food substances, plasma proteins,hormones and oxygen.
- Blood flow in capillaries is under pressure due to the narrowness of the capillaries.
- The afferent arteriole entering the glomerulus is wider than the efferent arteriole leaving it.
- This creates pressure in the glomerulus.
- Due to this pressure, dissolved substances such as urea, uric acid, glucose, mineral salts and amino acids are forced out of the glomerulus into the Bowman's capsule.
- Large sized molecules in the plasma such as proteins and red blood cells are not filtered out because they are too large.
- This process of filtration is called ***ultra-filtration or pressure filtration*** and the filtrate is called ***glomerular filtrate.***

Selective Reabsorption

- As the filtrate flows through the renal tubules the useful substances are selectively reabsorbed back into the blood.
- In the proximal convoluted tube all the glucose, all amino acids and some mineral salts are actively reabsorbed by active transport.
- The cells lining this tubule have numerous mitochondria which provide the energy needed.
- Cells of the tubule have microvilli which increases the surface area for re-absorption.
- The tubule is coiled, which reduces the speed of flow of the filtrate e.g. giving more time for efficient re-absorption.
- The tubule is well supplied with blood capillaries for transportation of reabsorbed substances.
- The ascending loop has thick wall and is impermeable to water.
- Sodium is actively pumped out of it towards the descending loop.
- As glomerular filtrate moves down the descending loop, water is reabsorbed into the blood by osmosis in the distal convoluted tubule and in the collecting duct.
- Permeability of the collecting duct and proximal convoluted tubule is increased by anti-diuretic hormone (ADH) whose secretion is influenced by the osmotic pressure of the blood.

- The remaining fluid consisting of water, urea, uric acid and some mineral salts is called urine.
- The urine is discharged into the collecting d ct and carried to the pelvis.
- The loop of Henle is short in semi-aquatic mammals, and long in some mammals like the desert rat.

Removal

- The urine is conveyed from the pelvis to the ureter.
- The ureter carries the urine to the bladder where it is stored temporarily and discharged to the outside through the urethra at intervals.

Role of Liver in Excretion

- The liver lies below the diaphragm and it receives blood from hepatic artery and hepatic portal vein.
- Blood flows out of the liver through hepatic vein.
- Excretion of Nitrogenous Wastes
- Excess amino acids cannot be stored in the body, they are deaminated in the liver.
- Hydrogen is added to amino group to form ammonia which combines with carbon (IV) oxide to form urea.
- The urea is carried in the blood stream to the kidneys.
- The remaining carboxyl group, after removal of amino group, is either oxidised to provide energy in respiration.
- or built up into carbohydrate reserve and stored as glycogen or converted into fat and stored.

Breakdown and Elimination of Haemoglobin

- Haemoglobin is released from dead or old red blood cells which are broken down in the liver and spleen.
- Haemoglobin is broken down in the liver and a green pigment biliverdin results which is converted to yellow bilirubin.
- This is taken to the gall bladder and eliminated as bile.

Elimination of Sex Hormones

- Once they have completed their functions, sex hormones are chemically altered by the liver and then taken to the kidney for excretion.

Other functions of the liver

- Formation of Red Blood Cells.
- In the embryo, red blood cells are formed in the liver.
- Breakdown and elimination of old and dead blood cells.

- Dead red blood cells are broken down in the liver and the pigments eliminated in bile.
- Manufacture of Plasma Proteins.
- Plasma proteins like albumen, fibrinogen and globulin are manufactured in the liver.
- Storage of blood, vitamins A, K, BI2 and D and mineral salts such as iron' and potassium ions.
- Detoxification. Toxic substances ingested e.g. drugs or produced from metabolic reactions in the body are converted to harmless substances in a process called detoxification.

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Homeostasis

- Homeostasis is the maintenance of a constant internal environment.
- The internal environment consists of intercellular or tissue fluid.
- This fluid is the medium in the space surrounding cells.
- Tissue fluid is made by ultra-filtration in the capillaries.
- Dissolved substances in the blood are forced out of the capillaries and into intercellular spaces.
- Cells obtain their requirements from tissue fluid while waste products from cells diffuse out into the tissue fluid.
- Some of the fluid gets back into the blood capillaries while excess fluid is drained into the lymph vessels.
- Cells function efficiently if there is little or no fluctuation in the internal environment.
- The factors that need to be regulated include temperature, osmotic pressure and pH.
- The body works as a self-regulating system and can detect changes in its working conditions bringing about corrective responses.
- This requires a negative feedback mechanism e.g. when body temperature falls below normal, mechanisms are set in place that bring about increase in temperature.
- And when the increase is above normal, mechanisms that lower the temperature are set in place.
- This is called a negative feedback and it restores the conditions to normal.

Neuro-Endocrine System and Homeostasis

- Homeostatic mechanisms are brought about by an interaction between nervous and endocrine systems.
- Nerve endings detect changes in the internal and external environment and relay the information to the brain.
- The hypothalamus and pituitary are endocrine glands situated in the brain.
- The hypothalamus detect changes in the blood.
- The pituitary secretes a number of hormones involved in homeostasis e.g. anti-duretic hormone (ADH).
- The discussion below shows the nature of these interactions.

The Skin and Temperature Regulation

- The optimum human body temperature is 36.8°C.
- A constant body temperature favours efficient enzyme reaction.
- Temperatures above optimum denature enzymes, while temperature below the optimum range inactivate enzymes.
- The skin is involved in regulation of body temperature as follows:
- The skin has receptors that detect changes in the temperature of the external environment.

When the body temperature is above optimum the following takes place:

Sweat:

- Sweat glands secrete sweat onto the skin surface.
- As sweat evaporates it takes latent heat from the body, thus lowering the temperature.

Vasodilation of Arterioles:

- The arterioles near the surface become wider in diameter.
- More blood flows near the surface and more heat is lost to the surrounding by convection and radiation.

Relaxation of hair erector muscle:

- When hair erector muscles relax, the hair lies flat thus allowing heat to escape from the skin surface.

When body temperature is below optimum the following takes place:

Vasoconstriction of Arterioles:

- The arterioles near the surface of the skin become narrower.
- Blood supply to the skin is reduced and less heat is lost to the surroundings.

Contraction of hair erector muscles.

- When hair erector muscles contract, the hair is raised.

- Air is trapped between the hairs forming an insulating layer.
- Animals in cold areas have a ***thick layer of subcutaneous fat***, which helps to insulate the body.
- Besides the role of the skin in thermoregulation as discussed above, the rate of metabolism is lowered when temperature is above optimum and increased when temperature is below optimum.
- The latter increases the temperature to the optimum.
- When this fails, shivering occurs.
- Shivering is involuntary contraction of muscles which helps to generate heat thus raising the body temperature.

Homeostatic Control of Body Temperature in Humans

Body size and Heat Loss

- The amount of heat produced by metabolic reactions in an animal body is proportional to its mass.
- Large animals produce more heat but they lose less due to small surface area to volume ratio.
- Small animals produce less heat and lose a lot, due to large surface area to volume ratio.
- Small animals eat a lot of food in relation .to their size in order to raise their metabolic rate.

Behavioural and Physiological Responses to Temperature Changes

- Animals gain or lose heat to the environment by conduction, radiation and convection.
- Birds and mammals maintain a constant body temperature regardless of the changes in the environment.
- They do this mainly by internally installed physiological mechanisms hence they are **endotherms,** also known as **homoiotherms.**
- At the same time behavioural activities like moving to shaded areas when it is too hot assist in regulating their body temperature.
- Other animals do not maintain a constant body temperature e.g. lizards.
- They are **poikilotherms (ectotherms)** as their temperature varies according to that of surroundings.
- They only regulate body temperature through behavioural means.
- Lizards bask on the rocks to gain heat and hide under rocks when it is too hot.

- Some animals have adaptive features e.g. animals in extreme cold climates have fur and a thick layer of subcutaneous fat like polar bear.
- Those in extremely hot areas have tissue that tolerate high temperatures e.g. camels.
- Some animals avoid cold conditions by **hibernating** e.g. the frog while others avoid dry hot conditions by **aestivation** e.g. kangaroo rat.
- This involves decreasing their metabolic activities.

Skin and Osmoregulation

- Osmoregulation is the control of salt and water balance in the body to maintain the appropriate osmotic pressure for proper cell functioning.
- Sweat glands produce sweat and thus eliminate water and salt from the body.

The Kidney and Osmoregulation

- The kidney is the main organ that regulates the salt and water balance in the body.
- The amount of salt or water reabsorbed into the bloodstream is dependent on the osmotic pressure of the blood.
- When the osmotic pressure of the blood rises above normal due to dehydration or excessive consumption of salt, the osmo-receptors in the hypothalamus are stimulated.
- These cells relay impulses to the pituitary gland which produces a hormone called **anti-diuretic hormone** - ADH (vasopressin) which is taken by the blood to the kidneys.
- The hormone (ADH) makes the distal convoluted tubule and collecting duct more permeable to water hence more water is reabsorbed into the body by the kidney tubules lowering the osmotic pressure in the blood.
- When the osmotic pressure of the blood falls below normal due to intake of a large quantity of water, osmoreceptors in the hypothalamus are less stimulated.
- Less antidiuretic hormone is produced, and the kidney tubules reabsorb less water hence large quantities of water is lost producing dilute urine (diuressis).
- The osmotic pressure of the blood is raised to normal.
- If little or no ADH is produced, the body may become dehydrated unless large quantities of water are consumed regularly.
- **Diabetes insipidus** is a disease that results from the failure of the pituitary gland to produce ADH and the body gets dehydrated.

- A hormone called **Aldosterone** produced by the adrenal cortex regulates the level of sodium ions.
- When the level of sodium ions in the blood is low, adrenal cortex releases aldosterone into the blood.
- This stimulates the loop of Henle to reabsorb sodium ions into the blood.
- Chloride ions flow to neutralise the charge on sodium ions.
- Aldosterone also stimulates the colon to absorb more sodium ions into the blood If the sodium ion concentration rises above optimum level, adrenal cortex